Estimating Hysteresis Effects in Times of Crises*

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Abstract

One of the most puzzling facts following the Global Financial Crisis (GFC) is that output in both advanced and emerging economies did not return to its pre-crisis trend, contrary to what standard macroeconomic models would have predicted. This paper analyzes the factors behind output hysteresis, with a special focus on the role played by financial crises. The paper shows that financial crises are associated with medium-term output and total factor productivity (TFP) losses, suggesting that these crises lead to "scarring" effects on the supply side of the economy. The paper also examines how additional factors, such as investment, research and development (R&D), and the effects of currency and debt crises, contribute to these permanent losses. Our empirical findings are broadly consistent with models featuring endogenous productivity and capital-embodied technological change, which suggest that a contraction in investment hinders the adoption of new technologies, ultimately reducing medium-term TFP and output.

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1 Introduction

One of the most puzzling facts after the Global Financial Crisis (GFC) is that output across advanced and emerging economies has failed to return to their pre-crisis trend. This outcome contradicts the predictions of standard textbook macroeconomic models and forecasting agencies, which typically view crises as transitory shocks. Cerra and Saxena (2008), IMF (2009, 2018), and Cerra and Saxena (2017), among others, have documented how major financial crisis episodes and large recessions are followed by permanent losses of output relative to its pre-crisis trend, often referred to in the literature as hysteresis effects. As discussed in Cerra et al. (2023) and Furlanetto et al. (2024), these permanent losses relative to trend might be puzzling through the lens of conventional macroeconomic models, where standard business cycle shocks have only transitory effects on output and long-term growth is driven by permanent supply shocks. However, in order to account for hysteresis effects, a unified framework is necessary—one in which transitory shocks hitting an economy not only explain business cycle patterns but also the permanent effects on output. While there is broad consensus in the empirical literature that large recessions might induce scarring effects on output, there is no agreement regarding the underlying channels driving permanent output losses. The main goal of this paper is to analyze the transmission channels of hysteresis effects, with a particular focus on the role played by banking crises and the associated investment contractions (in physical capital and research and development [R&D]) in accounting for permanent output losses.

Figures 1 and 2 motivate our analysis by showing the dynamics of median output, investment, R&D, and total factor productivity relative to the median trend for 39 advanced and 96 emerging economies.[1] Both groups of economies experienced a significant decline in output relative to the pre-crisis trend in the aftermath of the GFC. Moreover, contrary to the recovery path that would have been predicted by standard business cycle models, the level of output always remains below the pre-crisis trend, suggesting the presence of hysteresis effects. Consistent with the permanent losses of output, total factor productivity (TFP) also shows hysteresis effects, indicating a dislocation on the supply side of the economy. Given the prominence of TFP in accounting for long-term output growth (Solow, 1957), we examine two variables that could be influencing TFP. One is research and development (R&D), which, in the spirit of Romer (1990) and Comin and Gertler (2006), is a determinant of long-term productivity growth. As shown in Figures 1 and 2, while there is a decline in R&D relative to trend, the decline is gradual over time and weakly correlated with the permanent

[1] TFP is measured as a Solow residual, which is explained formally in Section 2.

losses of TFP. The other variable is aggregate investment, which, according to Solow (1960), might be relevant in accounting for productivity gains, since technological improvements are typically embedded in new capital. Investment dynamics in the aftermath of the global crisis show a much higher correlation with TFP, suggesting that the aggregate efficiency in the economy might be influenced by changes in investment, as discussed by De Long and Summers (1991, 1993).

In this paper, we systematically analyze the comovement between output, investment, R&D, and TFP dynamics in the aftermath of financial crises and other large recessions. We do so by estimating the relationships among these variables using three different approaches. First, we compute the cross-country distribution of deviations from pre-crisis trends for multiple variables. We show that output, investment, and TFP tend to experience significant permanent losses in the aftermath of banking crises, suggesting a channel through which tighter financial conditions can lead to depressed investment and permanent TFP losses. Second, following Cerra and Saxena (2008), we estimate the medium-term macroeconomic effects of banking crises on the aforementioned variables and corroborate the finding that crisis episodes are associated with significant and permanent negative effects not only on output but also on TFP, credit to the private sector, investment, and R&D. Interestingly, the results hold not only for banking crises but also for other types of crises (i.e., currency and debt crises) and large recessions unrelated to financial crises. Finally, we conduct cross-country regressions on the medium-term determinants of TFP during the GFC. We find that around half of the decline in medium-term TFP is associated with an initial reduction in investment in the years immediately following the GFC. These results starkly contrast with the predictions of standard business cycle models, which would imply a zero coefficient on TFP (i.e., transitory declines in investment do not have a long-term impact on the level of TFP). Together, these results provide empirical support for the existence of a mechanism through which tighter financial conditions and large recessions depress investment, slow the adoption of new technologies embedded in new capital, and, as a result, reduce TFP over the medium term, contributing to hysteresis effects.

Related literature. This paper relates to the growing literature on hysteresis. The seminal paper in the literature is Cerra and Saxena (2008), which, relying on panel data regressions, shows that financial and political crises lead to permanent output losses across various country groups. The International Monetary Fund (2009) builds on Cerra and Saxena (2008) by analyzing the impact of banking crises on medium-term output losses, showing that hysteresis affects not only output but also all components of the production function—employment, capital, and TFP. In addition, the IMF (2009) presented evidence that macroeconomic policies can mitigate the extent of permanent output losses. Ball (2014) finds large hysteresis effects on potential output in OECD economies as a result of the GFC, indicating permanent supply-side losses. Furthermore, Ball (2014) finds that hysteresis effects reduce not only the level of potential output but also its growth rate, suggesting that permanent potential output losses may be growing over time.

Blanchard et al. (2015) analyze the impact of hysteresis for alternative shocks and they find that permanent output losses are more likely under financial crises and oil price shocks. Although reverse causality is possible—i.e., the anticipation of future slow growth may trigger a recession—the authors find that approximately two-thirds of episodes of intentional disinflation (i.e., monetary policy tightening) are clearly associated with permanently lower output levels and reduced growth rates, suggesting that causality may run from recession to hysteresis effects under those shocks.[2] To formally capture the interaction of demand shocks and hysteresis effects, Furlanetto et al. (2023) extend the Blanchard and Quah (1989) identification scheme of a Vector Autoregression (VAR) model to incorporate permanent effects of demand shocks. The authors find that around 50 percent of long-run output growth is explained by these shocks, suggesting that hysteresis effects are quantitatively significant.

Finally, Queralto (2020) estimated a panel data model, as in Cerra and Saxena (2008), to analyze the hysteresis effects of banking crises, evaluating the role of R&D and Total Factor Productivity (TFP) in accounting for permanent output losses. The empirical results support the channel of the endogenous growth model by Romer (1990), where tighter financial conditions reduce investment in R&D, inducing a permanent decline in TFP. Our paper is closely related to Cerra and Saxena (2008) and Queralto (2020). As in those papers, we quantify the impact of banking crises on long-term output relying on panel data analysis. In addition, we explore the hysteresis channel linking investment and TFP through capital-embodied technological change. We also assess the relevance of this mechanism for other crises (i.e., currency and debt crises) and episodes of large recessions. We complement the results from the estimations of the dynamic effects of crises with cross-country regressions in order to explain the existing co-movement between medium-term TFP losses and investment after the GFC.

Outline. The remainder of the paper is organized as follows. Section 2 outlines the main data sources for the variables used in the analysis. Section 3

[2] Cerra and Saxena (2008) also examine the issue of reverse causality from lower growth expectations to crises and note that this possibility cannot be ruled out in their empirical analysis.

provides evidence of how financial crises induce hysteresis effects by examining the cross-country distribution of permanent output losses, comparing scenarios with and without banking crises. Section 4 presents panel data estimates of the medium-term effects of banking crises on output, investment, credit, research and development (R&D), and total factor productivity (TFP). This section also evaluates the robustness of the empirical findings by using alternative crisis definitions, such as currency crises and other severe recessions. Section 5 presents results from a cross-country regression analysis to investigate the drivers of medium-term TFP losses following the Global Financial Crisis (GFC). Finally, Section 6 concludes.

2 Data

The key variables in the dataset used in the empirical analysis are annual series for output, investment, research and development (R&D), credit, equipment investment, and the price of equipment for a broad set of countries. Additional variables, described in Section 5, include the world uncertainty index, interest rates, and GDP forecast revisions, among others. Some of the data series are obtained from the International Monetary Fund's World Economic Outlook (WEO), while others are from the World Bank's World Development Indicators (WDI) and the Penn World Table (PWT).

The real output variable corresponds to Gross Domestic Product (GDP) in constant prices (National Currency, Billions) from the WEO database. Total Factor Productivity (TFP) is computed as the Solow residual for each country i, using the following equation:

$$TFP_{i,t} = \frac{Y_{i,t}}{(K_{i,t})^{\alpha}(L_{i,t})^{1-\alpha}}, \tag{1}$$

where $Y_{i,t}$ is real GDP, $K_{i,t}$ denotes the capital stock, $L_{i,t}$ is total employment, and α is set at 0.3, consistent with the evidence from Golin (2002), which indicates that the labor income share is around 70 percent. To compute the TFP series, the capital stock ($K_{i,t}$) is obtained from the PWT database and corresponds to capital stock at constant 2011 national prices (expressed in 2011 USD). This series is converted into domestic currency using the exchange rate from the WEO database. Total employment ($L_{i,t}$) is measured in millions of persons and is obtained from the WEO database.

The investment series is represented by gross capital formation at constant prices from the WEO database (National Currency, Billions). Investment in equipment is measured as the real value of investment in machinery and non-transport equipment, calculated as the ratio of nominal investment in these categories to their respective price index. Both series are sourced from the PWT database. The relative price of equipment investment is defined as the ratio of the price index for machinery and non-transport equipment to the GDP deflator, both obtained from the WEO database.

Credit data is calculated by multiplying domestic credit to the private sector as a percentage of GDP by real GDP. The domestic credit data (as a percentage of GDP) is sourced from the WDI database. The real interest rate corresponds to the real short-term deposit rate from the WEO database. Research and development (R&D) expenditure is derived by multiplying the share of R&D expenditure as a percentage of GDP (from the WDI database) by the real GDP series.

Uncertainty indices are sourced from *World Uncertainty Index* site.[3] The indices are normalized by the total number of words and rescaled by multiplying by 1,000, with higher values indicating greater uncertainty. Quarterly data is averaged to obtain an annual frequency.

For the crises dummies, we use multiple sources. For the baseline analysis of banking crises, we rely on dates provided by Laeven and Valencia (2013, 2018), which is an updated version of the dataset by Caprio and Klingebiel (2002). To explore the impact of alternative crisis definitions, we also consider dates for banking and other crises from Gourinchas and Obstfeld (2012) and Queralto (2020). Appendix A includes a Table 5 which summarizes the observations for the main macroeconomic variables for each country during the period 1960-2019 along the years of banking crises according to Laeven and Valencia (2018). This table shows that the sample comprises 193 countries, with a maximum of 60 observations per variable spanning the period from 1960 to 2019.

