The transmission of international shocks to the UK. Estimates based on a time-varying Factor Augmented VAR

Liu, P., Mumtaz, H. and Theophilopoulou, A.

https://dx.doi.org/10.1016/j.jimonfin.2014.03.004

The transmission of international shocks to the UK. Estimates based on a time-varying Factor Augmented VAR

Philip Liu* Haroon Mumtaz† Angeliki Theophilopoulou‡

March 7, 2014

Abstract

The aim of this paper is to gauge the importance of foreign demand, supply and interest rate shocks on the UK economy and assess how their role has changed over time. To that end we devise a time-varying factor augmented VAR model that captures the relationship between 17 industrialised countries and the UK and accounts for any temporal evolution in this relationship. The response of UK macroeconomic variables to a foreign interest rate shock is estimated to have changed significantly since the early 1990s. International demand shocks play an important role in driving World and UK real activity, especially during the recent recession.

Key Words: International transmission, FAVAR, time-varying parameters
JEL codes: E5; F3; C3

1 Introduction

Understanding of the international transmission mechanism of economic shocks is an important step towards identifying the best policy response in an individual economy to international developments. In a world economy, which has experienced a steady increase in integration across goods, capital and financial markets, the international aspect of the transmission mechanism has become an essential ingredient in policy discussions. This issue has become vital for small open economies such as the United Kingdom over the recent recession.

A large empirical literature has investigated the international transmission of monetary and non-monetary shocks using small scale structural Vector Auto-Regression (VAR) models.[1] These papers share two important features. First, they do not allow for the

*Canadian Pension Plan Investment Board. pliu@cppib.ca
†Queen Mary College h.mumtaz@qmul.ac.uk
‡University of Westminister. A.Theophilopoulou@westminster.ac.uk

[1] See, for example, Grilli and Roubini (1995), Eichenbaum and Evans (1995), and Faust and Rogers (2003).

possibility of time-variation in the coefficients and variances of the model. This feature is surprising, especially as an important empirical regularity observed since the mid-1980s and shows a change in macroeconomic dynamics. Kim and Nelson (1999), McConnell and Perez-Quiros (2000), and Cogley and Sargent (2005) show that the volatility of US output and the volatility and persistence of US inflation has fallen significantly over the last three decades. Benati (2006) presents similar results for the U.K. In addition, Cogley and Sargent (2002), and Clarida et al. (2000) show that changing macroeconomic dynamics in the US were accompanied by a change in the monetary policy rule adopted by the Federal Reserve, with a higher weight given to inflation in the post-1982 period[2]. Similar results are reported by Nelson (2001) for the U.K. where the post-1992 period was associated with stronger response by the Bank of England to inflationary shocks. A related strand of this literature has focussed on the possibility of changes in the *domestic* transmission of monetary policy. Boivin and Giannoni (2006) estimate the response of output and inflation to a monetary policy shock in the US using a VAR based on two sub-samples: 1959-1979 and 1980-2002. Their results suggest that the response of output and inflation is smaller in the latter period. Castelnuovo and Surico (2005) show that similar results hold for the U.K. economy. The recent work by Campa and Goldberg (2005) provides some evidence of decline in the pass-through of exchange rate shocks to import prices for OECD countries. Taken together, this growing literature provides strong evidence that structural changes have occurred in prominent industrialized countries over the last 30 years. Moreover, the recent financial crisis and recession have again highlighted the strong possibility that the structure of industrialised economics and dynamics of macroeconomic variables may have changed. The implications of these changes for the international transmission mechanism remains largely unexplored.

Second, most empirical studies on the international transmission of shocks are based on VAR models that include only a few selected variables. Arguably, central banks across the world monitor (and possibly respond to) a far wider information set than typically assumed in these small-scale VARs leaving them open to the possibility of mis-specification and the possibility of non-fundamental shocks. Moreover, from a practical perspective small scale VARs are unable to provide inference on large number of variables that may be of interest. For example, little or no evidence exists on the transmission of foreign shocks to domestic asset prices such as house prices and equity prices.

The aim of this paper is to fill these gaps in the empirical literature on international transmission. In particular, this paper aims to provide an analysis of how the impact of foreign shocks on key macroeconomic variables of a small open economy like the U.K. has evolved over time.

We attempt to do this by devising an empirical model that: (a) allows for time-variation

[2]However, this claim is not without its critics. Prominent papers that find no change in the policy rule include Primiceri (2005), Sims and Zha (2006), and Gambetti et al. (2008) where the authors are more sympathetic to the idea that it is the absence of adverse non-policy shocks that has contributed to the great moderation.

in the international transmission mechanism, and (b) allows the simultaneous estimation of the response of a large set of U.K. variables to foreign monetary policy, demand and supply shocks. In particular, this paper proposes an open economy factor-augmented VAR (FAVAR) which incorporates time-varying coefficients and stochastic volatility in the shocks. The proposed model captures the changing co-movements among macroeconomic time series by allowing their dependence on common factors to evolve over time.

