Inflation Targeting as a Shock Absorber

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Abstract

We study the characteristics of inflation targeting as a shock absorber in response to large adverse shocks in the form of natural disasters for a sample of 76 countries over the period 1970-2015. We find that inflation targeting significantly improves macroeconomic performance following such shocks as it lowers inflation, raises output growth, and reduces both inflation and growth variability compared to countries without an inflation-targeting regime. This performance is mostly due to a stronger response of monetary policy and fiscal policy under inflation targeting. Finally, we find that only de facto but not de jure targeters reap the fruits: deeds, not words, matter for successful monetary stabilization.

Key words: Monetary policy, central banks, monetary regimes, dynamic effects.

JEL classification: E52, E42, E58.

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1 Introduction

Inflation targeting has become a dominant framework for monetary policy over the last two decades. It has been praised for its success in bringing down inflation and raising credibility and accountability of policymakers (Bernanke and Mishkin, 1997; Ball, 2010). Its popularity has been reflected in an increasing number of countries adopting inflation targeting (IT) at the end of 2015. The global financial crisis has, however, dramatically changed the perception of IT as an optimal framework for achieving macroeconomic stability, in particular at times when the economy is confronted with large real or financial shocks. It has been argued that IT, by focusing narrowly on inflation, may contribute to a build-up of financial instability (Taylor, 2007; Svensson, 2010; Frankel, 2012), lead central banks to neglect other important objectives, such as employment (Stiglitz, 2008), and constrain monetary authorities in dealing with deep recessions (Borio, 2014).

Many studies have analyzed whether inflation targeting affects the economic performance of a country, though no clear-cut consensus has emerged in the literature (Walsh, 2009; Ball, 2010). The focus of most of this literature has been on the performance of IT regimes during the relatively good times of the 1990s and till the beginning of the 2008 global financial crisis. During those two decades of the "great moderation", with declining and low inflation rates amid strong economic growth, very few countries operating under an IT regime experienced a deep economic or financial crisis. A different and arguably at least equally important question is whether an IT regime helps countries and their central banks in dealing with crisis, i.e. whether it allows them to stabilize inflation and output in response to large adverse shocks.

This paper focuses on this question and analyzes whether countries operating under IT regimes have a better macroeconomic performance in response to large adverse shocks than those with non-IT regimes. We choose to limit the analysis to the effects of natural disasters as these are the most exogenous large adverse shocks that can be identified and as they have been shown to have a large impact on the macro-economy (Noy, 2009). This analysis can be extended to include also other types of shocks, such as financial shocks and other real shocks, though this would entail the risk of endogeneity to the monetary policy regime.

Natural disasters can be considered exogenous to the choice of the monetary policy regime because they are largely unpredictable and not caused by economic conditions. These features allow us to identify the conditional effects of IT using relatively weak and verifiable assumptions about the distribution of the unobserved factors that determine macroeconomic outcomes and about the systematic relation between natural disasters and monetary regimes. In terms of the treatment literature, we assume that conditioned on country characteristics "treatment" is random, but instead of focusing on the effects of the treatment, we are interested in whether alternative monetary regimes imply different responses to the treatment.

To obtain a measure of such shocks, we use the reported insurance damage, in percent of national GDP, from the EM-DAT dataset, which globally documents natural disasters. As we are specifically interested in *large* real shocks, we focus on disasters in the upper half of the disaster frequency distribution associated with large declines in GDP. We match the shocks with quarterly macroeconomic data for 76 countries over the period 1970Q1-2015Q4. We then estimate a set of panel models similar to the single-equation regressions of Romer and Romer (2004), Basu *et al.* (2006), or Kilian (2008), but extend this to a panel framework, to trace out the responses of key macroeconomic variables to the shocks. The models contain country fixed-effects as well as time-varying control variables that correct for the general susceptibility of a country to natural disasters.

We find important differences in the dynamic responses of IT and non-IT countries to large real shocks. Inflation targeters perform significantly better regarding both the level and the volatility of output and prices. While GDP drops immediately under both regimes, the initial decline is smaller in IT countries and the subsequent recovery is stronger and faster. Four years after the shock, output is about three percentage points higher than in non-IT countries. Moreover, consumer prices increase significantly less under IT. The difference to non-IT countries is about six percentage points after four years.

These dynamics are reflected in statistically and economically significant differences across monetary regimes in average GDP growth and inflation following large shocks. The average quarterly growth rate of output is 0.2 percent higher under IT, and the average inflation rate is 0.4 percent lower. Moreover, there is robust evidence that inflation targeters are more successful in stabilizing both growth and inflation. The standard deviation of both variables in the four years following a natural disaster is only half of the size as under alternative monetary regimes.

We analyze these differences by studying the underlying mechanisms through which IT affects the adjustment process to large shocks. The results suggest that IT countries rely on a different monetary-fiscal policy mix, they profit from reduced macroeconomic volatility and financial frictions, and their external sector provides a better buffer. Most strikingly, in IT economies central banks tighten monetary policy more or loosen it less following the adverse shock to stabilize inflation, while fiscal policy is more accommodating. Theses policy responses also significantly lower the shock-induced volatility of changes in output, consumer prices, consumption and investment relative to non-IT countries. Lower volatility, in turn, is associated with smaller countercyclical private credit risk and lower term premia. The stability of consumer prices, in particular, translates into a more stable real exchange rate and implies relatively higher export and lower import growth in IT economies.

In contrast, monetary authorities in non-IT economies tend to ease monetary policy more aggressively and persistently in an effort to stabilize output, while fiscal policy is contractionary. The adverse effects of private credit risk and term premia reduce the effectiveness of monetary policy and the policy mix in these countries overall induces lower output growth and higher consumer price inflation than in IT economies. Macroeconomic volatility is also higher in non-IT countries, and the strong increase in inflation leads to a significant real appreciation of the currency.

Finally, we find that the better macroeconomic performance is only realized by *de facto* targeters, whereas there is no evidence that *de jure* IT targeting enhances performance. *De facto* IT countries are defined as those that both had declared themselves to have an IT regime and were able to meet their inflation objective most of the time during the tranquil, five years prior to a natural disaster. *De jure* IT regimes are those that had declared to be inflation targeters, but also missed their inflation objective more often during the previous five, tranquil years.

This result is important as it suggests that it is not the fact that a central bank formally adopts an IT regime that allows a superior macroeconomic performance in response to large adverse shocks. But this finding suggests that it is the track record and the ensuing credibility of an IT central bank that allows it as well as the fiscal authorities to respond differently and more successfully to the economic shock of natural disasters.

Our paper relates to a large literature on the impact of IT on macroeconomic outcomes. In a seminal contribution, Ball and Sheridan (2004) find no significant differences between IT and non-IT countries, as measured by the behavior of inflation, output, and interest rates, in a sample of 20 OECD member states and based on a difference-in-difference approach that controls for regression to the mean. Similarly, Lin and Ye (2007) detect no effect of IT on either inflation or inflation variability in industrial countries when employing propensity score matching methods. Using OLS to study the impact of IT on disinflation periods in OECD countries, Brito (2010) concludes that inflation targeters were not able to bring inflation down at less cost than non-targeters.

On the other hand, Gonçalves and Carvalho (2009) find in a sample of OECD countries that inflation targeters suffer significantly smaller output losses from disinflations than non-targeters when controlling for possible selection bias through Probit or Heckman regressions. Moreover, Lin and Ye (2009), Lin (2010), and De Mendonça and e Souza (2012) show evidence based on propensity score matching that IT does lower inflation and inflation variability in developing countries. These apparently contradicting findings about the effectiveness of IT extend to studies which focus on the performance of IT during specific time periods and across different country samples – IT may be particularly beneficial if it helps improve the credibility of monetary authorities, which may apply more to developing countries than to industrial countries.

Concerning the global financial crisis, Rose (2014) finds that IT did not substantially change how a country weathered the crisis. By contrast, Carvalho Filho (2010) and Andersen *et al.* (2015) present evidence that IT countries fared significantly better in terms of their macroeconomic performance than others during this episode.

To the best of our knowledge, our paper is the first one to analyze whether inflation targeting is effective as a shock absorber in response to large real shocks. Our econometric approach, which has not been used before to study the macroeconomic impact of IT, has several advantages. First and foremost, estimating the conditional effect of IT, given an exogenous event, bypasses the need to directly deal with the potentially endogenous choice of the monetary regime to macroeconomic conditions as it "nets out" the unconditional impact of IT on the response variables. Methodologically, this approach is inspired by Ramcharan (2007), who uses natural disasters to evaluate the effects of alternative exchange rate regimes on the economic adjustment to real shocks in an annual sample of developing countries and employing pooled OLS.

The remainder of the paper is structured as follows. Section 2 formulates the main hypotheses. It also describes the empirical strategy and the data. Section 3 contains the core results. Section 4 provides a sensitivity analysis, before the final section concludes.

2 Empirical strategy and data

In this section we present the data as well as the empirical strategy.

2.1 Data description

Following Svensson (2010), inflation targeting (IT) can be described as a monetary framework under which the central bank publicly announces an official numerical target or target range for the inflation rate over a specific time horizon. The monetary authority also explicitly communicates to the public that low and stable inflation is the main goal of monetary policy, bases its decisions on inflation forecasts, and enjoys a high degree of political independence. IT is typically associated with enhanced communication standards of monetary authorities with the public and aims at increasing accountability, possibly through implicit incentives or explicit contracts for central bankers. These features in the conduct of monetary policy ideally make announced inflation targets of the central bank more credible. The main advantage over alternative monetary regimes is thus that IT addresses the dynamic consistency problem.

According to a standard forward-looking Phillips curve, lower and better anchored inflation expectations are thought to be associated with reduced and more stable actual inflation (Walsh, 2009). Lower inflation variability in turn will potentially reduce the short-run tradeoff between inflation and output and thus the impact of macroeconomic shocks. A publicly announced and credible inflation target could thus also stabilize output. Finally, following Bernanke and Mishkin (1997), low and stable inflation promotes long-run economic growth. This is because lower uncertainty about future inflation supports long-term savings and investment decisions and reduces the riskiness of nominal financial and wage contracts. Especially in emerging and developing economies, nominal stability can be an important prerequisite for foreign direct investment and thereby foster growth.

These considerations lead us to the following hypotheses. When a country is confronted with macroeconomic shocks, we first expect that inflation targeting reduces inflation and increases output growth, and second, that inflation targeting reduces the variability of both inflation and output growth.

2.1.1 Large natural disaster shocks

We use the EM-DAT database from the Center for Research on the Epidemiology of Disasters (CRED) in order to select large natural disasters.[1] This database provides detailed information on disasters such as earthquakes, droughts, floods and storms, among others, which occurred worldwide since 1900 to the present day. The data is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies.

There are low threshold criteria for events to be registered. One condition out of the following four needs to be fulfilled: 10 or more people are killed; 100 or more people are affected; there is a declaration of a state of emergency; there is a call for international assistance. The low thresholds lead to many observations that require filtering for large disasters, as our research question focuses on extreme shocks which have economic consequences on a national scale.

