EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

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What has driven inflation dynamics in the Euro area, the United Kingdom and the United States

No 1802 / June 2015

Abstract

This paper studies factors behind inflation dynamics in the euro area, the UK and the US. It introduces a factor-augmented vector autoregression (FAVAR) framework with sign restrictions to study the effects of fundamental macroeconomic shocks on inflation in the three economies. The FAVAR model framework is also applied to study the effects on inflation subcomponents in the more recent past. The FAVAR models suggest that headline inflation in the three economies has reacted in a relatively similar fashion to macroeconomic shocks over the last four decades, with demand shocks causing the most persistent effects on inflation. According to the subcomponent FAVAR models, the responses of inflation subcomponents to macroeconomic shocks have also been relatively similar in the three economies. However, there is evidence of a stronger foreign exchange channel of monetary policy transmission as well as supply shocks in the responses of non-energy tradable goods prices in the UK than the other two economies, while the reaction of services inflation has been more muted to all types of shocks in the euro area than the other two economies.

Keywords: FAVAR, inflation, sign restrictions, macroeconomic shocks

JEL Classification: C22, C32, E31, E52

Non-technical summary

The aim of the paper is to study macroeconomic factors that have driven inflation dynamics in the euro area, the UK and the US over the past few decades. The emphasis is on using established empirical time-series techniques to highlight differences in inflation dynamics between the three economies. In particular, the current study examines the effects of different macroeconomic shocks (monetary policy, demand and supply shocks) on headline inflation dynamics with a multivariate model over the longer term, and then uses a version of the same model to study the effects of shocks on inflation subcomponents in the more recent past.

The study aims to make two main contributions to the literature on inflation dynamics in major advanced economies. First, it introduces a multivariate time-series framework identification scheme based on sign restrictions that allows for separating the relative importance of different macroeconomic shocks for inflation dynamics. Second, it uses the model framework to study responses of inflation subcomponents to different macroeconomic shocks. The emphasis is on comparisons between the effects in the three economies.

The most important results of the analysis carried out in the current study are as follows. Overall, the multivariate models suggest that, while there have been some cross-country differences in the responses, headline inflation in the three economies has reacted in a relatively similar fashion to macroeconomic shocks over the last four decades, with demand shocks causing the most persistent effects on inflation in all three cases. In the US, supply shocks have had more of a negative medium-term effect on the US economy, and the more pronounced short-term responses to shocks point to a more flexible pricing mechanism than in the European economies.

According to the inflation subcomponent models, the responses of inflation subcomponents to macroeconomic shocks have been relatively similar in the three economies. However, there is evidence of a stronger foreign exchange channel of monetary policy transmission as well as supply shocks in the responses of non-energy tradable goods prices in the UK than the other two economies, while the reaction of services inflation has been more muted to all types of shocks in the euro area than the other two economies.

No firm conclusions on the reasons behind the different responses between the three economies can be drawn based on the analysis, but there is tentative evidence for product market flexibilities, regulation and taxation being important drivers. This is most obviously evident in the more muted responses in the multivariate models for the euro area, which is typically a less flexible economy in terms of labour and product market functioning. Furthermore, over the past 10-20 years, shocks appear to have been transmitted more strongly to the non-tradables sector of the two countries with the more intense domestic competition (the UK and the US). Overall, from a policy perspective, it is obvious that policies promoting flexible and competitive product markets allow for quicker and more transparent transmission of macroeconomic shocks to the prices of final consumer goods and services. Regarding monetary policy, the current study offers further evidence on the importance of differentiating between demand and supply shocks in central bank reaction functions. In addition, country-specific responses to macroeconomic shocks can differ depending on the specific features of an economy, which can also imply differences from a policy perspective.

1. Introduction

The aim of the paper is to study macroeconomic factors that have driven inflation dynamics in the euro area, the UK and the US. The emphasis is on using established empirical techniques to highlight differences in inflation dynamics between the three economies. In particular, the current study examines the effects of general macroeconomic shocks on headline inflation dynamics with a factor-augmented vector autoregression (FAVAR) model over the longer term, and then uses simple two-variable VAR models to study the effects of shocks on inflation subcomponents in the more recent past.

Due mainly to data limitations, there has been very little research into comparing inflation subcomponent dynamics between different countries. However, recently published data on comparable inflation data for the main Harmonised Index of Consumer Prices (HICP) subcomponents allows for some comparisons to be made between the euro area, the UK and the US for the recent past.

The FAVAR approach was first introduced by Bernanke et al. (2005) to study the effects of monetary policy shocks in the US in a data-rich environment, where some of the forces driving the economy were unobserved. It has since been used extensively in various strands of empirical macroeconomic literature, both for studying the effects of structural shocks as well as for forecasting purposes. To mention a few examples of studies using structural analysis, FAVARs have been applied to study monetary policy shocks in other advanced economies (Blaes (2009), Lagana and Mountford (2005)), time-varying effects of monetary policy shocks (Eickmeier et al. (2011), Mumtaz (2010)), country-specific effects of various global shocks (Bagliano and Morana (2008), Mumtaz and Surico (2009), Vasishtha and Maier (2013)) and oil price shocks (Aastveit (2009)). Furthermore, Belviso and Milani (2006) extended the FAVAR framework to a case where the factors are given an economic interpretation.

Despite the popularity of the FAVAR approach in recent empirical macroeconomic literature, most studies have concentrated on the effects of monetary policy shocks, and primarily identified the shocks through some type of causal ordering (like the Choleski decomposition). However, it could also be useful to incorporate other shocks in the model, and use different identification schemes for the shocks. This would allow for comparisons of the relative importance of the different shocks for the variables in the model.

The current study aims to make two main contributions to the literature on inflation dynamics in major advanced economies. First, to my knowledge uniquely, it introduces a FAVAR framework identification scheme based on sign restrictions that allows for separating the relative importance of different fundamental shocks for inflation dynamics. In this respect, the current study is similar in spirit to Karagedikli and Thorsrud (2010), who study the effects of different global shocks on macroeconomic variables in New Zealand using sign restrictions. Second, it uses the FAVAR model to study responses of inflation subcomponents to different macroeconomic shocks. The emphasis is on comparisons between the effects in the three economies.

The most important results of the analysis carried out in the current study are as follows. The FAVAR models suggest that, while there have been some cross-country differences in the responses, headline inflation in the three economies has reacted in a relatively similar fashion to macroeconomic shocks over the last four decades, with demand shocks causing the most persistent effects on inflation in all three cases. In the US, supply shocks have had more of a negative medium-term effect on the US economy, and the more pronounced short-term responses to shocks point to a more flexible pricing mechanism than in the European economies. According to the subcomponent FAVAR models, the responses of inflation subcomponents to macroeconomic shocks have been relatively similar in the three economies. However, there is evidence of a stronger foreign exchange channel of monetary policy transmission as well as supply shocks in the responses of non-energy tradable goods prices in the UK than the other two economies, while the reaction of services inflation has been more muted to all types of shocks in the euro area than the other two economies. Overall, the study offers support for enhancing flexible and competitive product markets, and emphasises the importance of identifying the source of macroeconomic shocks for monetary policy reaction functions.

The paper is organised as follows. Section 2 looks at inflation subcomponents and stylised inflation facts in the euro area, the UK and the US. Section 3 presents the results of the FAVAR analysis and section 4 of the subcomponent FAVAR analysis. Section 5 concludes. Most of the charts and tables as well as details of the methodologies used are relegated to the appendices.

2. Inflation subcomponents and stylised facts

There have been relatively large differences in inflation dynamics in the three economies over the past 15 years or so[3] (Chart 1). Inflation in the US is traditionally much more volatile than in the other two areas, reflecting, among other things, the lower petrol taxes and hence larger effect of oil price changes for consumer price inflation in the US. Overall, inflation rates have been positively correlated between the three economies, especially in recent years.

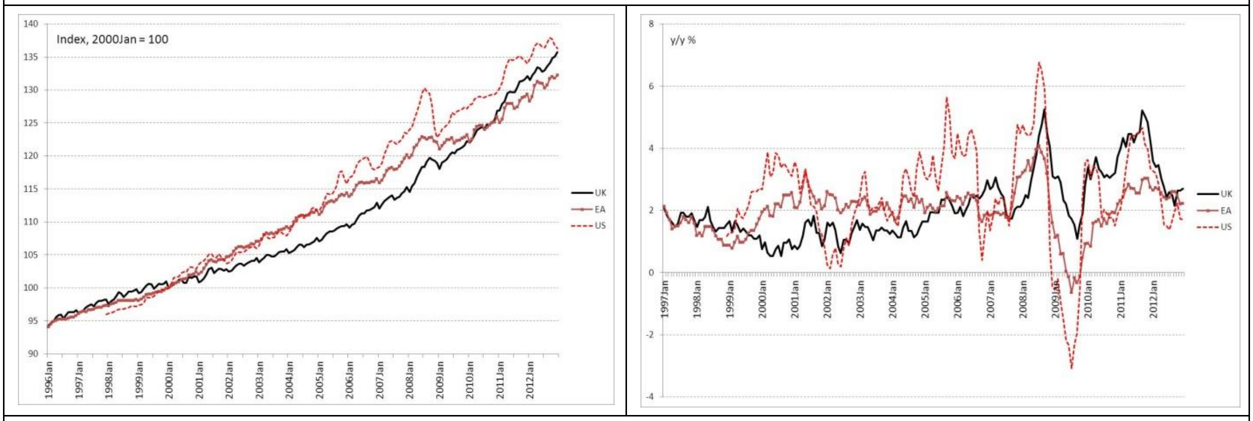
Chart 2 compares the main Classification of individual consumption by purpose (COICOP) components ("Special Aggregates", noted SA from now on) of HICP inflation for the euro area and the UK, as well as CPI inflation data for the US[4]. For some of the components, especially for the energy component, inflation dynamics have tended to be relatively similar for the three economies, although there are differences in all the components. In particular, when comparing the euro area and the UK, two features stand out, also reflecting the higher overall inflation in the UK in recent years. First, there was a large jump in non-energy industrial

[3] This section concentrates on recent inflation dynamics due to the availability of comparable data between the three economies. For constructions of longer historical inflation time series, see Section 3 and Appendix 7.

[4] The US CPI data is not comparable with the HICP data for the euro area and the UK in terms of methodologies and composition, and the "Special Aggregates" decompositions for the US are partly based on arbitrary divisions of components by the author. Hence, due caution should be exercised when interpreting the US data and results regarding the inflation SA subcomponents.

