Medium-term cycles: the role of occasionally binding collateral constraints*

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Abstract

What makes some economies more prone to swings in trend growth – medium frequency cycles – than others? This paper emphasizes the role of occasionally binding credit constraints that introduce state-dependence and asymmetry in the link between economic activity and endogenous growth. Negative shocks are highly detrimental to productivity growth in financially vulnerable economies that undergo leverage-deleverage cycles, but this is not the case in economies where agents can optimally borrow to offset temporary negative income shocks.

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1 Introduction

In addition to the regular short-run business cycle fluctuations, economies tend to oscillate between periods of robust growth and relative stagnation over longer horizons. These medium-frequency cycles are deemed to be the result of the endogenous response of productivity growth to business-cycle shocks.[1] Characteristics of medium-frequency cycles vary across countries and over time. In particular, they tend to be larger in amplitude and more negatively skewed in emerging rather than developed small open economies (figure 1 & table 1).[2]

What factors can account for the greater amplitude and negative skewness of medium-term fluctuations of output in emerging, as compared to developed, small open economies? In this paper, I argue that this evidence can be understood through the non-linear interaction between credit cycles, occasionally binding collateral constraints, and endogenous growth. Historically, emerging economies are more prone to volatile credit cycles that end with sudden stops and deleveraging. At the peak of the credit boom, when the economy is close to its leverage constraint, negative shocks cause the constraint to bind. The resulting decline in credit leads to a sharp drop in R&D spending, business and product creation: activities that drive productivity growth over the long run but require paying significant upfront sunk costs. As such, deleveraging not only exacerbates the contraction in the short-run but also weights down growth in the medium run through the endogenous productivity mechanism. Since collateral constraints bind only occasionally following adverse shocks, the economy exhibits negative skewness. This dynamics contrasts developed open economies with resilient financial markets that more often remain unconstrained to borrow from the rest of the wold to smooth temporary negative income shocks.

I begin my analysis providing new evidence on the dynamics of recessions and recoveries that occur at high and low points of credit cycles based on a panel of 43 small open economies. I show that recessions that are associated with credit boom and bust episodes tend to be not only deeper in the short-run but also more protracted with output and consumption persistently lagging relative to their initial trajectories. Almost half of this persistent decrease in economic activity can be directly attributed to the dynamic of utilization-adjusted total factor productivity (TFP). In contrast, recoveries from recessions that occur in "tranquil" times, when credit is not elevated relative to the long-run trend, tend to follow a more conventional

[1] See Comin and Gertler (2006), among others.

[2] I decompose the data using the optimal one-sided bandpass filter of Fitzgerald and Christiano (2003). As in Comin and Gertler (2006), I define the medium-term cycle as fluctuations with frequencies from 0 to 50 years, which consists of business cycles (from 0 to 8 years) and the medium-term component (from 8 to 50 years).

mean-reverting path with some debt accumulation along the way.

In the second part of the paper I present a dynamics general equilibrium model that I use to interpret these empirical observations. The model builds on the standard real business cycle small open economy framework extending it in two dimensions. First, productivity in the economy grows endogenously trough forward-looking investment in the creation of new intermediate products, akin to the innovation-driven growth model of Romer (1990). Returns on productivity-improving activities vary over the business cycle, leading to oscillations in productivity growth.

Second, borrowing from the rest of the world is subject to an occasionally binding collateral constraint tied to the value of the capital shock, as in the literature on emerging market crises pioneered by Mendoza (2010). This feature allows explaining financial crises – periods when the constraint binds – as rare events nested within the regular business cycle. When the economy is close to its debt limit, negative shocks cause the collateral constraint to bind triggering deleveraging that amplifies the downturn. As such, occasionally binding collateral constraints introduce asymmetry in the link between credit and economic activity. Endogenous productivity growth inherits these amplification and asymmetry properties. The response of productivity growth to negative shocks is more pronounced during economic downturns exacerbated by deleveraging as compared to "regular" recessions or expansions.

This paper contributes to several strands of literature. The empirical exercise that I conduct adds to the literature on the macroeconomic effects of credit cycles and financial distress. In this dimension the closest paper is Jordà et al. (2013), which also studies how past credit accumulation affects the dynamics of recessions.[3] Unlike their work, I study a broader variety of macroeconomic indicators, their dynamics over a longer horizon, and factors that can account for it. I also contribute to the theoretical literature on sudden stops.[4] Aguiar and Gopinath (2007) famously noted that shocks to trend growth — rather than transitory fluctuations around a stable trend — are an important feature of business cycles in emerging markets. My framework offers a view that these drastic swings in trend growth in emerging countries can be seen as an endogenous outcome of sudden stops, rather than an exogenous shock.

The paper relates to the literature on the interconnectedness between business cycles and

[3] Cerra and Saxena (2008), Romer and Romer (2017)

[4] The non-exhaustive list includes,Benigno et al. (2013), Benigno et al. (2016), Bianchi and Mendoza (2018), Devereux et al. (2017), Devereux and Yu (2017), Korinek (2008), Mendoza (2010).

endogenous growth.[5] The closet reference is Queraltó (2013) who study the transmission of world interest rate shocks in a small open economy with endogenous growth and frictional financial intermediaries. This paper differs in its treatment of financial frictions but more substantively, it focuses on the role of non-linearities that arise due to occasionally binding collateral constraints and how they interact with endogenous growth. Finally, the present work relates to the literature on non-linear effects of financial frictions.[6]

The rest of the paper is organized as follows. Section 2 discusses motivating empirical evidence. Section 3 describes the model. Section 4 summarizes the calibration, the simulation technique, and the main results. Section 5 concludes.

2 Empirical motivation

2.1 Recessions and debt overhang: cross-country evidence

In this section, I study the association between post-recession recovery dynamics and the level of pre-existing private debt. In particular, I document that recessions that happen in periods when private debt is above its long-run trend tend to be not only deeper in the short run, but also have a very persistent negative effect on the level of economic activity, almost a half of which can be attributed to a slowdown in the TFP growth.

To that end, I study a panel of 43 small open economies The unbalanced panel of macroeconomic indicators consists of annual observations from 1950 to 2017, and includes the following variables: (1) real per capita GDP; (2) real per capita consumption; (3) real per capita capital; (4) real per capita investment; (5) utilization-adjusted TFP; (6) current account to GDP; and (7) real exchange rate index. Appendix A summarizes the data and its sources.

In addition, to assess the prevailing credit market conditions I employ the data from the novel IMF Global Debt Database, Mbaye et al. (2018). I use this data to calculate private credit-to-GDP gaps. Similarly to output gaps, this variable is defined as a deviation of the credit-to-GDP ratio from its long-run trend. The long-run trend is commonly extracted using

[5] See also Garcia-Macia (2015), Gornemann (2015), Kung and Schmid (2015), Schumacher and Ochowski (2017), Guerron-Quintana and Jinnai (2015), Ates and Saffie (2020), Ikeda and Kurozumi (2014), Annicchiarico (2016), Benigno and Fornaro (2018), Garga and Singh (2020), Moran and Queralto (2018), Anzoategui et al. (2019) and Bianchi et al. (2019), Comin and Gertler (2006), among others

[6] See Maffezzoli et al. (2015), Guerrieri and Iacoviello (2017), Jensen et al. (2016) on the implications of households and entrepreneurs being occasionally financially constrained; as well as contributions by Aknc and Queralto (2017), Holden et al. (2019) focusing on the frictional banking sector.

the one-sided HP filter with the smoothing parameter of $4 \cdot 10^5$ for quarterly observations.[7] As common in the literature, I use credit-to-GDP gaps as a proxy for credit-market imbalances in my analysis.

In the absence of a comprehensive database on the timing of recessions, I proceed as follows. First, I calculate annual growth rates of real per-capita GDP and identify years when the growth rate was negative as recessionary periods. Whenever growth is negative for several consecutive years, the first year in the sequence is labeled as a beginning of a recession. I use the database of Laeven and Valencia (2013) to exclude recessions associated with wars. The result is an indicator variable $\{\mathbb{1}_{i,t}^{\text{recession}}\}$ of a recession onset in county i in year t. Finally, I separate the resulting sample of events into two groups: the ones that occurred when the credit-to-GDP gap was below 0% and above 10% (low-debt and high-debt recessions henceforth). This approach identifies 51 low-debt and 36 high-debt recessions.

I proceed estimating average recovery paths of the above-listed variables using Jordà (2005) local projections. Instead of extrapolating impulse responses from the estimated multivariate system, this model-free approach involves estimating following dynamic cross-country panel:

$$\Delta_h y_{i,t+h} = \alpha_i^h + \alpha_t^h + \beta^h \mathbb{1}_{i,t}^{\text{recession}} + \gamma^h \mathbb{1}_{i,t}^{\text{banking}} + \varepsilon_{it}^h$$

The dependent variable is the country i's h-period log difference of the response variable: $\Delta_h y_{i,t+h} = \log(Y_{i,t+h}) - \log(Y_{i,t})$; and the perturbation variable is recession indicator $D_{i,t}$ discussed above. Estimating this relation at different horizons h produces a set of coefficients $\{\beta^h\}_{h=1:H}$ that can be interpreted as an average recession path across the considered sample of events, controlling for country fixed effects (α_i^h) and year fixed effects (α_t^h), and the fact that some recessions in the sample coincide with systemic banking crises, captured by the variable $\mathbb{1}_{i,t}^{\text{banking}}$ based on the dates from Laeven and Valencia (2013).

Figure 2 shows estimated responses of GDP, consumption, investment, and capital, all in real per-capita terms, for high-debt and low-debt recessions. Recoveries after low-debt recessions, on average, exhibit mean reversion with the short-run consumption response being smoother than the output response. On the other hand, the effect of high-debt recessions is very persistent and remains significant beyond 5 years after the recession onset. Also, the responses of consumption and output are of comparable magnitudes.

What factors can account for this persistence? Figure 3 shows more responses of relevant variables. Two important observations emerge. First, high-debt recessions, as opposed to

[7] See, for example, Basel Committee on Banking Supervision (2010). The smoothing parameter of $4 \cdot 10^5$ for quarterly observations corresponds to $4 \cdot 10^5/4^4$ for annual observations, according to Martone (2002)

low-debt recessions, are associated with the gradual decline in utilization-adjusted TFP. The magnitude of this effect is such that I can directly explain up to a half of the persistent decline in output. Second, the dynamics of private debt, the current account, and the real exchange rate differ considerably across the two groups of recessions. Recessions that occur after credit-intensive booms are associated with gradual deleveraging with the debt-to-GDP ratio falling for up to 4%. There is also evidence of external adjustment: the sharp on-impact improvement in the current account of almost 4% and the real exchange rate depreciates in the medium run. On the other hand, low-debt recessions are associated with an increase in the debt-to-GDP ratio in the short run, a muted response of the current account, and no statistically significant movement of the real exchange rate.

2.2 Persistent effects of financial distress

What makes low-debt and high-debt recessions so different and why the lion's share of the persistent decline in the output level is due to the low productivity growth? My argument is as follows. Contractionary shocks in a high-debt environment make agents liquidity-constrained by reducing the value of their collateral. The resulting deleveraging not only exacerbates the short-run effect of the contractionary shock but also has generates a persistent effect by reducing productivity-enhancing investment and growth in the medium-run. Crucially, this effect is state-dependent and materializes to the full extent only when economy is in high-debt financially fragile state.

To support the proposed mechanism, in this section I present an evidence of comovement between financial conditions, private credit, measures of real activity, and TFP. For this purpose, fist employ the narrative quantitative measure of financial distress from Romer and Romer (2017). I use the variable as indicative of periods when economies become credit-constrained, as well as the severity of these episodes. The measure, which is an unbalanced panel that covers 30 countries from 1967 to 2017, is added to the database from the previous section. Responses to the financial distress shock are estimated by local projections as follows:

$$\Delta_h y_{i,t+h} = \alpha_i^h + \alpha_t^h + \beta^h D_{i,t} + X_{i,t}\Gamma + \varepsilon_{it}^h,$$

where $\{D_{i,t}\}$ in the index of financial distress in country i in year t, α_i^h and α_t^h are country and year fixed effects, respectively. Vector $X_{i,t}$ is a set of macroeconomic controls, which includes three lags of (1) financial distress index, (2) log of the response variable, (3) log private debt to GDP, and (4) current account to GDP. In addition, to account for the possible effect of an exchange-rate regime, I include fixed exchange rate indicators from Ilzetzki et al. (2019). The setting implies that the financial distress shock is identified with short-run restrictions: it is assumed not to react to the above macroeconomic variables contemporaneously.