The main contribution of the paper is to assess possible changes to the transmission of external monetary policy shocks to the UK. We find that there are important changes in the response of UK variables to foreign interest rate shocks. For example, our estimates suggest that the co-movement of UK real activity with foreign interest rates is positive before the early 1990s and negative after this date. This has important policy implications in a period characterised by the great recession and the resulting easing in monetary policy across the industrialised world. To our knowledge, this study is the first to provide estimates of the contribution of external shocks to key UK macroeconomic variables over the recent financial crisis. Our results suggest that foreign demand shocks played a key role in driving UK GDP growth and CPI inflation and these shocks were important over the recent crisis. Finally, our model also provides estimates of the common component in real activity and inflation for a panel of industrialised countries with the estimated common factors suggesting that the magnitude of the recent recession was unprecedented over the last 30 years.

The paper is organized as follows: Section (2) outlines the empirical model and discusses the identification assumptions. Section (3) presents the main results from the analysis while section 4 concludes.

2 An open economy FAVAR model with time-varying coefficients

We attempt to formulate an empirical model that allows us to efficiently model the relationship between a large set of U.K. and foreign variables, while simultaneously allowing this relationship to be time-varying. The starting point is the following restricted VAR model

$$\begin{pmatrix} F_t^* \\ F_t^{UK} \\ R_t \end{pmatrix} = \begin{bmatrix} B_{11}(L) & 0 & 0 \\ B_{21}(L) & B_{22}(L) & B_{23}(L) \\ B_{31}(L) & B_{32}(L) & B_{33}(L) \end{bmatrix} \begin{pmatrix} F_{t-1}^* \\ F_{t-1}^{UK} \\ R_{t-1} \end{pmatrix} + u_t \tag{1}$$

The VAR in equation (1) consists of two blocks, one for the U.K. and other for the rest of the world, which is ordered first.[3] The information about the U.K. and the rest of the world is summarized by the unobserved factors, $F_t = [F_t^* \; F_t^{UK}]'$, where $*$ denotes the foreign economies and UK denotes the domestic economy. The U.K. short-term interest rate, R_t, is included to account for domestic monetary policy. We treat the Bank rate R_t

[3] The terms foreign and world are used inter-changeably in this paper. The term home refers to the U.K.

as an observed factor and therefore assume that this variable is observed by the monetary authority and the econometrician. Given that R_t is the policy instrument of the Bank of England, and changes in R_t are highly publicized and observed by economic agents, it can be argued that this assumption is fairly innocuous in the context of our application. The zero restrictions in equation (1) reflect our assumption that being a small open economy, the U.K. is unable to influence the rest of the world[4]. Note that we set the lag length to 2. This choice follows Cogley and Sargent (2005) amongst others and allows us to maintain a parsimonious transition equation.

There are three foreign factors $F_t^* = F_t^{Y^*}$, $F_t^{\pi^*}$ and $F_t^{R^*}$, where $F_t^{Y^*}$ is a foreign real activity factor, $F_t^{\pi^*}$ is a foreign inflation factor, $F_t^{R^*}$ is a foreign interest rate factor. F_t^{UK} denote k factors for the U.K. These factors together summarize the variation in an underlying panel data set of foreign and U.K. variables. They are linked to the panel data set via the following observation equation:

$$\begin{pmatrix} X_t^{Y^*} \\ X_t^{\pi^*} \\ X_t^{R^*} \\ X_t^{UK} \\ R_t \end{pmatrix} = \begin{bmatrix} \Lambda_t^{Y^*} & 0 & 0 & 0 & 0 \\ 0 & \Lambda_t^{\pi^*} & 0 & 0 & 0 \\ 0 & 0 & \Lambda_t^{R^*} & 0 & 0 \\ 0 & 0 & 0 & \Lambda_t^{UK} & \Lambda_t^{R} \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} F_t^{Y^*} \\ F_t^{\pi^*} \\ F_t^{R^*} \\ F_t^{UK} \\ R_t \end{pmatrix} + v_t \tag{2}$$

where $X_t^{Y^*}$ denotes data on foreign real activity, $X_t^{\pi^*}$ denotes data on foreign inflation, $X_t^{R^*}$ denotes data on foreign interest rates and X_t^{UK} denotes a panel data set for the UK that includes indicators on real activity, inflation, money supply and asset prices. $\Lambda_t^{Y^*}$, $\Lambda_t^{\pi^*}$and $\Lambda_t^{R^*}$ are the factor loadings on foreign real activity data, foreign inflation data and foreign interest rate data. Λ_t^{UK} is $N^{UK} \times k$ matrix of factor loadings that link the k domestic unobserved factors to UK data and Λ_t^R, $N^{UK} \times 1$, captures the contemporaneous relationship between some of the "fast-moving" UK variables (e.g. asset prices) and the short-term interest rate. v_t represents the idiosyncratic error terms. These are assumed to be serially correlated and follow an AR process: $v_t = \rho(L)v_t + \epsilon_t$.

