

# Unconventional monetary policy shocks in OECD countries: how important is the extent of policy uncertainty?

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**Abstract** We study the effects of unconventional monetary policy shocks on output, inflation and uncertainty using a sign restricted panel VAR over the monthly period of 2008:1–2015:1. Our sample includes primarily OECD countries (Canada, Germany, France, Italy, Japan, Spain, UK and US) that reached the interest rate zero lower bound in response to the recent financial crisis. Central bank balance sheets are used to gauge the size of unconventional monetary policy reactions to the crisis. We control for the degree of uncertainty by estimating the economic response to balance sheet shocks in two economic states: high versus low uncertainty. We use sign restrictions to identify our shocks, but remain agnostic regarding price and output responses to balance sheet shocks. We show that the mean group response of prices and output increases in response to monetary policy. The results, however, vary by country and are sensitive to the degree of uncertainty. Prices and output do not necessarily increase uniformly across countries.

**Keywords** Unconventional monetary policy · Economic policy uncertainty · Macroeconomic effects · OECD countries

**JEL classification** C33 · E58

## 1 Introduction

What are the macroeconomic effects of unconventional monetary policy? Are they similar in periods of high policy uncertainty compared to low uncertainty? We make use

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of a panel VAR to study the dynamic response of the economy when interest rates are near the zero lower bound. This study uses cross-country information to explore the effects of unconventional monetary policy. We augment our VAR with a measure of policy uncertainty to take account of periods where elevated risk and low confidence are important. We concentrate primarily on the period following the financial crisis in 2008.

The financial crisis represents a laboratory for testing conventional theories and presents a period for out of the box thinking for policy makers. Conventional monetary policy tools, i.e. central bank interest rates, reached a limit in terms of their influence on the economy - i.e. the interest rate could not be lowered to stimulate an economy further (see Krugman 1998; McCallum 2000 and Williams 2014). Some central banks used alternative measures to cushion the financial blows on the economy - sometimes deemed as unconventional. Unconventional monetary policy is unconventional in terms of its targets, not necessarily its means. Policies such as quantitative easing, whereby a central bank increases its balance sheets (both assets and liabilities) is an established practice. What makes policies such as quantitative easing unconventional, in the case of the U.S. as an example, is the direct purchase of outstanding private debt as opposed to monetizing fiscal debts.

A primary concern for many central banks is how expectations regarding recoveries and prices are formed. When setting interest rates, as an example, central banks aim to influence inflation expectations and often attempt to anchor them to some specified target. These expectations or perceptions can change depending on the state of the economy, communication by authorities and credible policies (Ireland 2000). The financial crisis was formidable in the sense that it was associated with high uncertainty. Uncertainty both in terms of the appropriate policy responses as well as in terms of the economic response to said policy decisions. The impact of policy uncertainty on the economy has been well-documented (see Baker et al. 2015; Bloom 2009; Born and Pfeifer 2014; and Carriero et al. 2013). Uncertainty reduces investment, delays spending and investment decisions, reduces consumption and ultimately reduces economic growth (Bloom 2009). Models that do not control for uncertainty might be misspecified and yield results inconsistent with a specific state of an economy.

The policy maker should thus be concerned with both stimulating the economy while simultaneously attempting to reduce uncertainty. It can only do so if an institution is credible and if policy communication to the public is transparent - (it is unclear what the effects of delayed policies or amendments to policies were on the economy - we assume that a policy uncertainty variable captures these effects).

The period from the financial crisis up until 2015 is sufficient to study how the economy and uncertainty responded to some of these unconventional monetary policy shocks. There has been a trough and recovery phase. Barrero et al. (2016) distinguish between the effects of long and short run uncertainty on investment. They show that long run uncertainty has a larger effect on investment compared to short run uncertainty. They use a five-year average volatility measure as their long-run uncertainty measure. Our analysis covers both the short and long-run period. Monetary policy interest rates, however, have remained at the lower zero bound for both the U.S. and EU. Instead of averaging out the effects over time of monetary policy shocks, we study how the economy responds to periods of high versus low uncertainty - where low uncertainty coincides with the recovery period.

An ideal model, however, would capture the time-varying nature of unconventional monetary policy. This would mitigate possible concerns that economies respond differently during periods where interest rates are at normal levels compared to periods where interest rates are near zero. Such a nonlinear model would capture economic responses over multiple regimes. This would also likely control for targeting effects - central bank balance sheets could have been used for a different purpose before the financial crisis.

Our study is one in a line of recent research that attempt to quantify the impact of unconventional monetary policy shocks on the economy. Our paper is closest to Gambacorta et al. (2014) and uses a similar methodology. Instead of using policy uncertainty, Gambacorta et al. (2014) use the VIX (an indicator for stock market volatility) as a general measure for financial and economic uncertainty. The VIX measure is more closely associated with stock market volatility, while the uncertainty index here is a broader measure of uncertainty that includes policy and economic uncertainty. They use central bank balance sheets, as opposed to the monetary base, to assess movements in unconventional monetary policy. The use of central bank balance sheets for countries varies in terms of targets and scale concerning direct liquidity injection in financial institutions and purchases of public and private bonds. One shortcoming of our paper and many before us is that we do not test compositional effects in balance sheets and are thus unable to study their importance to economic recovery. We assume that significant differences in compositional effects should be reflected in the individual country responses - or deviations from the pooled estimates.

## 2 Literature review

Gambacorta et al. (2014) study the impact of unconventional monetary policy for eight countries using a panel VAR. In the wake of the financial crisis, monetary policy reached its limits to positively influence the economy, as interest rates for many countries neared the zero lower bound. They use monthly data starting from the financial crisis (2008–2011) and focus specifically on developed countries as many developing countries still had room to maneuver policy rates. The use of a panel VAR helps to uncover common factors among systemic shocks. These systemic shocks include the financial crisis and a similar monetary policy response. The setup uses Pesaran and Smith's (Pesaran and Smith 1995) mean group estimator to uncover country heterogeneity. They control for macroeconomic risks with the VIX that captures implied stock market volatility as a proxy for economic uncertainty. An increase in the central bank's balance sheet temporarily increases inflation and output. These results are consistent when compared to conventional monetary policy, albeit with a weaker inflation response. Thus, in normal periods when there is space to change monetary policy interest rates, the economic response equals that of expanding a central banks balance sheet. Interestingly and despite country heterogeneity, the countries responses to unconventional monetary policy are similar and not that much different from an average response over all the countries.

This corresponds to the findings of Bekaert et al. (2013) who study the effects of a variety of monetary policy shocks on risk and uncertainty using a structural VAR. Regardless of their measure of monetary policy (Fed funds rate or M1 money supply),

they show that looser monetary policy lowers risk and uncertainty in the short to medium run.

Borio and Disyatat (2009) argue that unconventional monetary policy is not unconventional, but it is the markets that they target that are unique. They also suggest that unconventional monetary policy does not "loosen the constraint on bank lending or act as a catalyst for inflation". Furthermore, they argue that central bank balance sheets should be viewed as part of the government's balance sheet - in effect implying that the economic response, in theory, should be the same regardless of using the central bank's balance sheet or the government's balance sheet. In essence, the government might as well have provided private institutions with guarantees against defaults - and if those defaults materialized, the central bank would simply expand the money supply (or use of reserves) to monetize the government's debt. One might suspect various difficulties with direct government guarantees - they can seem to provide contingent claims to state owned enterprises. However, direct injections from the central bank circumvent the issuing of government debt, and perhaps reduce concerns of fiscal sustainability.