3 Cross-country Distribution of Permanent Output Losses

In this section we analyze the role of banking crises and recessions in generating permanent losses. We follow a non-parametric approach (IMF, 2018) and estimate the kernel distribution of permanent losses of output, TFP, investment, and R&D for two groups of countries: those that experienced banking crises

[3]Available at `https://worlduncertaintyindex.com/`. For each country, the index is computed by counting the frequency of the term "uncertainty" (or related variants) in the *Economist Intelligence Uni*t country reports.

and those that did not during the GFC. [4] [5]

In figure 3, the blue line represents the kernel density distribution of the de-trended losses in countries that experienced a banking crisis and the red line depicts the distribution of losses in countries that were purely affected by the global financial crisis without a banking crisis. For output, we find that 65 percent of the sample of non-crisis countries (red line) experienced medium-term output losses (i.e., probability density area located on the negative side of the distribution). In contrast, the fraction of countries with permanent output losses increases to 90 percent for the sample of countries with banking crises (blue line). This implies a greater density area in the negative region of the distribution for countries with banking crises. There are two key implications from this distribution of output losses. First, consistent with the work of Cerra and Saxena (2017) permanent output losses can be observed even in the absence of banking crises. Recessions induced by other shocks (red line) can also result in hysteresis effects and permanent output losses. Second, the distribution suggests that financial factors may play an important role in amplifying medium-term losses. As noted by Blanchard et al. (2015), a decline in financial intermediation could lead to a reduction in the efficiency of the reallocation process, resulting in lower medium-term growth.

We also observe that permanent output losses are linked to hysteresis effects in Total Factor Productivity (TFP). Panel B shows that 80 percent of countries with banking crises exhibit permanent TFP losses, while only 55 percent of non-crisis countries exhibit hysteresis effects. As discussed by IMF (2018), investment could also play a role in the reduction in TFP, to the extent that new technology is embedded in new machinery and equipment. Consistent with this hypothesis, Panel C shows that investment also exhibits significant and persistent losses. While 80 percent of the countries experiencing banking crises exhibit persistent investment losses relative to trend, that fraction is only 60 percent for countries where banking crises were absent.

One plausible explanation for the sharper investment contraction during banking crises is that firms lose access to financing and are forced to curtail investment, as suggested by Gertler and Gilchrist (2018). Alternatively, Blanchard et al. (2015) also suggests that weaker growth prospects could lead to a persistent decline in investment as entrepreneurs postpone investment decisions until growth recovers and uncertainty dissipates. This slowdown in investment

[4] The permanent losses are computed for the period 2015-2017 as in described in Section 5. The pre-crisis trend was estimated for the period 2000-2008 following Cerra and Saxena (2008) and Ball (2014).

[5] The dataset includes 24 countries that experienced banking crises during 2007-2008 and 168 countries that did not. This is summarized in table 5 in Appendix A.

could interrupt the adoption of new technologies if firms delay purchasing newly produced capital goods. This limited adoption of new technologies can also contribute to the observed reduction in measured TFP.

Finally, Panel D shows significant permanent losses in R&D spending, which are similar across both crisis and non-crisis samples. As discussed in Adler et al. (2017), a permanent decline in R&D spending could also be an additional factor explaining the observed declines in TFP during the GFC.

To summarize, we find that medium-term output losses are a ubiquitous empirical feature of recessions, as illustrated in Figure 3. Nevertheless, we show that these losses tend to be amplified in episodes of banking crises. Moreover, the economic phenomenon of output hysteresis is strongly associated with permanent losses in TFP, investment, and R&D. In the next section, we explore the dynamic effects of crises and large recessions on all these variables to evaluate competing hypotheses for the underlying mechanisms accounting for output hysteresis.

4 Hysteresis Effects in the Aftermath of Banking Crises and Large Recessions

In this section, we extend the work of Cerra and Saxena (2008) and Queralto (2020) to delve deeper into the underlying mechanisms through which financial crises and large recessions lead to hysteresis effects and permanent output losses. Cerra and Saxena (2008) focused their analysis on output dynamics in the aftermath of financial and political shocks, trying to understand the differential impact across regions and groups of countries. In this paper in addition to analyzing the dynamics of output, we also include additional variables that might explain the underlying hysteresis effects, with particular emphasis on TFP, investment, and credit conditions. We also expand the dataset from Queralto (2020) to include a broader set of countries and evaluate the hysteresis effects under alternative adverse events, such as currency crises

We follow the same empirical approach as in Cerra and Saxena (2008) and estimate the panel data regression model:

$$x_{i,t} = \alpha_i + \sum_{j=1}^{J} \beta_j x_{i,t-j} + \sum_{l=0}^{L} \delta_l D_{i,t-l} + \varepsilon_{i,t}, \tag{2}$$

where $x_{i,t}$ is the log growth rate of variables of interest (GDP, TFP, Investment, R&D, and Credit) for country i and year t, α_i is a country fixed effect, and $D_{i,t-l}$ is a crisis dummy. In the baseline specification, the dummy corresponds to a banking crisis (Laeven and Valencia, 2018). We also consider dummies for other crises from Laeven and Valencia (2018), Gourinchas and Obstfeld (2012), and large recessions (Queralto, 2020). The chosen specification for estimating the dynamic effects of crises was based on the Bayesian Information Criterion (BIC). The details of these estimations are presented in Appendix B.

Figure 4 shows the dynamics of GDP and other variables in the aftermath of a banking crisis. We find that a banking crisis, on average, permanently depresses the level of output by 7.5 percentage points, with most of the effect materializing after the first three years. This result matches the findings in Cerra and Saxena (2008). Figure 4 also plots the Impulse Response Functions (IRF) of additional variables that shed light on the potential mechanisms behind the hysteresis effects. First, we find that real credit falls permanently 23 percent below trend, suggesting a significant tightening of credit conditions in the aftermath of a financial crisis. The magnitude of permanent losses for credit captures the significant slowdown in credit to the private sector following the credit booms preceding financial crises (Reinhart and Reinhart, 2010). As a result of tighter credit conditions, we observe a permanent loss of 20 percent of private investment, and a comparable impact for machinery and equipment. With an average share of investment to GDP of 20 percent, the contribution of the investment decline to output loss is about 4 percentage points, or more than 50 percent of the observed hysteresis effect on output in the baseline IRF. From the supply side, we see a permanent decline in investment in R&D activities of 10 percent and a permanent contraction of 5 percentage points in TFP. These macroeconomics dynamics are consistent with both a model of endogenous growth a la Romer (1990) and Comin and Gertler (2006), and capital-embodied technological change of Solow (1960). [6]

In Figure 5, we extend the empirical analysis to two separate samples of advanced and emerging economies. Our findings indicate that the output effect of banking crises in advanced economies is significantly larger (12 percent) than that in emerging economies (7 percent). This difference may reflect the larger impact of banking crises on the housing market in advanced economies during the Global Financial Crisis (Reinhart and Reinhart, 2010). However, for most variables, the differences between advanced and emerging economies are not statistically significant, suggesting that the underlying mechanism of hysteresis operates similarly across both groups of countries. One noteworthy exception is credit, which contracts more sharply in emerging economies than in advanced economies during the first two years, possibly reflecting steep reductions in private sector credit following financial crises in emerging economies (Mendoza

[6] We also estimated the IRFs for the relative price of machinery and equipment, but they are not statistically significant. Those results are available upon request.

and Terrones, 2012). The larger output losses observed in advanced economies may also be influenced by a greater contraction of investment, driven in part by significant declines in house prices and residential investment, in the years following the Global Financial Crisis.

In Figure 6 we evaluate whether the hysteresis effects presented in Figure 4 might hold for large recessions not related to banking crises. We follow Queralto (2020) and use dummies for episodes of large recessions in advanced economies. We compare these results against the estimated responses for banking crises for the same sample of countries to avoid biased results due to the composition of countries. We find that banking crises generate amplification effects resulting in statistically significant lower investment and TFP. Notice that in large recessions, R&D is not statistically significant, indicating that recessions without a significant tightening in credit conditions do not have a material impact on the dynamics of R&D spending. These results give more support to the Solow (1960) theory of capital-embodied technological change due to the fact that the decline in TFP is unrelated to movements in R&D but is positively correlated with changes in private investment.

Figure 7 presents the analysis for an extended definition of crisis, featuring currency, banking, and default crises (Gourinchas and Obstfeld, 2011). This alternative definition of crisis confirms the previous result that banking crises tend to have more severe effects on output. Under the general definition of crisis used by Gourinchas and Obstfeld (2011), we find that this crisis shocks generate an output loss of 3.5 percent, about half of the value found in the baseline specification. Similar to the previous results, this seems to be driven by stronger declines in TFP and investment that are not related to R&D, since the IRFs for this variable do not show a statistically significant difference for the two definitions of crises.

We conduct a final robustness check using dummies for Currency and Debt Crises from Laeven and Valencia (2018) in Figure 8. While the point estimates of the IRFs suggest that banking crises tend to generate a more severe output loss compared to other crises, the difference is not statistically significant, as shown in Laeven and Valencia (2013). Aadditionally, for other crises, the effects of R&D are not statistically significant, suggesting that an alternative transmission mechanism might underpin the hysteresis effects on TFP during currency and debt crises.

To summarize, we find robust evidence for hysteresis effects on output for several types of shocks (banking, currency, and debt crises and large recessions) and across different groups of countries (advanced and emerging economies). These permanent output losses are closely associated with hysteresis effects on investment and TFP, suggesting that capital-embodied technological change might be a relevant mechanism accounting for these effects. While R&D is a key variable in growth models that drive technological improvement and innovation over the medium-term, this variable seem to operate mostly during banking crises but plays a more limited role during other types of crises. As shown in Figures 1 and 2, this variable appears to be less sensitive to recessions compared to other macroeconomic variables. In the next section, we will examine the association between medium-term TFP losses, on one hand, and investment and R&D during the Global Financial Crisis, on the other hand, to distinguish between alternative theories on how recessions could generate hysteresis effects.

5 Drivers of Hysteresis Effects in the Aftermath of the Global Financial Crisis

In this section,we estimate the drivers of medium-term TFP losses in the aftermath of the Global Financial Crisis (GFC) for a large sample of advanced and emerging countries. In the regression analysis, the dependent variable is the average TFP loss during the period 2015-2017 for all countries, which captures protracted scarring effects on the supply side of the economy following the GFC. The loss is calculated as the deviation from the pre-crisis (2000–2008) linear trend. Formally, we compute the losses for variable x for period t as:

$$\hat{x}_t = l\bar{x}_t - \log(x_t) \tag{3}$$

where $l\bar{x}_t$ represents the linear trend for the log of variable x during the period 2000–2008. Hence, we obtain the average TFP loss for 2015–2017 as the cross-sectional variable that measures medium-term TFP losses.