Figure 4 shows responses to a one point increase in the financial distress shock. To put this shock in context of the scale use by Romer and Romer (2017), the value of the financial distress index in the US in 2008 was 11,5. The shock is associated with deleveraging with the debt-to-GDP gap falling by about 2% over the course of 7 years, as well a an improvement in the current account together with a sharp depreciation of the real exchange rate. Consistently with the previous results, the decline in output is very persistent and up to a half of it can be directly attributed to the dynamics of utilization-adjusted TFP.

The second exercise is a VAR model that provides an evidence supporting the conjecture that credit-market disruptions lead to persistent output losses by negatively affecting the pace of productivity-improving activities and hence the level of measured TFP. This exercise comes with a caveat: the cross-country data that could be used as a proxy for the scope of innovation activities is limited, especially at high frequencies. For this reason, I resort to the US data that offer the longest quarterly series of R&D spending. Although in general the transmission of shocks in the US is likely to somewhat different than in other, smaller, countries, I believe that this exercise highlights relations between variables that are not unique to the US economy.

The VAR model includes variables ordered as follows: (1) financial conditions index, (2) total employment, (3) real GDP, (4) utilization-adjusted TFP, (5) real R&D spending, (6) private credit to GDP. The data is quarterly spanning from Q1 1971 to Q3 2018. The TFP measure is the utilization-adjusted TFP of Fernald (2012) that takes out the effect of short-run fluctuations in factor utilization. The measure of financial conditions is the Chicago Feds National Financial Conditions Index (NFCI), which is a weighted average of a 105 measures of financial activity that intends to capture changes in financial-market risk, credit availability, and leverage. More specifically, I employ the adjusted version of this index (ANFCI) that isolates a component of financial conditions orthogonal to economic conditions, which motivates ordering this variable first. The of other variables implies that TFP reacts to R&D expenditure and real GDP reacts to TFP with a one-period lag. Credit is ordered last as financial markets tend to quickly react to changes in the real activity. Total employment is ordered before real GDP since the labor-market dynamics lags with respect to the business cycle. Variables except for the ANFCI enter the model in log-levels due to the potential cointegration between them. As noted by Kilian and Lütkepohl (2017) estimating a level VAR is an alternative to estimating a VECM model, which may be more robust to possible (near) cointegration of unknown form among the variables.

Figure 5 presents IRFs to a worsening of financial conditions (a one standard deviation increase in ANFCI). Short-term tightening of financial conditions is contractionary, it's associated with a drop in R&D spending and a decrease in the private-sector debt-to-GDP ratio. Notably, not all of the initial contraction is fully recovered in the medium-run. Even 15 years after the shock 0.01% decrease in the real GDP, 0.004% decrease in TFP, and 0.006% decrease in employment remain. In addition, Appendix A presents responses to an identified R&D spending shock. An increase in R&D spending is expansionary and has a very persistent effect in the real activity. Over the course of 60 quarters, an R&D shock of 0.6% leads to a 0.2% increase in the level of real GDP, 0.05% increase in the utilization-adjusted TFP, and a 0.1% increase in the total employment.

3 The model

This section lays out a real business cycle small open economy with capital accumulation extended in two dimensions. First, the model features financial frictions. Borrowing from the rest of the world is subject to an occasionally binding collateral constraint tied to the value of capital stock, as in Mendoza (2010), among others. Second, productivity in the economy growth endogenously trough introduction of new intermediate products as in Romer (1990). Figure 6 summarizes the structure of the model.

3.1 Production

3.1.1 Final good sector

The final good is produced by perfectly competitive firms using homogeneous labor, L_t, capital, K_t, and a CES basket of intermediate products $X_t = \left[\int_0^{N_t} x_t(\omega)^{\frac{1}{\nu}} d\omega\right]^{\nu}$, where $\frac{\nu}{\nu-1}$ is the elasticity of substitution between varieties. The aggregate production function takes the following Cobb-Douglas form:

$$Y_t = Z_t \left((\psi_t K_t)^{\alpha} L_t^{1-\alpha}\right)^{1-\xi} X_t^{\xi} = Z_t \left((\psi_t K_t)^{\alpha} L_t^{1-\alpha}\right)^{1-\xi} \left(\int_0^{N_t} x_t(\omega)^{\frac{1}{\nu}} d\omega\right)^{\nu\xi}$$

where ψ_t is a lognormally distributed capital quality shock, which at the beginning of period t determines the effective amount of physical capital in possession of the firm, $\psi_t K_t$. Following the finance literature,[8] this shock has become a common way to introduce an exogenous variation

[8] For instance Merton (1973)

to the total capital stock value.[9]

Firms are subject to a working capital requirement: a fraction ζ of the current-period wage bill needs to be financed in advance via an intra-period borrowing from households at a rate R_t^F. This is a reduced-form way to cause household financial frictions to also have supply side implications through labor demand. Other than that, the problem is standard. Given input prices a representative firm maximizes its discounted profit stream:

$$\max_{\left\{\substack{x_{t+j}(\omega),\\ L_{t+j},K_{t+j}}\right\}_{j=0}^{\infty}} \mathbb{E}_t \sum_{j=0}^{\infty} \beta_{t,t+j} \left[Y_{t+j} - R_{t+j}^K K_{t+j} - (1+\zeta(R_t^F - 1)) W_{t+j} L_{t+j} - \int_0^{N_t} p_{t+j}^x(\omega) x_{t+j}(\omega) d\omega \right],$$

which implies the following input demands:

$$W_t \underbrace{\left[1 + \zeta(R_t^F - 1)\right]}_{\text{working capital wedge}} = (1-\alpha)(1-\xi)\frac{Y_t}{L_t} \tag{1}$$

$$R_t^K = \alpha(1-\xi)\frac{Y_t}{\psi_t K_t} \tag{2}$$

$$p_t^x(\omega) = \xi \frac{Y_t}{X_t} x_t(\omega)^{\frac{1-\nu}{\nu}}$$

Firms are implicitly owned by households, so the future stream of profits is discounted by the households stochastic discount factor $\beta_{t,t+j} = \beta^j \frac{U'_{C_{t+j}}}{U'_{C_t}}$.

3.1.2 *Intermediate good sector*

The intermediate sector is populated by a mass $[0, N_t]$ of monopolistically competitive firms, each operating a roundabout technology that requires A^{-1} units of the domestic good to produce a unit of the intermediate good. One should not take this setup literally. The correct interpretation of this formal description is that the forgone final good is never manufactured. The resources that would have been used to produce the forgone output are used instead to manufacture intermediate goods.

Each firm maximizes its real profit subject to the production sector demand:

$$\max_{\{p_{t+j}^x(\omega)\}_{j=0}^{\infty}} \mathbb{E}_t \sum_{j=0}^{\infty} \beta_{t,t+1} \left(p_{t+j}^x(\omega) x_{t+j} - A^{-1} x_{t+j}(\omega) \right) \text{ s.t. } \qquad p_t^x(\omega) = \xi \frac{Y_t}{X_t} x_t(\omega)^{\frac{1-\nu}{\nu}}$$

In a symmetric equilibrium the optimal quantity of the intermediate good (x_t), the firm's profit

[9] See, for instance, Gertler and Karadi (2011). Gertler et al. (2012) provide an explicit microfoundation for this shock.

(d_t), and its relative price (p_t^x) are the following:

$$x_t = \left(\frac{A\xi}{\nu}\right)^{\frac{1}{1-\xi}} Z_t^{\frac{1}{1-\xi}} N_t^{\frac{\nu\xi-1}{1-\xi}} \tilde{K}_t^{\alpha} L_t^{1-\alpha} \tag{3}$$

$$d_t = \frac{\nu-1}{\nu} p_t^x x_t = \frac{\nu-1}{A} x_t \tag{4}$$

$$p_t^x = \nu \ A^{-1}$$

Positive profit in this sector motivates entry. To open a firm, an entrepreneur needs to pay an sunk entry cost that consists of the cost of buying a blueprint of a new product from innovators at a price p_t^b. New firms finance entry by selling shares of their equity to entrepreneurs. Free entry pins down the equilibrium value of an intermediate firm, which should be equal to the entry cost: $v_t = p_t^b$.

3.1.3 Innovators

The sector of innovators involves inventing blueprints for new types of intermediate goods. The sector is populated with the unbounded mass of potential innovators. Let S_t be the total innovation spending and ϕ_t^i be the innovators individual productivity parameter, which each innovator take as given. The individual production function blueprints of intermediate goods is then $N_t^{e\,i} = \phi_t^i S_t^i$. However, the aggregate innovators productivity ϕ_t depends on the existing stock of knowledge, measured by the number of existing intermediate goods, N_t. As in Romer (1990), this knowledge spillover externality is responsible for the existence of the balanced growth path in the model. In line with Comin and Gertler (2006), I include a congestion externally $N_t^{\rho} S_t^{1-\rho}$ that allows to control for the aggregate elasticity of blueprints output with respect to innovation spending. The resulting aggregate innovators productivity is:

$$\phi_t = \phi \frac{N_t}{N_t^{\rho} S_t^{1-\rho}},$$

where $S_t = \int S_t^i di$. The aggregate production function of innovators is then $N_t^e = \phi N_t \left(\frac{S_t}{N_t}\right)^{\rho}$. Perfectly competitive innovators set the price of blueprints p_t^b to maximize their expected discounted stream of profit:

$$\max_{\{S_{t+j}^i\}_{j=0}^{\infty}} \mathbb{E}_t \sum_{j=0}^{\infty} \beta_{t,t+j} \left(p_{t+j}^b \phi_{t+j} S_{t+j}^i - S_{t+j}^i\right)$$

The optimal price then is $p_t^b = \phi_t^{-1}$. Together with the intermediate sector free-entry condition this leads to the following expression that pins down intermediate firm value:

$$v_t = \phi^{-1}\left(\frac{S_t}{N_t}\right)^{\rho-1} \tag{5}$$

The model is calibrated at annual frequency, which motivates the assumption of no time-to-build lag: newly invented blueprints can be used for production within the same period. In each period existing varieties face a constant probability of becoming obsolete, δ_N. All of the above imply the following law of motion for the total number of varieties $N_t = (1-\delta_N)N_{t-1} + N_t^e$ so that the productivity growth rate is:

$$g_t = \frac{N_t}{N_{t-1}} = \phi\left(\frac{S_t}{N_t}\right)^{\rho} + (1-\delta_N) \tag{6}$$

R&D expenditure S_t vary over the business cycle that causes fluctuations in the growth rate. The sensitivity of growth to R&D expenditure is controlled by the parameter ρ.

3.2 Households

The economy is populated by a measure 1 of households. The representative household consumes; invests in capital that is rented out to firms at the rate R_{t+1}^K; supplies labor L_t; borrows from the rest of the world in domestic consumption units at the given rate R_t for its own use (B_t) and to provide inter-period working-capital loans to firms (B_t^F) at the rate R_t^F. Finally, households hold shares in a mutual fund of intermediate firms. In each period t the household buys e_{t+1} shares in a mutual fund of N_t currently active firms at the price of v_t per share; receives the dividend income from currently owned firms d_t; and receives the return on the shares purchased in the previous period, adjusted for the probability of a firm going out of business, δ_N.