To this end, we follow the existing literature on the macroeconomic consequences of disasters (Noy, 2009). In particular, we make use of the reported estimated damage, which is the direct damage to

[1] Guha-Sapir, Below, Hoyois – EM-DAT: International Disaster Database – www.emdat.be – Université Catholique de Louvain, Brussels, Belgium.

property, crops, and livestock, reported in US dollars and valued at the moment of the event. Further, we weight the reported damage according to the occurrence of the event within a quarter, which is based on the assumption that a natural disaster taking place at the beginning of the quarter has a larger impact on quarterly measures of macroeconomic variables than one towards the end of a period. The weighted reported damage is calculated as

$$wDAM = DAM(3\text{-}OM)/3,$$

where OM denotes the first month, that is, the reported starting month of the natural disaster. Next, we sum over all weighted damages across events within the same quarter that are classified as natural disasters.[2] This is reasonable for the research question at hand, which focuses on the consequences of extreme shocks on the economy in general, so that we can abstract from the specific type of event that lead to the damage. We standardize the disaster size variable by dividing the weighted and aggregated reported damage variable by the level of nominal GDP one year prior to the event.

The selection of natural disasters leaves us with 1.953 events over the years 1970 to 2015. The sample period is dictated by the joint availability of macroeconomic variables for a sufficient number of countries. We further reduce the number of disaster events in two steps as we are interested in the economic adjustment process to real shocks that are of economic relevance to a country. First, we take the upper 50th percentile of the constructed damage variable, i.e. those with relatively large direct costs. Second, we select from this remaining set those episodes which are associated with large drops in GDP growth relative to trend. We do this by computing the percentiles of contemporaneous GDP growth conditional on a large disaster to occur. We then select the largest 50th percentile of negative deviations from trend. This procedure gives us 254 events that we use as shocks for the subsequent analysis: 175 large disasters in non-IT countries and 79 shocks in IT countries. Our results are robust to using different thresholds in the robustness analysis.

We focus on those disaster episodes that lead to a substantial reduction in GDP growth since we are not interested in the macroeconomic effects of natural disasters *per se* but in an evaluation of the conditional impact of alternative monetary regimes given a large shock. The selection of large contemporaneous negative deviations from trend GDP growth is, however, also backed by recent findings in the literature on the growths effects of natural disasters. Felbermayr and Gröschl (2014) find an average negative effect of 0.46 percentage points of the 5 percent of worst disasters constructed from geophysical and meteorological information. Noy (2009), using also the EM-DAT database and the reported damage to measure the size of the shock in a panel at annual frequency, similarly finds evidence for the hypothesis that natural disasters reduce GDP growth.

2.1.2 Inflation targeting

Regarding the monetary regime, we distinguish between inflation targeting and non-IT countries. The dates at which a country adopted inflation targeting feature some heterogeneity in the literature, depending on the criteria used. While some studies classify a country to follow inflation targeting after simply having announced numerical targets for inflation, others use dates when inflation targeting has been effectively implemented. This implementation implies that other

[2] These fall in either of the following categories: geophysical, meteorological, hydrological, climatological, biological and extraterrestrial. We exclude technological disasters.

nominal anchors like exchange rate targets are abandoned.[3] For our analysis, we follow Roger (2009) and create a dummy variable for the list of countries that have effectively implemented an inflation targeting regime.[4] We declare a quarter-country pair to take the value of one if the central bank has adopted IT within the corresponding quarter. Further, we also consider the European Central Bank to follow an implicit inflation targeting regime and declare countries that have adopted the euro as inflation targeters in our analysis. In a sensitivity analysis we show that the results are unaffected by this. An overview of inflation targeting and euro adoption dates is provided in Table 1 in Appendix A.

2.1.3 Other macroeconomic data and controls

We collect a range of macroeconomic data at a quarterly frequency for the period 1970Q1 to 2015Q4. The panel includes up to 76 countries, mostly advanced economies and emerging markets. A list of the countries is provided in Table 3. We obtain real and seasonally adjusted data on output, private and government consumption, investment, exports and imports from the OECD national accounts statistics, as well as from national sources. If seasonal adjusted data are not available, we make this transformation by our own. Further, CPI price indices, money market rates, and lending rates are obtained from the International Financial Statistics from the IMF. We compute CPI-based real exchange rates relative to the US using bilateral nominal exchange rates and CPI differences as real effective exchange rates are not available for our country sample at the quarterly frequency. The policy rate of the monetary authority, the T-Bill rate at a three month maturity and longer term yields on government debt are obtained from Datastream.

We clean the data with respect to periods of extraordinary large nominal fluctuations. Specifically, we drop observations for all variables during periods of extremely high nominal volatility, when either the policy, the inflation or the nominal exchange rate exceeds a given threshold of quarterly rate of change.[5] Such periods of large volatility are mostly driven by financial crisis or times of continued bad policy and not the result of a large shock from a natural disaster. After dropping periods of extraordinary volatility, we country-wise also drop observations that are separated along the time dimension from the longest continuous sequence of observations to ensure that the country time-series are uninterrupted.

Finally, we collect a number of control variables. We obtain annual data on total population and the degree of urbanization as a percentage of the total population living in cities from the World Bank. These country characteristics have been used in the literature to control for the possible differential impact a natural disaster may have across countries given regional differences. As a proxy for the level of democracy, we use the polity IV variable from the Center for Systemic Peace. An overview of the variables and sources is in Table 2.

[3] The difference between these two dating conventions is referred to in the literature as '*soft IT'* versus '*fully fledged IT'* (see Vega Winkelried (2005))).

[4] We update this list with countries that have adopted inflation targeting since 2007 by collecting data available from central bank websites.

[5] This threshold was chosen to be 20 percent in the quarterly rate of change in the case of inflation, 40 percent in case of the nominal exchange rate, and 20 percent in case of the policy rate. The main results are largely insensitive to changing the thresholds by ±10 percentage points.

2.2 Empirical model and identification

In a first specification, we measure the dynamic average effect of the shocks on the macro-economy across countries at a quarterly frequency as

$$\Delta y_{i,t} = c + \nu_i + \nu_Y + \sum_{l=1}^{L} \mu_l \Delta y_{i,t-l} + \sum_{j=0}^{J} \beta_j S_{i,t-j} + \phi X_{i,t-4} + \varepsilon_{i,t}. \quad (1)$$

$\Delta y_{i,t}$ denotes the quarterly rate of change in the dependent variable of interest for country *i* in quarter *t*. The natural disaster shock is captured by $S_{i,t-j}$. In order to account for time-invariant country characteristics, such as the geographic exposure to large natural disasters, we include country fixed effects ν_i. Moreover, we allow for year fixed effects ν_Y to correct for common unobservable time-varying factors, such as global growth and inflation trends as well as climatic change. To remove possible autocorrelation in the error term, we include lags of the dependent variable.

This makes our approach similar to the single-equation regressions of Romer and Romer (2004) and Kilian (2008) for the analysis of monetary policy and oil supply shocks, respectively. Finally, we add several time-varying control variables in the vector $X_{i,t-4}$. They include the degree of urbanization, population density and a measure for the level of democracy and enter at a lag of four quarters in order to prevent endogenous feedback in response to the natural disaster shock. We estimate equation (1) by OLS based on a within-transformation, assuming that the error term $\varepsilon_{i,t}$ is independent and identically distributed $IID(0, \sigma_\varepsilon^2)$.

In order to estimate the differential effect of inflation targeting in the aftermath of large natural disaster shocks, we extent the framework by including the IT-dummy, denoted by $IT_{i,t-j}$, in levels and as an interaction term with the shock:

$$\Delta y_{i,t} = c + \nu_i + \nu_Y + \sum_{l=1}^{L} \mu_l \Delta y_{i,t-l} + \sum_{j=0}^{J} \left[\beta_j S_{i,t-j} + \gamma_j IT_{i,t-j} S_{i,t-j} + \delta_j IT_{i,t-j}\right] + \phi X_{i,t-4} + \varepsilon_{i,t}. \quad (2)$$

The main parameters of interest are the $\gamma_j{}'s$. They capture the difference between the dynamic effects of large real shocks in inflation targeting and non-inflation targeting countries. Throughout, we base statistical inference on 500 Monte Carlo draws.[6]

To illustrate the identification strategy, we consider the case of *J = L = 0* and summarize all explanatory variables in (2) outside the brackets in the vector $Z_{i,t}$. Further, we define as $\mathrm{E}(\Delta y_{i,t} | S_{i,t} > 0, Z_{i,t})$ the expected value of $\Delta y_{i,t}$ given that a natural disaster occurred and conditioned on the set of co-variates $Z_{i,t}$. Following Ramcharan (2007), the average effect of the disaster is then

$$\begin{aligned}\mathrm{E}(\Delta y_{i,t} | S_{i,t} > 0, Z_{i,t}) - \mathrm{E}(\Delta y_{i,t} | S_{i,t} = 0, Z_{i,t}) &= \beta_0 S_{i,t} + \gamma_0 \mathrm{E}(IT_{i,t} | S_{i,t} > 0, Z_{i,t}) S_{i,t} \\ &\quad + \delta_0 \left[\mathrm{E}(IT_{i,t} | S_{i,t} > 0, Z_{i,t}) - \mathrm{E}(IT_{i,t} | S_{i,t} = 0, Z_{i,t})\right]\end{aligned} \quad (3)$$

[6] Following Romer and Romer (2004), we use the estimated covariance matrix of the coefficients to draw new coefficients from a multivariate normal distribution, from which we compute a distribution of impulse responses.

$$+ \left[\mathrm{E}\left(\varepsilon_{i,t} \middle| S_{i,t} > 0, Z_{i,t}\right) - \mathrm{E}\left(\varepsilon_{i,t} \middle| S_{i,t} = 0, Z_{i,t}\right) \right]$$

We make two assumptions to simplify (3). First, the residual $\varepsilon_{i,t}$, which captures unobserved drivers of $\Delta y_{i,t}$, is unrelated to the occurrence of the disaster shock $S_{i,t}$. The assumption is motivated by the random nature of these shocks and our strategy of accounting for country characteristics that capture the general susceptibility to these shocks. Then, $\mathrm{E}\left(\varepsilon_{i,t} \middle| S_{i,t} > 0, Z_{i,t}\right) = \mathrm{E}\left(\varepsilon_{i,t} \middle| S_{i,t} = 0, Z_{i,t}\right) = 0$.

Second, natural disaster shocks do not systematically affect the choice of the monetary regime. This assumption is motivated on the one hand by the remarkable stability of inflation targeting as a monetary regime (Rose, 2007; 2014). No country that adopted IT has ever abandoned it. This stability rules out the possibility that a country abolished IT in response to a large natural disaster. On the other hand, it is easy to check whether in our sample countries adopted IT (in the four years) following a large shock. We find only three such cases and excluding these countries from the analysis does not change the results. The assumption of exogeneity of the monetary policy regime to large natural disasters is also backed by the independency of the frequency at which a country is affected by a shock and its monetary regime.

Figure 1 shows the distribution of large disasters in the sample. Albeit the shocks are not equally distributed across countries, both inflation targeting and non-IT countries are present among countries with high and low frequency of being hit by large natural disasters. Hence, we assume that $\mathrm{E}\left(IT_{i,t} \middle| S_{i,t} > 0, Z_{i,t}\right) = \mathrm{E}\left(IT_{i,t} \middle| S_{i,t} = 0, Z_{i,t}\right) = IT_{i,t}$.