Since the ultimate goal is to estimate the drivers of hysteresis effects after the GFC, the explanatory variables are measured in the period 2008–2010. In standard macroeconomic models, the coefficients of the explanatory variables should be zero, as transitory shocks do not have a permanent effect on TFP. On the contrary, when there are hysteresis effects, the coefficients should be statistically significant to the extent that business cycle shocks generate permanent deviations from trend.[7]

In the regression analysis, we considered six different drivers that could potentially account for medium-term TFP losses: (i) Permanent investment losses, (ii) permanent losses in R&D expenditure, (iii) Increase in uncertainty,

[7]While it is possible to analyze the contemporaneous effect of different variables on TFP, such regression analysis wouldn't be able to quantify hysteresis effects since it would not capture the impact over long periods of time. Hence we introduce a lag of seven years between the dependent and explanatory variables to properly capture hysteresis effects.

measured by the World Uncertainty Index (WUI) from Ahir et al. (2022), (iv) Revisions of medium-term GDP forecasts, (v) permanent losses in credit, and (vi) changes in the real interest rate during the global financial crises. All these variables capture changes in the economic environment during the GFC that could shed light on the underlying mechanism determining hysteresis effects on TFP and the supply side of the economy.

[Insert Table 1]

Table 1 shows our initial sets of results. Consistent with the original hypothesis of Capital-Embodied technological change by Solow (1960) we find that a 1 percent contraction in private investment relative to trend during the GFC results in a decline of medium-term TFP by 0.4 percentage points (Model 1). De Long and Summers (1991, 1993) also found a strong association between investment and medium-term growth, arguing that investment can have long-lasting consequences on output and productivity. Greenwood et al. (1997) also discussed that, in models with learning-by-doing in the production of capital, a contraction in investment could result in lower total factor productivity.

We also find that a decline of 1 percent in R&D expenditure also has a medium-term negative effect of 0.4 percentage points on TFP. This is consistent with the hypothesis of Romer (1990) that R&D is an important driver of innovation and productivity growth. However, our results show that not only is R&D a relevant factor for hysteresis effects but that overall investment is quantitatively important.

Investment and R&D could also be declining due to other underlying factors occurring during crises. We also consider additional macroeconomic factors that could be affecting hysteresis over the medium term. When we consider credit losses or changes in the real rate, we do not find statistically significant effects on TFP losses. While these factors are empirically relevant for explaining contemporaneous effects on economic activity, and potentially TFP, our regression analysis indicates that these effects have dissipated after the GFC with no statistically significant medium-term impacts.

Uncertainty is another relevant factor that manifested during the GFC. It has been widely documented that uncertainty increases during recessions (Bloom, 2014) and that investment is highly sensitive to changes in uncertainty (Pyndick, 1991). To evaluate if uncertainty could be influencing hysteresis effects, we consider the World Uncertainty Index (WUI). This variable is measured as the number of times uncertainty is mentioned in the reports of the Economist Intelligence Unit. As shown in column 5, these variables have large, statistically significant coefficients, suggesting that uncertainty has lasting scarring effects on TFP that persist over the medium term. We also consider a variable that is closely related to uncertainty, which is the medium-term growth forecast revision at the time of the GFC. This variable is measured as the revision of 5-year ahead growth forecast between 2008 and 2009. In column 6, we find that a downward revision significantly reduces medium-term TFP. The fact that investment, uncertainty, and growth revisions are positively related to TFP losses brings the question of whether the losses in investment would indirectly be capturing a higher uncertainty and pessimistic growth expectations during periods of crises. In order to disentangle the uncertainty and investment channels, we explore expanding the number of regressors. These possibilities are explored in Table 2.[8]

[Insert Table 2]

In the first column of Table 2, we assess the joint impact of R&D and medium-term growth revisions. In this specification, the statistical significance of R&D is not robust, while the growth forecast revision variable remains statistically significant. In the second column, we repeat the analysis with investment losses, finding that it remains significant at the 5 percent level even with the inclusion of the growth forecast revisions. In the third column, when incorporating uncertainty and growth forecast revisions, R&D becomes significant, though only at the 10 percent level. Finally, in the fourth column, we find that investment losses remain significant at the 5 percent level, while the uncertainty index (WUI) retains its significance.

To summarize, the results from Table 2 suggest that uncertainty and growth forecast revisions are significant across different specifications. In contrast, while investment losses appear to be a variable robust to alternative specifications, the impact of R&D is not always significant.One explanation is that the decline in RD already reflects the effects of heightened uncertainty during crises, while overall investment losses directly impact technology adoption and, consequently, medium-term TFP.

[Insert Table 3]

In Table 3, we conduct robustness exercises to further investigate alterna-

[8] In Appendix C we show that these empirical results are robust to alternative definitions of the pre-crisis trend.

tive channels through which the investment process might influence aggregate efficiency and TFP. In Column 2, we assess the impact of investment in machinery and equipment on TFP, following the approach of De Long and Summers (1992). We find that this variable is statistically significant only at the 10 percent level, with the coefficient value being lower than that for total investment. We also examine the impact of the detrended price of investment on TFP. As documented by Greenwood et al. (1997, 2000), the price of investment is an important driver of U.S. growth and business cycles. The IMF (2019) also highlighted that the persistent decline in the relative price of investment has been a key driver of capital deepening in emerging and developing countries over the last three decades. Moreover, IMF (2019) noted that advanced economies experienced a slowdown in the pace of decline in the relative price of machinery and equipment around the GFC, which may have desincentivized the purchase of new machinery and the adoption of new technologies.

In Column 3, we assess the impact of the decline in the price of investment during the GFC. While the sign of the coefficient is consistent with theoretical predictions (i.e., higher investment prices reduce medium-term TFP), the effect is statistically insignificant. Additionally, we find that the contemporaneous impact of a decline in capital prices on TFP is also statistically insignificant. Finally, in Table 4 we explore the role of changes in the price of capital using four alternative specifications that include additional control variables. In all cases, the change in the price of capital remains statistically insignificant. This lack of significance suggests that the dynamics of the relative price of investment are likely driven by long-term trends rather than being directly influenced by the GFC across the entire sample of countries. Therefore, the relative price of capital does not appear to play a major role in accounting for the post-crisis hysteresis effects.

[Insert Table 4]

6 Concluding Remarks

One of the most puzzling facts in the wake of the Global Financial Crisis is that output across advanced and emerging economies did not recover relative to the pre-crisis trend as a textbook macroeconomic model would have predicted. The literature of hysteresis has widely documented the existence of permanent output losses in response to alternative shocks (i.e., financial, political, policy, and energy shocks) for a wide array of countries with different levels of development. However, there is still a debate in the literature regarding the specific channels through which transitory shocks manifest into permanent output losses. We contributed to the literature by studying the interaction between banking crises, investment, R&D, and TFP in accounting for permanent output losses. We show that periods of decline in investment are highly correlated with medium-term permanent losses in TFP, consistent with models of endogenous productivity and capital-embodied technological change. During periods of financial disruption, firms are unable to obtain financing for investing (in new physical capital and R&D), leading to a subsequent decline in innovation and productivity. We showed that this mechanism is also presented in response to other types of crises and large recessions for both advanced and emerging economies, however the effects tend to be amplified during banking crises as emphasized by Blanchard et al. (2015). We also showed that during the GFC, investment slumps can explain about half of the permanent TFP losses 7 years after the GFC unfolded.

These results have important implications for macroeconomic policy and the stabilization of business cycles. If investments contractions are a key driver of output hysteresis and medium-term TFP losses, then policies aimed at stabilizing investment could provide sizable welfare gains. Since banking crises in most instances disrupt the credit available to finance new investment, there is a role for macroprudential policies that could potentially contain a collapse in investment. Ex-ante policies that ensure financial stability, and ex-post policies that lower the costs of borrowing for new private investment or stimulates public investment during recessions could have a material impact in preventing investment slumps and the associated hysteresis effects on output and TFP. As a next step, we are planning on evaluating the trade-offs associated with these policies in the context of a DSGE model.

References

Adler, G., Duval, R., Furceri, D., Çelik, S.K., Koloskova, K., and Poplawski-Ribeiro, M., 2017, “Gone with the Headwinds: Global Productivity.” *IMF Staff Discussion Note* SDN/17/04.

Ahir, H., Bloom, N., and Furceri, D., 2022, “The World Uncertainty Index.” *National Bureau of Economic Research* Working Paper No. 29763.

Ball, L., 2014, “Long-term Damage from the Great Recession in OECD Countries.” *European Journal of Economics and Economic Policies: Intervention*, 11(2), pp. 149-160.

Blanchard, O. and Quah, D., 1989, “The Dynamic Effects of Aggregate Demand and Supply Disturbances.” *American Economic Review*, 79(4), pp. 655-673.

Blanchard, O., Cerutti, E. and Summers, L., 2015, “Inflation and Activity–Two Explorations and Their Monetary Policy Implications.” *National Bureau of Economic Research* Working Paper No. 21726.

Bloom, N., 2014, “Fluctuations in Uncertainty.” *Journal of Economic Perspectives*, 28(2), pp. 153-176.

Cerra, V., and S.C. Saxena, 2008, ”Growth Dynamics: The Myth of Economic Recovery.” *American Economic Review*, 98(1), 439–457.

Cerra, V., and S. Saxena, 2017, ”Booms, Crises, and Recoveries: A New Paradigm of the Business Cycle and its Policy Implications.” *International Monetary Fund* Working Paper No. WP/17/250.

Cerra, V., A. Fatas, and S. C. Saxena, 2023, ”Hysteresis and Business Cycles.” *Journal of Economic Literature*, 61(1), 181-225.

Comin, D., and M. Gertler, 2006, ”Medium-term business cycles.” *American Economic Review*, 96(3), 523-551.

De Long, J.B. and Summers, L.H., 1991, “Equipment Investment and Economic Growth.” *Quarterly Journal of Economics*, 106(2), pp. 445-502.

De Long, J.B. and Summers, L.H., 1992, “Equipment Investment and Economic Growth: How Strong is the Nexus?” *Brookings Papers on Economic Activity*, 1992(2), pp. 157-211.

De Long, J.B. and Summers, L.H., 1993, “How Strongly Do Developing Economies Benefit from Equipment Investment?” *Journal of Monetary Economics*, 32(3), pp. 395-415.

Furlanetto, F., A. Lepetit, Ø. Robstad, J. Rubio-Ramírez, and P. Ulvedal, 2025, ”Estimating Hysteresis Effects.” *American Economic Journal: Macroeconomics*, 17(1), 35-70.

