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The Impact of US Uncertainty Shocks on Small Open Economies*

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Abstract

In this paper, we investigate the impact of US uncertainty shocks on GDP growth in nine small open economies: Australia, Canada, Denmark, Finland, Iceland, New Zealand, Norway, Sweden and the United Kingdom. We compare the impact of two types of shocks: *i)* stock market volatility shocks and *ii)* policy uncertainty shocks. Using quarterly data from 1986Q1 to 2016Q1, this issue is analysed using Bayesian VAR models. Our results suggest that policy uncertainty seems to matter more than stock market volatility. Stock market volatility shocks appear to robustly have significant effects on Danish GDP growth. Policy uncertainty shocks, on the other hand, reliably lowers GDP growth in all five Nordic countries in a statistically significant manner. Statistically significant effects of policy uncertainty shocks on the Anglo-Saxon countries in our sample are harder to establish and are, in our preferred specification, only found for the United Kingdom.

JEL Classification: C32, F43

Keywords: VXO, Policy uncertainty, Bayesian VAR, Spillovers

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1. Introduction

It is widely accepted that increased uncertainty can have negative consequences for the real economy. Convincing theoretical arguments have been presented for why both business investment and household consumption should be affected, and the empirical evidence for real effects of uncertainty is also plentiful.[1] But while most economists would agree with the general statement that uncertainty affects the real economy, there are several issues that would benefit from further empirical investigation in this area of research. One of these issues relates to forecasting and analysis concerning small open economies. In an economically integrated world – both regarding trade and financial markets – uncertainty in important foreign economies may have consequences for the domestic economy. This points to the relevance of studying spillover effects from larger economies to small open economies.

In this paper we accordingly study if uncertainty shocks in the United States have real effects on a number of small open economies. The analysis is carried out using the mean-adjusted specification of the Bayesian VAR model introduced by Villani (2009) and quarterly data from 1986Q1 to 2016Q1. More specifically, we study how GDP growth in Australia, Canada, Denmark, Finland, Iceland, New Zealand, Norway, Sweden and the United Kingdom is affected by shocks to uncertainty. Since which measure of uncertainty to use can be an issue of some discussion, we employ two different measures. We initially follow what may be described as the mainstream approach in the empirical literature and rely on stock market volatility.[2] Thereafter, we turn to a measure which has gained popularity rapidly recently, namely the policy uncertainty index of Baker *et al.* (2015).[3]

The contribution of this paper is twofold: First, we contribute to a fairly large and diverse literature on spillovers in general between countries and/or regions. This literature has confirmed important spillover effects of GDP growth from the United States to growth in a number of other countries and regions; see, for example, Artis *et al.* (2007) or Bayoumi and Swiston (2009). Linkages within financial markets have also been recognised. For example, Forbes and Chinn (2004) established that US market movements were important for most studied regions; similarly, Pesaran *et al.* (2004) found that shocks to the US stock market affected other stock markets across the world. Concerning policy-related spillover effects, Nicar (2015) recently established that US fiscal policy shocks

[1] See, for example, Leland (1968), Bernanke (1983), Ferderer (1993), Bloom (2009) and Gilchrist *et al.* (2014).

[2] See, for example, Leahy and Whited (1996), Bloom *et al*. (2007), Bloom (2009) and Adler *et al.* (2016).

[3] For empirical applications relying on policy uncertainty, see, for example, Aastveit *et al*. (2013), Colombo (2013), Klößner and Sekkel (2014) and Stockhammar and Österholm (2016).

affected GDP growth in Canada, the United Kingdom and Japan, and Neely (2015) showed that the large scale asset purchases conducted by the Federal Reserve in the wake of the global financial crisis reduced bond yields in Australia, Canada, Germany, Japan and the United Kingdom.[4] However, the issue of spillovers of uncertainty has not been studied as much and there has been less focus on GDP growth. The literature concerned with the effect that US financial uncertainty has on variables abroad tends to focus on financial variables; see, for example, Hofmann and Takáts (2015) and Adler *et al.* (2016). Turning to policy uncertainty, the IMF (2013) and Stockhammar and Österholm (2016) address how uncertainty shocks in the United States affect GDP growth in foreign economies; the latter study is methodologically similar to our study in that it also relies on Bayesian VAR models for its main analysis but it is rather limited in its scope since it only studies effects on Sweden. Second, we provide information concerning the empirical properties of the two uncertainty measures studied here. While Baker *et al.* (2015) provided some comparisons between their policy uncertainty index and stock market volatility – as measured by the VIX – there has been little analysis conducted in this area. This is not too surprising though, given the relative novelty of the policy uncertainty index.

The rest of this paper is organised as follows. In Section 2, we present the data and the modelling framework. We also discuss the results from the empirical analysis and assess the sensitivity of these results to a number of assumptions. Finally, Section 3 concludes.

2. Empirical analysis

2.1 A Small Bayesian VAR model

Our empirical analysis is conducted in a Bayesian VAR framework. More specifically, we employ the mean-adjusted model of Villani (2009). In its general form, this is given by

$$\boldsymbol{G}(L)(\boldsymbol{x}_t - \boldsymbol{\mu}) = \boldsymbol{e}_t \qquad (1)$$

where $\boldsymbol{G}(L) = \boldsymbol{I} - \boldsymbol{G}_1 L - \boldsymbol{G}_2 L^2 - \cdots - \boldsymbol{G}_m L^m$ is a lag polynominal of order *m*, $\boldsymbol{x}_t$ is an *n*x1 vector of stationary variables and $\boldsymbol{e}_t$ is an *n*x1 vector of *iid* error terms fulfilling $E(\boldsymbol{e}_t) = 0$ and $E(\boldsymbol{e}_t \boldsymbol{e}'_t) = \boldsymbol{\Sigma}$. $\boldsymbol{\mu}$ is an *n*x1 vector describing the steady-state values of the variables in the system and by specify-

[4] Additional examples of various spillover effects include Österholm and Zettelmeyer (2008), Bagliano and Morana (2010), Erten (2012) and Hájek and Horváth (2016).

ing the model this way, an informative prior distribution for $\boldsymbol{\mu}$ often can often be provided.[5] In this paper, the prior on $\boldsymbol{\mu}$ is given by $\boldsymbol{\mu} \sim N_n(\boldsymbol{\theta}_{\boldsymbol{\mu}}, \boldsymbol{\Omega}_{\boldsymbol{\mu}})$ and is given in detail in Table A1 in the appendix; we will return to it below as we discuss the choice of variables in the model in more detail. The priors on the rest of the parameters follow those in Villani (2009); the prior on $\boldsymbol{\Sigma}$ is given by $p(\boldsymbol{\Sigma}) \propto |\boldsymbol{\Sigma}|^{-(n+1)/2}$ and the prior on $vec(\boldsymbol{G})$, where $\boldsymbol{G} = (\boldsymbol{G}_1 \quad \dots \quad \boldsymbol{G}_m)'$, is given by $vec(\boldsymbol{G}) \sim N_{mn^2}(\boldsymbol{\theta}_{\boldsymbol{G}}, \boldsymbol{\Omega}_{\boldsymbol{G}})$. It can be noted that the prior on $\boldsymbol{G}$ has been slightly modified relative to the traditional Minnesota prior. Instead of a prior mean of unity on the first own lag and zero on all other lags, the prior mean on the first own lag is here set to 0.9 for variables which are modelled in levels and zero for variables which are growth rates. This is motivated by the fact that a univariate random walk – which is the origin for the traditional specification – is not a reasonable starting point for the mean-adjusted model. Finally, the hyperparameters of the model, which describe how tight the priors on the dynamic coefficients in $\boldsymbol{G}$ are, follow the standard in the literature; we set the overall tightness to 0.2, the cross-variable tightness to 0.5 and the lag decay parameter to 1.[6]

2.2 The US block of the model

Concerning the variables of the model, we have a main block which consists of five US variables. The first four are "traditional" macroeconomic variables, namely the unemployment rate (u_t) [seasonally adjusted, percent], GDP growth (y_t) [fixed prices, quarter-on-quarter, percent], CPI inflation (π_t) [quarter-on-quarter, percent] and the effective Fed funds rate (i_t) [percent]. These variables are often used in small VAR models of the US economy.[7]

The fifth variable in the system is the uncertainty measure. In the first specification, this is given by the CBOE S&P 100 volatility index (VXO_t). Following, for example, Caldara *et al.* (2014), we use this index rather than the slightly more commonly used VIX (which is an updated version of the VXO, reflecting the volatility of the S&P 500).[8] In the second specification, we use the US policy uncertainty index of Baker *et al.* (2015) (PU_t) which aims to measure the extent of uncertainty concerning economic policy in the United States. This index is based on three components. The first is a news component which measures the frequency of references to fiscal and monetary policy uncer-

[5] This has shown to be useful from a forecasting perspective; see, for example, Beechey and Österholm (2010).

[6] See, for example, Doan (1992) and Villani (2009) for details.

[7] See, for example, Cogley and Sargent (2001), Ribba (2006) and Österholm (2012).

[8] The reason for this is that the VXO is available starting 1986Q1 and the VIX is only available from 1990Q1. We argue that the longer time series is to be preferred. It can be noted that the correlation between the VXO and the VIX for the common sample is 0.99 (at the quarterly frequency).

tainty in ten major US newspapers. The second component reflects upcoming expirations of federal tax code provisions. Finally, forecast disagreement over future inflation and government expenditures is the third component. When constructing the index, the components are normalised (using the standard deviation of the variable in question) and then weighted together; see Baker *et al.* (2015) for details.

Treating the US block of the model as a model of its own, this is described by equation (1) where

$$\boldsymbol{x}_t = (u_t \quad y_t \quad \pi_t \quad i_t \quad VXO_t)' \tag{2}$$

or

$$\boldsymbol{x}_t = (u_t \quad y_t \quad \pi_t \quad i_t \quad PU_t)' \tag{3}$$

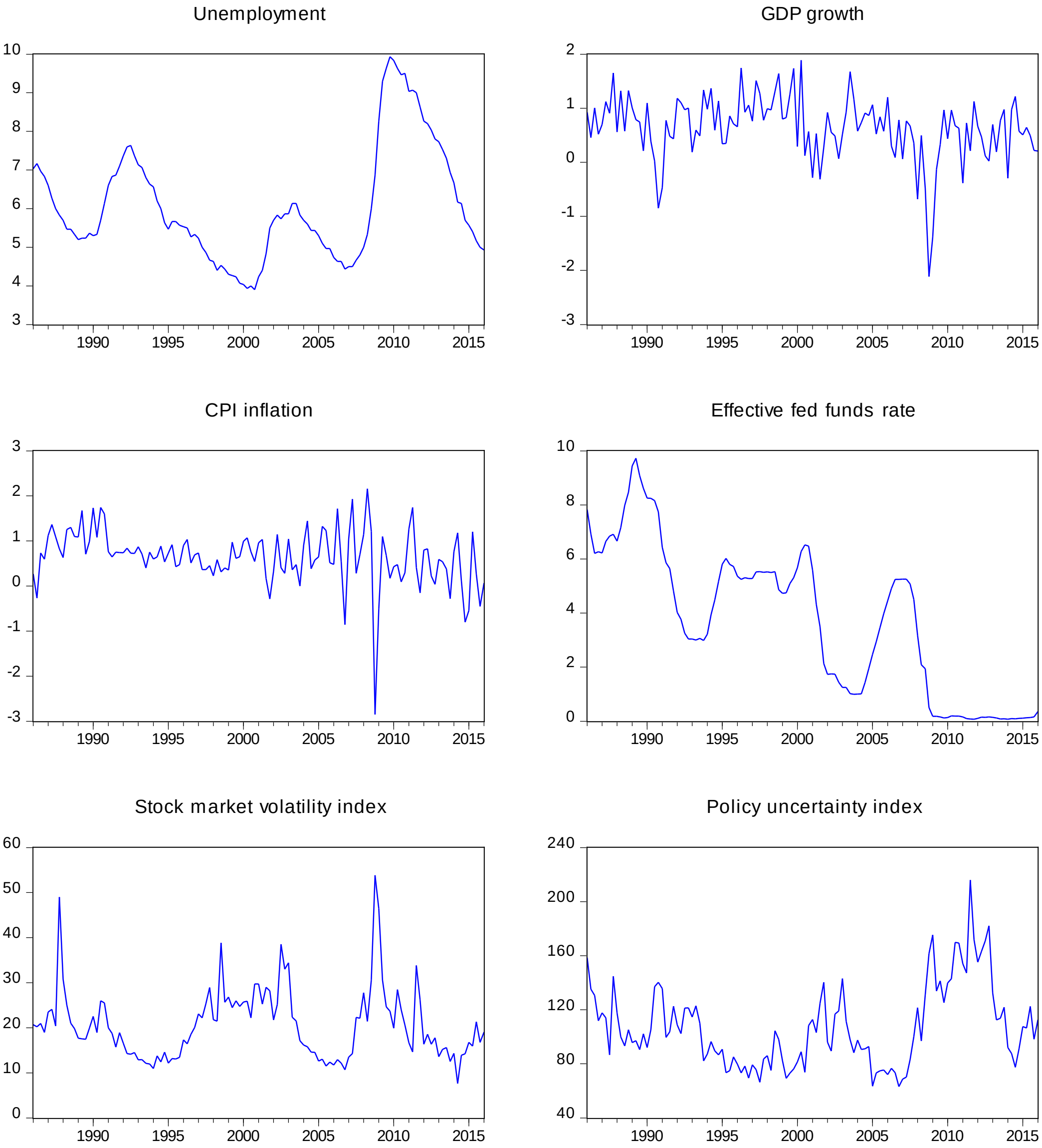
depending on the uncertainty measure used. The US data, which range from 1986Q1 to 2016Q1, are shown in Figure 1.[9] The thought underlying this US block is to obtain a reasonable measure of the uncertainty shock; by controlling for other potentially relevant information, we are less likely to overstate the importance of the uncertainty shocks.