Under these two assumption (3) simplifies to

$$\mathrm{E}\left(\Delta y_{i,t} \middle| S_{i,t} > 0, Z_{i,t}\right) - \mathrm{E}\left(\Delta y_{i,t} \middle| S_{i,t} = 0, Z_{i,t}\right) = \beta_0 S_{i,t} + \gamma_0 IT_{i,t} S_{i,t},$$

where γ_0 measures the difference between the average effect of the shock in targeting and non-inflation targeting countries. However, to attach a causal interpretation to γ_0, we need to carefully control for other potential country features that could affect both the choice of the monetary regime and the response of the economy to the shock. In the sensitivity analysis, we will therefore control for the level of development of a country, as there is some evidence that the introduction of IT is mostly relevant for the performance of developing countries (Lin and Ye, 2007; Ball, 2010; Lin, 2010), and for those variables which have been used in the literature on natural disasters to account for different shock absorption capacities of countries.

3 Inflation targeting and macroeconomic performance

In this section, we first present the estimated dynamic effects of large real shocks on the macro-economy. Then we test whether IT economies respond to these shocks significantly differently to non-inflation targeting economies along a number of macroeconomic dimensions. Finally, we highlight several channels through which IT may alter economic performance.

3.1 The dynamic effects of large real shocks

Figure 2 summarizes the point estimates of the dynamic effects of large natural disasters on the first (log) difference of key macroeconomic variables on average across inflation targeting and non-IT economies, and their 68 and 90 percent confidence bands. We find a significantly negative effect on GDP growth, which declines by about 0.3 percent upon impact. It then overshoots for roughly two quarter, before returning to the level where it would have been without the shock.[7] The economic consequences of natural disasters can be viewed as those of a negative shock to the capital stock of an economy which distorts production. They typically cause direct damages to houses and contents, machinery, and infrastructure as well as indirect impacts due to business interruption. Post-disaster, the replacement of destroyed capital through potentially more productive investments and new technologies, spending of insurance payouts, and possible multiplier effects of increased household and business outlays generate catch-up demand and increase GDP growth.

As production is interrupted, various products - and labor - are in short supply, and more expensive substitutes are used, inflation increases significantly; by about 0.2 percentage points upon impact. When demand surges in the following quarters, inflation rises further to roughly 0.4 percentage points above trend, before the effects fade out. Despite the immediate price pressure, central banks on average aim at accommodating the adverse shock and the drop in output growth by lowering policy rates. When GDP growth recovers and inflation rises further, there is a tendency to tighten policy. Looking at the components of domestic absorption, government consumption seems largely unresponsive, leaving private consumption and investment as the main drivers of the overshooting of output growth. They both rise significantly in the quarter following the shock. Regarding the external sector, the real exchange rate is not affected much upon impact, as higher inflation and a weaker currency balance each other out, on average – with a depreciation contributing to an increase in inflation via higher import prices – but it then significantly appreciates when inflation reaches its peak and policy rates are raised. Real export growth drops immediately after the shock, contributing to the initial decline in GDP growth, before recovering. Import growth, on the other hand, tends to be above trend simultaneously with the other domestic demand components and the real exchange rate.

Figure 3 shows the dynamic effects of large natural disasters in cumulative terms. In particular, they show that the shocks have long-lasting and significant effects on GDP, several of its components, and consumer prices. After the negative impact of the natural disasters, the affected economies start recovering and return to the pre-crisis level of GDP after one to two years. Net exports are a drag on GDP as exports persistently decline and imports increase, consistent with the propensity of the currency to appreciate in real terms. The appreciation in turn appears to be a result of the sustained increase in the domestic price level. Finally, on average monetary and fiscal policy appear to be largely neutral over this horizon.

These average effects, however, mask important differences in the conduct of both monetary and fiscal policy across monetary regimes, as we will show next, which in turn has significant implications also for the evolution of the other variables under alternative regimes. Overall, these findings on the macroeconomic effects of natural disasters are by and large in line with the literature (Noy (2009) and Felbermayr and Gröschl (2014)).

[7] Our analysis does not aim at contributing specifically to the literature on the growth effects of natural disasters, which has not come to a consensus. Cavallo *et al.* (2013) find no significant effect of large natural disasters on GDP growth once controlling for political turmoil occurring in the aftermath of natural disasters. Loayza *et al.* (2012) find negative growth effects only for a subset of natural disasters, like earthquakes, windstorms, and droughts, while floods tend to have a mildly positive impact. Kousky (2014) provides a survey of this literature.

3.2 The effects of inflation targeting on macroeconomic dynamics

We now assess whether and how IT changes the dynamic adjustment to large real shocks. Specifically, we compute impulse responses for targeting and non-inflation targeting countries and test whether they are significantly different from each other. For brevity and because they provide a clearer picture of the dynamic effects of IT, we concentrate on the level effects and defer the underlying responses of first (log) differences to Appendix C. Figure 4 shows the adjustment of both targeting and non-inflation targeting economies. There are a number of statistically and economically significant differences. First and foremost, output is significantly higher and prices increase significantly less under IT. In fact, output persistently rises above the level without the shock, whereas it falls below the pre-shock level in non-inflation targeting countries. Consumer prices tend to rise under both monetary regimes, but only mildly and mostly indistinguishable from zero under IT, while there is a strong and long-lasting price increase otherwise. Together, these findings provide first tentative support for our first hypothesis.

Several mechanisms are relevant for understanding the pronounced differences. Regarding the response of economic policy, IT countries tentatively rely on fiscal policy to buffer the adverse shock, whereas non-IT economies strongly use monetary policy for that purpose. Specifically, in the latter group central banks aggressively lower policy rates, by cumulatively three percentage points two years after the shock. In sharp contrast, monetary authorities actually raise interest rates under IT; albeit only mildly and with some lag in response to the pickup in prices. For fiscal policy this country pattern is reversed. While in targeting countries accommodate the shock, non-inflation targeters reduce fiscal spending. Next to public, private spending seems to play a relevant share of the difference in the output responses between groups. Finally, regarding the external sector, there is some evidence that IT countries benefit from a more stable real exchange rate, which tends to appreciate in real terms in the other group where consumer prices increase sharply.

The cumulative differential effects between targeters and non-targeters, which allow for a more precise estimation and quantification of the dynamic effects of IT, are presented in Figure 5. They add to the evidence in favor of the first hypothesis as they underline the superior performance of IT economies. GDP is significantly higher under IT in the quarter of impact and subsequently. After four years, the difference is roughly 3 percent. At the same time, consumer prices are more than 5 percent lower. As indicated earlier, some of these marked differences in the behavior of output and prices across monetary regimes seem to be attributable to the direct effects of divergent monetary and fiscal policies across regimes, as well as to the differing paths of private consumption. After four years, the level responses of the respective variables differ by 3, 2, and 4 percent, respectively, between regimes.

Finally, to formally compute the average inflation and output growth rate in targeting and non-inflation targeting economies over the response horizon of four years and test whether the means are different across groups. As the underlying impulse responses are random vectors with distributions, we first investigate the precision and distribution of our estimates of average inflation and output growth, following Cecchetti and Rich (2001). Figure 6 plots the empirical density functions of the estimates obtained from the Monte Carlo simulations.

Several observations are worth mentioning. First, the figure corroborates the conclusion based on the impulse responses of a significantly better macroeconomic performance of targeting economies.

For both variables, the distributions overlap only marginally. Second, it shows that the effects for non-inflation targeters are estimated less precisely as the distributions have fatter tails. Third, it indicates that it is reasonable to assume that the true means, which are nonlinear functions of normally distributed variables, are also normally distributed. Based on the last observation, we proceed by estimating the means of these distributions and testing whether they are significantly different across regimes.

Table 4 contains the results for output growth and inflation, as well as for the other variables shown in the impulse responses. The first two columns lend strong support to the Hypothesis. The quarterly rate of output growth is 0.2 percentage points higher under IT, and the quarterly change in the price level is 0.4 percentage points lower. These differences are statistically highly significant according to the corresponding t-statistics and p-values. The results for the other variables are mostly equally stark and point to the same two reasons for the superior growth and inflation performance of targeters as the impulse responses: a different policy mix and better shock absorption through the external economy. All in all, we conclude from this section that inflation targeting significantly reduces inflation and increases output growth when the economy is subject to large real shocks.

3.3 Macroeconomic volatility and financial frictions

The finding that IT generates both higher output growth and lower inflation is remarkable given that there is also a contention in the literature whether IT can only reduce inflation at the expense of depressing output (Cecchetti and Rich, 2001; Friedman, 2004; Gonçalves and Carvalho, 2009). And the direct effects of the different policy mix adopted by targeting economies seem not to reveal the full story behind the success. There are additional features of IT, however, that are prominently discussed in the literature and which are thought to contribute to its superiority over alternative monetary regimes: the attainment of a generally more stable economic environment, and a reduction of financial frictions (see Bernanke and Mishkin, 1997).

To test the first argument, we assess the effect of IT on macroeconomic volatility. For this, we again rely on the distributions of the estimated impulse responses and compute, analogously to the procedure for mean growth rates, for each variable the distribution of the standard deviation of its growth rate over the response horizon of four years. With these distributions and the implied means at hand, we can formally evaluate our second hypothesis by testing whether IT reduces the mean variability of inflation and output growth in the presence of large real shocks.

Table 5 presents strong evidence in favor of argument (i). All standard deviations are significantly lower under IT. This observation holds for both nominal and real variables as well as for the domestic and external sector. The differences are all highly statistically significant.[8] Regarding the domestic economy, the standard deviation of inflation is roughly 40 percentage points lower under IT, and that of output growth about 20 percentage points. Based on these results, we accept the second hypothesis. Regarding the external economy, lower volatility of real exchange rate growth is coupled with lower fluctuations in export and import growth. Together with the model-consistent superior output growth performance of targeting economies documented in the previous section, these differences in volatility lend empirical support to the idea that IT supports output growth by

[8] The empirical density functions for the estimated standard deviations are shown in Figure 15 in Appendix C. As with the density functions for estimated means, they all appear to be well, that is, normally shaped.

establishing a generally more stable macroeconomic environment. This stability could also influence the degree of financial frictions in an economy.

We focus on two particular types of frictions to evaluate argument (ii): credit risk premia and term premia. To see whether the behavior of these premia is affected by the monetary regime, we study the behavior of different private and public interest rates. The first panel of Figure 7 repeats the differential responses of the policy rate between targeting and non-inflation targeting countries for comparison. The following panels contain the differences in the behavior of the short-term Treasury bill rate, the money market rate, and the lending rate of the private sector. The panels show that there are substantial differences in the pass-through of monetary interventions from the public to the private sector across regimes. While the difference between the response of the policy and the T-Bill rate is roughly 2 percentage points on average over four years, this gap narrows to 1.5 percentage points for the money market rate and to 1 percentage point for the lending rate. In the latter case, the difference is also less statistically significant. These numbers and underlying interest rate dynamics suggest that larger countercyclical private credit risk premia reduce the effectiveness of monetary policy in non-inflation targeting countries. This seems to partially explain their poorer output performance notwithstanding aggressive monetary easing. On the other hand, the results indicate that the behavior of public credit risk premia is similar across countries and thus does not help explain the different responses of fiscal policy as the response of the T-Bill rate is quantitatively similar to that of the policy rate.