The utility-maximization problem of a representative household is as follows:

$$\max_{\left\{\substack{C_{t+j}, e_{t+j}, L_{t+j},\\ K_{t+1+j}, B^F_{t+j}, B_{t+1+j}}\right\}_{j=0}^{\infty}} \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(C_{t+j} - \Upsilon_t \frac{L_{t+j}^{1+\epsilon}}{1+\epsilon}\right)^{1-\gamma} \frac{1}{1-\gamma} \qquad \text{s.t.}$$

$$\begin{aligned} C_t + e_{t+1}v_tN_t + I_t + R_tB_t = W_tL_t + R_t^K\psi_tK_t + e_{t+1}N_td_t + \\ e_tv_t\{N_{t-1}(1-\delta_N)\} + B_{t+1} + (R_t^F - 1)B_t^F \end{aligned} \tag{7}$$

$$K_{t+1} = (1-\delta_K)\psi_tK_t + (1 - AC_{I,t})I_t \tag{8}$$

$$B_{t+1} + B_t^F \leq \varrho q_t K_{t+1}$$

I resort to GHH preference of Greenwood et al. (1988), which is widely used in the small open economy analysis. This preference does away from the wealth effect in labor supply and isolates the labor supply decisions from the dynamics of consumption, saving, and portfolio choices and improves the performance of open-economy real business cycle models.[10] As in Queralto (2019), the disutility of labor is governed by the following process:[11]

$$\Upsilon_t = \Upsilon_{t-1}^{\rho_\Upsilon} N_t^{1-\rho_\Upsilon} \tag{9}$$

The parameter ρ_Υ determines the responsiveness of the disutility of labor to changes in productivity growth. This formulation ensures that the BGP with constant hours exists, but the medium-run swings in growth do not excessively affect labor supply.[12]

External borrowing is limited to a fraction ϱ of the capital stock value. Effectively, this parameter sets the maximum loan-to-value ratio and can be linked to the liquidity of the collateral. It can also be interpreted as the degree of domestic financial market development. As Kiyotaki and Moore (1997), I do no explicitly model the origins of this constraint. A natural interpretation, however, should be that due to the imperfect enforceability of contracts, the ability of households to borrow is bounded by a fraction of their collateral value that can be seized by creditors in a case of default. However, the model abstracts from endogenous default and debt is always repaid. Capital accumulation is subject to a convex adjustment cost, which implies an upward-sloping supply curve of capital and gives rise to endogenous fluctuations in the price of capital. Changes in the capital stock valuation cause endogenous fluctuations of the borrowing limit.[13]

Denote Lagrange multipliers with respect to the budget constraint, the law of motion for capital, and the borrowing constraint as λ_t, q_t and μ_t, respectively. The consumption Euler equation and the complementary slackness condition for the borrowing constraint are then the

[10] See contributions of Mendoza (1991) and Raffo (2008), among others.

[11] Jaimovich and Rebelo (2009) suggest a similar preference that allows parameterizing the short-run wealth effect on the labor supply

[12] One way to interpret this feature of the preference is as follows. As noted by Benhabib et al. (1991), the GHH preference can be interpreted as a reduced form of an economy with home production. The disutility of work then consists of the forgone output in home production. This disutility increases as productivity improvements in the formal sector spill over to the home production. However, to the extent this process takes time, the disutility of labor exhibits inertia.

[13] An alternative way that brings about endogenous fluctuations in the collateral price is the assumption that there are physical constraints to the supply of the collateralizable asset. This approach is common in the literature on the macro effects of the housing market. See, for instance, Iacoviello (2005), Liu et al. (2013), Ferrero (2015), Liu et al. (2016).

following:

$$\mathbb{E}_t\left[\beta_{t,t+1}R_{t+1}\right] = 1 - \frac{\mu_t}{\lambda_t} \tag{10}$$

$$\left[\varrho q_t K_{t+1} - B_{t+1} - B_t^F\right]\mu_t = 0, \quad \mu_t \geq\ 0 \tag{11}$$

Binding collateral constraint ($\mu_t > 0$) introduces an external financing premium in consumption and labor demand. Effectively, households become more impatient when the constraint binds, as it distorts optimal borrowing and the consumption level is suboptimally low. Moreover, binding collateral constraint increases the effective cost of labor for firms trough the working capital requirement: $R_t^F = \mu_t + 1$. As Bianchi and Mendoza (2018) I assume that working capital incurs no explicit interest rate payments, so at the unconstrained steady state the factor shares are not distorted by this feature of the model.

The next two first order conditions describe capital accumulation:

$$q_t = 1 + q_t(AC_{I,t} + AC'_{I,t}I_t) - \mathbb{E}_t\left(\beta_{t,t+1}q_{t+1}AC'_{I,t+1}I_{t+1}\right) \tag{12}$$

$$q_t = \mathbb{E}_t\left[\beta_{t,t+1}((1-\delta_K)q_{t+1} + R^K_{t+1})\psi_{t+1} + \varrho\frac{\mu_t}{\lambda_t}q_{t+1}\right] \tag{13}$$

The first is the standard condition describing fluctuations of Tobin's q due to the presence of investment adjustment costs. The second condition is the capital supply that takes into account the role of capital as collateral. Binding collateral constraint affects the current capital supply through two channels. The direct effect of $\mu_t > 0$ is positive. When credit-constrained, households have an incentive to accumulate more capital to relax the borrowing constraint. The second, indirect, effect works through the households stochastic discount factor. As noted above, $\mu_t > 0$ effectively makes households more impatient which, other factors fixed, reduces their willingness to accumulate capital. As noted by Mendoza (2010), for plausible values of ϱ the latter effect dominates. Binding borrowing constraint causes the collateral demand to fall, capital price to decrease, which further tightens the constraint in a classic Fisherian debt deflation vicious circle.

From the first order condition with respect to shares of intermediate firms equity it follows that:

$$v_t = d_t + \mathbb{E}_t\left[\beta_{t,t+1}(1-\delta_N)v_{t+1}\right] \tag{14}$$

When iterated forward, it implies that in equilibrium the current firm value, v_t, equals to the future discounted profit stream. Factoring in the growth equation (6) along with the free-entry condition $v_t = p^b_t = \phi^{-1}_t$ results in:

$$g_t = \phi^{\frac{2\rho-1}{\rho}} \sum_{j=0}^{\infty} (1-\delta_N)^j \, \mathbb{E}_t \left[\beta_{t,t+j} d_{t+j}\right] + (1-\delta_N) \tag{15}$$

The productivity growth rate is determined by the future expected discounted stream of profits from investing in business creation. Finally, the labor supply condition is standard:

$$\chi_t L_t^{\epsilon} = W_t \tag{16}$$

3.3 Symmetric equilibrium and market clearing

A representative household owns all intermediate firms, so $e_{t+1} = e_t = 1$. Under symmetric equilibrium all intermediate good producers are alike, so $x_t(\omega) = x_t$, $p_t(\omega) = p_t$, and $d_t(\omega) = d_t$, $\forall \omega$. Since some of the final good sector output is used by the intermediate sector, the correct measure of real GDP in the model is output of the final sector net intermediate consumption. Final output equals to consumption, capital and R&D investment, net investment income and the net change in the foreign asset position:

$$Y_t^{GDP} = Y_t - N_t \frac{x_t}{A} = C_t + I_t + S_t - (B_{t+1} - (1+R_t)B_t)$$

Equilibrium choices of intermediate producers along with other optimality conditions allow to express the production-sector output as follows:

$$Y_t = N_t^{\frac{\xi(\nu-1)}{1-\xi}} \left(\frac{A\xi}{\nu}\right)^{\frac{\xi}{1-\xi}} Z_t^{\frac{1}{1-\xi}} \mu_t^{\frac{\xi}{\xi-1}} \tilde{K}_t^{\alpha} L_t^{1-\alpha} \tag{17}$$

This expression makes it clear that the following condition on structural parameters needs to be satisfied for growth to take a labor-augmenting form: $\frac{\xi(\nu-1)}{1-\xi} = 1-\alpha$. To close the model and to avoid the non-stationarity of the net foreign asset position, I assume that the world interest rate is debt-elastic: $R_t = R + \psi_B \left[e^{\left(\frac{B_t}{N_t} - b\right)} - 1 \right]$. This assumption pins down the level of borrowing in the non-stochastic steady state.[14] The model features endogenous growth with all variables growing at the same rate $g_t = \frac{N_t}{N_{t-1}}$ on the balanced growth path. For solution purposes, I stationarize the model defining productivity-adjusted lower-case counterparts for the variables that exhibit growth, e.g. $y_t = \frac{Y_t}{N_t}$, $c_t = \frac{C_t}{N_t}$, $k_t = \frac{K_t}{N_t}$, etc.

Equilibrium definition: equations (1-14, 16, 17) determine 16 endogenous variables ($y_t, c_t, b_{t+1},$

[14] Schmitt-Grohé and Uribe (2003) presents a summary of other ways to stationarize the NFA position for models solved with perturbation methods. An alternative model-based approach to obtain a stationary distribution of assets as in Mendoza (2010) is more accurate for studying nonlinear effects and the effects of precautionary savings, but requires a global solution method.

$R_t, \chi_t, L_t, w_t, R_t^K, k_{t+1}, i_t, q_t, v_t, s_t, d_t, x_t, g_{t+1})$ as a function of endogenous states $(k_t, i_{t-1}, \chi_{t-1}, b_t)$ and exogenous states. Table 2 summarizes all equilibrium conditions.

4 Simulations

4.1 Calibration

The model is calibrated at annual frequency. I set the relative risk aversion to $\gamma = 2$, a common in the real business cycle literature. I calibrate innovators productivity ϕ to match the 1% annual TFP growth rate on the BGP. The steady-state real interest rate is then pinned down by the savers discount rate as follows: $R = g^\sigma/\beta$. I set the Frisch elasticity of labor supply to $\frac{1}{\epsilon} = 4$, consistent with the King and Rebelo (1999) calibration. The capital share is set to the conventional value of $\alpha = 0.33$. The intermediate goods share is set to $\xi = 0.5$, as in Comin and Gertler (2006). The elasticity of substitution between varieties of intermediate goods is then set to satisfy the condition necessary for growth to be of labor-augmenting form $\xi(\nu - 1)/(1 - \xi) = 1 - \alpha$.

Following Comin and Gertler (2006), I set the annual rate of intermediate product obsolescence to 3% ($\delta_N = 0.03$), and the elasticity of innovators output with respect to R&D expenditure to $\rho = 0.8$. Annual capital depreciation is set to the conventional value of 10% ($\delta_K = 0.1$). The following four parameters are borrowed from Mendoza (2010): capital adjustment cost $\phi_K = 2.5$; maximum loan-to-value ratio ϱ; working capital requirement $zeta = 0.25$; and the steady-state debt-to-GDP ratio $b = 0.85$. Finally, the debt-elastic interest rate parameter is set to be very low so that this feature does not compromise the dynamics of endogenous variables in the short-run. I choose $\psi_B = 0.0007$, as suggested by Schmitt-Grohé and Uribe (2003). Table 3 summarizes the choice of parameters.

4.2 Solution method

The model features an occasionally binding collateral constraint that generates non-linearities and poses a computational difficulty since the model cannot be solved using standard perturbation methods. One way to tackle this issue is to resort to value function iteration or other global solution methods that allow to fully account for the non-linearities and precautionary behavior linked to the possibility that the constraint may become binding in the future. However, these methods are computationally demanding and are not easily scalable due to the curse of dimensionality. The simplest alternative solution was introduced by Guerrieri and Iacoviello (2015) and involves using a piecewise-linear solution. This method builds on the insight that occasionally binding constraints can be handled as different regimes of the same model. Under one regime, the occasionally binding constraint is slack. Under the other regime, the same constraint is binding. The piecewise linear solution method involves linking the first-order approximation of the model around the same point under each regime. However, just like any linear solution, this method does not allow capturing the effects of uncertainty and so to account for precautionary behavior. I use a similar approach developed by Holden (2019) and implemented as an extension to Dynare: DynareOBC.[15] Unlike the Guerrieri and Iacoviello (2015) method, its compatible with higher-order approximations and by integrating over future uncertainty allows to capture some of the precautionary behavior.