Borio and Disyatat (2009) provide an excellent summary of the possible transmission mechanism of unconventional monetary policy. The main channel in which monetary policy affects the economy is through private sector balance sheets in addition to altering expectations (that is why including uncertainty is important). Before the crisis, short-term interest rates were used as the main monetary policy while using "liquidity management operations" to achieve the desired interest rate - especially ensuring that overnight rates track the desired interest rate closely. Monetary policy interest rate decisions affect government bond yields and are often seen as a signaling device for investors - thus the effects of monetary policy interest rate shocks are far-reaching. The same holds true for central bank balance sheet shocks. The target market makes this approach unconventional, not the method as it includes open market operations. Balance sheet shocks can be independent of interest rate shocks - "decoupling effect". They are decoupled when (i) the market for bank reserves are independent or (ii) by making sure that it does not have an effect on reserves by paying interest on reserves at the policy rate. They identify three types of balance sheet policies: (i) foreign exchange market with the aim of influencing the currency directly; (ii) debt management policies with the aim of altering the composition of public debt held by the private sector (they do this primarily to affect the yield on government bonds); (iii) credit policy by targeting specific segments of market debt and securities (this is achieved by changing the profile of a given amount of private sector claims held by the central bank or changing the composition of private and public sector claims - this is done by acquiring private sector claims such as equities, modifications to collateral, maturity, operations or by providing loans).

The transmission mechanism can be summarized as: (i) signaling channel (as an example if the central bank announces that it will purchase illiquid assets it might make investors more comfortable and hence reduce the liquidity premium). (ii) the direct effect on private sectors balance sheets by taking into account imperfect substitutability between assets or liabilities. Central banks increase their liquidity service by acquiring assets or accepting them as collateral. This makes portfolios more liquid which complies with risk-based capital constraints - effectively supporting credit growth by lowering the external finance premium. The only difference now is that debts are guaranteed by the government, which hopefully reduces uncertainty. The impact on

inflation depends on the financing measure of reserves. If the central bank remunerates excess reserves below the policy rate then the overnight rate will be pushed down - this effectively lowers the interest rate and as such is a demand shock that could increase inflation. If, however, excess reserves are remunerated at the policy rate then the effect of inflation is practically the same as when government issues bonds.

The Federal Reserve implemented an example of unconventional monetary policy. They used quantitative easing and forward guidance as “unconventional” monetary policy measures after interest rates reached the zero lower bound. Engen et al. (2015) control for perceptions of the implicit interest (the rate that would have prevailed if it did not reach the zero lower bound) rate rule by using survey data. They show that real effects and inflation responded only moderately to unconventional monetary policy due to gradual changes in policy, which should have perhaps been immediate changes. Unemployment only decreased gradually with a peak reduction of 1.25 percentage points in 2015, while inflation is set to peak in 2016 only. This suggests that there is a large time lag between the economic responses to unconventional measures - even larger than conventional monetary policy (for a summary of monetary policy lags see Ehrmann 2000; Goodhart 2001; Taylor and Wielan 2012). The inclusion of the public’s perception in their model is important. The inclusion is justified because forward guidance and asset purchases by the Fed changed the public’s view on the implicit monetary policy rule - which they estimate puts downward pressure on long-term rates and have eased financial conditions. The economic response could have likely been different if perceptions or expectations were different. The various Fed announcements, first periodically and then conditional on the state of the economy, were meant to guide expectations. However, various revisions to potential interest rate liftoff and changes to the thresholds that would imply liftoff make the market more uncertain. It is this uncertainty that we control for in our setup.

Wen (2014) argues that unconventional monetary policy in the U.S. was slightly unsuccessful due to the scale of Fed’s purchase program. In an interesting theoretical framework Wen (2014) shows that had the Fed increased its balance sheet by a considerable factor more than the existing size, the economy would have been on a healthier path. The reason cited can be explained as follows: Unconventional monetary policy by the Fed effectively increases money supply by purchasing private debt as opposed to traditional purchases of government debt - this is referred to as credit easing. Despite credit easing effectively lowering interest rates on private debt, credit easing has done very little to reduce unemployment or boost output. In a simple DSGE-type model calibrated for the U.S. economy, Wen (2014) shows that asset purchases can significantly reduce interest rates and inflate asset prices, but is however limited in expanding the real economy significantly unless the purchase is large, highly persistent and operates in a high inflation targeting environment. The results rely on an important assumption; debtors are productive while lenders are less productive. Thus if debtors become lenders, despite an increase in loans, then productivity does not change by much. This happens when the demand for liquid assets are strong. When the Fed increases its credit easing program then there is a flight away from scarce assets to abundant assets (liquid assets such as government bonds). This leads to an overall reduction in the cost of borrowing. In this setup marginal creditors become debtors, which lead to an increase in loans but a decrease in the quality of loans that are ultimately needed to expand output.

Jannsen et al. (2015) test whether the traditional channels of monetary policy is impaired during financial crises and non-crises. They suggest that the economy responds in a nonlinear fashion to policy shocks during a financial crisis and just after a crisis driven by many factors including higher uncertainty and lower confidence. Jannsen et al. (2015) use a panel VAR to test the monetary transmission channel. They interact each of the endogenous variable with a dummy for financial crises based on a narrative approach. They emphasize the importance of uncertainty and confidence indicators in obtaining their results. They use GDP, inflation, stock market volatility as the main variables with the short-term interest rate as the monetary policy tool. They show that GDP and inflation are more responsive to a monetary policy shock during a financial crisis compared to the recovery phase of a crisis. More importantly, they show that the response of GDP and inflation is higher with the inclusion of uncertainty. During the crisis, monetary policy reduces uncertainty by a much larger extent compared to the recovery phase. This reduction in uncertainty leads to a stronger expansion in prices and output.

Two papers most directly related to our work are that of Aastveit et al. (2013) and Balcilar et al. (2016). Aastveit et al. (2013) uses an interactive structural Bayesian VAR model to analyze the effectiveness of monetary policy under high and low levels of US uncertainty in the US itself, Canada, United Kingdom and Norway; while, Balcilar et al. (2016) uses the same methodology to analyze the impact of US uncertainty on the effectiveness of the monetary policy in the Euro Area. However, to the best of our knowledge, our paper is the first paper to analyze the impact of high and low levels of own-country uncertainty on the effectiveness of unconventional monetary policy in a multi-country set-up, using a panel VAR methodology for eight OECD countries. The use of a news-based measure of uncertainty, developed by Baker et al. (2015), allows us to incorporate the variable explicitly as an endogenous element in the model, rather than the usage of dummy variables. In the process, we are also able to analyze the impact of monetary policy on the uncertainty variables besides the other macroeconomic variables.

### 3 The role of uncertainty in the monetary policy transmission mechanism

What is the role of uncertainty in the monetary policy transmission mechanism? A useful starting point is to summarize different sources of uncertainty and how they are related to monetary policy. Dixit and Pindyck (1994) study role of uncertainty on irreversible investment. They show that investment decisions in the real world are more responsive to volatility and uncertainty and less sensitive to interest rates and tax policy.