What is striking nevertheless, is that despite the sharp relative increase of the T-Bill rate in targeting economies, there is no significant difference in the path of long-term rates (see middle panel). Together, these two observations suggest that the term premium responds quite different across monetary regimes. The expectations hypothesis of the term structure in its linear form implies that the nominal long-term rate is the sum of the path of the current and future expected nominal short-term rates and the term premium. To obtain a measure of the expected short rates, we compute and plot the cumulative difference in the policy rate, which can also be interpreted as the model-based differential change in the yield curve between countries in the quarter of impact. The sharp relative steepening of the curve in targeting economies can only be consistent with an essentially unchanged difference in the long rate if the difference between the term premia in targeting and non-inflation targeting countries strongly declines. Indeed, looking at the (unreported) country-specific responses suggests that the term premium remains roughly constant in targeting countries, whereas it sharply increases in non-inflation targeting economies, such that the differential term premium drops.

We reach similar conclusions when looking at the behavior of expected real rates and inflation. The standard term structure theory further implies that the nominal long rate is the sum of current and future expected real short rates, expected inflation, and the term premium. To obtain a measure of expected real short rates we first estimate the response of current real rates, computed as the difference between the policy rate and realized inflation, and then cumulate the response. To approximate expected inflation, we employ the model-based change in the price level. As the figure shows, the relative increase in the expected real rates in targeting countries is quantitatively not fully compensated by relative declines in inflation expectations, which implies that the relative term premium must decline for the difference in the nominal long rate to remain stable. Altogether, the results of the section help to understand why a strong monetary stimulus coupled with a mild fiscal contraction in non-inflation targeting economies yields significantly inferior outcomes than a moderate monetary tightening with fiscal accommodation in targeting countries.

3.4 Does de facto or de jure targeting make a difference?

As a final step in the main analysis we try to determine whether the adoption of IT per se generates macroeconomic improvements. Such a finding would speak against the "conservative window-dressing" view which postulates that the very features of IT have little or no effects on output or inflation and instead the stronger emphasis of the central bank on inflation and the corresponding conduct of monetary policy achieves the better outcomes (Romer, 2006). To test this argument we split the IT group into *de jure* and *de facto* targeters according to their average duration of missing the inflation target. For each IT country, we compute the average duration of the CPI inflation rate outside of the target range. For countries that do not report a target range, we compute a hypothetical range around the point target with the average width of target ranges in the sample.

Figure 8.A shows the histogram of the average duration of target misses in the sample. The distribution is highly skewed to the right. There is no country with an average duration of target misses at zero or one quarter and the highest density is at two quarters, rapidly declining to 14 quarters. There are several outliers of up to 40 quarters of continued misses. Figure 8.B exhibits the maximum duration spell of each IT country. This is the measure we use to separate *de facto* from *de jure* inflation targeting regimes. We split IT countries according to the 50^{th} percentile of the maximum duration spell of target misses, labeling the lower percentile with a shorter maximum duration as *de facto* targeters, whereas the upper 50^{th} percentile represent the *de jure* targeters.

Our classification follows the idea that temporary deviations from the inflation target are fully in line with an inflation target which should be reached over the medium term, while different shocks drive the actual inflation rate occasionally out of the target range. In fact, there is no country in our sample for which inflation has never deviated from the target. Depending on the size of the shock, this might also occur by a substantive amount. Further, monetary policy moves inflation only with some lag, which gives rise to some persistence in the deviation from target. However, in order to maintain credibility in the overall target, a prolonged deviation should result in an enhanced effort by the central bank to restore the target (Roger and Stone, 2005). We thus argue that the maximum duration that the inflation rate was out of the target range is a good proxy for the commitment of the central bank to maintaining and defending the inflation target.

The first row of Figure 9 repeats the baseline results for output, prices, and the policy rate for comparison. They are based on the differential responses of all targeting versus all non-inflation targeting countries. The middle row contains the differential effects of only de jure versus all non-inflation targeting economies and the last row those of only de facto against all non-inflation targeting countries. There are hardly any differences between how de jure and non-inflation targeting economies whether large adverse shocks. If anything, there is a stronger increase in prices for de jure targeters, although this relative increase is mostly insignificant. In sharp contrast, de facto targeters perform significantly better than non-inflation targeters. In fact, the differential responses for only de facto targeters are quantitatively similar to those for all targeters. Together, the findings suggest that the baseline results are mostly driven by de facto targeters and that it is the actual conduct of monetary policy that matters for successful macroeconomic stabilization.

4 Sensitivity analysis

In this section we perform various sensitivity tests to see whether our main results are robust. We control for other potential shock absorbers, we consider modified versions of the shock and IT measures, and we use an alternative estimator as well as different model specifications.

4.1 Controlling for other potential shock absorbers

We estimate modified versions of model (2) in order to control for alternative channels that potentially affect the response of a country to a natural disaster shock. Specifically, we extend the model with a second level and interaction term for a generic additional variable $W_{i,t-j}$:

$$\Delta y_{i,t} = c + \sum_{j=0}^{J} \left[\beta_i S_{i,t-j} + \gamma_j IT_{i,t-j} S_{i,t-j} \; + \; \delta_j IT_{i,t-j} + \tau_j W_{i,t-j} S_{i,t-j} + \lambda_{i,t-j} W_{i,t-j} \right] + \sum_{l=1}^{L} \mu_l \Delta y_{i,t-l} + \phi X_{i,t-4} + \nu_i + \nu_Y + \varepsilon_{i,t}. \tag{4}$$

Given our lag lengths *J* and *L*, this model contains up to 36 additional parameters to be estimated. We therefore mostly use alternative variables for $W_{i,t-j}$, one at a time, to obtain precise estimates, and include control interaction (and level) terms for several variables simultaneously only in a final specification.

First, we correct for the level of development of a country. On the one hand, richer economies might be more likely to adopt IT, given their typically more developed democratic and financial institutions, and at the same time to weather large natural disasters better. On the other hand, there is evidence in the literature that the introduction of IT has in particular an impact on economic performance in developing economies (Ball, 2010; De Mendonça and e Souza, 2012). Lin and Ye (2007), for example, find no effect of IT in seven industrial countries, whereas Lin (2010) detects a significant impact of IT in developing countries.

The first row in Figure 10 shows the cumulative difference between targeting and non-inflation targeting countries of selected variables when controlling for a country being member of the G7 through interaction terms. The second row broadens the definition of advanced economies and replaces the G7 dummy with an indicator variable for all 20 OECD founding countries. The last row generalizes the classification further by instead using GDP per capita in 1997Q1.[9] This measure is used as a proxy for the average degree of development of an economy, which may affect its capabilities to adjust to natural disaster shocks. For example, higher security standards and higher quality of the infrastructure might improve resilience and be conducive to recover faster. The figure shows however that the main results do not change qualitatively and that there are only minor quantitative differences in the dynamic behavior of GDP, consumer prices, and the policy rate when compared to the baseline specification.

The impression that controlling for the level of development through interaction terms does not change the main results is supported by formal tests. Rows (2)-(4) of Table 6 show the difference

[9] In all three cases, we leave out the level term as it is constant over time and hence captured by the country fixed effects.

between targeting and non-inflation targeting countries of the estimated average first and second moment of GDP growth and inflation over a response horizon of four years following a shock and the corresponding t-statistics, obtained from Monte Carlo simulations. In all three cases, output growth is significantly higher, inflation is lower, and both output growth and inflation variability are lower. The differences remain highly statistically significant and tend to be larger in absolute value than in the baseline specification, which is repeated in the first row for comparison. As a final cross-check of whether the level of development matters for our results, we use the polity IV variable as W_{it-j} since advanced economies usually have better institutions. This variable is also motivated by the results of Noy (2009), who finds that the quality of institutions reduces the impact of natural disasters on aggregate growth. Row (5) suggests, however, that the main results are not driven by institutional quality, as the differences between targeting and non-inflation targeting countries remain relatively unchanged.

In row (6), we instead control for the exchange rate regime, as Ramcharan (2007) shows that flexible exchange rates are conducive to the adjustment to real shocks. Specifically, we use a dummy variable which is equal to one in case of a fixed exchange rate regime, and zero in case of flexible exchange rates.[10] In rows (7)-(9) we replace the exchange rate dummy with the frequency by which a country is hit by shocks, an island dummy, and the size of a country in squared *km*, respectively, following Ramcharan (2007). All three interaction terms capture geographic characteristics of a country that potentially affect both the choice of the monetary regime and the response to the shock. In rows (10) and (11) we instead use GDP and government size, respectively, as measures of the ability of a country to provide internal assistance to disaster-hit regions. In all specification (6)-(11) the main results hold qualitatively, and the differences between targeting and non-inflation targeting countries are quantitatively reasonably similar to the baseline specification.

In the last row we include several of the control interaction terms simultaneously. Specifically, we combine one measure of development (*GDP p.c.*) with the exchange rate regime dummy, the frequency, the island dummy, and one size measure (*size in* km^2). The estimated effect of IT on first moments is somewhat smaller but the impact on second moments increases. Moreover, the differences remain highly significant although they are less precisely estimated. We conclude that while other factors also play a role in the absorption of shocks, they are not the explanation for the differential behavior of targeting and non-inflation targeting countries shown in the previous sections.

4.2 Alternative lag length selection and estimator

In this section we evaluate whether the choice of the lag length of the endogenous variables or the choice of the estimator changes our main conclusions. The first sensitivity test is motivated by Coibion (2012), who shows that the quantitative size of the effects of monetary policy estimated by Romer and Romer (2004) depends, among others, on the number of lags of the endogenous variables that are included to control for autocorrelation in the error terms. The second check addresses remaining concerns about biased estimates when using lagged endogenous variables as

[10] We use the measure of Reinhart and Rogoff (2004) and map their classification which describes exchange rate regimes on the interval (1,6) into the exchange rate regime dummy variable according to Ramcharand (2007). Specifically, regimes ≤3 are classified as fixed (dummy =1), while 4 and 6 are classified as flexible (dummy=2). We exclude 5=freely falling from the sample.

regressors (see Nickell, 1981), although this bias is known to be small in samples where the time-dimension is long (T>30, see Judson and Owen, 1999), as in our case.

Figure 11 shows the differential response of output, prices, and the policy rate between targeting and non-inflation targeting countries. The first row contains the results for including three lags of the endogenous variables on the right hand side, instead of four lags as in the baseline specification. The difference in the impacts is qualitatively not and quantitatively as well as in terms of statistical significance only mildly affected by this change of the empirical model. We obtain similar results when reducing the number of lags to two in the middle row.

In the final row, we explicitly model the error term structure using panel corrected standard errors, following Beck and Katz (1995). The error structure accounts for panel heteroskedacticity and contemporaneously as well as serially correlated errors. Specifically, we allow for common first-order autocorrelation. Panel heteroskedasticity and contemporaneous correlation can arise in large cross-country panels where the level of the endogenous variables differs noticeable across countries and where countries are potentially affected by correlated shocks. We include a full set of country dummies and report the point estimates together with their 90 percent asymptotic standard errors. The responses are qualitatively and quantitatively similar to the baseline results using the fixed-effects estimator with lagged endogenous variables and Monte Carlo based standard errors. Their statistical significance improves, however, for all three variables, and in particular for prices, suggesting that our baseline estimator tends to provide a lower bound of the effects of IT.