In order to get a feeling for the properties of the US block of the model, we first estimate the BVAR with $\boldsymbol{x}_t$ defined as in equations (2) and (3). The priors on $\boldsymbol{\mu}$ are given in Table A1 in the appendix. As can be seen, the prior mean for the unemployment rate is centred on five percent, in line with, for example, recent estimates made by the Congressional Budget Office (2015). The prior for GDP growth is the same as that used in Stockhammar and Österholm (2016); the mean of the distribution is 0.625, a number which is close to the sample mean of the series. The priors for CPI inflation and the effective Fed funds rate follow the ones used in Beechey and Österholm (2010) and Österholm (2012) respectively; the first of these is simply based on the Federal Reserve's inflation target and the second combines the inflation target with a real interest rate of approximately two percent.[10] The VXO is centred on 20, roughly in line with its historical average. Finally, the policy uncertainty index is centred on 100. This is based on the fact that Baker *et al.* (2015) normalise the index to have a mean of 100 over the period 1985 to 2009. Lag length in the model is set to $m = 4$.

[9] Data on the unemployment rate, CPI and Fed funds rate were supplied by the National Institute of Economic Research. GDP data were supplied by the OECD. Data on the VXO were sourced from the FRED database at the Federal Reserve Bank of St. Loius. Policy uncertainty data were downloaded from http://www.policyuncertainty.com/.

[10] These values were suggested already by Taylor (1993) in his groundbreaking paper on monetary policy rules.

Figure 1. US data.



Note: The unemployment rate, GDP growth, CPI inflation and the effective Fed funds rate are measured in percent. The stock market volatility index and policy uncertainty index are given as indices.

Figures A1 and A2 in the appendix show the impulse response functions from these models. The impulse response functions have been calculated using the Cholesky decomposition of the covariance matrix. We choose to rely on a Cholesky decomposition – rather than, for example, more general short-run restrictions – since we are not trying to estimate structural shocks; similar to Adolfson *et al.* (2007) and Beechey and Österholm (2008), we are simply trying to recover orthogonal shocks corresponding to each variable.[11] The Cholesky decomposition implies a recursive structure, where the ordering of the variables in the system matters. In our main analysis, we have cho-

[11] This stands in contrast to studies where the shocks are given a structural interpretation, such as aggregate demand shocks, aggregate supply shocks, wage setting shocks and monetary policy shocks. See Blanchard (1989) for an example and Amisano and Giannini (1997) for a more general discussion of identification in VAR models.

sen to employ the ordering of equations (2) and (3) respectively;[12] we argue that this is a reasonable ordering but nevertheless investigate the importance of this assumption in Section 2.4.2 below.

Turning to Figure A1, it can be seen that while the shocks to the unemployment rate and GDP growth roughly behave in line with economic intuition, the same cannot be said for the shocks to the effective Fed funds rate. For example, CPI inflation increases at all horizons shown. Here it should be remembered though that the shocks – as pointed out above – should not be given a structural interpretation. The fact that it does not seem consistent with a monetary policy shock is therefore not a major shortcoming.

Our focus is on the shock to the uncertainty measure, which in Figure A1 is given by the VXO. As can be seen, a shock to the VXO significantly increases the unemployment rate.[13] The maximum effect can be found after eight quarters where the unemployment rate is 0.13 percentage points higher. According to the point estimate, a shock to the VXO also decreases US GDP growth with a rather short delay. This effect is, however, not significant.

Changing the uncertainty measure to policy uncertainty, we get the impulse response functions shown in Figure A2. As can be seen, the model also in this case has intuitive impulse responses with respect to the unemployment rate shock and GPD growth shock, whereas shocks to the effective Fed funds rate again yield a somewhat counterintuitive response for several variables (though they are typically not significant). Turning to the shock which we focus on, we see that the policy uncertainty shock significantly increases the unemployment rate.[14] The effect and delay is very similar to the ones originating from a VXO shock. In contrast to a VXO shock however, a policy uncertainty shock also significantly lowers GDP growth and the effective Fed funds rate. Thus, policy uncertainty shocks seem to matter more than shocks to stock market volatility in the US block of the BVAR model.

2.3 Spillovers to the small open economies

Having briefly looked at the properties of the US block of the model, we next turn to the spillover effects of uncertainty shocks to small open economies. We address this issue in a straightforward

[12] This is based on a fairly commonly employed principle where slow-moving variables appear before fast-moving ones. The recursive structure for identification was also used in Sims (1980) original article on VARs.

[13] The standard deviation of the VXO shock is 5.1 units.

[14] The standard deviation of the policy uncertainty shock is 15.2 units.

manner in this framework: It is simply done by adding GDP growth [fixed prices, quarter-on-quarter, percent] for one small open economy (y_t^{so}) at a time to the US block. The vector of variables to be modelled is accordingly given by:

$$\boldsymbol{x}_t = (u_t \quad y_t \quad \pi_t \quad i_t \quad VXO_t \quad y_t^{SO})' \tag{4}$$

or

$$\boldsymbol{x}_t = (u_t \quad y_t \quad \pi_t \quad i_t \quad PU_t \quad y_t^{SO})' \tag{5}$$

depending on the uncertainty measure used.

It should be noted that in the following analysis, the US variables will be block exogenous with respect to y_t^{SO}. This is based on the notion that the small open economies are unlikely to affect the US economy to a meaningful extent. We achieve this block exogeneity with an additional hyperparameter which forcefully shrinks the parameters on the GDP growth of the small open economies in the US equations to zero;[15] see Villani and Warne (2003) for a technical description. The steady-state prior for y_t^{SO} is for all countries set to be the same as that for US GDP growth; see Table A1 in the appendix.

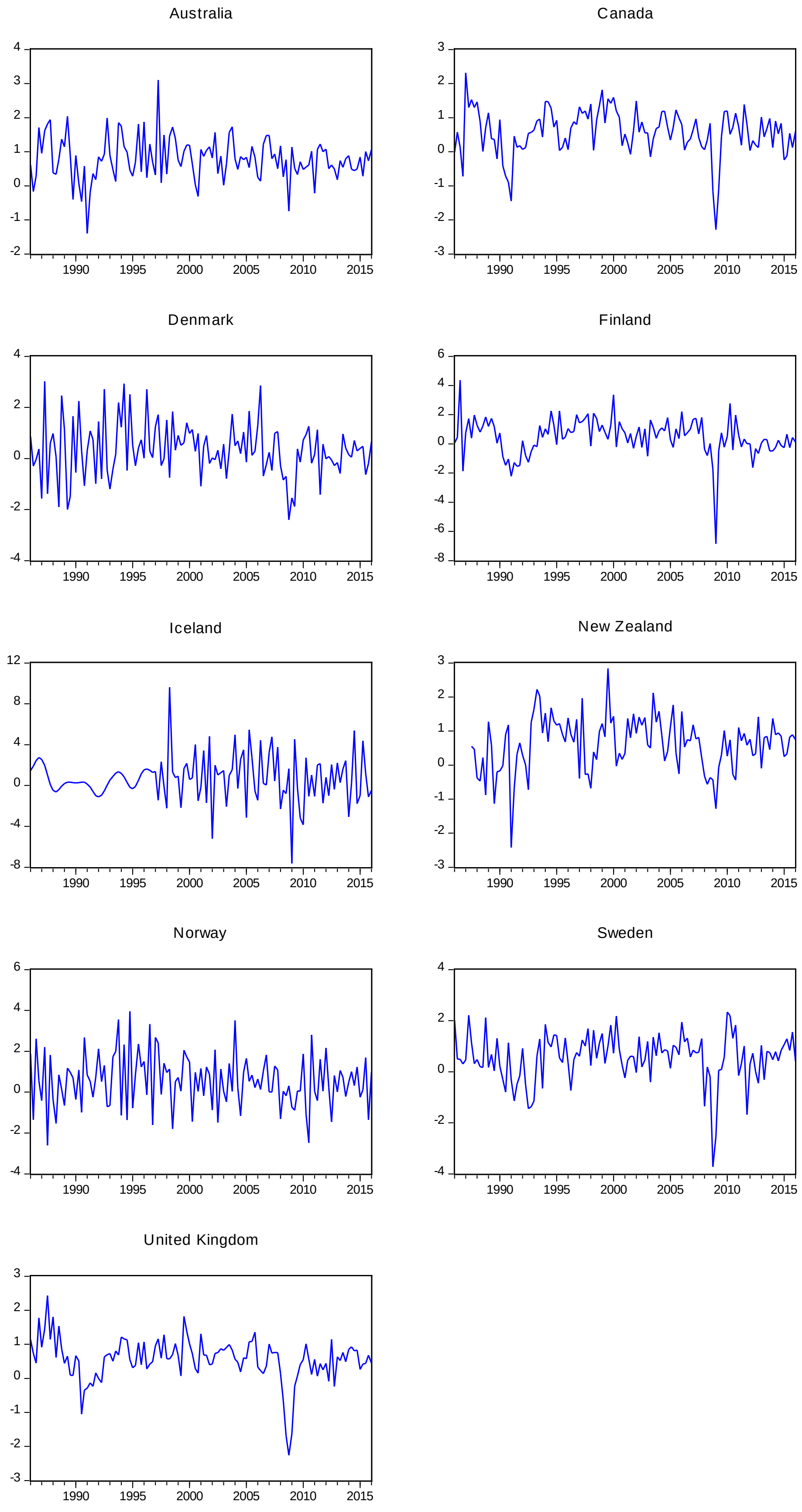
We conduct the analysis for nine different small open economies which form two distinctive groups. The first group is the five Nordic countries, that is, Denmark, Finland, Iceland, Norway and Sweden; this group stands out in several ways when making international comparisons, for example through their generous welfare systems and high taxes. The second group consists of the Anglo-Saxon countries Australia, Canada, New Zealand and the United Kingdom. Not only do these countries share a language with the United States, they also generally have more liberal economic systems than the Nordic countries. Employing data from these nine countries, we study traditional examples of small open economies and it might also be possible to see if patterns differ across these two groups of countries.

Data on GDP growth for the small open economies are shown in Figure 2.[16]

[15] This parameter of exogenity tightness is set to 0.001.

[16] These data were supplied by the OECD.

Figure 2. GDP growth of the small open economies.



Note: All series are measured in percent.

Looking at the data, it can first be noted that the early data for Iceland and Sweden have both different dynamics and volatility than the rest of the respective sample. This is due to the fact that these data are estimates and, accordingly, based on different methodologies than the rest of the two samples. This does not seem important for our results though. Starting the estimation 1993Q1 for Sweden and 1997Q1 for Iceland does not change the conclusions made in this paper.[17] GDP growth data for New Zealand are only available from 1987Q3.

Turning to the effect of the uncertainty shock measured through the VXO first, the results are shown in the first column of Figures 3 and 4. As can be seen, many have the expected sign when looking at the point estimates. In, for example, Norway, the point estimate also indicates a quantitatively meaningful reduction in GDP growth from an uncertainty shock. However, it is only for Denmark and Iceland that we can find a statistically significant effect; while not being statistically significant, it can be noted though that the point estimate for Iceland on impact has the wrong sign and is fairly large in magnitude. We also find – perhaps somewhat surprisingly – that some of the least appealing impulse response functions are associated with Australia and Canada. While we cannot find statistically significant results at any horizon, the point estimates for both countries have the wrong sign on impact and are after that very close to zero. These findings were not in line with our expectations for two Anglo-Saxon countries with – particularly in the Canadian case – close ties to the United States.

If we finally turn to the effect of uncertainty shocks measured through policy uncertainty, the second column of Figures 3 and 4 show a somewhat different result. As can be seen, we now find a significant reduction in GDP growth in all of the Nordic countries, even if the response on impact in some cases has the wrong sign (though this is in no case statistically significant). The effect on the Nordic countries also seem fairly similar in magnitude, where an effect of more than -0.1 percentage point at the one- to two-quarter horizon is found in general. Judging by the point estimates, the impact of a policy uncertainty shock on the Anglo-Saxon countries seems to be bigger than that of a VXO shock and generally has the correct sign. The point estimate of the effect is still small though, almost exclusively less than -0.05 percentage points, and significant effects can only be found for the United Kingdom.

Summing up, our results indicate that policy uncertainty shocks seem to matter more than VXO shocks for GDP growth. Not only is the impact on US GDP growth bigger and, in addition, statistically significant; spillovers to small open economies are also more commonly found and tend to be larger in magnitude.