It is not a given that uncertainty reduces investment. It can be path dependent, in which case it depends on the state of an investor (Belke and Gros 2001). As an example, the option value of waiting becomes larger when uncertainty increases (Dixit and Pindyck 1994), which implies patience by an investor. Investment decisions are delayed for those investors willing to invest, while disinvestment also gets delayed for those who already invested.

Belke and Gocke (2009) investigate the relation among monetary policy and investment decisions by means of a stylized treatment of the “uncertainty trap”. For this purpose, they assess the effectiveness of monetary policy under cash flow

uncertainty and investment irreversibility in a simple model. If future net revenues are uncertain and investment expenditure cannot be recovered, there is an option value of waiting. The value of waiting derives from the possibility of deferring investment and seeing if future net revenue has gone up or down, minus the cost of delaying the income stream from investing today. The option value of waiting increases in line with the cost of immediate investment, and therefore the threshold revenue above which the firm finds investing today profitable. Alternatively, it lowers the interest rate, which triggers immediate investment.

The same option value of uncertainty creates bands of inaction in terms of hiring decisions (Belke and Gocke 1999, 2005, and Belke and Kronen 2016). They show that there exists an area of inaction in which exports respond to the exchange rate, in which case not every depreciation will necessarily lead to an increase in exports. This could happen when exporters hedge against a less competitive currency. The persistence, or in this case hysteresis can in part explain why economies do not necessarily reverse when policy is enacted, or at least take longer than expected to recover or require a stronger policy response.<sup>1</sup>

The role of institutions and political policy is another source of uncertainty that affects economies. Belke et al. (2005) construct an option-value of waiting model of uncertainty on job creation and destruction, where uncertainty is a result of institutional/political uncertainty. As an example, Central and Eastern European are to adopt various labour market directives to gain entry into the European Union. While adopting these set of rules can foster structural change that minimizes uncertainty, it may also lead to unintended labour market rigidities. Institutional uncertainty leads to a persistence of inaction, but taking action can also lower uncertainty. This has an interesting bearing on monetary policy – monetary policy action, in our case an increase in asset purchasing, can reduce uncertainty, while at the same time uncertainty can be a cause of persistence in different states of the world (do nothing, vs. continue with unconventional monetary policy).

The timing of policy also seems to be correlated to uncertainty. Belke et al. (2016) show that QE1 was implemented at the height of the crisis (here defined as the VIX index), while the remaining QE interventions took place when markets were considerably more stable. This invariably had different effects on the economy.

The role of uncertainty and consumption is another channel which affects monetary policy decisions. Mumtaz and Zanetti (2013) show that monetary policy uncertainty, as an example, increases the dispersion between interest rates and inflation. This causes volatility in consumption. Higher volatility in consumption can lead to a reduction in expected consumption due to Jensen's inequality.

Furthermore, high political/policy uncertainty may incentivize consumers to spend less and to build up a buffer stock of liquid assets (Baker et al. 2015).

It is important to note that the uncertainty measures included in this study is country specific. It would be interesting to analyze how U.S. monetary policy is transmitted to the other countries in the face of U.S. specific uncertainty and compare the results to other studies of FED spillover in a Stackelberg leader setup (see Belke and Cui (2010); Beckmann et al. (2014)). The panel aspect of the study controls for country specific effects and hence country specific responses to monetary policy and uncertainty.

<sup>1</sup> See Belke and Kronen 2016 for a more detailed treatment between hysteresis, uncertainty and investment.

It is unclear whether the Federal Reserve and the ECB asset-purchasing programme stabilized markets and revived low economic growth, and to what extent uncertainty thwarted these efforts. To analyze the efficacy of the central banks' attempts we use inflation (price stability, in this case avoiding deflation) and output (demand injection) as a metric. We restrict ourselves to one policy tool - the Fed and ECB's balance sheet and analyze the economic response in periods of high and low uncertainty. This provides us with a hypothesis that we can test: Does asset purchasing by a central bank raise output and prices during periods of uncertainty. Our empirical methodology is simple and used frequently in studying the effects of monetary policy on output and prices.

## 4 Methodology

VARs have been extensively used to study the impact of conventional and unconventional monetary policy - but mainly through the credit channel. The extension to a panel setup seems like a natural way to control for cross-sectional heterogeneity and uncover the dynamics of shocks. This approach takes care of cross-country effects reflected in country residuals.

Our approach is similar to Gambacorta et al. (2014). We use the mean group estimator to allow for cross-country heterogeneity. We use the Baker et al. (2015) policy uncertainty index instead of the VIX. The VIX captures just one aspect of uncertainty, or mainly volatility in the financial markets of listed companies. The uncertainty index, however, captures a host of uncertainty aspects related to policy - such as the decreased risk appetite of bankers to forward loans to consumers, or the lower demand for credit by households. Uncertainty might also affect delayed investment decisions by firms (see Bloom 2009). As pointed out by Gambacorta et al. (2014), the mean group estimator provides consistent estimates when cross-country coefficients differ. The functional form of the model has to be considered. A VAR assumes that the relationship between variables is linear. It is possible that nonlinearities can exist (see Belke and Gocke (2005) on the nonlinear relationship between investment and economic freedom as an example). If any nonlinearity is present than the model is misspecified. We use the Ramsey RESET to test for equation nonlinearity. The results suggest that the model is linear.<sup>2</sup> The model.

Our specification includes four variables: the log of industrial production, the log of the price index, the log of the central bank monetary base and the log of the policy uncertainty index. We also control for state effects by creating a high and low uncertainty index. High uncertainty is calculated as all the positive values of demeaned uncertainty, while low uncertainty is all the negative values from the demeaned series. The policy uncertainty index is stationary for all countries. A simple average is used to demean the series.<sup>3</sup> We do this to control for possible correlations of uncertainty with recoveries from financial crises - thus giving us estimates of unconventional monetary policy shocks over two regimes.

<sup>2</sup> Results available upon request.

<sup>3</sup> We also estimated thresholds to split the series into high-vs. low uncertainty. The threshold values are estimated using a Threshold regression (TAR). The threshold values are close to the simple calculated averages. Results available upon request.

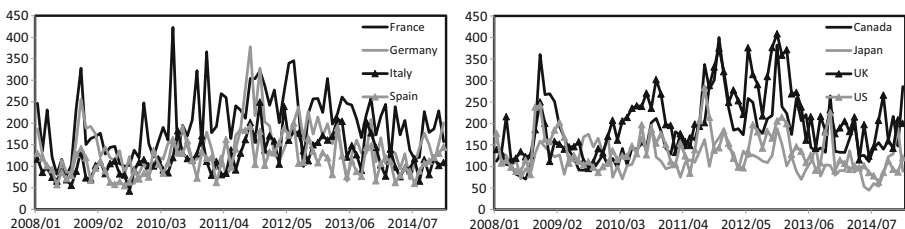


The data in this model is not supposed to represent all aspects of the monetary policy transmission mechanism, but covers the data that is used in a standard New-Keynesian DSGE model. Industrial production proxies the IS-curve, the price index proxies the Phillips-curve, and the model is closed with monetary policy, which in our case is the balance sheets of the Central Banks.

There is of course an argument to be made for not removing the correlation of uncertainty across countries. As an example Beckmann et al. (2014) show that policy uncertainty can spill-over to other countries - in this case the U.S. to the Euro Area. However, our aim is to study the idiosyncratic response of each of the economies to monetary policy. One would typically think of monetary policy in the Euro Area as being by a central interest rate. However, monetary policy during the financial crisis used different tools, and as such are country specific. To proxy this country specific instrument we use balance sheets of each country's Central Bank.