4.3 Alternative shock selection and modified classification of inflation targeters

In this section we assess whether the main results are sensitive to the selection of shocks or to the classification of inflation targeting. Figure 12 shows the differential effects across targeting and non-inflation targeting countries of large natural disasters on output, prices, and the policy rate. The first row is based on a subset of the shocks considered in the main analysis. Specifically, we use only the upper 75th percentile of the damage variable, instead of the upper 50th percentile in the baseline specification, and from those select the bottom 50th percentile of GDP deviations, as before. This choice leaves us with 57 shocks for non-inflation targeters and 23 shocks for targeters, instead of 175 and 79 shocks, respectively, in the baseline specification. By focusing on an even narrower set of large shocks, we aim at further eliminating noise, in particular in the damage reporting variable. Indeed, as the first row shows, the differential effects tend to be larger and more precisely estimated.

Next, we keep the upper 75th percentile of the damage variable, but leave out the second step in the shock selection procedure, where we condition on the decline in GDP, to see whether this latter choice affects the main results. In this case, we obtain 112 shocks for non-inflation targeting and 49 shocks for targeting economies. The middle row shows that the differential effects are qualitatively unaffected, but tend to be less precisely estimated. The differential impacts on GDP and the policy rate are somewhat smaller between targeting and non-inflation targeting economies, whereas the difference in the response of the prices level is much more pronounced.

Finally, we use an alternative classification of IT as there is no consensus in the literature whether the ECB is an inflation targeter nor not (Ball, 2010; Rose, 2014). We thus re-define all 18 euro area countries as non-inflation targeters, different to the baseline classification where all countries are coded as targeters when entering the euro. The bottom row shows that the results are mostly unchanged, with the differential effect on prices slightly more significant than in the baseline specification.

5 Conclusions

In this paper we present robust empirical evidence for the hypothesis that inflation targeting leads to better economic outcomes. IT countries experience significantly lower inflation and inflation variability than non-inflation targeting countries confronted with large real shocks, and at the same time enjoy higher and more stable output growth. We show that the success of inflation targeting rests on a number of pillars. First, only de facto targeting stabilizes the economy, while de jure targeting has no effect on macroeconomic dynamics. Second, our results suggest that a tougher stance on inflation does not only reduce consumer price fluctuations but also real exchange rate movements, which translates into a better adjustment of the economy through the external sector. Third, the findings indicated that IT, by reducing also the volatility of public and private interest rates, increases the effectiveness of monetary policy by lowering credit risk and term premia. Moreover, private consumption and investment are more stable under IT, which is supportive of growth. Finally, the adoption of IT with its focus on price stability appears to be coupled with a stronger orientation of fiscal policy towards output stabilization. All in all, our findings show that inflation targeting is well and alive and rationalize the remarkable success of this monetary regime which, once adopted, has never been abandoned (Rose, 2007; 2014).

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Appendix A: Tables

Table 1: Inflation targeting adoption dates

Country	IT adoption date[2]	euro adoption date
Albania	January 2009	
Australia[1]	April 1993	
Brazil	June 1999	
Canada[1]	February 1991	
Chile[1]	September 1999	
Colombia	September 1999	
Czech Rep[1]	December 1997	
Ghana	May 2007	
Guatemala	January 2005	
Hungary[1]	June 2001	
Iceland[1]	March 2001	
Indonesia	July 2005	
Israel[1]	June 1997	
Korea Rep[1]	January 2001	
Mexico[1]	January 2001	
New Zealand[1]	January 1990	
Norway[1]	March 2001	
Peru	January 2002	
Philippines	January 2002	
Poland[1]	December 1998	
Romania	August 2005	
Serbia	September 2006	
South Africa	February 2000	
Sweden[1]	January 1993	
Thailand	May 2000	
Turkey[1]	January 2006	
United Kingdom[1]	December 1992	
Finland[1]	February 1993	January 1999
Slovakia[1]	January 2005	January 2009
Spain[1]	January 1995	January 1999
Austria[1]		January 1999
Belgium[1]		January 1999
Cyprus		August 2008
Estonia[1]		January 2011
France[1]		January 1999
Germany[1]		January 1999
Greece[1]		January 2001
Ireland[1]		January 1999
Italy[1]		January 1999
Latvia[1]		January 2014
Lithuania		January 2015
Luxembourg[1]		January 1999
Malta		January 2008
Netherlands[1]		January 1999
Portugal[1]		January 1999
Slovenia[1]		January 2007

Notes: [1)] OECD member country. [2)] Date of adopting fully fledged inflation targeting

Sources: Roger (2009), National central banks, European Central Bank.

Table 2: Data sources

Variable	Definition	Source
DAMw50X50	Damage from disasters in % of GDP: upper 50^{th} percentile of damage reported, lower 50th percentile of deviations from GDP per capita trend growth rate	EM-DAT, IMF-IFS
DAMw50	Damage from disasters in % of GDP: upper 50th percentile of damage reported	EM-DAT, IMF-IFS, OECD, National Sources
itecb	Dummy for inflation targeting, including the euro area	see Table 1
it	Dummy for inflation targeting	see Table 1
GDP	Real per capita GDP	OECD, national sources, WDI
Prices	CPI price index,	IMF-IFS
Policy rate	Core rate at which banks can borrow from the national central bank, end of period, percent	Datastream
Government consumption	Real government consumption, seasonally adjusted	OECD, national sources
Private consumption	Real private consumption, seasonally adjusted	OECD, national sources
Investment	Gross capital formation, seasonally adjusted	OECD, national sources
REER	Real effective exchange rate index	BIS
Exports	Real exports, seasonally adjusted	OECD, national sources
Imports	Real imports, seasonally adjusted	OECD, national sources
Tbill rate	Yield on government bond, 3 month maturity, percent	Datastream
Money rate	Money market rate, percent	IMF-IFS
Lending rate	Lending rate, percent	IMF-IFS
Long rate	Yield on long-term government bond, percent	IMF-IFS
Democracy	Polity IV, scaled and standardized on the interval [0,1], with 1 indicating a high level of democratic institutions	Center for Systemic Peace
Urbanization	Urban population in percent of total population, annual frequency	World Bank/WDI
Density	Population (thousand) per land area (square kilometers), annual frequency	World Bank/WDI

Table 3: Country list

Albania	India	Pakistan
Algeria	Indonesia	Peru
Argentina	Ireland	Philippines
Australia	Israel	Poland
Austria	Italy	Portugal
Belgium	Japan	Romania
Brazil	Jordan	Russia
Bulgaria	Kazakhstan	Serbia
Canada	Kenya	Singapore
Chile	Korea Rep	Slovakia
Colombia	Kyrgyzstan	South Africa
Croatia	Latvia	Spain
Cyprus	Lithuania	Sri Lanka
Czech Rep	Luxembourg	Sweden
Denmark	Malaysia	Switzerland
Egypt	Malta	Thailand
Estonia	Mauritius	Trinidad and Tobago
Finland	Mexico	Tunisia
France	Mongolia	Turkey
Georgia	Morocco	Ukraine
Germany	Namibia	United Kingdom
Greece	Netherlands	United States
Guatemala	New Zealand	Viet Nam
Honduras	Nigeria	Yemen
Hungary	Norway	
Iceland	Oman	

Table 4: Testing for differences in means

Variable	D. GDP	D. Prices	D. Pol. rate	D. Gov. cons.	D. Priv. cons.	D. Investm.	D. RER	D. Exports	D. Imports
IT	0.07	0.07	0.03	0.03	0.09	0.10	0.01	-0.05	0.07
non-IT	-0.13	0.51	-0.12	-0.15	-0.14	0.10	-0.41	-0.11	0.18
Difference	0.20	-0.44	0.15	0.18	0.23	0.00	0.42	0.06	-0.11
t-statistic	57.91	-35.92	71.79	39.64	51.41	0.40	26.60	8.19	-12.04
p-value	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00

Notes: The table shows the estimated mean of the (log) change of main macroeconomic variables over four years following a natural disasters in inflation targeting and non-inflation targeting economies, as well as the differences between the means together with their t-statistics and p-values based on 500 Monte Carlo draws.

Table 5: Testing for differences in volatility

Variable	D. GDP	D. Prices	D. Pol. rate	D. Gov. cons.	D. Priv. cons.	D. Investm.	D. RER	D. Exports	D. Imports
IT	0.15	0.15	0.07	0.29	0.13	0.54	0.60	0.48	0.45
non-IT	0.38	0.54	0.32	0.66	0.36	1.15	1.60	1.15	1.04
Difference	-0.22	-0.39	-0.25	-0.37	-0.24	-0.61	-1.00	-0.67	-0.59
t-statistic	-72.82	-54.07	-127.95	-56.48	-81.62	-60.63	-81.39	-75.89	-66.43
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: The table shows the estimated average standard deviation of the (log) change of main macroeconomic variables over four years following a large real shock in inflation targeting and non-inflation targeting economies, as well as the differences between the mean standard deviations together with their t-statistics and p-values based on 500 Monte Carlo draws.

Table 6: Controlling for other shock absorbers

		mean change				mean standard deviation			
		D.GDP		D.Prices		D.GDP		D.Prices	
Specification		Diff.	t-stat	Diff.	t-stat	Diff.	t-stat	Diff.	t-stat
(1)	*Baseline*	0.20	58.89	-0.42	-35.70	-0.23	-76.89	-0.39	-54.75
(2)	*G7*	0.17	43.55	-0.59	-43.53	-0.31	-88.44	-0.73	-70.54
(3)	*OECD 20*	0.22	49.20	-0.36	-24.09	-0.30	-83.28	-0.66	-66.89
(4)	*GDP p.c.*	0.23	50.64	-0.49	-34.06	-0.37	-88.31	-0.83	-73.02
(5)	*Institutions*	0.20	43.00	-0.57	-43.64	-0.20	-31.00	-0.10	-6.74
(6)	*FX regime*	0.22	39.44	-0.29	-15.98	-0.10	-21.66	-0.18	-14.49
(7)	*Frequency*	0.10	20.46	-0.36	-22.78	-0.40	-90.94	-0.73	-64.90
(8)	*Island*	0.17	42.34	-0.41	-30.11	-0.28	-80.05	-0.61	-65.48
(9)	*Size (km^2)*	0.20	53.49	-0.46	-38.72	-0.22	-68.96	-0.37	-51.74
(10)	*GDP size*	0.16	44.97	-0.69	-51.41	-0.31	-88.90	-0.69	-67.17
(11)	*Gov. size*	0.21	59.58	-0.44	-37.98	-0.20	-61.16	-0.39	-45.79
(12)	*Combined*	0.19	28.15	-0.27	-9.85	-0.31	-45.88	-0.69	-34.91

Notes: The table shows the difference between the average estimated mean and standard deviation of GDP growth and inflation over four years following a large real shock in inflation targeting and non-inflation targeting economies, together with their t-statistics based on 500 Monte Carlo draws and when controlling for other potential shock absorbers.

