Monetary Policy during Financial Crises: Is the Transmission Mechanism Impaired?*

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Abstract

We study the macroeconomic effects of monetary policy during financial crises using a Bayesian panel vector autoregressive (PVAR) model for 20 advanced economies. We interact all of the endogenous variables with financial crisis dummies, which are constructed using the narrative approach. We also distinguish between an acute initial phase of financial crises and a subsequent recovery phase. We show that an expansionary monetary policy shock has large positive effects on output and inflation during the acute phase of a financial crisis. These effects are larger than those during non-crisis periods. Decreased uncertainty as well as increases in consumer confidence and share prices explain these large effects, whereas these variables are much less relevant for monetary policy transmission outside financial crises. Counterfactual analysis shows that the transmission mechanism would be impaired without the effects of monetary policy on these variables, where credit would not react at all and the response of output would be substantially lower. During the recovery phase of a financial crisis, output and inflation are generally non-responsive to monetary policy shocks.

Keywords: monetary policy transmission, financial crisis, financial stability, state-dependence, uncertainty, panel VAR
JEL-Codes: C33, E52, E58, G01

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1 Introduction

During the global financial crisis that started in 2007 many central banks eased monetary policy aggressively in order to alleviate financial market distress, boost output and stabilize inflation. Monetary policy was largely successful in mitigating financial market distress, but output growth remained lower than expected in many advanced economies (see e.g. Pain et al., 2014). There are many possible explanations for the unexpectedly sluggish recovery from the Great Recession including underestimation of the persistently adverse impact of the crisis. However, a particularly interesting hypothesis is that the monetary policy transmission mechanism is impaired during financial crises, thereby making monetary policy less effective in stimulating output and inflation compared with non-crisis periods (see e.g. Bouis et al., 2013).

Financial crises are characterized by a high degree of financial market distress, substantial balance-sheet adjustments of financial institutions, private households and firms, a high degree of uncertainty and low confidence of firms and consumers (see e.g. Reinhart and Rogoff, 2008; Bloom, 2009; Dées and Brinca, 2013). All of these characteristics might potentially impair the transmission of monetary policy (see e.g. Bouis et al., 2013; Bloom, 2014). However, it is also possible that the effects of monetary policy could be amplified during financial crises if central banks can mitigate some of the adverse characteristics of financial crises and prevent adverse feedback loops between the financial sector and the real economy (see e.g. Bernanke et al., 1999; Mishkin, 2009). This ambiguity of the effectiveness of monetary policy during financial crises is further complicated by the fact that the characteristics of crises and their effects on monetary policy transmission may vary throughout a financial crisis. For example, financial market distress and high uncertainty are primarily relevant in the initial and most acute phase of a financial crisis when the economy is typically also in a recession. However, balance-sheet adjustments, may also be relevant in the subsequent phase when financial market distress and uncertainty decrease, and the economy begins to recover.

In this paper, we empirically analyze whether monetary policy has different effects on the economy during financial crises compared with non-crisis periods. In particular, we estimate a panel vector autoregressive (VAR) model for 20 advanced economies, where we interact all of the endogenous variables with a financial crisis indicator, which is constructed based on the narrative approach by Laeven and Valencia (2013). Our analysis contributes to the literature in several ways. First, we provide a comprehensive analysis of the effectiveness of monetary policy during financial crises compared with non-crisis periods. Second, we allow for heterogeneity in monetary policy transmission within financial crisis periods by differentiating between the acute phase and the subsequent recovery phase of a financial crisis, thereby, reconciling the seemingly opposing findings of the small number of studies that have empirically analyzed the effectiveness of monetary policy during financial crises. Third, our results provide new insights into the monetary policy transmission mechanism during financial crises compared with non-crisis times. We show that uncertainty and confidence indicators, which are not important for monetary policy transmission during non-crisis periods, play a critical role in financial crises.

The question of monetary policy effectiveness during financial crises is of great interest to policy makers. If they are effective, monetary expansions can be used as an important tool to mitigate the adverse effects of financial crises on the economy. However, if monetary policy transmission is impaired during financial crises, larger monetary policy interventions may be required to achieve a given effect, which can potentially increase the undesirable costs of highly expansionary monetary policy, such as excessive risk-taking, increased risks of asset price bubbles and systemic financial risks (see e.g. Rajan, 2005; Altunbasa et al., 2014; Jiménez et al., 2014).

From a theoretical perspective, a number of previously reported results suggest that monetary policy is less effective during financial crises because the standard transmission channels are impaired. First, the credit channel may be impaired. Financial institutions face losses from credit defaults as well as considerable problems obtaining new funding, which causes them to adjust their balance-sheets (Bouis et al., 2013). The risk of further credit defaults increases due to high uncertainty, thereby reducing the willingness of financial institutions to provide bank lending (Valencia, 2013; Buch et al., 2014). Moreover, financial crises often mark the end of periods with low risk perceptions, asset price bubbles, and credit and consumption booms, and thus they are characterized by strong balance-sheet adjustments and deleveraging (Reinhart and Rogoff, 2008). In this environment, changes in monetary policy are likely to become less important for determining credit supply and demand compared with non-crisis periods. Second, the interest rate channel may be impaired. Firms and consumers tend to postpone investment decisions in times of high uncertainty. If investment is partially irreversible, investors wait and postpone investment decisions until more information arrives and uncertainty is at least partially resolved (see e.g. Bernanke, 1983; Dixit and Pindyck, 1994). Therefore, uncertainty may become a major determinant of investment decisions, whereas monetary policy loses its impact (Bloom et al., 2007). Similarly, the interest rate responsiveness of investment may decline when firms and consumers have very low confidence in their business or employment prospects (Morgan, 1993). Finally, it may become more difficult for central banks to stabilize output because in times of high macroeconomic volatility firms tend to adjust their prices more often. Hence, monetary expansions mostly generate inflation rather than output growth (Vavra, 2014).

However, other contributions suggest that monetary policy is more effective during financial crises. This may be the case if a central bank is able to ease the adverse effects of a financial crisis, thereby restoring the functioning of the credit and interest rate channels. In particular, firms and private households are more likely to be credit constrained during financial crises because of a decrease in the value of their financial assets and losses of collateral. In this situation, monetary policy may reduce the external finance premium by easing these constraints via the financial accelerator (Bernanke and Gertler, 1995; Bernanke et al., 1999). Moreover, while being less effective in the presence of high financial market distress and uncertainty, a monetary policy expansion may be all the more powerful if it is able to significantly alleviate financial market distress and to reduce uncertainty (Basu and Bundick, 2012; Bekaert et al., 2013). Similarly, monetary policy can be more effective if it is able to raise confidence from very low levels.[1] Monetary policy can do so directly by providing signals about future economic prospects (Barsky and Sims, 2012) or indirectly by decreasing the probability of worst-case outcomes, as well as by improving the ability of agents to make probability assessments about

[1] Bachmann and Sims (2012) provided evidence that the confidence channel is important for the effectiveness of fiscal policy in stimulating economic activity.

future events (Ilut and Schneider, 2014).

Given these mixed theoretical predictions, the effectiveness of monetary policy during financial crises becomes an important empirical question. However, empirically analyzing monetary policy transmission during financial crises is challenging because financial crises are rare events and there is no unique definition of a financial crisis. To address these challenges, we estimate the effects of monetary policy based on a panel of 20 advanced economies over the period from 1984 to 2013. Furthermore, we use systematic banking crises, which are identified via the narrative approach from Laeven and Valencia (2013), to date financial crisis episodes. This approach captures systemic disruptions in the banking system, but it excludes periods during which financial stress is high for other reasons, such as political events or natural catastrophes. Our sample includes 20 financial crisis episodes, which last 4.5 years on average and that together cover about 350 quarters. To address potential heterogeneities in the monetary policy transmission mechanism within financial crises, we identify recession episodes using the Bry-Boschan algorithm.[2] This allows us to distinguish between four regimes. In particular, we define the acute phase of a financial crisis as the period during which a financial crisis is accompanied by a recession, whereas the recovery phase of a financial crisis is the period during which a financial crisis is accompanied by an expansion. The two other regimes are recessions and expansions outside of financial crises.

We estimate potential asymmetries in the transmission of monetary policy across these four regimes using the interacted panel VAR (PVAR) methodology of Sá et al. (2014). This method exploits the cross-section dimension of the data to improve the precision of the estimation, while allowing for a large degree of heterogeneity across countries. Our PVAR includes GDP and CPI as the main variables of interest and the short-term interest rate as the monetary policy instrument. In addition, we include several key macroeconomic and financial variables, which are potentially important for the monetary policy transmission mechanism, i.e. private credit, house prices, consumer confidence, share prices and stock market volatility as a proxy for uncertainty. We identify monetary policy shocks using the standard Cholesky identification rather than employing sign restrictions. We argue that in the financial crisis regime, a priori restrictions on the sign of impulse responses of variables such as GDP or CPI can be more restrictive than zero contemporaneous restrictions because financial crises exhibit very specific characteristics, and because theoretical predictions of the effects of monetary policy in financial crises are not as clear-cut as those in non-crisis periods.

We report three main findings. First, by comparing monetary policy transmission in financial crises and in non-crisis times, we show that the effects of a monetary policy shock on output and inflation are significantly greater and occur faster during financial crises. Second, distinguishing between the acute and the recovery phases of financial crises provides a much more exhaustive picture of asymmetries in monetary policy transmission. In particular, we find that an expansionary monetary policy shock has large positive effects on output and inflation during

[2] A number of empirical studies have analyzed the effectiveness of monetary policy during recessions and expansions. Weise (1999), Garcia and Schaller (2002), Peersman and Smets (2002) and Lo and Piger (2005) show that monetary policy is more effective during recessions than expansions, whereas more recent studies by Tenreyro and Thwaites (2013) and Caggiano et al. (2014) find the opposite.

the acute phase of a financial crisis. These effects are significantly greater and occur faster than those during normal recessions and normal expansions. However, during the recovery phase of a financial crisis monetary policy loses its effectiveness, and thus output and inflation do not react significantly to a monetary policy shock. Hence, restricting the analysis to two regimes only (financial crisis and non-crisis times) masks the highly heterogeneous effects of monetary policy during the course of a financial crisis. Third, we find important differences in the specific transmission channels of monetary policy between the two phases of financial crises and non-crisis periods. During the acute phase, an expansionary monetary policy shock strongly decreases uncertainty, while it raises share prices and, initially, confidence. Counterfactual analysis shows that the response of output to a monetary policy shock would be substantially smaller if the reactions of uncertainty, share prices and confidence were shut down. Moreover, credit would not increase at all in this counterfactual scenario, which suggests that monetary policy can strengthen traditional transmission channels, such as the credit channel or the interest rate channel, by cushioning the adverse effects of the crisis during the acute phase of a financial crisis. By contrast, during the recovery phase of a financial crisis and in non-crisis periods, uncertainty, share prices and confidence do not appear to be important drivers of monetary policy transmission.

Our results may reconcile the seemingly opposing findings of related empirical studies by differentiating between the acute and recovery phases of a financial crisis. Ciccarelli et al. (2013) analyze the effects of monetary policy in the euro area in the period from 2002 to 2011. By extending the end of their sample recursively from 2007 until 2011 they assess the evolution of the effects of a monetary policy shock when moving from a non-crisis period to the global financial crisis. In agreement with our results, they find that monetary policy became more effective at stimulating economic activity during the acute phase of the global financial crisis, mainly via the credit channel. Dahlhaus (2014) focuses on the US and studies the effects of monetary policy conditional on financial stress, which shows that monetary policy is more effective in stimulating the economy during a high stress regime. Financial stress is usually high at the beginning of a financial crisis, such that these results also agree with ours. By contrast, Bech et al. (2014) focus on the recovery period of financial crises by studying the effects of the monetary policy stance during recession episodes on the strength of the subsequent recovery for a panel of 24 advanced economies. They measure the stance of monetary policy as the deviation of the monetary policy instrument from a standard Taylor rule. In agreement with our results, they find that monetary policy is not effective in stimulating GDP growth during the recovery phase of a financial crisis, whereas it is effective outside financial crises.[3]

Our results are robust in several dimensions. Most importantly, our results persist when we control for the zero lower bound of monetary policy and for the use of quantitative easing measures during the global financial crisis. For this purpose, we use estimated shadow interest rates from Wu and Xia (2014) instead of short-term interest rates for the US, the United Kingdom,

[3]Other studies on monetary policy transmission during financial crises have focused on the effects of unconventional monetary policy (e.g., see Gambacorta et al., 2014, for a panel analysis or Williams, 2014, for a survey). However, it is not possible to conclude whether monetary policy is more or less effective during financial crises compared with non-crisis times based on these studies because of the limited comparability of shocks to unconventional and conventional monetary policy measures.

and the euro area. We also apply a more deterministic approach by excluding all observations where monetary policy reached the zero lower bound. Moreover, our results are robust when we use sign restrictions instead of the recursive approach to identify monetary policy shocks. Finally, our results pass a large set of additional robustness checks such as excluding the global financial crisis from our sample, using alternative identification methods to identify the acute and recovery phases of a financial crisis, and including additional control variables in our model, e.g. monetary aggregates, long-term interest rates, and government spending.