In my solution technique, I deviate from the existing literature that mostly relies on global methods. I do it for simplicity, as I focus on illustrating the key qualitative properties of the model, for which the solution method is likely to be less crucial. First is the state dependence induced by occasional financial frictions: the dynamic response to shocks may be very different depending on the pre-existing level of debt. Second, the model produces occasional financial crises nested within normal business cycle fluctuations and need not to rely on the exceptionally large shock to explain them. These crises are not only deeper than regular contractions but also are characterized by abnormally low productivity growth that leaves a permanent footprint on the level of output.

4.3 Simulation results

4.3.1 High-debt and low-debt economy

The first simulation illustrates the state dependence that exists in the model due to the presence of the occasionally binding constraint. Specifically, I show that the effect of temporary negative income shocks on endogenous productivity depends significantly on the preexisting level of debt in the economy relative to the upper bound for the loan-to-value-ratio. This effect is much larger in situations when the level of debt is high and the shock causes the borrowing constraint to bind triggering deleveraging. For illustrative purposes I consider a one-time unanticipated productivity shock ε_t^Z. Exogenous productivity follows the standard autoregressive process: $\log(Z_t) = (1 - \rho_Z)\log(Z) + \rho_Z \log(Z_{t-1}) + \varepsilon_t^Z$.

Figure 7 shows responses to a 1% negative productivity shock with the persistence parameter

[15] Available at https://github.com/tholden/dynareOBC

$\rho_Z = 0.15$, which means that the shock dies out after about two years. I consider two scenarios: when the preexisting level of debt is 50% and 99% of the upper bound for borrowing (low-debt and high-debt cases henceforth). In the low-debt scenario, the collateral constraint is slack and the multiplier with respect to the collateral constraint remains zero. In this case, the economy responds like a standard small open economy RBC model. The shock causes a temporary contraction in economic activity. Driven by the consumption-smoothing motive, the economy runs a current account deficit and accumulates net foreign debt to offset a temporary fall in income. As a result, the fall in consumption is almost twice lower than the fall in output.

The response of the economy is significantly different in the high-debt regime when the negative productivity shock causes the collateral constraint to bind by reducing the price of capital. As per equation (13), when the constraint binds, the price of capital falls further. This effect can be interpreted as the outcome of the fire sale of capital as debtors strive to satisfy the tightened borrowing constraint. This endogenous fall in Tobin's q further tightens the collateral constraint exacerbating deleveraging setting in motion a classic Fisherian debt-deflation amplification mechanism. As the result of being temporary credit constrained, the economy runs a temporary current account surplus and accumulates net foreign assets in stark contrast to the low-debt scenario. Moreover, binding constraint affects the supply side of the economy by increasing the effective cost of working capital for firms and hence reducing their labor demand, as implied by the equation (1). This working-capital effect amplifies the fall in output.

The endogenous growth mechanism of the model makes measured productivity to respond to business-cycles shocks. Indeed, in both scenarios a negative shock causes a temporary slowdown in productivity growth adding persistence to responses of other endogenous variables. However, this effect is much more pronounced in the high-debt regime when the collateral constraint binds and the economy undergoes a phase of deleveraging. The reason is straightforward: households deleverage through a combination of a fall in consumption, capital investment, and innovation. The consumption-smoothing motive causes deleveraging to disproportionately affect capital investment and innovation prolonging the negative effect of the shock on output. To be more specific, the binding collateral constraint reduces innovation spending through two channels, as per equation (15). First, it amplifies the cyclical downturn and hence reduces incentives to invest in innovation due to lower returns: *the market-size effect*. Second, according to the equation (10), it temporarily reduces the stochastic discount factor of households. Other factors equal, lower discount factor decreases entrepreneurs incentives to innovate because of the higher discounting of future profits: *the discounting effect*. Moreover, atomistic agents do not internalize positive externalities of private R&D spending on aggregate growth. The endogenous decline in TFP in the high-debt case is more than five times greater than in the low-debt case. For comparison, I also plot the response of a counterfactual economy without endogenous in the low-debt regime. As one can see, the presence of endogenous growth does not significantly affect the dynamics of the economy in the low-debt regime keeping it close to the standard RBC benchmark.

4.3.2 An average financial crisis

How does an economy end up in the high-debt state where contractionary shocks have especially disruptive effects? To illustrate this, as standard in the literature, I run a 100k periods stochastic simulation, identify periods when the borrowing constraint binds, and then consider the median dynamics of variables within a ten-period window centered around the first period when the constraint binds. The economy is subject to persistent log-normally distributed productivity, world interest rate, and capital quality shocks:

$$\begin{aligned}
\log(Z_t) &= (1-\rho_Z)\log(Z) + \rho_Z \log(Z_{t-1}) + \varepsilon_t^Z \\
\log(R_t) &= (1-\rho_Z)\log(R) + \rho_R \log(R_{t-1}) + \varepsilon_t^R \\
\log(\psi_t) &= \rho_\psi \log(\psi_{t-1}) + \varepsilon_t^\psi
\end{aligned}$$

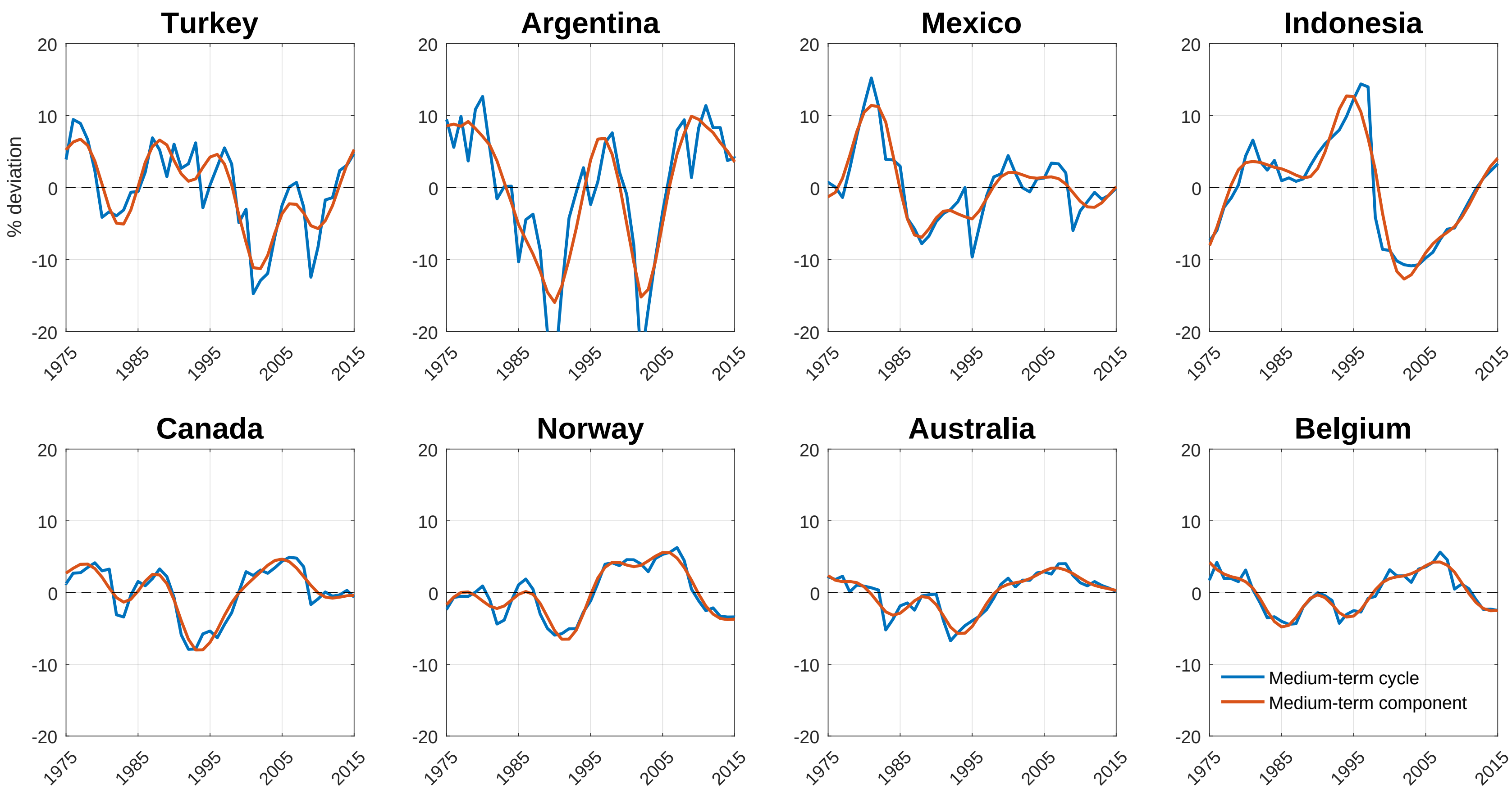
I borrow the parameters of producitivity and interest rate processes from Mendoza (2010) and set $\rho_Z = 0.537$, $\rho_R = 0.572$, $\sigma_Z = 0.0134$, $\sigma_R = 0.0196$. The capital-quality shock parameters are the following: $\rho_\psi = 0.5$ and $\varepsilon_\psi = 0.01$.

As figure 8 suggests, periods leading to a crisis are – on average – characterized by low world interest rates and low exogenous productivity, both of which cause the economy to run current account deficits and gradually accumulate foreign debt. Things go south when the world interest rate sharply increases and the economy is hit by a negative capital quality shock, which decreases the effective value of the county's capital stock that determines its borrowing capacity. The rest of the dynamics is consistent with the description in the previous section. The financial crisis is characterized by a sharp decrease in the price of capital, current account reversal, and an overall deep decline in economic activity.

5 Conclusion

This paper contributes to the emerging literature on the interconnectedness between business cycle fluctuations and long-run growth. I argue that rare and deep contractions exacerbated by financial frictions result in a sizable persistent output loss. In my analysis, I point to the state-dependence of this effect: the degree of endogenous productivity losses crucially depends on the pre-existing level of debt. What are the main lessons from this simple exercise? First and foremost, the real costs of financial crises may be significantly larger than commonly perceived if at least a fraction of the observed post-crisis productivity dynamics is endogenous to the crisis event. The potential endogeneity of these productivity losses rises stakes for policy, which can not only smooth out transitory shocks but also indirectly affect the supply side of the economy in the long run.

Figure 1: Medium-term cycles of real per-capita GDP, developed and emerging countries [cited on page 2]



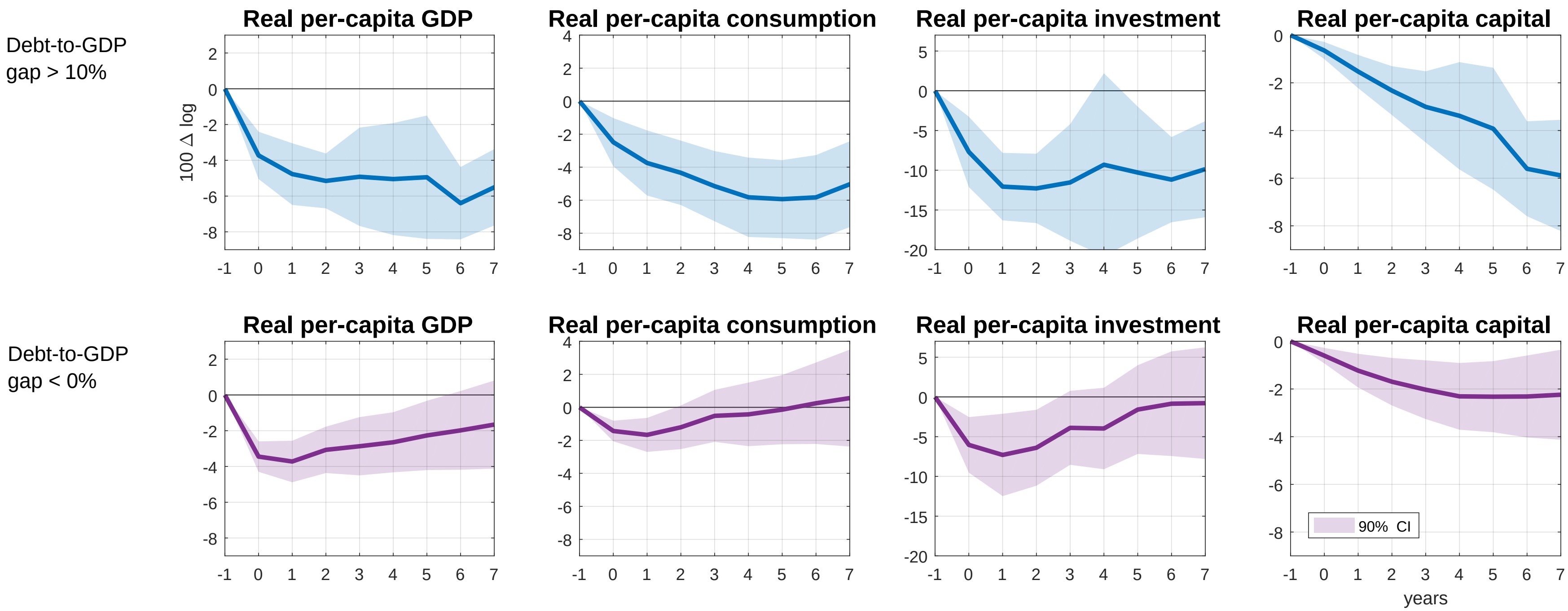
Note: the data is decomposed using the optimal one-sided bandpass filter of Fitzgerald and Christiano (2003). As in Comin and Gertler (2006), I define the medium-term cycle as fluctuations with frequencies from 0 to 50 years, which consists of business cycles (from 0 to 8 years) and the medium-term component (from 8 to 50 years).