Appendix B: Figures

Figure 1: Distribution of large disaster shocks

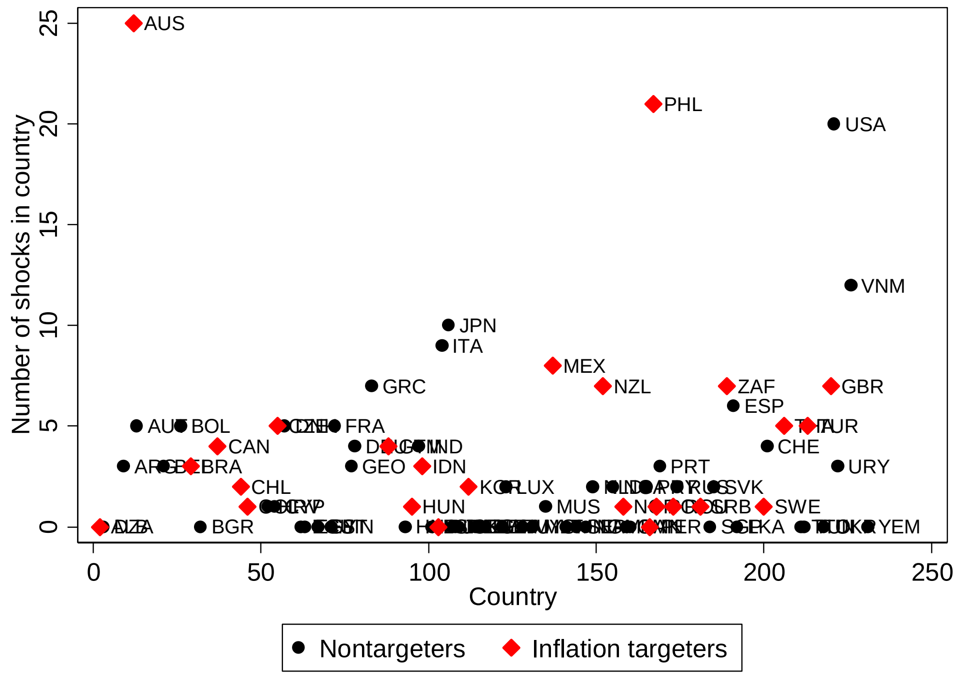
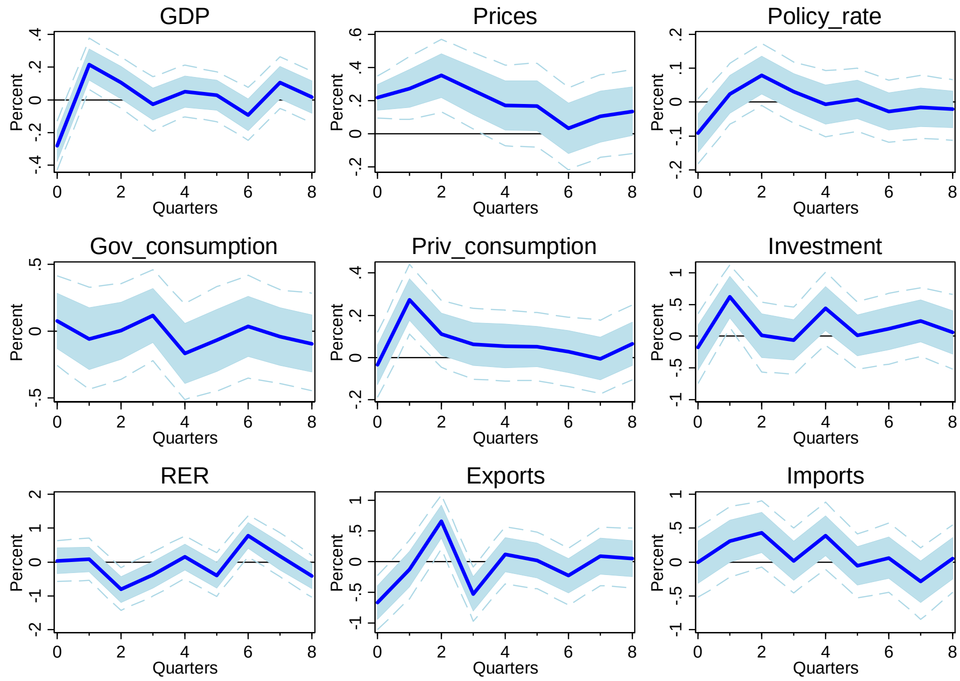
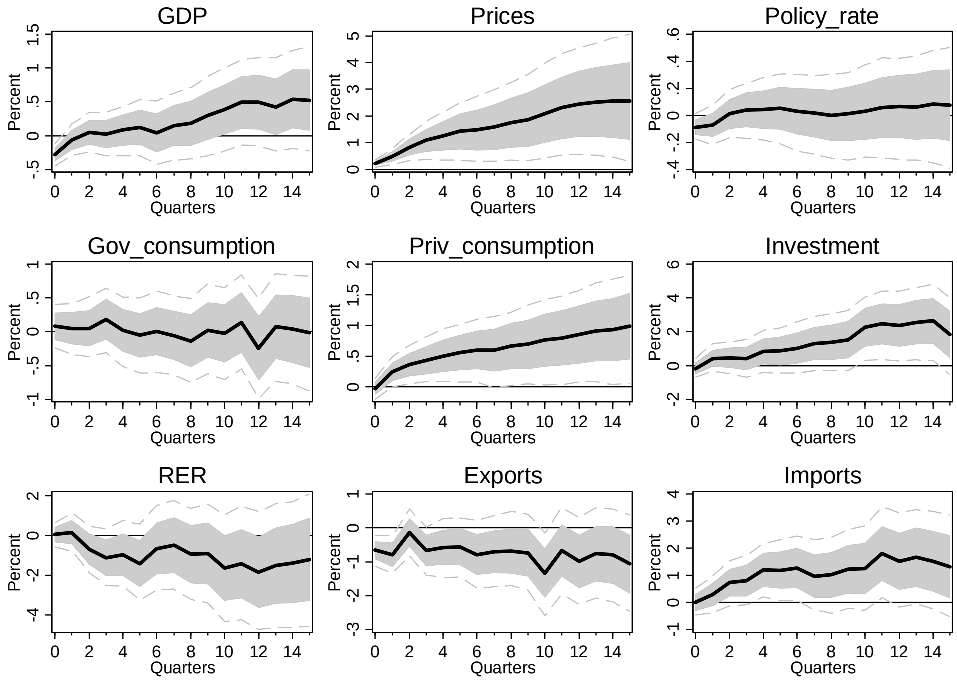


Figure 2: Dynamic effects of large natural disasters on the first (log) differences of key variables



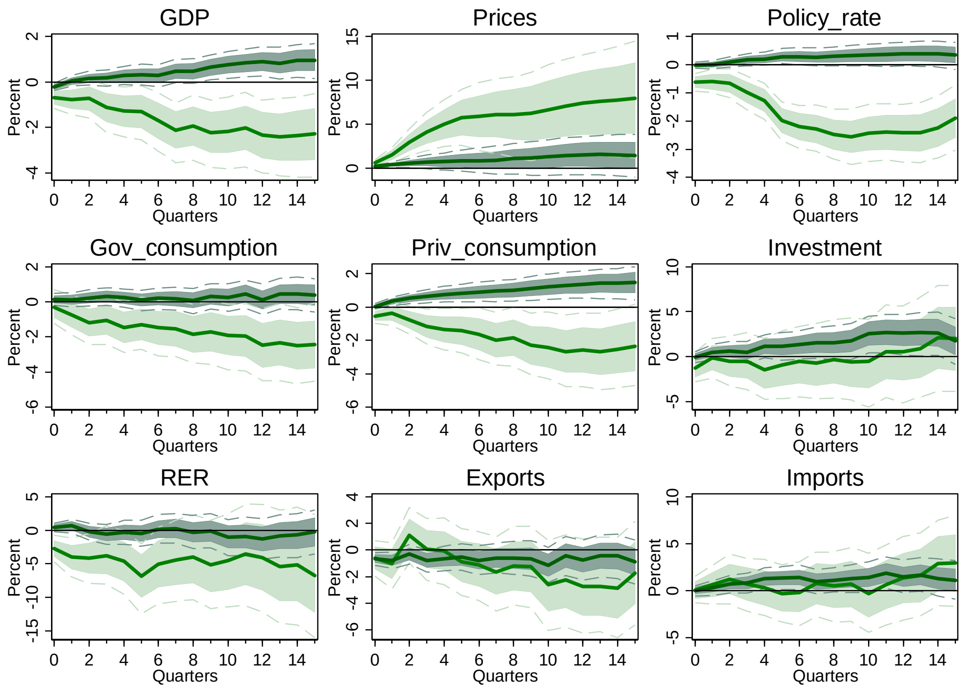
Note: The figure shows the average response of the first (log) differences of key macroeconomic variables to large natural disasters in a sample of 76 inflation targeting and non-inflation targeting countries over the period 1970Q1-2015Q4. Statistical inference is based on 500 Monte-Carlo draws.

Figure 3: Dynamic effects of large natural disasters on the level of key macroeconomic variables



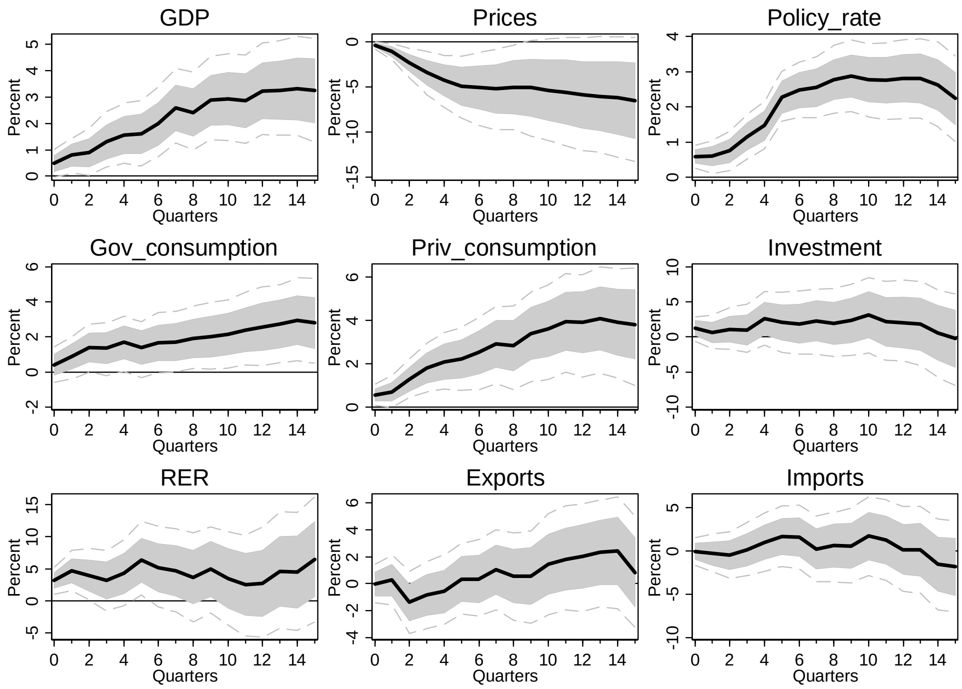
Note: The figure shows the average response of the level (cumulated first (log) difference) of key macroeconomic variables to large natural disasters in a sample of 76 inflation targeting and non-inflation targeting countries over the period 1970Q1-2015Q4. Statistical inference is based on 500 Monte-Carlo draws.