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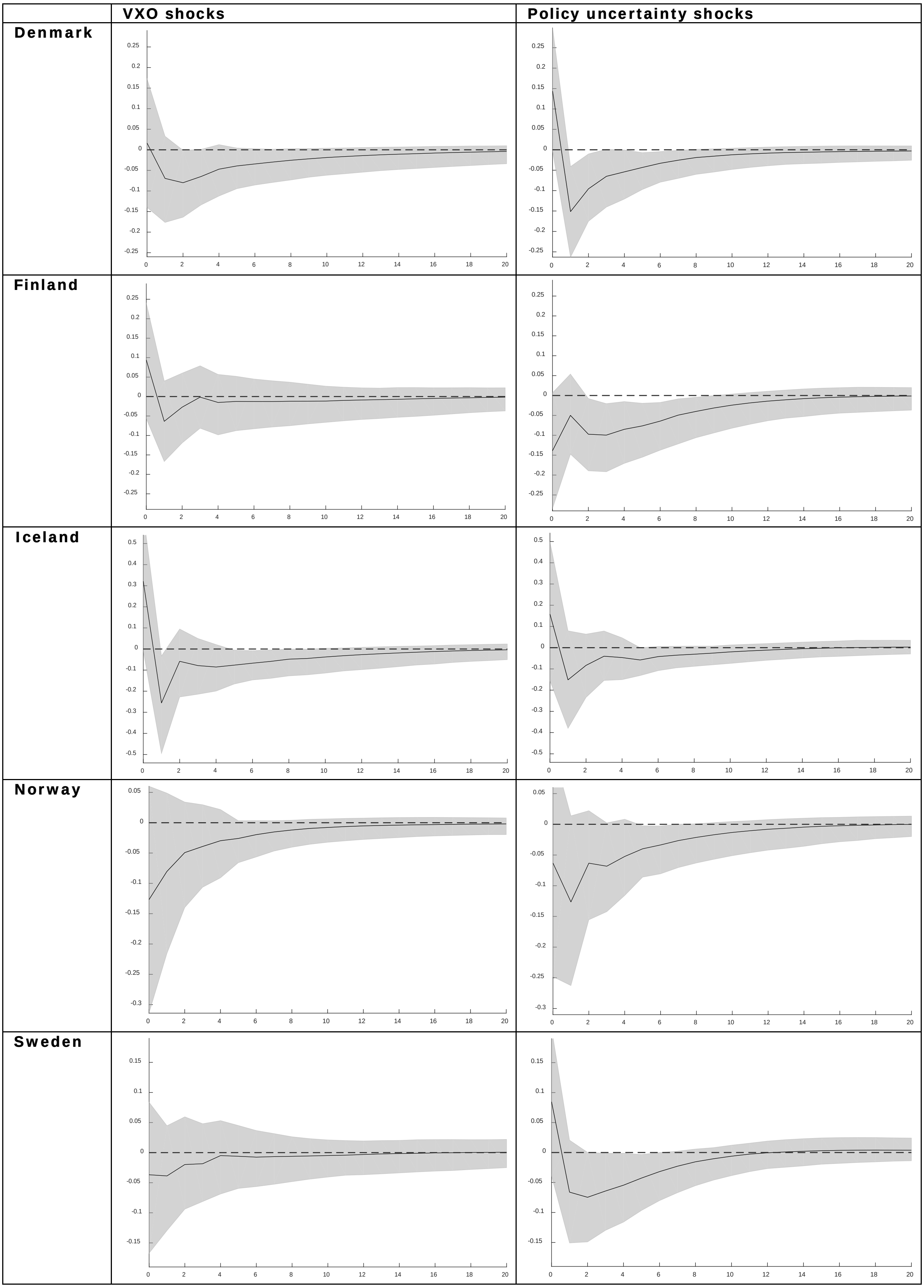
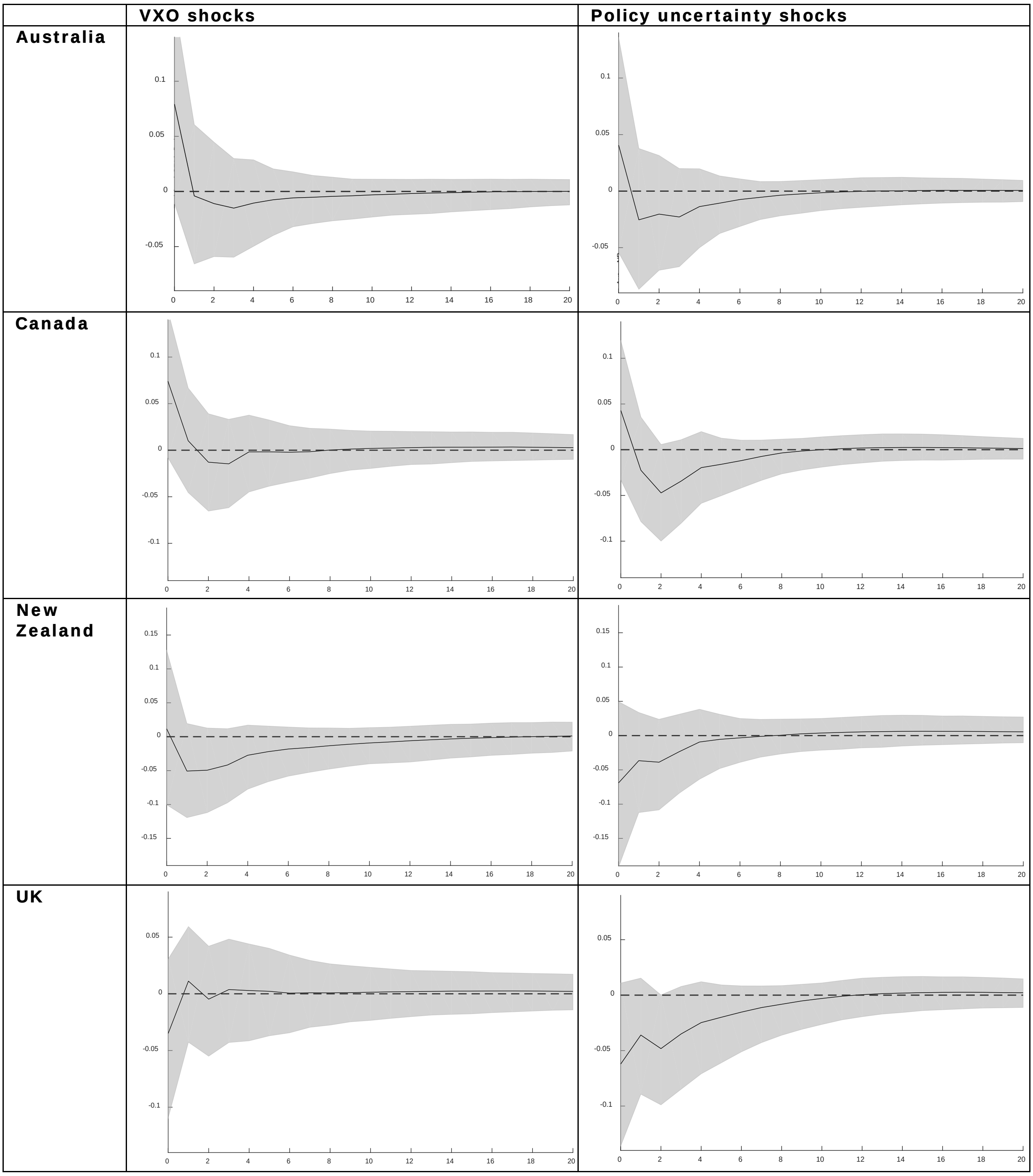
[17] Results are not reported but are available from the authors upon request.

Figure 3. Impulse response functions. Estimated effects on GDP growth in the Nordic countries.



Note: Percentage points on the vertical axis and quarters on the horizontal axis. Black line is the median and the coloured band is the 90% confidence band.

Figure 4. Impulse response functions. Estimated effects on GDP growth in the Anglo-Saxon countries.



Note: Percentage points on the vertical axis and quarters on the horizontal axis. Black line is the median and the coloured band is the 90% confidence band.

2.4 Sensitivity analysis

There are many ways to specify and estimate VAR models. In order to assess the robustness of the results presented above, we next conduct some sensitivity analyses. We look into three aspects of our results. First, we investigate how important it is that we have used Villani's framework rather than a more traditional BVAR specification. Second, we explore whether the ordering of the variables in the system matter much to our conclusions. Finally, we assess how much the transformation of GDP and CPI matters.

2.4.1 ABANDONING THE INFORMATIVE STEADY-STATE PRIOR

Using Villani's mean-adjusted specification meant that we could provide an informative prior distribution for the steady state of the variables in the system. The importance of this assumption for our results can be assessed by instead estimating the more traditional specification of the BVAR, namely

$$\boldsymbol{G}(L)\boldsymbol{x}_t = \boldsymbol{a} + \boldsymbol{e}_t \tag{6}$$

where $\boldsymbol{G}(L)$, $\boldsymbol{x}_t$ and $\boldsymbol{e}_t$ are defined as in Section 2.1 above; $\boldsymbol{a}$ is an *n*x1 vector of intercepts. Since it is much harder to have an opinion concerning the coefficients in $\boldsymbol{a}$, we accordingly employ a diffuse prior, $\boldsymbol{a} \sim N_n(\boldsymbol{0}, 100\boldsymbol{I}_n)$. In line with how priors typically are specified in the literature using this version of the BVAR model, we also set the prior mean on the first own lag to unity in all cases.

Having made these changes to the model, we get the impulse response functions reported in Figures A3 and A4 in the appendix for the US block of the model. As can be seen, these are extremely similar to those reported in Figures A1 and A2 respectively. This is also the case for the effects on the small open economies, shown in Figures A5 and A6 in the appendix. We accordingly conclude that using Villani's mean-adjusted BVAR rather than a more traditional BVAR specification does not affect our conclusions.

2.4.2 CHANGING THE ORDER OF THE VARIABLES IN THE SYSTEM

In the main specification in Sections 2.2 and 2.3 above, we calculated impulse-response functions using a Cholesky decomposition where the uncertainty measure was placed last in the US block of the model. Since the ordering of the variables in the system typically matters, we next assess the importance of this choice.

The ordering in equations (4) and (5) together with the Cholesky decomposition means, for example, that the unemployment rate can affect all other variables in the system contemporaneously but not vice versa. We believe that this ordering – which is based on the principle that slow-moving variables appear before fast-moving variables in the system – is a reasonable one. For example, the VXO changes basically continuously as traders take new information, such as the unemployment rate or GDP, into account. Unemployment is sluggish though and it seems unlikely that firms take information regarding the VXO into account in the very short run when making their hiring and firing decisions. As a starting point, it therefore seemed reasonable to have the VXO last in the US part of the system in the benchmark specification. For symmetry reasons, the policy uncertainty index got the same position.

Needless to say though, our suggested ordering can be questioned. In particular, the argument provided above about sluggishness is less and less valid the lower the frequency of the data. At a low enough frequency, it instead seems reasonable to assume that all variables can affect each other simultaneously. It hence seems reasonable to assess the importance of the ordering. This has been done by putting the uncertainty variables first in the system, thereby maximizing their potential effect. We accordingly specify the vector $\boldsymbol{x}_t$ in equation (1) as

$$\boldsymbol{x}_t = (VXO_t \quad u_t \quad y_t \quad \pi_t \quad i_t)' \tag{7}$$

or

$$\boldsymbol{x}_t = (PU_t \quad u_t \quad y_t \quad \pi_t \quad i_t)' \tag{8}$$

and calculate new impulse response functions.

The impulse response functions for the US block of the model when using the VXO are shown in Figure A7 in the appendix. Most of the effects are similar to those shown in Figure A1, but a few noteworthy changes can be found. First, the effect of a shock to the VXO now has a significant effect on GDP growth and CPI inflation. Second, in Figure A1 we saw that a shock to the unemployment rate had a significantly positive effect on the VXO. In Figure A7, on the other hand, the effect is no longer significant; it can also be noted that the point estimate has changed sign so that a shock now is associated with a decrease in the VXO.

Turning to the system with policy uncertainty, it can be seen from Figure A8 in the appendix that these largely resemble those in Figure A2. Also in this case are some differences worth pointing out though. First, the effect of a policy uncertainty shock on GDP growth appears much larger when policy uncertainty is first in the system. In Figure A8, the maximum effect is -0.2 percentage points whereas it is only approximately -0.05 percentage points in Figure A2. Second, shocks to GDP growth now have no significant effect on policy uncertainty; this stands in contrast to the significant, and fairly large, negative effect that could be seen in Figure A2. Third, the effect of policy uncertainty shocks on unemployment is approximately doubled in Figure A8 compared to Figure A2.

Concerning the effects on the small open economies, these are given in Figures A9 and A10 in the appendix. Looking at the effect of shocks to the VXO, we can see that results are fairly different for the Nordic countries. Using the original ordering (see Figure 3), we found significant results for Denmark and Icleand. With the ordering given by equation (7), we instead find significantly negative effects on all Nordic countries except Norway. For the Anglo-Saxon countries, the conclusions are less affected. For Australia, Canada and New Zealand, we still find no significant effect. For the United Kingdom, on the other hand, we find a significantly negative effect when the VXO is first in the system.

Looking at the effect of policy uncertainty shocks, we find that placing policy uncertainty first in the system generates effects on growth in the Nordic countries which are qualitatively similar to when it was ordered last; in all five cases do policy uncertainty shocks still reduce GDP growth. Judging by the point estimates though, the estimated effect is generally a fair bit larger. For the Anglo-Saxon countries, we find that results are more affected; policy uncertainty shocks now have significantly negative effects on GDP growth in all countries except Australia.

Summing up this exercise, we find that some of our results are reasonably stable. For example, it seems fair to conclude that VXO shocks have little effect on Australia, Canada and New Zealand and that policy uncertainty shocks have significant effects in the Nordic countries. Other results are less obvious how to interpret. It would, needless to say, have been convenient if our results had been even more stable with respect to the ordering of the variables in the system than what was the case. While there is no clear cut right and wrong here, we do, however, believe that more weight should be given to the results obtained where the uncertainty measures appear last in the US block of the model. As was argued above, we think that this is the more appealing order and, accordingly, that the effects of the VXO and policy uncertainty shocks discussed in this subsection are likely to be overstated.