Table 1: Standard deviation and skewness of the medium-term component of fluctuations [cited on page and 2]

Advanced economies					Emerging economies				
	σ_Y	σ_{TFP}	S_Y	S_{TFP}		σ_Y	σ_{TFP}	S_Y	S_{TFP}
AUS	3.29	2.55	-0.19	-0.05	ARG	7.76	5.47	-0.29	-0.67
AUT	2.56	2.11	0.07	0.27	BRA	9.18	4.54	-0.04	0.52
BEL	3.63	2.47	-0.12	0.19	CHL	7.67	8.79	-0.46	-0.42
CAN	3.6	2.37	-0.6	0.62	COL	6.08	3.07	-0.41	-0.80
CHE	2.92	2.07	0.66	0.14	CZE	5.14	8.94	0.22	-1.08
DNK	3.62	2.09	-0.16	0.14	HUN	9.05	4.36	-0.68	-1.24
ESP	6.81	1.50	-0.19	-0.76	IDN	8.26	4.95	0.09	0.18
FIN	5.49	2.88	-0.6	0.51	KOR	5.5	2.67	-0.98	-0.68
HKG	6.34	6.02	-0.22	0.21	MEX	4.43	4.72	0.74	-0.64
IRL	9.41	4.12	-0.39	0.07	MYS	7.11	5.52	-0.83	-0.93
ISR	4.4	2.97	0.68	0.87	PER	9.82	6.16	-0.44	-0.44
NLD	4.52	3.02	0.18	0.71	POL	10.34	3.33	-0.26	-0.25
NOR	2.8	3.51	0.09	-0.19	THA	9.68	5.36	-0.56	0.50
NZL	4.03	3.47	-0.54	-0.12	TUR	6.36	2.82	-0.36	-0.93
PRT	5.78	5.42	-0.12	0.43	TWN	4.48	3.43	-1.18	-0.27
SWE	4.06	3.77	-0.75	-0.07	ZAF	6.12	5.01	-0.47	-0.01
mean	4.58	3.15	-0.14	0.19	mean	7.31	4.95	-0.37	-0.45
median	4.05	2.93	-0.17	0.17	median	7.39	4.83	-0.42	-0.54

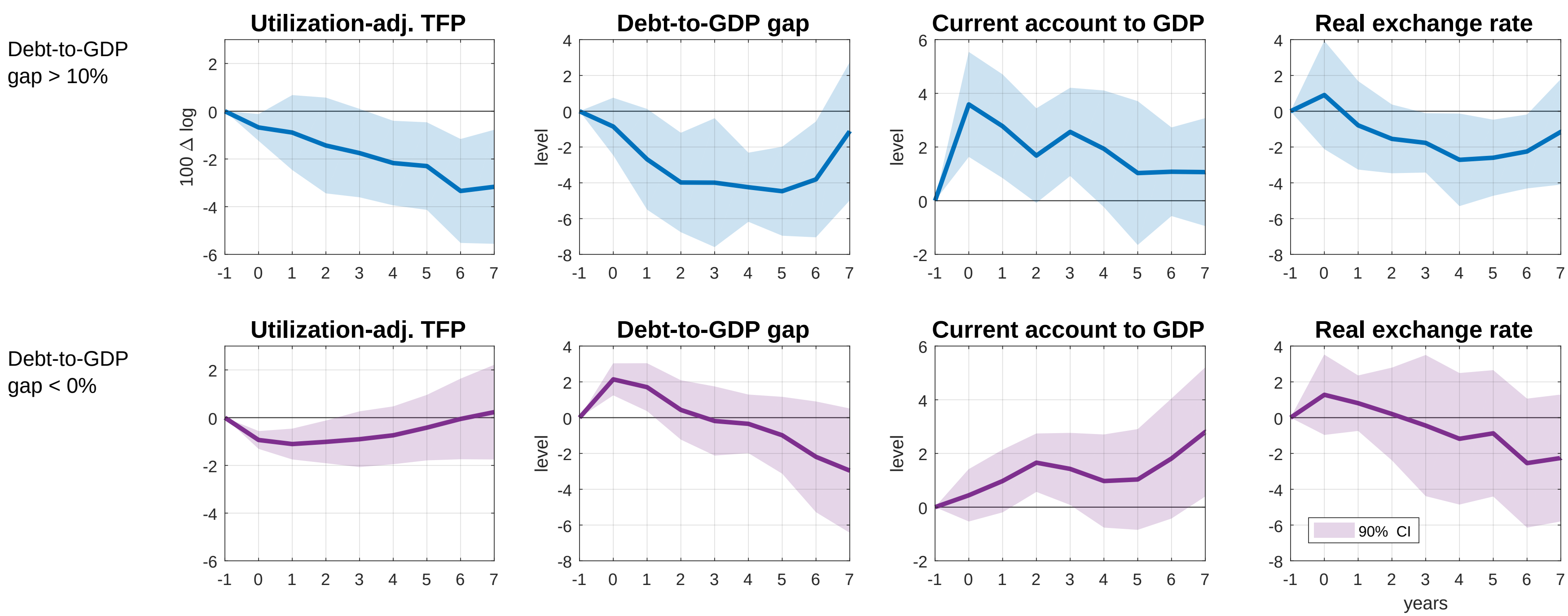
Note: the medium-term component is defined as fluctuations with frequencies from 8 to 50 years, using the optimal one-sided bandpass filter of Fitzgerald and Christiano (2003). Country classification is according to MSCI, G7 economies are excluded. Y is real per-capita GDP, TFP is utilization-adjusted TFP from Brizhatyuk (2020).

Figure 2: Recession paths conditional on the preexisting debt-to-GDP gap [cited on page 5]



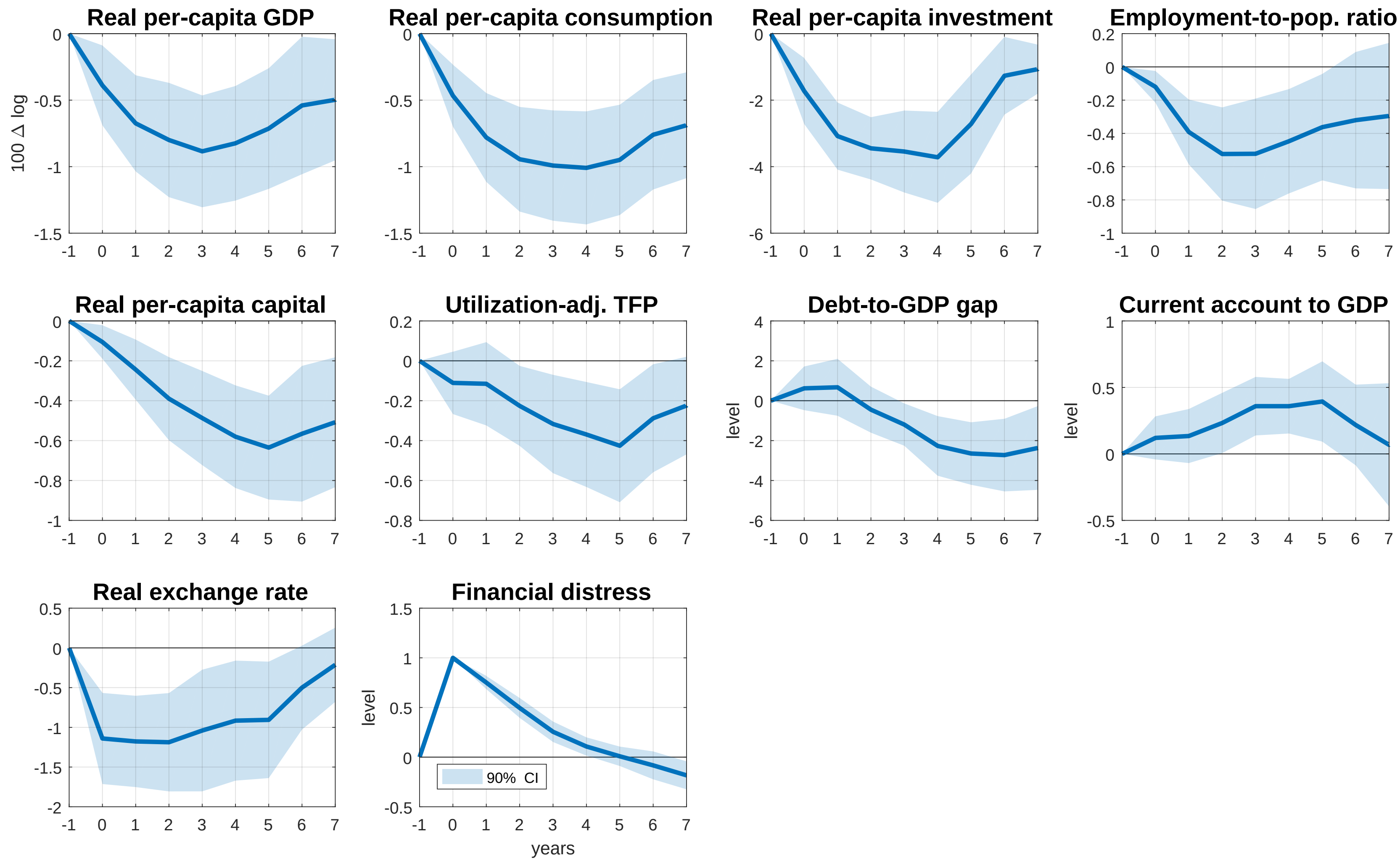
Note: Cross-country panel local projections. Responceses of level variables contingent on the debt-to-GDP value at the onset of a recession. Shaded areas correspond to 90% confidence bounds. Standard errors are clustered at the country level.