We assume two sources of time-variation in equations (1) and (2) . First, we allow the VAR covariance matrix $\text{Var}(u_t) \equiv \Omega_t$ to evolve over time as a random walk. In particular, we factor the covariance matrix as Ω_t as:

$$\Omega_t = A_t^{-1} H_t \left(A_t^{-1}\right)\prime \tag{3}$$

with the log of the diagonal elements of H_t (denoted as $h_{i,t}$) $\ln h_{i,t}$, and the non-zero and non-unit elements of the matrix A_t (denoted as $\alpha_{ij,t}$) are assumed to evolve as driftless random walks:

$$\ln h_{i,t} = \ln h_{i,t-1} + \mu_{i,t}, \mu_{i,t} \tilde{} N(0, W) \tag{4}$$

$$\alpha_{ij,t} = \alpha_{ij,t-1} + \xi_{ij,t}, \xi_{ij,t} \tilde{} N(0, S) \tag{5}$$

[4]We expand on this in our discussion of the VAR identification scheme below.

Second, following Del Negro and Otrok (2008), the factor loadings $\Lambda_t = \{\Lambda_t^{Y^*}, \Lambda_t^{\pi^*}, \Lambda_t^{R^*}, \Lambda_t^{UK}, \Lambda_t^{R}\}$ are also assumed to evolve over time as random walks:

$$\Lambda_t = \Lambda_{t-1} + \eta_t, \eta_t \tilde{} N(0, M) \tag{6}$$

This assumed structure is an efficient way of introducing time-varying dynamics within our model. In particular, the time-varying factor loadings allow the relationship between the foreign variables ($X_t^{Y^*}$, $X_t^{\pi^*}$ and $X_t^{R^*}$) and domestic variables X_t^{UK} to be time varying. This can easily be seen by substituting the equation for F_t^{UK} from (1) to the equation for X_t^{UK} in (2). This gives $X_t^{UK} = \Lambda_t^{UK}\left[B_{21}(L)F_{t-1}^{*} + B_{22}(L)F_{t-1}^{UK} + B_{23}(L)R_{t-1} + u_t\right] + \Lambda_t^{R}R_t + v_t^{UK}$ where the product of Λ_t^{UK} $B_{21}(L)$ is time-varying. Similarly, allowing Ω_t to be time-varying implies a time-varying contemporaneous relationship between foreign and domestic variables. [5]

Equations (1) and (2) capture the time-varying dynamic relationship between macroeconomic conditions in the rest of the world (as summarized by $F_t^{Y^*}$, $F_t^{\pi^*}$and $F_t^{R^*}$) and the U.K. economy (as summarized by F_t^{UK}). By using the VAR in equation (1) it is possible to estimate the impulse response of F_t^{UK} to an innovation in F_t^{*}. Moreover, by using equation (2), it is possible to recover the response of any of the variables in the U.K. panel X_t^{UK} to this foreign shock. Therefore, although the structure of our VAR model is similar to that in Cushman and Zha (1997) and Kim (2001), (as in Mumtaz and Surico (2009)) our specification offers the distinct advantage that the response of wide range of U.K. variables to foreign shocks can easily be derived. Note also that as the factor loadings are time-varying, the impulse response of X_t^{UK} can be estimated at each point in time over the sample period.

Finally, our model summarises information from about 500 data series (see section 2.3). The use of a large data set makes it less likely that there is a large discrepancy between the information set of the economic agent and the econometrician. Therefore the possibility that structural shocks cannot be recovered using our empirical model is reduced. In other words, the problem of non-fundamental structural shocks is mitigated (see Hansen and Sargent (1991) and Lippi and Reichlin (1994)).

2.1 Estimation

The model in equations (1) to (2) is estimated using Bayesian methods described in Kim and Nelson (1998), Primiceri (2005) and Del Negro and Otrok (2008) to approximate the posterior distribution. The Multi-step Gibbs sampling procedure can be broken down into four main steps. [6]

[5] Note that introducing time-variation in the transition equation of the model makes the estimation algorithm substantially more computationally intensive. This is mainly because with eight endogenous variables the stability of the transition equation is difficult to ensure at each point in time, with the Gibbs sampling algorithm unable to find stable draws for infeasibly long periods of time.

[6] A technical appendix with detailed description of the Gibbs sampler is available on request from the authors.

Step 1 Conditional on all other parameters, the VAR coefficients have a normal posterior distribution where the mean and variance of this distribution can be derived via the Kalman filter (this is needed as the VAR covariance is time-varying). We impose the small open economy restrictions as a tight prior centered on zero on the appropriate elements of the VAR coefficient matrix.

Step 2 The unobserved factors can be sampled using the algorithm described in Carter and Kohn (1994).

Step 3 Similarly the methods for state space models in Carter and Kohn (1994) are used to sample the time-varying factor loadings.

Step 4 We use the methods described in Primiceri (2005) and Jacquier et al. (1994) to sample the time-varying VAR covariance matrix.

Our algorithm cycles through these steps 50,000 times using the last 1000 draws for inference. The recursive means of the retained draws (shown in the appendix) show little variation thus providing evidence in favor of convergence.

In our implementation, we set k, the number of UK factors, to 4. This choice is based on three considerations. First, based on a principal components estimator, the panel information criteria introduced by Bai and Ng (2002) suggest the presence of 3 to 4 factors in the UK data series. The first four factors explain around 40% of the variation in the 350 UK data series indicating that they provide an adequate representation of the important dynamics in the panel dataset. Finally, the total number of factors determines the total number of time-varying factor loadings to be estimated. A larger value for k therefore implies an increase in model complexity in a specification which is already highly parameterised.

