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Financial Crises, Investment Slumps, and Slow Recoveries

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Financial Crises, Investment Slumps, and Slow Recoveries[1]

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Abstract

One of the most puzzling facts in the wake of the Global Financial Crisis (GFC) is that output across advanced and emerging economies recovered at a much slower rate than anticipated by most forecasting agencies. This paper delves into the mechanics behind the observed slow recovery and the associated permanent output losses in the aftermath of the crisis, with a particular focus on the role played by financial frictions and investment dynamics. The paper provides two main contributions. First, we empirically document that lower investment during financial crises is the key factor leading to permanent loss of output and total factor productivity (TFP) in the wake of a crisis. Second, we develop a DSGE model with financial frictions and capital-embodied technological change capable of reproducing the empirical facts. We also evaluate the role of financial policies in stabilizing output and TFP in response to disruptions in financial markets.

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1 Introduction

One of the most puzzling facts in the wake of the Global Financial Crisis (GFC) has been that output across advanced and emerging economies recovered at a much slower rate than anticipated by most forecasters. Cerra and Saxena (2008), IMF (2010; 2018), and Cerra and Saxena (2017), among others, have documented how major financial crisis episodes are followed by slow recoveries of output. Moreover, Cerra and Saxena (2008) show that crises typically generate permanent output losses relative to pre-crisis trend. While there is now a consensus on the empirical facts of output dynamics in the aftermath of financial crises, there is no agreement in the literature regarding the underlying mechanism driving the permanent output losses. The main goal of this paper is to understand the mechanics of slow recoveries with a particular focus on the role played by financial frictions and investment dynamics in the aftermath of crises.

Figure 1 motivates our analysis by showing the dynamics of output, investment, R&D, and total factor productivity in Brazil, France, South Korea and the US.[1] All four countries experienced a permanent loss of output relative to the pre-crisis trend. This decline is associated with a persistent reduction in Total Factor Productivity (TFP) as it is shown in the fourth column. Recent papers rationalize the decline of output and TFP using endogenous growth models with a research and development (R&D) sector.[2] However, in practice, the data shows that the decline in TFP might be unrelated to shifts in R&D. As shown in the third column, R&D continued to grow in most countries at the pre-crisis trend in the aftermath of the global financial crisis.[3]

In this paper, we develop an alternative hypothesis for the persistent decline in TFP observed across countries, focusing on the role of financial frictions and investment dynamics. As shown in the second column, the dynamics of investment are correlated with those of TFP. One key element of investment is that it can enhance TFP in the case of capital-embodied technological change. In the paper, we evaluate the role of investment slumps and financial frictions,

[1]The TFP is measured as a Solow residual, by subtracting factors of production from output: $LnTFP_t = LnY_t - \alpha LnK_t - (1-\alpha)LnL_t$, where Y_t, K_t, and L_t are output, capital and labor, respectively. We set $\alpha = 0.3$, which is in the mid-range of the estimates obtained by Gollin (2002) for a cross section of countries.

[2]See Anzoategui et al. (2019), Bianchi et al. (2019), Guerron-Quintana and Jinnai (2019), Ikeda and Koruzomi (2018), and Queralto (2019).

[3]In the US, R&D spending experienced a small permanent loss relative to the pre-crises trend. However, the dynamics of TFP is more correlated with investment. In section 2.3 we evaluate in a regression analysis the relationship between R&D spending, investment, and TFP.

which are exacerbated during crises, in accounting for slow recoveries.

We provide empirical evidence accounting for the dynamics of output, investment, and TFP following financial crises. We do so by presenting three different empirical results. First, cross-country distributions of deviations from pre-crisis trends show that output, investment, and TFP tend to be lower after banking crises. Second, following Cerra and Saxena (2008), we estimate the medium-term effects of banking crises and corroborate the result that crises episodes are associated with negative permanent effects not only on output but also on TFP. Credit also declines, suggesting that a tightening of financial conditions play a role in accounting for the output losses. Finally, we conduct regressions of the medium-term determinants of TFP losses during the GFC. We find that around half of the decline of medium-term TFP is associated with an initial reduction of investment experienced in the immediate years of the GFC. All these results provide empirical support for the existence of a mechanism through which tighter financial conditions constrain investment, and thereby also depress TFP in the medium-term, implying a persistent decline in aggregate supply and a weak recovery.

We also develop a DSGE model consistent with these empirical facts. We build a closed economy real business cycle model which is extended in two dimensions. First, we add a financial accelerator mechanism as in Bernanke et al. (1999) where financial frictions at the firm level amplify the shocks in the economy through the investment channel. Second and most importantly, we introduce a model with endogenous capital-embodied technological change (Greenwood et al., 1997), where investment leads not only to the accumulation of physical capital but also to an increase in the quality of capital and a higher measured total factor productivity (TFP).

There are two main results from the model simulations. First, the model is capable of reproducing the key dynamics of output, investment, and TFP in both advanced and emerging economies in the aftermath of the global financial crisis. The two key frictions featured in our model are essential for reproducing the data. Second, we evaluate the role of financial policies in reducing the magnitude of permanent output losses. We find that macroprudential polices, modeled as a state contingent spread on borrowing, can not only stabilize financial intermediation and investment in the short run but also can lead to smaller TFP losses in the medium term.

Our paper is related to the literature on slow recoveries and hysteresis. Since the recent global financial crisis, significant attention has been devoted to the literature of slow economic recoveries (Ball (2014), Rawdanowicz et al. (2014), Reinhart and Rogoff (2009, 2014) Reifschneider, Wascher and Wilcox (2015), Cerra and Saxena (2017), Fatas and Mihov (2013), among others).

In particular, our paper is closely related to a growing literature trying to account for the hysteresis effects of financial crises such as Bianchi et al. (2019), Guerron-Quintana and Jinnai (2019), Ikeda and Koruzomi (2019), and Queralto (2019) based on R&D endogenous growth models. The contribution of our paper is to develop an alternative hypothesis for explaining slow recoveries consistent with the observed investment and TFP dynamics. The model also provides a specific role for financial policies in stabilizing output in the short and medium run.

Finally, the endogenous relationship between investment and total factor productivity featured in our model is related to the broader literature on endogenous growth, such as learning by doing externalities, human capital accumulation, and R&D (Stadler (1986), Stadler (1990), Stiglitz (1993), and Fatas(2000))[4].

The remainder of the paper is organized as follows. Section 2 presents evidence on macroeconomic dynamics in the aftermath of financial crises. Section 3 lays out the DSGE model featuring capital-embodied technological change and financial frictions. Section 4 presents the simulation results for advanced and emerging economies. Section 5 concludes.

2 Empirical Evidence

This section provides empirical evidence on the dynamics of output, investment, and productivity surrounding financial crises. We focus our analysis on three different estimations. First, we look at the cross-country distribution of the losses of output, investment, and productivity relative to their pre-crisis trends. Second, we document the dynamics of the same variables following the work of Cerra and Saxena (2008). Third, we estimate the medium-term determinants of TFP.

