Taper Tantrums as News to Emerging Markets*

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Abstract

US monetary policy announcements and news about fundamentals gives rise to *expected interest rate movements* in the international financial center. We study their consequences for emerging markets in terms of domestic activity, borrowing costs, and welfare. In the data, tight monetary policy in the US is associated with high spreads and depressed activity in emerging markets. However, a standard sovereign default model augmented with (news) shock to the risk-free short-term rate cannot replicate these patterns: in equilibrium yields rise but spreads fall, as sovereigns endogenously reduces new issuance when bond prices are low. We solve this puzzle by introducing domestic financial frictions in production, which allows the model to generate recessions and debt crises caused by higher (expected) interest rates in the financial center. These working capital loans have a side-effect of eliminating the "consumption boom before default" puzzle. We argue that the interplay between sovereign and domestic financial frictions is key for replicating patterns in the data.

Keywords: emerging markets, sovereign default, news shocks, global financial cycle
JEL classification: F34, F41, E52

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1 Introduction

We revisit the consequences of changes in default-risk-free rates in the international financial center for emerging markets' sovereign cost of borrowing, level of activity, and welfare. Complementary to prior work, we focus on the impact of *expected* interest rate movements induced by news in the financial center and the role domestic financial frictions play in shaping the response of production to sovereign distress. Whether movements in US rates account for a sizable share of emerging market volatility has been the topic of an extensive and influential literature, which we briefly reference below, but relatively less is known about the impact of monetary policy announcements or other "early warning" information available to market participants on emerging markets vulnerable to crises.

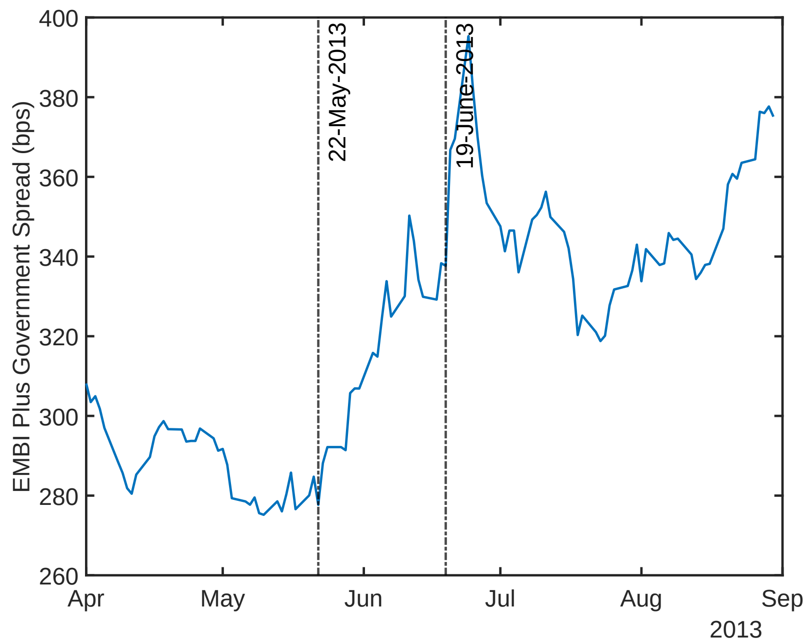

Figure 1: Spreads Around US FRB Announcements (2013 "Taper Tantrum" Episode)

Figure 1 illustrates one of the events motivating our work. We plot the EMBI+ spread for the entire set of emerging markets during the "taper tantrum" episode in 2013. In May 22nd, Federal Reserve Chairman Bernanke suggested that tapering of the ongoing Quantitative Easing program is imminent, causing the start of a "taper tantrum" in US bond markets. On June 19th, the FRB officially announced the tapering of the program, quickly leading to a new increase of the spreads of emerging markets.

The empirical literature has broadly conclude that tight monetary policy in the US is associated with a heightened risk of recession and higher spreads in emerging markets, e.g., as exemplified recently by Kalemli-Özcan (2019). We make two related contributions. First, we investigate whether a standard sovereign default model in the tradition of Eaton and Gersovitz (1981) and Arellano (2008), once augmented with news shocks to the risk-free rate, can replicate this evidence. We find that, following an increase in the risk-free rate, such a model exhibits lower default risk and spreads in equilibrium, in contrast to the data. We explain the mechanism behind this puzzle. Second, we argue that the missing model ingredient is domestic financial frictions along the lines of Neumeyer and Perri (2005), more precisely the interplay between sovereign borrowing, household consumption, and the interest rate on working capital loans required for production. A final by-product of our work is that, by incorporating financially-constrained domestic production, we eliminate the "consumption booms before default" puzzle discussed by, among others, Hatchondo, Martinez, and Sosa-Padilla (2016), whereby sovereign default models with positive recovery rates give an incentive for "full dilution" and a spike in consumption in the period just prior to default.