Our data on the macroeconomic variables comes from the OECD database, while the data on economic policy uncertainty is obtained from [www.policyuncertainty.com](http://www.policyuncertainty.com). The economic policy uncertainty index, as devised by Baker et al. (2015), is compiled using three components. The first is based on count of the number of newspaper articles in major daily newspapers of various countries, containing the terms uncertain or uncertainty, economic or economy, and one or more policy-relevant terms. The second measure includes the number of federal tax provisions set to expire in future years and the third component uses disagreements among economic forecasters. The countries in our study for which we collected all the data described above includes Canada, France, Germany, Japan Italy, Spain, U.S. and U.K. We use monthly data from 2008:1 until 2015:1. A sample prior to 2008 might bias the results - we stick to the period since the financial crisis where our interpretation of uncertainty and monetary policy reactions are conditional on crisis as opposed to other effects. These series are plotted in Fig. 1. Figure 1 shows that heightened periods of uncertainty are correlated across countries. After the 2008/09 financial crisis policy uncertainty stabilized for a couple of years before picking up in 2010 until the end of the period under investigation. As noted in Gambacorta et al. (2014), excluding a measure of uncertainty could bias the results as both innovations in the unconventional monetary policy measure and uncertainty occurred roughly over the same period. A consequence being that the econometric specification could pick up movements in production and prices that are due to uncertainty, as responses to monetary policy.

A panel VAR is used for the following reasons: (i) It allows for the dynamic response of output and prices to a monetary policy shock. This allows us to evaluate



**Fig. 1** Economic uncertainty

how long it takes a shock to influence the variables under consideration. The inclusion of uncertainty will improve our understanding of whether responses take longer or shorter. The length of uncertainty matters as shown by Barrero et al. (2016). They show that investment is more sensitive to long run uncertainty while employment more sensitive to short run uncertainty. (ii) It helps us identify the strength of the response and evaluate its statistical significance. Do output and prices respond more to a monetary policy shock during uncertainty or less? (iii) It controls for the feedback mechanism of prices to output and vice versa during periods of uncertainty. (iv) The panel aspect helps us control for monetary policy spillover effects to other economies. Husted, et al. (2016) show that there are significant spillover and contagion effects of monetary policy uncertainty across the U.S, Japan, Canada and the EU. Furthermore, the justification of a panel setup is in line with the findings of Belke et al. (2016), Belke and Gros (2005) and Belke and Cui (2010, US-EU Area monetary policy interdependence) that establish an empirical interdependent relationship between the Fed and the EU. Their results suggest that the ECB follows the Fed. More importantly, the decision of ECB to follow the Fed is related to uncertainty and the option value of making an interest rate decision. Belke et al. (2016) show that quantitative easing by the U.S. was not isolated, but had an effect on Euro long-term interest rates. It is thus possible that the asset-purchasing programme of the Fed might affect output and prices in the Euro Area, and more importantly this relationship can be different under uncertainty and as consequence affect monetary policy decisions of the ECB.

We can represent the panel VAR as:

$$Y_{i,t} = C_i + A(L)_i Y_{i,t-1} + B \varepsilon_{i,t}$$

$Y_{i,t}$  is a vector of endogenous variables for country  $i$  and period  $t$ ,  $C_i$  is a vector of constants,  $A(L)_i$  is a vector of lag polynomials for each country,  $B$  is the contemporaneous impact matrix and  $\varepsilon_{i,t}$  is a vector of disturbances..

The unconventional monetary policy shock is identified as an exogenous shock to the monetary base. This requires us to set restrictions on the parameters to identify how monetary policy reacts to production and prices. Zero contemporaneous restrictions are imposed on the reaction of output and inflation to central bank balance sheet shocks (see Bernanke and Mihov (1998), Bernanke and Blinder (1992) and Christiano et al. (1997)), while the balance sheet reacts to immediately to shocks in both production and prices. We ensure that balance sheets of central banks react to market uncertainty by expanding its balance sheet. We assume that market uncertainty decreases due to balance sheet shocks, as motivated by recent studies that emphasize the role of market liquidity and credit channels in reducing uncertainty (Gambacorta et al. 2014; Janssen et al. 2015). Thus, the model is identified by placing both zero and sign restrictions on  $B$ .

The process of estimating the mean group panel VAR can be summarized as:

1. Estimate each equation of the reduced form VAR for each country separately using Feasible Generalized Least Squares (FLS), which controls for residual cross correlations of countries.
2. Draw a random decomposition of the variance-covariance matrix for each country ensuring that the restrictions come from the same model.

3. Calculate impulse responses and keep the draws that satisfy the restrictions.
4. The mean-group impulse responses are the averages of impulse responses across countries.

## 5 Results

### 5.1 Baseline results

In Figs. 2, 3, 4 and 5 we plot the response of our variables to changes in central bank balance sheets for each country in our sample with its confidence intervals. We also plot the group mean response with each figure shown as grey lines, which represent the 16th and 84th percentiles. We use one lag in our VAR as given by BIC.<sup>4</sup>

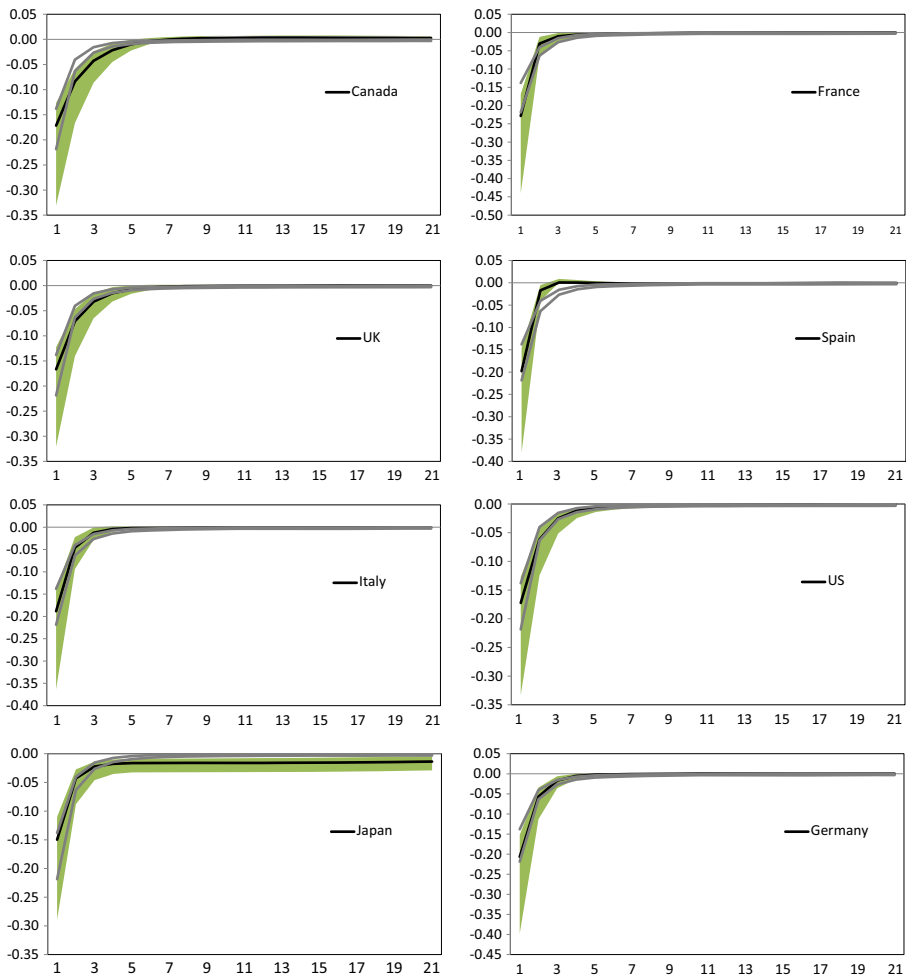
Figure 2 is a plot of how uncertainty responds. Each country's uncertainty response is similar to the mean response. The duration and size of responses are similar too. The confidence intervals are close to the median response – indicating that all responses are significant. This result is consistent with other studies (see Peersman 2011) and in line with our assumption on the sign restriction. This is interesting considering that central bank balance sheet shocks differ across countries. For some countries the shocks lasts for close to a year, while for the U.S. and Japan shocks last considerably longer (Fig. 3).