2.1 Distribution of Deviations from Pre-crisis Trend

Figure 2 summarizes the distributions of post-crisis (i.e., 2015-2017) deviations of output, investment, R&D and productivity from their pre-crisis trends estimated for the period 2000-2008. The distributions are computed for two different samples: countries that experienced a banking crisis and countries that did not experience a crisis during the global financial crisis (i.e. 2007-2008). The sample of countries that experienced banking crises are chosen from the database developed by Laeven and Valencia (2013). The number of countries

[4]See Cerra, Fatas, and Saxena (2021) for the detailed survey of the literature.

with a banking crisis is 24, and the countries that did not have a banking crisis are 168. The blue line represents the kernel density distribution of the countries that experienced a crisis and the red line represents the distribution of the non-crisis sample. There is a common pattern for investment, output, and productivity. Namely, the distributions of the countries experiencing a banking crisis are shifted to the left of the distributions of the non-crisis sample, which indicates that financial crises and tightening of financial conditions amplify the deviations or losses relative to the pre-crisis trend. In addition, we can observe a reduction in the variance of the distribution for the crisis samples, indicating that permanent output losses become more likely in the aftermath of a financial crisis. This suggests a potential link between investment, productivity, and output during the banking crisis. In contrast, R&D did not show any notable difference between the two samples of countries. This implies that R&D might not be playing a crucial role in amplifying the impact on output in the aftermath of a banking crisis.

2.2 Hysteresis Effects in the Aftermath of Financial Crises

In order to evaluate the dynamics of our variables of interest in the aftermath of a banking crisis, we conducted a univariate autoregressive panel data analysis following Cerra and Saxena (2008). The univariate model includes lagged variables in growth rates (e.g. GDP growth) and lagged dummy variables of banking crisis (Laeven and Valencia 2018). The number of lags for the model were determined by using the AIC and BIC criteria. We estimate the following univariate model:

$$x_{i,t} = \alpha_i + \sum_{j=1}^{J} \beta_j x_{i,t-j} + \sum_{l=0}^{L} \delta_l D_{i,t-l} + \varepsilon_{i,t},$$

where $x_{i,t}$ is the growth rate of variables of interest (Output, TFP, Investment, and Credit) for country i and year t, α_i is a country fixed effect following Cerra and Saxena (2008), $D_{i,t-l}$ is a banking crisis dummy variable.

Figure 3 presents the impulse responses in levels at an annual frequency. Output dropped 7 percent initially and remained persistently depressed for 10 years in response to a banking crisis shock. TFP declined around 5 percent. Investment exhibits a persistent contraction of around 20 percent after 10 years. Credit (domestic credit to the private sector by banks) falls nearly 40 percent over the medium to long run. These results suggest a strong comovement between financial intermediation, TFP, and investment in the aftermath of banking crises across countries.

2.3 Regression Analysis of Medium-term Determinants of TFP

In this subsection, we evaluate the effects of a contraction in investment on medium-term TFP across countries. In the regression analysis, the dependent variable is the average TFP loss during the period 2015-2017 for all countries for which data is available. The loss is calculated as the deviation from the pre-crisis linear trend. The pre-crisis trend is estimated for the sample period 2000-2008. Table 1 and 2 summarize the empirical results. The independent variables are calculated as the average deviation from trend for the period 2008-2010. The time gap between dependent and independent variables helps to avoid endogeneity or a reverse causality relationship in the regression analysis, and also enables us to quantify the impact of a drop in the independent variable on medium-term TFP losses.

Table 1 shows two main results from the regression analysis. First, the investment loss has a positive and statistically significant coefficient on medium-term TFP losses. A 1 percent loss of investment leads to 0.5 percent loss of TFP in the medium term. The effect is robust in alternative model specifications with multiple control variables (Model 6) and including investment in equipment (Table 2). This differs from standard growth theories in two key ways. First, the standard endogenous growth theory assumes that TFP is driven by technological change in the R&D sector that is independent from the investment in physical capital. Second, the standard neoclassical growth model associated with RBC theory assumes diminishing returns to capital. This implies a high growth spurt in investment and capital accumulation in the aftermath of an adverse shock to capital, which is contrary to the empirical findings.

The second finding is that the drop in credit (domestic credit to the private sector by banks) has a significant impact on medium-term productivity loss. This implies that a shock to financial intermediation can result in medium-term losses in TFP, leading to a contraction in the aggregate supply. Moreover, losses in R&D do not have a significant effect on mid-term productivity after a financial crisis according to results from a single factor regression and a regression with multiple control variables.

Table 1: Medium-term TFP Losses and Investment

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$inv_{loss}^{0810,ave}$	0.529**					0.601*
	(0.149)					(0.263)
$credit_{loss}^{0810,ave}$		-0.115*				-0.188
		(0.049)				(0.301)
$Real\ Rate^{0810,diff}$			0.000			-0.010*
			(0.003)			(0.004)
$R\&D_{loss}^{0810,ave}$				0.109		0.143
				(0.193)		(0.193)
$ygap^{0810,ave}$					0.002	-0.016
					(0.003)	(0.011)
Constant	-0.038**	-0.040**	-0.055**	-0.098**	-0.046**	-0.043*
	(0.013)	(0.014)	(0.016)	(0.021)	(0.012)	(0.020)
Observations	107	104	76	50	80	35
R-squared	0.107	0.052	0.000	0.007	0.005	0.369

Standard errors in parentheses
** p<0.01, * p<0.05

Dependent Variable: Deviations of TFP from pre-crisis trend during 2015-2017.

Table 2: Medium-term TFP Loss and Equipment Investment

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$equip_{loss}^{0810,ave}$	0.187**					0.303
	(0.053)					(0.157)
$credit_{loss}^{0810,ave}$		-0.115*				-0.043
		(0.049)				(0.320)
$Real\ Rate^{0810,diff}$			0.000			-0.006
			(0.003)			(0.005)
$R\&D_{loss}^{0810,ave}$				0.109		0.241
				(0.193)		(0.189)
$ygap^{0810,ave}$					0.002	-0.014
					(0.003)	(0.011)
Constant	-0.018	-0.040**	-0.055**	-0.098**	-0.046**	-0.020
	(0.015)	(0.014)	(0.016)	(0.021)	(0.012)	(0.027)
Observations	107	104	76	50	80	35
R-squared	0.107	0.052	0.000	0.007	0.005	0.340

Standard errors in parentheses
** p<0.01, * p<0.05

Dependent Variable: Deviations of TFP from pre-crisis trend during 2015-2017.

3 Model

We follow Carlstrom and Fuerst (1997) and Bernanke et al. (1999) and consider a closed economy model with flexible prices and a financial accelerator mechanism. The model features entrepreneurs, capital goods producers, households, and a financial intermediary. Households earn their income from wages, interest from deposits, and firm's profits. Deposits are allocated to financial intermediaries. Entrepreneurs produce output by purchasing capital produced by capital goods producers and hiring labor supplied by households. Entrepreneurs funds their projects by relying on their own net worth and borrowing from financial intermediaries. The model also features capital-embodied technological change following Greenwood et al. (1997).