We formulate two version of our model: a baseline model with financially-constrained production and interest rate news, as well as an endowment version of this baseline, in which income is stochastic and uncorrelated to the international risk-free rate. We calibrate our models and illustrate their dynamics though selected business cycle statistics and by plotting fully nonlinear impulse response functions, using the method of Koop, Pesaran, and Potter (1996). Our model assumes a constant expected haircut rate and a delay to resumption of international borrowing following default. The inclusion of a positive recovery rate leads to our endowment model to exhibit the "consumption boom before default" puzzle, unless borrowing is constrained by an underwriting standard as in Chatterjee and Eyigungor (2015). We show that the full model, with domestic production subject to working capital constraints, endogenously prevents these "booms" even absent any constraint on the bond price or the default probability, as in prior work.

Related Literature. Earlier contribution such as Neumeyer and Perri (2005) and Uribe and Yue (2006) studied theoretically and empirically the role of interest rate shocks for the behavior of small open economies, but abstracted from endogenous default risk and preannounced or predetermined interest rate movements, i.e., news. Fernández-Villaverde et al. (2011) document the importance of interest rate volatility and Johri, Khan, and Sosa-Padilla (2020) revisit this feature in a model with endogenous sovereign default. Wolf and Zessner-Spitzenberg (2021) study the consequences of interest rate hikes in a monetary union, for a two-goods economy with downward rigid wages, where tight monetary policy is recessionary and does lead to high spreads. In contrast with these works, we focus on *news* to interest rates in the financial center and the role domestic financial frictions play in translating these expected rate movements into recessionary pressures, as well as the sovereign's ability to use borrowing to mitigate their impact.

Our work here also relates to the broader question of international comovement, the "global financial cycle," as discussed by Longstaff et al. (2011), Bai, Perri, and Kehoe (2019), and Miranda-Agrippino and Rey (2021) among others. This line of research stresses the role of a small number of global factors in explaining the cross-section and comovement of spreads. Other spillover channels from which we abstract include lenders' risk-aversion and wealth effects, as in Lizarazo (2013) and Arellano, Bai, and Lizarazo (2017).

News shocks were studied extensively in applications to total factor productivity, both theoretical and empirical, as in Beaudry and Portier (2004, 2006) and more recently Görtz, Tsoukalas, and Zanetti (2016). We abstract from news about productivity and instead allow only early warning about future interest rate movements in the financial center, leaving the question of their interaction for future work.

2 Model

This section introduces our model with defaultable, long-term debt, as in Chatterjee and Eyigungor (2012), augmented with stochastic movements in the risk-free rate, which is the opportunity cost for international lenders, as in Johri, Khan, and Sosa-Padilla (2020). Domestic financial frictions follow Neumeyer and Perri (2005). We argue that these elements are essential for replicating the impact of expected and unexpected movements of risk-free rate in the international financial center on emerging markets' production and spreads. We relegate the endowment version of our model to Appendix B and the strategy for computing the model, using discrete choice methods, to Appendix C.

2.1 The Dynamics of the Risk-free Rate

The opportunity cost for international lenders is the short-term default-risk-free rate in the financial center, denoted by r_t^{rf}. We assume it is governed by the following process with news shocks,

$$r_{t+1}^{\text{rf}} = (1-\rho_r)\overline{r^{\text{rf}}} + \rho_r r_t^{\text{rf}} + \sigma_{r,\nu}\nu_t + \sigma_{r,\varepsilon}\varepsilon_{t+1} \tag{1}$$

where ε_{t+1} is a standard Normal innovation, $\varepsilon_t \sim \mathcal{N}(0,1)$, and ν_t is a news shock, known at time t, also following a standard Normal distribution, $\nu_t \sim \mathcal{N}(0,1)$.

The news shock ν_t shifts the one-step-ahead conditional distribution of the interest rate and thus provides information about future interest rate movements,

$$r_{t+1}^{\mathrm{rf}} | r_t^{\mathrm{rf}}, \nu_t \sim \mathcal{N}\left((1-\rho_r)\overline{r^{\mathrm{rf}}} + \rho_r r_t^{\mathrm{rf}} + \sigma_{r,\nu}\nu_t,\, \sigma_{r,\varepsilon}^2\right) \tag{2}$$

and the specification nests the standard AR(1) case, for $\sigma_{r,\nu} = 0$.

This short-term rate induces a price for a random-maturity, long-term default-risk-free bond in the financial center through the no-arbitrage condition,

$$q_t^{\mathrm{rf}} = \frac{1}{1+r_t^{\mathrm{rf}}}\left[\kappa + (1-\delta)\,\mathbb{E}_t q_{t+1}^{\mathrm{rf}}\right] \tag{3}$$

where we have assumed that each unit of outstanding debt calls for a service payment κ next period and a fraction $1-\delta$ will remain outstanding the following period. The implied yield-to-maturity is given by $\kappa/q_t^{\mathrm{rf}} - \delta$. This will be also the maturity structure of the defaultable debt issued by the sovereign.

2.2 The Domestic Private Sector

The domestic private sector consists of a representative household, a representative firm, and a representative financial intermediary.

Household. The representative household supplies labor competitively and receives the profits of domestic firms and financial intermediaries, as well as a lump-sum tax or transfer from the fiscal authority. Its problem is static and given by

$$\max_{\ell_t} u\left(c_t, \ell_t\right) \text{ s.t. } c_t = w_t \ell_t + \Pi_t + \Pi_t^f + T_t \tag{4}$$

where c_t is domestic consumption, w_t is the wage rate, ℓ_t is labor supply, Π_t are the profits of domestic final goods producers, Π_t^f are the profits of financial intermediaries, and T_t is the fiscal authority's lump-sum transfer or tax.