Gertler, M. and Gilchrist, S., 2018, “What Happened: Financial Factors in the Great Recession.” *Journal of Economic Perspectives*, 32(3), pp. 3-30.

Gourinchas, P.O. and Obstfeld, M., 2012, “Stories of the Twentieth Century for the Twenty-First.” *American Economic Journal: Macroeconomics*, 4(1), pp. 226-265.

Greenwood, J., Hercowitz, Z., and Krusell, P., 1997, “Long-Run Implications of Investment-Specific Technological Change.” *American Economic Review*, 87(3), pp. 342-362.

Greenwood, J., Hercowitz, Z., and Krusell, P., 2000, “The Role of Investment-Specific Technological Change in the Business Cycle.” *European Economic Review*, 44(1), pp. 91-115.

International Monetary Fund, 2009,”What’s the Damage? Medium-Term Output Dynamics After Financial Crises.” In *World Economic Outlook*, Chapter 4, October 2009. Washington, D.

International Monetary Fund, 2018,”The Global Recovery 10 Years after the 2008 Financial Meltdown.” In *World Economic Outlook*, Chapter 2, October 2018. Washington, DC.

International Monetary Fund, 2019, “The Price of Capital Goods: A Driver of Investment Under Threat?” In *World Economic Outlook*, Chapter 3, April 2019. Washington, DC.

Laeven, L. and Valencia, F., 2013, “Systemic Banking Crises Database.” *IMF Economic Review*, 61(2), pp. 225-270.

Laeven, L. and Valencia, F., 2018, “Systemic Banking Crises Revisited.” *IMF Working Paper* No. 18/206.

Mendoza, E.G. and Terrones, M.E., 2012, “An Anatomy of Credit Booms and Their Demise.” *National Bureau of Economic Research* Working Paper No. 18379.

Pyndick, R.S., 1991, “Irreversibility, Uncertainty, and Investment.” *Journal of Economic Literature*, 29(3), pp. 1110-1148.

Queralto, A., 2020, “A Model of Slow Recoveries from Financial Crises.” *Journal of Monetary Economics*, 114, pp. 1-25.

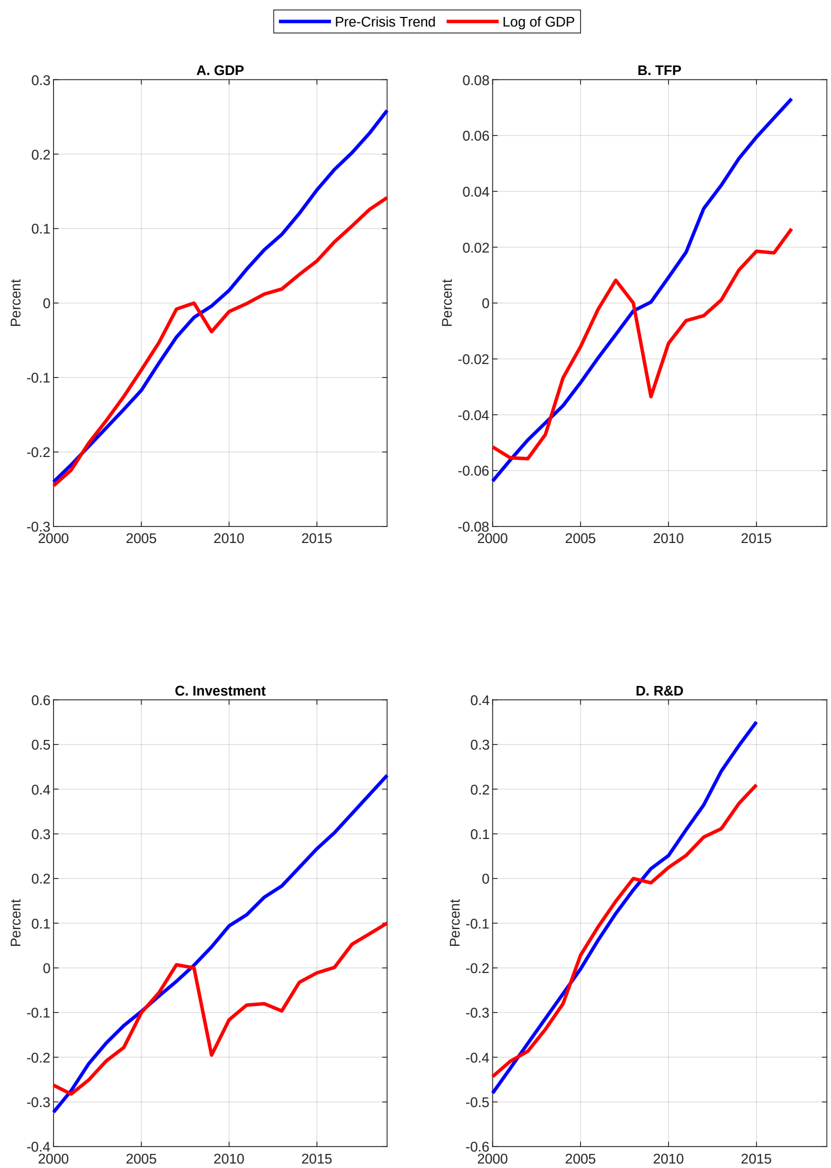
Reinhart, C.M. and Reinhart, V.R., 2010, “After the Fall.” *National Bureau of Economic Research* Working Paper No. 16334.

Romer, P. M., 1990, ”Endogenous Technological Change.” *Journal of Political Economy*, 98(5), S71-S102.

Solow, R. M., 1957, ”Technical Change and the Aggregate Production Function.” *The Review of Economics and Statistics*, 39(3), 312-320.

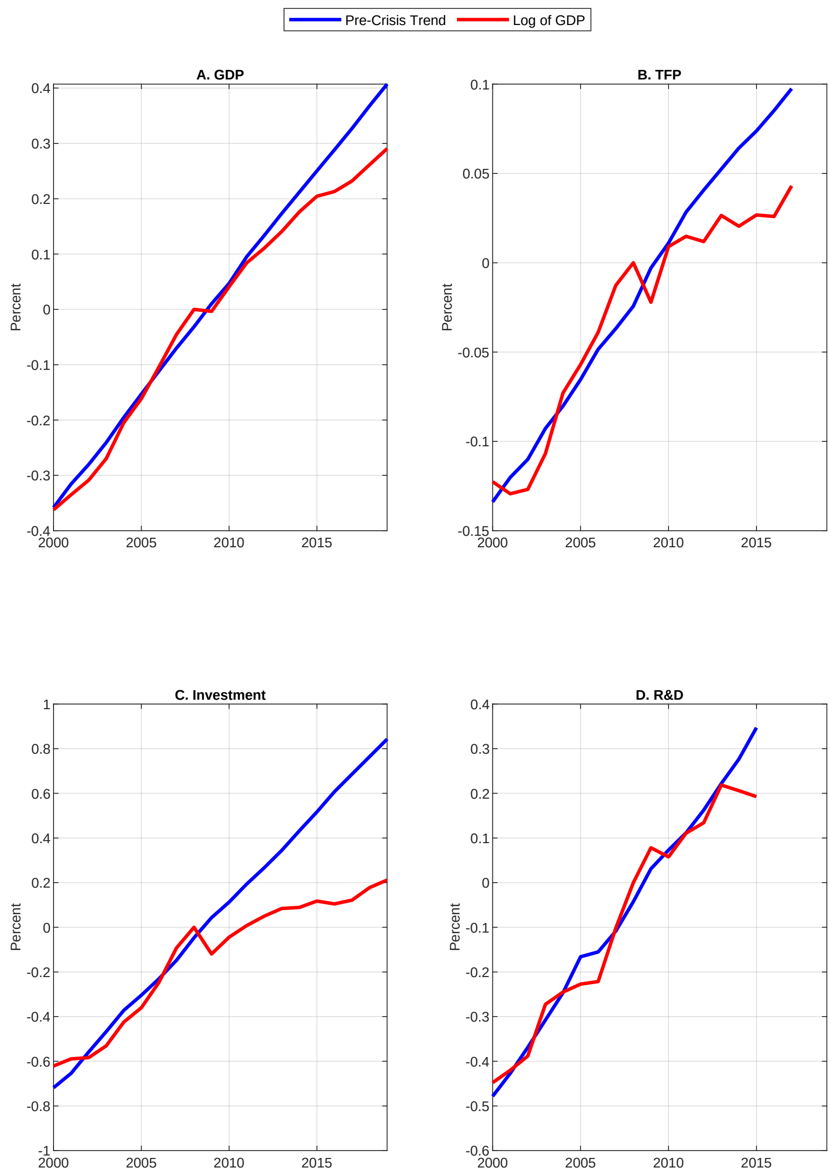
Solow, R.M., 1960, ”Investment and Technical Progress.” In K.J. Arrow, S. Karlin, and P. Suppes (eds.), *Mathematical Methods in the Social Sciences* (pp. 89-104). Stanford, CA: Stanford University Press.