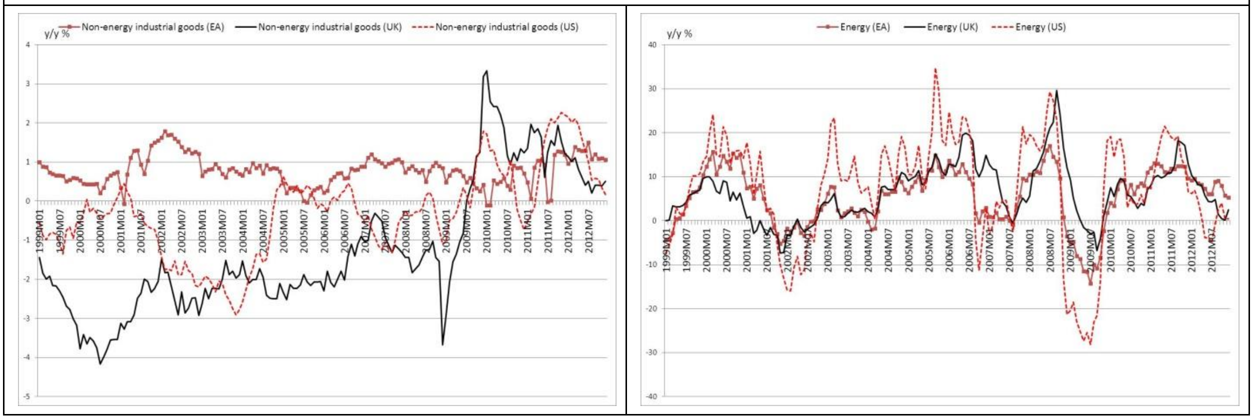
goods inflation in the UK in 2009, and second, services inflation has been persistently higher in the UK than in the euro area. The former development is related to clothing and car prices, which were probably particularly strongly affected by the lagged effects of the depreciation of the pound sterling in 2008. The latter development appears to be due to persistently higher inflation in the UK for a broad-based range of services subcomponents, although large inflation differences in education and restaurant services subcomponents stand out. Overall, no single component explains the recent differences in inflation between the three economies. The higher inflation rates in the UK are apparent in many components, probably reflecting both domestic and external factors.

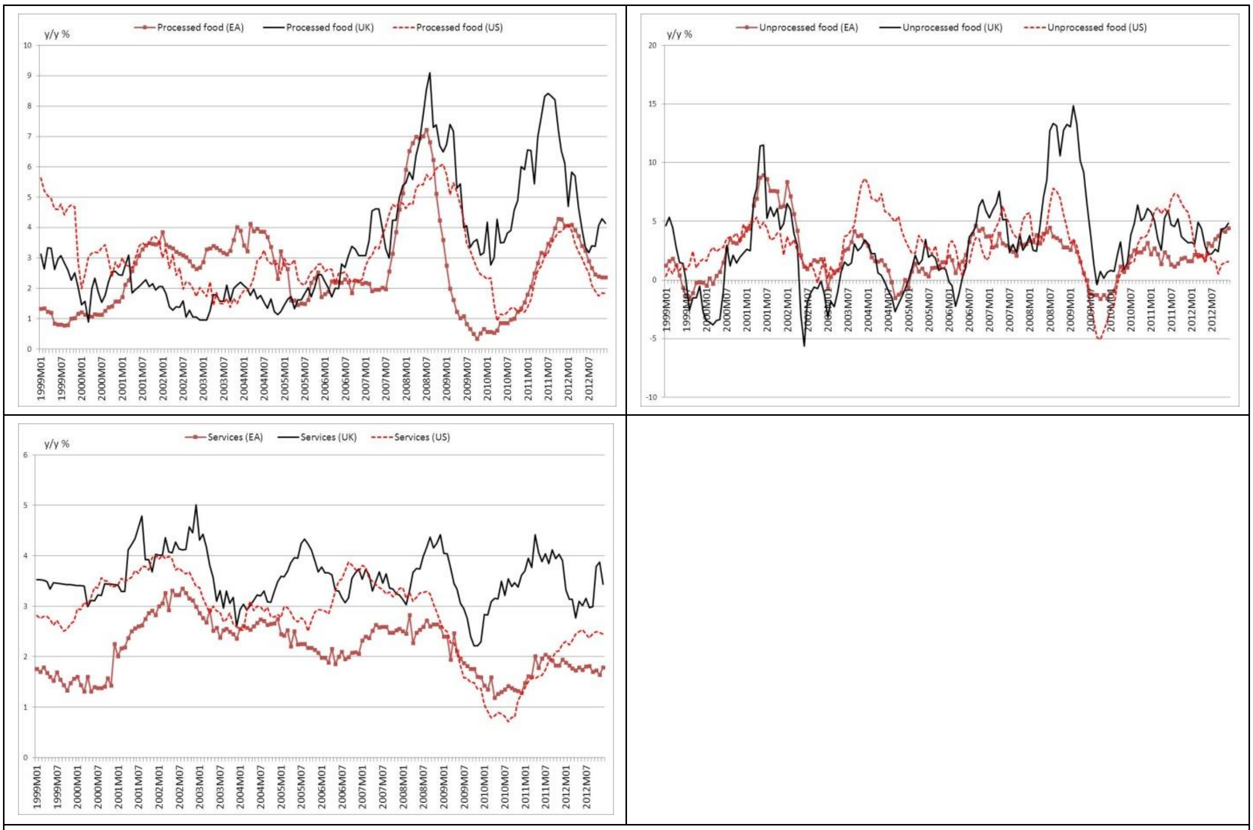
Chart 1. Inflation (HICP measure) in the EA, UK and US



Source: Eurostat

Chart 2. Inflation (HICP definition) components in the EA and the UK





Source: Eurostat

As a further illustration of the differences in subcomponent inflation dynamics between the three economies, the probability distributions of the inflation rates of the 12 main COICOP/HICP subcomponents[5] are presented in Appendix 1 (see legend key in the appendix for details of the subcomponent groups) with a sample[6] of 1999M1 to 2012M12. The charts suggest that the distributions of the subcomponents are relatively diverse both within and across countries, although most of the modes of the distributions tend to be in slightly positive territory (which is not surprising given the explicit/implicit monetary policy targets of the three economies). Overall, some of the distributions (especially the transport subcomponent) for the US tend to be much more dispersed than for the other two cases.

To conclude, despite similarities in general inflation trends in the three economies, there have been some large differences in inflation dynamics, especially when examining inflation subcomponents. This serves as motivation for the next two sections, which use econometric frameworks to look at the effects of general macroeconomic shocks on inflation in the three economies, and also attempts to draw conclusions on cross-country differences.

[5] Unlike the SA subcomponents presented above, the 12 main subcomponents are available in comparable form for the US as well. The kernel smoothing density estimates are calculated with the Epanechnikov smoother with 100 data points.

[6] This is the longest sample available so that all three economies can be included with identical sample lengths and data coverage.

3. FAVAR approach to inflation shocks

To analyse further the macroeconomic factors affecting inflation in the three economies over a longer historical time period, this section studies the effects of different shocks in a structural econometric modelling framework. The first subsection introduces the model, and the second highlights the main results.

3.1 Modelling strategy and data

One way of studying the effects of different macroeconomic shocks on inflation dynamics is with vector autoregression (VAR) innovation accounting. More specifically, I use factor augmented VARs (FAVAR) to allow for a large set of time series to define factors which might affect inflation dynamics. The FAVAR approach[7] used in the current study is a modification of the original model introduced by Bernanke et al. (2005). In the original model, only monetary policy shocks are identified through a traditional Choleski identification scheme. However, in the current study, the aim is to identify different kinds of orthogonal shocks driving inflation developments, not merely the monetary policy shock. To achieve the identification of the shocks without reverting to arbitrary Choleski type ordering of the shocks, I use two types of sign restriction strategies[8], as introduced by Uhlig (2005) (and refined by Rubio-Ramirez et al. (2010)) and Inoue and Kilian (2013). The first one of these (called RWZ method from now on) is a traditional way of imposing sign restrictions in a VAR model, while the second one is used as a complementary tool based on more solid theoretical foundations than the first one. Hence, the results presented below based on the Inoue-Kilian method can be interpreted as a check on the validity of the results based on the traditional methodology.

Sign restrictions imposed to identify the shocks in the model are presented in Table 1. There are four types of shocks in the model; demand, supply, monetary policy and "residual". In a traditional demand/supply framework, demand shocks can be thought of as shocks that move the demand curve to the right, causing an increase in both activity and prices. Monetary policy can be expected to react with a rate hike to this shock[9]. Supply shocks (typically cost shocks, like oil supply disruptions), on the other hand, move the supply curve to the left, leading to an increase in prices but a decrease in activity. As the reaction of monetary policy to this type of shock is not ex ante obvious, this restriction is not imposed for the supply shock. In addition to the demand and supply shocks, monetary policy shocks are also included, with the conventional restrictions that in the short term, a rate cut will lead to an increase in prices and in real activity (or at least not to a decrease in prices and activity). The last, "residual" shock captures all effects not captured by the other three shocks. This can be assumed to include mainly expectational shocks, like changes in monetary policy credibility, as well as shocks to inflation persistence. Note that all shocks are orthogonal to each other (as per the structural VAR framework), and that all shocks are defined so as to increase inflation to facilitate comparisons.

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[7] For more details of the FAVAR approach see Appendix 2.

[8] For more details of the sign restriction strategies see appendices 3 and 4.

[9] The results reported below are also qualitatively similar without this restriction.

Table 1: Sign restrictions with pure sign restriction approach

Shock\variable	Interest rate	Demand factor	Cost factor	Inflation
Monetary policy shock	-	+		+
Demand shock	+	+		+
Supply shock		-	+	+
"Residual" shock				+
Note: empty cell indicates the sign is not restricted. All restrictions also include a zero response.				

The model used is a 4-variable VAR, with monthly data[10] from 1975M1 to 2012M12. The model includes 8 lags[11]. The four variables in the model are monetary policy rate (for the euro area, the 3-month short term market rate), a real activity factor, a cost factor (price variables in y/y change terms) and an inflation factor[12] (in y/y change terms). The factors are computed by methods introduced by Banbura and Modugno (2010), as their algorithm is especially suited for estimating dynamic factors in the presence of missing data[13]. The variables included in the real activity, cost and inflation factors are listed in Appendix 6, and the estimated factors themselves (along with the interest rate variable) are presented in Appendix 7. The dynamics of the factors appear largely plausible. The real activity factor exhibits cyclical movement, which differs somewhat across the three economies, with the euro area cycle tending to lag the other two economies. In contrast, the cost factors are relatively similar, especially in the euro area and the UK, due to the global nature of commodity price shocks in particular. The inflation factor shows how inflation has stabilised at low levels after the volatile dynamics in the beginning of the sample. All the factors are stationary, as required for the FAVAR model formulation.

The variable selection in the VAR requires some justification. Bernanke et al. (2005) demonstrate how a simple structural macroeconomic model can be written in VAR form, and in particular, they show that equation A(3) (Appendix 2) takes the following form:

[10] For the euro area, there are significant limitations to data prior to 1985. However, using the ECB Area Wide Model database, quarterly data for inflation, short-term interest rate and unemployment rate are available. For the current study, this data is transformed to monthly frequency with linear disaggregation.

[11] While it is more conventional to use 12 lags, guided by standard lag selection criteria and also in the interest of keeping the models parsimonious, 8 lags are used in all the models, even though most of the results are qualitatively robust to both longer and shorter lag lengths. Standard diagnostic tests suggest that the models are stable, i.e. no roots lie outside the unit circle.

[12] In the spirit of Bernanke et al. (2005), only the interest rate is considered to be a directly observable variable, while the other variables in the model are presented by the factors. Inflation, despite being available as a monthly CPI/HICP series, is also presented by different type of inflation time series (including quarterly national accounts deflators) in the three economies, and hence, is defined as an inflation factor in the models. Note that all variables in the factors are mean-variance standardised before the estimation procedure, facilitating comparisons across the three economies.