We consider a setting with centralized borrowing, as standard in the quantitative sovereign default literature, by assuming that all external lending or borrowing is done by the government, on behalf of the private sector. The sovereign operates in international financial markets, lacking commitment over repayment and future borrowing choices, and transfers the net proceeds from these operations to the private sector through the T_t term.

Domestic Producer. Competitive domestic producers hire labor to produce final goods, using a decreasing return technology. A fraction θ of the wage bill must be financed with an *intra-period* working capital loan from the domestic financial intermediary.[1] The profit maximization problem of the producer is thus

$$\Pi_t = \max_{\ell_t} \{A_t \ell_t^\alpha - [(1-\theta) w_t \ell_t + \theta (1+i_t) w_t \ell_t]\} \tag{5}$$

where i_t is the domestic interest rate carried by the intra-period working capital loan, ℓ_t is the resulting labor demand, and A_t is a productivity level common to all firms in the economy.

The resulting demand for labor is given by

$$\ell_t = \left(\frac{\alpha}{1+\theta i_t} \cdot \frac{A_t}{w_t}\right)^{1/(1-\alpha)} \tag{6}$$

which implies that tighter domestic financial conditions, as captured by a higher interest rate for working capital loans, depress production.

We assume that the productivity level A_t is stochastic and endogenously lowered by the sovereign default decision, as described later. Net of any such reductions induced by sovereign default, the productivity term evolves according to

$$\log A_{t+1} = \rho_A \log A_t + \sigma_{A,\epsilon} \epsilon_{t+1} \tag{7}$$

and $\epsilon_{t+1} \sim \mathcal{N}(0,1)$ is standard Normal.

Domestic Financial Intermediary. The domestic financial intermediary extends working capital loans to producers and transfers the profits resulting from this activity to the household

$$\Pi_t^f = -a_t + (1+i_t) a_t = i_t a_t, \tag{8}$$

where a_t is the working capital loan size. In equilibrium firms take loans $a_t = \theta w_t \ell_t$.

The rate for this intra-period loan is given by

$$i_t = \frac{u_c(c_t, \ell_t)}{\beta \mathbb{E}_t u_c(c_{t+1}, \ell_{t+1})} - 1 \tag{9}$$

1. A similar constraint is used by Mendoza and Yue (2012) to expose the importing of intermediate goods to default risk, in their approach to endogenize the real costs of default. Modeling such intra-period loans follows Fuerst (1992).

which is the domestic cost of funding in this economy, measured by the expected marginal rate of intertemporal substitution of the household. This is consistent with common timing assumptions made in modeling intra-period loans, e.g., the loan is extended in the "morning" of period t while production and repayments are done in the "evening" of period t.

2.3 Sovereign Borrowing

The benevolent fiscal authority can borrow abroad, lacking commitment over future repayment and borrowing decisions. It starts each period t with an initial debt level b_t, which, if it chooses not to default, it must service with a payment of κb_t, at which point it can issue or retire units of its long-term bond so that to adjust the next period's debt level to b_{t+1}. The resulting proceeds from operating in international markets are transferred to the domestic representative household:

$$T_t = q_t \left[b_{t+1} - (1-\delta)\, b_t\right] - \kappa b_t \tag{10}$$

If the sovereign chooses to default, we encode this decision in a policy variable $d_t = 1$, no debt service payments are made and no new issuance or buyback of bonds are possible, resulting in $T_t = 0$. If instead the sovereign services its debt, we write $d_t = 0$.

We assume that following a decision to default, the sovereign spends a random length of time being excluded from international financial markets. With a constant probability λ the sovereign resumes international market access and applies a haircut to its creditors, so that upon reentry the outstanding debt level is ϕb_t with $\phi < 1$. Furthermore, a state of default carries a direct productivity reduction for domestic producers, that is $A_t^d \leq A_t$.

International Lenders. Competitive, risk-neutral international lenders price the bonds issued by the sovereign with an opportunity cost given by the short-term rate in the financial center r_t^{rf},

$$q_t = \frac{1}{1+r_t^{\mathrm{rf}}}\mathbb{E}_t \left\{ (1-d_{t+1}) \left[\kappa + (1-\delta) q_{t+1}\right] + d_{t+1} q_{t+1}^d \right\} \tag{11}$$

where q_t^d is the secondary market price of defaulted debt, which satisfies

$$q_t^d = \frac{1}{1+r_t^{\mathrm{rf}}}\mathbb{E}_t \left\{ (1-\lambda)\, q_{t+1}^d + \lambda\phi \left[d_{t+1} q_{t+1}^d + (1-d_{t+1})\left(\kappa + (1-\delta) q_{t+1}\right) \right] \right\}, \tag{12}$$

where the right-hand side reflects the assumption that the sovereign has the option to immediately default again after returning to market and applying the haircut.

The yield-to-maturity spread of the sovereign bond is given by $\kappa/q_t - \kappa/q_t^{\text{rf}}$ where q_t^{rf} is the price of the default-risk-free bond trade in the financial center, with the same maturity structure with the sovereign's bond, defined in Section 2.1.