2.2 Identification of structural shocks

We are interested in studying the dynamic effects of three shocks on the U.K. economy: an unanticipated fall in the interest rates in the rest of the world, a demand shock in the rest of the world and a supply shock in the rest of the world. Note that the analysis of these shocks is important from a theoretical and policy point of view. For example, a key question in International Macroeconomics is the impact of external monetary shocks to a small open economy with different assumptions about pricing behaviour implying a potentially different effect on domestic variables. Using our model one can approach this question in a framework that is flexible (i.e. allows the impact of the shock to be time-varying) and possibly robust to mis-specification due to the data rich nature of the model (see Mumtaz and Surico (2009)). Estimating the impact of these shocks is also policy relevant. For example, the recent recession has been characterised by a reduction in interest rates by a large group of countries (in particular by most of the countries included in the

foreign block of our model). Similarly, several previous economic events (and arguably the current recession) can be characterised as common demand or supply shocks abroad.

In our model, these foreign shocks are identified using a scheme based on a mixture of sign and zero restrictions. The ordering of the FAVAR is $[F_t^{Y^*},\ F_t^{\pi^*},\ F_t^{R^*},\ F_{j,t}^{UK},\ R_t]$ with $j = 1, \ldots, k$ and the superscripts denote international real activity growth, inflation and interest rates, domestic factors and domestic short-term interest rate, respectively.

In our identification scheme shown in Table 1, we impose a mixture of sign and zero restrictions:

	$F_t^{Y^*}$	$F_t^{\pi^*}$	$F_t^{R^*}$	$F_{j,t}^{UK}$	R_t
Foreign aggregate demand	+	+	−	×	×
Foreign aggregate supply	+	−	×	×	×
Foreign interest rate	−	−	+	×	×
Domestic factors	0	0	0	×	×
Domestic interest rate	0	0	0	×	×

Table 1: Sign Restrictions

The sign restrictions are imposed as described in Rubio-Ramirez et al. (2006). In the foreign block, a shock to aggregate demand is associated, on impact, with an increase in foreign activity, inflation, and interest rates; a positive supply shock implies a fall in inflation and a rise in real activity, the interest rate response is left unrestricted; a positive shock to the short-term interest rates comes with a decline in real activity and inflation. Notice that the impact of international shocks on the domestic economy is left unrestricted and domestic shocks have no impact on foreign variables reflecting the small open economy assumption for the U.K.. These zero restrictions in the identification scheme combined with the block-zero structure for the lag polynomial matrix $B(L)$ imply that the rest of the world does not react to U.K. domestic conditions contemporaneously or with lags.

2.3 Data description

To estimate the benchmark model we use quarterly data from 1974Q1 to 2005Q1. In section 3.3, we re-estimate the model adding data up to 2010Q3 in order to examine the financial crisis period.

The data set spans 17 countries and 558 series. We refer to the U.K. as the "domestic" economy. The "foreign" countries are Australia, Belgium, Canada, Finland, France, Germany, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden and United States. The foreign block includes most of the U.K. main trading partners and the major industrialized economies across the world.

2.3.1 International Data

Our international data set contains data on real activity, inflation and interest rates. All data series are seasonally adjusted. We take log differences of all series apart from interest rates. The data are then standardized.

Where available, our real activity data contains real GDP, industrial production, real household consumption expenditure, investment, exports, gross national income and unemployment. Most of the data are obtained from Datastream and International Financial Statistics (IFS) database. The unemployment data are taken from the Global financial database and the U.S. series are obtained from Federal Reserve Economic Data (FRED). Our basic inflation data contain CPI, GDP deflator, measures of wage growth and import prices. The series are obtained from Datastream and IFS. The international interest rate data primarily contain short-term interest rates. These include discount rates, money market rates, treasury bill rates and central bank interest rates. The data are obtained from the Global Financial Database.

2.3.2 U.K. Data

Similar to the international data, our data set on the U.K. contains data on real activity and inflation. We also include some indicators of money and key asset prices. We take log differences of non-stationary data series. The data are then standardised. Real activity data include real GDP, industrial production (with a broad sectoral break down), imports and exports, investment and real household consumption expenditure. The data set includes a very detailed sectoral breakdown of consumption quantities. The data are obtained from the Office of National Statistics (ONS). Inflation data include the main price indices (GDP deflator, CPI, RPI and RPIX) and components of the consumption deflator. ONS and the Bank of England are the main sources for the data. Money data for the U.K. include M0 and M4, with a sectoral breakdown of the latter. These data are obtained from the Bank of England. The asset price data include house prices, stock prices, exchange rates (pounds in terms of US dollars, Euros, Yen, Canadian and Australian Dollars) and the term structure of interest rates. The data are obtained from the Global Financial Database and the Bank of England. A full list of the 558 series, the data transformations and the dataset are available from the authors on request.