Figure 4: Level effects of large real shocks in targeting and non-inflation targeting economies



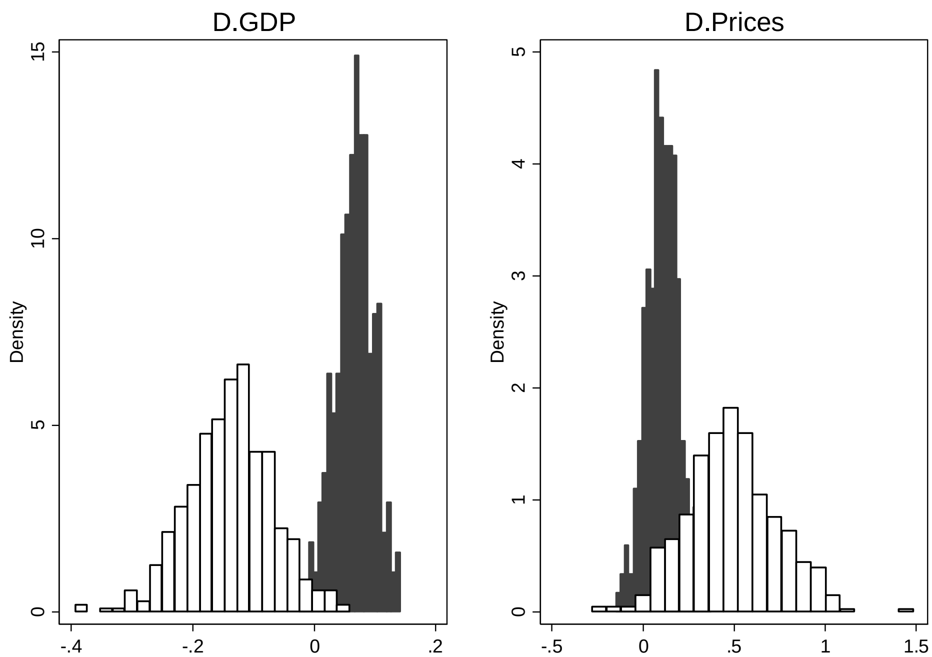
Note: The figure shows the response of the level (cumulated first (log) difference) of key macroeconomic variables in both targeting (dark green) and non-inflation targeting countries (light green) to large natural disasters over the period 1970Q1-2015Q4. Statistical inference is based on 500 Monte-Carlo draws.

Figure 5: Differential level effects of large real shocks between targeting and nontargeting economies



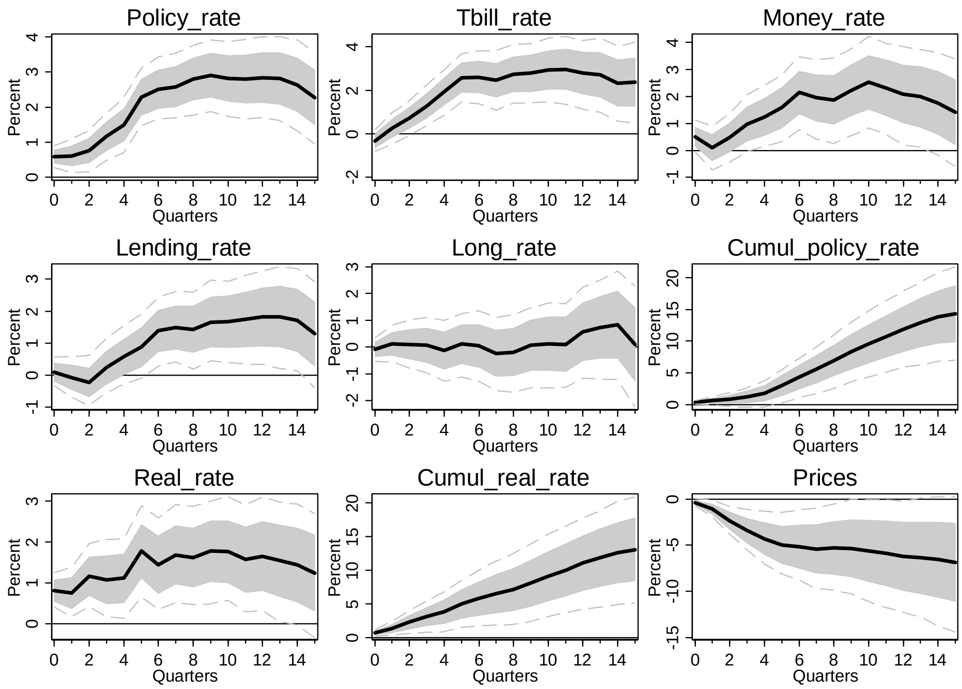
Note: The figure shows the difference between inflation targeting and non-inflation targeting countries with respect to the response of the level (cumulated first (log) difference) of key macroeconomic variables to large natural disasters over the period 1970Q1-2015Q4. Statistical inference is based on 500 Monte-Carlo draws.

Figure 6: Empirical density function for estimated mean output growth and inflation



Note: The figure shows the simulated density function of mean output growth and mean inflation over a horizon of four years following a large natural disaster in inflation targeting (black bars) and non-inflation targeting economies (white bars).

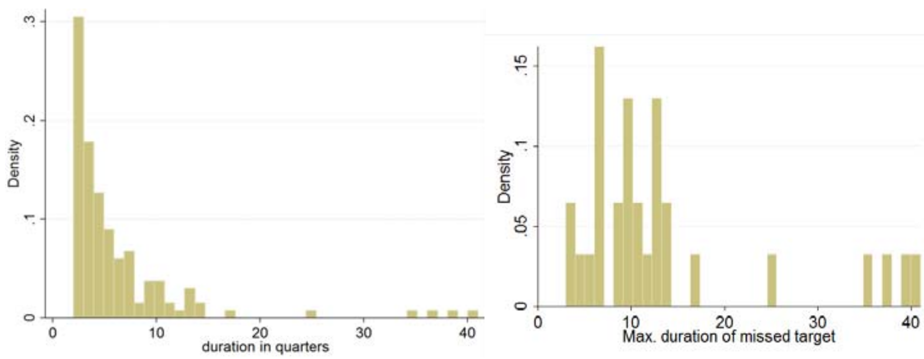
Figure 7: Differential responses of private and public interest rates



Note: The figure shows the difference between the responses of public and private interest rates in inflation targeting and non-inflation targeting countries to large natural disasters over the period 1970Q1-2015Q4. Statistical inference is based on 500 Monte-Carlo draws.

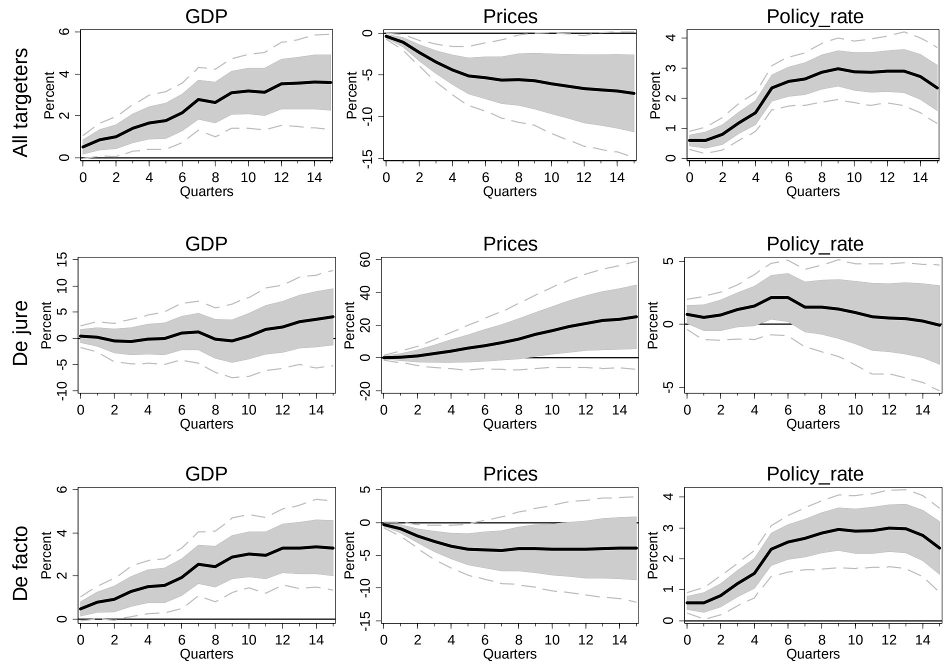
Figure 8: Duration of missed inflation targets

A. Duration of spells of missed target B. Max. duration of missed target per country



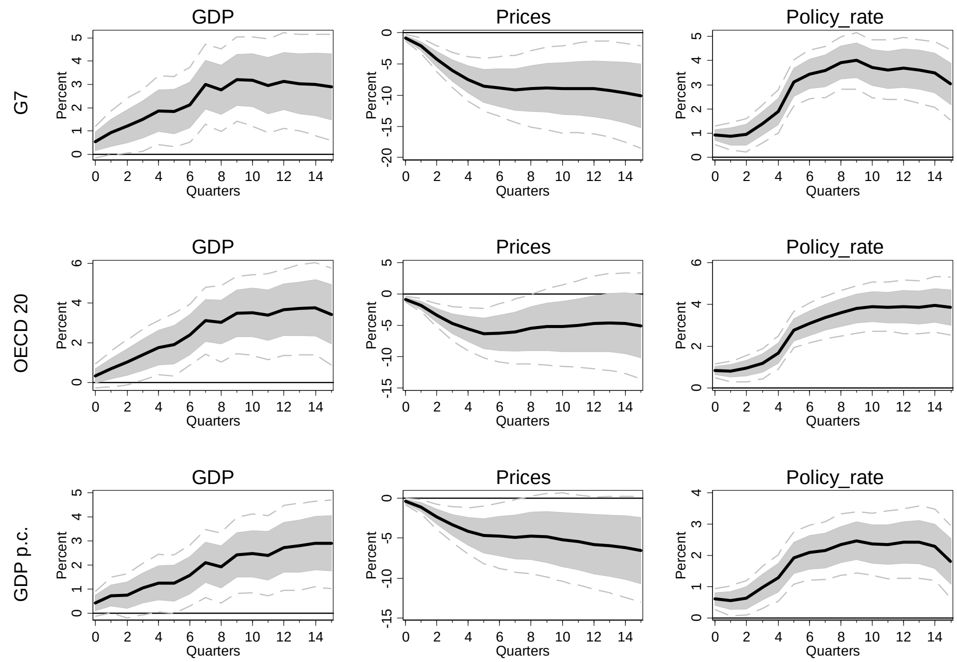
Note: Target misses are defined as CPI inflation rates outside of the target corridor

Figure 9: De jure and de facto versus non-inflation targeting



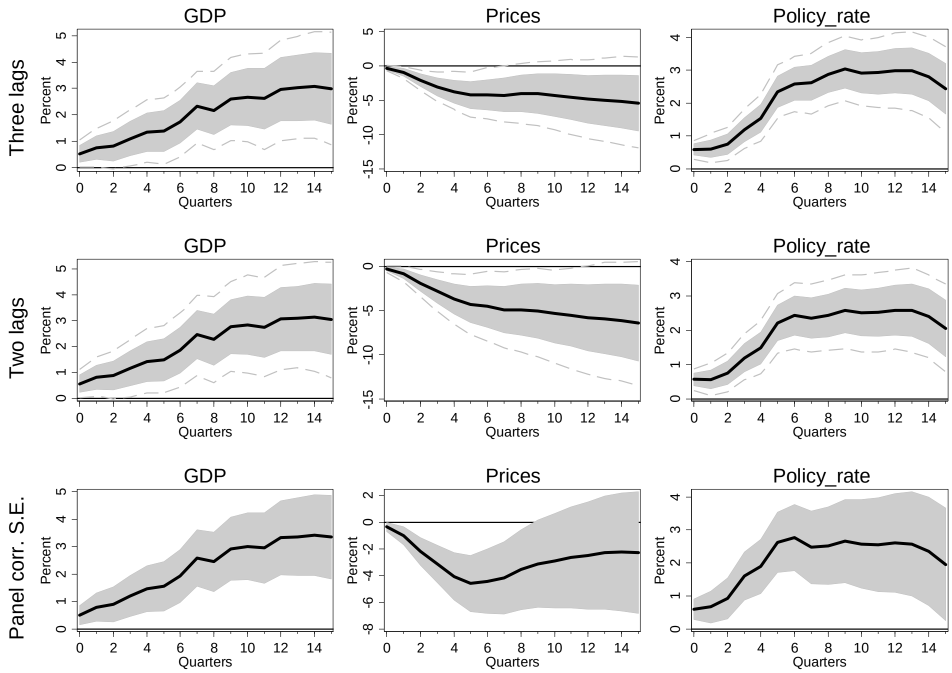
Note: The figure shows the difference between the responses of all inflation targeting, only de jure targeting, and only de facto targeting countries, respectively, versus all non-inflation targeting economies to large natural disasters over the period 1970Q1-2015Q4. Statistical inference is based on 500 Monte-Carlo draws.