[13] For more details of the methodology, see Appendix 5.

$$\begin{bmatrix} y_t^n \\ s_t \\ \pi_t \\ y_t \\ R_t \end{bmatrix} = \begin{bmatrix} \rho & 0 & 0 & 0 & 0 \\ 0 & \alpha & 0 & 0 & 0 \\ 0 & \alpha & \delta & \kappa & -\kappa \\ 0 & 0 & \psi & \phi & -\psi \\ -\gamma\psi & \beta\alpha & (\beta\delta+\gamma\psi & (\beta\kappa+\gamma\phi) & -(\beta\kappa+\gamma\rho) \end{bmatrix} \begin{bmatrix} y_{t-1}^n \\ s_{t-1} \\ \pi_{t-1} \\ y_{t-1} \\ R_{t-1} \end{bmatrix} + \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ \gamma & 1 & -\gamma & \beta \end{bmatrix} \begin{bmatrix} d_t \\ \varepsilon_t \\ \eta_t \\ \upsilon_t \end{bmatrix} \quad (1)$$

where y_t^n is potential output at time t, y_t is actual output, s_t is a cost-push shock, π_t is inflation, R_t is monetary policy rate, d_t is a demand shock, ε_t is a monetary policy shock, η_t and υ_t are error terms for potential output and cost-push shock equations, respectively, and all the other terms are parameters of the model to be estimated. Note that the third row corresponding to the inflation variable relates inflation to the past cost-push shock, output, monetary policy rate and inflation itself. Hence, based on this formulation, the choice of variables in the FAVAR used in the current study, linking inflation to its fundamental theoretical drivers, appears intuitive. Also note that only the interest rate is assumed to be observable (i.e. term Y in equation (A4)), while the other factors are unobservable and consequently need to be obtained through the FAVAR methodology.

3.2 Results

The impulse response functions (for a one-standard-deviation shock) of the FAVAR estimations for the euro area, the UK and the US are presented in Chart 3 and Appendix 8 (the latter facilitating cross-country comparisons). These are the result of 2,000 accepted draws, and the sign restrictions are set for 6 months (although qualitatively similar results can be achieved with setting the restrictions for only 1 month). An additional restriction requiring the response to the monetary policy shock to be higher during the first six months than the initial impact period is also made. This is done to ensure that only draws mimicking known lags in the monetary policy transmission mechanism are accepted.

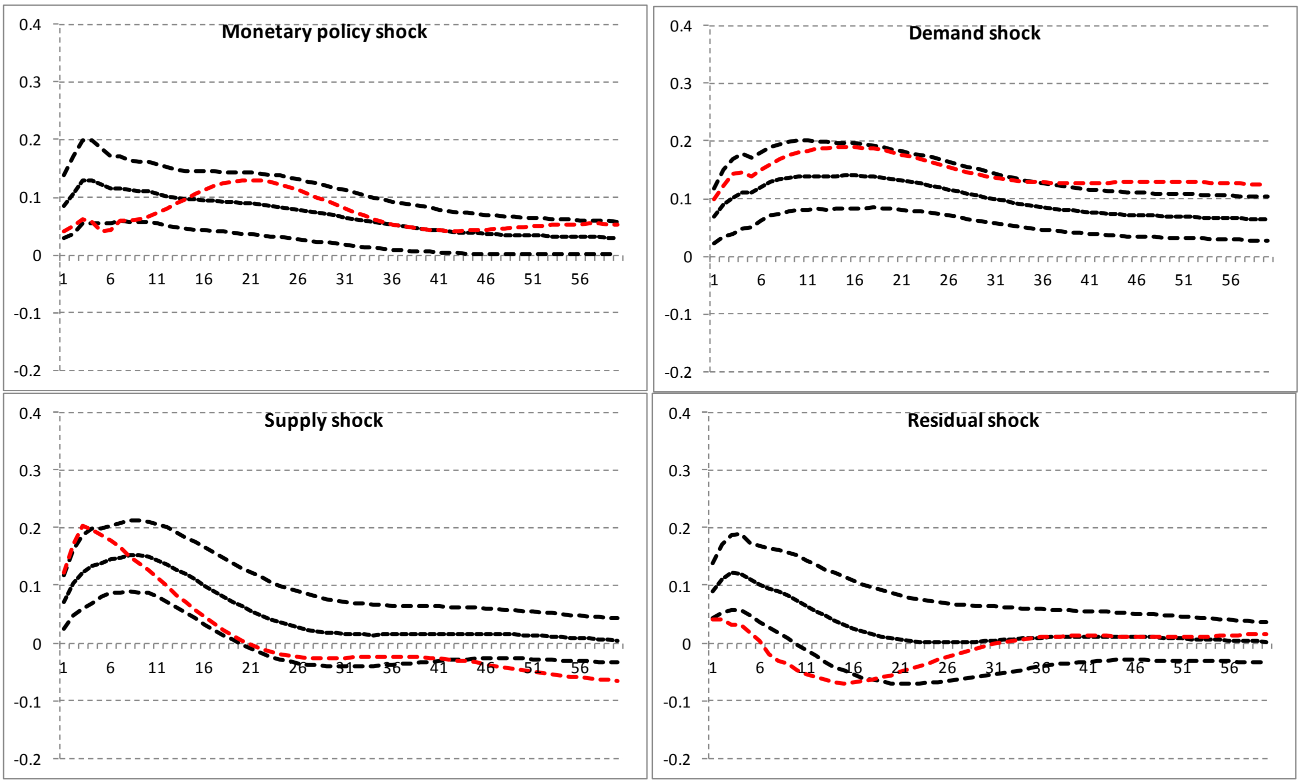
Overall, the results conveyed by the impulse responses are relatively similar for the three economies studied, probably also due to the similarity of shocks and business cycles affecting them. In particular, the effects of the residual shocks have been relatively muted, suggesting that there have not been major problems related to monetary policy credibility in these economies. However, there have also been some interesting cross-country differences, as the size and shape of the responses has been somewhat different across the three economies. The results suggest that over the sample period, demand shocks have been the most persistent drivers of inflation in the euro area and the UK, whereas monetary policy shocks have had the most persistent effect in the US. Furthermore, the short-term responses to shocks have tended to be more pronounced in the US, possibly due to a more flexible pricing mechanism than in the European economies. In the US, medium-term responses to supply shocks show more of a deflationary effect than in the other two economies, suggesting that supply shocks (possibly caused by oil shocks) have had more of a negative effect on the US economy. In the euro area, the shocks have tended to cause a more muted, but also more persistent response than in the other two economies. This could be related to labour and product market rigidities, which have generally been more apparent in the euro area than in the UK or the US[14].

Given the disruptions to economic growth during the recent global financial crisis period starting in 2008, an interesting question is to what extent the results of the current analysis change during this period. Overall, the benchmark results stay qualitatively similar if one excludes the crisis period (sample ends in 2007M12). However, the benchmark model overlooks the fact that various unconventional monetary policy measures have been introduced in all three economies in recent years and hence, it is questionable whether the interest rate variable reflects monetary policy stance to a satisfactory degree. While measuring the monetary policy stance in this simple model framework is challenging, a tentative analysis (where the interest rate variable is replaced by an indicator that also takes into account changes in narrow money (M1)) was carried out. Again, the results are qualitatively quite similar to the benchmark results. One needs to keep in mind that the crisis period is a small part of the overall sample, and the results are mainly driven by dynamics prior to the crisis. Nevertheless, while a more detailed analysis of the effects of the Great Recession is left for future research, the analysis suggests that there have not been any fundamental changes in the response of inflation to different shocks despite the volatile nature of the main model variables in recent years.

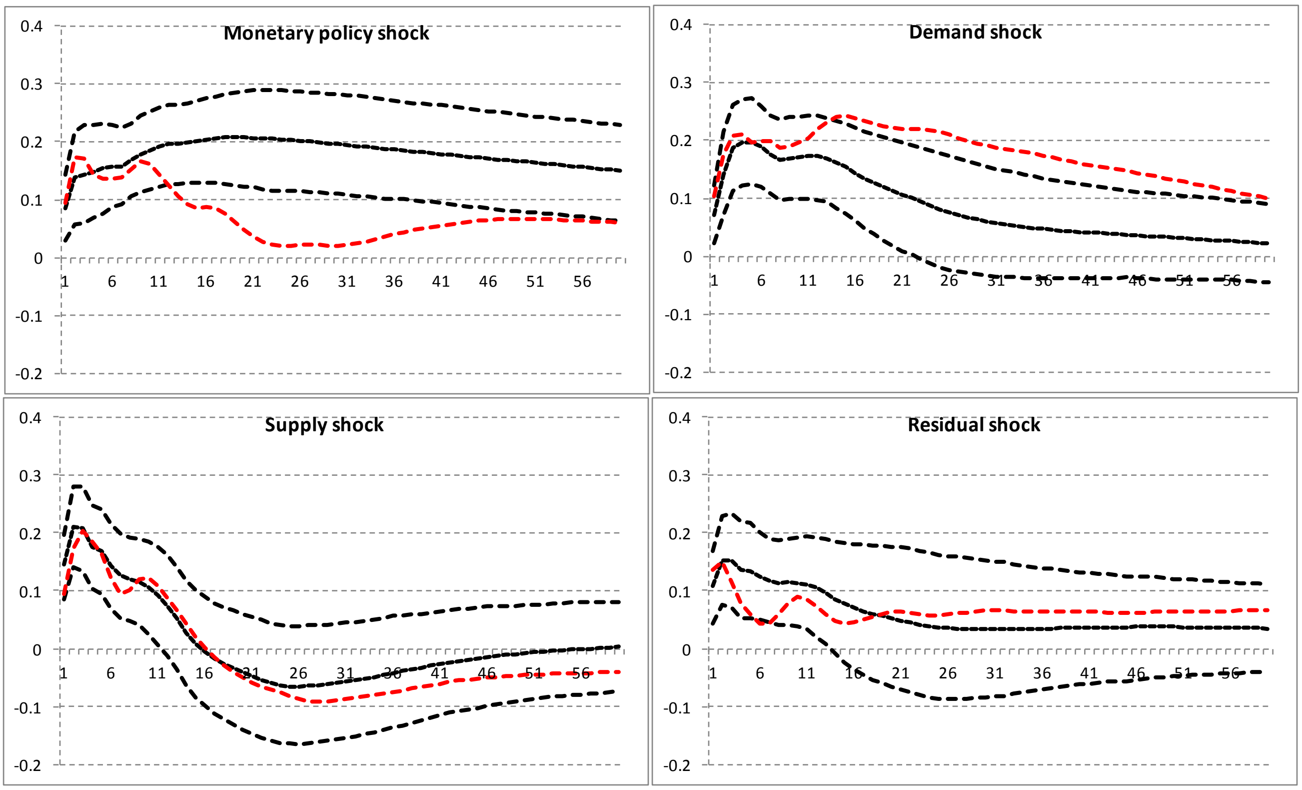
The modes of the Inoue-Kilian methodology are also presented in the charts (the lighter solid lines). Generally, these tend to fall within the confidence intervals of the RWZ method and hence support the latter results. Two exceptions are the responses to monetary policy and demand shocks in the US. The former have been more muted and the latter more pronounced with the Inoue-Kilian method compared with the RWZ method. The one common theme emerging from both the RWZ and the Inoue-Kilian method is the persistence of the inflationary effects of demand and monetary policy shocks compared to supply shocks, whereas the responses to residual shocks do not indicate problems with the credibility of monetary policy.