2.4.3 USING YEAR-ON-YEAR GROWTH RATES

The final part of our sensitivity analysis concerns the transformations of GDP and CPI used. In the main analysis in Sections 2.2 and 2.3, we used quarter-on-quarter growth rates (in percent). It is also very common to employ year-on-year growth rates when modelling macroeconomic time series and we accordingly conduct such analysis next.

Specifically, we calculate GDP growth in each country as $100(Y_t/Y_{t-4} - 1)$, where Y_t is seasonally adjusted GDP in fixed prices. Similarly, US CPI inflation is given by $100(P_t/P_{t-4} - 1)$, where P_t is the CPI. We then redo the analysis in Sections 2.2 and 2.3 using these measures instead of the quarter-on-quarter growth rates previously employed.[18]

Results from the US block of the model are given in Figures A11 and A12 in the appendix. These are qualitatively very similar to Figures A1 and A2 apart from the effect of shocks to CPI inflation. In both the model using the VXO (see Figure A11) and the model using policy uncertainty (see Figure A12), shocks to CPI inflation significantly increases the unemployment rate and decreases GDP growth. This can be compared to the benchmark specifications shown in Figures A1 and A2 where there was no significant effect on either of these two variables.

Regarding the effects on GDP growth in the small open economies, these are shown in Figures A13 and A14 in the appendix. As can be seen from Figure A13, the results for the Nordic countries are qualitatively similar to what can be found in Figure 3. Policy uncertainty shocks appear to have significant effect in all five countries. VXO shocks have significant effects in Denmark and Norway but not in the other three countries; this differs somewhat from the results shown in Figure 3 where significant results were found in Denmark and Iceland. For the Anglo-Saxon countries, the results are also roughly in line with those in the benchmark specification presented in Figure 4. A couple of differences are however worth pointing out. First, VXO shocks have a significant effect on Canadian GDP growth; the effect is positive though, which goes against the economic intuition. Second, the significantly negative effect on UK GDP growth which was found in Figure 4 vanishes when year-on-year growth rates are being employed. Third, the effects of policy uncertainty shocks generally have the expected sign, although they are not significant for any of the Anglo-Saxon countries. Overall though, we believe that the results largely confirm our previous conclusions.

[18] Having moved to year-on-year growth rates, we have to change the steady state priors for the variables concerned. We set the 95 per cent prior interval to (2, 3) in all countries. For US CPI inflation the corresponding interval is given by (0.5, 3.5).

3. Conclusions

In this paper we have studied the effect of uncertainty shocks in the United States on GDP growth in nine small open economies. Two different measures, stock market volatility and the policy uncertainty index, were employed within a Bayesian VAR framework. Concerning our results, it is a robust finding in this paper that policy uncertainty shocks significantly lowers GDP growth in the Nordic countries. As can be seen when comparing our main analysis to the sensitivity analysis, other results depend somewhat on the chosen specification. We do, however, as an overall summary think that it is fair to conclude that stock market volatility – which perhaps is the most widely used measure of uncertainty – appears to matter less than policy uncertainty. Robust effects of stock market volatility shocks on GDP growth across specifications can only be found for Denmark; and in our preferred version of the model, Denmark is the only small open economy where a statistically significant effect can be established.

That US uncertainty affects other economies is not surprising. The most obvious way to think about this is probably that uncertainty in the United States will reduce US aggregate demand, primarily through reduced business investment and household consumption.[19] As the US economy slows down, this will affect the trading partners of the United States through reduced exports. However, it also seems reasonable to believe that businesses and households in the small open economies which trade with the United States, when faced with what they fear will be an international aggregate demand shock, will react to a similar manner to their US counterparts, thereby opening up a more direct channel to reduced business investment and household consumption in the small open economies. It also seems possible that financial turbulence in the United States could spread to other countries and affect the real economy. The findings in this paper indicate that financial contagion might be less of an issue though.

We believe that the results presented in this study should be of interest to forecasters as well as policymakers. When observing policy uncertainty shocks in the United States, forecasters concerned with, for example, the Nordic countries should adjust their forecasts and policy makers should take the likely effects on the domestic economy into account when judging what the appropriate policy is. Our findings should also provide relevant information to researchers doing applied work where uncertainty is involved. As has been shown in this paper, the uncertainty measure used in the empirical analysis can matter for the conclusions drawn.

[19] The irreversibility of investments and precautionary saving are two standard explanations; see, for example, Leland (1968) and Bernanke (1983).

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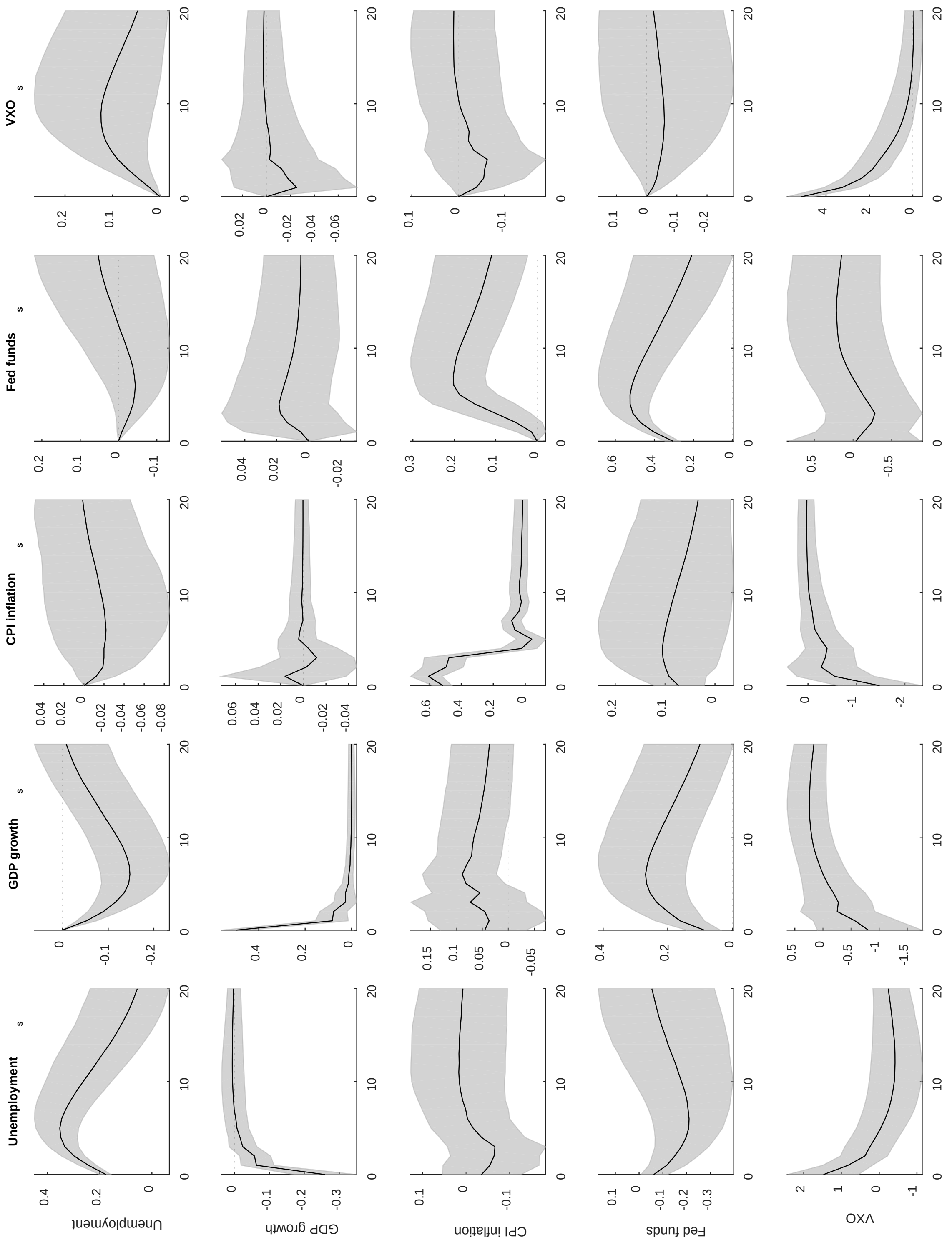
4. Appendix

Table A1. Steady-state priors for the Bayesian VARs.

Variable	Prior interval
u_t	(3.0, 7.0)
y_t	(0.5, 0.75)
π_t	(0.125, 0.875)
i_t	(3.0, 5.0)
PU_t	(95.0, 105.0)
VXO_t	(15.0, 25.0)
y_t^{SO}	(0.5, 0.75)

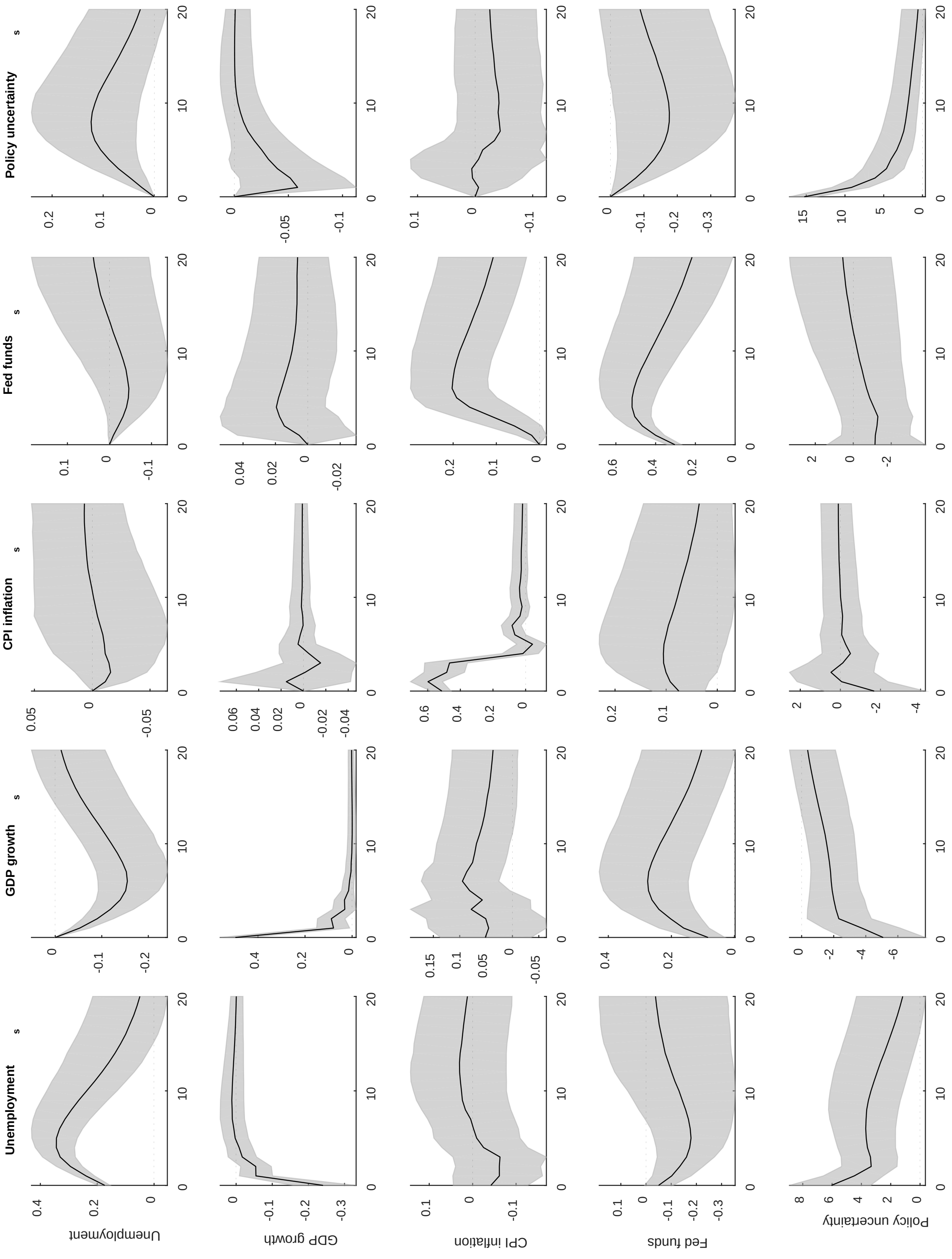
Note: Ninety-five percent prior probability intervals for parameters determining the unconditional means. Prior distributions are all assumed to be normal. Variables are defined in equations (2)-(5).

Figure A1. Impulse response functions of BVAR model with variables given by equations (1) and (2).