3 Empirical results

3.1 International co-movements

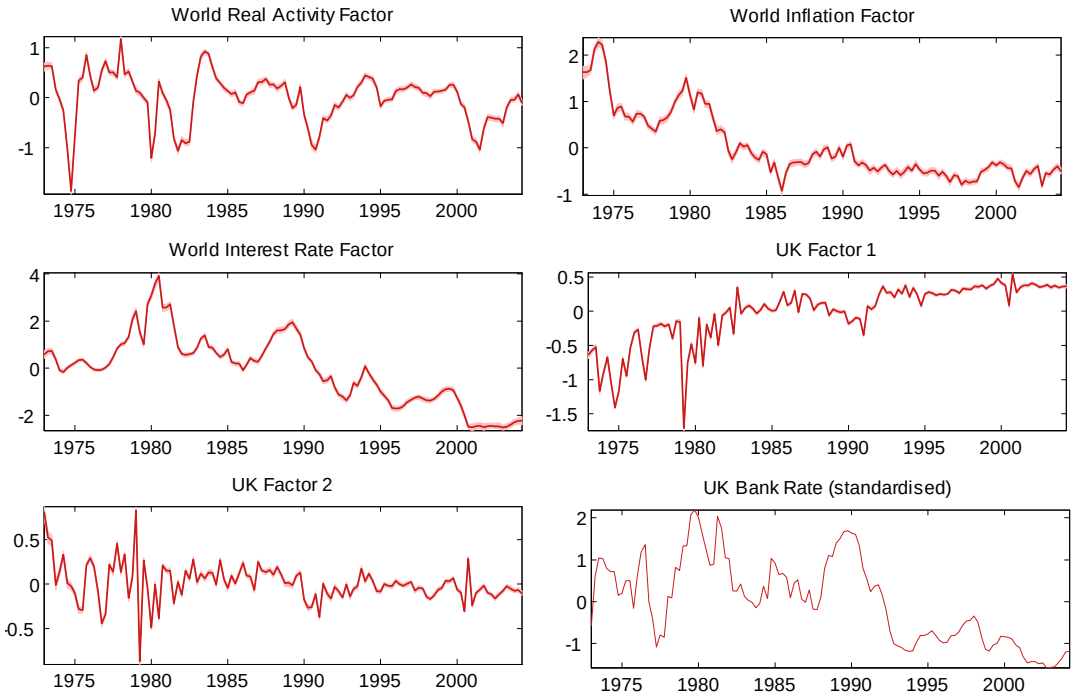

Figure 1: The estimated world and UK factors. Solid line is the median and the shaded area is the 68% error band.

Figure 1 plots the estimated world and first two UK factors. Consider the world real activity factor. In the pre-1990 period, the estimated pattern is very similar to that reported in Kose et al. (2003). As in Kose et al. (2003) we identify the severe contraction in the mid-1970s and the early 1980s. Interestingly, by using higher frequency observations (quarterly data rather than annual), we identified the early 1980's recession as a "double-dip" in economic activity whereas estimates from Kose et al. (2003) suggest a prolonged recession. As in Mumtaz et al. (2011) we identify the recessions during the early 1990s and the downturn following the collapse of the "dotcom" bubble in 2001. The estimated world inflation factor confirms the well known pattern of high inflation during the early and the late 1970s followed by a period of disinflation. This decline in the measure of international inflation is consistent with the notion of global disinflation put forward by Rogoff (2003). Despite the steady increase in oil and commodity prices between 2003 - 2005, world inflation remained relatively stable with a large drop associated with the recent financial crisis and output contraction. The world interest rate factor peaked in the early 1980s. Since then,

it has declined significantly reaching historical lows in the very recent past. The first UK factor appears to capture inflationary pressure in the UK and has a correlation of over 90% with UK CPI inflation. The second UK factor is highly correlated with UK GDP and appears to capture changes in real activity. Factors 3 and 4 for the UK (available on request) are more volatile and harder to interpret directly, but seem to capture the high frequency movements in disaggregated price and consumption data included in the UK dataset.