[14] For independent evidence of this, see , for example, labour and product market efficiency indicators published by World Economic Forum (2013).

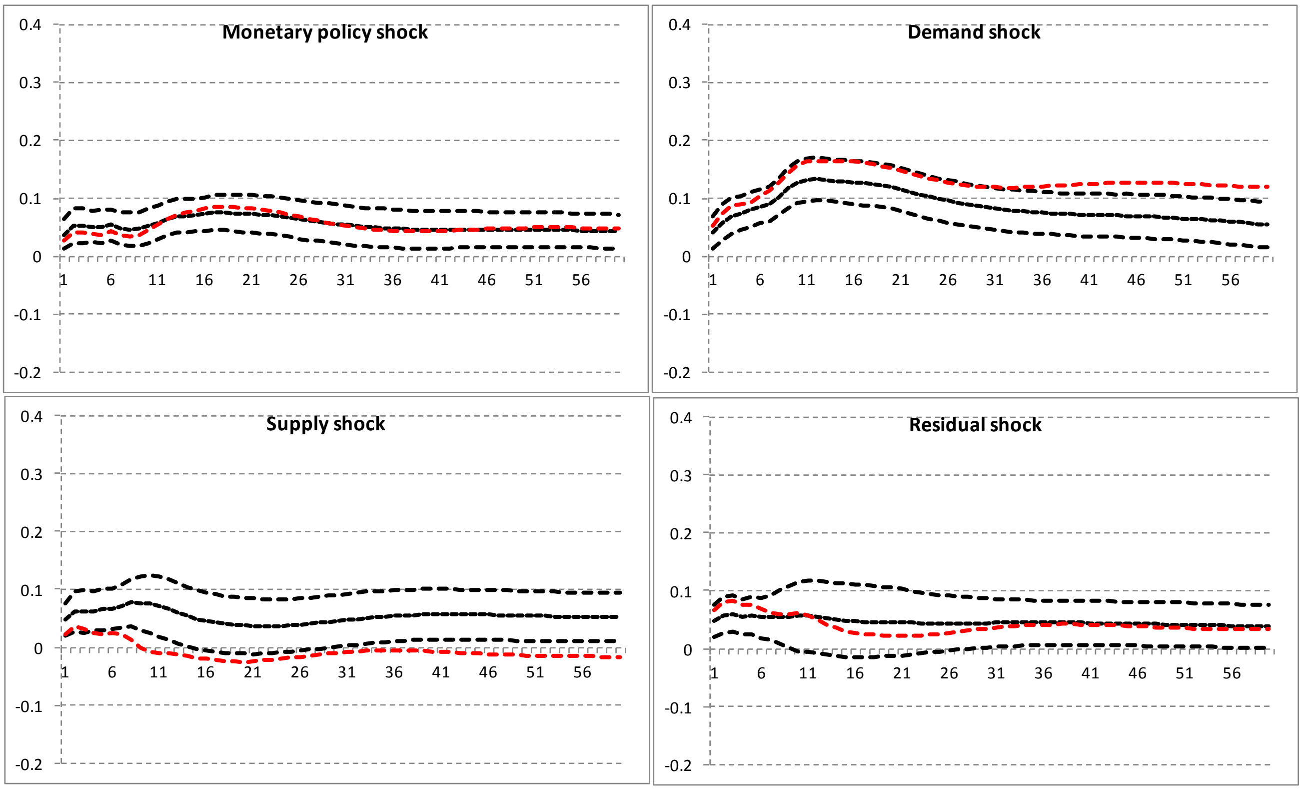
Chart 3. Impulse response analysis (16th, 50th and 84th percentiles)



(1) The UK



(2) The US



(3) The EA

4. Subcomponent analysis

4.1 Methodology

To shed further light on recent inflation dynamics in the three economies, an empirical analysis of the main inflation subcomponents, concentrating on the more recent past than the FAVAR analysis above, was also carried out. More specifically, I want to study the effects of the shocks in the FAVAR models on different inflation subcomponents for the three economies. The data sample available for the subcomponents is relatively short for most of the subcomponents. Specifically, for the subcomponent analysis I will use the five COICOP SA subcomponents for each country (available from 1999M1 to 2012M12) and in addition, I will use a split of headline inflation into goods and services subcomponents (available for all countries from 1991M1 to 2012M12). Methodologically, I will use, in turn, the seven different subcomponents as the 5th variable in the benchmark FAVAR models, hence preserving the theoretical foundations of the model introduced above[15]. Furthermore, as for the benchmark FAVAR model, the identification of shocks is carried out by sign restrictions of the RWZ type, where inflation subcomponents are restricted to show a non-negative response to positive demand and supply shocks and negative monetary policy shocks (see Table 2). In addition, the sign restriction framework is completed by two types of "residual" shocks. Residual shock 1, which is defined in the same way as in the benchmark model, and residual shock 2, which is defined the

[15] This approach is similar in spirit to the one used by Christiano et al. (1996) for studying the effects of monetary policy shocks.

residual shock in the specific CPI subcomponent. It is also worth noting that even though in the subcomponent analysis, the two different residual shocks cannot be empirically disentangled from each other, for analytical completeness, a positive residual shock 2 automatically has a positive effect on headline CPI inflation, whereas residual shock 1 does not necessarily affect the subcomponents. This is because the CPI headline inflation includes the subcomponent and hence must move in the same direction as the subcomponent, whereas a particular subcomponent, of course, does not necessarily include all residual shocks affecting the headline inflation. Analogously with the benchmark FAVAR approach above, I will use a parsimonious lag structure (in the subcomponent case, six lags) in the subcomponent models, also because the samples are relatively short.

Table 2: Sign restrictions with pure sign restriction approach – subcomponent models

Shock\variable	Interest rate	Demand factor	Cost factor	Inflation	Inflation subcomponent
Monetary policy shock	-	+		+	+
Demand shock	+	+		+	+
Supply shock		-	+	+	+
“Residual” shock 1				+	
“Residual” shock 2				+	+

Note: empty cell indicates the sign is not restricted. All restrictions also include a zero response. For the distinction between “residual” shocks 1 and 2, see main text.

4.2 Results

The results of the subcomponent analysis are presented in Chart 4. The reactions of different subcomponents are presented in rows and the three economies in columns to facilitate cross-country comparisons. Overall, no consistent patterns of different dynamics emerge between the three economies, and most responses have been relatively similar, as could be expected from three advanced open economies. The responses in the euro area have tended to be slightly more muted for most subcomponents, which is also consistent with the information in Appendix 1. There are also some diverging subcomponent-specific dynamics worth noting.

In terms of absolute magnitude, the energy subcomponent has been the one most strongly affected by all types of shocks in all three economies. This is in line with the large movements seen in energy prices over the last decade or so. The results are further proof that energy prices have been buffeted by large shocks in recent years, and these shocks are transmitted relatively quickly and strongly to the final energy prices. It is also worth noting that the short-term energy inflation reactions have been larger in the US than in the other two economies for all types of shock. This most likely reflects the lower petrol taxation in the US, which means that shocks of similar size are transmitted to a larger extent to energy prices without the cushioning effect of higher taxation. Furthermore, demand shocks tend to have a much more persistent positive effect on energy inflation than supply shocks, especially in the US. While the short sample period prevents drawing strong conclusions, this result is consistent with recent evidence from oil market VARs of supply shocks having deflationary medium-term effects (see, for example, Melolinna (2012)).

The UK stands out as having larger and more persistent responses to supply and monetary policy shocks for non-energy goods than the other two economies, especially in the shorter sample (row 3 in Chart 4). One plausible explanation for this interesting result could be a larger exposure of goods prices to exchange rate movements in the UK and in fact, there is supporting evidence for this. First, the share of imported goods of final household consumption has been consistently higher in the UK over the past 25 years than in the other two economies and hence, *ceteris paribus*, exchange rate movements are likely to have a larger effect on goods prices in the UK. Second, carrying out a tentative structural VAR analysis on the effects of monetary policy on nominal effective exchange rates[16] also suggests that the exchange rate has reacted more strongly to monetary policy shocks in the UK than in the other two economies. Hence, it suggests that monetary policy could be more effective in the way it affects tradable goods prices in the UK. While a more detailed analysis beyond the scope of the current study would be required to confirm these results, it would appear that due to a larger exposure to foreign exchange and import price fluctuations, monetary policy and supply shocks have been transmitted to a larger extent to final tradable goods prices in the UK than in the other two economies.

For the food subcomponents, the results are relatively similar across the three economies. The one thing standing out is the relatively large short-term reaction to shocks for the UK. Again, to the extent that food is imported rather than produced domestically, this could be linked to the sensitivity of import prices and foreign exchange rates to shocks detailed above.

For the services subcomponent, demand and monetary policy shocks have tended to be larger and more persistent drivers of inflation than supply shocks. This is probably due to the import price/exchange rate channel being less important for non-tradable services than for tradable goods. There are some interesting cross-country differences in the services subcomponent response functions, especially when the longer sample is considered[17] (row 7 in Chart 4). In particular, for the euro area, the response to demand and supply shocks

[16] The VAR includes four variables; interest rate, demand factor, inflation and a nominal effective exchange rate index (from the IMF IFS database) with a sample of 1990M1 to 2012M12. The model is identified with sign restrictions for a monetary policy shock, where a positive policy shock (i.e., an interest rate hike) is restricted to cause a non-positive short-term response for the demand factor and inflation and a non-negative short-term response for the spot exchange rate. For monetary policy identification schemes of similar type, see, for example, Scholl and Uhlig (2008).

[17] It is worth emphasising that for the services subcomponent, the longer sample contains more relevant information as the definition of the subcomponent is the same as for the shorter sample. In contrast, the longer sample for the goods subcomponent is a cruder measure than the different goods subcomponents in the shorter sample, and hence additional information can be elicited from the shorter sample for goods.

has been more muted than in the other two economies. Without more detailed analysis and data, it is difficult to know the reasons for this result[18], but it is worth noting that in the World Economic Forum Global Competitiveness Indicators subcategory measuring the intensity of local product market competition, the UK and the US have, on average, ranked higher (indicating more competition) than the euro area. Hence, it is possible that the quicker and larger transmission of shocks to services inflation in the UK and the US is at least partly related to more intense competition in the services sector.

5. Conclusions

The analysis carried out in the current study leads to a number of conclusions. Overall, the structural FAVAR models suggest that headline inflation in the three economies has reacted in a fairly similar fashion to standard macroeconomic shocks over the last four decades, with demand shocks causing the most persistent effects on inflation in all three cases. However, there are differences between the three economies in the way inflation has responded to shocks. Demand shocks have been more persistent drivers of inflation in the UK and the euro area compared to the US, where monetary policy has been more important. Furthermore, in the US, supply shocks have had more of a negative medium-term effect on the US economy, and the more pronounced short-term responses to shocks point to a more flexible pricing mechanism than in the European economies. The fact that shocks have tended to cause a more muted, but also more persistent response in the euro area than in the other two economies is consistent with other studies finding labour and product market to be less flexible in the euro area.

The FAVAR model framework was also applied to study the effects of general macroeconomic shocks on inflation subcomponents since 1991. The results of this analysis reveal that, overall, the responses to shocks have tended to be relatively similar across the three economies, with slightly more muted responses in the euro area than the other two economies. The main finding from the subcomponent analysis is the more pronounced and more persistent response of tradable goods prices to monetary policy and supply shocks in the UK compared with the other two economies in the recent past, which is also corroborated by other evidence on a stronger foreign exchange channel of monetary policy transmission in the UK. There have been some differences in the response of services prices to macroeconomic shocks across the three economies. In particular, there are some signs of services inflation in the euro area reacting in a more muted fashion to all types of shocks than the other two economies, which may be related to competitiveness issues.