The remainder of the paper is organized as follows. Section 2 describes the data set. Section 3 explains the econometric methodology. Section 4 presents and discusses the estimation results including various robustness checks. Finally, Section 5 concludes.

2 Data

We analyze the effectiveness of monetary policy in a VAR framework. Our analysis is based on a panel data set because financial crises are very rare events. First, we describe the panel data set and the endogenous variables of the VAR model in more detail. Second, we describe how we identify financial crises and acute and recovery phases of financial crises.

2.1 Data on endogenous variables

Our panel data set covers 20 advanced economies.[4] We use data for the period Q1 1984 to Q4 2013.[5] Our baseline PVAR includes nine variables: real GDP, CPI, real house prices, the short-term interest rate, bank credit to the private non-financial sector, the effective exchange rate, consumer confidence, share prices and stock price volatility.

GDP, CPI, short-term (money-market) interest rates, effective exchange rates and share prices data are taken from the OECD (Economic Outlook and Main Economic Indicators).[6] Real house prices data come from the International House Price Database from the Dallas Fed. Data for bank credit to the private non-financial sector are taken from the Bank for International Settlements.

Our consumer confidence variable is based on survey data and is obtained from various national sources via Thomson Financial Datastream. For example, for economies in the European Union, data stem from the Business and Consumer Surveys of the European Commission. Consumer confidence data are standardized to ensure an identical scale across countries.

Finally, we follow Bloom (2009) and Cesa-Bianchi et al. (2014) and use stock market volatility as a measure of uncertainty. We calculate this measure as the average realized volatilities of

[4]The panel data set includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the US.

[5]We select 1984 as the starting year in order to include data from the beginning of the Great Moderation only. This year was also chosen in previous studies that used panel models similar to ours (Sá et al., 2014). Moreover, some of the endogenous variables, such as consumer confidence, are not available for several countries for longer samples. Starting our sample in 1970 instead of 1984, would only have added one financial crisis to our sample, i.e., the crisis in Spain between 1977 and 1981. Indeed, our results are robust when we estimate a model without consumer confidence from 1970 to 2013.

[6]Table 2 in the appendix provides an overview of our data set and our data sources.

daily stock returns for each quarter (see Cesa-Bianchi et al., 2014). Stock returns are computed as log changes in daily stock market indicators. The stock market indicators represent the major stock indexes in each country and are obtained from Thomson Financial Datastream. We take logs of all variables except interest rates and consumer confidence indices. Data not available in seasonally adjusted form are adjusted using a stable seasonal filter.[7]

2.2 Financial crises

We use the systematic banking crises identified by Laeven and Valencia (2013) to date financial crises. The data set of Laeven and Valencia (2013) is provided in annual frequency for the period from 1970 to 2011 for all of the 20 economies in our panel. To adapt this measure to a quarterly frequency, we assume that a banking crisis starts in the first quarter of its first year and ends in the fourth quarter of its last year.

Laeven and Valencia (2013) define the starting year of a banking crisis as when two of the following criteria are met in the same year for the first time:

1. Significant signs of financial distress in the banking system (as indicated by significant bank runs, losses in the banking system, and/or bank liquidations).

2. Significant banking policy intervention measures in response to significant losses in the banking system.

They consider the first criterion as a necessary and sufficient condition for a banking crisis. The second criterion is added as an indirect measure because financial distress is often difficult to quantify. Laeven and Valencia (2013) define the end of a banking crisis as the year before both real GDP growth and real credit growth remain positive for at least two consecutive years. Independently of these criteria, they also truncate episodes of financial crises after a maximum duration of 5 years.

The data set of Laeven and Valencia (2013) only covers up to 2011 and does not include the end of some of the financial crises that started in 2008. Therefore, we extend their database until the year 2013. We use their identification criteria for the end of financial crises based on real GDP and credit data.[8] We also follow Laeven and Valencia (2013) by defining a banking crisis as lasting at most five years so the banking crises that start in 2008 end no later than in 2012. Based on these financial crisis dates, we construct a dummy variable which takes the value one during a financial crisis and zero otherwise.

We identify recessions and expansions using the Harding and Pagan (2002) version of the Bry-Boschan algorithm. This algorithm identifies local peaks and troughs in real GDP and defines a recession as the period from the peak to the trough and an expansion from trough to peak. Based on this algorithm, we build a recession dummy variable that equals one in recessions and zero in expansions.

[7]In order to seasonally adjust the series, we first detrend the data using a 5-term moving average filter. Next, we calculate a centered estimate of the seasonal component by using seasonal dummies and by averaging the detrended data over each quarter. Finally, we subtract the estimated seasonal component from the original data.

[8]Nominal bank credit to the private non-financial sector data are taken from the International Financial Statistics from the International Monetary Fund. We use CPI to adjust this series for price developments. CPI and GDP are the same data that we use in our empirical model.

Based on the financial crisis dummy variable and the recession dummy variable we distinguish between four regimes: the acute and the recovery phase of a financial crisis, and recessions and expansions outside of financial crises. We understand the acute phase of a financial crisis as a period of extremely high volatility. Various different methods could be used to date this period, but we define the acute phase as a period when a financial crisis is accompanied by a recession. In particular, we create a dummy variable for the acute phase of a financial crisis, which takes the value one when the financial crisis dummy and the recession dummy are simultaneously equal to one and zero otherwise. Accordingly, we create another dummy for the recovery phase which is defined as an episode when a financial crisis is accompanied by an expansion. Finally, we define normal recessions and normal expansions as recession and expansion episodes that are not accompanied by a financial crisis.[9] Thus, expansions outside of financial crises are the benchmark regime when all three dummy variables (acute phase of a financial crisis, recovery phase of a financial crisis, and recessions outside of financial crises) are zero.

Table 1 shows some summary statistics regarding the frequency and length of financial crises and recessions. Recessions occur much more frequently (85 episodes) than financial crises (20 episodes). However, given their average length of 18 quarters, financial crises are much more persistent than recessions (five quarters on average), and thus the number of about 350 financial crisis observations is comparable to the number of recession observations (about 400).

Table 1: Summary Statistics: Financial Crises and Recessions (1984–2013)

	Financial Crises	Recessions
Number of episodes	20	85
Number of quarters	352	406
Average length (quarters)	18	5
Proportion of recession quarters	46%	
Proportion of recessions outside financial crises		51%

All 20 financial crises are accompanied by at least one recession, which usually occurs at the beginning of a financial crisis. In some European countries, the global financial crisis that started in 2007 was accompanied by two separate recessions. According to our identification scheme, the financial crisis observations are distributed roughly equally across the acute and the recovery phases of a financial crisis. In terms of the regional distribution, two financial crises occurred in Sweden and the United States, no financial crises occurred in Australia and Canada, and there was one financial crisis in all other economies. The number of recessions per economy ranges from two (Canada, Australia, Netherlands, and Ireland) to seven (Greece). Our sample of financial crises is dominated by the global financial crisis that started in 2007, as 15 out of 20 financial crises took place in this period. Apart from that, one financial crisis event occurred

[9] We make one exception to this deterministic identification scheme. If a financial crisis has ended, but the economy is still in a recession, we attribute the corresponding quarters to the recessionary phase of a financial crisis and not to a normal recession. This is the case for 12 quarters during the year 2013 when the financial crisis ends based on the assumption that financial crises episodes can last for maximum 5 years. However, it does not seem plausible to impose an end to a financial crisis episode at a time when the accompanying recession has not yet finished. Despite this, our results are robust when we calculate the acute phase dummy as a simple product of the financial crisis and recession dummies.

in the US during 1988, three during the early 1990s in Finland, Norway, Sweden, and one in Japan around the year 2000.

3 Methodology

We base our empirical model on the Bayesian interacted PVAR methodology developed in Sá et al. (2014), which extends the model of Towbin and Weber (2012) using cross-country heterogeneous coefficients.[10] The model exploits the cross-country dimension of the data, accounts for the dynamics between the main macroeconomic variables and allows for interactions between macroeconomic variables and exogenous terms, i.e. financial crisis and recession dummy variables in our study.

3.1 Interacted PVAR model

We start by describing the simple PVAR model without interaction terms.[11] The PVAR in structural form is given by:

$$J_i Y_{i,t} = \tilde{A}_{i,0} + \sum_{k=1}^{L} \tilde{A}_{i,k} Y_{i,t-k} + \tilde{u}_{i,t}, \tag{1}$$

where $t = 1, ..., T$ denotes time, $i = 1, ..., N$ denotes the country, $Y_{i,t}$ is a $q \times 1$ vector of endogenous variables, $\tilde{A}_{i,0}$ is a vector of country-specific intercepts, and $\tilde{A}_{i,k}$ is a $q \times q$ matrix of autoregressive coefficients up to lag L.[12] The $q \times q$ matrix of contemporaneous effects J_i is lower triangular with a vector of ones on the main diagonal. The $q \times 1$ vector of structural residuals $\tilde{u}_{i,t}$ is assumed to be normally distributed with a mean of zero and with a diagonal $q \times q$ covariance matrix $\tilde{\Sigma}$.

We follow Sá et al. (2014) by allowing for heterogeneous intercept parameters $\tilde{A}_{i,0}$ and heterogeneous slope parameters $\tilde{A}_{i,k}$ across countries. Moreover, we also allow the parameters of the contemporaneous coefficients matrix J_i to vary across countries by estimating the model recursively, i.e., directly in its structural form. We estimate the average effect over countries by averaging over the country-specific coefficients. For the PVAR without interaction terms, this approach is equivalent to the mean group estimator of Pesaran and Smith (1995) and it gives consistent estimates for dynamic panels in the presence of cross-country heterogeneity.[13]

The PVAR is then augmented with interactions between the endogenous variables and an exogenous indicator variable. The structural interacted PVAR (IPVAR) model with a single

[10] We would like to thank Filipa Sá and Sebastian Weber for sharing their Matlab codes with us.

[11] PVARs have been used in various empirical applications to improve the precision of the estimation and to detect common country dynamics. For example, see Goodhart and Hofmann (2008), Assenmacher-Wesche and Gerlach (2008), Carstensen et al. (2009), Calza et al. (2013) and Gambacorta et al. (2014).

[12] We assume that there are no dynamic interdependencies across countries, i.e., the endogenous variables of country i are not affected by other countries' variables and residuals are uncorrelated across countries. This can be a rather strong assumption in a cross-country framework, but it drastically reduces the number of parameters that need to be estimated, and thus it is used frequently in PVAR applications.

[13] Pesaran and Smith (1995) estimate separate VAR models for each country and then calculate averages over the estimated coefficients, whereas Sá et al. (2014) introduce cross-country heterogeneity by augmenting parameters with country dummies. The latter approach allows the combination of cross-country heterogeneous coefficients and country-invariant interaction terms in the interacted PVAR model.

interaction term is given by:

$$J_{i,t}Y_{i,t} = \tilde{A}_{i,0} + \sum_{k=1}^{L} \tilde{A}_{i,k}Y_{i,t-k} + \tilde{B}_0 D_{i,t} + \sum_{k=1}^{L} \tilde{B}_k D_{i,t} Y_{i,t-k} + \tilde{u}_{i,t}, \tag{2}$$

$$J_{i,t}(w,q) = J_i(w,q) + J(w,q)D_{i,t}, \tag{3}$$

where $\tilde{A}_{i,0}$, $\tilde{A}_{i,k}$ and $\tilde{u}_{i,t}$ are defined as in equation (1). $D_{i,t}$ is a dummy variable that takes a value of 1 if there is a financial crisis in country i during period t, and a value of 0 otherwise. $\tilde{B}_0$ are intercepts and $\tilde{B}_k$ is a $q \times q$ matrix of autoregressive coefficients up to lag L, which correspond to the financial crisis regime, respectively. The matrix of contemporaneous coefficients $J_{i,t}$ is again lower triangular with a vector of ones on the main diagonal.[14]

The coefficients that capture the dynamics in normal times, $\tilde{A}_{i,0}$ and $\tilde{A}_{i,k}$, remain country-specific, but the coefficients that capture changes in the dynamics during financial crises, $\tilde{B}_0$ and $\tilde{B}_k$, are assumed to be homogenous across countries. This assumption is necessary to make estimation feasible because of the small number of financial crisis observations per country. We make a similar assumption for the contemporaneous coefficients $J_{i,t}$. Equation (3) shows that each lower triangular element (w,q) of $J_{i,t}$, where w indicates the row, q the column and $q < w$, comprises a country-specific part, $J_i(w,q)$, for the non-crisis regime and a regime-specific part, $J(w,q)D_{i,t}$, which does not vary across countries.

Using this approach, we exploit the panel structure of our data and address the problem of a small number of financial crisis observations per country. In addition, we allow for as much cross-country heterogeneity as possible and we assume that only the coefficients that capture the dynamics during financial crises are homogenous across countries.[15] Although the latter is a restrictive assumption, our approach allows for more cross-country heterogeneity than a fixed effect estimator does and therefore provides estimates that are less likely to suffer from inconsistency.[16] At the same time, the use of country dummies to allow for cross-country heterogeneity is more flexible than the mean group estimator of Pesaran and Smith (1995). It allows to combine country-specific and pooled effects within a PVAR when facing a trade-off between heterogeneity in the data and the aim of pooling information across countries in order to increase precision of estimated parameters.