Figure 1: Deviations from Pre-crisis Trend – Advanced Countries



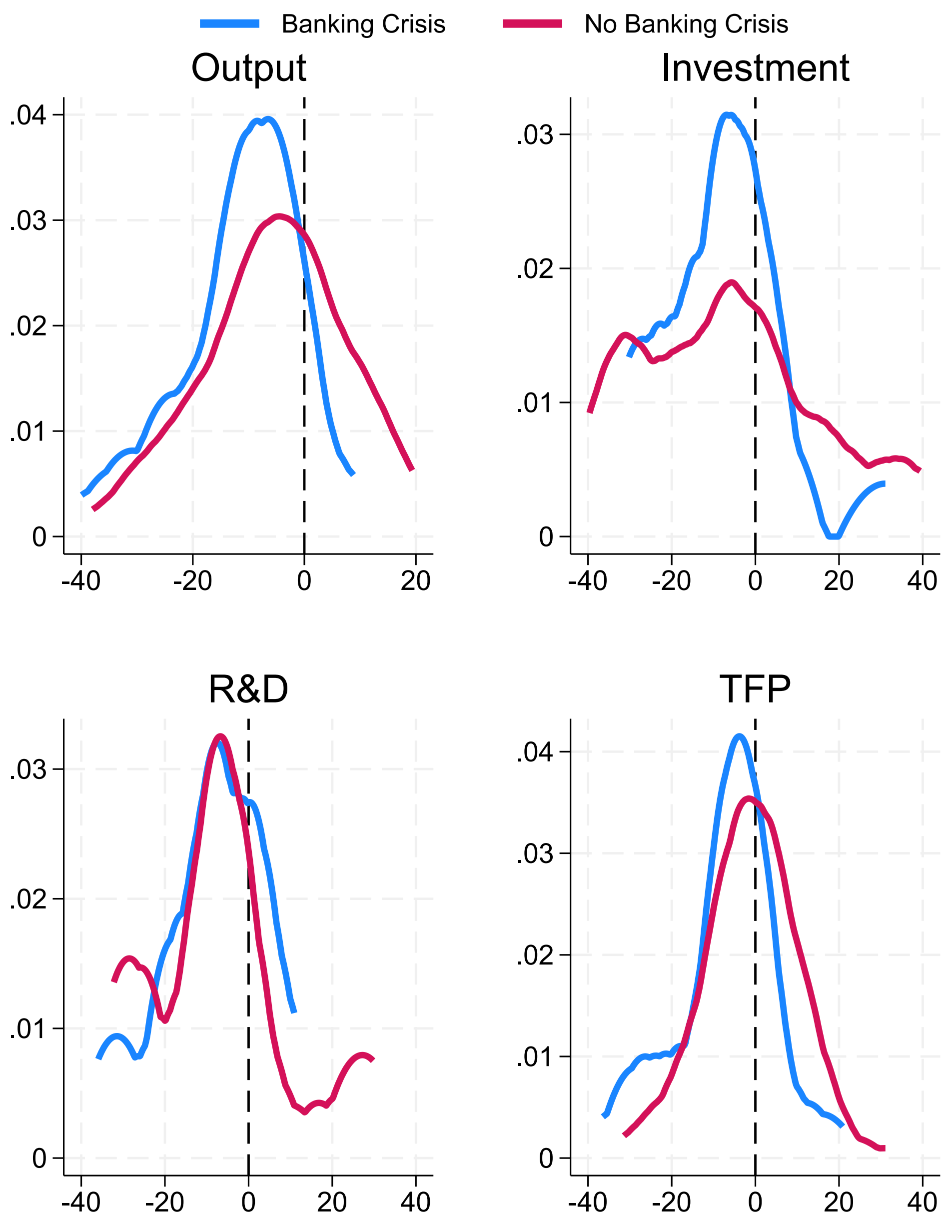
Source: authors' calculations based on data described in Section 2.
Note: The blue lines are pre-crisis linear trends estimated from filtered (Hodrick-Prescott filter) series between 2000 and 2008 and are extrapolated linearly thereafter. 2008 log variables normalized to zero. There are 39 countries in the sample of advanced economies.

Figure 2: Deviations from Pre-crisis Trend – Emerging Countries



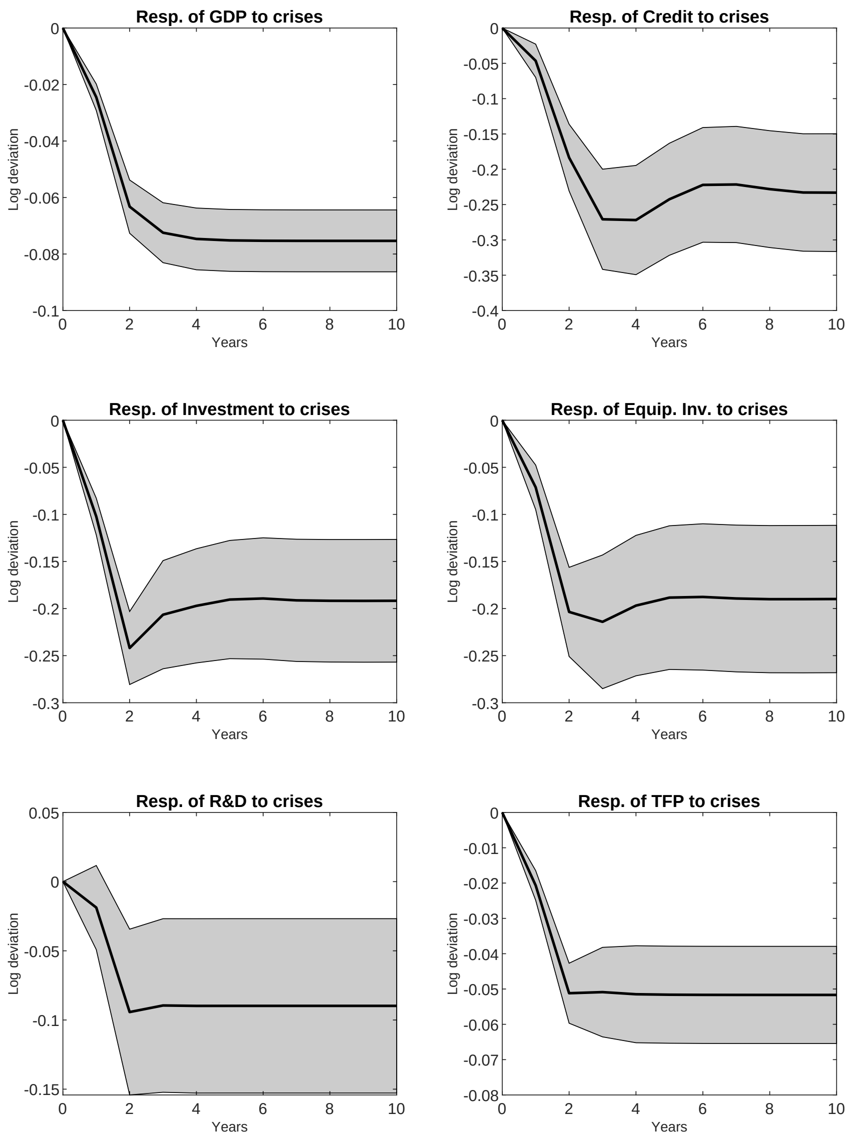
Source: authors' calculations based on data described in Section 2.
Note: The blue lines are pre-crisis linear trends estimated from filtered (Hodrick-Prescott filter) series between 2000 and 2008 and are extrapolated linearly thereafter. 2008 log variables normalized to zero. There are 96 countries in the sample of emerging economies.

Figure 3: Distribution of average percent deviations from pre-crisis trend



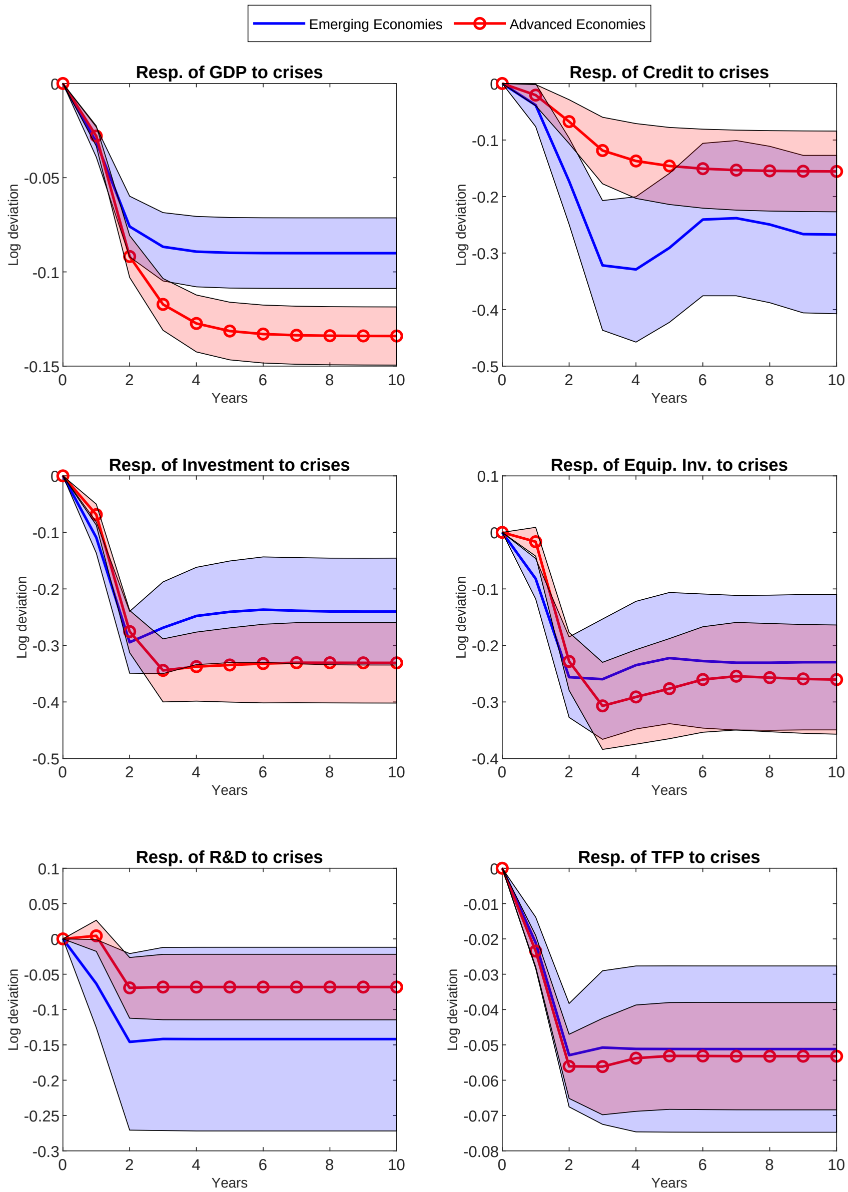
Source: authors' calculations based on data described in Section 2.
Distribution of average percent deviations in years 2015-2017 from pre-crisis trend. The deviations from pre-crisis trend are calculated by detrending each variable using a linear trend estimated for the sample period 2000-2008. The 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 4: Empirical Impulse Response Functions to banking crises. Total sample.