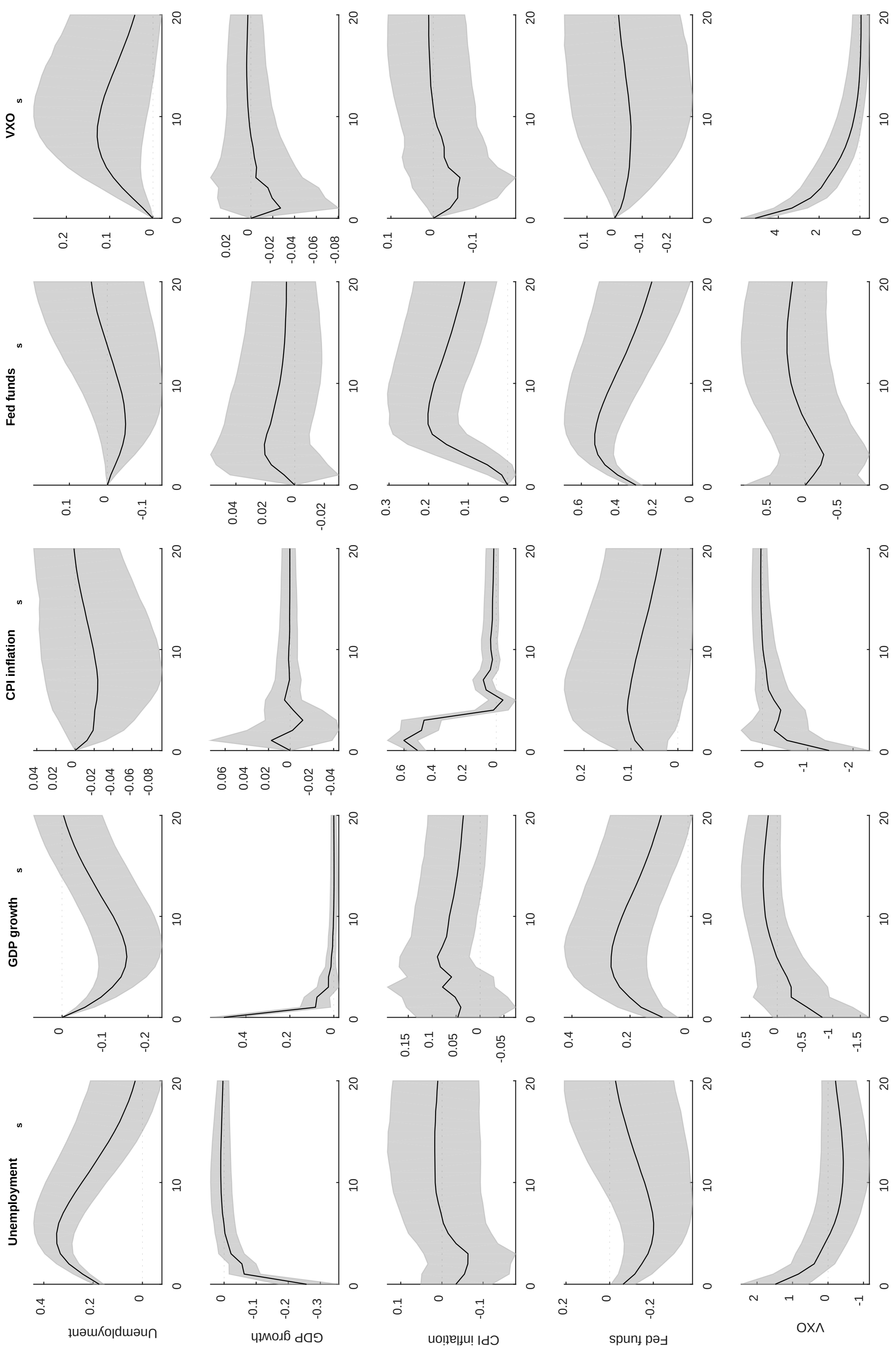
Note: Shocks in columns, responses in rows. Black line is the median and the coloured band is the 90% confidence band. Quarters are given on the horizontal axis.

Figure A2. Impulse response functions of BVAR model with variables given by equations (1) and (3).



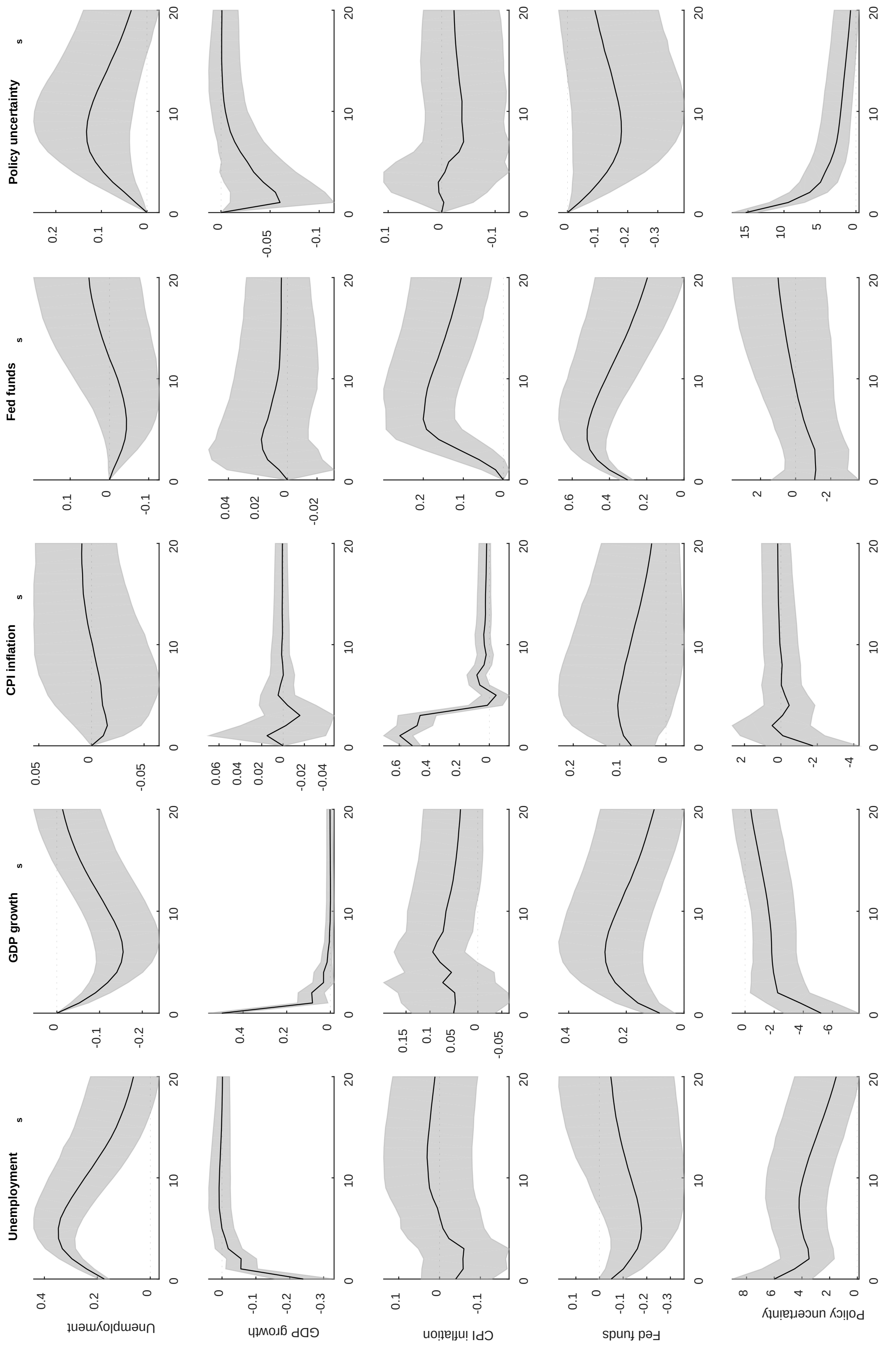
Note: Shocks in columns, responses in rows. Black line is the median and the coloured band is the 90% confidence band. Quarters are given on the horizontal axis.

Figure A3. Impulse response functions of BVAR model with variables given by equations (6) and (2).



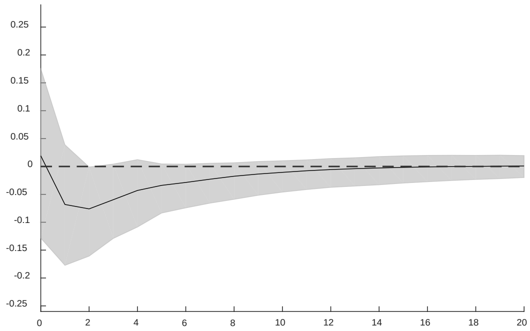
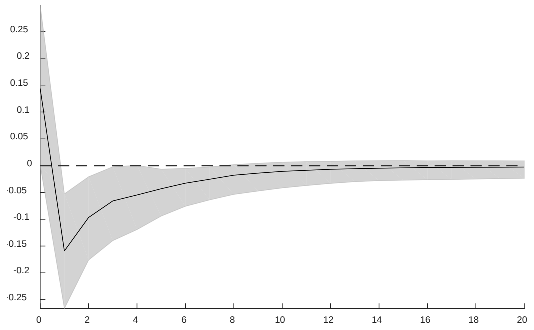
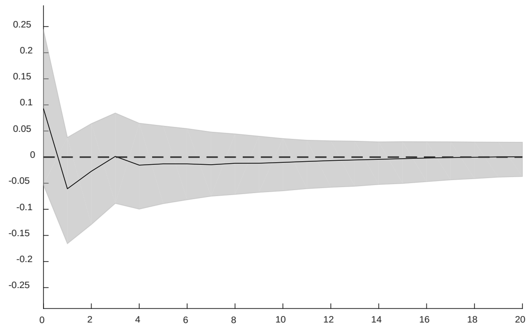
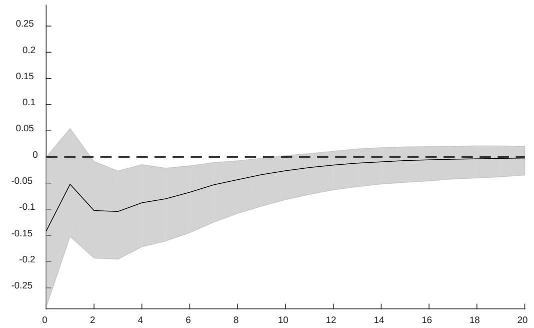
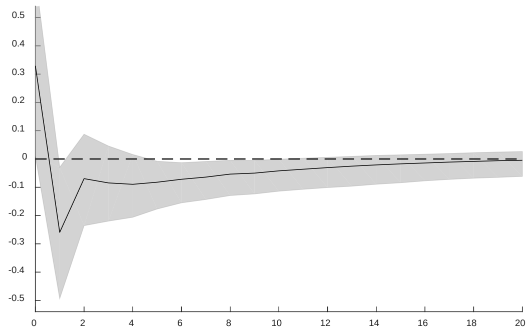
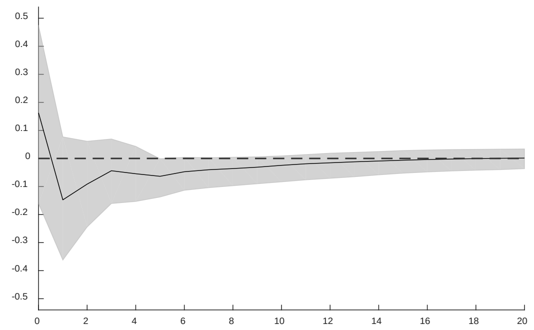
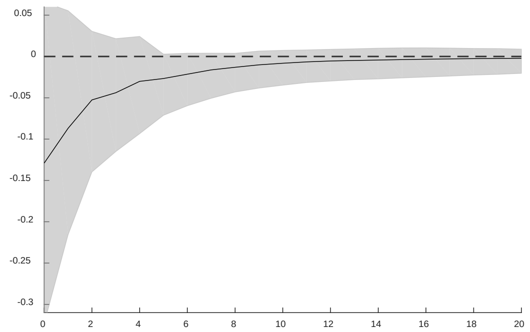
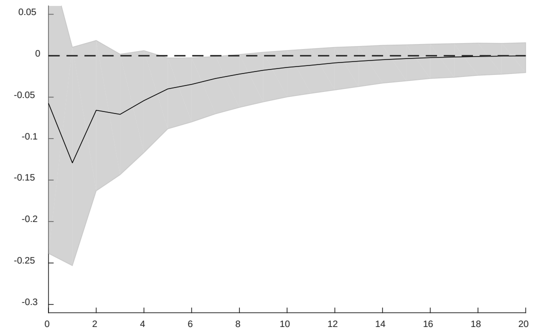
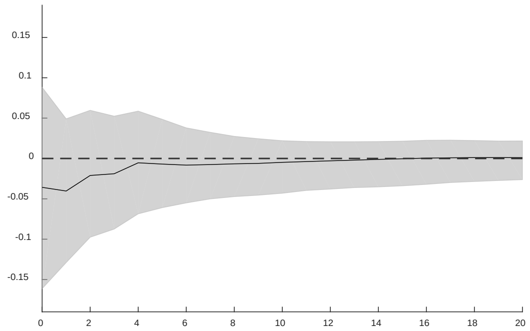
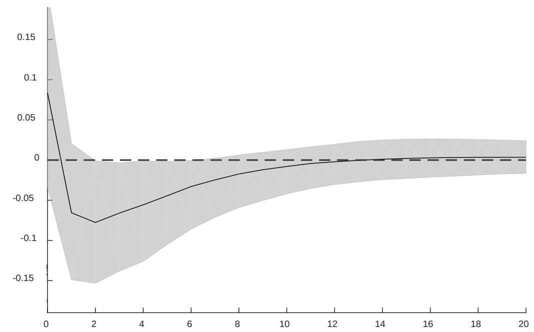
Note: Shocks in columns, responses in rows. Black line is the median and the coloured band is the 90% confidence band. Quarters are given on the horizontal axis.

Figure A4. Impulse response functions of BVAR model with variables given by equations (6) and (3).