Model (2) can easily be extended to allow for more than two regimes. In our preferred model, we extend $D_{i,t}$ to a vector of three dummy variables, $D_{i,t} = [D_{i,t}^{FCR}, D_{i,t}^{FCE}, D_{i,t}^{R}]$, thereby

[14] The subscript t indicates the interaction with $D_{i,t}$.

[15] Georgiadis (2014) shows that the heterogeneity of monetary policy transmission is quite large across advanced economies and it can be explained mainly by differences in the financial structure, labor market rigidities, and the industry mix.

[16] When we estimate the IPVAR with fixed effects (i.e., only allowing for country-specific intercepts), the impulse responses to a monetary policy shock are highly persistent and the responses of CPI exhibit strong signs of the price puzzle. This may be attributable to the fixed effects estimator being biased in dynamic panels when the time dimension is small (Nickell, 1981) as well as when the time dimension is large, but the coefficients of lagged endogenous variables are heterogeneous across countries (Pesaran and Smith, 1995). The pooled mean group estimator used by Pesaran and Smith (1995) is only biased if the time dimension is small. In our case, $T = 120$, so the bias from this source is negligible. The introduction of interaction terms that are assumed to be homogeneous across countries introduces some bias to the extent that the homogeneity assumption is violated by the data. However, we consider our setup as a good solution to the trade-off between minimizing bias and enabling the estimation of financial crisis effects.

allowing for four different regimes, as described in section 2.2:

1. $D^{FCR}_{i,t} = 1$, $D^{FCE}_{i,t} = 0$, $D^{R}_{i,t} = 0$: acute phase of a financial crisis (financial crisis and recession),

2. $D^{FCR}_{i,t} = 0$, $D^{FCE}_{i,t} = 1$, $D^{R}_{i,t} = 0$: recovery phase of a financial crisis (financial crisis and expansion),

3. $D^{FCR}_{i,t} = 0$, $D^{FCE}_{i,t} = 0$, $D^{R}_{i,t} = 1$: normal recession (no financial crisis and recession),

4. $D^{FCR}_{i,t} = 0$, $D^{FCE}_{i,t} = 0$, $D^{R}_{i,t} = 0$: normal expansion (no financial crisis and expansion).

Pre-multiplying the recursive-form IPVAR in equation (2) with $J^{-1}_{i,t}$ yields the reduced-form version of the model:

$$Y_{i,t} = A_{i,0} + \sum_{k=1}^{L} A_{i,k} Y_{i,t-k} + B_0 D_{i,t} + \sum_{k=1}^{L} B_k D_{i,t} Y_{i,t-k} + u_{i,t}, \tag{4}$$

with the reduced form coefficient matrices defined as $A_{i,0} = J^{-1}_{i,t}\tilde{A}_{i,0}$. Note that the reduced form residuals $u_{i,t} = J^{-1}_{i,t}\tilde{u}_{i,t}$ and their covariance matrix $\Sigma_{i,t} = J^{-1}_{i,t}\tilde{\Sigma}(J^{-1}_{i,t})'$ will also vary across countries and regimes due to the variation in $J_{i,t}$. Thus, estimating the model recursively across different regimes allows for heteroscedasticity of residuals and for country- and regime-specific contemporaneous correlations.

The impulse responses of endogenous variables to a monetary policy shock can be computed from the reduced form of the VAR. In the IPVAR model, the impulse responses depend on the values of the interaction terms, and thus on the regime. Regime-dependent impulse responses are calculated after evaluating the interaction terms at their values corresponding to the four regimes. Thus, we assume that the economy remains in the regime that prevailed when the monetary policy shock occurred. Thereby, we follow most previous studies that analyze asymmetries in monetary policy transmission during recessions and expansions and during periods of high financial stress using VAR methods.[17]

3.2 Estimation and inference

We follow Sá et al. (2014) by estimating the model with Bayesian methods. We start by estimating the recursive form of the IPVAR in equation (2) using OLS. We choose two lags in the baseline IPVAR specification according to the Akaike information criterion.[18] We then update the initial OLS estimate with prior information using an uninformative Normal-Wishart prior. The posterior also belongs to the Normal-Wishart family so we can draw all recursive-form parameters jointly from the posterior using Monte Carlo integration methods (see Uhlig, 2005, and

[17] An exception is Zheng (2013) who calculates regime-independent, non-linear impulse responses in a threshold VAR model for the US. She finds that only large monetary policy shocks of two standard deviations or more are able to endogenously move the economy from a low to a high financial stress regime or vice versa, while small shocks do not increase the probability of regime switches. Hence, imposing the regimes exogenously rather than allowing for regime switches in response to monetary policy shocks does not seem to be a very restrictive assumption.

[18] Two lags are also used in comparable PVAR models in previous studies, see Calza et al. (2013) or Sá et al. (2014).

Koop and Korobilis, 2010). We also impose the prior that responses are non-explosive, according to Cogley and Sargent (2005) and Sá et al. (2014). In particular, we proceed as follows. For each draw from the posterior, we evaluate the interaction terms $D_{i,t}$ at their values of interest, as described in Section 3.1. We then compute the Cholesky decomposition of the covariance matrix, which allows us to compute the reduced form parameters. Finally, we discard draws that lead to explosive parameters and we compute the impulse responses for each regime.[19] We continue drawing from the posterior until we have 1000 non-explosive draws, which we use to compute the median, as well as the 5% and 95% quantiles to represent 90% confidence bands.

3.3 Identification of monetary policy shocks

As described in the previous sections, we estimate the interacted PVAR directly in its recursive form. Hence, monetary policy shocks are identified implicitly by the ordering of the variables in the VAR. We order GDP, CPI, and house prices before the short-term interest rate, and thus we assume that these variables do not react to a monetary policy shock on impact. This assumption has been employed in a large number of VAR studies and it also agrees with the theoretical predictions from DSGE models, i.e., a delayed response of output and prices to monetary policy. We order banks' credit to private sector, the exchange rate, consumer confidence, share prices and stock market volatility after the interest rate, and thus allow these variables to react to monetary policy shocks on impact. This is consistent with the view that financial market variables or variables of market confidence are less rigid, so they can react to monetary policy shocks contemporaneously. Nonetheless, our results are robust when we choose alternative orderings, such as ordering house prices after the interest rate or ordering banks' credit to the private sector and consumer confidence before the interest rate.

As a robustness check, we also identify monetary policy shocks using the sign restrictions approach developed in Canova and De Nicoló (2002) and Uhlig (2005), which was applied in a PVAR context in Carstensen et al. (2009), Gambacorta et al. (2014) and Sá et al. (2014). This approach has the advantage that identification is independent of the ordering in the VAR and no zero contemporaneous restrictions need to be imposed. Instead, the sign of the impulse responses of a subset of endogenous variables is restricted in line with theoretical predictions. However, the latter can also be restrictive, particularly in the analysis of financial crises when the economy might behave very differently from the predictions of standard theoretical models. Therefore, we only restrict the impulse response of the short-term interest rate to being negative during the first four quarters and the response of CPI to being positive between the second and fourth quarter, whereas we remain agnostic about the responses of GDP and the other variables in the VAR.

[19] In the baseline model with two regimes, only 1.5% of the draws are explosive. In the model with four regimes, the proportion of discarded draws is still relatively small at 15% and the results look very similar when we do not impose the prior of non-explosive parameters. However, the prior becomes more important for the results of some robustness checks, particularly when we estimate the model for the sub-sample 1984–2007 where 50% of draws are discarded.

4 Results

First, we describe our results for the model that differentiates between two regimes—financial crisis and non-crisis periods—before proceeding to the results obtained using the model that additionally differentiates between recessions and expansions to allow for four regimes. Furthermore, we present the results of our counterfactual analysis and various robustness checks.

4.1 Monetary policy transmission in financial crisis and non-crisis periods

Figure 1 shows the impulse responses and the 90% confidence intervals to a one percentage point expansionary monetary policy shock in the model that differentiates between two regimes. The first column shows the effects of a monetary policy shock during financial crises and the second column shows the effects during non-crisis periods. Column 3, shows the difference between the two regimes.

During non-crisis periods, our results for output and prices are in line with the results reported in previous empirical studies of the effects of monetary policy shocks (see e.g. the Handbook article of Christiano et al., 1999). The response of output is hump-shaped and it responds faster than consumer prices. Consumer prices start increasing after about two years. Monetary policy shocks have permanent effects on the price level, whereas the effect on output is not significantly different from zero in the long-run.

However, during financial crises, the reaction of output and prices is quite different. The responses of output and prices are significantly stronger and occur faster. Within the first two years after an expansionary monetary policy shock, output increases by 0.5 to 1 percent more compared with non-crisis periods. Subsequently, there is no significant difference between the two regimes. Prices increase already within the first few quarters after the shock. Overall, the increase in prices is about 0.5 percent higher than that during non-crisis periods. The differences in the responses between the regimes are much more persistent for prices than for output and last for about five years.

The difference in the impulse responses of the interest rate shows that the higher effects of output and prices during financial crises are not caused by differences in the systematic part of monetary policy. Monetary policy is even less expansionary in the financial crisis regime during the first year after a monetary policy shock and only slightly more expansionary after two to three years.

Regarding the transmission channels, we find significant differences between the two regimes in terms of all variables except house prices. Credit increases faster and, for about two years, significantly stronger during financial crises. The differences between the regimes are more short-lived for all other variables. We detect large and significant differences in the response of uncertainty to an expansionary monetary policy shock. Our measure of uncertainty exhibits a marked decline of three percent during financial crises, whereas it barely reacts during non-crisis periods. We also find large differences in the reactions of share prices. Share prices increase faster and by six percent more than during normal times. We observe a similar pattern for consumer confidence. Finally, the effective exchange rate depreciation is only on impact slightly stronger during financial crises.

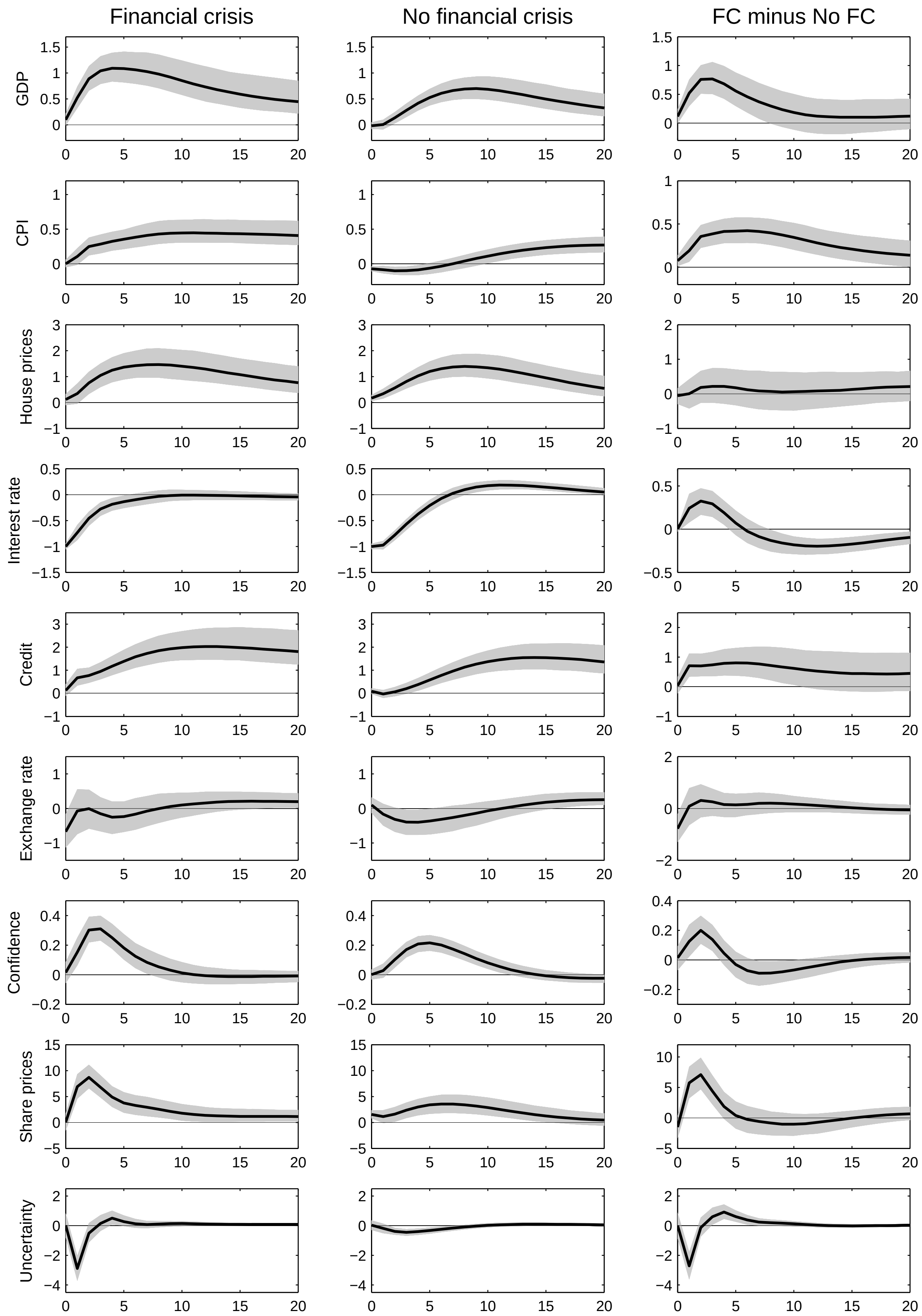

Figure 1: Effects of a monetary policy shock during financial crises and normal periods.
Notes: Column 1 shows the median of the average impulse response across countries during financial crises, column 2 shows the same measure during non-crisis periods and column 3 shows the difference between these two. Gray areas represent 90% confidence intervals.