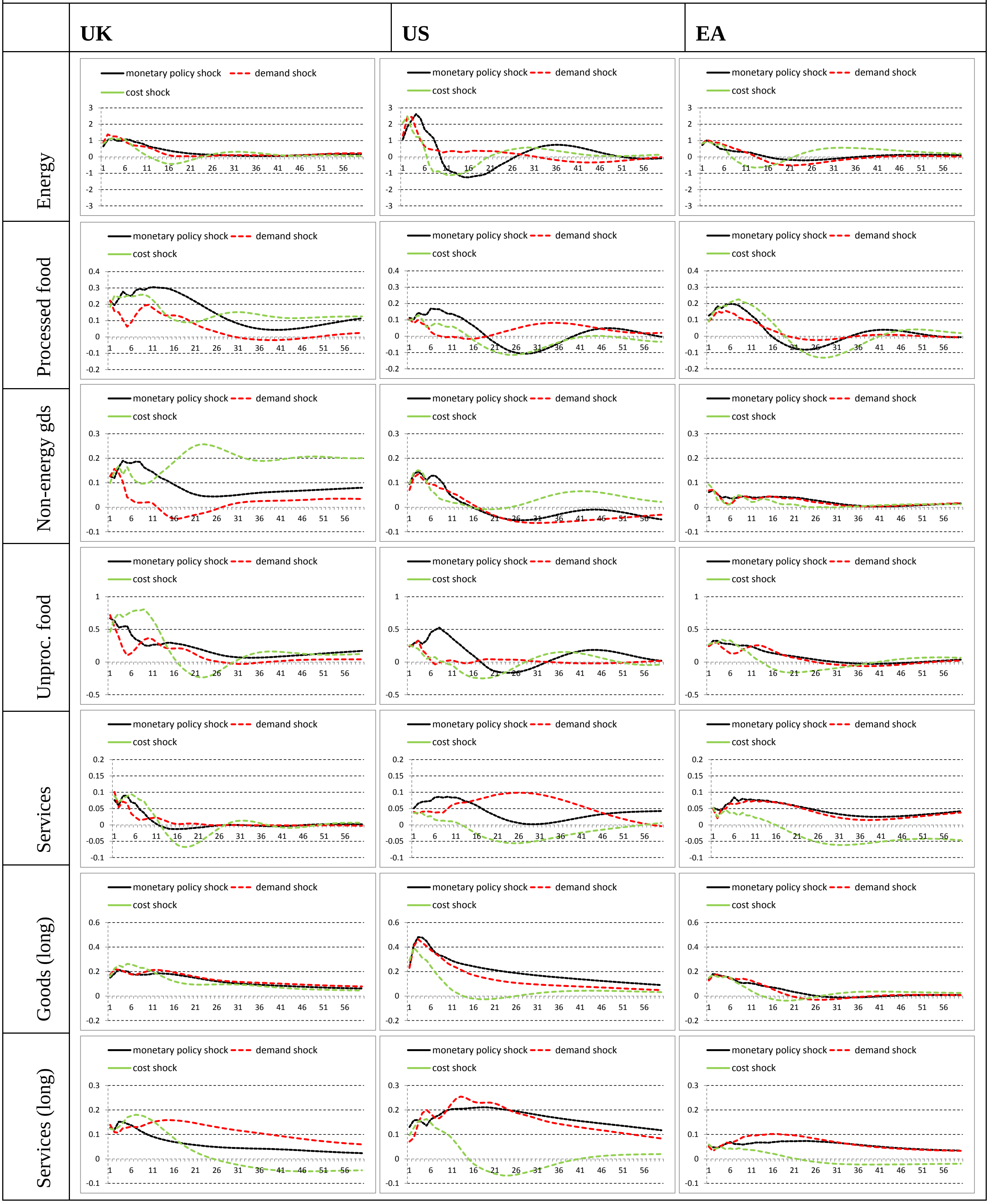
No firm conclusions on the reasons behind the different responses between the three economies can be drawn based on the analysis, but there is tentative evidence for product market flexibilities, regulation and taxation

[18] An attempt to shed light on this issue was made by drilling deeper into the services subcomponent and placing five available subcategories of the HICP data with a large services content (health, education, recreation & culture, communication, hotels & restaurants) in the 5-variable FAVAR model instead of the headline services subcomponent. No clear patterns or explanations for the differences between the three economies emerge from the sample period of 1999M1 to 2012M12.

being important drivers. This is most obviously evident in the more muted responses in the FAVAR models for the euro area, which is typically a less flexible economy in terms of labour and product market functioning. Furthermore, over the past two decades, shocks appear to have been transmitted more strongly to the non-tradables sector of the two countries with the more intense domestic competition (the UK and the US). Overall, from a policy perspective, it is obvious that policies promoting flexible and competitive product markets allow for quicker and more transparent transmission of macroeconomic shocks to the prices of final consumer goods and services. Regarding monetary policy, the current study offers further evidence on the importance of differentiating between demand and supply shocks in central bank reaction functions. In addition, country-specific responses to macroeconomic shocks can differ depending on the specific features of an economy, which can also imply differences from a policy perspective.

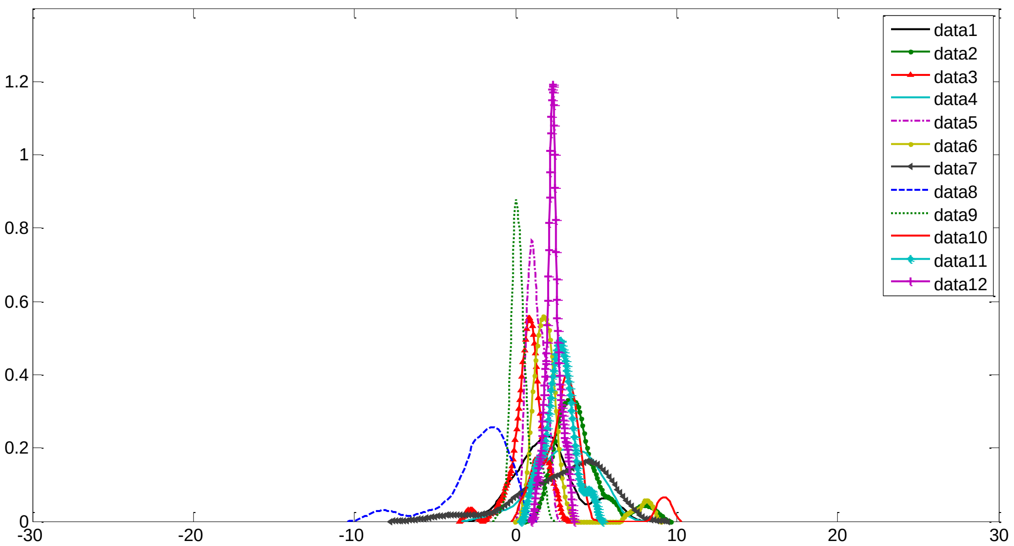
The results of the current study offer several avenues for further research. For example, the availability of longer and more granular inflation subcomponent datasets would allow for more detailed analysis of differences between components and economies. In particular, it would be informative to conduct a more comprehensive analysis on which macroeconomic shocks have affected which type of products and whether there are differences in the transmission of shocks between countries and between tradable and non-tradable sectors. Furthermore, applying a time-varying FAVAR framework would help shed light on the time variation of the inflation responses, especially in light of the large disruptions caused by the Great Recession.

Chart 4: Impulse responses of inflation subcomponents to (1-standard deviation) structural shocks

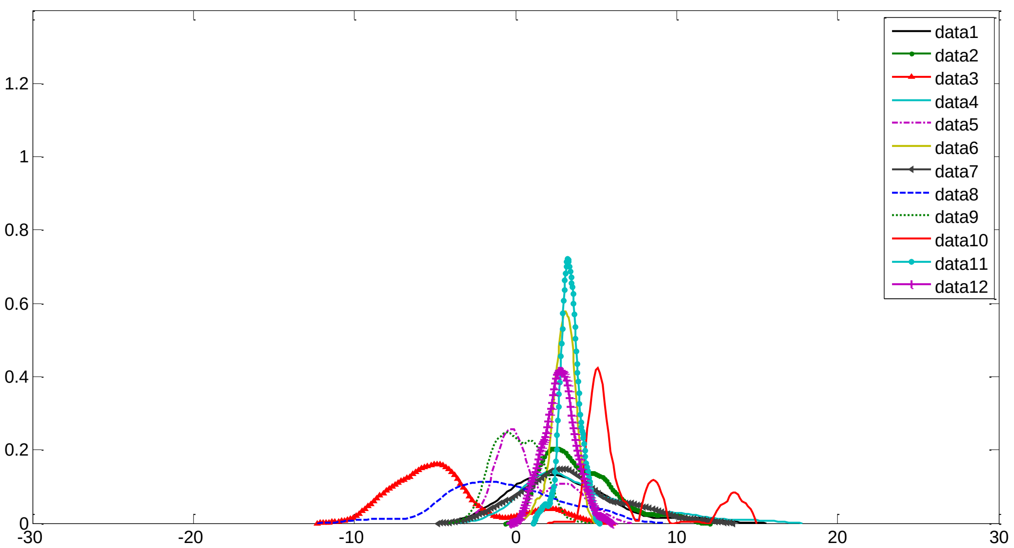


Appendix 1

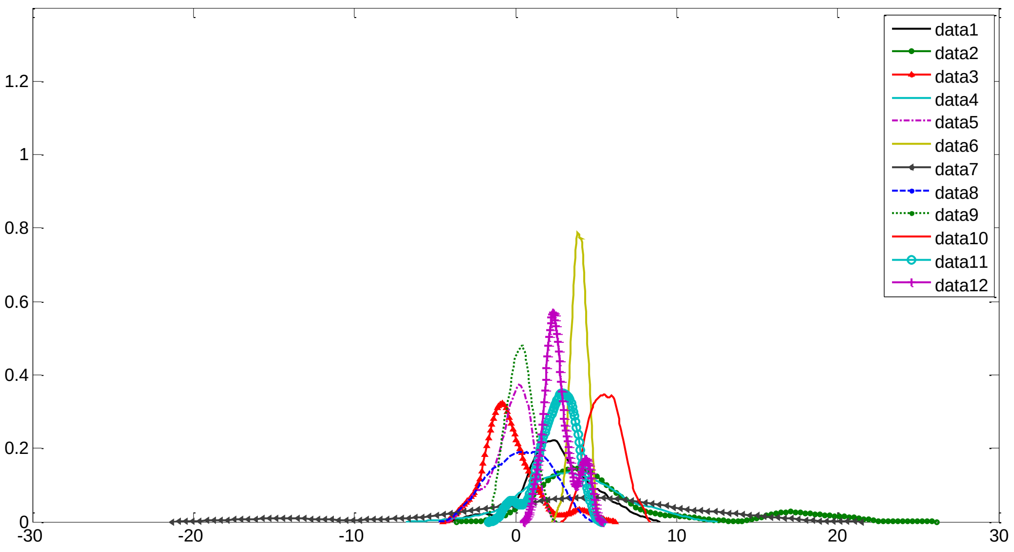
EA



UK



US



KEY:

data1	Food & Non-Alcoholic Beverages
data2	Alcoholic Beverages & Tobacco
data3	Clothing & Footwear
data4	Housing, Water, Electricity, Gas & Other Fuels
data5	Furniture, Household Equipment & Routine Maintenance
data6	Health
data7	Transport
data8	Communication
data9	Recreation & Culture
data10	Education
data11	Hotels, Cafes & Restaurants
data12	Miscellaneous Goods & Services