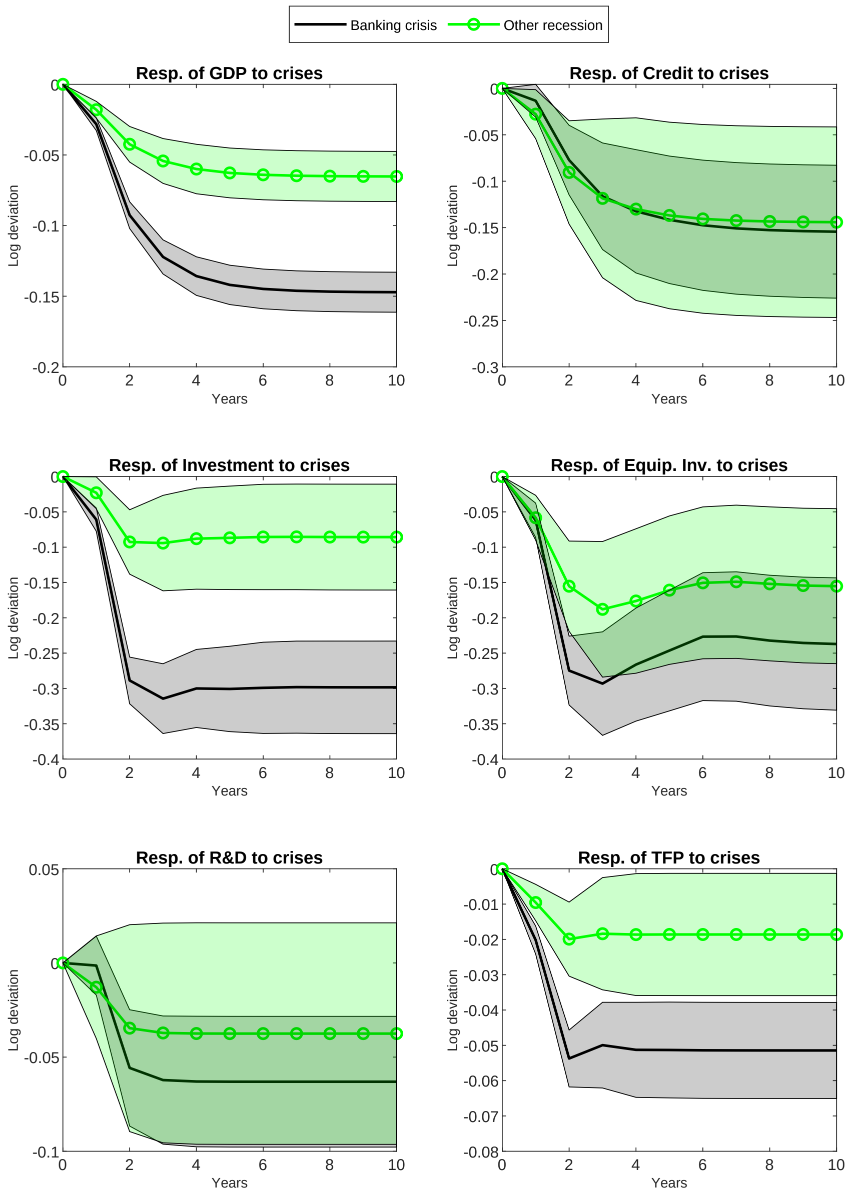
Source: authors' calculations based on data described in Section 2.
Note: The figure reports impulse responses to banking crises for the entire sample, using the estimated equation. (2) for each reported variable. The black solid line represents the point estimates of the responses, while the shaded regions indicate the one-standard-deviation intervals around the point estimates.

Figure 5: Empirical Impulse Response Functions to banking crises. Separating emerging and advanced and economies



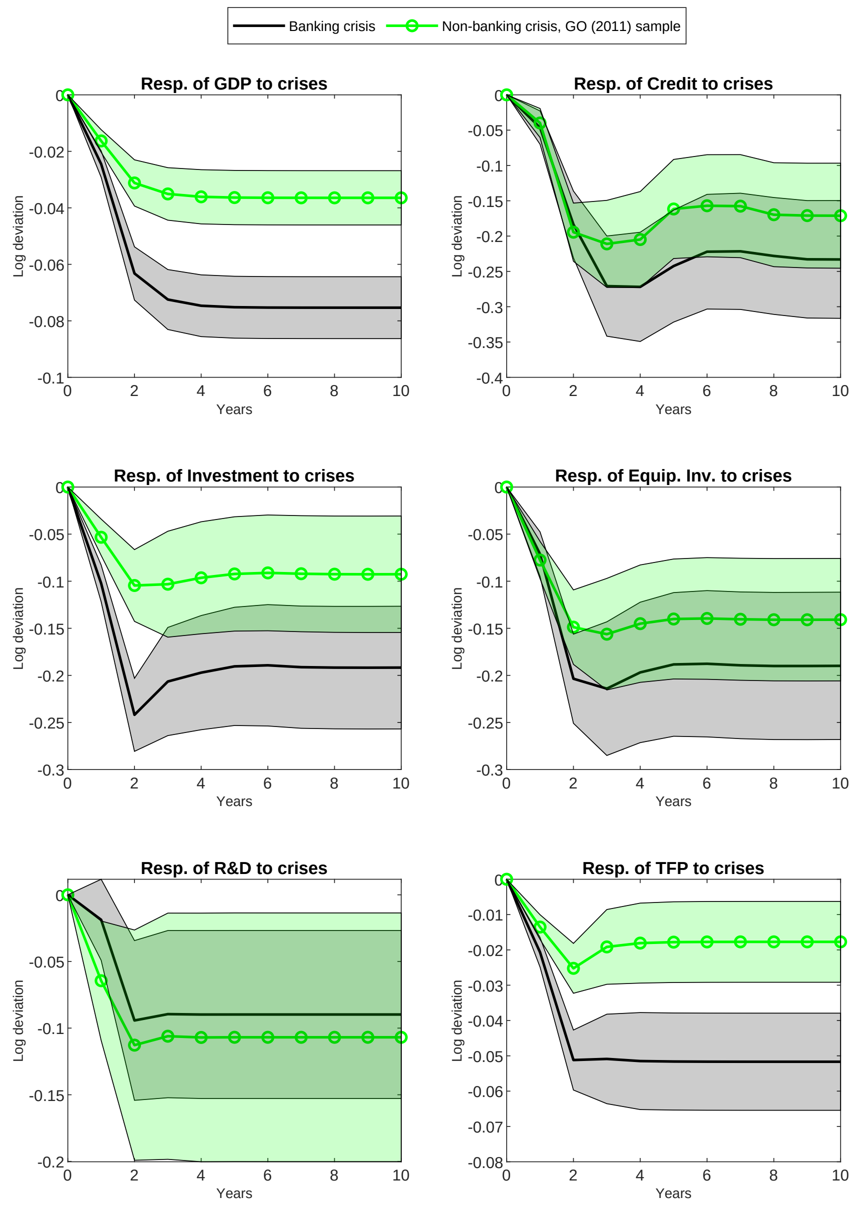
Source: authors' calculations based on data described in Section 2.
Note: The figure reports impulse responses to banking crises for emerging (red) and advanced (blue) economies variable using the estimated equation (2) for each reported variable. The solid lines represent the point estimates of the responses, while the shaded regions indicate the one-standard-deviation intervals around the point estimates.

Figure 6: Empirical Impulse Response Functions to crises. Queralto (2020) sample.



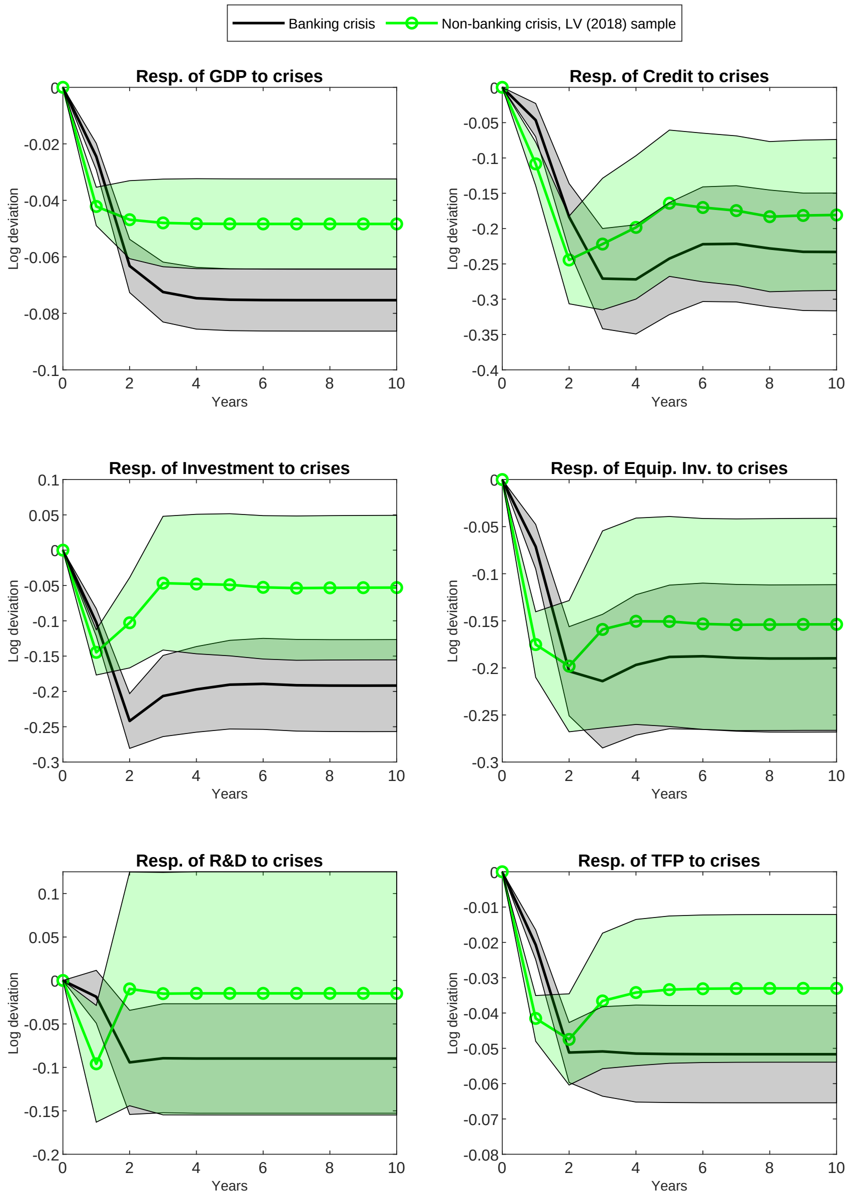
Source: authors' calculations based on data described in Section 2.
Note: The figure reports impulse responses to banking (black) and other (green) crises based on the Queralto (2020) sample and using the estimated equation (2) for each reported variable. The solid lines represent the point estimates of the responses, while the shaded regions indicate the one-standard-deviation intervals around the point estimates.

Figure 7: Empirical Impulse Response Functions to crises. Gourinchas and Obstfeld (2011) sample.



Source: authors' calculations based on data described in Section 2.
Note: The figure reports impulse responses to banking (black) and other (green) crises based on the Gourinchas and Obstfeld (2011) sample and using the estimated equation (2) for each reported variable. The solid lines represent the point estimates of the responses, while the shaded regions indicate the one-standard-deviation intervals around the point estimates.

Figure 8: Empirical Impulse Response Functions to crises. Banking and other crises according to Laeven and Valencia (2018).



Source: authors' calculations based on data described in Section 2.
Note: The figure reports impulse responses to banking (black) and other (green) crises based on the Laeven and Valencia (2018) sample and using the estimated equation (2) for each reported variable. The solid lines represent the point estimates of the responses, while the shaded regions indicate the one-standard-deviation intervals around the point estimates.