Figure 10: Controlling for country-characteristics as potential shock absorbers



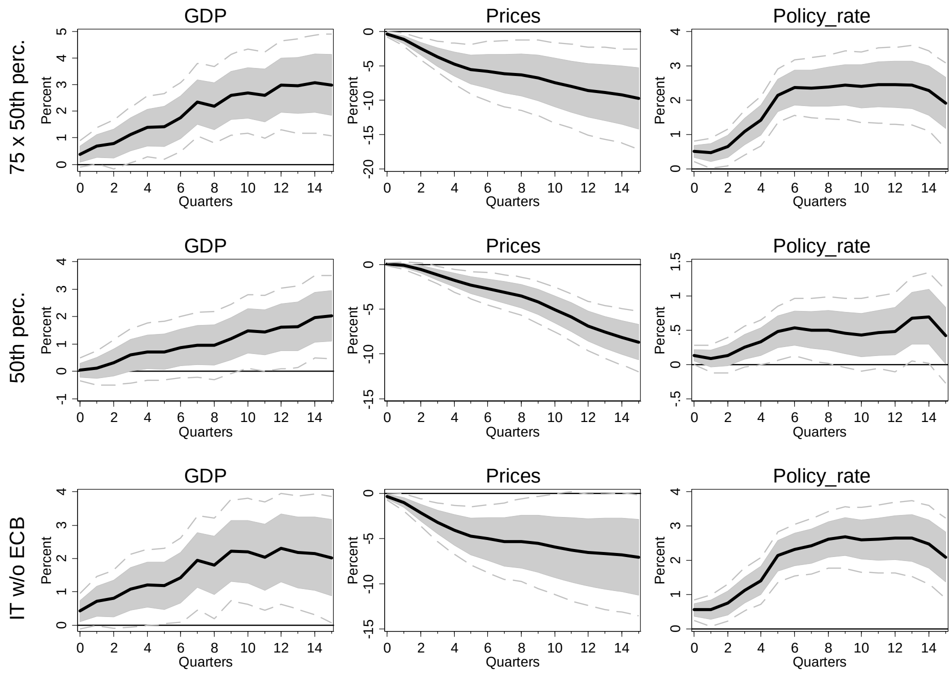
Note: The figure shows the difference between the responses of inflation targeting and non-inflation targeting countries to large natural disasters when controlling for different country classifications as potentially alternative shock absorption capacities. Statistical inference is based on 500 Monte-Carlo draws.

Figure 11: Alternative lag length and estimator



Note: The figure shows the difference between the responses of inflation targeting and non-inflation targeting countries to large natural disasters based on alternative number of lags of the endogenous variable (first rows two lags, second row three lags) and based on panel corrected standard errors (last row). Statistical inference is based on 500 Monte-Carlo draws.

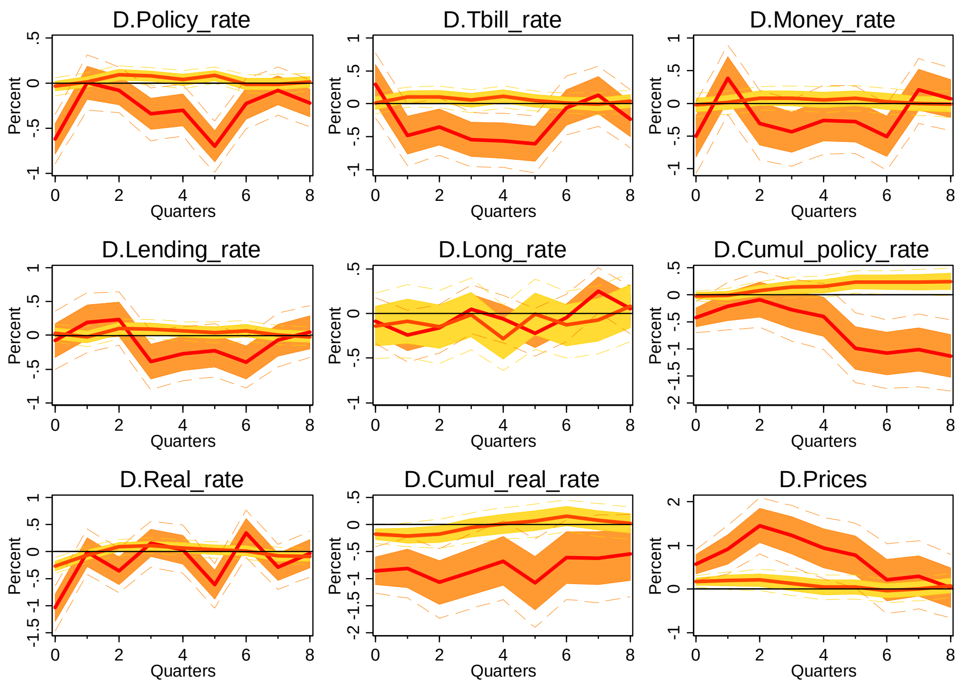
Figure 12: Alternative inflation targeting definition and shock measures



Note: The figure shows the difference between the responses of inflation targeting and non-inflation targeting countries to large natural disasters based on alternative selections of the shocks (first two rows) and a modified definition of IT (last row). Statistical inference is based on 500 Monte-Carlo draws.

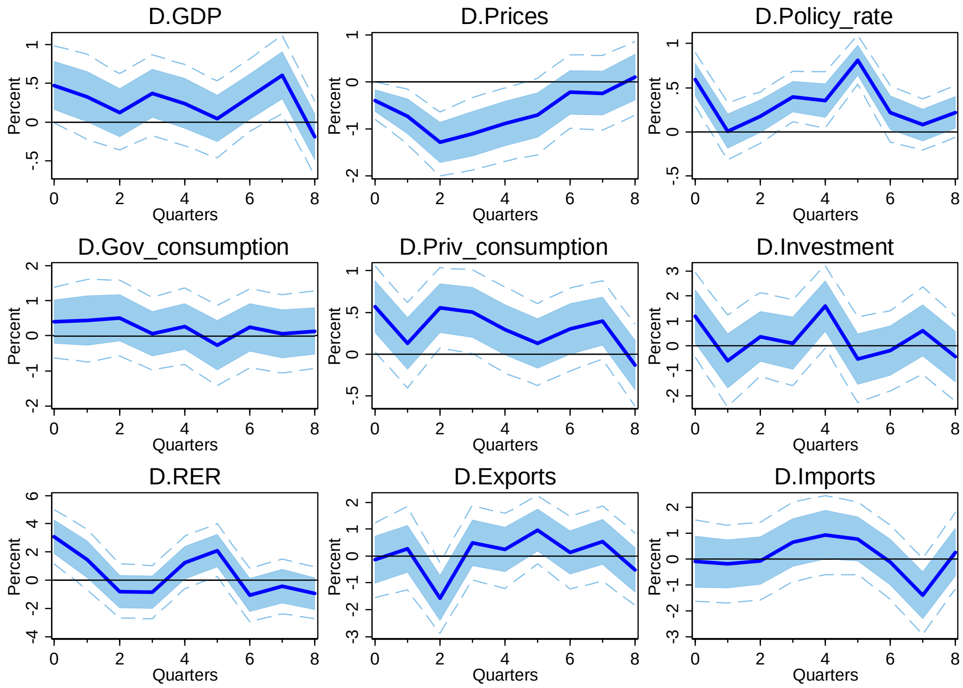
Appendix C: Additional tables and figures – not for publication

Figure 13: Effects of large real shocks on first (log) differences in targeting and nontargeting economies



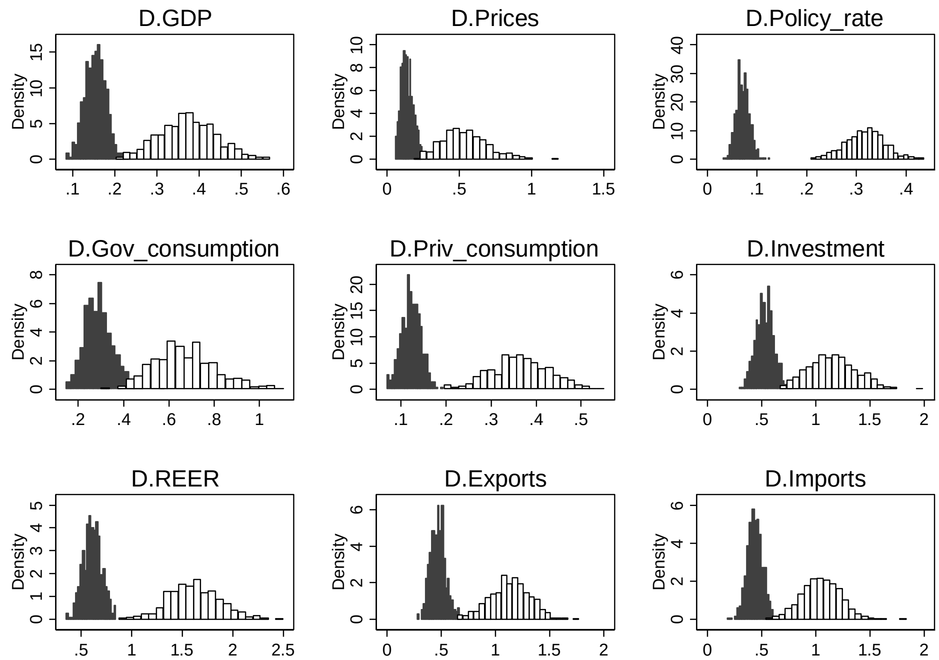
Note: The figure shows the response of the first (log) difference of key macroeconomic variables to large natural disasters in inflation targeting (black line, grey area) and non-inflation targeting countries (red line, orange area) over the period 1970Q1-2015Q4. Statistical inference is based on 500 Monte-Carlo draws.

Figure 14: Differential effects of large real shocks on first (log) differences between targeting and non-inflation targeting economies



Note: The figure shows the difference between the response of the first (log) difference of key macroeconomic variables in inflation targeting and non-inflation targeting countries to large natural disasters over the period 1970Q1-2015Q4. Statistical inference is based on 500 Monte-Carlo draws.

Figure 15: Empirical density functions for estimated standard deviations



Note: The figure shows the simulated density function of the standard deviations of selected macroeconomic variables over a horizon of four years following a large natural disaster in inflation targeting (black bars) and non-inflation targeting economies (white bars).