2.4 A Recursive Formulation

We consolidate our model and provide a recursive formulation, using exogenous state variables $s = \langle r^{\text{rf}}, \nu, A \rangle$ and the endogenous state variable b. Implicitly, whether the sovereign has or lacks market access is also recorded as a state variable but we choose to express this dependency by writing down separate value and policy functions for a country in default. As standard in the study of equilibrium default, we restrict attention to Markov Perfect Equilibria.

Domestic Outcomes. In state $\langle s, b \rangle$, if the sovereign chooses b' as next period's debt level, domestic outcomes are summarized by policy functions $\mathcal{C}(s, b, b')$ for consumption, $\mathcal{L}(s, b, b')$ for employment, $\mathcal{I}(s, b, b')$ for the domestic interest rate, the wage rate $\mathcal{W}(s, b, b')$, and the profits of firms and financial intermediaries $\mathcal{P}(s, b, b')$. These satisfy the labor supply condition

$$-\frac{u_\ell(\mathcal{C}, \mathcal{L})}{u_c(\mathcal{C}, \mathcal{L})} = \mathcal{W} \tag{13}$$

the labor demand condition

$$\mathcal{L} = \left(\frac{\alpha}{1 + \theta \mathcal{I}} \cdot \frac{A}{\mathcal{W}} \right)^{1/(1-\alpha)} \tag{14}$$

the household's budget constraint

$$\mathcal{C} = \mathcal{W}\mathcal{L} + P + q(s, b') \left[b' - (1-\delta) b \right] - \kappa b \tag{15}$$

a profit condition for $\mathcal{P}$ consistent with the problems in Section 2.2, and the domestic interest rate condition

$$u_c(\mathcal{C}, \mathcal{L}) = \beta (1 + \mathcal{I}) H(s, b'), \tag{16}$$

for any state and choice $\langle s, b, b' \rangle$, where q is the bond price schedule and H is expected future marginal utility of consumption, both to be defined shortly.

Domestic Outcomes in Default. Analogously, domestic outcomes in default are characterized by functions of $\langle s, b \rangle$ alone, as there is no borrowing choice, e.g., $\mathcal{C}^d(s,b), \mathcal{L}^d(s,b)$, $\ldots$, and an expected marginal utility of consumption while in default, $H^d(s,b)$.

Forward-looking Functions. We can facilitate the construction of the bond price schedules by introducing an auxiliary function

$$Q(s,b) = \mathcal{D}(s,b)q^d(s,b) + [1 - \mathcal{D}(s,b)]\{\kappa + (1-\delta)q(s, \mathcal{B}(s,b))\} \tag{17}$$

so that the bond price schedule with market access is simply

$$q(s,b') = \frac{1}{1+r^{\mathrm{rf}}} \mathbb{E}_{s'|s} Q(s',b') \tag{18}$$

and the secondary market value of defaulted bonds is

$$q^d(s,b) = \frac{1}{1+r^{\mathrm{rf}}} \mathbb{E}_{s'|s} \left\{ (1-\lambda) q^d(s',b) + \lambda \phi Q(s', \phi b) \right\} \tag{19}$$

and $\mathcal{B}(s,b)$ and $\mathcal{D}(s,b)$ are the sovereign's equilibrium issuance and default policies function, to be described shortly.

Similarly, the expected marginal utility functions, with market access and in default, can be expressed parsimoniously by introducing

$$J(s,b) = [1 - \mathcal{D}(s,b)]\, u_c\left(\mathcal{C}(s,b,\mathcal{B}(s,b)), \mathcal{L}(s,b,\mathcal{B}(s,b))\right) + \mathcal{D}(s,b) u_c\left(\mathcal{C}^d(s,b), \mathcal{L}^d(s,b)\right), \tag{20}$$

as

$$H(s,b') = \mathbb{E}_{s'|s} J(s',b') \tag{21}$$

and

$$H^d(s,b) = \mathbb{E}_{s'|s} \left\{ \lambda J(s', \phi b) + (1-\lambda) u_c\left(\mathcal{C}^d(s',b), \mathcal{L}^d(s',b)\right) \right\}. \tag{22}$$

Sovereign. The sovereign chooses whether to default,

$$V(s,b) = \max_{d \in \{0,1\}} \left\{ d\, V^d(s,b) + (1-d) V^r(s,b) \right\} \tag{23}$$

with its choice encoded in the policy function $\mathcal{D}(s,b)$, and how much debt to carry into next period, conditional on not defaulting,

$$V^r(s,b) = \max_{b'} \left\{ u\left(\mathcal{C}(s,b,b'), \mathcal{L}(s,b,b')\right) + \beta \mathbb{E}_{s'|s} V(s',b') \right\} \tag{24}$$

with solution encoded in the policy function $\mathcal{B}(s,b)$. The value in default satisfies

$$V^d(s,b) = u\left(\mathcal{C}^d(s,b), \mathcal{L}^d(s,b)\right) + \beta \mathbb{E}_{s'|s} \left\{ \lambda V(s',\phi b) + (1-\lambda) V^d(s',b) \right\}. \tag{25}$$