Table 1: Medium-term TFP Losses 2015-2017 and other variables 2008-2010 (Part I)

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6
Inv. loss	0.422***					
(2008-10)	(0.0838)					
RD loss		0.422**				
(2008-10)		(0.197)				
Credit loss			0.0221			
(2008-10)			(0.0552)			
Rates diff.				0.00207		
(2010 vs 2008)				(0.00388)		
WUI					0.549***	
(Max 2007-10)					(0.178)	
For. 2013 GDP loss						1.153***
(oct 09 vs apr 08)						(0.226)
Constant	0.0423*	0.152***	0.106***	0.112***	0.0182	-0.0339
	-0.0221	-0.0335	-0.0211	-0.0247	-0.0288	-0.0324
Observations	107	50	104	76	82	106
R-squared	0.194	0.087	0.002	0.004	0.107	0.200

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The explanatory variables are the average investment loss from 2008 to 2010 (Inv. loss (2008–10)), the average R&D loss over the same period (RD loss (2008–10)), the average credit loss to the private sector over the same period (Credit loss (2008–10)), the change in the real short-term deposit rate between 2008 and 2010 (Rates diff. (2010 vs. 2008)), the maximum value of the World Uncertainty Index during 2007–2010 (WUI Max (2007–10)), and the loss in the forecasted 2013 GDP level based on WEO projections from April 2008 and October 2009 (For. 2013 GDP loss (Oct. 08 vs. Apr. 08)).

Table 2: Medium-term TFP Losses 2015-2017 and other variables 2008-2010 (Part II)

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
RD loss	0.171		0.372*	
(2008-10)	(0.190)		(0.199)	
For. 2013 GDP loss	1.282***	0.739***	0.843**	0.292
(oct 09 vs apr 08)	(0.310)	(0.280)	(0.388)	(0.327)
Inv. loss		0.265**		0.272**
(2008-10)		(0.111)		(0.125)
WUI			0.195	0.400**
(Max 2007-10)			(0.301)	(0.174)
Constant	-0.0170	-0.0221	-0.0105	-0.0310
	(0.0501)	(0.0321)	(0.0671)	(0.0374)
Observations	49	106	39	82
R-squared	0.331	0.243	0.261	0.218

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The explanatory variables are the average R&D loss from 2008 to 2010 (RD loss (2008–10)), the loss in the forecasted 2013 GDP level based on WEO projections from April 2008 and October 2009 (For. 2013 GDP loss (Oct. 08 vs. Apr. 08)), the average investment loss from 2008 to 2010 (Inv. loss (2008–10)), and the maximum value of the World Uncertainty Index during 2007–2010 (WUI Max (2007–10)).

Table 3: Robustness I - Medium-term TFP Losses 2015-2017. Adding machinery investment loss and price of machinery

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
Inv. loss (2008-10)	0.422*** (0.0838)			
EQ. loss (2008-10)		0.151* (0.0827)		
P. EQ. loss (2008-10)			-0.241 (0.249)	
P. EQ. loss (2015-17)				-0.0341 (0.0566)
Constant	0.0423* (0.0221)	0.0827*** (0.0234)	0.0997*** (0.0209)	0.101*** (0.0213)
Observations	107	107	107	107
R-squared	0.194	0.031	0.009	0.003

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The explanatory variables are the average investment loss from 2008 to 2010 (Inv. loss (2008–10)), the average investment in equipment loss from 2008 to 2010 (EQ. loss (2008-10)), the average price of equipment loss from 2008 to 2010 (P. EQ loss (2008–10)), and the average price of equipment loss from 2015 to 2017 (P. EQ. loss (2015-17)).

Table 4: Robustness II - Medium-term TFP Losses 2015-2017. Adding machinery investment loss and price of machinery with other variables simultaneously

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
Inv. loss	0.258**	0.262**	0.281**	0.243*
(2008-10)	(0.112)	(0.112)	(0.129)	(0.127)
For. 2013 GDP loss	0.738**	0.740***	0.286	0.295
(oct 09 vs apr 08)	(0.282)	(0.282)	(0.330)	(0.326)
P. EQ. loss	-0.111		0.0841	
(2008-10)	(0.227)		(0.256)	
P. EQ. loss		-0.0107		-0.0636
(2015-17)		(0.0517)		(0.0527)
WUI			0.398**	0.428**
(Max 2007-10)			(0.175)	(0.175)
Constant	-0.0236	-0.0231	-0.0300	-0.0389
	(0.0324)	(0.0326)	(0.0378)	(0.0379)
Observations	106	106	82	82
R-squared	0.244	0.243	0.220	0.233

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The explanatory variables are the average investment loss from 2008 to 2010 (Inv. loss (2008–10)), the loss in the forecasted 2013 GDP level based on WEO projections from April 2008 and October 2009 (For. 2013 GDP loss (Oct. 08 vs. Apr. 08)), the average price of equipment loss from 2008 to 2010 (P. EQ loss (2008–10)), the average price of equipment loss from 2015 to 2017 (P. EQ. loss (2015-17)), and the maximum value of the World Uncertainty Index during 2007-2010 (WUI (Max 2007-10)).

A Sample of countries

This appendix shows the observations available for each country to obtain the responses of macroeconomic variables in Figure 4 and also the years used to mark the banking crises. This information is shown in Table 5.

Table 5: Observations Hysteresis Estimations

Country	Obs. GDP	Obs. TFP	Obs. Investment	Obs. R&D	Obs. Credit	Years of banking crises
Afghanistan	18	0	18	0	11	
Albania	60	38	40	2	23	1994
Algeria	57	43	40	5	53	1990
Angola	58	0	40	0	22	
Antigua and Barbuda	57	0	43	0	40	
Argentina	58	2	40	19	54	1980 1989 1995 2001
Armenia	28	24	26	19	25	1994
Australia	60	54	41	10	57	
Austria	60	53	41	20	16	2008
Azerbaijan	28	23	0	20	25	1994
Bahamas, The	58	24	31	0	48	
Bahrain	58	28	32	1	36	
Bangladesh	58	0	41	0	43	1987
Barbados	57	38	34	0	20	
Belarus	39	25	25	20	23	1995
Belgium	60	53	50	20	16	2008
Belize	57	28	39	0	41	
Benin	58	0	40	0	55	1988
Bhutan	57	0	20	0	34	
Bolivia	57	29	40	8	54	1986 1994
Bosnia and Herzegovina	26	21	22	11	20	1992
Botswana	58	38	40	3	45	
Brazil	58	38	40	15	53	1990
Brunei Darussalam	35	27	25	3	18	
Bulgaria	60	38	24	20	16	1996
Burkina Faso	58	0	40	10	55	1990
Burundi	57	0	40	5	53	1994
Cabo Verde	57	38	40	1	37	1993
Cambodia	33	0	33	2	24	
Cameroon	58	38	40	0	55	1987 1995

Table 5 (cont.)

Country	Obs. GDP	Obs. TFP	Obs. Investment	Obs. R&D	Obs. Credit	Years of banking crises
Canada	60	53	41	19	49	
Central African Republic	57	0	40	0	54	1976 1995
Chad	57	0	40	0	54	1983 1992
Chile	60	58	60	9	57	1976 1981
China	58	28	40	20	40	1998
Colombia	58	41	43	18	53	1982 1998
Comoros	57	0	36	0	35	
Congo, Dem. Rep. of the	58	0	29	6	50	1983 1991
Congo, Republic of	57	0	42	0	54	1992
Costa Rica	60	38	35	16	57	1987 1994
Croatia	28	26	28	17	16	1998
Cyprus	57	37	43	18	16	2011
Czech Republic	25	23	25	20	16	1996
Côte d'Ivoire	58	38	40	0	55	1988
Denmark	55	53	55	19	16	2008
Djibouti	30	0	30	0	26	1991
Dominica	57	0	0	0	40	
Dominican Republic	58	18	43	0	55	2003
Ecuador	51	30	30	15	48	1982 1998
Egypt	58	28	33	17	52	1980
El Salvador	57	30	39	10	52	1989
Equatorial Guinea	57	0	40	0	32	1983
Eritrea	28	0	28	0	17	1993
Estonia	27	25	25	18	13	1992
Ethiopia	57	0	39	4	28	
Fiji	57	0	0	0	54	
Finland	60	53	55	20	16	1991
France	60	53	41	20	16	2008
Gabon	57	0	42	3	54	
Gambia, The	57	0	39	3	49	
Georgia	30	21	0	13	22	1991

Table 5 (cont.)

Country	Obs. GDP	Obs. TFP	Obs. Investment	Obs. R&D	Obs. Credit	Years of banking crises
Germany	60	58	60	20	16	2008
Ghana	58	0	50	2	55	1982
Greece	60	53	60	16	16	2008
Grenada	57	0	0	0	40	
Guatemala	57	0	37	8	54	
Guinea	57	0	39	0	25	1985 1993
Guinea-Bissau	40	0	40	0	31	1995 2014
Guyana	58	0	0	0	55	1993
Haiti	57	0	46	0	26	1994
Honduras	57	39	41	5	54	
Hong Kong SAR	59	40	50	18	27	
Hungary	58	38	50	20	16	1991 2008
Iceland	60	38	60	16	57	2008
India	60	39	41	17	57	1993
Indonesia	60	30	34	4	37	1997
Iran	60	31	60	10	56	
Iraq	22	0	0	7	12	
Ireland	60	32	60	19	16	2008
Israel	59	40	50	20	56	1983
Italy	60	53	41	20	16	2008
Jamaica	60	41	30	2	57	1996
Japan	60	58	41	20	57	1997
Jordan	58	34	30	2	52	1989
Kazakhstan	28	26	26	19	24	2008
Kenya	58	38	38	2	55	1985 1992
Kiribati	40	0	0	0	0	
Korea	60	53	50	20	57	1997
Kosovo	20	0	0	0	16	
Kuwait	58	28	41	17	51	1982
Kyrgyz Republic	28	24	27	19	22	1995
Lao P.D.R.	57	0	0	1	22	

Table 5 (cont.)

Country	Obs. GDP	Obs. TFP	Obs. Investment	Obs. R&D	Obs. Credit	Years of banking crises
Latvia	28	26	28	20	7	1995 2008
Lebanon	58	0	30	0	28	1990
Lesotho	57	0	40	6	44	
Liberia	20	0	0	0	16	1991
Libya	60	0	0	0	22	
Lithuania	25	19	25	20	7	1995
Luxembourg	60	53	35	14	16	2008
Macao SAR	19	17	19	15	16	
Macedonia, FYR	28	26	22	19	24	1993
Madagascar	60	0	42	16	55	1988
Malawi	57	0	43	0	52	
Malaysia	58	33	35	13	55	1997
Maldives	57	0	30	0	37	
Mali	58	0	40	2	50	1987
Malta	41	35	38	14	12	
Marshall Islands	23	0	0	0	0	
Mauritania	30	0	22	0	10	1984
Mauritius	60	58	42	10	41	
Mexico	58	38	40	20	55	1981 1994
Micronesia	25	0	0	0	22	
Moldova	30	24	28	15	22	2014
Mongolia	60	38	44	19	26	2008
Montenegro, Rep. of	20	0	20	9	15	
Morocco	58	22	44	6	51	1980
Mozambique	57	0	40	5	28	1987
Myanmar	23	20	22	6	20	
Namibia	30	0	30	2	27	
Nauru	16	0	0	0	0	
Nepal	60	0	35	3	57	1988
Netherlands	40	38	40	20	16	2008
New Zealand	55	53	55	9	45	

Table 5 (cont.)