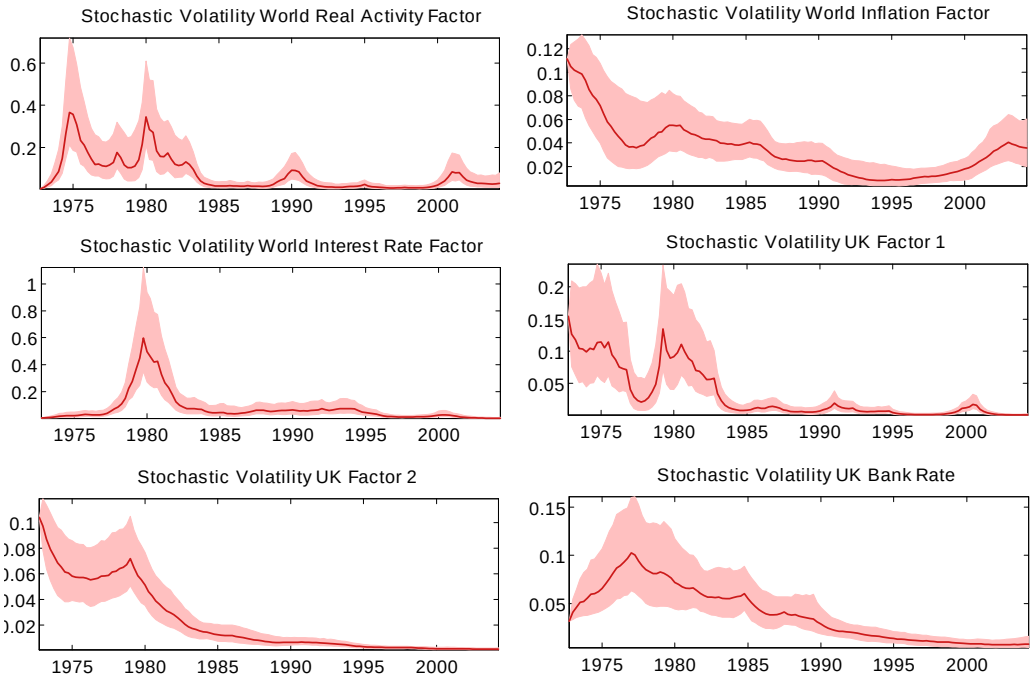

Figure 2: The estimated stochastic volatilities. Solid line is the median and the shaded area is the 68% error band.

Figure 2 shows the estimated stochastic volatilities $h_{i,t}$. The stochastic volatility associated with the shock to the world real activity factor is high during the pre-1985 period before declining over the 'great moderation'. The volatility of the shock to the world inflation factor shows a very similar pattern. In contrast, the volatility associated with the shock to the world interest rate factor remained low in the post 1995 period. It is interesting to note that the volatility of the shock to UK factors 1 and 2 and the Bank of England rate has remained low in the post 1985 period.

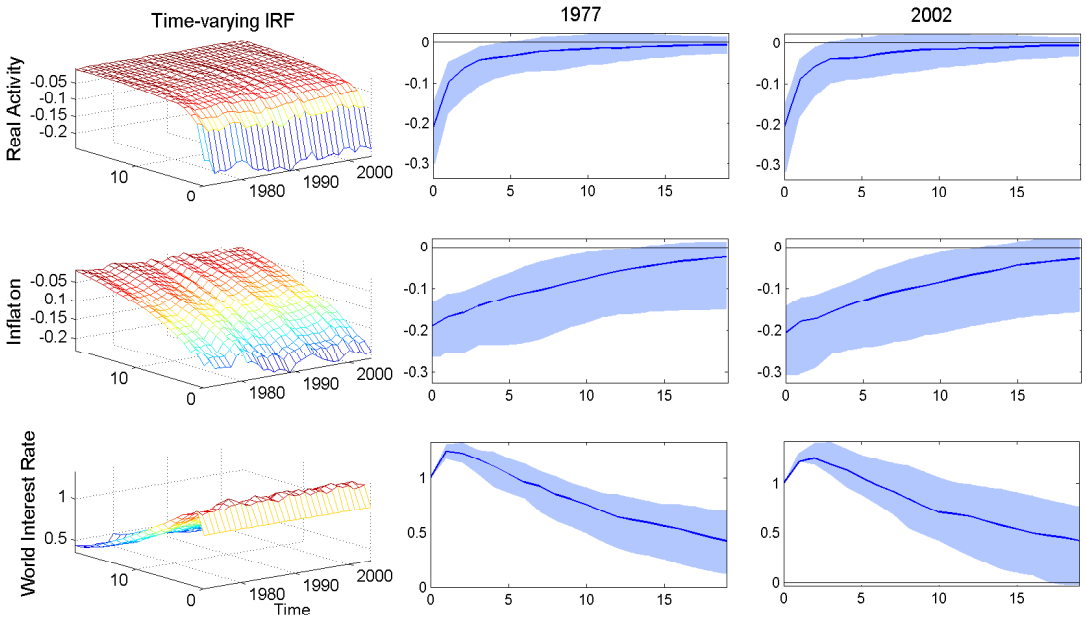

Figure 3: Time-varying Impulse Response of world factors to a world interest rate shock

3.2 Time varying impulse response to foreign interest rate shocks

Estimating the response of UK variables to changes in foreign interest rates is interesting both from a theoretical and policy point of view. Our empirical model allows us to assess if the response in the data matches the predictions of theoretical models of international transmission and if these results have changed over time. In addition, any changes in the response of UK real activity and inflation to this shock are important when assessing the impact of the recent response of industrialised economies to the financial crisis and recession over the last few years with interest rates reaching historical lows.

Figure 3 plots the response of the world factors to a contractionary world interest rate shock. The size of the shock is normalized to be a 1% increase in the world interest rate factor. The first column plots the median impulse response functions (IRFs) to the shock estimated for each year in the sample, while the second and third columns illustrate the response in two representative years in the earlier and the later part of the sample: 1977 and 2002 together with the 68% error bands (light blue band).

The increase in world interest rates generates a contraction in real world activity and inflation. Once we control for the time-varying volatility of the shock, the response of the

world factors is very similar over most of the sample period.