We are agnostic about our a priori assumptions on prices and output. Prices increase for the majority of countries, but decreases for some (Fig. 4). The response of prices is also insignificant for some countries (notably for the EU countries). Interestingly, the mean group response is negative for almost a year before it becomes positive, this is in spite of an immediate reduction in uncertainty. Prices increase almost immediately for the U.S. and Japan and are persistent, not returning to a baseline after two years. These results suggest that inflationary fears are not always warranted regarding an increase in balance sheet shocks. More importantly, it shows that the financial accelerator mechanism of Bernanke et al. (1999) does not hold for each country – there is no value increase due to price changes, because prices do not necessarily increase when there is a positive financial shock – in this case a monetary injection of liquidity for private firms. We can only speculate why inflation responds in this manner – and why for example inflation in the U.S. and Japan has not materially increased after successive injections by their central banks. It is possible that the low monetary policy rate in many of these countries anchor inflation expectations significantly as given by the Fisher relation, and counteracts the possible inflationary effects of balance sheet shocks. It is also possible that the new banking regulations since the financial crisis sufficiently limit credit expansion despite an increase in liquidity and collateral. This then corresponds to Wen (2014) and suggests that the persistence and size of credit easing needed to have been larger to influence the economy.

The response of output (Fig. 5) for the majority of the countries is generally positive but also mostly insignificant. The group mean response is insignificant for the first four months and becomes significant afterwards.<sup>5</sup> These results suggest that

<sup>4</sup> The results are robust to different lag lengths, and to different ordering of the variables.

<sup>5</sup> Uhlig (2005) shows that the effects of monetary policy shocks on output are not clear.

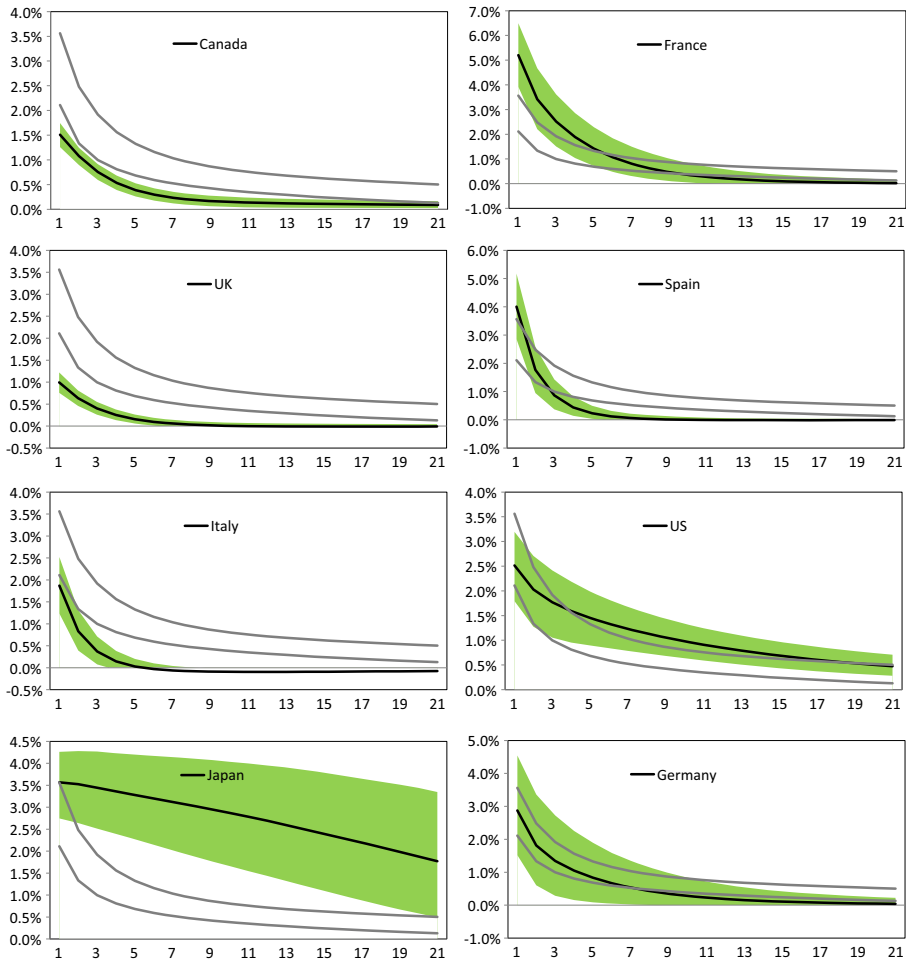


**Fig. 2** Monetary policy reduces uncertainty consistently across countries

it is possible for output to increase with an expansion of balance sheet shocks even if the inflationary response is muted. This then limits the potential for an interest rate hike sometime in the future. The literature and these results make it difficult to identify serious problems associated with balance sheet shocks during financial crisis. What are the economic costs associated with an increase in a central bank's balance sheet? Are central bank balance sheets vulnerable to exogenous shocks? Will it only be a matter of time before inflation responds to the increase in market liquidity? None of the empirical work we studied seems to provide concrete answers to these questions and remains open for analysis.