Appendix 2[19]

A2.1 FAVAR methodology

Consider a standard vector autoregression model of order p (VAR(p)) in reduced form (see, for example, Lutkepohl (2005)):

$$y_t = v + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t \tag{A1}$$

where y_t is a (Kx1) vector of dependent variables, v is a (Kx1) constant term vector, u_t is an i.i.d. error term and $A_1 \ldots A_p$ are (KxK) coefficient matrices. Any VAR(p) process can be written in VAR(1) form in the following way:

$$Y_t = \boldsymbol{v} + \boldsymbol{A} Y_{\boldsymbol{t-1}} + U_t \tag{A2}$$

where the terms are defined as follows:

$$Y_t = \begin{bmatrix} y_t \\ y_{t-1} \\ \vdots \\ y_{t-p+1} \end{bmatrix} \qquad \boldsymbol{v} = \begin{bmatrix} v \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

and

$$\boldsymbol{A} = \begin{bmatrix} A_1 & A_2 & \cdots & A_{p-1} & A_p \\ I_K & 0 & \cdots & 0 & 0 \\ \vdots & & \ddots & & \vdots \\ 0 & 0 & \cdots & I_K & 0 \end{bmatrix} \qquad U_t = \begin{bmatrix} u_t \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

Traditionally in VAR models, a limited number of dependent variables can be used (i.e., K is small) due to the overparameterisation of the model. However, Bernanke et al. (2005) introduce a way of incorporating a large amount of dependent variables in a VAR model in a so-called factor-augmented VAR (FAVAR) framework. To develop the methodology, let us first define a (Mx1) vector Y_t of observable economic variables assumed to drive the dynamics of the economy. In addition to this, there may be other relevant economic information, for which let us define a (Kx1) vector F_t, where K is “small”. F_t are unobserved factors, which can be thought of capturing such economic concepts as economic activity or price pressures.

Next, assume that the joint dynamics of F_t and Y_t are given by the following transition equation in a state-space framework:

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + v_t \tag{A3}$$

[19] This section draws on Bernanke et al. (2005).

where $\Phi(L)$ is a conformable lag polynomial of finite order d, and the error term v_t is i.i.d. with covariance matrix Q.

Equation (A3) cannot be estimated directly due to the existence of the unobserved factors. However, as the factors represent known economic concepts, we may be able to infer something about them from existing economic time series. Suppose we have a "large" number of these informational time series in an (Nx1) vector X_t. Then, it can be assumed that X_t is related to F_t and Y_t through an observation equation of the form:

$$X_t = \Lambda^f F_t + \Lambda^y Y_t + e_t \qquad \text{(A4)}$$

where Λ^f is an (NxK) matrix of factor loadings, Λ^y is an (NxM) matrix and e_t is an (Nx1) vector of (usually) i.i.d. error terms. Hence, equations (A3) and (A4) form the state space form of the model.

A2.2 Estimation

As detailed in Bernanke et al. (2005), there are two ways of estimating a FAVAR model; a two-step principal components approach and a single-step Bayesian likelihood approach. In the current study, the two-step approach is used. In the two-step procedure, the first step involves estimating the space spanned by K+M principal components of X_t, denoted $C(F_t, Y_t)$. In the current study, only the first principal component is actually used, as it has a clear economic interpretation (for example, demand or cost push factors). Having extracted the first principal component (or dynamic factor) from the X_t for each of the economic concepts in the model, the model consisting of (A3)-(A4) can then be estimated with standard VAR methods, as applicable to equations (A1)-(A2).

Appendix 3[20]

Let ε_t denote the (Kx1) vector of structural VAR model innovations derived from equation (A1). To construct structural impulse responses, one needs an estimate of the KxK matrix C in $u_t = C\varepsilon_t$. Let

$\Sigma_u = P\Lambda P$ and $C = P\Lambda^{1/2}$ such that C satisfies $\Sigma_u = CC'$. Then C = BD (where B is a matrix of structural parameters obtained through a Choleski decomposition of the reduced form parameters) also satisfies $\Sigma_u = CC'$ for any orthonormal KxK matrix D.

It is possible to examine a wide range of possibilities for C by repeatedly drawing at random from the set **D** of orthonormal rotation matrices D. Following Rubio-Ramirez et al. (2005), I construct the set **C** of admissible models by drawing from the set **D** of rotation matrices and discarding candidate solutions for C that do not satisfy a set of a priori sign restrictions on the implied impulse response functions. The procedure follows these steps:

1. Draw a KxK matrix K of NID(0,1) random variables. Derive the QR decomposition (to produce an orthonormal matrix and an upper-triangular matrix) of K such that K = QR with the diagonal of R normalised to be positive.
2. Let D = Q. Compute impulse responses using the orthogonalisation C = BD. If all implied impulse response functions satisfy the sign restrictions, keep D. Otherwise, discard D.
3. Repeat the first two steps a large number of times, recording each D (and the corresponding impulse response functions) that satisfy the restrictions. The resulting **C** comprises the set of admissible structural VAR models.

[20] This section draws on Rubio-Ramirez et al. (2010).

Appendix 4[21]

To produce a complementary analysis for the impulse response analysis in the sign-restricted FAVAR models, I use a recent methodology suggested by Inoue and Kilian (forthcoming). The basic idea in their paper is to identify the most likely admissible model(s) within the set of structural VAR models that satisfy the given sign restrictions.

First, write a conventional VAR(p) model in the following form:

$$Y = XB + e \tag{A5}$$

where $Y = [y_1\ y_2 \dots y_T]'$ for an n-variate model for t=1,…,T, $X = [X_1\ X_2 \dots X_T]'$, $X_t = [1\ y'_{t-1} \dots y'_{t-p}]'$, $B = [c\ B_1 \dots B_p]'$ and $e = [e_1\ e_2 \dots e_T]'$, with Σ being the positive definite covariance matrix of the error term. Next, similarly to the conventional sign restriction methodology (Appendix 3), define C = AD (where A is the lower triangular Cholesky decomposition of Σ, such that AA'=Σ, and D is an orthonormal matrix), and C is then a potential solution for the structural impact multiplier matrix.

Let vech(A) denote the n(n+1)/2x1 vector that consists of the on-diagonal and below-diagonal elements of A, and let veck(D) denote the n(n-1)/2x1 vector that consists of the above-diagonal elements of D. Also, ignoring the intercept, let $B = [B_1 \dots B_p]'$. As shown by Inoue and Kilian, because there is a one-to-one mapping between B and the reduced-form vector moving average coefficient matrices Φ_i, i=1,2,…,p and because Σ is nonsingular and D is orthonormal, there is a one-to-one mapping between the first p+1 structural impulse responses $\Theta = [A, \Phi_1 A, \Phi_2 A, \dots, \Phi_p A]'$ on the one hand and the tuple formed by the reduced-form VAR parameters and the rotation matrix, (B,vech(A),veck(D)), on the other. Hence, the nonlinear function $\Theta = h(B, vech(A), veck(D))$ is known. The posterior density function of Θ can then be written as (for details on the derivation see Inoue and Kilian):

$$f(\Theta) \propto \left(\left| \frac{\partial vec(\Theta)}{\partial [vec(B)' vech(A)' veck(D)']} \right| \right)^{-1} \left| \frac{\partial \Sigma}{\partial A} \right| f(B|\Sigma) f(\Sigma) \tag{A6}$$

Furthermore, the authors also show that because the probability of Θ belonging to the set of responses that satisfy the sign restrictions in the model does not depend on Θ itself, finding the mode of the posterior of the sign-identified structural impulse responses reduces to finding the maximum of the right hand side of (A6) subject to the sign restrictions. In particular, it is not necessary to reweight this probability to account for draws from the posterior that have been rejected.

In practice, the procedure works as follows:

1) Take a random draw, (B,Σ) from the posterior of the reduced-form parameters.

[21] This section draws on Inoue and Kilian (forthcoming).

2) For each (B,Σ), consider N random draws of the matrix D, and for each combination (B,Σ,D) compute the set of implied structural impulse responses Θ.

3) If Θ satisfies the sign restrictions, store the value of Θ and the value of $f(\Theta)$. Otherwise discard Θ.

4) Repeat steps 2) and 3) M times and find the draw that maximizes (A6).

Appendix 5[22]

To estimate the factors in the FAVAR model, I use a method suggested by Banbura and Modugno (2010). They introduce a methodology to estimate a dynamic factor model on data sets with an arbitrary pattern of missing data, which is particularly relevant for my models, as they include data on both monthly and quarterly frequency. An Expectation Mechanism (EM) algorithm is then used to estimate the model.

To define the model, let $y_t = [y_{1,t}, y_{2,t}, \dots, y_{n,t}], t = 1, \dots, T$ denote a stationary n-dimensional vector process (like, for example, the variables in the cost factor in my FAVAR model) standardised to mean 0 and unit variance. The y_t process is then assumed to admit the following factor model presentation:

$$y_t = \Lambda f_t + e_t \qquad \text{(A7)}$$

where f_t is a rx1 vector of unobserved common factors and $e_t = [e_{1,t}, e_{2,t}, \dots, e_{n,t}]$ is an idiosyncratic component uncorrelated with f_t at all leads and lags. In my models, as the focus is on finding one factor to represent the main variable groups (cost factor, inflation factor and real economy factor), r=1. The nxr matrix (or in my case, vector) Λ then contains the factor loadings. It is also assumed in the model that e_t is normally distributed and serially uncorrelated.

It is further assumed that the common factor f_t follows and AR process of order p:

$$f_t = a_1 f_{t-1} + a_2 f_{t-2} + \dots + a_p f_{t-p} + u_t \qquad \text{(A8)}$$

where u_t is an i.i.d. error term and $a_{1,}\dots,a_p$ are the autoregressive components. In practice, a low p is usually sufficient; for my factor models, p=1 (although p=2 produces similar results).

As f_t is unobserved, the maximum likelihood estimators of the model in equations (A7)-(A8) are in general not available in closed form. For this reason, and to preserve computational simplicity, an approach based on the EM algorithm can be applied, as suggested by Banbura and Modugno (2010). The EM algorithm is a two-step iterative procedure, with the following general idea (for more technical details, see Banbura and Modugno (2010)):

1) In the E-step, the expectation of the log-likelihood is calculated, conditional on data (including missing data that is filled in), using estimates for the relevant parameters (in my case, Λ, the AR process parameters $a_1,\dots a_p$, as well as the variances of the error terms e an u) from the previous iteration
2) In the M-step, the parameters are re-estimated through the maximisation of the log-likelihood to produce the set of parameters for the next iteration.

[22] This section draws on Banbura and Modugno (2010).

Under certain conditions, the EM algorithm converges towards a local maximum of the likelihood. With the resulting parameters at the end of the iteration process, one can then obtain the relevant unobserved factors f_t that I use in my FAVAR models.