3.1 Households

Households optimally supply labor, consume, and save by allocating a fraction of their income to deposits in a financial intermediary. The households' optimization problem is the following:

$$\max_{C_t, D_t, L_t} E_t \sum_{k=0}^{\infty} (\xi_t^P \beta)^k \left[u(C_{t+k}, 1 - L_{t+k}) \right]$$

subject to

$$C_t + D_t = W_t L_t + D_{t-1} R_t + T_t + \Pi_t,$$

where D_t are deposits, C_t is consumption, L_t is the labor supply, Π_t are profits from firms, and T_t is a lump-sum tax from the government. ξ_t^P is a preference shock which follows an AR(1) process $log\xi_t^P = \rho_P log\xi_{t-1}^P + \varepsilon_t^P$.The first-order conditions for consumption yields the standard Euler equation:

$$E_t \left[\frac{\xi_t^P \beta E_t u'(C_{t+1})}{u'(C_t)} R_{t+1} \right] = 1.$$

The labor supply is determined by:

$$W_t = \frac{u_{c,t}}{u_{l,t}}.$$

3.2 Entrepreneurs

Entrepreneurs finance the purchase of capital goods ($K_{i,t+1}$) by relying on their own net worth ($N_{i,t+1}$) and borrowing from financial intermediaries ($B_{i,t+1}$). Their balance sheet is given by:

$$Q_t K_{i,t+1} = N_{i,t+1} + B_{i,t+1},$$

where Q_t is the price of capital. The return to capital is subject to idiosyncratic risk. The return to capital by the entrepreneur "i" is given by $\omega^i R_{k,t}$, where ω^i is the idiosyncratic risk and $R_{k,t}$ is the aggregate return to capital. The idiosyncratic disturbance ω^i follows a log-normal distribution $ln\ \omega \sim N\left(\frac{-\sigma_\omega^2}{2}, \sigma_\omega^2\right)$. This process has a mean $E[\omega] = 1$ with a cdf $F(\omega)$.

At "t-1" entrepreneurs borrows B_t from a financial intermediary at a gross interest rate Z_t. After the idiosyncratic and aggregate risk are materialized, the entrepreneurs receive a gross revenue of $\omega R_{k,t} Q_{t-1} K_t$. The entrepreneurs solve the following profit-maximization problem:[5]

$$\max_{K_t,\overline{\omega}_t} E_{t-1} \int_{\overline{\omega}_t}^{\infty} [\omega R_{k,t} Q_{t-1} K_t - Z_t B_t] dF(\omega).$$

subject to

$$R_t(Q_{t-1}K_t - N_t) = [\Gamma(\overline{\omega}_t) - \mu G(\overline{\omega}_t)] R_{k,t} Q_{t-1} K_t.$$

where

$$\Gamma(\overline{\omega}_t) \equiv \int_0^{\overline{\omega}} f(\omega) d\omega + \overline{\omega} \int_{\overline{\omega}}^{\infty} f(\omega) d\omega.$$

$$\mu G(\overline{\omega}_t) \equiv \mu \int_0^{\overline{\omega}} \omega f(\omega) d\omega.$$

The objective function is the expected profit of the entrepreneurs. The budget constraint is the zero-profit condition of the lenders. The left-hand side of the equation indicates the opportunity cost of lending to the entrepreneurs ($R_t B_t = R_t(Q_{t-1}K_t - N_t)$). The right-hand side of the equation indicate the net returns from risky lending to the entrepreneurs. $\Gamma(\overline{\omega}_t)$ captures the gross return for lenders and $\mu G(\overline{\omega}_t)$ as the expected monitoring costs incurred by the financial intermediary to verify the underlying financial condition of the entrepreneurs that go bankrupt and exhibit a low idiosyncratic return on capital ($\omega < \overline{\omega}$).

[5] Notice that the optimal contract and the aggregate loan supply is the same across entrepreneurs, therefore we dropped the index "i".

Since there is a perfect competition in the financial market in equilibrium, the return of lending at the risk-free rate should equalize the net returns from risky loans, hence the budget constraint is satisfied with equality. The solution to the profit-maximization problem generates an equilibrium relationship between the external finance premium $E\left\{\frac{R_{k,t+1}}{R_{t+1}}\right\}$ and the leverage ratio $\left(\frac{Q_t K_{i,t+1}}{N_{i,t+1}}\right)$:

$$E\left\{\frac{R_{k,t+1}}{R_{t+1}}\right\} = s\left(\frac{Q_t K_{i,t+1}}{N_{i,t+1}}\right).$$

The return on capital is defined as:

$$R_{k,t} = \frac{X_t + (1-\delta)Q_t}{Q_{t-1}},$$

where the marginal productivity of capital $X_t = \alpha\frac{Y_t}{K_t}$. A fraction of entrepreneurs $(1-\gamma)$ fail and consume the entrepreneurial profit V_t:

$$C_t^e = (1-\gamma)V_t,$$

where

$$V_t = R_{k,t}Q_{t-1}K_t - \left(R_t + \frac{\mu\int_0^{\overline{\omega}_t} dF(\omega)R_{k,t}Q_{t-1}K_t}{Q_{t-1}K_t - N_t}\right)(Q_{t-1}K_t - N_t),$$

and V_t is the gross return on capital less the cost of servicing the debt by solvent firms, less total monitoring costs. The fraction γ of entrepreneurs who are still in business reinvest the entrepreneurial profit in the net worth of the firm. The evolution of the net worth is given by:

$$N_t = \gamma V_t + W^e - \xi_t^N,$$

where W^e is a "start up" lump transfer from households to new entrepreneurs and ξ_t^N is a net worth shock that follows an AR(1) process $log\xi_t^N = \rho_N log\xi_{t-1}^N + \varepsilon_t^N$.[6]

3.3 Aggregate Production Function

The aggregate production function in this economy is given by:

$$Y_t = A_t(e_t K_t)^{\alpha}(L_t)^{(1-\alpha)},$$

[6] The net worth shock induces fluctuation in the entrepreneurs' net worth. This shock plays a similar role to financial shock in Jermann and Quadrini (2012).

where L_t is labor, K_t the stock of capital, and e_t is a variable capturing capital-embodied technological change which evolves according to the following process:

$$e_t = \phi e_{t-1} + \mu^i i_t.$$

where i_t is aggregate real investment. The parameter μ^i governs the impact of investment on technological change and ϕ determines the persistence of e_t. This equation departs from the standard neoclassical framework, since productivity can endogenously change because of the technology embodied in the purchase of new capital goods. Iterating backwards this last equation, we obtain the following expression:

$$e_t = \sum_{j=0}^{\infty} \phi^j((1-\phi)\mu^i i_{t-j}).$$

This specification is the same formulation as in Greenwood et al. (1997) which propose a model that endogenize investment-specific technological shocks.[7] A_t is an exogenous technology shock, which follows a first-order autoregressive process with an iid error term:

$$logA_t = \rho_A logA_{t-1} + \varepsilon_{A,t},$$

where $\varepsilon_{A,t} \overset{iid}{\sim} N(0, \sigma_A^2)$. Measured total factor productivity (TFP) is defined as:

$$TFP_t \equiv \frac{Y_t}{(K_t)^{\alpha}(L_t)^{(1-\alpha)}} = A_t(e_t)^{\alpha}.$$

3.4 Capital Goods Producer and Market Clearing Conditions

Capital goods firms produce capital and the production process entails investment adjustment costs. Their maximization problem is given by:

$$\max_{K_{t+1}, I_t} E_t \sum_{k=0}^{\infty} (\beta)^k \left[Q_{t+k}K_{t+k+1} - Q_{t+k}(1-\delta)K_{t+k} - I_{t+k}\right]$$

subject to

$$K_{t+1} = \Phi\left(\frac{I_t}{K_t}\right)K_t + (1-\delta)K_t$$

[7]Greenwood et al. (1997) call this mechanism "investment-specific externalities", which is a way to endogenize investment-specific technological shocks.