## 5.2 Robustness checks

In this section, we control for periods when uncertainty is high versus when uncertainty is low. The model setup is similar as in the previous section. The

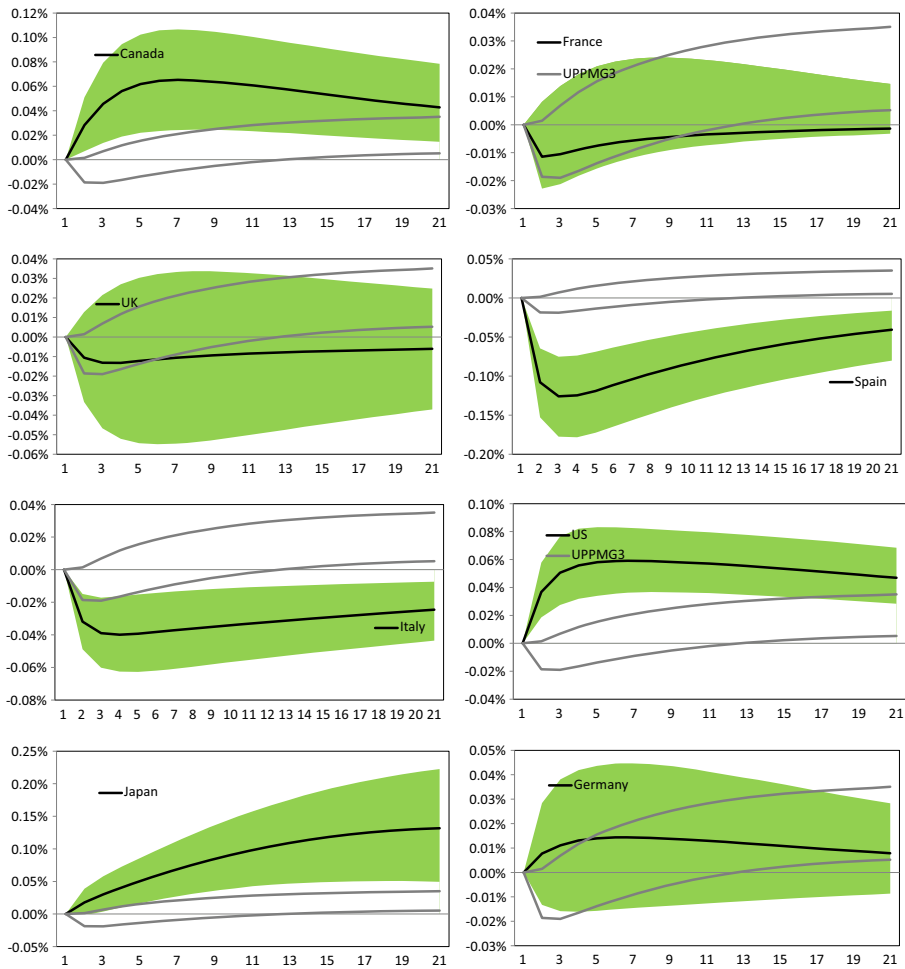


**Fig. 3** The persistence of central bank balance sheet shocks differs across countries

only difference is that we substitute the uncertainty variable for the high and then the low uncertainty variable. This means that we estimate three distinct VARs using different measures of uncertainty. We include the baseline results in the Figures for a comparison. This check is similar in approach in Janssen et al. (2015) where we control for the trough and recovery phase of the financial crisis – assuming that low uncertainty is correlated with the recovery phase.

Figure 6 shows that uncertainty, whether high or low, is fairly similar in terms of duration and size. Note that uncertainty responds immediately to a balance sheet shock, but dissipates well within a year.

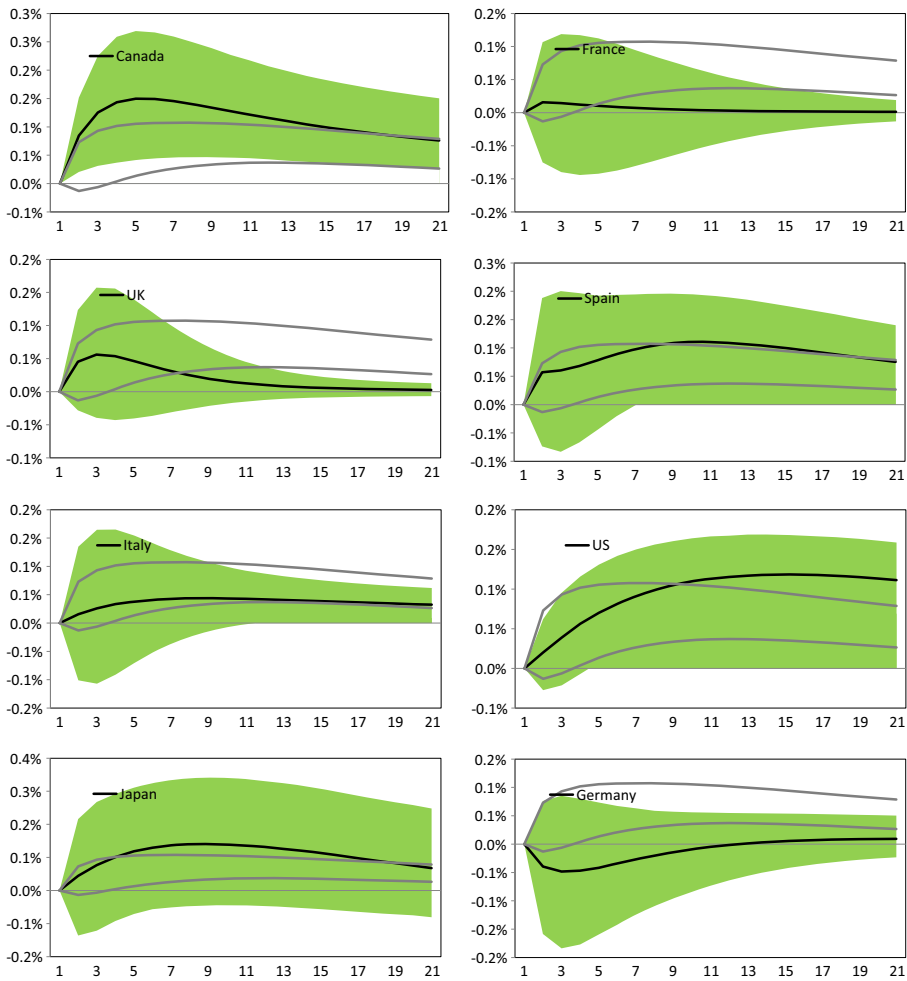
Figure 7 shows that balance sheet shocks do not materially differ during high versus low uncertain periods. The size of the balance sheet shock is equal to the contemporaneous response in the balance sheet. The size and the persistence of



**Fig. 4** Prices do not always increase with an expansion in central bank balance sheet

the shock differs by country. The persistence is driven by the endogenous response of monetary policy to output and prices and the size of the shock is estimated from the data using the identification scheme listed above. Most notably is the persistence in Japan’s response with its history of using its balance sheet to stimulate the economy.. As such, it would seem that monetary policy is not that concerned with uncertainty as much as it is with the general health of the economy given by output and prices.

The results become more interesting when we analyze the response of prices (Fig. 8). Under a high uncertainty environment, prices react quite strongly to balance sheet shocks compared to our baseline and low uncertainty environment. This result is more consistent with the financial accelerator model and shows that financial shocks, in this case an injection of liquidity and an increase in collateral due to central bank purchases of private assets, lead to an increase in prices. This



**Fig. 5** Output response is mostly positive, but not always significant

does not necessarily translate into a direct increase in output (thus, the wealth channel is not sufficiently consistent with an increase in prices) (Fig. 9). The results would suggest that there is a degree of uncertainty that is conducive for growth – any excess uncertainty, high or low, would materially change the reaction of the macro economy to balance sheet shocks. As an example, output response for Canada for both high and low uncertainty is lower than in the baseline case. Under low uncertainty (or the recovery phase), monetary policy shocks do not necessarily translate into higher output. A high uncertainty environment is clearly associated with lower output. As suggested in studies elsewhere, a high uncertainty state reduces investors’ willingness to invest, delays consumption decisions that rely on credit and reduces overall output. For some countries like Spain, Italy and Japan, output is significantly higher in a low uncertain environment – which is more in line with our expectations.