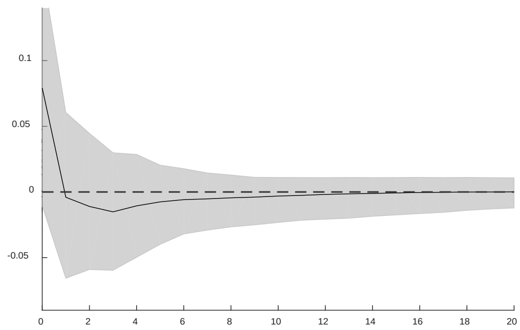
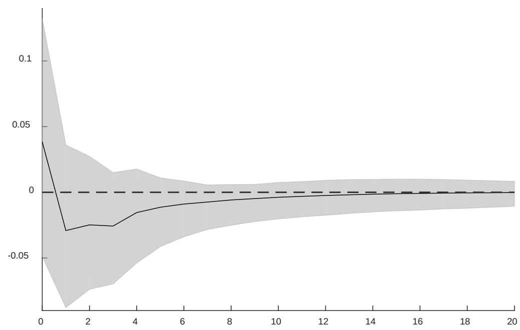
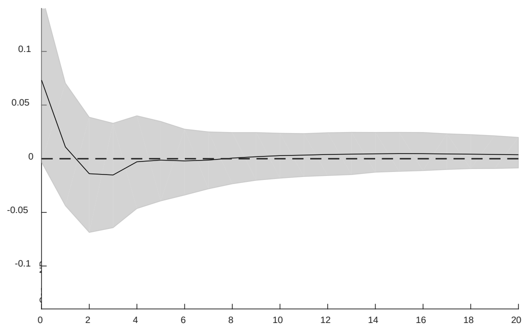
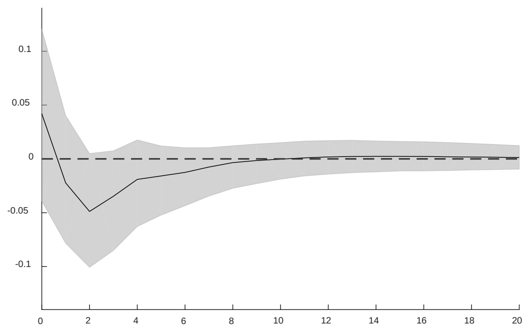
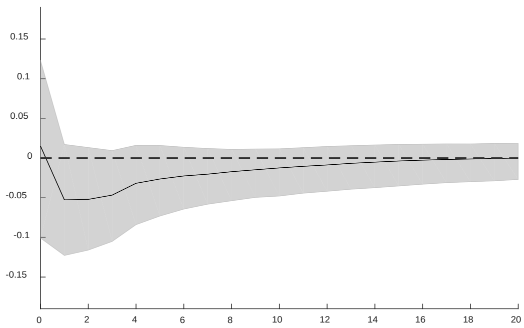
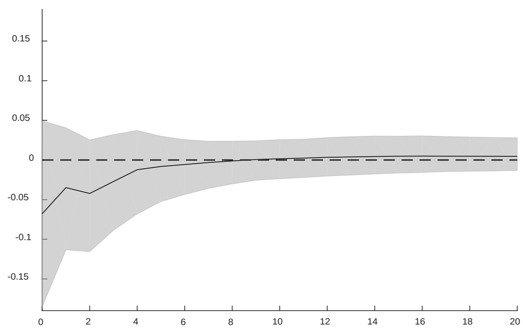
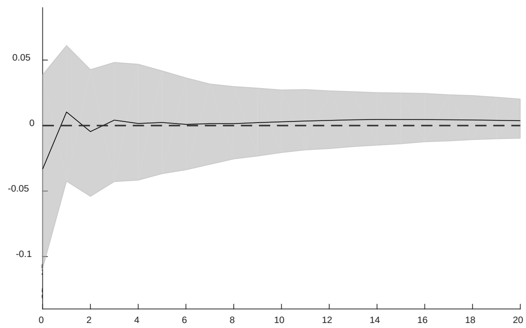
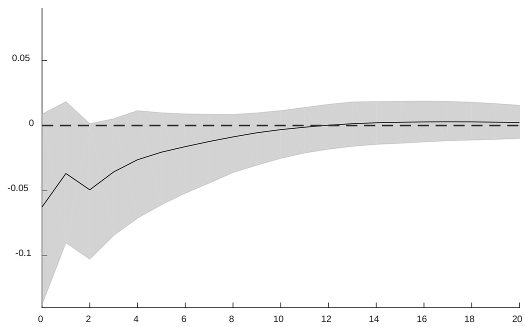
Note: Shocks in columns, responses in rows. Black line is the median and the coloured band is the 90% confidence band. Quarters are given on the horizontal axis.

Figure A5. Impulse response functions. Estimated effects on GDP growth in the Nordic countries of BVAR model with variables given by equations (6) and (4)/(5).

	VXO shocks	Policy uncertainty shocks
Denmark		
Finland		
Iceland		
Norway		
Sweden		

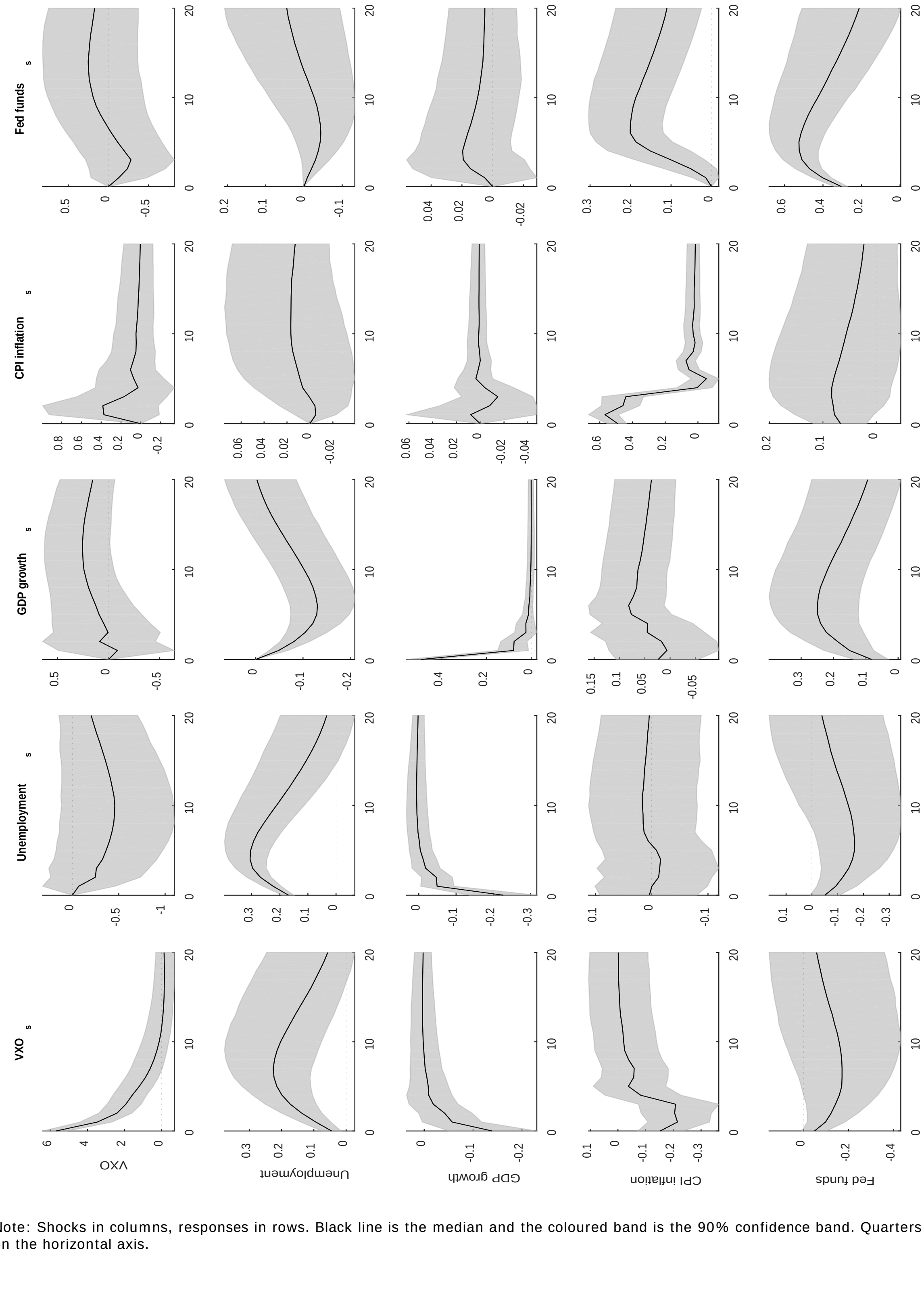
Note: Percentage points on the vertical axis and quarters on the horizontal axis. Black line is the median and the coloured band is the 90% confidence band.

Figure A6. Impulse response functions. Estimated effects on GDP growth in the Anglo-Saxon countries of BVAR model with variables given by equations (6) and (4)/(5).

	VXO shocks	Policy uncertainty shocks
Australia		
Canada		
New Zealand		
UK		

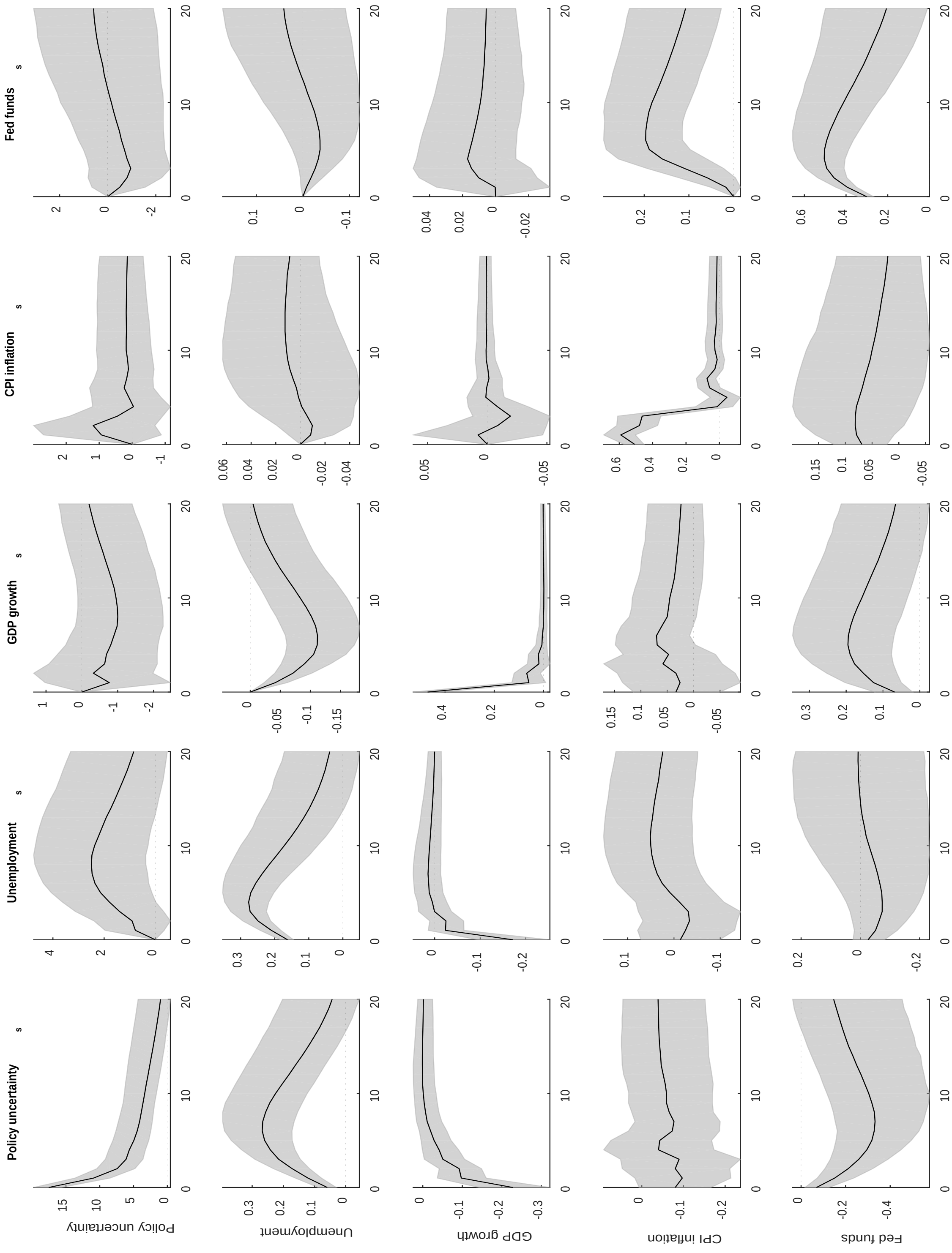
Note: Percentage points on the vertical axis and quarters on the horizontal axis. Black line is the median and the coloured band is the 90% confidence band.

Figure A7. Impulse response functions of BVAR model with variables given by equations (1) and (7).