Figure 3: Recession paths conditional on the preexisting debt-to-GDP gap, cont'd [cited on page 5]



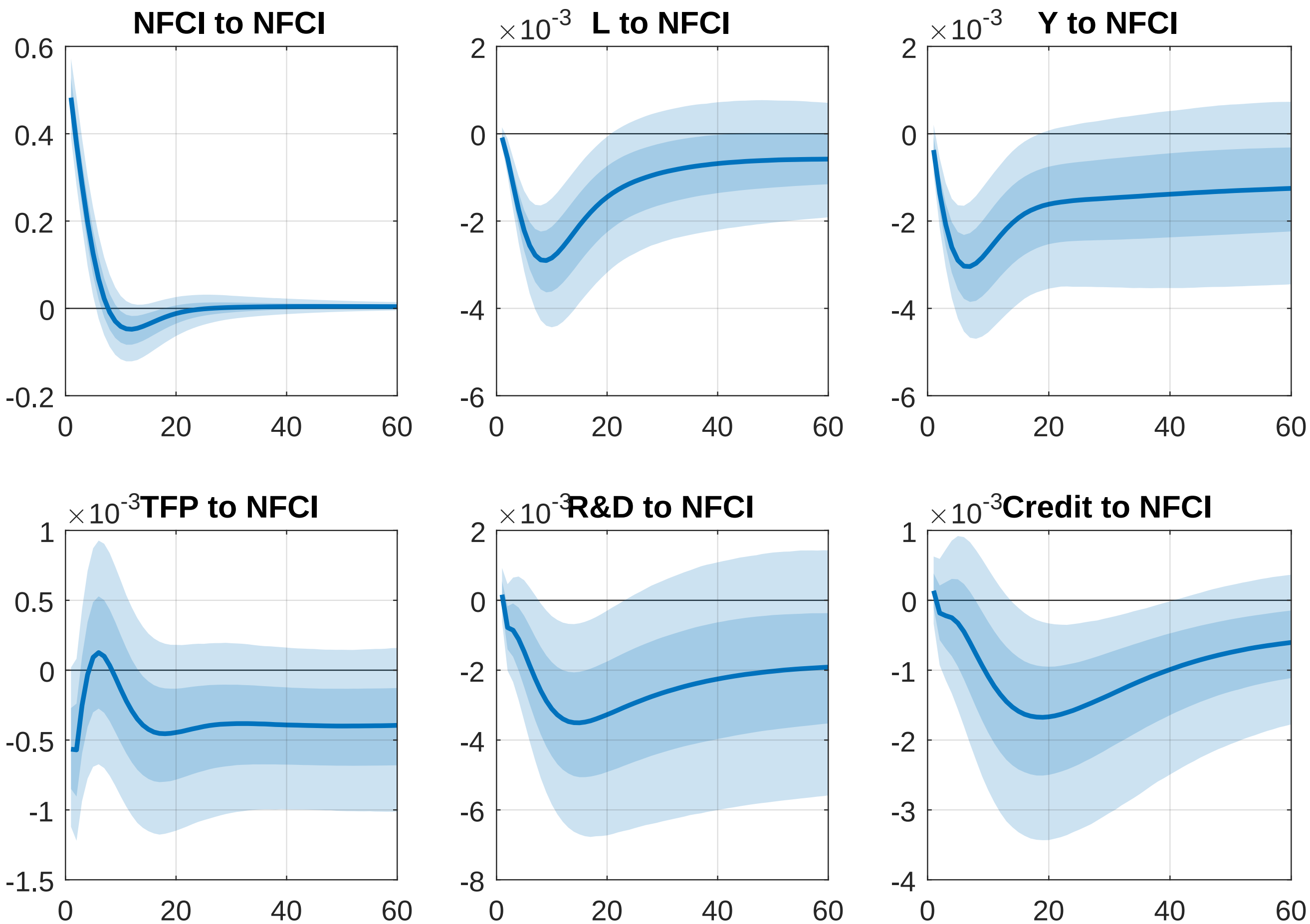
Note: Cross-country panel local projections. Responceses of level variables contingent on the debt-to-GDP value at the onset of a recession. Shaded areas correspond to 90% confidence bounds. Standard errors are clustered at the country level.

Figure 4: Responses to the financial distress shock [cited on page 7]



Note: Cross-country panel local projections. Responceses of level variables to the financial distress shock of Romer and Romer (2017). Shaded areas correspond to 90% confidence bounds. Standard errors are clustered at the country level.

Figure 5: US VAR, responses to the financial conditions shock [cited on page 8]



VAR(2), IRFs of (1) Adjusted NFCI; (2) Total employment; (3) Real GDP; (4) Utilization-adjusted TFP; (5) Real R&D expenditure; (6) Total credit to private non-financial sector, % of GDP. Shaded areas correspond to 90% confidence bound. Responces to variables other than NFCI are expressed in log deviations.

Figure 6: Baseline model flow chart [cited on page 8]

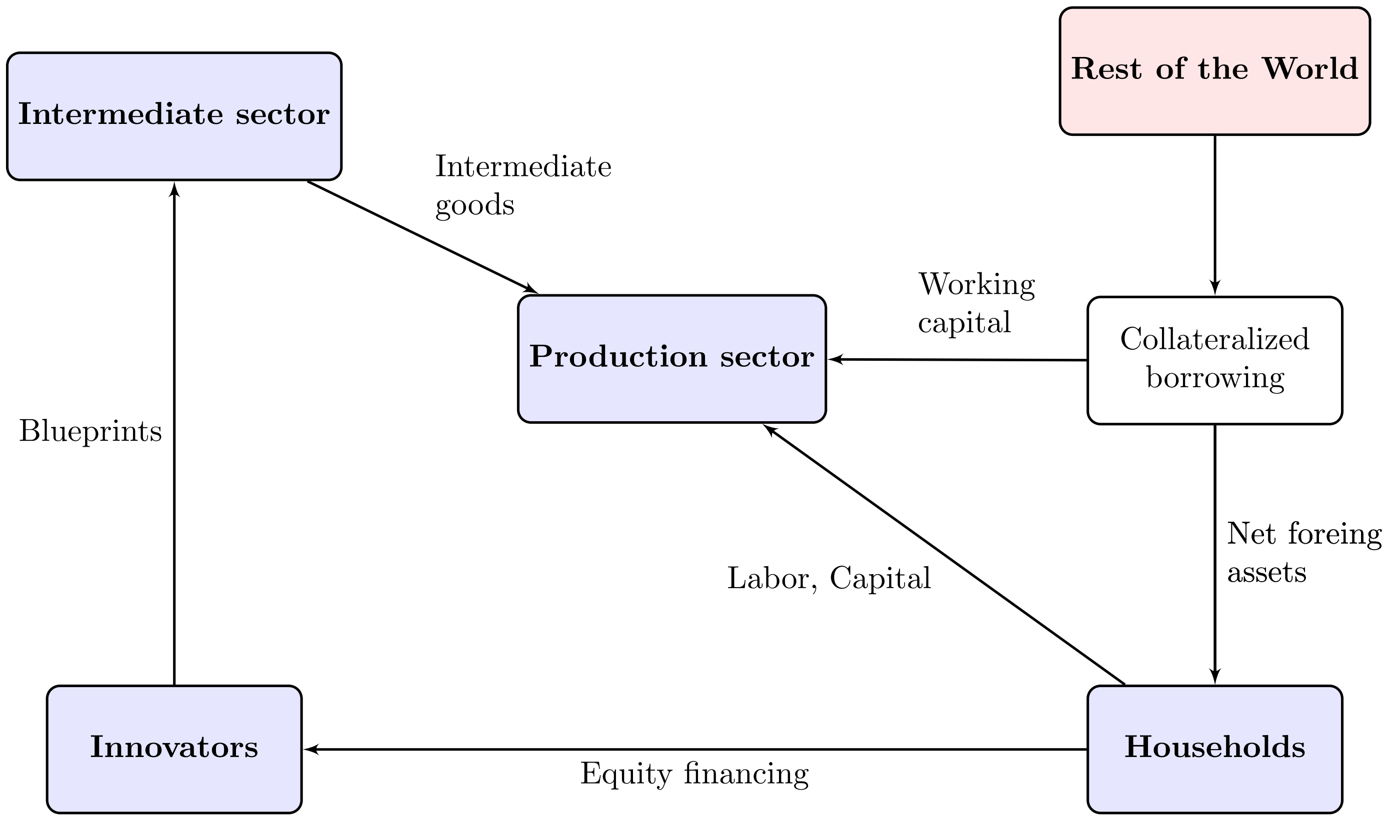


Table 2: Model summary [cited on page 15]

1. Resource constraint	$y_t = c_t + s_t + i_t + \frac{x_t}{A_t}$
2. Capital supply	$q_t = \mathbb{E}_t\left[\beta_{t,t+1}((1-\delta_K)q_{t+1} + R^K_{t+1})\psi_{t+1} + \varrho\mu_t q_t\right]$
3. Capital demand	$R^K_t = \alpha(1-\xi)\frac{y_t}{\psi_t k_t}$
4. Capital accumulation	$k_{t+1}g_{t+1} = (1-\delta_K)\psi_t k_t + (1 - AC_{I,t})i_t$
5. Tobin's q	$q_t = 1 + q_t(AC_{I,t} + AC'_{I,t}i_t) - \mathbb{E}_t\left(\beta_{t,t+1}q_{t+1}AC'_{I,t+1}i_{t+1}\right)$
6. Labor supply	$w_t = \upsilon_t L_t^{\epsilon}$
7. Disutility of labor	$\upsilon_t = (\upsilon_{t-1}/g_t)^{\rho_\Upsilon}$
8. Labor demand	$w_t\left[1 + \zeta\mu_t\right] = (1-\alpha)(1-\xi)\frac{y_t}{L_t}$
9. Consumption Euler	$\mathbb{E}_t\left[\beta_{t,t+1}R_{t+1}\right] = 1 - \mu_t$
10. Borrowing constraint	$\left[\varrho q_t k_{t+1} - b_{t+1} - b^F_{t+1}\right]\mu_t = 0, \quad \mu_t \geq 0$
11. Equity demand	$v_t = d_t + \mathbb{E}_t\left[\beta_{t,t+1}(1-\delta_N)v_{t+1}\right]$
12. Equity supply (free entry)	$v_t = \phi^{-1}s_t^{1-\rho}$
13. Growth rate	$g_t = \phi s_t^{\rho} + (1-\delta_N)$
14. Final output	$y_t = \left(\frac{A\xi}{\nu}\right)^{\frac{\xi}{1-\xi}} Z_t^{\frac{1}{1-\xi}}(\psi_t k_t)^{\alpha}(L_t)^{1-\alpha}$
15. Intermediate output	$x_t = \left(\frac{A\xi}{\nu}\right)^{\frac{1}{1-\xi}} Z_t^{\frac{1}{1-\xi}}(\psi_t k_t)^{\alpha}L_t^{1-\alpha}$
16. Intermediate firm profit	$d_t = (\nu - 1)\frac{x_t}{A}$

Note: where appropriate, lower-case letters denote stationary counterparts of original variables, i.e. $c_t = \frac{C_t}{N_t}$.

Table 3: Structutal parameters [cited on page 15]

			Source / target
γ	Inverse elasticity of intertemporal substitution	2	Conventional
R	Steady-state world interest rate	1.04	Conventional
β	Discount factor	0.9809	g^{γ}/R
ϵ	Inverse elasticity of labor supply	0.25	King and Rebelo (1999)
ρ_{χ}	Disutility of labor inetria	0.95[4]	
α	Capital share	0.33	Conventional
ξ	Intermediate good share	0.5	Comin and Gertler (2006)
ν	Intermediate good elasticity of substitution	1.6	BGP condition: $\frac{\xi(\nu-1)}{1-\xi} = 1-\alpha$
δ_N	Intermediate good depreciation	0.09	Comin and Gertler (2006)
δ_K	Capital depreciation	0.1	Conventional
ψ_K	Capital adjustment cost	2.5	Mendoza (2010)
ψ_B	Debt-elastic interest rate	0.000742	Schmitt-Grohé and Uribe (2003)
b	Steady-state world debt-to-gdp ratio	0.85	Mendoza (2010)
ϱ	Maximum loan-to-value ratio	0.5	Mendoza (2010)
ζ	Working capital requirement	0.25	Mendoza (2010)
ρ	R&D output elasticity	0.8	Comin and Gertler (2006)
ϕ	R&D productivity	0.1650	Annual growth rate = 1%
Z	Steady-state final sector productivity	2.0039	Steady state GDP = 1
A	Intermediate sector productivity	1	Normalization

Note: the model is calibrated at annual frequency.