The price of capital (Tobin's Q) is given by:

$$Q_t = \left[\Phi'\left(\frac{I_t}{K_t}\right)\right]^{-1}.$$

Labor market clearing condition is given by:

$$(1-\alpha)\frac{Y_t}{L_t} = \frac{u_{c,t}}{u_{l,t}}.$$

The resource constraint of the economy is given by:

$$Y_t = C_t^e + C_t + \Phi\left(\frac{I_t}{K_t}\right)K_t + G_t + \mu\int_0^{\overline{\omega}_t} dF(\omega)R_{k,t}Q_{t-1}K_t,$$

where C_t^e is the consumption by entrepreneurs and $\mu\int_0^{\overline{\omega}_t} dF(\omega)R_{k,t}Q_{t-1}K_t$ are the aggregate monitoring costs.

4 Quantitative Analysis

4.1 Calibration

The benchmark model is calibrated to the United States economy at an annual frequency. Most of the model parameters are standard in the literature. The ones pertaining to the financial accelerator are taken from Bernanke et al. (1999). We set the discount factor $\beta = 0.96$, consistent with an annual interest rate of 4 percent. The elasticity of labor supply is set to $\eta = 3$. The labor share α is set to 0.65. Consistent with the literature, we consider an annual depreciation rate of 10 percent ($\delta = 0.10$). We follow Bernanke et al. (1999) and assume that the elasticity of the price of capital with respect to the investment capital ratio φ is 0.25. We calibrate the share of government spending to 20 percent of GDP ($G/Y = 0.2$).We also consider a log-separable utility function:

$$u(C, 1-L) = \ln(C) + ln(1-L)$$

Following Bernanke et al. (1999), the external finance premium at the steady $R^K - R$ is set to 200 basis points, which corresponds to the historical spread between the prime lending rate and the six-month Treasury bill rate. The capital to net worth ratio K/N is assumed to be 4, and the business failure rate $F(\overline{\omega})$ three percent in annual basis (where $F(\omega)$ is the cdf of the idiosyncratic shock ω). We consider that 10.88 percent of the entrepreneurs exit every period. We set the monitoring cost parameter μ to 0.12 .

The other key parameters in the model are the ones that determine the dynamics of endogenous TFP (ϕ and μ^i). We impose a restriction of homogeneity ($\mu^i = 1 - \phi$) and calibrate the parameter values to match the dynamics of TFP and investment presented in Figure 3 ($\phi = 0.31$ and $\mu = 0.69$).[8] We consider a persistence of 0.95 for technology and net worth shock and a persistence of 0.85 for the preference shock. Table 3 summarizes the calibrated parameters of the model for the US economy.

We also explore the model implications with an alternative calibration for a benchmark emerging economy. The calibration of the financial accelerator block for the emerging economy follows Gulan and Fernandez (2015). The discount rate is set to β= 0.922. We consider a depreciation rate of 20 percent ($\delta\ = 0.2$). The exit rate of entrepreneurs $1 - \gamma$ is set to 0.34. The monitoring parameter μ is calibrated to 0.324, the external finance premium $R^K - R$ to 0.025, and the bankruptcy rate $F(\overline{\omega})$ to 0.05. Section 4.5 reports the simulations under the emerging economy calibration.

Table 3: Baseline Calibration

Parameter	Value	Description
β	0.96	Discount rate
η	3.00	Elasticity of labor supply
α	0.35	Effective capital share
δ	0.1	Normal (Aggregate) capital depreciation rate
φ	0.25	Elasticity of the price of capital w.r.t. investment capital ratio
$1-\gamma$	0.1088	Death rate of entrepreneurs
ϕ	0.31	Depreciation parameter
ν	0.77	Investment-specific technological change
μ	0.12	Monitoring parameter
$R^k - R$	0.02	Steady-state external finance premium
K/N	4.00	Ratio of capital to net worth
$F(\overline{\omega})$	0.03	Target failure rate
C/Y	0.61	Steady-state proportion of consumption
C^e/Y	0.01	Steady-state proportion of entrepreneur consumption
I/Y	0.18	Steady-state proportion of investment
G/Y	0.20	Steady-state proportion of government expenditures
ρ^a	0.95	TFP shock persistence
ρ^p	0.85	Preference shock persistence
ρ^N	0.95	Net Worth shock persistence

[8]For a given the path of investment, those parameters are capable of reproduce the dynamics of TFP in response to a financial crisis (Figure 3). The homogeneity condition ensures a unique rational expectations equilibrium, and prevents an explosive path for TFP.

4.2 Impulse Response Functions

Figure 4 plots the impulse response functions of the model calibrated to the US economy. We report the responses to negative technology, preference, and net worth shocks. We consider three versions of the model for obtaining intuition of how the proposed combination of frictions can lead to slow recoveries.

The first row reports the responses to a 1 percent technology shock. The blue line shows the responses in the frictionless RBC model.[9] As expected, a decline in productivity leads to lower consumption, investment, and output. The red line represents the model with the financial accelerator mechanism (BGG). The financial accelerator amplifies the effect of investment in response to a negative technology shock, leading to a larger contraction of investment and output. The green line considers both the financial accelerator mechanism and capital-embodied technological change (CETC). In this last specification we observe an amplifying effect on the measured TFP, due to the fact that a decline in the purchase of equipment leads to a lower efficiency in the production function. Notice that this last specification leads to a substantial decline in output and consumption. Since a decline in investment has a first-order effect on TFP, on impact firms prefer not to cut investment as much as in the specification without capital-embodied technological change in the medium term. The fact that lower TFP reduces the profits of the firms, optimally, they decide to reduce investment by less.

The second row shows the responses to a preference shock. For this shock we obtain similar results to the previous case. Under the financial accelerator the decline in output is magnified. When we add capital-embodied technological change (CETC) the model generates a large and persistent decline in GDP. Notice that CETC is necessary to generate a decline in the endogenous component of TFP in response to the preference shock. The third row reports the model dynamics in response to a net worth shock. Notice that in the RBC model, in the absence of financial frictions, the net worth shocks do not have any impact on the economy. The effects of the net worth shock also generate a large and protracted impact on the output and TFP in the CETC specification.

To summarize, for different shocks, we find that the financial accelerator mechanism adds persistence to the output through a larger response of investment. Furthermore, the capital-embodied technological change adds additional persistence to output through endogenous changes in TFP. The combination of these two frictions reinforce each other generating output losses and slow

[9] Notice that in the RBC and BGG models, blue and red lines respectively, the dynamics of TFP are the same as in both cases and this variable is purely exogenous. In the case of the CETC model, TFP differs from the other two cases, as it has an endogenous component driven by capital-embodied technological change.

recoveries. In the next sections we simulate the macroeconomic impact of a financial crisis in the US and in emerging economies. We simulate a financial crisis through a destruction of net worth that propagates to the real economy through the financial accelerator mechanism and capital-embodied technological change. The goal is to evaluate to what extent our model is capable of reproducing the macroeconomic data during episodes of financial crises.