Overall, our results suggest that financial market variables and sentiment measures are more important for monetary policy transmission during financial crises, and that they respond much more rapidly and strongly than during non-crisis periods.

4.2 Acute and recovery phases of financial crises

Figure 2 shows the impulse responses to an expansionary monetary policy shock in the model that differentiates between four regimes: acute phase of a financial crisis (column 1), recovery phase of a financial crisis (column 2), recessions in non-crisis times (columns 3), and expansions in non-crisis times (columns 4). It is clear that the effects of monetary policy shocks differ substantially between the different regimes, particularly between the acute and recovery phases of a financial crisis.

During the acute phase of a financial crisis monetary policy is very effective in stimulating economic activity: an expansionary monetary policy shock leads to a very rapid, strong, and persistent increase in output and consumer prices. By contrast, monetary policy is ineffective during the subsequent recovery phase of a financial crisis, where an expansionary monetary policy shock has no significant effects on output and consumer prices. In addition, the responses of output and consumer prices are relatively similar during recessions and expansions in non-crisis periods and are, by and large, in line with the results from previous empirical studies.

Regarding the transmission channels, the responses of share prices and uncertainty exhibit the most apparent differences between regimes. Share prices exhibit the strongest increase during the acute phase of a financial crisis. To a lesser extent, they also increase during normal recessions and normal expansions, whereas they do not react significantly during the recovery phase of a financial crisis. Uncertainty declines strongly during the acute phase of a financial crisis in the first quarters after the shock, but hardly plays any visible role for the monetary transmission mechanism during recessions and expansions outside financial crises. During the recovery phase of a financial crisis, uncertainty even increases on impact, but this effect dies out after one quarter. The responses of house prices, credit, exchange rates, and consumer confidence after an expansionary monetary policy shock are largely comparable across the four regimes and show the expected signs. House prices and credit increase significantly in most regimes. A notable exception is that the increase in credit is not significant during the recovery phase of a financial crisis. The effective exchange rate tends to depreciate in all four regimes and the strongest depreciation occurs during the recovery phase of a financial crisis. However, this effect is rather short-lived and it only differs significantly from zero for two quarters. Consumer confidence increases significantly in all four regimes and exhibits the fastest response during the acute phase of a financial crisis.

To illustrate whether these differences between regimes are significant, Figure 3 shows the differences in the median impulse responses between regimes, as well as the corresponding 90% confidence intervals for four selected cases. Columns 1–3 compare the acute phase of a financial crisis, the recovery phase of a financial crisis, and normal recessions with normal expansions, respectively. Column 4 shows the differences between the acute phase of a financial crisis and normal recessions.

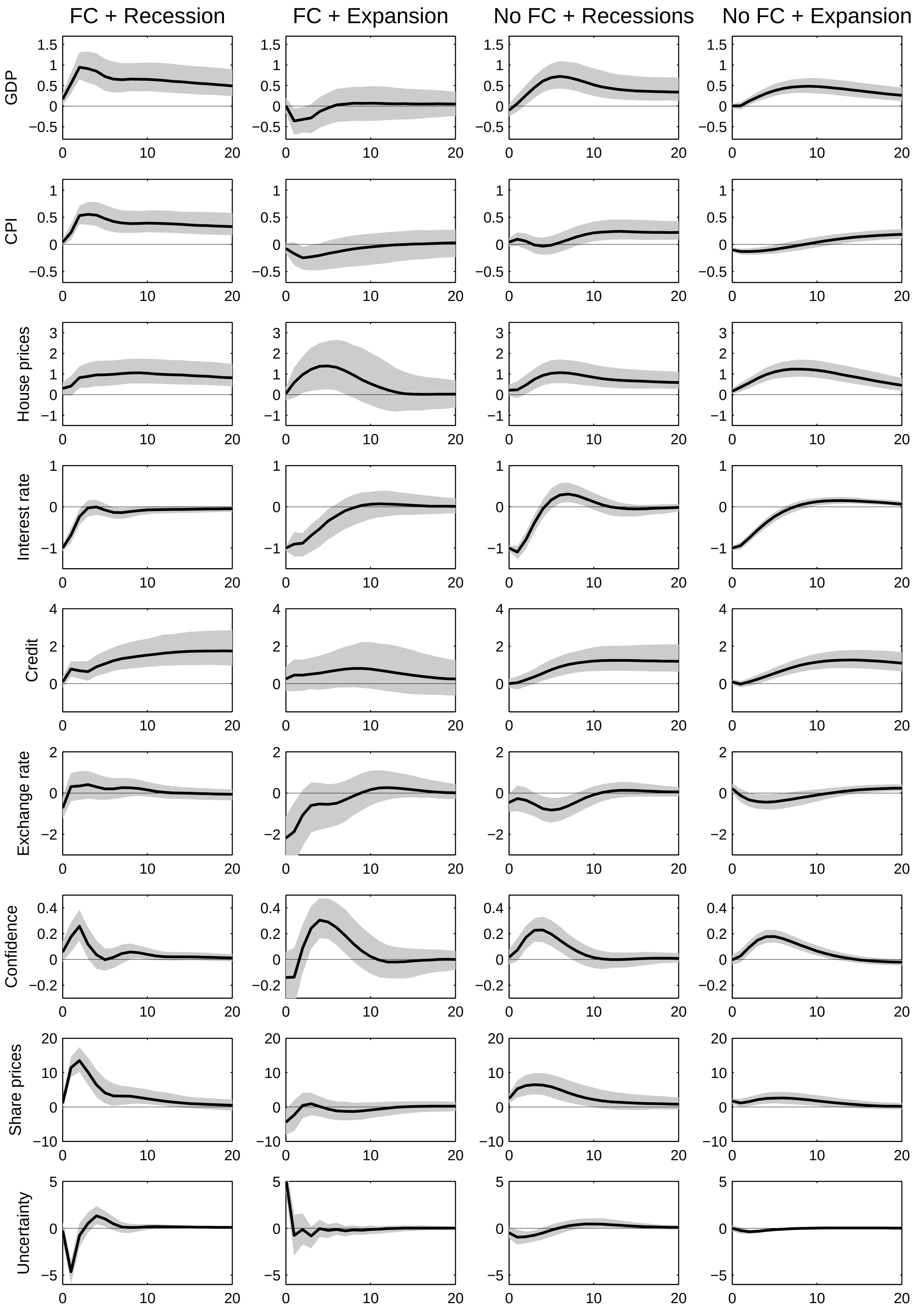

Figure 2: The role of recessions and expansions during financial crises.

Notes: Column 1 shows the median impulse response during the acute phase of financial crises (FC+REC) and column 2 during the recovery phase of a financial crisis (FC+EXP). Column 3 shows the same measure during normal recessions (No FC+REC) and column 4 during normal expansions (No FC+EXP). Gray areas represent 90% confidence intervals.

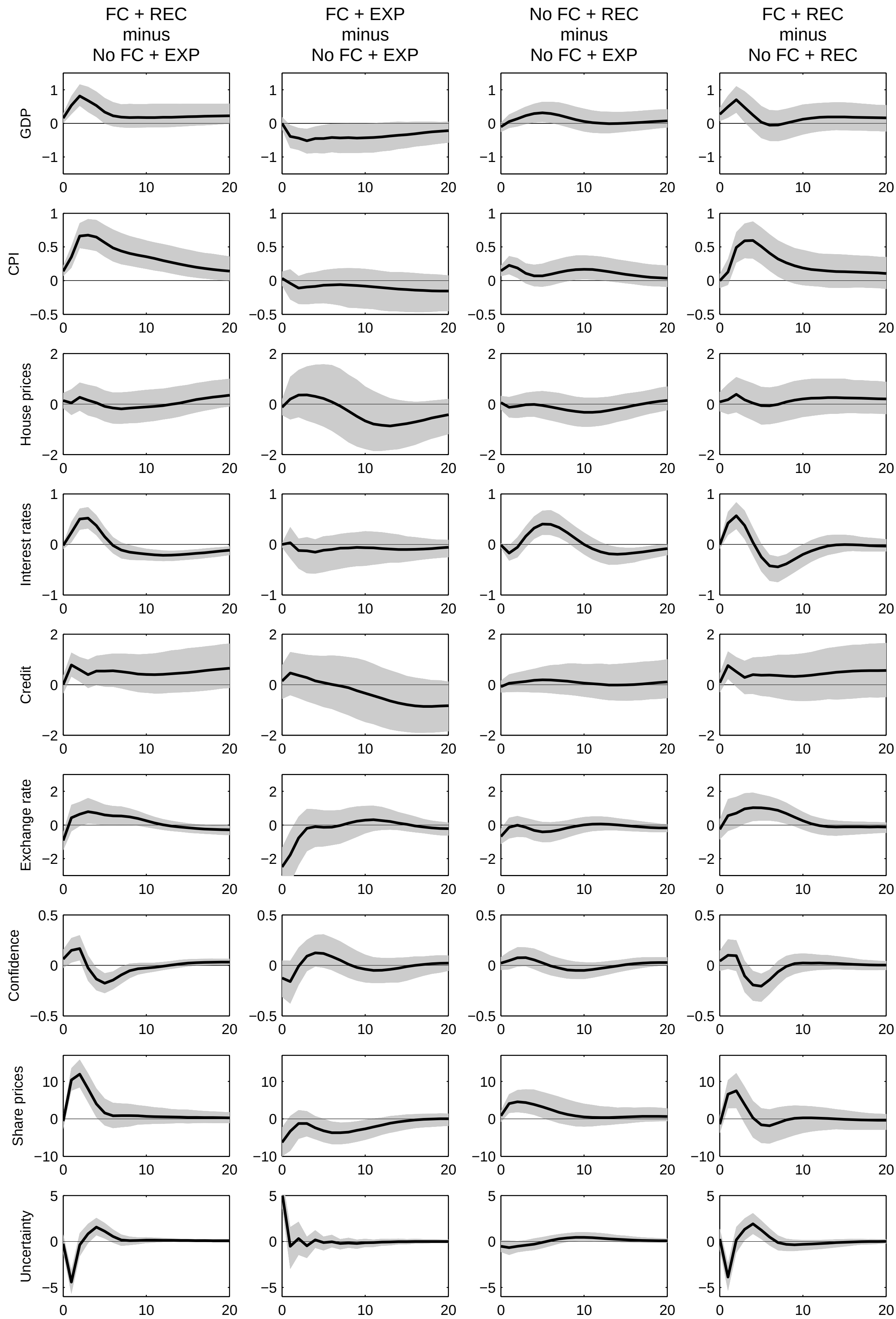

Figure 3: Differences between crisis, recession, and expansion regimes.

Notes: Columns 1–3 show differences between the median impulse responses in the first three regimes (acute phase: FC+REC, recovery phase: FC+EXP, normal recessions: No FC+ REC) compared with the normal expansion regime (No FC+EXP). Column 4 shows the difference between the acute phase of a financial crisis and normal recessions. Gray areas represent 90% confidence intervals.

The effects of an expansionary monetary policy shock on output and prices are significantly larger during the acute phase of a financial crisis compared with all other regimes.[20] The differences in the effects on output are large (up to almost one percent), but they are significantly different from zero only during the first quarters after the shock. The differences in the effects on consumer prices are much more persistent. The effects on both output and prices are smaller during the recovery phase of a financial crisis compared with normal expansions, but these differences are only significant for output shortly after the shock. The effects on output and consumer prices are somewhat stronger during normal recessions compared with normal expansions.

Turning to the transmission channels, share prices and uncertainty exhibit strong and significant differences between the acute phase of a financial crisis and the other regimes. We also observe a stronger increase in consumer confidence on impact, even though the differences are hardly significant. Interestingly, the depreciation of the effective exchange rate is significantly less pronounced during some quarters during the acute phase of a financial crisis, which suggests that foreign trade does not have a crucial role in the stronger effects on output during the acute phase of a financial crisis. The differences in the effects on house prices and credit across regimes are hardly significant significantly different from zero.

4.3 Counterfactual analysis

We find large differences between regimes in terms of the responses of output and prices, but also for some variables that are potentially relevant to the transmission channels of monetary policy. To obtain a better understanding of whether causality runs from these potential transmission variables to output and prices or the other way around, we perform a number of counterfactual experiments. In particular, we construct hypothetical impulse responses by shutting down the responses of selected transmission variables to the monetary policy shock. By comparing the counterfactual and baseline impulse responses, we investigate how much of the responses of output and consumer prices to the monetary policy shocks can be explained by these transmission variables. Similar exercises were performed by Bernanke et al. (1998), Sims and Zha (2006) and Kilian and Lewis (2011) to analyze the role of systematic monetary policy in the transmission of other shocks and by Bachmann and Sims (2012) to analyze the role of confidence in fiscal policy transmission. We experiment with shutting down each of the potential transmission variables, as well as shutting down combinations of variables. Shutting down the responses of house prices, exchange rates, or credit jointly or individually leads to counterfactual responses of output and consumer prices that are very similar to our baseline results. By contrast, confidence, share prices, and uncertainty are found to be highly important for monetary policy transmission during financial crises.