Figure 7: 1% negative productivity shock [cited on page 16]

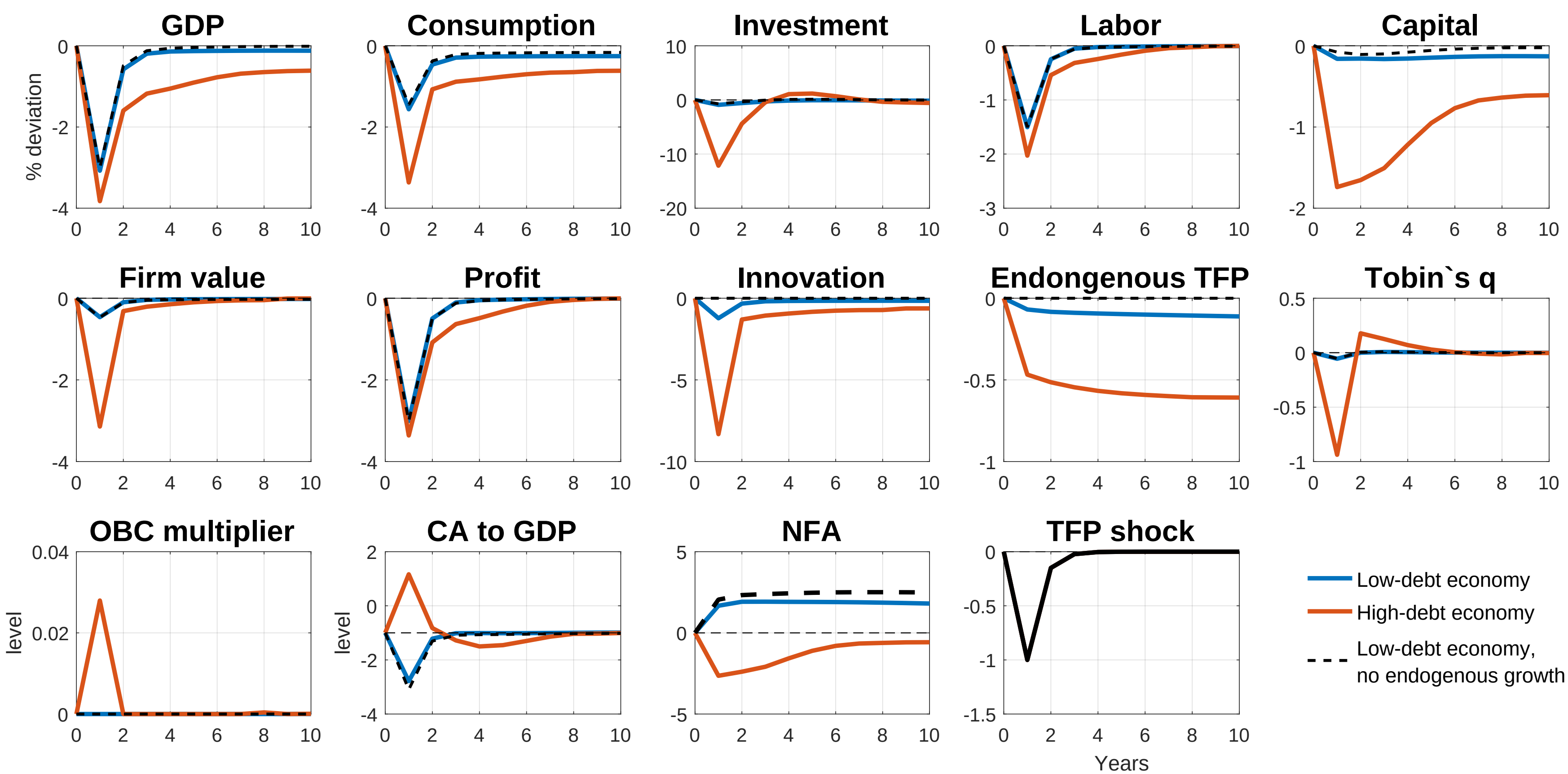
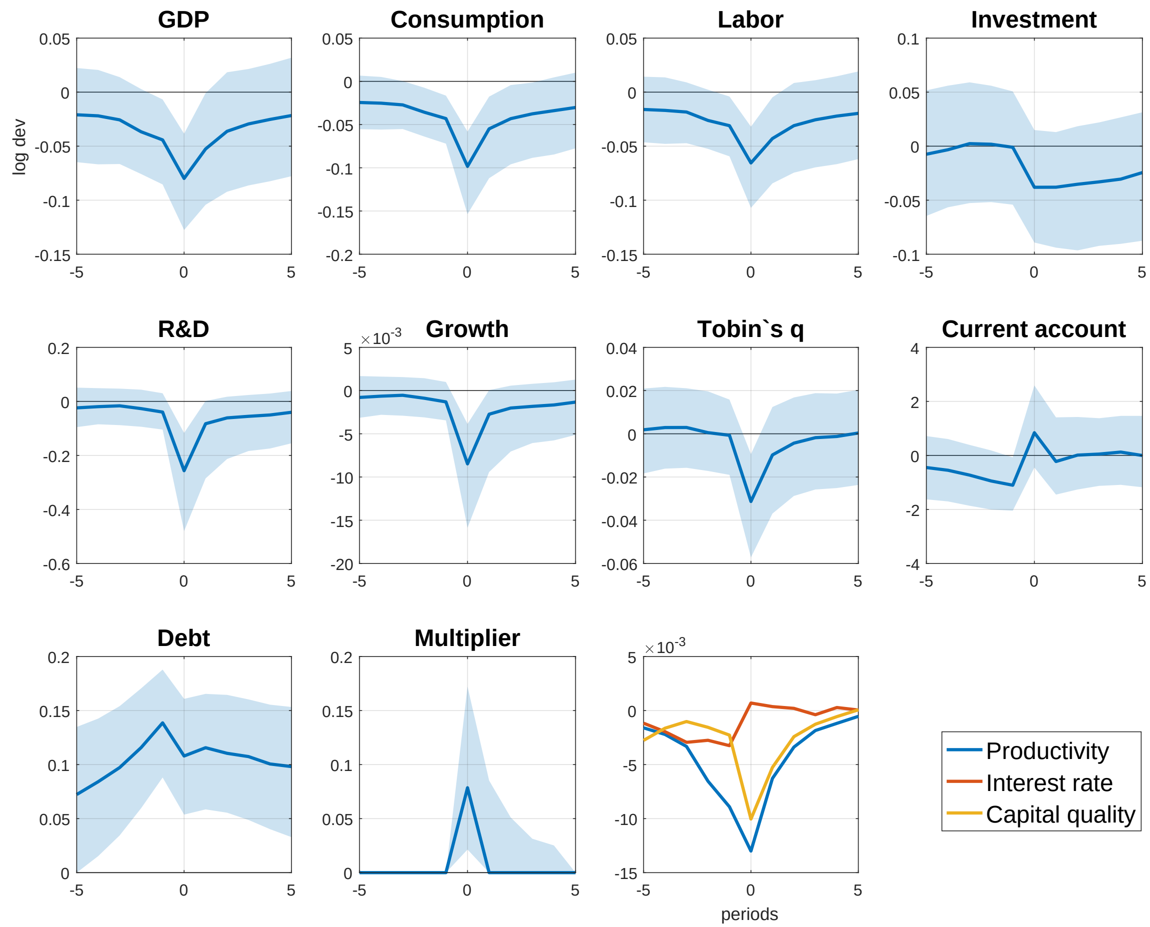


Figure 8: An average financial crisis [cited on page 18]



Note: ten-period windows centered around the periods when the collateral constraint binds ("financial crisis"). Median paths over 100k period simulation. Shaded areas corespond to 64% confidence intervals. Bottom right panel present a median path of exogenous variables driving the dynamics.

References

1. Aguiar, M. and Gopinath, G. (2007). Emerging Market Business Cycles: The Cycle Is the Trend. *Journal of Political Economy*, 115(1):69–102. [Cited on page 3.]
2. Aknc, Ö. and Queralto, A. (2017). Credit Spreads, Financial Crises, and Macroprudential Policy. *Federal Reserve Bank of New York Staff Reports*, 802. [Cited on page 4.]
3. Annicchiarico, B. (2016). Innovation, Growth, and Optimal Monetary Policy. [Cited on page 4.]
4. Anzoategui, D., Comin, D., Gertler, M., and Martinez, J. (2019). Endogenous Technology Adoption and R&D as Sources of Business Cycle Persistence. *American Economic Journal: Macroeconomics*, 11(3):67–110. [Cited on page 4.]
5. Ates, S. T. and Saffie, F. E. (2020). Fewer but Better: Sudden Stops, Firm Entry, and Financial Selection. *American Economic Journal: Macroeconomics*. [Cited on page 4.]
6. Basel Committee on Banking Supervision (2010). Guidance for national authorities operating the countercyclical capital buffer. Technical Report December. [Cited on page 5.]
7. Benhabib, J., Rogerson, R., and Wright, R. (1991). Homework in Macroeconomics: Household Production and Aggregate Fluctuations. *Journal of Political Economy*, 99(6):1166–1187. [Cited on page 12.]
8. Benigno, G., Chen, H., Otrok, C., Rebucci, A., and Young, E. R. (2013). Financial Crises and Macro-prudential Policies. *Journal of International Economics*, 89(2):453–470. [Cited on page 3.]
9. Benigno, G., Chen, H., Otrok, C., Rebucci, A., and Young, E. R. (2016). Optimal Capital Controls and Real Exchange Rate Policies: a Pecuniary Externality Perspective. *Journal of Monetary Economics*, 84:147–165. [Cited on page 3.]
10. Benigno, G. and Fornaro, L. (2018). Stagnation Traps. *Review of Economic Studies*, 85(3):1425–1470. [Cited on page 4.]
11. Bianchi, F., Kung, H., and Morales, G. (2019). Growth, Slowdowns, and Recoveries. *Journal of Monetary Economics*, 101:47–63. [Cited on page 4.]
12. Bianchi, J. and Mendoza, E. G. (2018). Optimal Time-Consistent Macroprudential Policy. [Cited on pages 3 and 13.]
13. Brizhatyuk, D. (2020). Housing Market Cycles, Household Debt, and Productivity Growth. [Cited on pages 21 and 35.]
14. Cerra, V. and Saxena, S. C. (2008). Growth Dynamics: The Myth of Economic Recovery. *American Economic Review*, 98(1):439–457. [Cited on page 3.]
15. Comin, D. and Gertler, M. (2006). Medium-term Business Cycles. *American Economic Review*, 96(3):523–551. [Cited on pages 2, 4, 10, 15, 20, and 28.]
16. Devereux, M. B., Young, E. R., and Yu, C. (2017). A New Dilemma: Capital Controls and Monetary Policy in Sudden-Stop Economies. *SSRN Electronic Journal*, 21791. [Cited

on page 3.]

17. Devereux, M. B. and Yu, C. (2017). Exchange Rate Adjustment in Financial Crises. *IMF Economic Review*, 65(3):528–562. [Cited on page 3.]

18. Fernald, J. G. (2012). A Quarterly, Utilization-Adjusted Series on Total Factor Productivity. *Federal Reserve Bank of San Francisco, Working Paper Series*, pages 01–28. [Cited on page 7.]

19. Ferrero, A. (2015). House price booms, current account deficits, and low interest rates. *Journal of Money, Credit and Banking*, 47(S1):261–293. [Cited on page 12.]

20. Fitzgerald, T. J. and Christiano, L. J. (2003). The Band Pass Filter. *International Economic Review,*, 44(2):435–465. [Cited on pages 2, 20, and 21.]

21. Garcia-Macia, D. (2015). The Financing of Ideas and the Great Deviation. *SIEPR Discussion Paper*. [Cited on page 4.]

22. Garga, V. and Singh, S. (2020). Output Hysteresis and Optimal Monetary Policy. *Journal of Monetary Economics*. [Cited on page 4.]

23. Gertler, M. and Karadi, P. (2011). A Model of Unconventional Monetary Policy. *Journal of Monetary Economics*, 58(1):17–34. [Cited on page 9.]

24. Gertler, M., Kiyotaki, N., and Queralto, A. (2012). Financial Crises, bank Risk Exposure and Government Financial Policy. *Journal of Monetary Economics*, 59(SUPPL.):S17–S34. [Cited on page 9.]