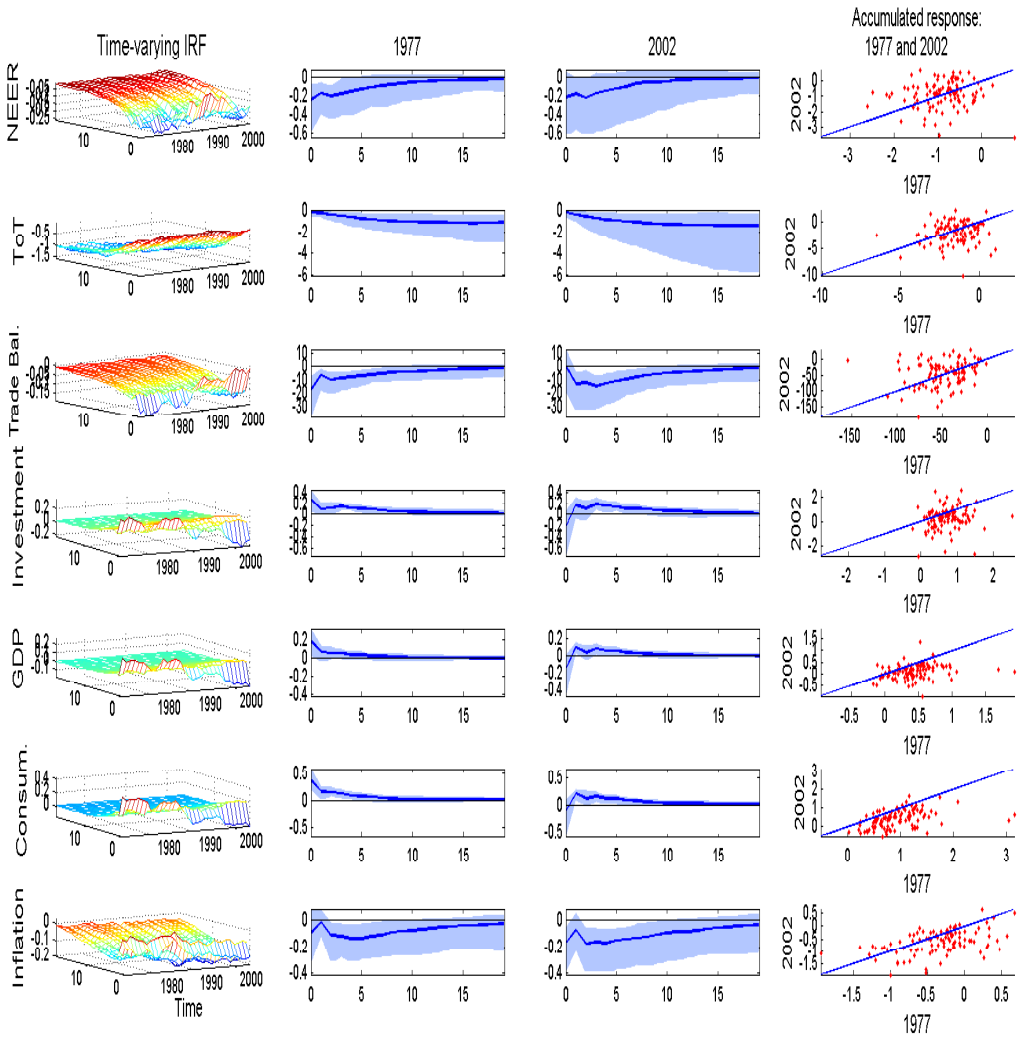

Figure 4: Time-varying impulse response of UK variables to an increase in world interest rates

Figure 4 plots the time-varying response of key UK variables to this shock. Note that the final column of the figure compares the distribution of average impulse responses (cumulated at the one year horizon) in 1977 and 2002. If majority of the draws lies below the 45^{o} line, this indicates that the cumulated response is larger in 1977 relative to 2002 and vice versa.

Throughout the sample, the nominal effective exchange rate (NEER) depreciates in response to higher capital outflows from the lower interest rate differential. While the response of the terms of trade is close to zero over the sample period, the response of the trade balance shows some time-variation with the median response becoming less negative over time at shorter horizons.

The response of real activity shows marked time-variation. The median response of investment, GDP and consumption growth is positive and persistent before the 1990s. Note that the impulse response of these variables estimated in 1977 suggests that the null hypothesis of a zero response can be rejected at short horizons. In the contrast, in the later part of the sample these variables decline in response to the increase in foreign interest rates with the response estimated in 2002 close to zero over most of the horizon. Note that over the recent crisis period most industrialised countries have been pursuing expansionary monetary policy. Given this background, the shift in the transmission mechanism highlighted by our estimates implies that the UK is less affected (compared to the past) by potential negative output implications of foreign monetary expansion.