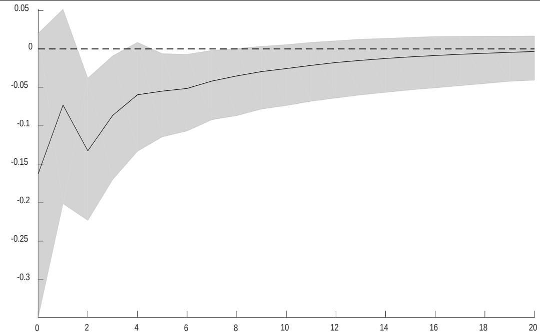
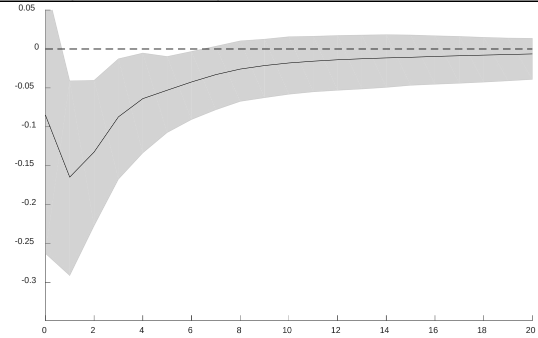
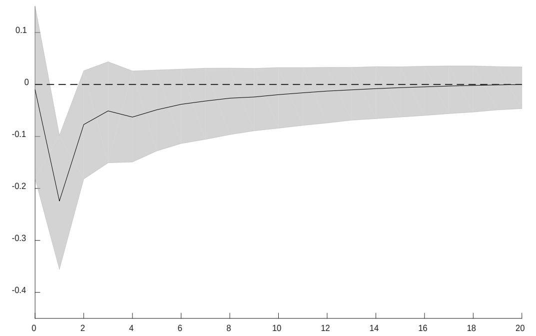
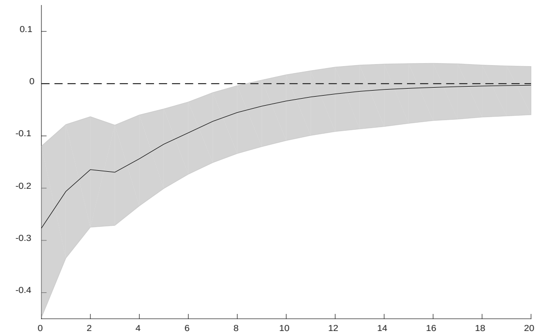
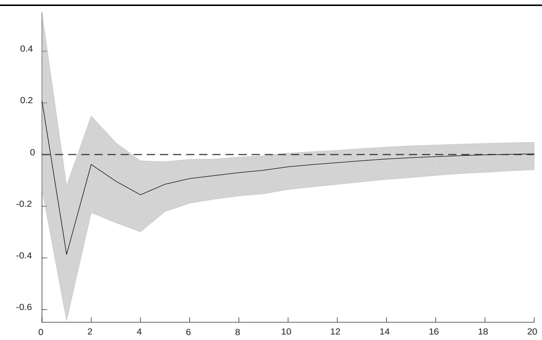
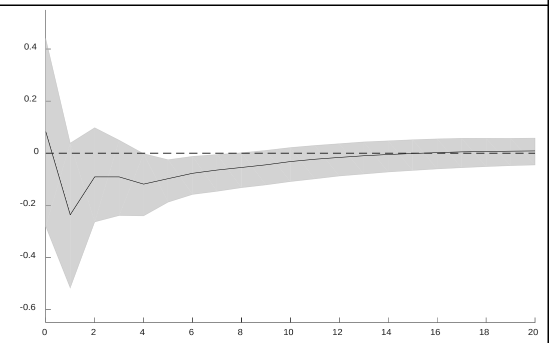
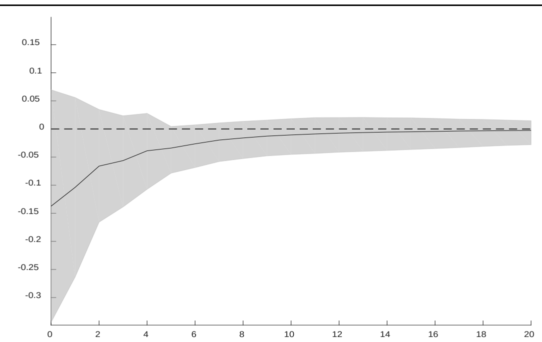
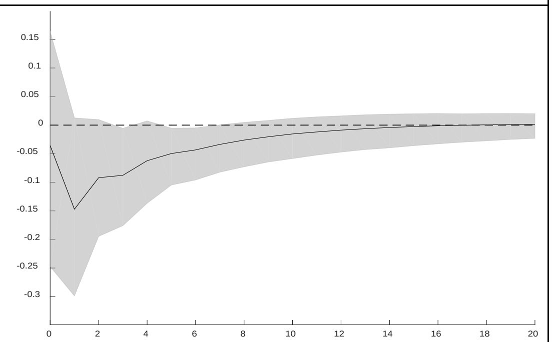
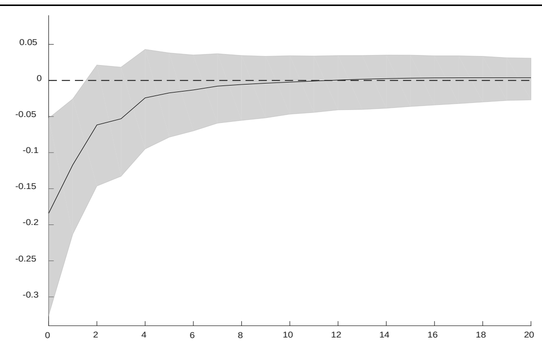
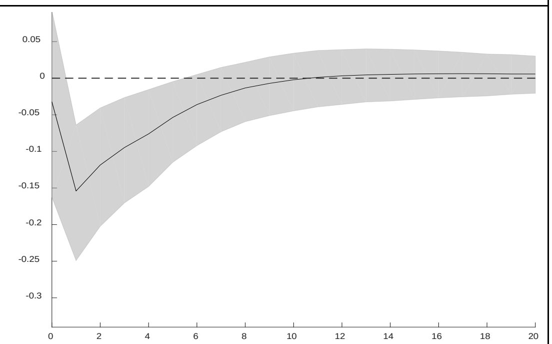
Note: Shocks in columns, responses in rows. Black line is the median and the coloured band is the 90% confidence band. Quarters are given on the horizontal axis.

Figure A8. Impulse response functions of BVAR model with variables given by equations (1) and (8).



Note: Shocks in columns, responses in rows. Black line is the median and the coloured band is the 90% confidence band. Quarters are given on the horizontal axis.

Figure A9. Impulse response functions of BVAR model with variables given by equations (1) and (7)/(8). Estimated effects on GDP growth in the Nordic countries.

	VXO shocks	Policy uncertainty shocks
Denmark		
Finland		
Iceland		
Norway		
Sweden		

Note: Percentage points on the vertical axis and quarters on the horizontal axis. Black line is the median and the coloured band is the 90% confidence band.

Figure A10. Impulse response functions of BVAR model with variables given by equations (1) and (7)/(8). Estimated effects on GDP growth in the Anglo-Saxon countries.

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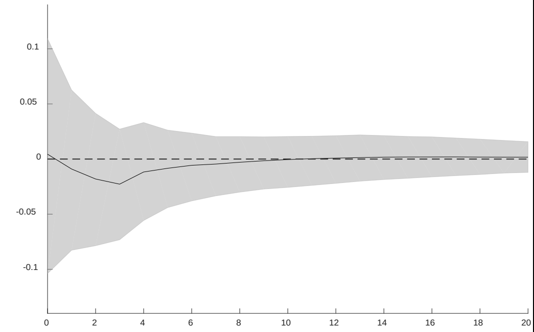
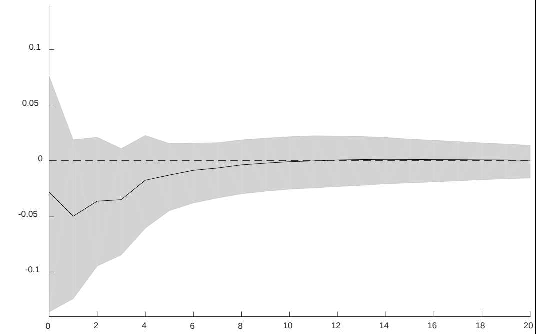
<tr><th></th><th>VXO shocks</th><th>Policy uncertainty shocks</th></tr>
<tr><td>Australia</td><td>
</td><td>
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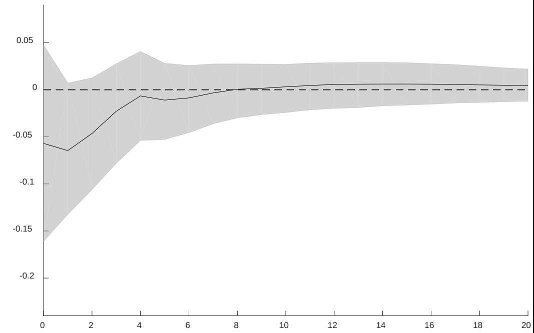
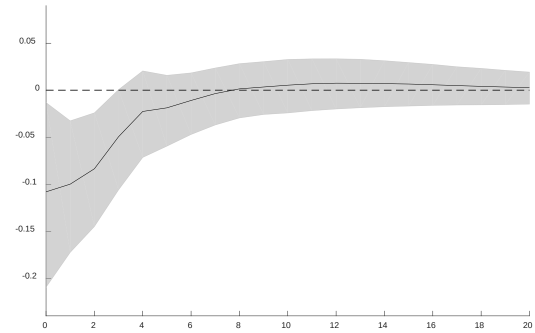
<tr><td>Canada</td><td>
</td><td>
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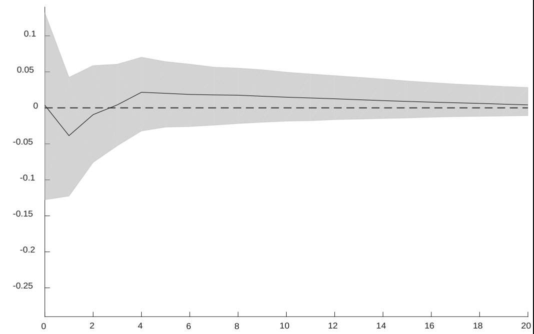
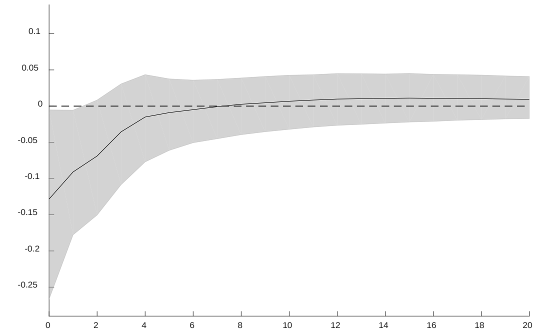
<tr><td>New Zealand</td><td>
</td><td>
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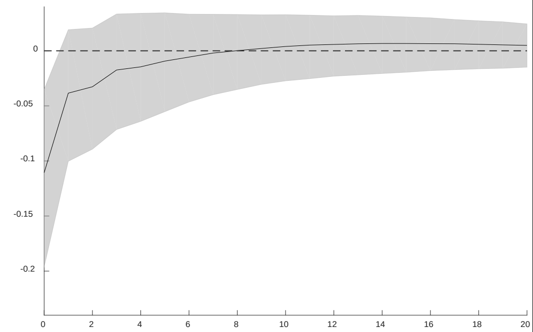
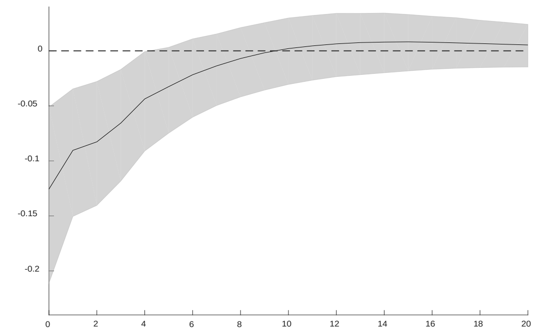
<tr><td>UK</td><td>
</td><td>
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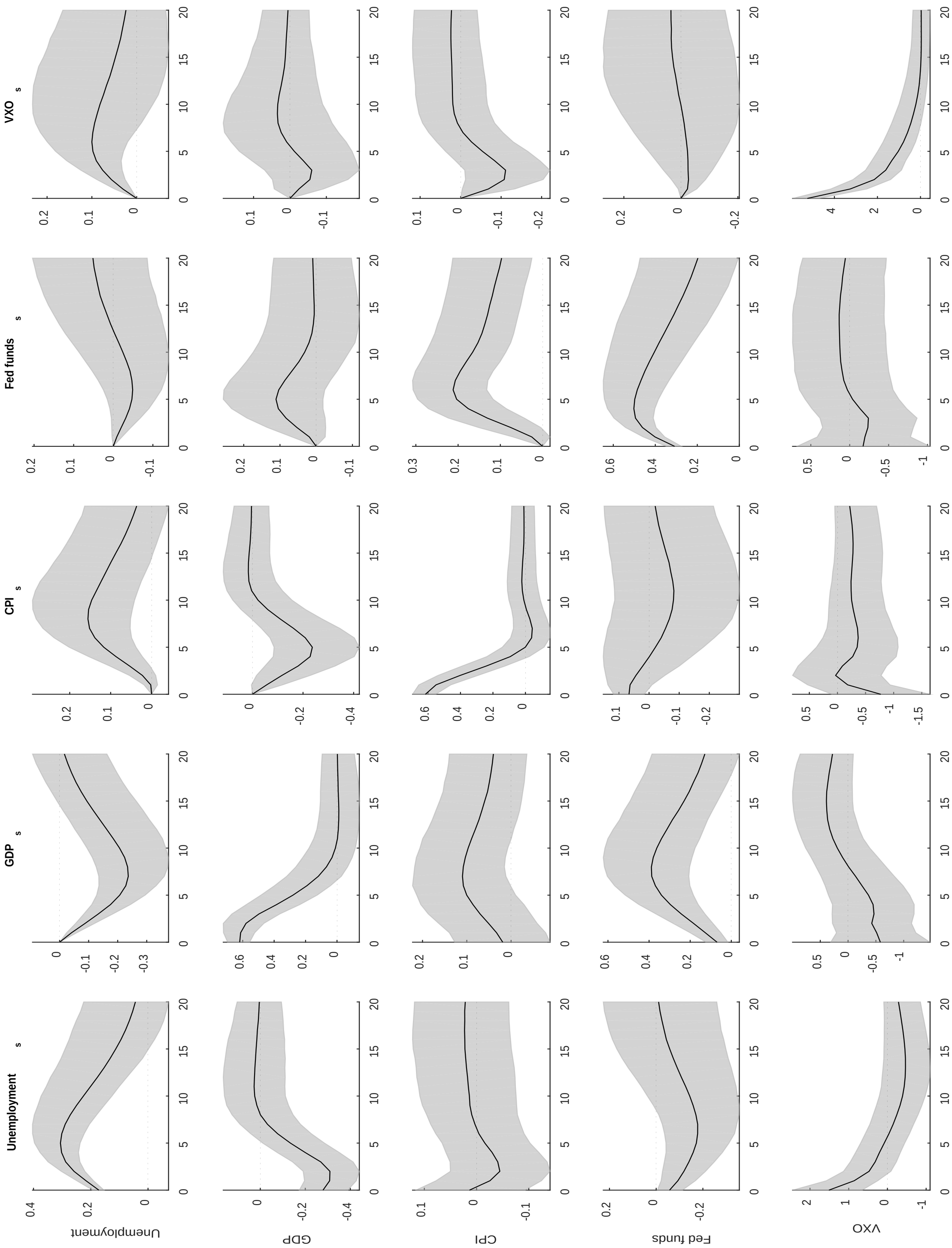
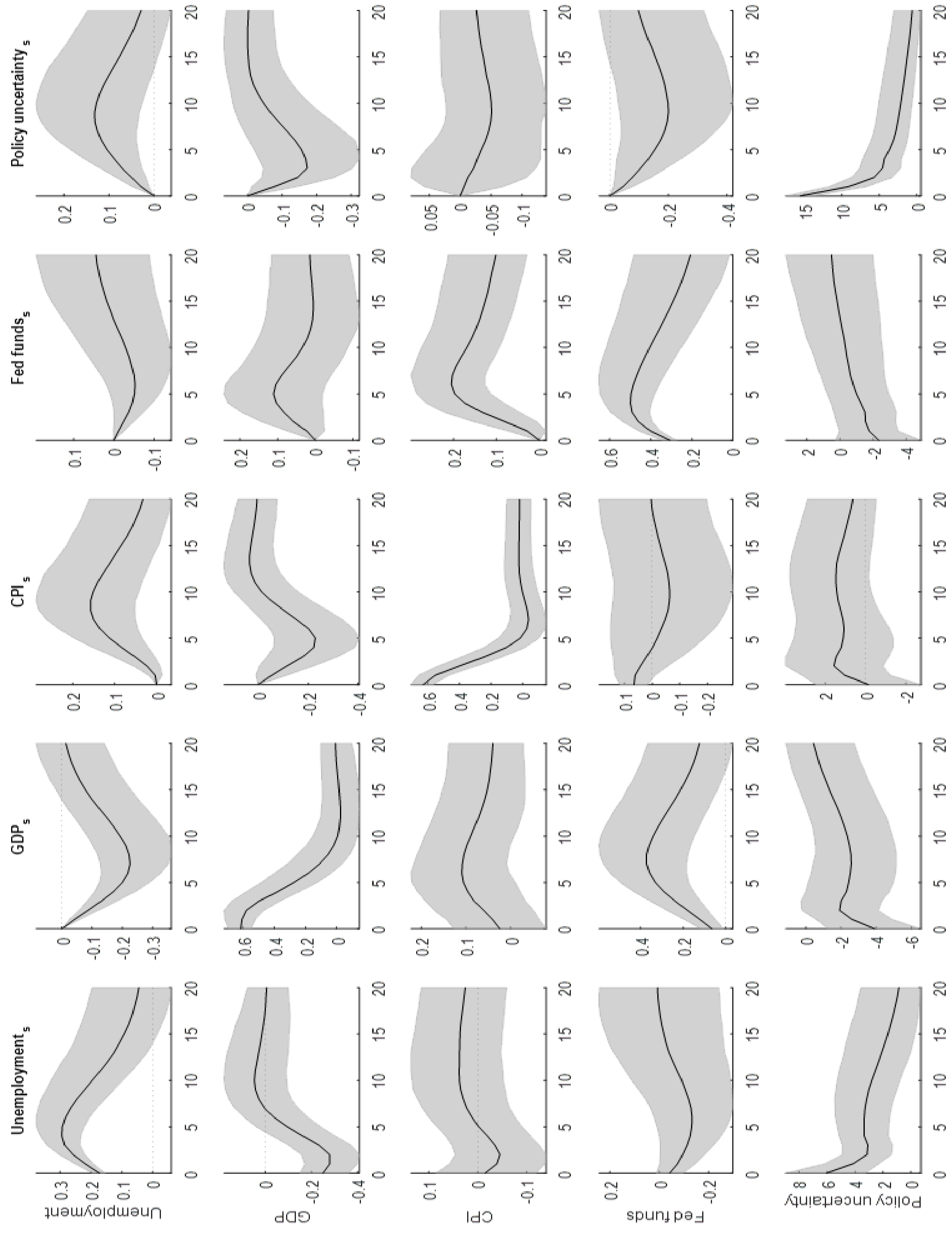
Note: Percentage points on the vertical axis and quarters on the horizontal axis. Black line is the median and the coloured band is the 90% confidence band.