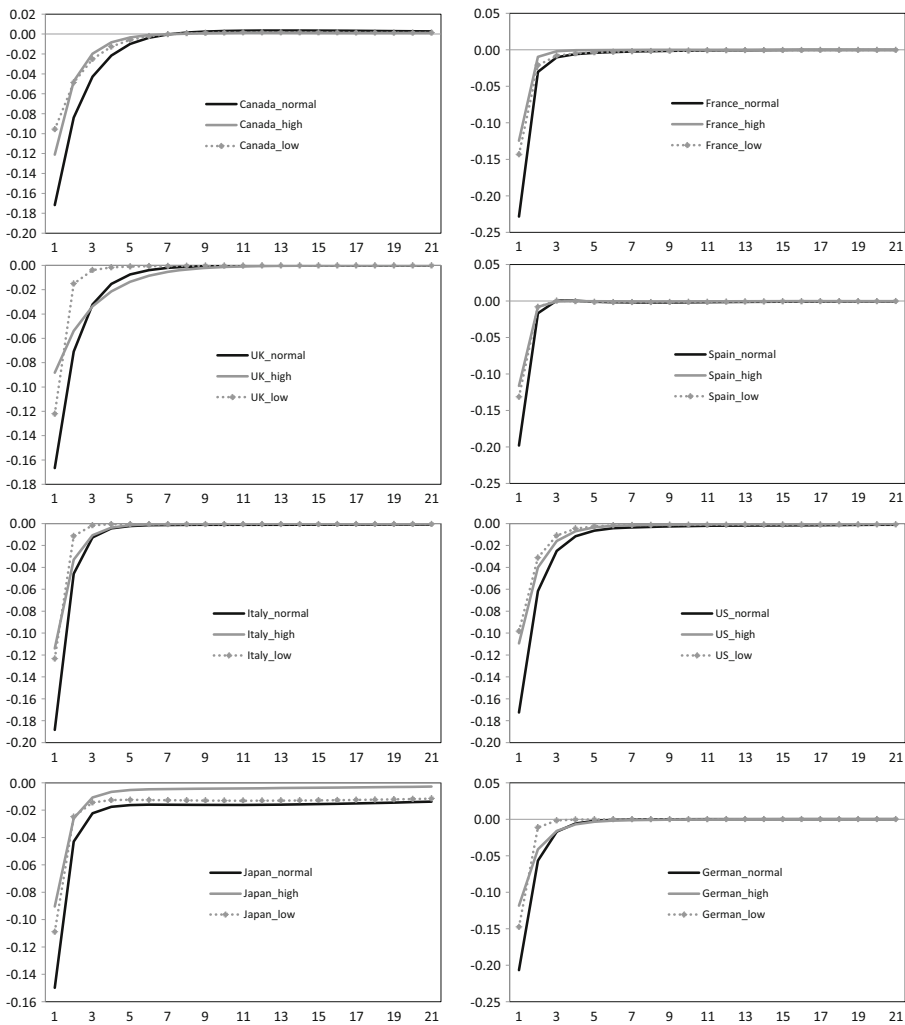
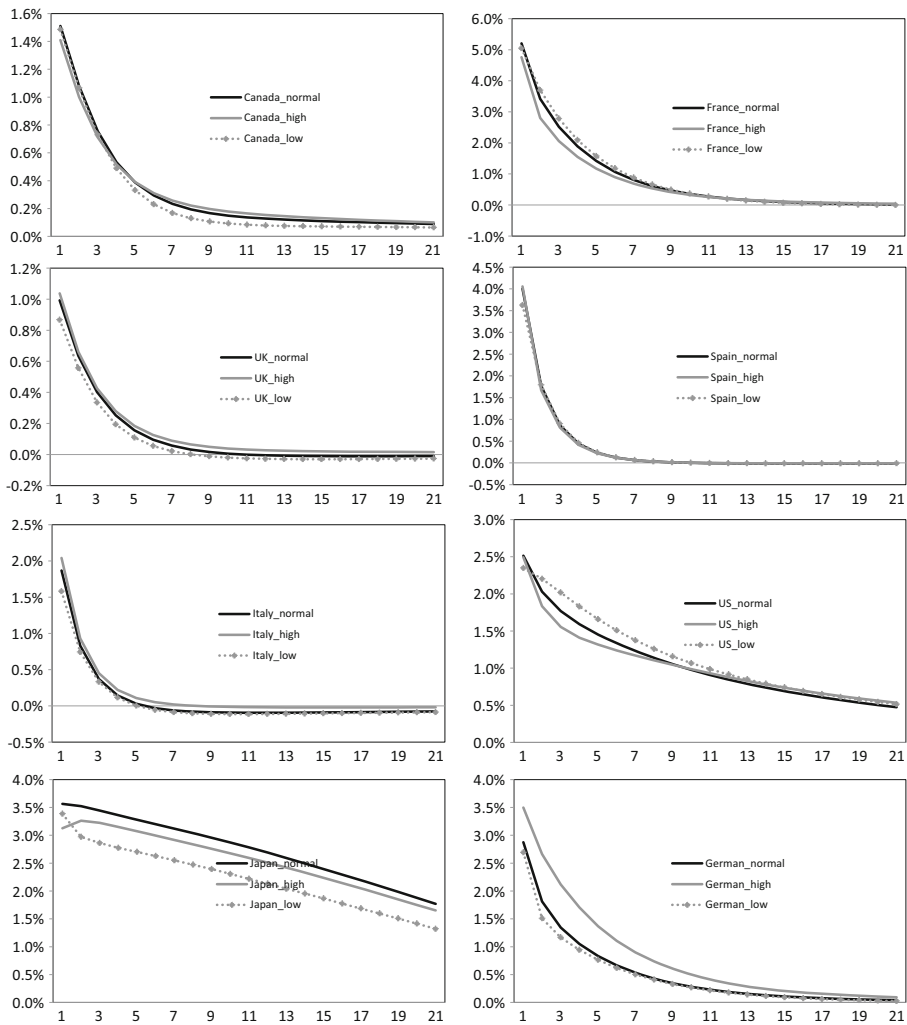


Fig. 6 Uncertainty responses are similar despite high versus low uncertainty environments

### 6 Conclusion

Central banks reached a limit in their standard response to economic slumps, with monetary policy reaching the zero lower bound in many countries and fiscal debts reaching unsustainable levels. The U.S. Fed and ECB response the 2008/09 financial crisis included an expanded balance sheet in light of these constraints. It is a unique response given that central banks purchased assets directly from troubling financial institutions instead of monetizing government debt. Some economists feared that this balance sheet expansion would lead to unsustainable increases in prices, which could hurt the economy. The inflation response during and after the financial crisis, remains mute however. Although output growth has