Definition of Equilibrium. A *Markov Perfect Equilibrium* consists of

- Value functions for the sovereign, V, V^r, V^d
- Policy functions for the sovereign, $\mathcal{D}, \mathcal{B}$
- Domestic outcome functions with market access, $\mathcal{C}, \mathcal{L}, \ldots$
- Domestic outcome functions in default, $\mathcal{C}^d$, $\mathcal{L}^d$, ...
- Bond price schedules, q, q^d
- Expected marginal utility of consumption functions, H, H^d

such that

- The policy functions solve the maximization problems of the value functions, given domestic outcomes
- Bond prices are consistent with the sovereign's policy functions, lenders break even
- The expected marginal utility functions are consistent with the sovereign's policies and the domestic outcomes
- Domestic outcomes are consistent with market clearing for labor and working capital, in default and with market access, respectively.

3 Quantitative Analysis

We calibrate our model and compare its quantitative properties to the data and to a version without domestic production subject to financial frictions, an endowment economy version, describe in detail in Appendix B.

3.1 Calibration and Quantitative Properties

We assume household preferences are CRRA and GHH, following Greenwood, Hercowitz, and Huffman (1988),

$$u(c, \ell) = \frac{\left(c - \psi \frac{\ell^{1+\mu}}{1+\mu}\right)^{1-\sigma} - 1}{1-\sigma} \tag{26}$$

and the functional form for the cost of default in terms of productivity follows Chatterjee and Eyigungor (2012),

$$h(A) = A - \max\left\{0,\ \lambda_0 A + \lambda_1 A^2\right\} \leq A \tag{27}$$

and focus on the concave case, $\lambda_0 \leq 0 \leq \lambda_1$.

We use the Shadow Rate of Wu and Xia (2016) as a measure of the risk-free rate in the financial center, to circumvent issues arising from the extended period at the zero lower bound (ZLB/ELB). We estimate an AR(1) process and vary the share of variance attributed to news shock (ν) as opposed to regular innovations (ε).

Table 1 summarizes parameter values for our quarterly calibration.

TODO

3.2 Impulse Response Functions

We produce stochastic impulse response functions for our nonlinear model following the method of Koop, Pesaran, and Potter (1996). For other applications of this approach to impulse response functions to sovereign default models see, among others, Arellano, Bai, and Mihalache (2018) and Dvorkin et al. (2020).

We construct these impulse response panels by simulating a wide and long panel of uncorrelated countries, such that after a long enough time the cross-sectional distribution converges to the ergodic distribution of the model. We then shock all economies by the same amount (except if the grid is binding) and plot average dynamics over time. We include in all calculation the simulated economies that are in a state of default. These make up about 6% of all economies in the ergodic distribution. Note that in a state of default, the spread variable reflects the secondary market price of defaulted bonds, so that the variable has a valid value.

The Endowment Model Case. We start by examining the behavior of the endowment model, without financial frictions in domestic production. Figure 2 plots the responses of endowment, consumption, spreads, and default likelihood to a negative endowment

	Value	Comment
σ	2.0	CRRA
β	$\star$	Discounting
δ	≈ 0.05	5 year duration
$\overline{r^{\mathrm{rf}}}$	$\star$	Mean rate
κ	$\delta + \bar{r}$	Normalization
ψ	$\star$	Normalization, mean ℓ
μ	2.0	Inverse of Frisch elasticity
$\overline{q}$	$\star$	Threshold price for the new issuance
λ_0	$\star$	Penalty, linear
λ_1	$\star$	Penalty, quadratic
λ	≈ 0.13	2 year exclusion
ϕ	0.7	Recovery rate
ρ_r	$\star$	Autocorrelation of international rate
ρ_y	$\star$	Autocorrelation of endowment
σ_ν	$\star$	Variance of news shock
σ_ε	$\star$	Variance of interest rate shock
σ_y	$\star$	Variance of endowment shock
ρ_D	$\star$	Default shock
ρ_B	$\star$	Borrowing shock