Figure 4 shows the responses of output, consumer prices, interest rates, and credit for the model with two different regimes in the most interesting counterfactual scenario, where we jointly shut down the responses of confidence, share prices, and uncertainty.[21] During financial

[20] We do not explicitly show the differences between the acute and the recovery phases of a financial crisis, but it is clear from figure 2 that the effects of GDP and CPI are smaller during the recovery phase than in all of the other regimes.

[21] House prices and exchange rates are allowed to respond in this counterfactual scenario, but their counterfactual

crises, the counterfactual responses (dashed-dotted lines) of output and—to a lesser extent—of consumer prices are considerably less pronounced than those in the baseline. The largest change is visible for the response of credit, which increases by far less in the counterfactual scenario. Moreover, the interest rate remains considerably lower for a longer time. During non-crisis periods, confidence, share prices and uncertainty also influence monetary policy transmission, but are somewhat less important than during financial crises.

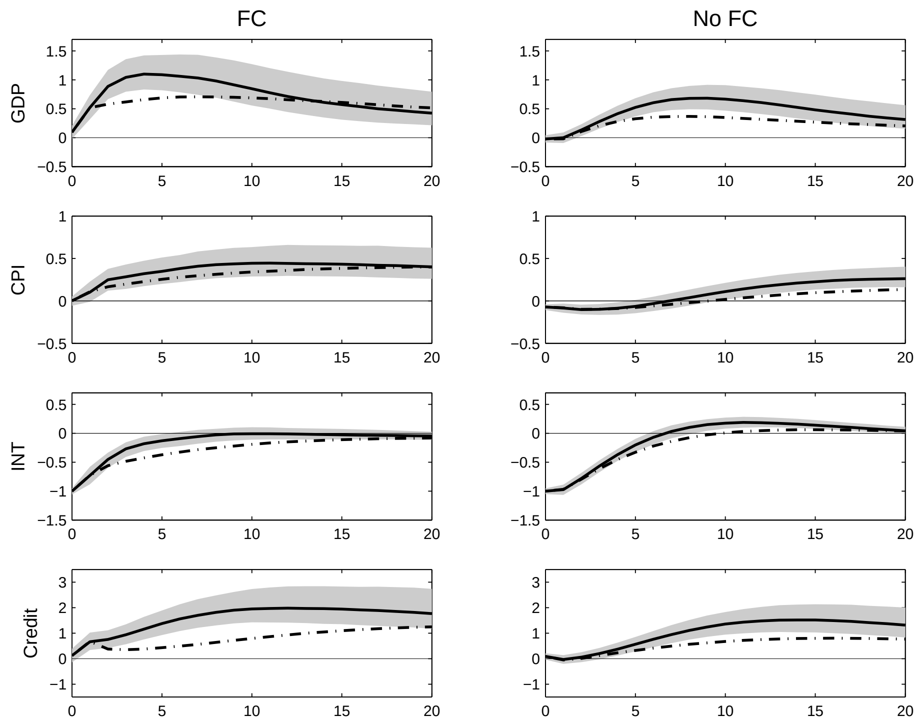

Figure 4: Counterfactual analysis with two regimes: shutting down confidence, share prices, and uncertainty.

Notes: Dashed-dotted lines show the counterfactual median impulse responses. Solid lines show the baseline median impulse responses and gray areas represent 90% confidence intervals. The two regimes are financial crisis (FC) and non-crisis periods (No FC).

Figure 5 shows the results of the same counterfactual analysis for the model that differentiates between four regimes, where the results are even more pronounced. Confidence, share prices and uncertainty have the largest influence during the acute phase of a financial crisis. When we shut these channels down, credit is almost unresponsive to a monetary policy shock, while the increase in output is substantially lower. Hence, the effects of a monetary policy shock on confidence, share prices, and uncertainty appear to restore monetary policy transmission via credit, whereas this channel would be impaired otherwise. Interestingly, the counterfactual response of prices during the acute phase of a financial crisis is similar to the baseline response for the first six quarters and becomes larger afterwards. This can be explained by the more persistent counterfactual response of the short-term interest rate, which implies that monetary policy remains more expansionary for a longer time in the counterfactual scenario. By contrast, in the baseline scenario, the early tightening after an initial interest rate cut seems to be driven

impulse responses are very similar to the baseline. The results for alternative counterfactual scenarios where we shut down different variables individually or jointly are quite similar to the counterfactual presented here, or to the baseline, and they are available from the authors upon request.

by a systematic response of monetary policy to the increases in confidence and share prices as well as to the drop in uncertainty. This also shows that the large response of output during the acute phase of a financial crisis in the baseline scenario occurs despite a relatively restrictive monetary policy compared with the other regimes.[22] In the recovery phase of a financial crisis, the counterfactuals responses are very similar to the baseline results. Hence, consumer confidence, share prices and uncertainty play no important roles in monetary policy transmission. During normal recessions and normal expansions, the counterfactual responses are smaller than those in the baseline for most variables, but these differences are less pronounced than those during the acute phase of a financial crisis.

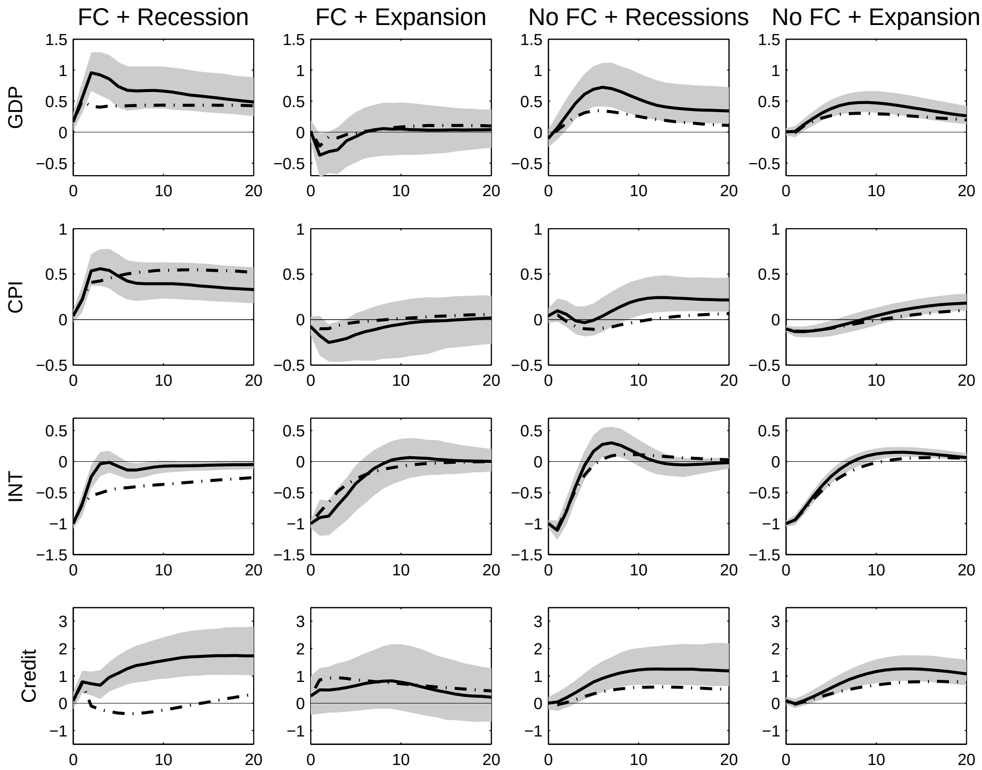

Figure 5: Counterfactual analysis with four regimes: shutting down confidence, share prices, and uncertainty.
Notes: Dashed-dotted lines show the counterfactual median impulse responses. Solid lines show the baseline median impulse responses and gray areas represent the baseline 90% confidence intervals. Column 1 shows the impulse response during the acute phase of financial crises (FC+REC) and column 2 during the recovery phase of a financial crisis (FC+EXP). Column 3 shows the the impulse responses during normal recessions (No FC+REC) and column 4 during normal expansions (No FC+EXP).

4.4 Discussion of the results

Our results demonstrate that monetary policy is very effective during the acute phase of a financial crisis. An expansionary monetary policy shock during this phase raises GDP and

[22]We also investigated potential differences in the systematic response of monetary policy across regimes by enforcing the same interest rate response in all regimes as it is estimated for normal expansions. We implemented this scenario by evaluating all of the regime dummy variables at zero for the interest rate equation only. The larger effects on output and inflation during the acute phase of a financial crisis were then amplified even further. This confirms that the systematic reaction of monetary policy to other variables in the VAR is actually less expansionary during the acute phase of a financial crisis than in the non-crisis regimes.

prices to a higher extent than during non-crises times or than during the recovery phase of a financial crisis. Moreover, our results demonstrate that an expansionary monetary policy shock significantly reduces uncertainty, whereas it raises share prices and confidence during the acute phase of a financial crisis. Credit also increases, but not significantly more than in the other three regimes. On the one hand, this result suggests that monetary policy transmission is not impaired entirely during the acute phase of a financial crisis. On the other hand, credit does not appear to be particularly important for monetary policy transmission during this regime compared with the other three regimes. Furthermore, our counterfactual analysis shows that due to its effects on uncertainty, share prices and consumer confidence monetary policy is able to effectively stimulate economic activity in the acute phase. Moreover, without the effect of monetary policy on these three variables, credit does not react at all to a monetary policy shock; possibly due to weakened balance sheets of borrowers and lenders, high risk premia and postponement of consumption and investment.[23] Thus, we conclude that monetary policy is very effective not only due to the direct effects of lower uncertainty and higher share prices and consumer confidence on economic activity, but presumably also because it is able to strengthen the traditional transmission channels, such as the credit channel or the interest rate channel, which would be partially impaired otherwise during the acute phase of a financial crisis. Overall, we show that monetary policy can trigger an acceleration mechanism during the acute phase of a financial crisis because it cushions the adverse effects of the financial crisis, but also strengthens the traditional transmission channels of monetary policy, thereby leading to stronger effects of monetary policy on output and prices compared with non-crisis periods.

Our finding of an acceleration mechanism of monetary policy during the acute phase of a financial crisis is in line with various results in the literature. In terms of the effects of monetary policy on uncertainty, Basu and Bundick (2012) show that monetary policy can play a key role in offsetting the negative impact of uncertainty shocks in a DSGE model with countercyclical mark-ups and sticky prices. Bekaert et al. (2013) provide empirical evidence for the effectiveness of expansionary monetary policy in decreasing risk aversion and uncertainty. Once monetary policy is successful in reducing uncertainty, various second-round effects can be expected. First, in line with findings of Bloom (2009), lower uncertainty can lead to higher output because investment revives as investors receive new information. Second, a lower degree of uncertainty can stimulate credit supply and thus restore the credit channel of monetary policy. In particular, a lower degree of uncertainty should decrease liquidity risk and ease refinancing in interbank markets which improves lending conditions for banks (Buch et al., 2014). Banks also have less need to retain capital for reasons of self-insurance and can thus extend their lending (Valencia, 2013). Third, a reduction in uncertainty can improve consumer sentiment by enhancing the ability of agents to make probabilistic assessments about future events (Ilut and Schneider, 2014).

A monetary policy expansion can also raise consumer confidence directly by providing signals

[23]See Reinhart and Rogoff (2008), and Bouis et al. (2013) for the potential negative implications of weak balance sheets on credit, Valencia (2013) and Buch et al. (2014) for the link between high uncertainty, risk premia and low credit supply and Bernanke (1983), Dixit and Pindyck (1994) and Morgan (1993) for the link between high uncertainty and weak investment and consumption spending.

about future economic prospects (Barsky and Sims, 2012; Bachmann and Sims, 2012). Therefore, expansionary monetary policy might be interpreted as a a sign that the central bank will prevent a further deepening of the crisis. An increase in consumer confidence can then restore the interest rate responsiveness of borrowing, investment, and spending on durables. Finally, an increase in share prices driven by a monetary policy expansion can increase the value of collateral and the worth of firms, thereby, contributing to a softening of credit constraints and to higher credit demand (Bernanke and Gertler, 1995; Dahlhaus, 2014). An increase in share prices also makes it easier to finance investment by retaining profits.

Interestingly, our counterfactual analysis shows that the inflation output trade-off worsens considerably (weaker increase of output and in tendency stronger increase of CPI) during the acute phase of a financial crisis without the effects of monetary policy on uncertainty, share prices, and consumer confidence. This result is in line with (Vavra, 2014) who finds that the trade-off worsens in times of high volatility. Hence, our results suggest that monetary policy can improve the inflation output trade-off during the acute phase of a financial crisis.