4.3 Financial Crises and Slow Recoveries in the US

In this subsection we investigate to what extent our model can account for the slow recovery observed in the US in the aftermath of the global financial crisis. In figure 5 we present the deviations of the data with respect to the pre-crisis trend for GDP, consumption, investment, and TFP, following the same methodology as in the empirical section. We then evaluate to what extent the model is successful in replicating the slow recovery following the financial crisis. We consider a shock to the net worth that is calibrated to match medium-term effect on GDP. While by construction the model is capable of matching the output dynamics, we find that it also broadly reproduces the medium-term losses of investment, consumption, and TFP. These three variables in the theoretical model were not calibrated to match the data, yet they broadly reproduce the dynamics of the data in the aftermath of a crisis, indicating support for our proposed mechanism. Interestingly, our model can account for almost all the decline in TFP with an endogenous mechanism, in which the aggregate efficiency is influenced by new investment. Figure 6 presents a sensitivity analysis to the elasticity of the spread to leverage ratio ($\nu = (s'/s)(QK/N)$), the elasticity of investment to TFP (μ^i), and the steady-state ratio of investment to GDP.[10] The higher ν and μ^i, the larger the effects of the financial accelerator and the capital-embodied technological change. Furthermore, a higher investment to GDP ratio amplifies the hysteresis effects in the model as it increases the impact of both the financial accelerator and the capital-embodied technological change channels. We find that for a wide range of parameter values, the key results of the model hold, and the combination of financial frictions and endogenous productivity induce slow recoveries.

[10]Notice that ν captures the intensity of the financial accelerator mechanism. In the log-linearized model, the financial contract leads to the following log-linear relationship: $E_t(r^k_{t+1} - r_t) = \nu(n_t - q_t - k_t)$ where x_t is the log-deviation of the variable X_t. The larger ν, the larger the amplification effects due to the financial accelerator mechanism.

4.4 Financial Crises and Slow Recoveries in Emerging Economies

Figure 7 plots the responses of the model calibrated to emerging economies. In the figure, we compare the model dynamics against the deviations of the data with respect to the trend. The data reflects the average macroeconomic detrended series for those emerging economies that experienced a banking crisis in the aftermath of the global financial crisis: Hungary, Kazakhstan, Mongolia, Russia, and Ukraine. We calculate detrended GDP, TFP, Investment, and Consumption for each of these economies and Figure 7 reports for each variable the weighted average of these countries, using 2017 PPP GDP as weights. Notice that in this sample of emerging economies the impact of the financial crisis on the real economy is significantly higher than in the US. Over the medium term these economies report a decline in detrended output of 30 percent and a decline of investment of 60 percent.

We follow the same approach before, and simulate the financial crisis as a shock to the net worth. We calibrate the shock to match the decline of GDP and evaluate the endogenous response of the other variables. Consistent with the results obtained for the US economy, we observe that a financial shock is propagated in the economy resulting in a significant reduction of TFP, investment, and consumption. The model broadly reproduces the data, and more importantly it broadly captures the decline in TFP associated with the slump in investment and the financial crisis.

4.5 Financial Polices and Macroeconomic Stabilization in the Aftermath of Financial Crises

In this subsection, we study the role of financial policies in preventing slow recoveries in the aftermath of a financial crisis. Following Carrillo et al. (2018) we consider a financial policy that consists of a subsidy to financial intermediaries. This financial subsidy modifies the incentive compatible constraint of the financial contract:

$$R_t(Q_{t-1}K_t - N_t) = (1+\tau_t)[\Gamma(\overline{\omega}_t) - \mu G(\overline{\omega}_t)]R_{k,t}Q_{t-1}K_t.$$

The subsidy τ_t increases the profits of the financial intermediary resulting in an expansion of the credit supply. Furthermore, the external financial premium of the entrepreneurs is reduced according to the following equation:

$$E_t\left\{\frac{R^K_{t+1}}{R_{t+1}}\right\} = \frac{s\left(\frac{Q_tK_{t+1}}{N_{t+1}}\right)}{1+\tau^f_t.}$$

We follow Carrillo et al. (2018) and assume that the policy rule for this financial subsidy responds to the external finance premium according to the following equation:

$$1+\tau_t^f = \left(\frac{1+\tau_{t-1}^f}{1+\tau^f}\right)^{\rho_f} \cdot \left(\frac{E_t\{R_{t+1}^k/R_{t+1}\}}{R^k/R}\right)^{\theta},$$

where $\theta > 0$ governs how strongly the subsidy reacts to the external finance premium. The intuition behind this equation is that the larger the external finance premium, the greater is the financial subsidy to intermediaries, resulting in an expansion of credit to the corporate sector and a reduction in the borrowing costs. In turn, this stabilizes the economy by stimulating credit to the entrepreneurs, investment, output, and ultimately TFP.

Figure 8 shows the model dynamics for the US in response to a net worth shock. The blue line presents our baseline model in the absence of any policy intervention and this is consistent with the simulation for the US presented in Figure 5. The black line is the model dynamics assuming that firms fully internalize the impact of investment on TFP.[11] In this situation, in spite of having a financial shock, the recession is mild as firms decide not to reduce investment as much as in the baseline scenario, resulting in a much smaller contraction of TFP, consumption, and GDP. The green line assumes $\theta = 1$, and financial policies can reduce the extent of the slow recovery by stimulating investment, with positive effects on TFP and GDP. Finally, the red line assumes $\theta = 8.5$, which minimizes the distance between the model with policies and the one with the efficient allocation. This policy brings the allocation close to the efficient one, and largely reduces the output losses associated with the financial crisis. The model suggests a prominent role for financial policies in preventing output losses by stimulating credit to the corporate sector and investment, and allowing firms to adopt newer technologies with positive effects on TFP and output.

5 Concluding Remarks

One of the most puzzling facts in the wake of the Global Financial Crisis is that output across advanced and emerging economies has not recovered relative to the pre-crisis trend. Most of the literature accounts for this slowdown by relying on endogenous growth models where the slowdown in productivity is

[11] In this case, firms can fully appropriate the social returns from investing in physical capital. The return to capital incorporating the additional impact from capital-embodied technological change is defined as $R_{k,t} = \frac{X_t+(1-\delta)Q_t}{Q_{t-1}}$, where $X_t = \alpha\frac{Y_t}{K_t} + \alpha\frac{Y_t}{e_t}(1-\phi)$.

generated by a reduction in R&D. In this paper, we present evidence against this hypothesis and show that instead, the fall in investment and the associated capital-embodied technological change seems to be the main factor behind the persistent slowdown in output and productivity.

This paper provides two main contributions. First, we empirically document the dynamics of output, investment, and TFP in the aftermath of financial crises and show that crises generate permanent losses of output and TFP. Second, we develop a DSGE model with capital-embodied technological change and financial frictions capable of reproducing the empirical facts. We also evaluate the role of financial policies in stabilizing output and TFP in response to disruptions in financial markets. We leave for future research the role of alternative polices (fiscal and monetary) in preventing slow recoveries.