Appendix 6

The following tables list the variables included in the real activity, cost and inflation factors for the EA, the UK and the US. The transformation column indicates whether the data series has been included in original level (or in case of price variables, y/y change) form (1) or log differenced form (5). Quarterly data is in italics. Source for all data is Haver Analytics.

UK real activity indicators	Transformation
UK: Industrial Production: Total (SA, 2008=100)	5
UK: Industrial Production: Manufacturing(SA, 2008=100)	5
U.K.: IP: Consumer Durable Goods (SA, 2005=100)	5
U.K.: IP: Consumer Nondurable Goods (SA, 2005=100)	5
UK: LFS: Unemployment Rate: Aged 16 and Over (SA, %)	1
U.K.: Retail Sales Volume Index (SA, 2008=100)	5
U.K.: Passenger Cars Registered (SA, 2005=100)	5
U.K.: Export Volume Index: Goods (SA, 2008=100)	5
U.K.: Import Volume Index: Goods (SA, 2008=100)	5
U.K.: PMI: Composite (SA, 50+=Expansion)	1
U.K. PMI: Manufacturing (SA, 50+=Expansion)	1
U.K. PMI: Manufacturing Employment (SA, 50+=Expansion)	1
U.K. PMI: Manufacturing New Orders (SA, 50+=Expansion)	1
U.K. PMI: Services Business Activity (SA, 50+=Expansion)	1
U.K. PMI: Services Employment (SA, 50+=Expansion)	1
U.K. PMI: Services Business Expectations (SA, 50+=Expansion)	1
U.K.: Consumer Confidence Indicator (SA, % Bal.)	1
U.K.: Total Leading Indicator (NSA, Amplitude Adjusted)	1
UK: LFS: Employment: Aged 16 and Over (SA, Thous)	5
U.K.: Real Gross Domestic Product (SA, Mil.Chn.2009.GBP)	5
UK: Gross Fixed Capital Formation: Total (SA, Mil.Chn.2009.GBP)	5
U.K.: Exports of Goods & Services (SA, Mil.Chn.2009.Pounds)	5
U.K.: Imports of Goods & Services (SA, Mil.Chn.2009.Pounds)	5
U.K.: Hhold Final Consumption Expenditure (SA, Mil.Chn.2009.GBP)	5
U.K.: Mfg Survey: Rate of Capacity Utilization (SA, %)	1

UK cost indicators	Transformation
CRB Spot Commodity Price Index: All Commodities (1967=100) (y/y%)	1
CRB Spot Commodity Price Index: Metals (1967=100) (y/y%)	1
European Free Market Price: Brent Crude Oil ($/Barrel) (y/y%)	1
U.K.: PPI: Net Output Prices: Manufactured Products (SA, 2005=100) (y/y%)	1
U.K.: Import Price Index: Total Goods (SA, 2008=100) (y/y%)	1
UK: JP Morgan Nominal Broad Effective FX rate (2000=100) (-y/y%)	1
U.K.: Domestic PPI: Manufacturing (NSA, 2005=100) (y/y%)	1
U.K.: Domestic PPI: Energy (NSA, 2005=100) (y/y%)	1

U.K.: Consumer Prices: Future Tendency (SA, % Bal.)	1
U.K. PMI: Manufacturing Input Prices (SA, 50+=Expansion)	1
U.K. PMI: Services Input Prices (SA, 50+=Expansion)	1
CRB Spot Commodity Price Index: Raw Industrials (1967=100) (y/y%)	1
CRB Spot Commodity Price Index: Foodstuffs (1967=100) (y/y%)	1
Reuters/Jefferies CRB Futures Price Index: All Commodities (1967=100) (y/y%)	1
UK: Unit Labor Costs: Whole Economy (SA, 2009=100) (y/y%)	1

UK inflation indicators	Transformation
UK: Consumer Price Index: All Items (NSA, 2005=100) (y/y%)	1
UK: Retail Prices Index: All Items (NSA, Jan-87=100) (y/y%)	1
UK: Consumer Price Index: All Goods (NSA, 2005=100)	1
UK: Consumer Price Index: All Services (NSA, 2005=100)	1
U.K.: GDP Deflator at Market Prices (SA, 2009=100) (y/y%)	1
UK: Final Consumption Expenditure Deflator (SA, 2009=100) (y/y%)	1

US real activity indicators	Transformation
U.S.: Industrial Production excluding Construction (SA, 2007=100)	5
U.S.: Industrial Production: Manufacturing (SA, 2007=100)	5
IP: Durable Consumer Goods (SA, 2007=100)	5
IP: Nondurable Consumer Goods (SA, 2007=100)	5
Capacity Utilization: Total Index (SA, % of Capacity)	1
U.S.: Civilian Unemployment Rate (SA, %)	1
U.S.: Retail Sales & Food Services (SA, Mil.Chn.2005$)	5
U.S.: Passenger Cars Registered (SA, 2005=100)	5
U.S.: Export Volume (SA, 2000=100)	5
U.S.: Import Volume (SA, 2000=100)	5
ISM Composite Index (SA, >50=Increasing)	1
US PMI: Manufacturing (SA, 50+=Expansion)	1
US PMI: Manufacturing Employment Index (SA, 50+=Expansion)	1
US PMI: Manufacturing New Orders Index (SA, 50+=Expansion)	1
US PMI: Services Business Activity Index (SA, 50+=Expansion)	1
US PMI: Services Employment Index (SA, 50+=Expansion)	1
US PMI: Services Inc. New Business Index (SA, 50+=Expansion)	1
U.S.: Consumer Confidence Indicator (SA, 2005=100)	1
U.S.: Total Leading Indicator (NSA, Amplitude Adjusted)	1
All Employees: Total Nonfarm Payrolls (SA, Thous)	5
Real Gross Domestic Product (SAAR, Bil.Chn.2005$)	5
Real Private Fixed Investment (SAAR, Bil.Chn.2005$)	5
Real Exports of Goods & Services (SAAR, Bil.Chn.2005$)	5
Real Imports of Goods & Services (SAAR, Bil.Chn.2005$)	5

Real Personal Consumption Expenditures (SAAR, Bil.Chn.2005.$)	5

US cost indicators	Transformation
CRB Spot Commodity Price Index: All Commodities (1967=100) (y/y%)	1
CRB Spot Commodity Price Index: Metals (1967=100) (y/y%)	1
Domestic Spot Market Price: West Texas Intermediate, Cushing ($/Barrel) (y/y%)	1
U.S.: PPI: Finished Goods (SA, 1982=100) (y/y%)	1
U.S.: Import Price Index: All Imports (SA, 2000=100) (y/y%)	1
JP Morgan Nominal Broad Effective Exchange rate: US (2000=100) (-y/y%)	1
U.S.: PPI: Manufacturing (NSA, 2005=100) (y/y%)	1
U.S.: PPI: Energy (NSA, 2005=100) (y/y%)	1
Univ. of Michigan consumer infl. expec. (y/y%)	1
US PMI: Manufacturing Input Prices Index (SA, 50+=Expansion)	1
US PMI: Services Input Prices Index (SA, 50+=Expansion)	1
CRB Spot Commodity Price Index: Raw Industrials (1967=100) (y/y%)	1
CRB Spot Commodity Price Index: Foodstuffs (1967=100) (y/y%)	1
Reuters/Jefferies CRB Futures Price Index: All Commodities (1967=100) (y/y%)	1
Business Sector: Unit Labor Cost (SA, 2005=100) (y/y%)	1

US inflation indicators	Transformation
CPI-U: All Items (SA, 1982-84=100) (y/y%)	1
U.S.: Harmonized Index of Consumer Prices [HICP] (SA, Dec-97=100) (y/y%)	1
CPI-U: Commodities (SA, 1982-84=100) (y/y%)	1
CPI-U: Services (SA, 1982-84=100) (y/y%)	1
Gross Domestic Product: Chain Price Index (SA, 2005=100) (y/y%)	1
Personal Cons. Expenditures: Chain Price Index (SA, 2005=100) (y/y%)	1

EA real activity indicators	Transformation
EA 17: IP: Industry excluding Construction (SA/WDA, 2005=100)	5
EA 17: Industrial Production: Manufacturing (SA/WDA, 2005=100)	5
Euro Area: IP: Consumer Durable Goods (SA, 2005=100)	5
Euro Area: IP: Consumer Nondurable Goods (SA, 2005=100)	5
EA 17: Unemployment Rate (SA, %)	1
EA 17: Retail Sales Volume Index (SA/WDA, 2005=100)	5
Euro Area: Passenger Cars Registered (SA, 2005=100)	5
EA 17: Export Volume (SA, 2000=100)	5
EA 17: Import Volume (SA, 2000=100)	5
Euro-zone: PMI: Composite (SA, 50+=Expansion)	1
Euro-zone PMI: Manufacturing (SA, 50+=Expansion)	1
Euro-zone PMI: Manufacturing Employment (SA, 50+=Expansion)	1
Euro-zone PMI: Manufacturing New Orders (SA, 50+=Expansion)	1

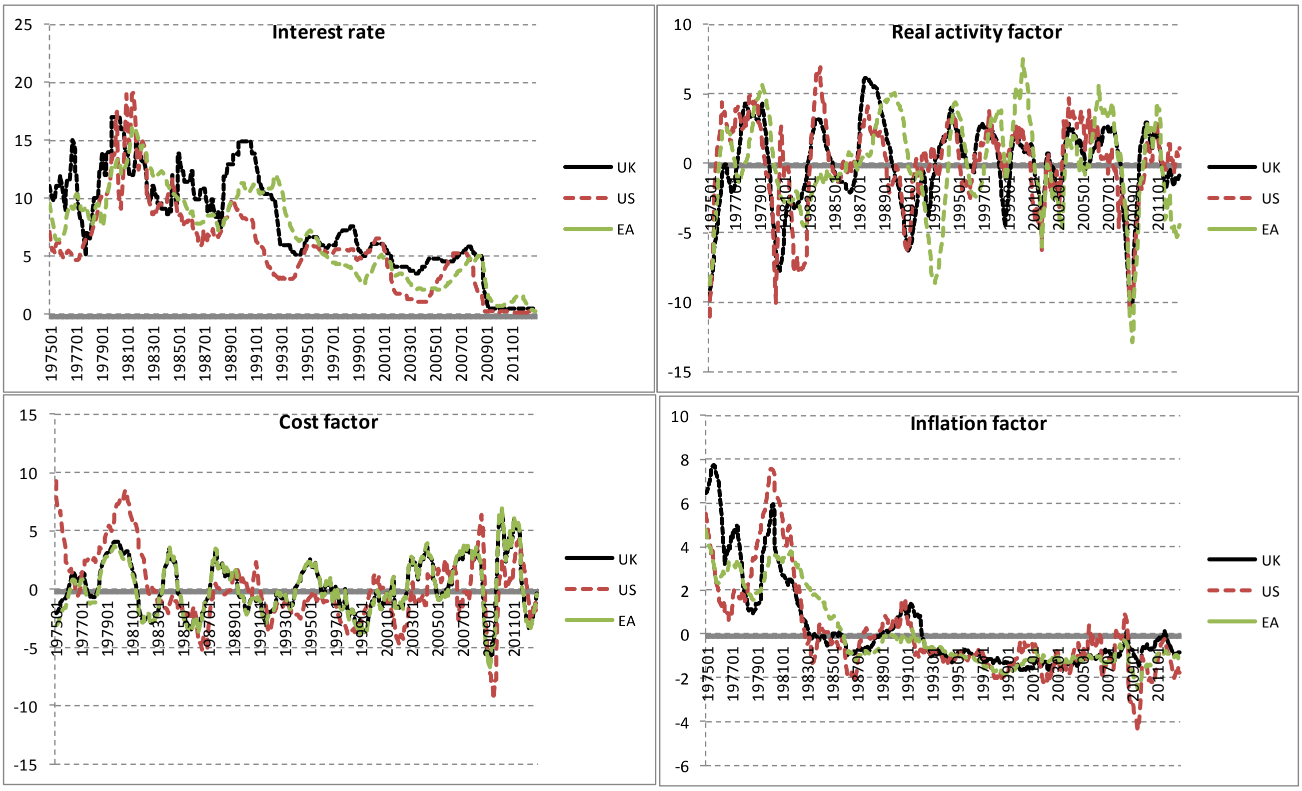
Euro-zone PMI: Services Business Activity (SA, 50+=Expansion)	1
Euro-zone PMI: Services Employment (SA, 50+=Expansion)	1
Euro-zone PMI: Services Business Expectations (SA, 50+=Expansion)	1
Euro Area: Consumer Confidence Indicator (SA, % Bal.)	1
Euro Area: Total Leading Indicator (NSA, Amplitude Adjusted)	1
Euro Area17: Total Employment (SWDA, Thous)	5
EA17: Gross Domestic Product (SWDA, Mil.Ch.05.EUR)	5
EA17: Gross Fixed Capital Formation (SWDA, Mil.Ch.2005.EUR)	5
EA17: Exports of Goods and Services (SWDA, Mil.Ch.05.EUR)	5
EA17: Imports of Goods and Services (SWDA, Mil.Ch.05.EUR)	5
EA17: HH and NPISH Final Cons. Expenditure (SWDA, Mil.Ch.05.EUR)	5
Euro Area: Mfg Survey: Rate of Capacity Utilization (SA, %)	1