Our results also indicate that monetary policy is ineffective in stimulating economic activity during the recovery phase of a financial crisis. Expansionary monetary policy shocks have no significant effects on output and consumer prices. In addition, house prices, credit, and share prices exhibit no significant responses. Confidence increases with a delay of some quarters and uncertainty even increases on impact. Overall, our results are less clear-cut for this phase. It is also more difficult to interpret the underlying transmission channels during this phase because in the counterfactual scenario the responses of output and prices remain weak and thus cannot be explained by any of the potential transmission variables included in the VAR.

Nonetheless, a cautious interpretation of our results might be that during the recovery phase of a financial crisis, when the crisis has been ongoing for some time, an unexpected cut in the interest rate is regarded as confirmation of incipient financial difficulties (for a similar interpretation see Hubrich and Tetlow, 2015). Thus, continued monetary policy interventions could thus be interpreted as a negative signal about weak future fundamentals, thereby increasing uncertainty in probabilistic assessments. This may explain why share prices drop slightly and uncertainty increases on impact. The general non-responsiveness of macroeconomic aggregates during the recovery phase of financial crises can also be explained by a predominance of balance-sheet adjustments and deleveraging by firms and financial institutions (Reinhart and Rogoff, 2008). Monetary policy usually works via intertemporal substitution, but very few people are willing to increase their credit exposure in such periods. Hence, even highly expansionary monetary policy has little effect on credit, output and inflation.

Overall, our results indicate that during the recovery phase of a financial crisis, factors predominate that make monetary policy less effective, such as adverse signals about fundamentals or balance-sheet adjustments and deleveraging. In addition, the mechanisms that are important for monetary policy transmission during the acute phase of a financial crisis, such as the reduction of uncertainty, lose ground during the recovery phase. At this late stage of a financial crisis, uncertainty has typically been mitigated already and share price and consumer confidence have stabilized, and thus potential acceleration mechanisms in monetary policy transmission have already been exhausted.

4.5 Robustness checks

In the following, we show the results of a number of robustness checks.

4.5.1 Zero lower bound and Quantitative Easing

The majority of the financial crises in our sample are associated with the global financial crisis that started in 2007. In this crisis, several central banks reached the zero lower bound on nominal interest rates and therefore switched to unconventional monetary policy measures such as quantitative easing. In our baseline model, we do not account for unconventional monetary policy because it is difficult to handle conventional and unconventional monetary policy shocks in the same empirical framework.

We check whether our results are affected by not accounting for unconventional monetary policy measures in two different ways. First, we use the shadow rate by Wu and Xia (2014) instead of the money market short-run interest rate for the US, the UK, and the euro area as monetary policy instrument in our model. This shadow rate is an estimate of the level of the short-term interest rate that would prevail in the absence of the zero lower bound. The shadow rates are estimated based on forward rates and a Nelson-Siegel-Svensson yield curve model, so they also reflect quantitative easing policy measures and other unconventional monetary policy measures.[24]

Figure 6 shows the results obtained for the model that differentiates between two regimes and figure 7 shows the results for the model that differentiates between four regimes. For comparison, the dashed lines show the baseline estimates presented in figures 1 and 2 (without confidence bands). Overall, the results are very similar to our baseline. Not accounting for the zero lower bound and quantitative easing policies possibly slightly overstates the large effects on output, prices, credit, uncertainty, and share prices during financial crises and during the acute phase of a financial crisis, respectively. However, the main pattern of differences between the regimes is very similar to the baseline results, and thus the interpretation of our results is unaffected. For the non-crisis regimes and for the recovery phase of a financial crisis results are very similar to the baseline.

We also perform a second, more agnostic, robustness check with respect to the zero lower bound and unconventional monetary policy measures. We identify all of the observations in which monetary policy reached the zero lower bound. In our identification scheme, monetary policy reaches the zero lower bound when the interest rate of the main monetary policy instrument is smaller or equal to 0.25%. Overall, we identify 127 observations where monetary policy reaches the zero lower bound, and 36 of these observations occur in financial crises. When we exclude these observations from our sample our results are basically unchanged.[25] Thus, we conclude that the zero lower bound and unconventional monetary policy measures have no significant impact on our results.

[24]Shadow interest rates are not available for other economies; therefore, we do not control for unconventional monetary policy measures in Japan, which is the only remaining economy in our sample where such measures have been applied for a longer period. However, our results do not change when we also exclude Japan from our sample in this robustness check.

[25]The results of this robustness check are available on request.

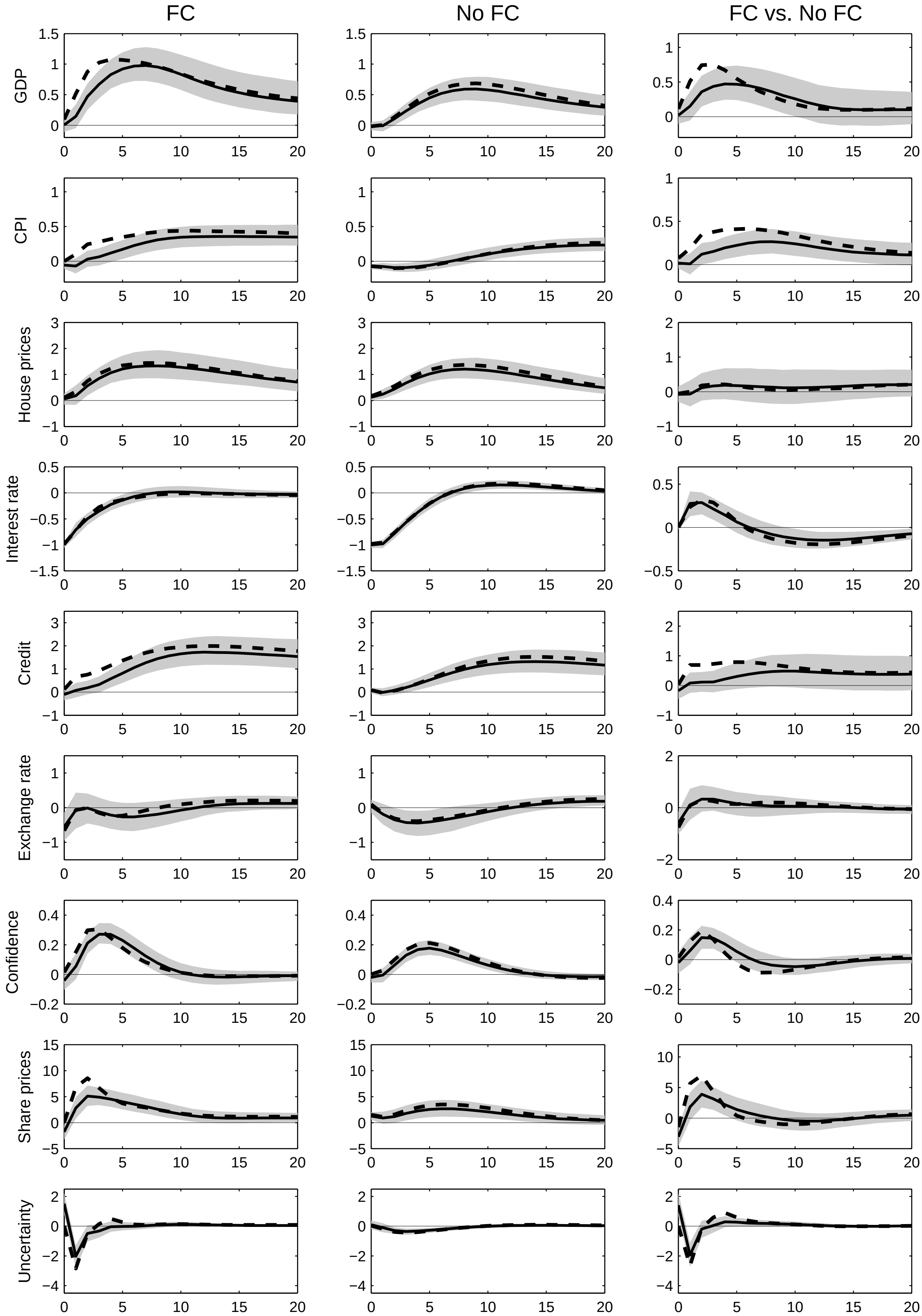

Figure 6: Effects of a monetary policy shock during financial crises and normal periods using shadow interest rates.

Notes: For the US, the UK and euro area economies the short term interest rate is replaced by the shadow rate estimates of Wu and Xia (2014). Gray areas represent 90% confidence intervals. Dashed lines show the baseline estimates from Figure 1 (without confidence intervals) for comparison. Column 1 shows the median impulse response during financial crises (FC), column 2 shows the same measure during non-crisis times (No FC) and column 3 shows the difference between the two.

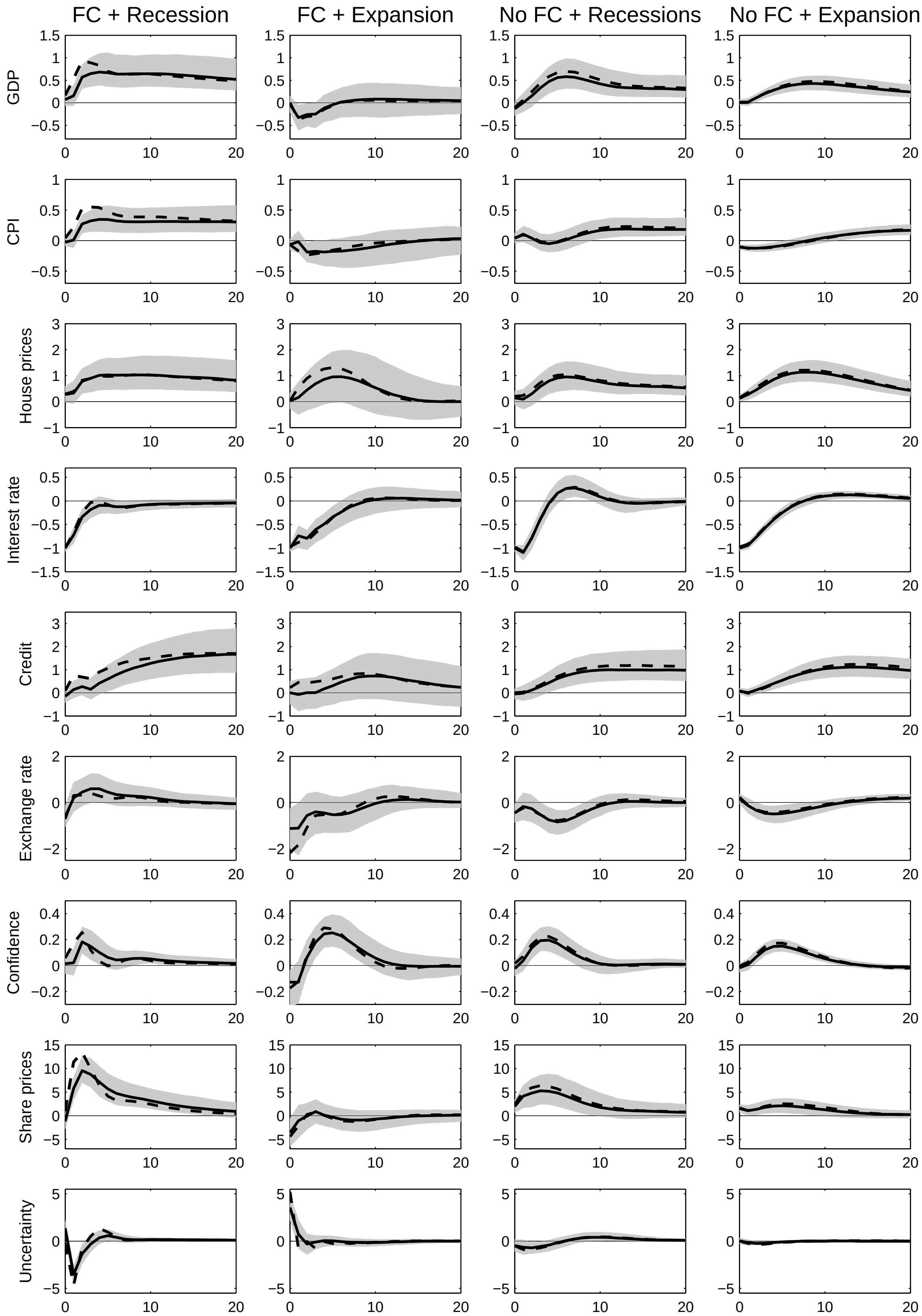

Figure 7: Effects of a monetary policy shock during financial crises, recessions, and expansions using shadow interest rates.

Notes: For the US, the UK and euro area economies the short term interest rate is replaced by the shadow rate estimates of Wu and Xia (2014). Gray areas represent 90% confidence intervals. Dashed lines show the baseline estimates from Figure 2 (without confidence bands) for comparison. Column 1 shows the median impulse response during the acute phase of financial crises (FC+REC) and column 2 during the recovery phase of a financial crisis (FC+EXP). Column 3 shows the same measure during normal recessions (No FC+REC) and column 4 during normal expansions (No FC+EXP).

4.5.2 Is the Great Recession special?

The global financial crisis that started in 2007 differs from other financial crises in our sample because of its high degree of international synchronization. Apart from the global financial crisis, our sample includes five other financial crises: one in the US in the late 1980s, one in Japan around the year 2000 and the Scandinavian crisis of the 1990s in Sweden, Norway and Finland. Hence, it is possible that our results are driven mainly by the global financial crisis.