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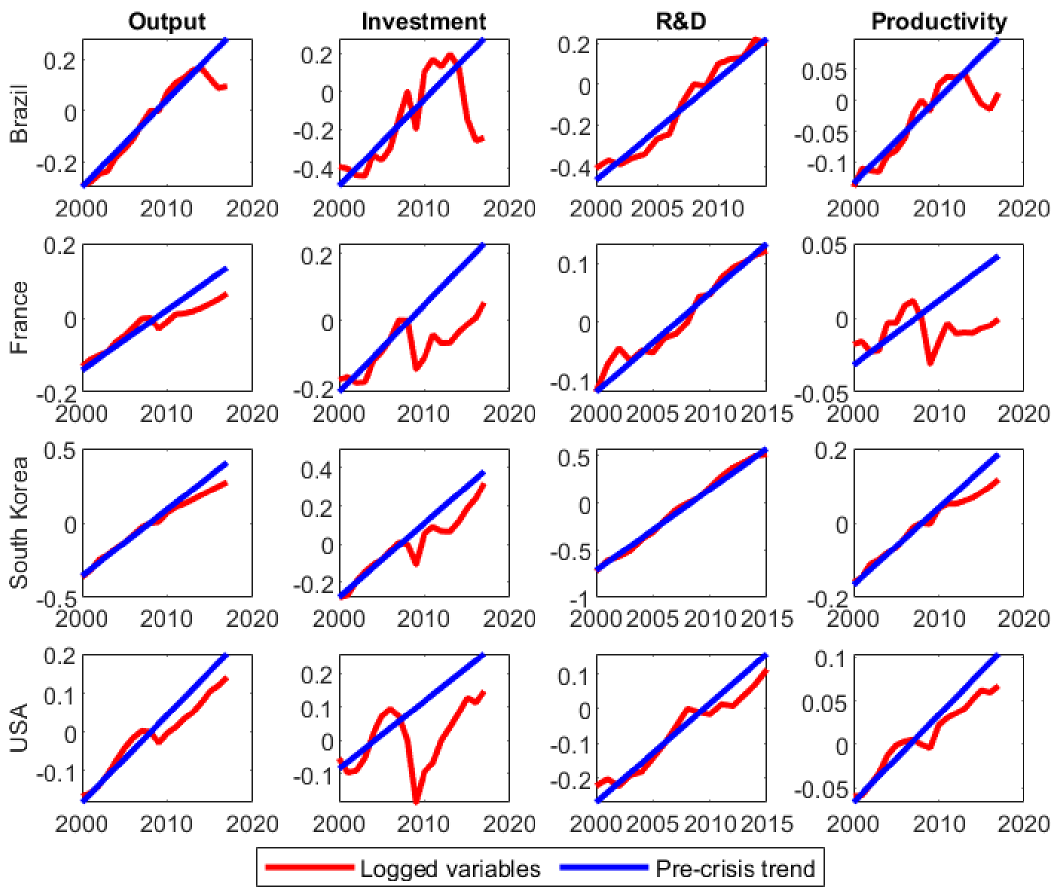
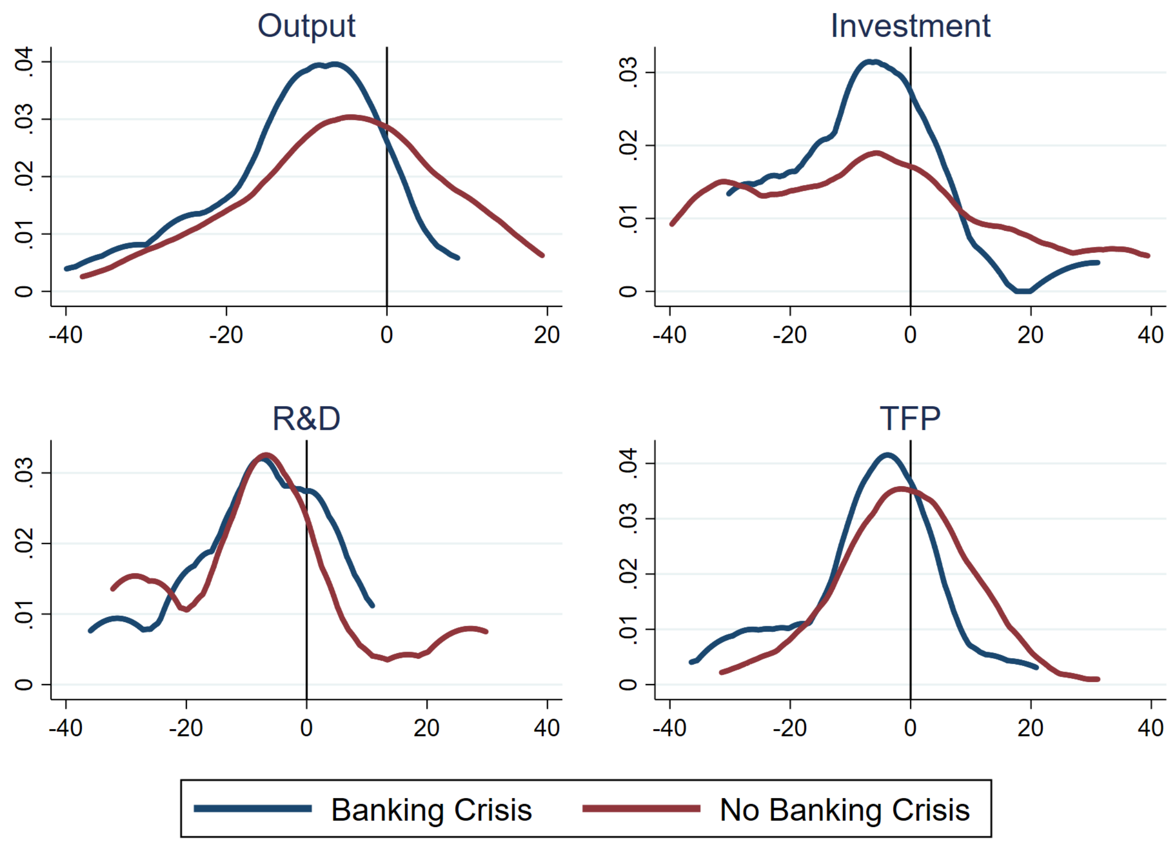
Figure 1: Deviations from Pre-crisis Trend: US, Korea, Brazil, and France



Source: IMF World Economic Outlook; and authors' calculations
Note: The blue lines are pre-crisis linear trends estimated from filtered (Hodrick-Prescott filter) series between 2000 and 2008 and are extrapolated linearly thereafter. 2008 log variables normalized to zero.