Country	Obs. GDP	Obs. TFP	Obs. Investment	Obs. R&D	Obs. Credit	Years of banking crises
Nicaragua	57	39	42	7	54	1990 2000
Niger	58	0	40	0	55	1983
Nigeria	30	0	30	1	27	1991 2009
Norway	60	58	55	17	57	1991
Oman	58	37	30	5	45	
Pakistan	60	30	41	12	57	
Palau	20	0	20	0	0	
Panama	60	38	24	18	57	1988
Papua New Guinea	57	0	0	0	44	
Paraguay	60	0	43	10	57	1995
Peru	60	39	40	13	52	1983
Philippines	60	33	43	7	57	1983 1997
Poland	57	34	36	20	16	1992
Portugal	60	53	41	20	16	2008
Puerto Rico	40	0	40	3	0	
Qatar	57	28	30	1	47	
Romania	58	19	34	20	21	1998
Russia	30	28	30	20	17	1998 2008
Rwanda	60	0	40	0	53	
Samoa	59	0	0	0	35	
San Marino	23	0	23	0	0	
Saudi Arabia	58	38	39	11	49	
Senegal	57	0	40	2	54	1988
Serbia	23	21	23	19	20	
Seychelles	57	35	37	5	46	
Sierra Leone	57	0	40	0	54	1990
Singapore	60	40	42	19	54	
Slovak Republic	27	25	27	20	11	1998
Slovenia	28	26	28	20	13	1992 2008
Solomon Islands	57	0	40	0	39	
Somalia	9	0	0	0	0	
South Africa	58	39	40	13	51	
South Sudan	9	0	0	0	5	

Table 5 (cont.)

Country	Obs. GDP	Obs. TFP	Obs. Investment	Obs. R&D	Obs. Credit	Years of banking crises
Spain	60	53	41	20	16	1977 2008
Sri Lanka	58	0	40	7	55	1989
St. Kitts and Nevis	58	0	0	0	38	
St. Lucia	58	0	0	2	40	
St. Vincent & the Grenadines	57	0	0	2	42	
Sudan	58	33	0	7	55	
Suriname	57	28	29	0	50	
Swaziland	57	0	40	0	44	1995
Sweden	60	58	60	16	16	1991 2008
Switzerland	60	58	55	5	47	2008
Syria	51	0	33	0	48	
São Tomé and Príncipe	57	38	19	0	16	1992
Taiwan Province of China	60	39	47	0	0	
Tajikistan	28	23	0	15	19	
Tanzania	58	23	40	3	29	1987
Thailand	60	30	40	17	57	1983 1997
Timor-Leste	20	0	20	0	15	
Togo	58	0	40	3	55	1993
Tonga	44	0	0	0	41	
Trinidad and Tobago	57	37	39	19	54	
Tunisia	58	28	30	14	52	1991
Turkey	60	41	43	19	57	1982 2000
Turkmenistan	28	22	0	0	0	
Tuvalu	20	0	0	0	0	
Uganda	57	0	37	9	49	1994
Ukraine	29	27	28	19	25	1998 2008 2014
United Arab Emirates	51	40	42	3	42	
United Kingdom	60	58	42	20	57	2007
United States	60	58	41	20	57	1988 2007
Uruguay	58	35	39	15	55	1981 2002
Uzbekistan	29	24	0	16	0	
Vanuatu	57	0	18	0	38	
Venezuela	58	38	43	0	52	1994
Vietnam	57	29	28	3	24	1997
Yemen	30	0	30	0	24	1996
Zambia	58	0	40	7	51	1995
Zimbabwe	22	0	11	0	8	1995

B Estimations of the IRF specifications

This appendix details the specification used to compute the responses of macroeconomic variables following crises, as discussed in Section 3. For each variable, the specification was selected using the Bayesian Information Criterion (BIC), considering alternative models with 1 to 4 lags of the dependent variable and 0 to 4 lags of the crisis dummy. The chosen specification for the entire sample, along with the estimated coefficients in each case, is presented below for each of the macroeconomic variables analyzed in Section 3. These chosen specifications are maintained when analyzing alternative samples and different types of crises.

Table 6: Output

VARIABLES	(1) dlog(Output$_t$)
dlog(Output$_{t-1}$)	0.238***
	(0.00959)
Crisis dummy$_t$	-0.0245***
	(0.00468)
Crisis dummy$_{t-1}$	-0.0329***
	(0.00459)
Constant	0.0289***
	(0.000656)
Observations	9,887
Number of countries	195
R-squared	0.070

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 7: TFP

VARIABLES	(1) dlog(TFP_t)
dlog(TFP_{t-1})	0.226***
	(0.0153)
dlog(TFP_{t-2})	0.0221
	(0.0143)
Crisis $dummy_t$	-0.0207***
	(0.00420)
Crisis $dummy_{t-1}$	-0.0259***
	(0.00416)
Crisis $dummy_{t-2}$	0.00766*
	(0.00403)
Constant	0.00966***
	(0.000660)
Observations	3,782
Number of countries	114
R-squared	0.081

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Investment

VARIABLES	(1) dlog(Investment$_t$)
dlog(Investment$_{t-1}$)	-0.103***
	(0.0130)
dlog(Investment$_{t-2}$)	-0.0583***
	(0.0127)
dlog(Investment$_{t-3}$)	-0.0480***
	(0.0122)
dlog(Investment$_{t-4}$)	-0.0292**
	(0.0118)
Crisis dummy$_t$	-0.102***
	(0.0195)
Crisis dummy$_{t-1}$	-0.150***
	(0.0193)
Crisis dummy$_{t-2}$	0.0151
	(0.0188)
Constant	0.0558***
	(0.00288)
Observations	5,777
Number of countries	165
R-squared	0.030

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Credit

VARIABLES	(1) dlog($Credit_t$)
dlog($Credit_{t-1}$)	0.0790***
	(0.0132)
dlog($Credit_{t-2}$)	0.0434***
	(0.0127)
dlog($Credit_{t-3}$)	-0.253***
	(0.0124)
dlog($Credit_{t-4}$)	0.0297**
	(0.0120)
Crisis $dummy_t$	-0.0464**
	(0.0236)
Crisis $dummy_{t-1}$	-0.133***
	(0.0235)
Crisis $dummy_{t-2}$	-0.0745***
	(0.0235)
Constant	0.0742***
	(0.00360)
Observations	5,786
Number of countries	181
R-squared	0.081

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 10: R&D

VARIABLES	(1) dlog(R&D_t)
dlog(R&D_{t-1})	-0.0630**
	(0.0280)
Crisis dummy_t	-0.0187
	(0.0304)
Crisis dummy_{t-1}	-0.0767***
	(0.0296)
Constant	0.0613***
	(0.00520)
Observations	1,216
Number of countries	101
R-squared	0.010

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 11: Equipment investment

VARIABLES	(1) dlog($Equipment_t$)
dlog($Equipment_{t-1}$)	-0.0863***
	(0.0114)
dlog($Equipment_{t-2}$)	-0.0922***
	(0.0111)
dlog($Equipment_{t-3}$)	-0.0581***
	(0.0110)
dlog($Equipment_{t-4}$)	-0.0183*
	(0.0107)
Crisis $dummy_t$	-0.0712***
	(0.0236)
Crisis $dummy_{t-1}$	-0.138***
	(0.0237)
Crisis $dummy_{t-2}$	-0.0285
	(0.0237)
Constant	0.0930***
	(0.00375)
Observations	7,524
Number of countries	172
R-squared	0.022

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

C Alternative regression Analysis: Robustness for the pre-crisis trend

This appendix presents the regression results using two alternative methods for estimating the trend to compute the losses. One approach relies on observations from 2000 to 2007, while the other extends the period to 1995-2008. The tables below display the estimation results under these alternative specifications.

Table 12: Medium-term TFP losses with 2000-2007 trend

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6
Inv. loss	0.389***					
(2008-10)	(0.0673)					
RD loss		0.365**				
(2008-10)		(0.153)				
Credit loss			0.0233			
(2008-10)			(0.0395)			
Rates diff.				0.00201		
(2010 vs 2008)				(0.00434)		
WUI					0.590***	
(Max 2007-10)					(0.190)	
For. 2013 GDP loss						1.352***
(oct 09 vs apr 08)						(0.240)
Constant	0.0737***	0.182***	0.125***	0.132***	0.0286	-0.0393
	(0.0213)	(0.0357)	(0.0230)	(0.0277)	(0.0308)	(0.0345)
Observations	107	50	104	76	82	106
R-squared	0.241	0.106	0.003	0.003	0.107	0.233

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The explanatory variables are the average investment loss from 2008 to 2010 (Inv. loss (2008–10)), the average R&D loss over the same period (RD loss (2008–10)), the average credit loss to the private sector over the same period (Credit loss (2008–10)), the change in the real short-term deposit rate between 2008 and 2010 (Rates diff. (2010 vs. 2008)), the maximum value of the World Uncertainty Index during 2007–2010 (WUI Max (2007–10)), and the loss in the forecasted 2013 GDP level based on WEO projections from April 2008 and October 2009 (For. 2013 GDP loss (Oct. 08 vs. Apr. 08)).

Table 13: Medium-term TFP losses with 1995-2008 trend

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6
Inv. loss	0.517***					
(2008-10)	(0.0746)					
RD loss		0.244				
(2008-10)		(0.159)				
Credit loss			0.00214			
(2008-10)			(0.0532)			
Rates diff.				-0.00161		
(2010 vs 2008)				(0.00357)		
WUI					0.199	
(Max 2007-10)					(0.181)	
For. 2013 GDP loss						1.054***
(oct 09 vs apr 08)						(0.221)
Constant	0.0105	0.148***	0.0893***	0.0974***	0.0396	-0.0399
	(0.0196)	(0.0302)	(0.0203)	(0.0228)	(0.0293)	(0.0316)
Observations	107	50	104	76	82	106
R-squared	0.314	0.047	0.000	0.003	0.015	0.180

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The explanatory variables are the average investment loss from 2008 to 2010 (Inv. loss (2008–10)), the average R&D loss over the same period (RD loss (2008–10)), the average credit loss to the private sector over the same period (Credit loss (2008–10)), the change in the real short-term deposit rate between 2008 and 2010 (Rates diff. (2010 vs. 2008)), the maximum value of the World Uncertainty Index during 2007–2010 (WUI Max (2007–10)), and the loss in the forecasted 2013 GDP level based on WEO projections from April 2008 and October 2009 (For. 2013 GDP loss (Oct. 08 vs. Apr. 08)).