We check whether our results are robust after restricting our estimation period from 1984 to 2007 in order to exclude the global financial crisis. Because of the very limited number of financial crisis observations that remain for this period (84 quarters), we have to restrict our empirical analysis to the model that differentiates between two regimes only.

Figure 8 shows the result of this robustness check. For comparison, the dashed lines show the results of our baseline estimates from 1984 to 2013. First, it can be seen that the confidence intervals are much wider and the impulse responses are less smooth in the financial crisis regime, which reflects the small number of observations available for this regime. Nevertheless, the results are generally similar to our baseline estimates. Output and prices respond faster during financial crises than during non-crisis times. Furthermore, the responses of share prices and uncertainty are larger during financial crises. In terms of the interest rate response, it can be seen that during the earlier financial crises monetary policy was less expansionary than in the full sample including the global financial crisis.

Overall, based on this robustness check, we conclude that our results do not apply specifically to the global financial crisis. Our results indicate that the general patterns in the differences in monetary policy transmission during crisis and non-crisis periods are similar for regionally bounded and global financial crises. However, the results are much more uncertain for the earlier regionally bounded financial crises, and thus further research is needed in this direction.

4.5.3 Sign Restrictions

We check whether our results are robust when we use sign restrictions instead of the Cholesky identification to identify monetary policy shocks. We remain agnostic about the response of output and we only impose restrictions on prices and the interest rate. We restrict the impulse response of the short-term interest rate to being negative during the first four quarters and the response of prices to being positive between the second and fourth quarter. We follow Sá et al. (2014) and do not restrict the CPI response in the first quarter to allow for a sluggish response by this variable. Nonetheless, this specification could still be quite restrictive given that the results obtained in our baseline model showed that the response of consumer prices to an expansionary monetary policy shock is not necessarily positive during financial crises. However, the sign restriction approach has the advantage that it allows for non-zero responses by all variables in the VAR.

Figure 9 shows the results for the two regime case. Column 1 shows the financial crisis regime, column 2 the non-crisis regime, and column 3 the difference between the two. The results are similar to the results obtained based on Cholesky identification. Output and inflation react faster and stronger during financial crises. Again, the increase in confidence and share prices

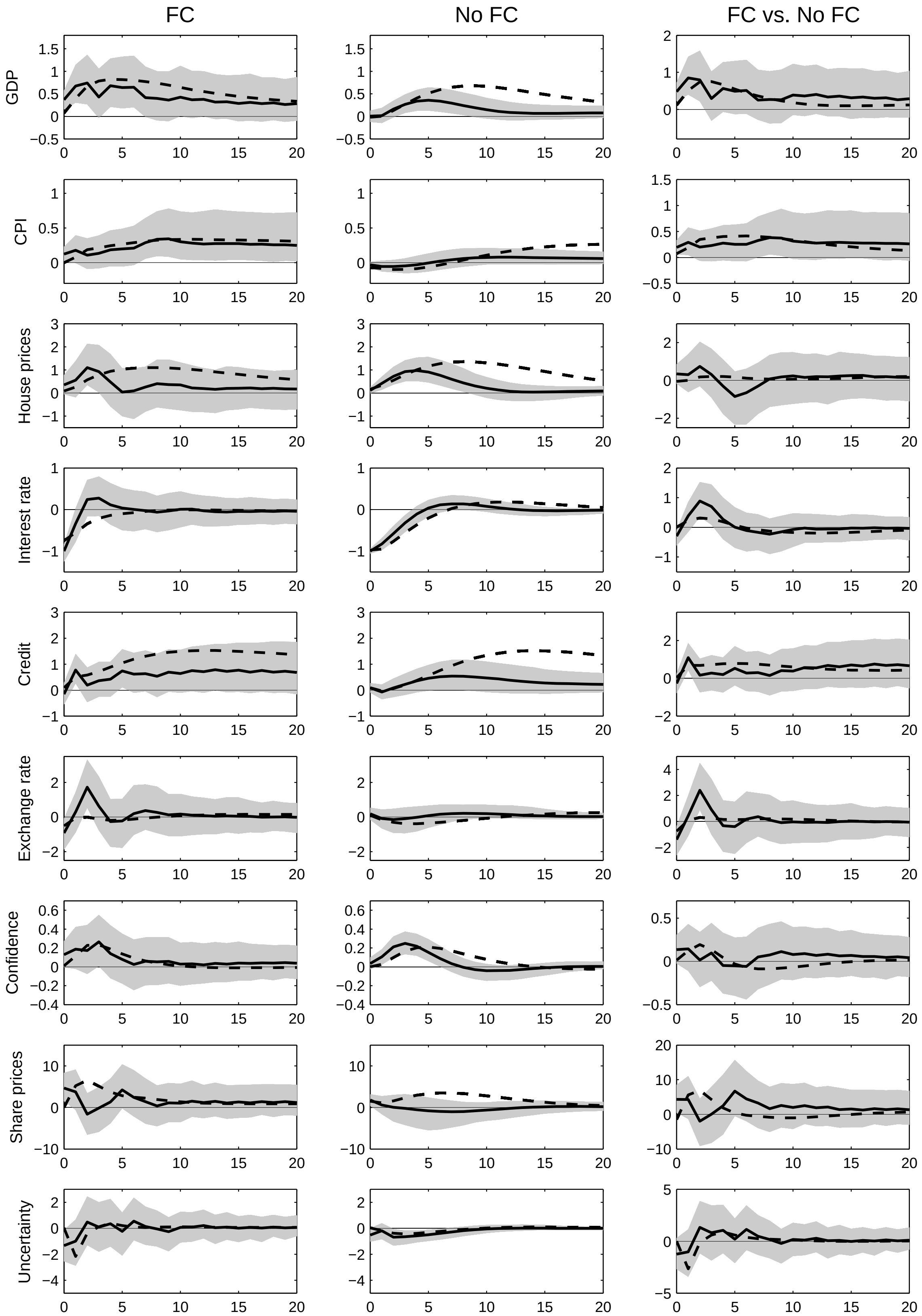

Figure 8: Effects of a monetary policy shock during financial crises and normal periods: 1984–2007.

Notes: In contrast to the baseline estimates, the sample ends before the global financial crisis. Estimation for the financial crisis regime is based on five financial crises only. Gray areas represent 90% confidence intervals. Dashed lines show the baseline estimates from Figure 2 (without confidence intervals) for comparison. Column 1 shows the median impulse response during financial crises (FC), column 2 shows the same measure during non-crisis times (No FC) and column 3 shows the difference between the two.

as well as the reduction in uncertainty seem to be important for these differences, whereas the responses of other variables do not differ significantly between crisis and non-crisis periods.

Figure 10 shows the results for the four regime case. These results are similar to those based on Cholesky identification. The only differences are in terms of the consumer prices response and consumer confidence, but to a much smaller extent. By definition, our sign restrictions on prices lead to an increase in prices in all four regimes. Using Cholesky identification, we observed an instantaneous increase in prices during the acute phase of a financial crisis, whereas prices did not increase at all during the recovery phase and only with a delay of two years in the non-crisis regimes. With sign restrictions, the differences in the effects on prices are smaller between the regimes. During the recovery phase of a financial crisis the response of prices is somewhat less pronounced after the first year compared with the other three regimes. The response of consumer confidence during the acute phase of financial crises is smaller compared with the results based on Cholesky identification and even slightly negative on impact; however, this decrease is insignificant.

4.5.4 Other robustness checks

We perform several additional robustness checks.[26] We successively augment the baseline PVAR with additional endogenous variables that could potentially be relevant for monetary policy transmission during financial crises, i.e., a monetary aggregate (M1), long-term interest rates, term spreads, and government lending as a measure of fiscal policy. Our results are robust when we include each of these variables. The additional endogenous variables respond to an expansionary monetary policy shock according to theoretical predictions (i.e., money increases, long-term rates decrease, term spreads increase, and fiscal policy is expansionary after a monetary policy expansion), but there are no major differences in their reactions between financial crises and non-crisis regimes. Only the increase in money is stronger during financial crises—in both the acute and in the recovery phase—compared to non-crisis periods, whereas the decline in long-term rates is strongest during the recovery phase of a financial crisis. In another specification, we also replace GDP by investment and consumption and both variables exhibit almost the same differences across regimes as GDP.

We also check whether our results are affected by the sovereign debt crisis that occurred in several euro area economies after the global financial crisis. For this purpose, we restrict our estimation period from 1984 to 2010 because the sovereign debt crisis only became severe in 2011 when it led to a double-dip recession in some euro area countries. Our results are robust when we estimate our model for this period.

Finally, we examine whether our results are also applicable for sub-groups of countries. We perform two separate PVAR regressions for euro area countries and for countries outside the euro area. Over half of the countries in our sample are members of the euro area and were subject to a common monetary policy during the second half of our estimation period, which might have resulted in distinct dynamics. We only have about half of the total observations for

[26] Due to space constraints, we do not provide graphs for these robustness checks, but these graphs are available upon request.

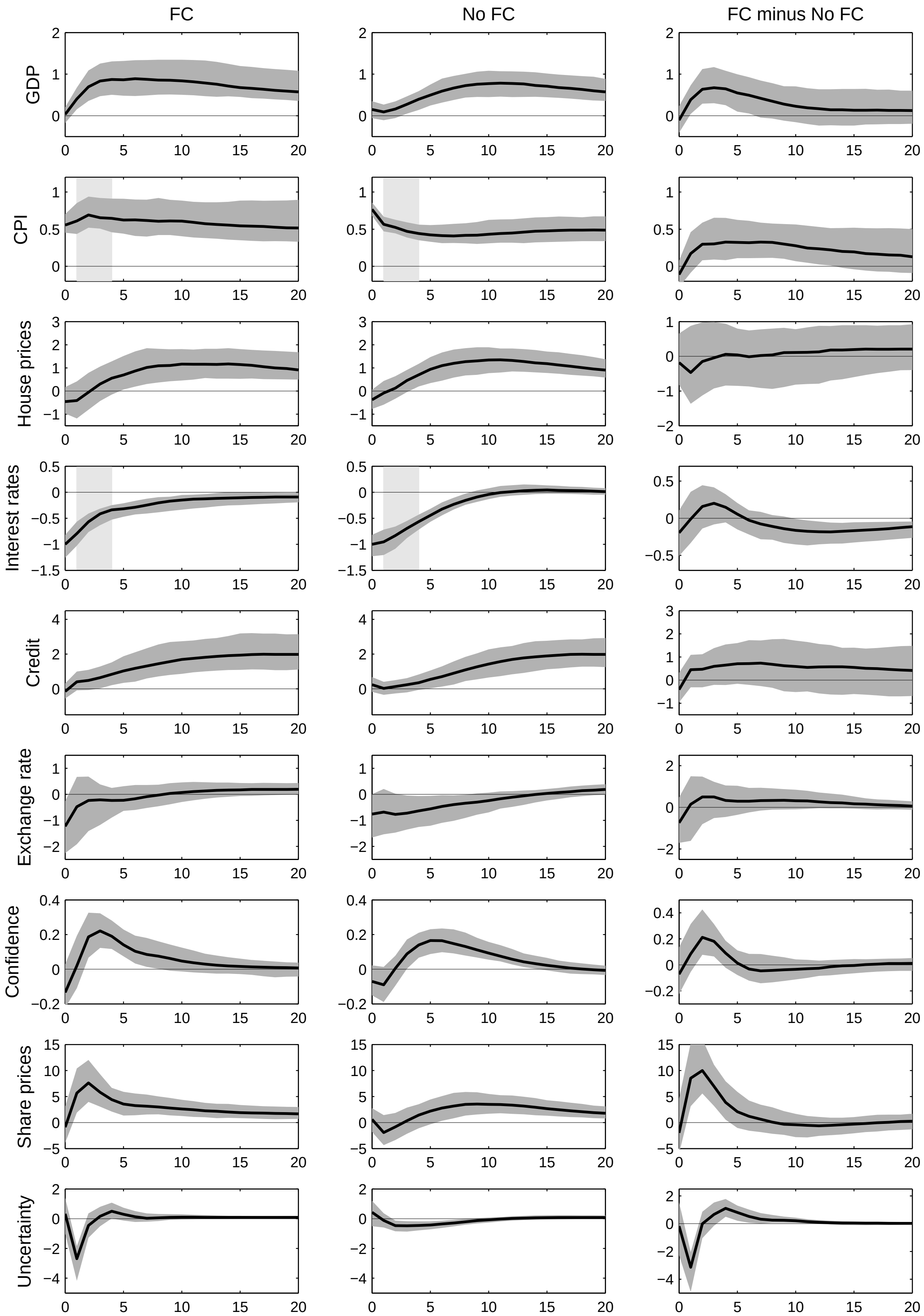

Figure 9: Effects of a monetary policy shock during financial crises and non-crisis periods.
Notes: Sign restrictions identification. Light shaded areas show the variables and the horizons on which sign restrictions are imposed. Dark shaded areas represent 90% confidence intervals accounting for parameter uncertainty. Column 1 shows the median impulse response during financial crises (FC), column 2 shows the same measure during non-crisis times (No FC) and column 3 shows the difference between these two.