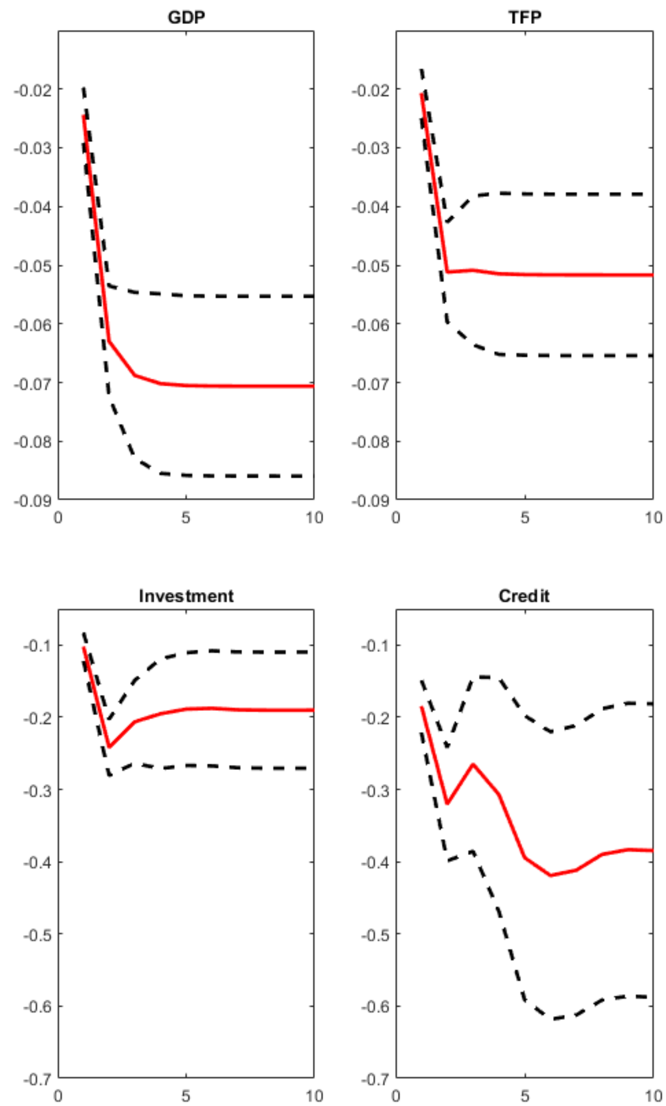
Figure 2: Distribution of Deviations from Pre-crisis Trend



Source: Laeven and Valencia (2013); IMF World Economic Outlook; and authors' calculations

Distribution of average percent deviations in years 2015-2017 from pre-crisis trend. The deviations from pre-crisis trend are calculated by detrending each variable using a linear trend estimated for the sample period 2000-2008. The blue line represents the kernel density distribution of the countries that experienced a crisis and the red line represents the distribution of the non-crisis sample.