Figure A11. Impulse response functions of BVAR model with VXO using year-on-year growth rates for GDP and CPI.



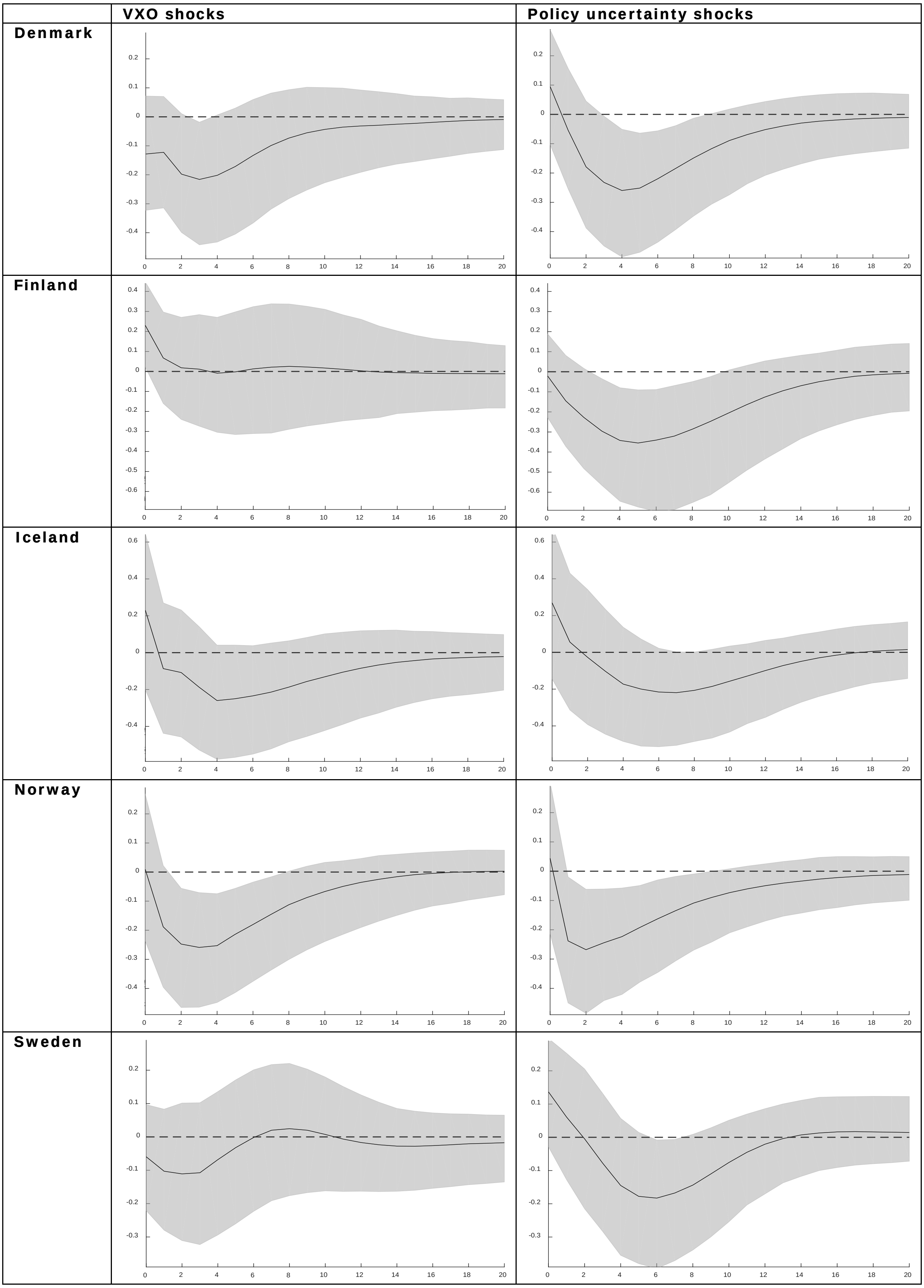
Note: Shocks in columns, responses in rows. Black line is the median and the coloured band is the 90% confidence band. Quarters are given on the horizontal axis.

Figure A12. Impulse response functions of BVAR model with policy uncertainty using year-on-year growth rates for GDP and CPI.



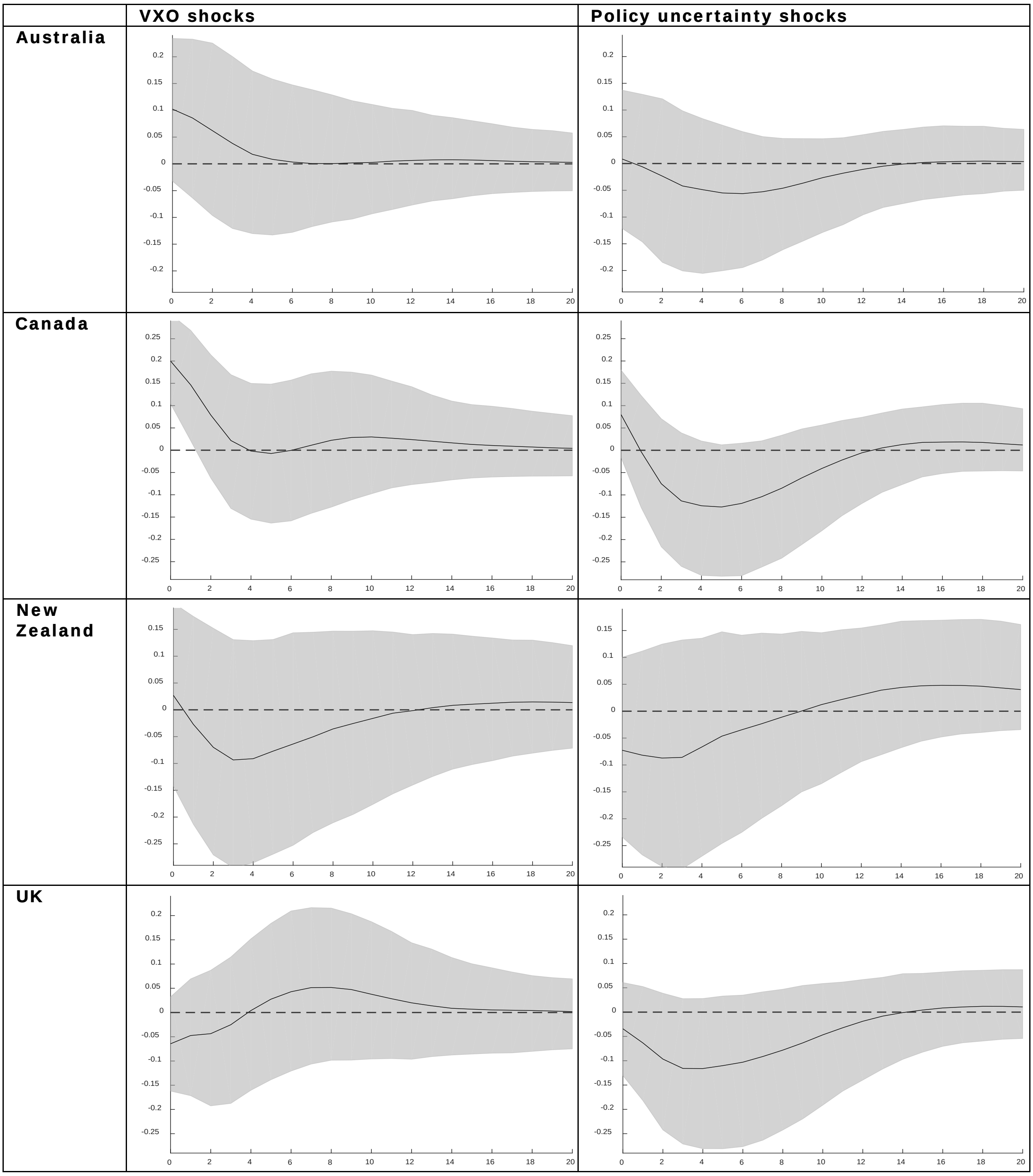
Note: Shocks in columns, responses in rows. Black line is the median and the coloured band is the 90% confidence band. Quarters are given on the horizontal axis.

Figure A13. Impulse response functions. Estimated effects on GDP growth in the Nordic countries of BVAR model using year-on-year growth rates for GDP and CPI.



Note: Percentage points on the vertical axis and quarters on the horizontal axis. Black line is the median and the coloured band is the 90% confidence band.

Figure A14. Impulse response functions. Estimated effects on GDP growth in the Anglo-Saxon countries of BVAR model using year-on-year growth rates for GDP and CPI.



Note: Percentage points on the vertical axis and quarters on the horizontal axis. Black line is the median and the coloured band is the 90% confidence band.