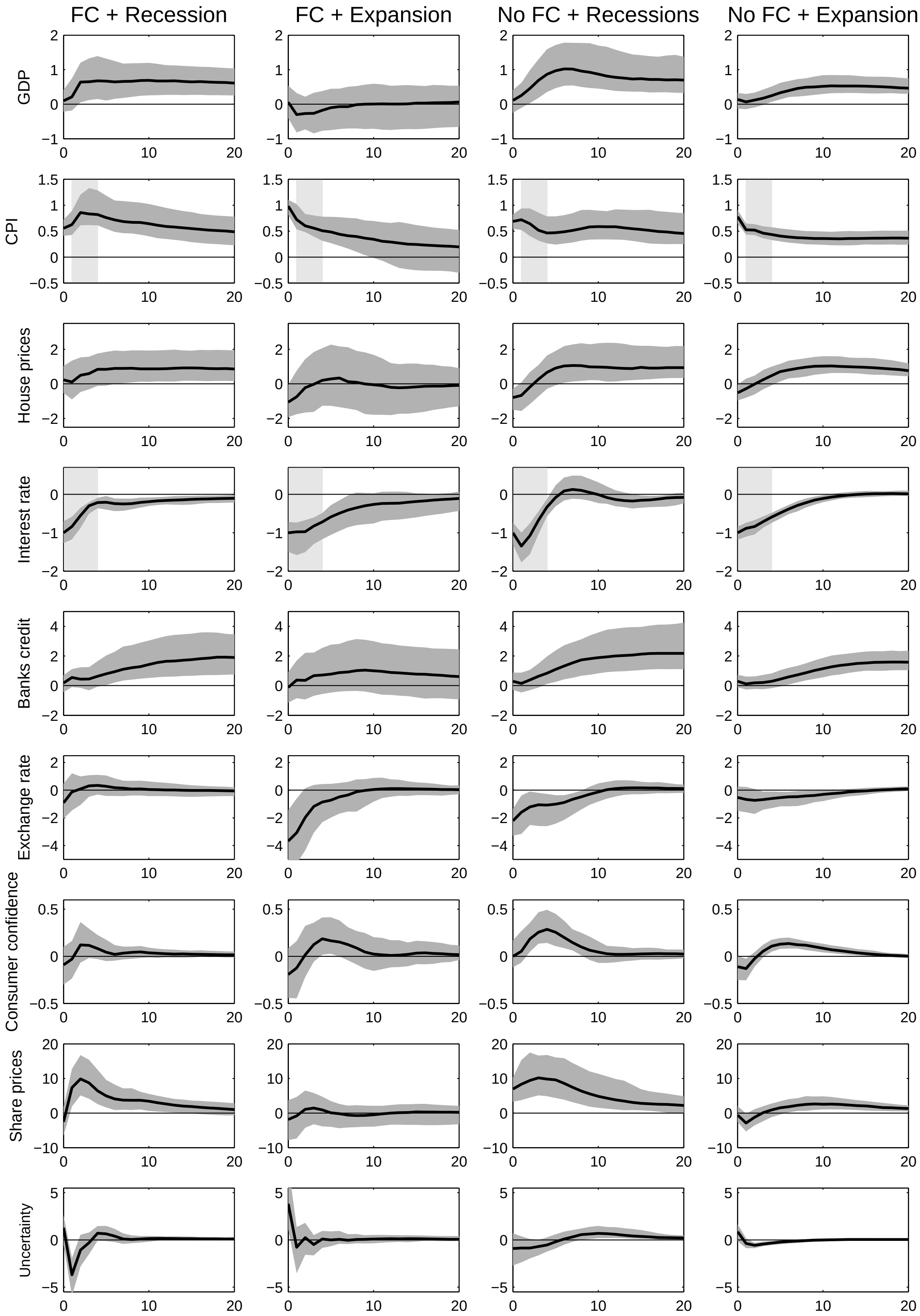

Figure 10: The role of recessions and expansions in financial crises.

Notes: Sign restrictions identification. Light shaded areas show the variables and the horizons on which sign restrictions are imposed. Dark shaded areas represent 90% confidence intervals accounting for parameter uncertainty. Column 1 shows the median impulse response during the acute phase of financial crises (FC + Recession) and column 2 during the recovery phase of a financial crisis (FC + Expansion). Column 3 shows the same measure during normal recessions (No FC + Recession) and column 4 during normal expansions (No FC + Expansion).

each sub-group, so estimation was only feasible for the case with two regimes (financial crisis and non-crisis). Results are comparable to the baseline estimation and mostly similar for both sub-groups. Output and inflation react stronger and faster during financial crises in both the euro area sample and in non-euro area countries. Differences in confidence, share prices, and uncertainty across regimes are present in both sub-groups, but they are stronger in the euro area. By contrast, in the non-euro area countries, the effective exchange rate has a larger role in explaining asymmetries between crises and non-crisis periods. During financial crises, the effective exchange rate strongly depreciates on impact in this sub-group, whereas it reacts little during non-crisis periods.

5 Conclusion

In this paper, we analyze the transmission of monetary policy during financial crises. Our analysis shows that there is no simple answer to the question of whether the transmission mechanism is impaired during financial crises. In fact, our results demonstrate that it is crucial to distinguish between the acute phase of a financial crisis and the subsequent recovery phase of a financial crisis.

During the acute phase of a financial crisis, uncertainty is usually high and confidence is low, which presumably impairs the traditional transmission mechanism of monetary policy. However, an expansionary monetary policy shock reduces uncertainty and increases share prices and confidence during this phase. Lower uncertainty and higher share prices and confidence then stimulate output and prices directly, but also indirectly by strengthening the traditional transmission channels of monetary policy. Overall, monetary policy triggers an acceleration mechanism that leads to stronger effects on output and inflation compared with non-crisis periods.

By contrast, the transmission mechanism of monetary policy is impaired during the recovery phase of a financial crisis. Output and inflation do not respond significantly to an expansionary monetary policy shock. Uncertainty even increases on impact and share prices and consumer confidence fall, albeit insignificantly. Market participants may interpret an expansionary monetary policy shock in different ways, depending on whether it occurs during the acute or the recovery phases of a financial crisis. During the acute phase, such a policy measure might be viewed as a sign of stabilization and prevention of adverse tail events, whereas perceptions may change if the financial crisis becomes more prolonged. At this later stage, a further unexpected expansion of monetary policy might be viewed as a signal that the state of the economy is worse than expected.

Overall, our results suggest that monetary policy is a very effective stabilization tool during the acute phase of a financial crisis. However, in the subsequent recovery phase of a financial crisis, monetary is largely ineffective and even large expansionary monetary policy interventions will have no significant stimulating effects. Hence, according to our results, expansionary monetary policy mitigated the adverse effects of the global financial crisis in 2008 and 2009, but the sluggish subsequent recovery can be partially explained by the low effectiveness of monetary policy during this period. Our results also show that it is important to distinguish between the different phases of a financial crisis to avoid incorrect policy conclusions, particularly with respect to recovery periods of financial crises.

This paper contributes to the analysis of monetary policy transmission during financial crises, but cannot address all open questions in this area. Future research that provides empirical evidence for earlier financial crises and for emerging market economies would be helpful, but extending the sample is not easy due to the large heterogeneity across these countries and limited data availability. Furthermore, we focused on exogenous dummy indicators of financial crises and recessions. Using continuous indicators that reflect the time varying severity of systemic financial crises would be beneficial and might allow for endogenous regime switches in response to monetary policy shocks. Moreover, our discussion relates our empirical results to various economic theories, but a clearer identification of the particular transmission channels during the different regimes would certainly be useful. Finally, we focused on banking crises. Future work regarding differences in monetary policy transmission during sovereign debt and exchange rate crises would also be very interesting, because of the very different nature of these crises.

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Table 2: Data sources and description

Variable	Source	Remarks
Gross domestic product	OECD Economic Outlook	Seasonally adjusted (SA). At 2005 market prices.
CPI, all items	OECD Main Economic Indicators	SA (seasonal filter). Index including all items, 2010=100.
Short-term interest rate	OECD Economic Outlook	3-months short-term interest rate, Greece from 1995, Ireland from 1990.
House prices	Federal Reserve Bank of Dallas	SA (seasonal filter). Portugal from 1988, Austria from 2000, Greece from 1997.
Total credit to private sector	Bank for International Settlements	SA (seasonal filter). Total amount of nominal credit (i.e. loans and debt securities) provided by domestic banks to non-financial corporations, households and non-profit institutions serving households. In national currency. See http://www.bis.org/statistics/credtopriv.htm)
Effective exchange rate	OECD Economic Outlook	SA (seasonal filter). Greece from 1995, Ireland from 1990.
Consumer confidence indicator	National sources	SA (seasonal filter). Standardized. From 1985 for most countries. Norway from 1992, Sweden from 1990, Austria from 1996.
Share prices	OECD Main Economic Indicators	SA (seasonal filter). Spain, Belgium, Greece from 1985, Norway from 1986, Portugal from 1988.
Stock volatiltiy	Based on daily major stock market indices from Datastream	SA (seasonal filter), own calculation as in Cesa-Bianchi et al. (2014). Spain, Finland, Greece from 1988, Portugal from 1990.
Countries included	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK, US	

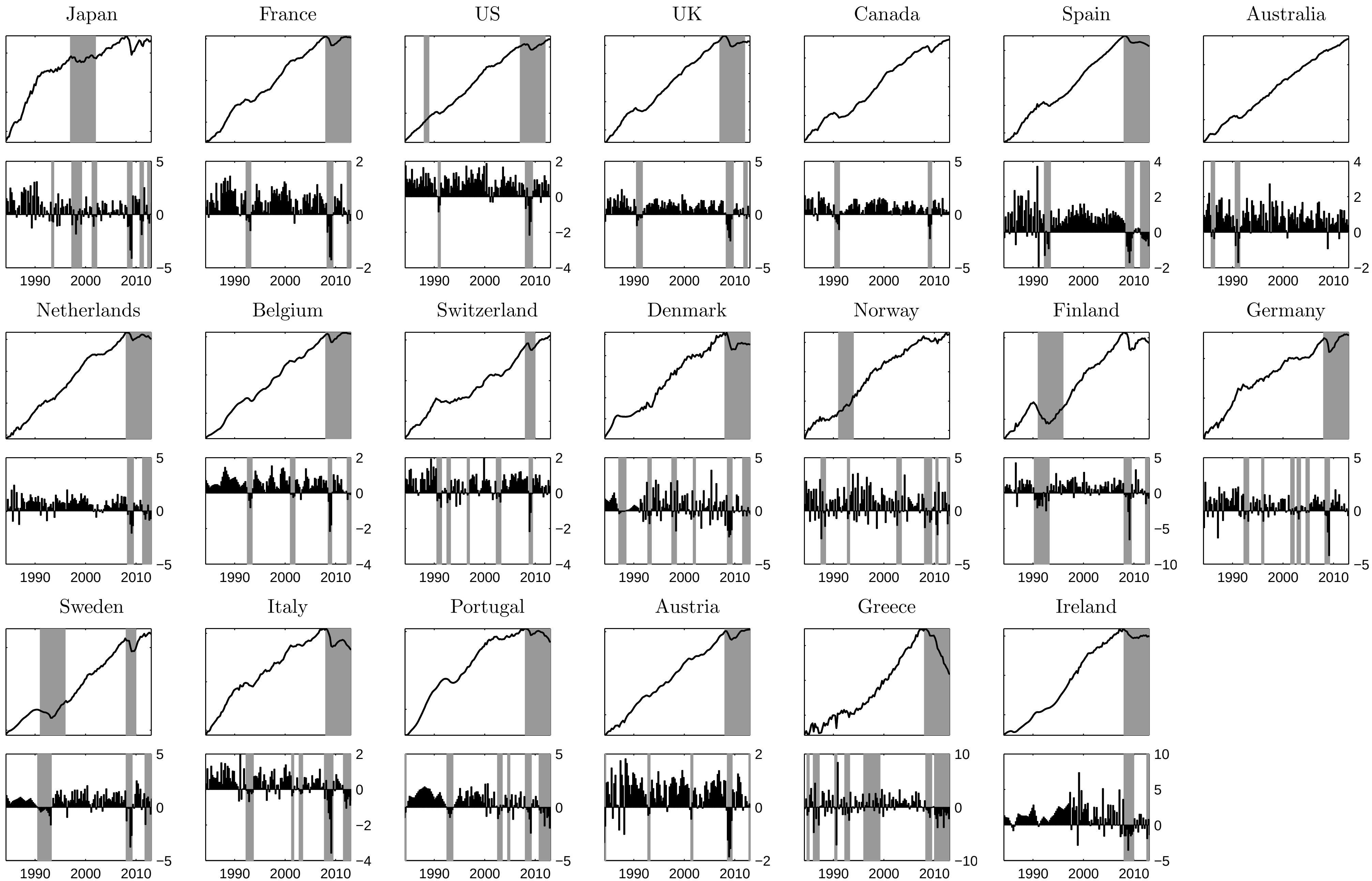

Figure 11: Financial crises and recessions data for 20 OECD economies. Notes: The figures in the upper part show log real GDP and the figures in the lower part show quarterly (non-annualized) real GDP growth. Shaded areas represent identified financial crisis episodes in the upper part and identified recessions in the lower part.