Figure 3: Empirical Impulse Response Functions



Source: IMF World Economic Outlook; and authors' calculations

Figure 4: Model-based Impulse Response Functions

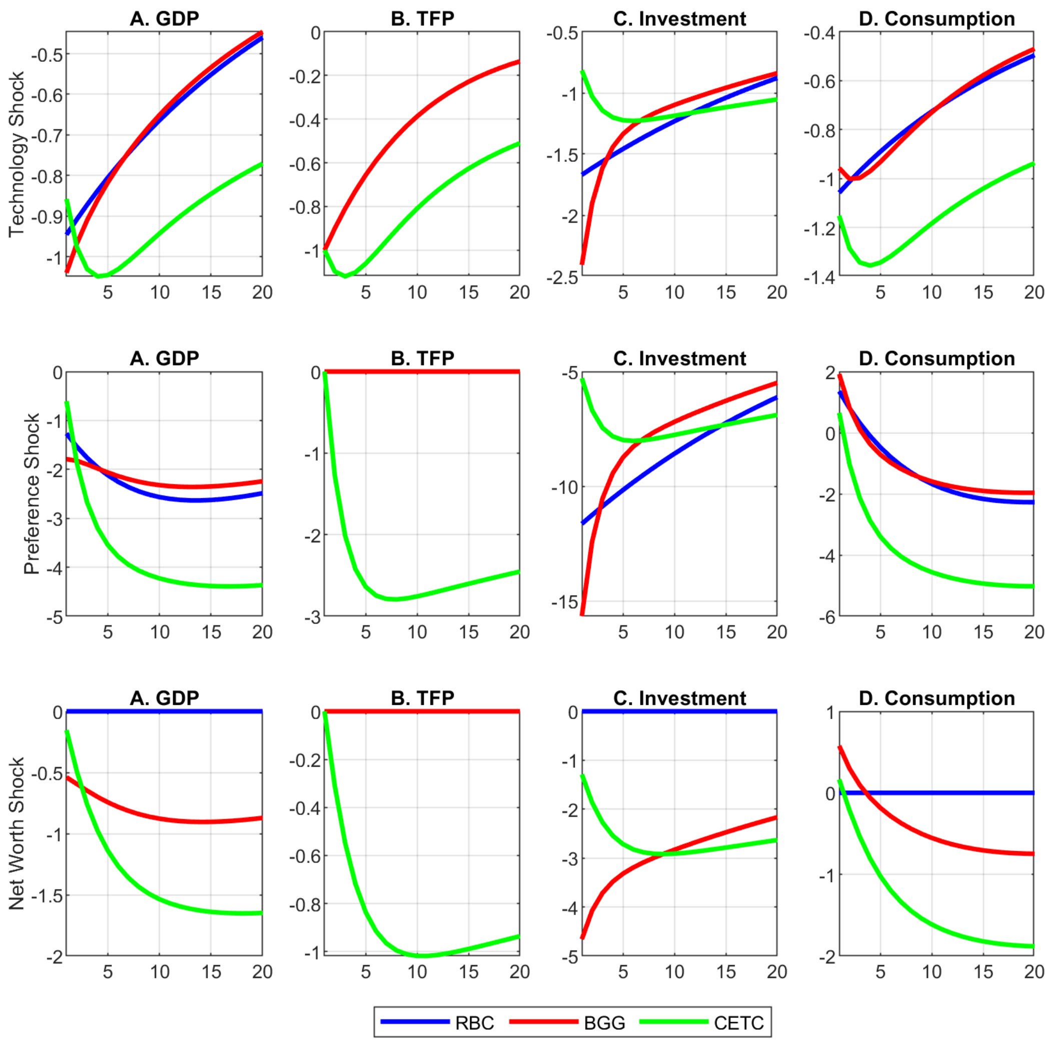


Figure 5: Financial Crises and Hysteresis Effects in the US

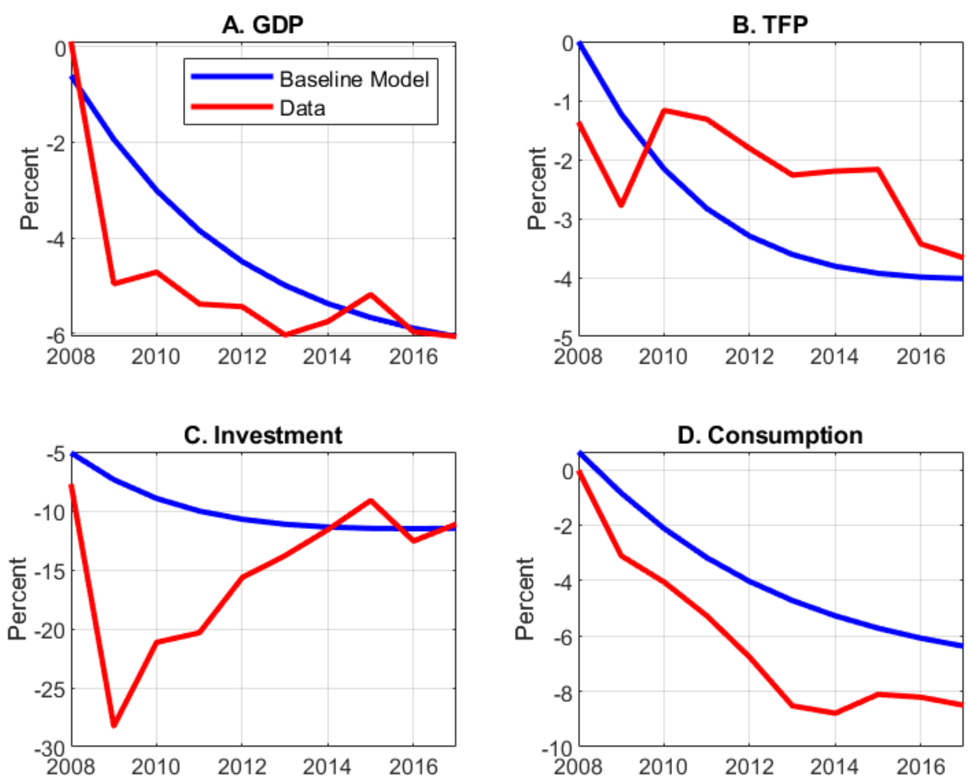


Figure 6: Sensitivity Analysis

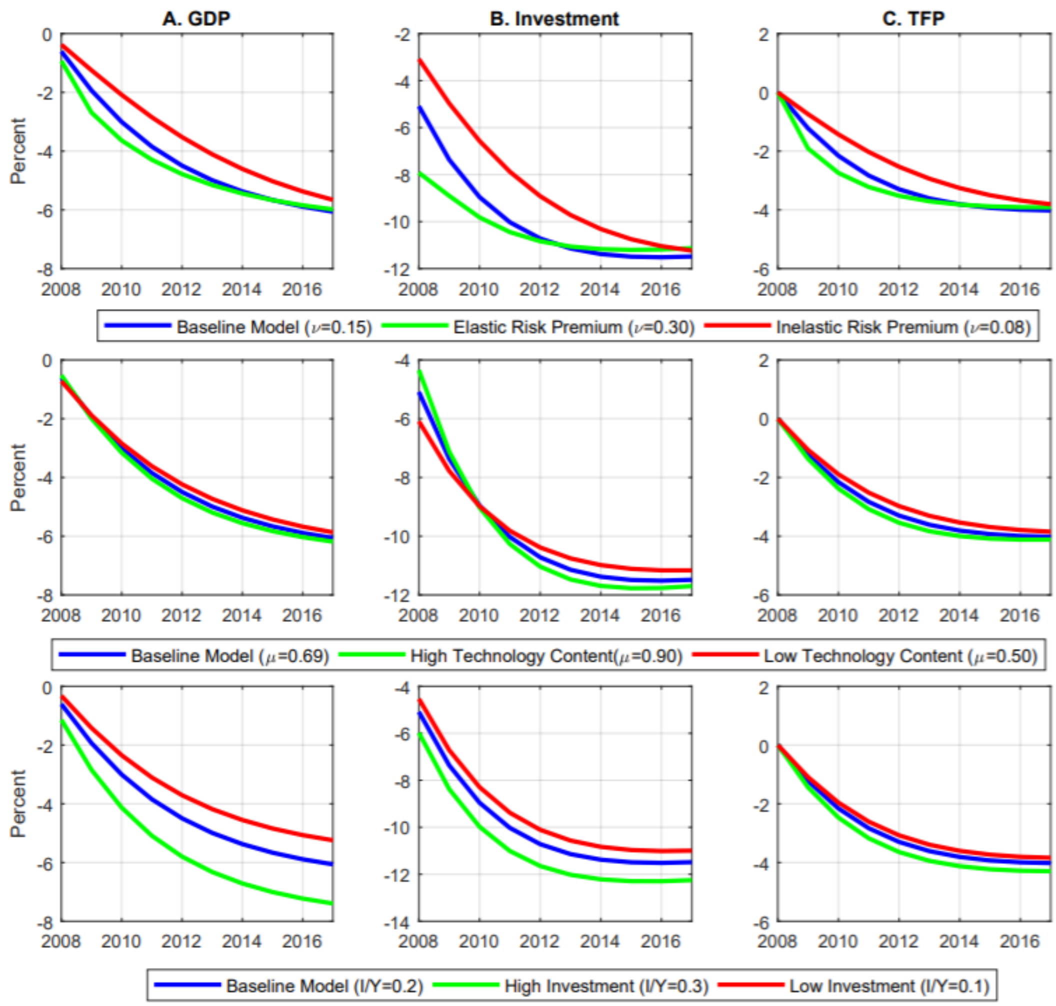


Figure 7: Financial Crises and Hysteresis Effects in the Emerging Economies

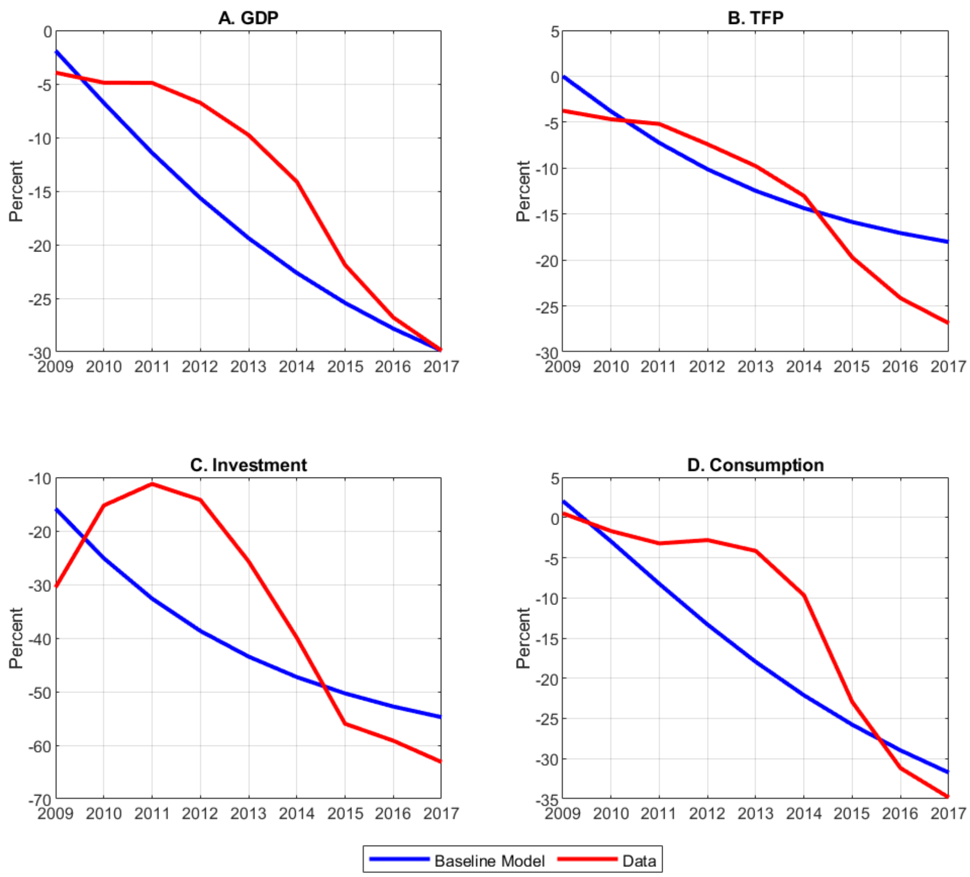


Figure 8: Financial Policies and Hysteresis Effects