EA cost indicators	Transformation
CRB Spot Commodity Price Index: All Commodities (1967=100) (y/y%)	1
CRB Spot Commodity Price Index: Metals (1967=100) (y/y%)	1
European Free Market Price: Brent Crude Oil ($/Barrel) (y/y%)	1
EA 17: PPI: Industry excluding Construction (SA, 2005=100) (y/y%)	1
EA 17: Import Prices: Total (SA, 2000=100) (y/y%)	1
JP Morgan Nominal Broad Effective Exchange rate: Euro (2000=100) (-y/y%)	1
Euro Area: Domestic PPI: Manufacturing (NSA, 2005=100) (y/y%)	1
Euro Area: Domestic PPI: Energy (NSA, 2005=100) (y/y%)	1
Euro Area: Consumer: Prices: Future Tendency (SA, % Bal.)	1
Euro-zone PMI: Manufacturing Input Prices (SA, 50+=Expansion)	1
Euro-zone PMI: Services Input Prices (SA, 50+=Expansion)	1
CRB Spot Commodity Price Index: Raw Industrials (1967=100) (y/y%)	1
CRB Spot Commodity Price Index: Foodstuffs (1967=100) (y/y%)	1
Reuters/Jefferies CRB Futs Price Index: All Commodities (1967=100) (y/y%)	1
EA 17: Unit Labor Costs (SA, 2005=100) (y/y%)	1

EA inflation indicators	Transformation
EA 17: Monetary Union Index of Consumer Prices (SA, 2005=100) (y/y%)	1
EA11-17: MUICP: Goods (NSA, 2005=100) (y/y%)	1
EA11-17: MUICP: Services (NSA, 2005=100) (y/y%)	1
EA17: EUR Price Index: Gross Domestic Product (y/y%)	1
EA17: EUR Price Index: Private Final Cons Expend. (y/y%)	1

Appendix 7

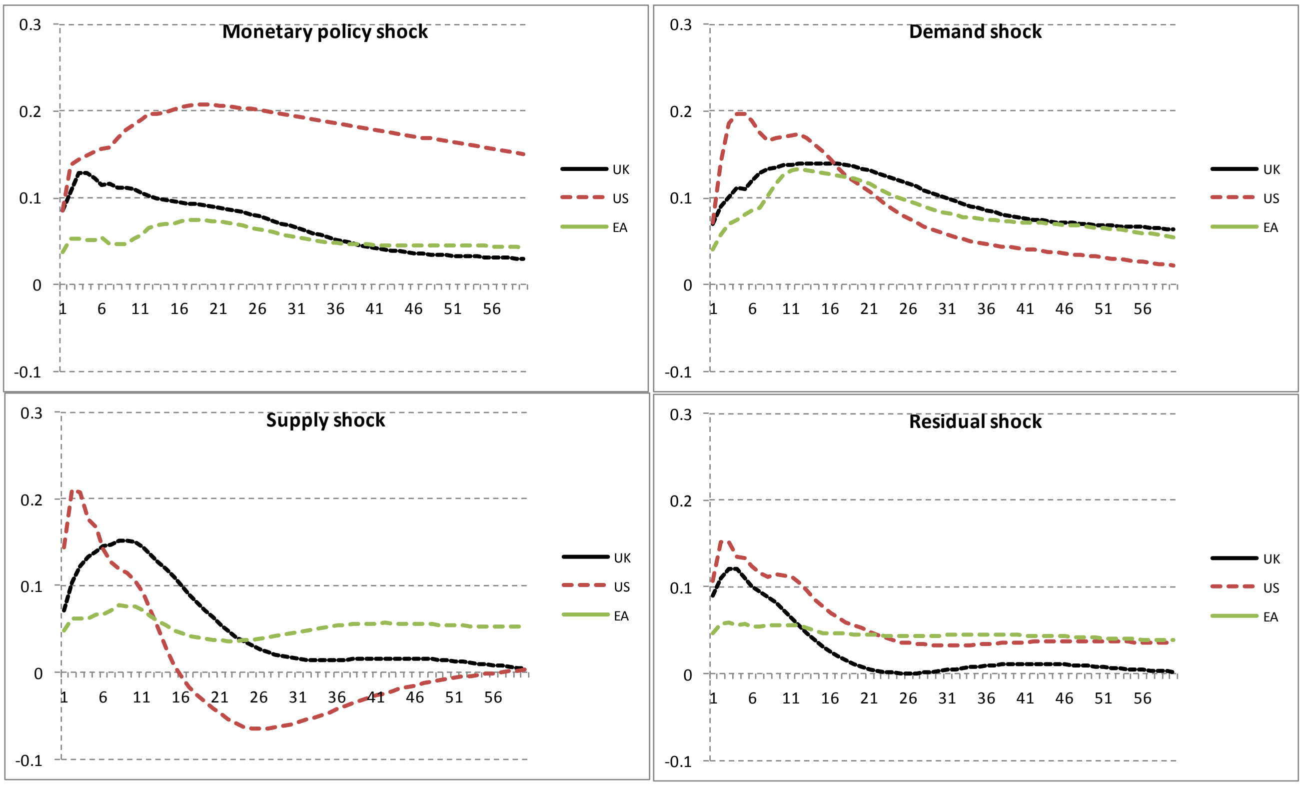
Chart A1. FAVAR variables



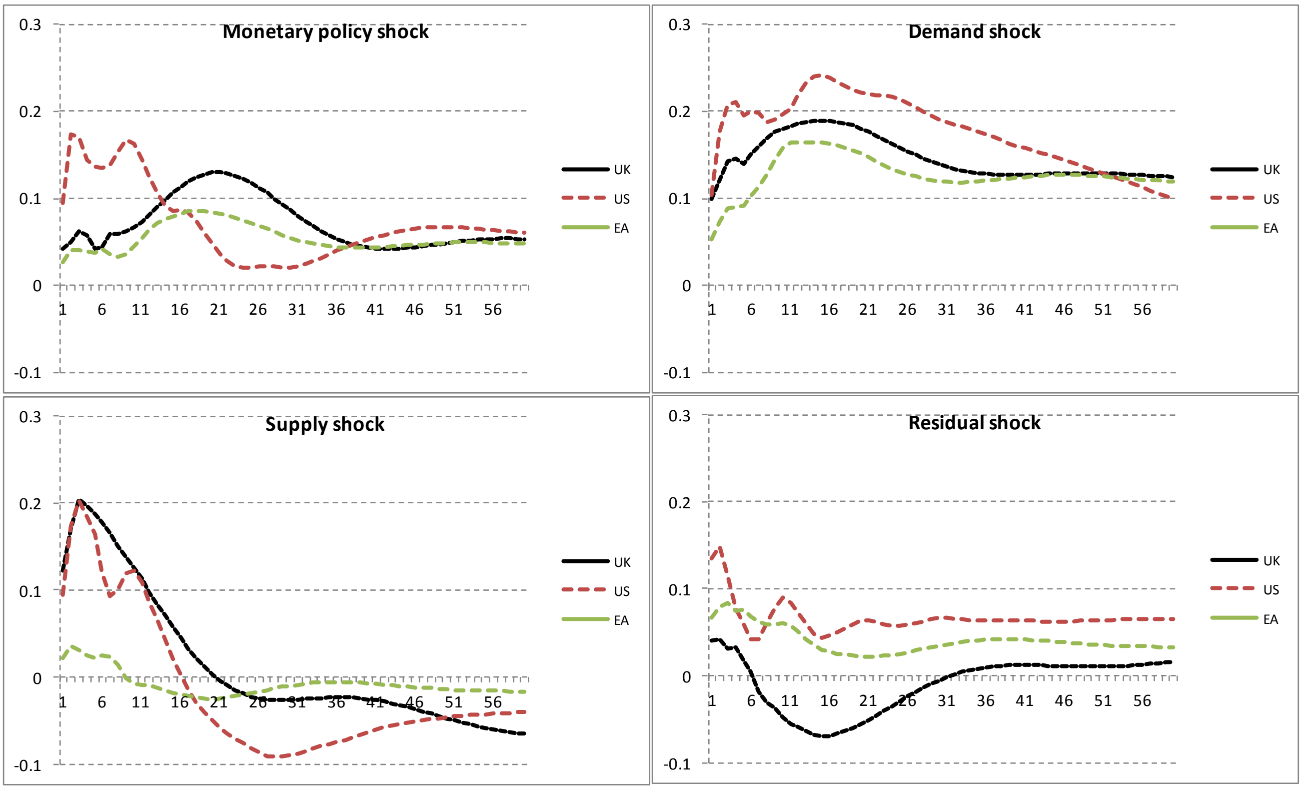
Note: the scale of the interest rate is % and the scale of the factors are mean-variance standardised factor values.

Appendix 8

Chart A2. Comparison of median/mode impulse responses for UK, US and EA



(1) RWZ sign restrictions



(2) Inoue-Kilian sign restrictions

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Acknowledgements
I thank Marta Banbura and Lutz Kilian for providing me with the code to their estimation methods. I also thank Gianni Amisano and other colleagues at the ECB Directorate General Research as well as an anonymous referee for their helpful comments. The views expressed are those of the author and do not necessarily reflect those of the ECB or the Bank of England.

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ISSN	1725-2806 (online)
ISBN	978-92-899-1615-8
DOI	10.2866/049069
EU catalogue number	QB-AR-15-042-EN-N