Table 1: Parameter Value, Endowment Model

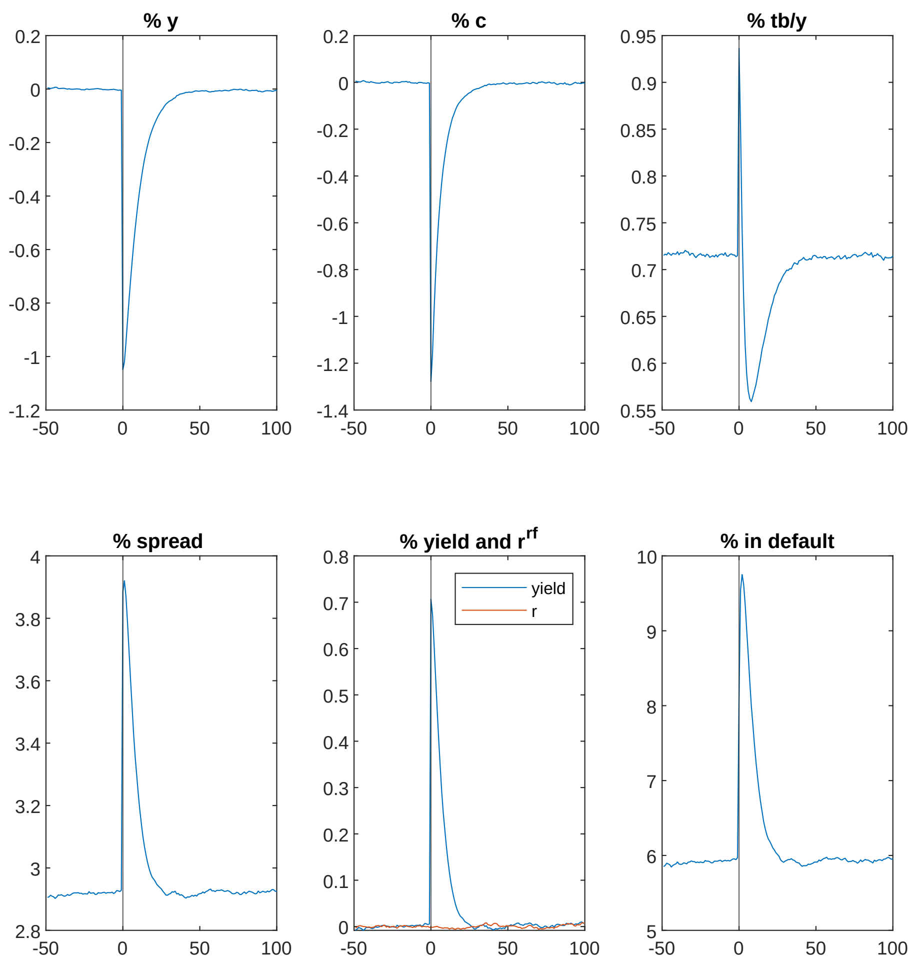

Figure 2: Impulse Response Functions, Endowment Model, *Endowment Shock*

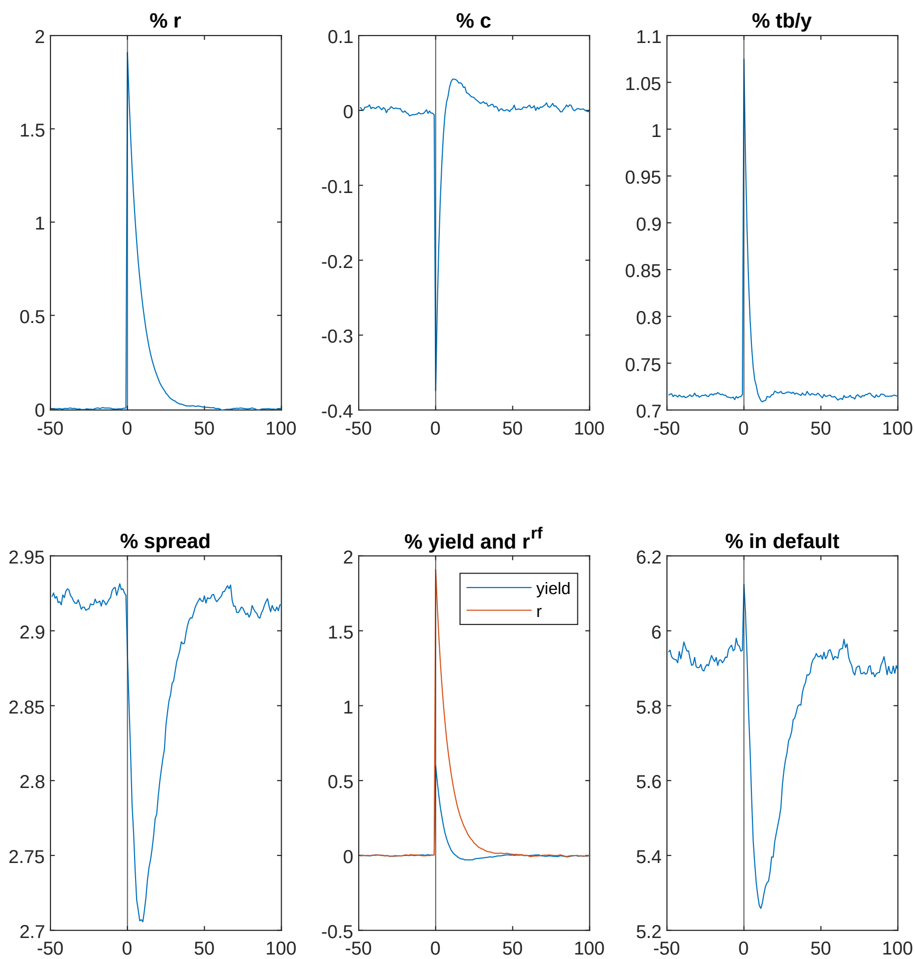

Figure 3: Impulse Response Functions, Endowment Model, *Risk-free Rate Shock*

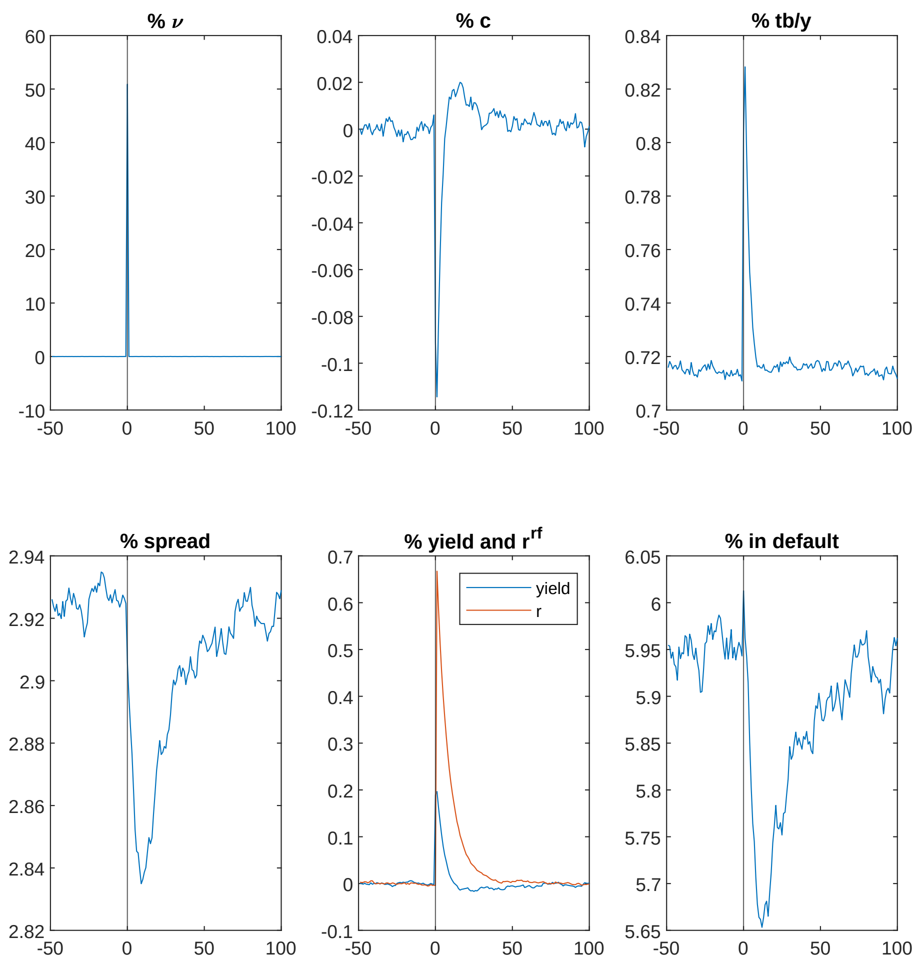

Figure 4: Impulse Response Functions, Endowment Model, *News Shock*

shock, a 1% drop below average. As expected, a low endowment depresses consumption and raises spreads as well as the risk of default. The economy exhibits a Current Account reversal, as net exports spike. The "% in default" panel plots the share of simulated economies in the cross section who are in a state of default.

Figures 3 and 4 plot the responses to shocks to the risk-free rate and news about the risk-free rate, respectively. In this endowment economy, expectations of tight conditions in the financial center are associated with modest reductions in consumption but no change in output, as the endowment is exogenous and uncorrelated. Critically, spreads and the risk of default *fall*, unlike in the data. This is because an increase in the cost of borrowing, gives the sovereign an incentive to reduce issuance or to even retire debt: the yield on the sovereign's bond does increase but it increases by less than compared with the long-term risk-free rate. As a result, the spread over the financial center falls. If the sovereign was optimally choosing a certain level of default risk and associated borrowing cost at the initial risk-free rate, the same b' would imply higher default risk and yields, more than what the sovereign would now optimally want. As a result, b' falls with r^{rf} and ν.