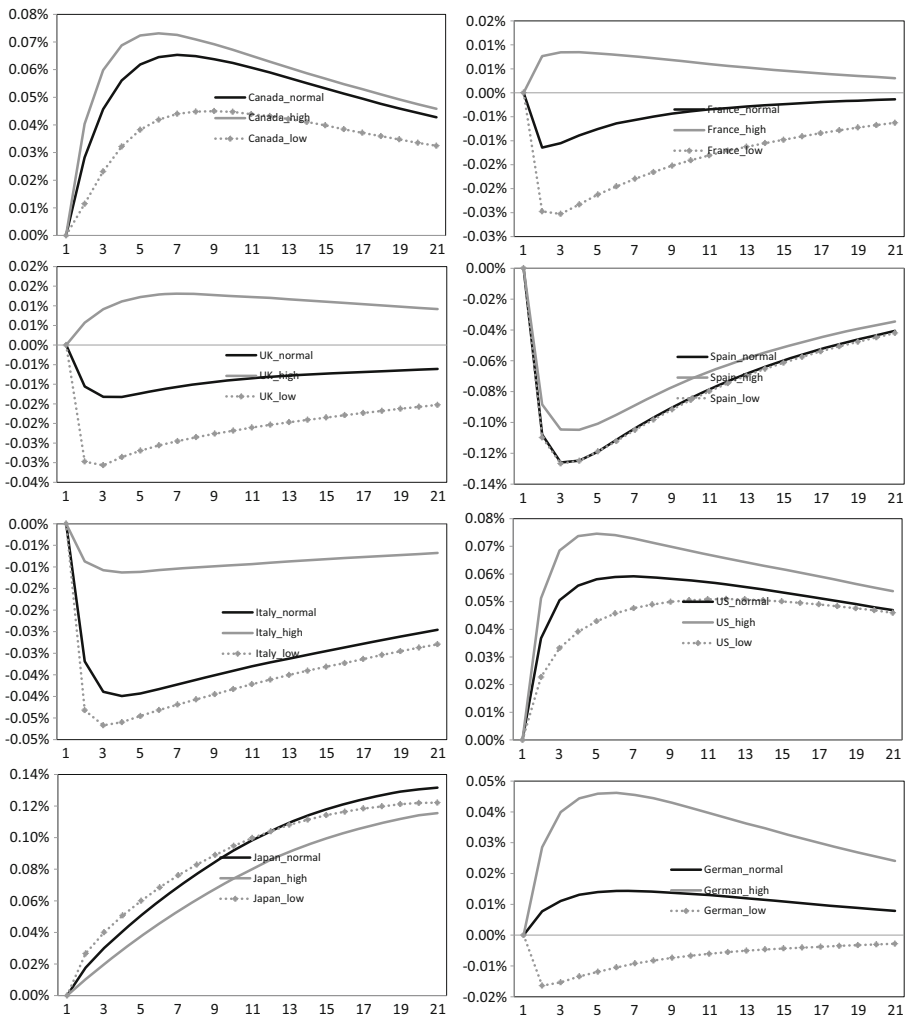




**Fig. 7** Central bank balance sheet shocks do not differ by much in various uncertain environments

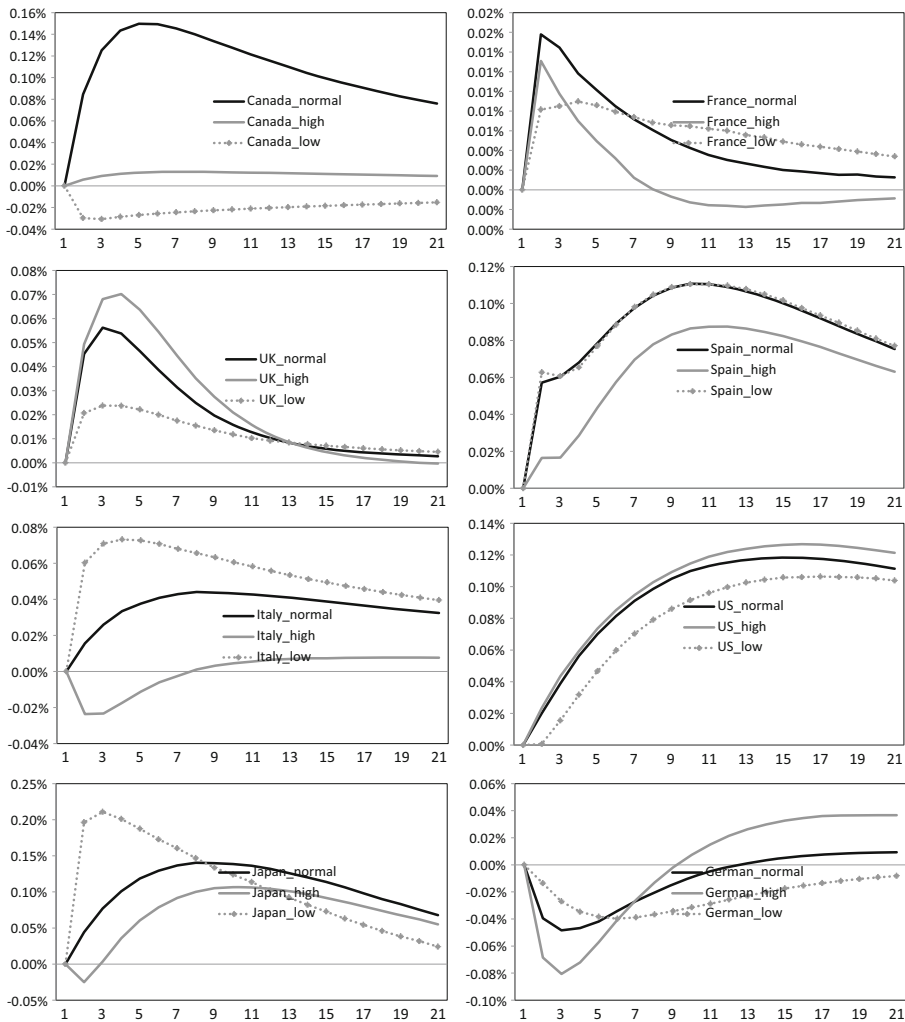
increased since the financial crisis, growth rates have not matched pre-crisis levels. Economic and policy uncertainty is one of the reasons for the muted economic response.

We quantify how the economies of the U.S., U.K., Spain, France, Japan, Canada, Italy and Germany reacted to monetary policy shocks since the financial crisis using a panel VAR for countries where the interest rate reached the zero lower bound. Our panel structure accounts for significant cross section heterogeneity but imposes a similar model structure for each economy with the use of sign restrictions and contemporaneous restrictions. Our contribution to the literature studies the economic response to balance sheet shocks controlling for policy uncertainty. We decompose policy uncertainty into high and low uncertainty and analyze how output and inflation respond.



**Fig. 8** Prices increase more when uncertainty is high

Our results show that unconventional monetary policy helped reduce uncertainty, and led to moderate increases in prices and output. In line with the literature, the response of output to a monetary policy shock is not clear – not all the countries in our study had a statistically significant response. Prices also did not increase significantly for most of the countries in the sample. We show that price and output responses depend on the degree of uncertainty. On average, uncertainty decreases while prices and output increase with expansionary monetary policy. However, prices and output do not respond with the same intensity when uncertainty is in a different regime. As an example the reaction of prices are stronger to monetary policy when uncertainty is high, while output responds more to monetary policy when uncertainty is low. At the same time, monetary policy reaction to output and prices were similar during periods of high vs. low uncertainty. This has



**Fig. 9** Uncertainty changes the output response

an interesting consequence for the conduct of unconventional monetary policy during periods of uncertainty, which will depend on the objective – price or output stability.

One avenue of future research would be to extend this analysis to include the time varying economic response to monetary policy during periods of uncertainty. The scale and use of monetary policy during and after the financial crisis varied and this introduces some nonlinearities. As an example, the scale of asset purchasing decreased as the effects of the crisis dissipated and uncertainty reduced.

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