25. Gornemann, N. (2015). Sovereign Default, Private Investment, and Economic Growth. *Mimeo*. [Cited on page 4.]

26. Greenwood, J., Hercowitz, Z., and Huffman, G. W. (1988). Investment, Capacity Utilization and the Real Business Cycle. *The American Economic Review*, 78(3):402–417. [Cited on page 12.]

27. Guerrieri, L. and Iacoviello, M. (2015). OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics*, 70:22–38. [Cited on page 16.]

28. Guerrieri, L. and Iacoviello, M. (2017). Collateral Constraints and Macroeconomic Asymmetries. *Journal of Monetary Economics*, 90:28–49. [Cited on page 4.]

29. Guerron-Quintana, P. A. and Jinnai, R. (2015). Financial Frictions, Trends, and the Great Recession. [Cited on page 4.]

30. Holden, T. D. (2019). Existence and Uniqueness of Solutions to Dynamic Models with Occasionally Binding Constraints. [Cited on page 16.]

31. Holden, T. D., Levine, P., and Swarbrick, J. M. (2019). Credit Crunches from Occasionally Binding Bank Borrowing Constraints. *Journal of Money, Credit and Banking*. [Cited on page 4.]

32. Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, 95(3):739–764. [Cited on page 12.]

33. Ikeda, D. and Kurozumi, T. (2014). TCER Working Paper Series Post-Crisis Slow

Recovery and Monetary Policy. [Cited on page 4.]

34. Ilzetzki, E., Reinhart, C. M., and Rogoff, K. S. (2019). Exchange Arrangements Entering the Twenty-First Century: Which Anchor will Hold? *The Quarterly Journal of Economics*, 134(2):599–646. [Cited on page 6.]

35. Jaimovich, N. and Rebelo, S. (2009). Can News about the Future Drive the Business Cycle? *American Economic Review*, 99(4):1097–1118. [Cited on page 12.]

36. Jensen, H., Ravn, S. H., and Santoro, E. (2016). Deepening Contractions and Collateral Constraints. [Cited on page 4.]

37. Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American Economic Review*, 95(1):161–182. [Cited on page 5.]

38. Jordà, Ò., Schularick, M., and Taylor, A. M. (2013). When Credit Bites Back. *Journal of Money, Credit and Banking*, 45(2):3–28. [Cited on page 3.]

39. Kilian, L. and Lütkepohl, H. (2017). *Structural Vector Autoregressive Analysis*. [Cited on page 7.]

40. King, R. G. and Rebelo, S. T. (1999). Resuscitating Real Business Cycles. *Handbook of Macroeconomics*, 1:927–1007. [Cited on pages 15 and 28.]

41. Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2):211–248. [Cited on page 12.]

42. Korinek, A. (2008). Regulating Capital Flows to Emerging Markets : An Externality View Externalities in borrowing. *NBER Working Paper 24152*. [Cited on page 3.]

43. Kung, H. and Schmid, L. (2015). Innovation, Growth, and Asset Prices. *Journal of Finance*, 70(3):1001–1037. [Cited on page 4.]

44. Laeven, L. and Valencia, F. (2013). Systemic Banking Crises Database. *IMF Economic Review*, 61(2):225–270. [Cited on page 5.]

45. Liu, Z., Miao, J., and Zha, T. (2016). Land Prices and Unemployment. *Journal of Monetary Economics*, 80:86–105. [Cited on page 12.]

46. Liu, Z., Wang, P., and Zha, T. (2013). Land-Price Dynamics and Macroeconomic Fluctuations. *Econometrica*, 81(3):1147–1184. [Cited on page 12.]

47. Maffezzoli, M., Monacelli, T., and Maffezzoli, M. (2015). Deleverage and Financial Fragility Deleverage and Financial Fragility. [Cited on page 4.]

48. Martone, A. (2002). On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations. [Cited on page 5.]

49. Mbaye, S., Moreno Badia, M., and Chae, K. (2018). Global Debt Database: Methodology and Sources. *IMF Working Paper*. [Cited on page 4.]

50. Mendoza, E. G. (1991). Real Business Cycles in a Small Open Economy. *The American Economic Review*, 81(4):797–818. [Cited on page 12.]

51. Mendoza, E. G. (2010). Sudden Stops, Financial Crises, and Leverage. *American Economic Review*, 100(5):1941–1966. [Cited on pages 3, 8, 13, 14, 15, 18, and 28.]

52. Merton, R. C. (1973). An Intertemporal Capital Asset Pricing Model. *Econometrica*, 41(5):867. [Cited on page 8.]

53. Moran, P. and Queralto, A. (2018). Innovation, Productivity, and Monetary Policy. *Journal of Monetary Economics*, 93:24–41. [Cited on page 4.]

54. Queraltó, A. (2013). A Quantitative Model of Slow Recoveries from Financial Crises. *International Finance Discussion Papers, Board of Governors*, pages 1–48. [Cited on page 4.]

55. Queralto, A. (2019). A Model of Slow Recoveries from Financial Crises. *Journal of Monetary Economics*. [Cited on page 12.]

56. Raffo, A. (2008). Net Exports, Consumption Volatility and International Business Cycle Models. *Journal of International Economics*, 75(1):14–29. [Cited on page 12.]

57. Romer, C. D. and Romer, D. H. (2017). New Evidence on the Aftermath of Financial Crises in Advanced Countries. *American Economic Review*, 107(10):3072–3118. [Cited on pages 3, 6, 7, and 24.]

58. Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy*, pages 71–102. [Cited on pages 3, 8, and 10.]

59. Schmitt-Grohé, S. and Uribe, M. (2003). Closing Small Open Economy Models. *Journal of International Economics*, 61(1):163–185. [Cited on pages 14, 15, and 28.]

60. Schumacher, M. and Ochowski, D. (2017). The Risk Premium Channel and Long-Term Growth. *SSRN Electronic Journal*. [Cited on page 4.]

A Appendix

Table 4: Country sample [cited on page 4]

AUS	ESP	ITA	PRT
AUT	FIN	KOR	RUS
BEL	FRA	LTU	SGP
BGR	GBR	LUX	SVK
BRA	GRC	MEX	SVN
CAN	HKG	MYS	SWE
CHE	HRV	NLD	THA
CHL	HUN	NOR	TUR
COL	IDN	NZL	ZAF
CZE	IRL	PER	
DNK	ISR	POL	

Note: ISO 3166-1 alpha-3 codes. 42 small open economies.

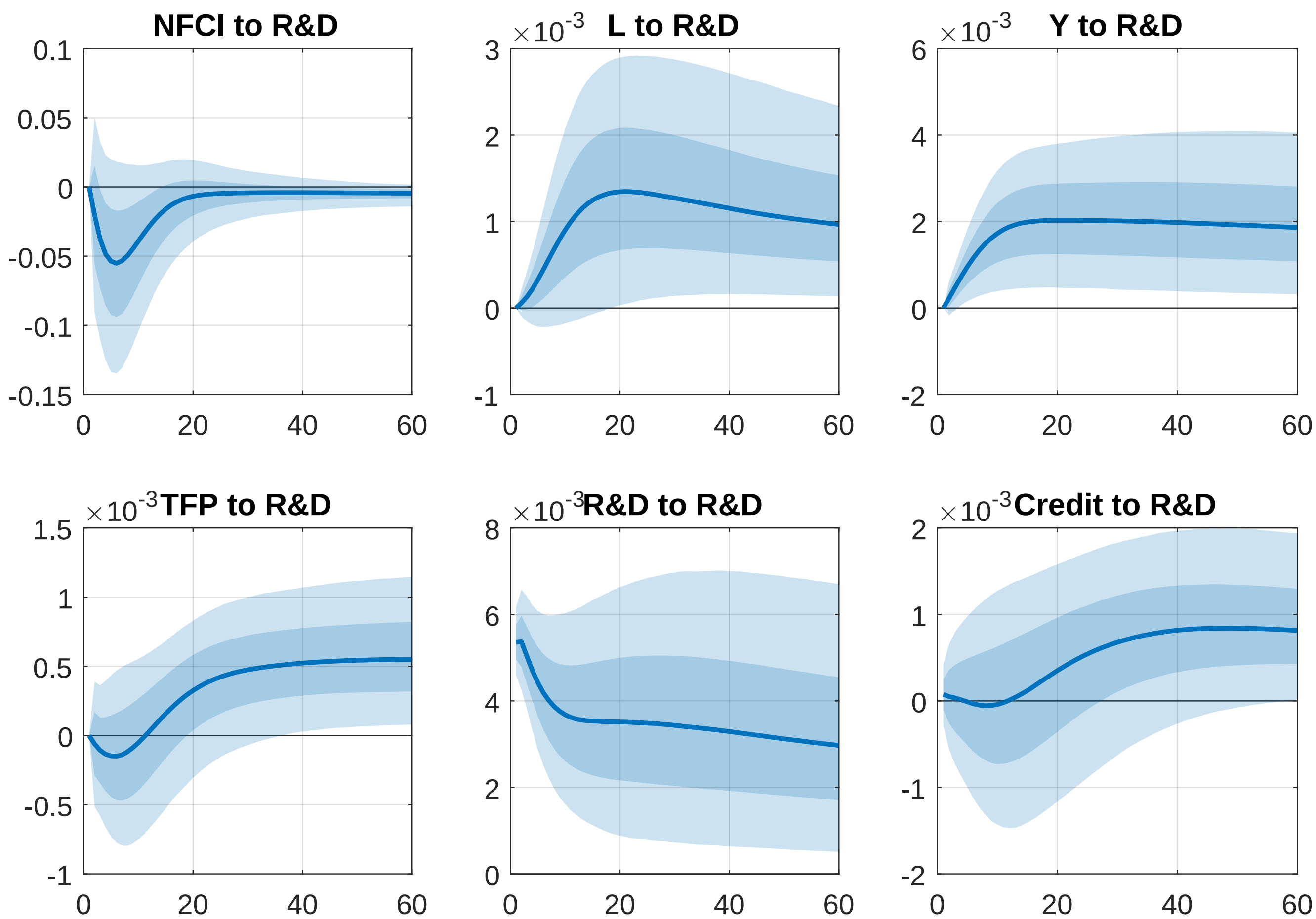
Table 5: Summary statistics

		Obs.	Mean	Median	St. dev.
1.	ΔY	2474	0.025	0.026	0.037
2.	ΔC	2474	0.023	0.023	0.0364
3.	ΔK	2474	0.027	0.023	0.022
4.	ΔI	1967	0.038	0.042	0.101
5.	ΔTFP_{adj}	2306	0.007	0.006	0.021
6.	ΔB	1838	0.026	0.023	0.089
7.	Credit gap	1796	1.614	1.055	10.357
8.	CA to GDP	1543	-0.477	-1.005	6.368
9.	$\log(RER)$	2289	4.556	4.562	0.326

Note: Unbalanced panel of 42 small open economies, annual observations 1950-2017. Δ denotes log differences. (1) Real per capita GDP; (2) Real per capita consumption; (3) Real per capita capital, all from Penn World Table, v. 9.0. (4) Real per capita investment, World Bank. (5) Utilization-adjusted TFP index, Brizhatyuk (2020). (6) Private debt, loans and debt securities, % of GDP, IMF Global Debt Database. (7) Private credit-to-GDP gap, (8) Current account to GDP, author's calculations based on the IMF data. (9) Real exchange rate index, Bruegel.

Private credit-to-GDP gap is defined as a deviation of the private debt-to-GDP ratio from the long-run HP trend. According to the BIS definition, the smoothing parameter of the HP trend is 400000 for quarterly data (corresponds to $400000/4^4$ for annual data)

Figure 9: US VAR, responses to an R&D shock [cited on page 8]



VAR(2), IRFs of (1) Adjusted NFCI; (2) Total employment; (3) Real GDP; (4) Utilization-adjusted TFP; (5) Real R&D expenditure; (6) Total credit to private non-financial sector, % of GDP. Shaded areas correspond to 68% and 95% confidence bounds and are obtained by bootstrap with 50000 replications. Responces to variables other than NFCI are expressed in log deviations.