The sovereign is a monopolist in the market for its own bonds and optimally chooses to cut issuance when demand for its bonds is low, as caused by high risk-free rates. We conjecture that, at least in part, the counterfactual prediction of the model is driven by the fact that interest rates have no impact on domestic production, itself an assumption in conflict with the evidence referenced above. We, therefore, turn to a case in which financial conditions abroad impact the domestic working capital market and thus constraint production and employment.[2]

The Case of Financial Frictions and Production. TODO

4 Conclusion

TODO

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A Data Sources

We use the Shadow Rate of Wu and Xia (2016) as a measure for the default-risk-free rate in the US. We rely on National Accounts data from the IMF's IFS database. The EMBI+ spread series is from JP Morgan, via Bloomberg.

B Endowment Model

The endowment economy has state variables $s = \langle y, r^{\mathrm{rf}}, \nu \rangle$ and b. s are exogenous state variables, including the endowment y, the risk-free rate r^{rf}, and news ν. b is the debt level of the sovereign. The sovereign's policies are the default decision $\mathcal{D}(s, b)$ and the borrowing choice $\mathcal{B}(s, b)$. Bond pricing schedules are determined in the equilibrium with international lenders, $q(s, b')$ for the price at initial issuance and $q^d(s, b)$ for defaulted bonds, priced in secondary market.

The sovereign's value function are, at the start of the period,

$$V(s,b) = \max_{d \in \{0,1\}} \left\{ (1-d) \cdot V^r(s,b) + d \cdot V^d(s,b) \right\} \tag{28}$$

for repayment

$$V^r(s,b) = \max_{b'} \left\{ u\left[y - \kappa b + q(s,b')(b' - (1-\delta)b) \right] + \beta \mathbb{E}_{s'|s} V(s', b') \right\} \tag{29}$$

and in default, respectively,

$$V^d(s,b) = u\left[h\left(y\right)\right] + \beta \mathbb{E}_{s'|s} \left\{ (1-\lambda)\, V^d(s', b) + \lambda V(s', \phi b) \right\}. \tag{30}$$

As for our baseline model, we can facilitate the construction of the bond price schedules by introducing an auxiliary function

$$Q(s,b) = d(s,b) q^d(s,b) + [1 - d(s,b)] \left\{ \kappa + (1-\delta) q(s, \mathcal{B}(s,b)) \right\} \tag{31}$$

which allow us to write

$$q(s,b') = \frac{1}{1 + r^{\mathrm{rf}}(s)} \mathbb{E}_{s'|s} Q(s', b') \tag{32}$$

and

$$q^d(s,b) = \frac{1}{1 + r^{\mathrm{rf}}(s)} \mathbb{E}_{s'|s} \left\{ (1-\lambda)\, q^d(s', b) + \lambda \phi Q(s', \phi b) \right\}. \tag{33}$$

This model abstracts from domestic production and labor supply. The choice of GHH preferences imply that, absent the financial friction, domestic production endogenously resembles an endowment economy. This aids the comparison with reference models in the literature.

C Computation

We compute our model with defaultable, long-term debt using discrete choice methods, following Mihalache (2020) and Dvorkin et al. (2021). We introduce Extreme Value Type I shocks for the choices over b' and d, so that ex-ante there is a choice probability function over b' levels, as well as an interior default probability for any ex-post state. These "taste shocks" facilitate convergence in models with defaultable long-term debt and smooth policies and values. The appendix of Arellano, Bai, and Mihalache (2020) provides additional discussion for these methods.

We describe here the taste shocks version of our endowment economy, from Appendix B, to keep notation simple. The full model follows an analogous strategy, with minor complications raised by the forward-looking functions H and H^d. With taste shocks, the default decision becomes

$$V(s,b) = \rho_D \log \left\{ \exp\left[\frac{V^d(s,b)}{\rho_D}\right] + \exp\left[\frac{V^r(s,b)}{\rho_D}\right] \right\} - \rho_D \cdot \text{em} \tag{34}$$

where em is the Euler-Mascheroni constant, and the default probability after observing the state s but before observing the taste shocks is

$$d(s,b) = \frac{1}{1 + \exp\left[\dfrac{V^r(s,b) - V^d(s,b)}{\rho_D}\right]}. \tag{35}$$

The parameter ρ_D controls the amount of "noise" in the taste shock.

Analogously, for the new debt level, define the value for an arbitrary choice of b' as

$$W(s,b,b') = u\left[y - \kappa b + q\left(s,b'\right)\left(b' - (1-\delta)b\right)\right] + \beta \mathbb{E}_{s'|s} V(s',b') \tag{36}$$

and set $W(s,b,b') = -\infty$ for all b' value that yield negative consumption. Then,

$$V^r(s,b) = \rho_B \log \left\{ \sum_{b'} \exp\left[\frac{W(s,b,b')}{\rho_B}\right] \right\} - \rho_B \cdot \text{em} \tag{37}$$

and the probability of choosing any particular $b' = x$ after observing s is given by

$$\Pr(b' = x|s, b) = \frac{\exp\left[\frac{W(s,b,x)}{\rho_B}\right]}{\sum_j \exp\left[\frac{W(s,b,j)}{\rho_B}\right]}. \tag{38}$$

The value of default is unaltered, as

$$V^d(s,b) = u\left[h(y)\right] + \beta \mathbb{E}_{s'|s}\left\{(1-\lambda)V^d(s',b) + \lambda V(s',\phi b)\right\}.$$

The choice probabilities for default and borrowing are reflected in the lenders' pricing of the debt. Define as before the "helper" function

$$Q(s,b) = d(s,b)q^d(s,b) + [1 - d(s,b)]\left[\kappa + (1-\delta)\sum_{b'} \Pr(b'|s,b)q(s,b')\right] \tag{39}$$

and use it to write

$$q(s,b') = \frac{1}{1+r^{\mathrm{rf}}}\mathbb{E}_{s'|s}Q(s',b') \tag{40}$$

and

$$q^d(s,b) = \frac{1}{1+r^{\mathrm{rf}}}\mathbb{E}_{s'|s}\left\{(1-\lambda)q^d(s',b) + \lambda\phi Q(s',\phi b)\right\}. \tag{41}$$

Note that now, in the definition of Q, the continuation value is given by an expectation over future bond prices, across taste shock realization, and that d now takes value in $(0,1)$ rather than in $\{0,1\}$.

As ρ_B and ρ_D go to zero, we recover the original model, without taste shocks, albeit at the cost of poor convergence properties. $\rho_B > 0$ in particular is key for near-uniform convergence, while ρ_D can only play a quantitative role.