A number of factors could lie behind this change in the response of real activity indicators. For example, this change is consistent with the possibility of a shift from producer to local currency pricing and a fall in exchange rate pass-through.[7] Under producer currency pricing, high exchange rate pass-through to import prices give domestic consumers more incentives to shift consumption towards relatively cheaper home goods - the expenditure switching effect. If this expenditure switching effect dominates the negative income effect from the contraction in world money supply, then domestic real activity is positively affected as appears to be the case in the earlier part of the sample. On the other hand, if imports are priced in local currency and exchange rate pass-through is low, then there is less incentive for consumers to switch from imports to domestic goods and the beggar-thy-neighbor effect is ameliorated. Betts and Devereux (1999) provide details from a theoretical perspective. The change in the response of GDP in the early 1990s also coincides with the Pickford review of government economic statistics in the UK. This led to a change in the method used to calculate GDP perhaps making the estimates of GDP growth less volatile. The change in the impulse response of real activity indicators highlighted may therefore also reflect the impact of this methodological change

The final row of the figure shows the response of CPI inflation to the foreign interest rate shock. Inflation declines in response to this shock throughout the sample with the decline slightly larger in the later part of the sample.

[7] Mumtaz et al. (2006) show that the pass-through of the exchange rate into UK import prices fell over the period 1987-2004. Similar evidence for declining exchange rate pass-through is presented for the Euro area in Sekine (2006) and for Canada in Murchison (2009).

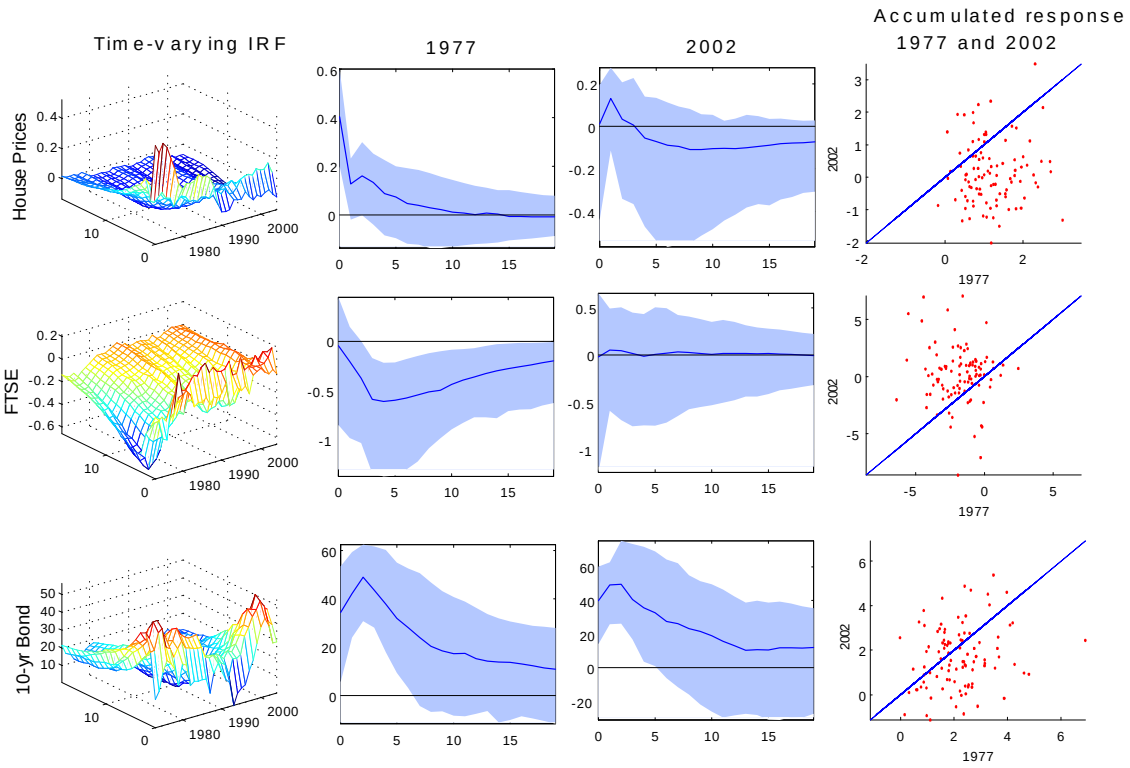

Figure 5: Time-varying impulse response of UK variables to an increase in world interest rates

The response of UK asset prices to the foreign interest rate shock is shown in Figure 5. The response of house price growth to this shock is similar to the GDP response. The median response is positive in the early part of the sample and close to zero in the post-1990 period. The FTSE response is negative over the earlier part of the sample which then becomes close to zero. The response of the 10 year government bond yield shows some time-variation. The bond yield rises by about 40 basis points in response to this shock in the pre-1985 period. This declines to about 20 basis points in the late 1980s and early 1990s, before increasing again over the remaining sample.

3.3 The importance of foreign shocks and the recent financial crisis

In this section we examine the historical contribution of world aggregate demand and aggregate supply shocks in driving the world factors and UK macroeconomic variables. The aim of this analysis is to gauge the importance of these identified shocks in driving world co-movements in real activity, inflation and interest rates and key UK macroeco-

nomic variables, especially over the recent financial crisis.[8] To this end, we re-estimate our model using data up to 2010Q3. Using the estimated model, we calculate the historical decomposition of the VAR that defines the transition equation of the model via the Kalman smoother. Note that this takes into account the feature of our specification that the volatility of structural shocks is allowed to be time-varying. The decomposition for each underlying variable in our dataset can then be derived using the observation equation (equation 2) which allows for time-varying factor loadings.

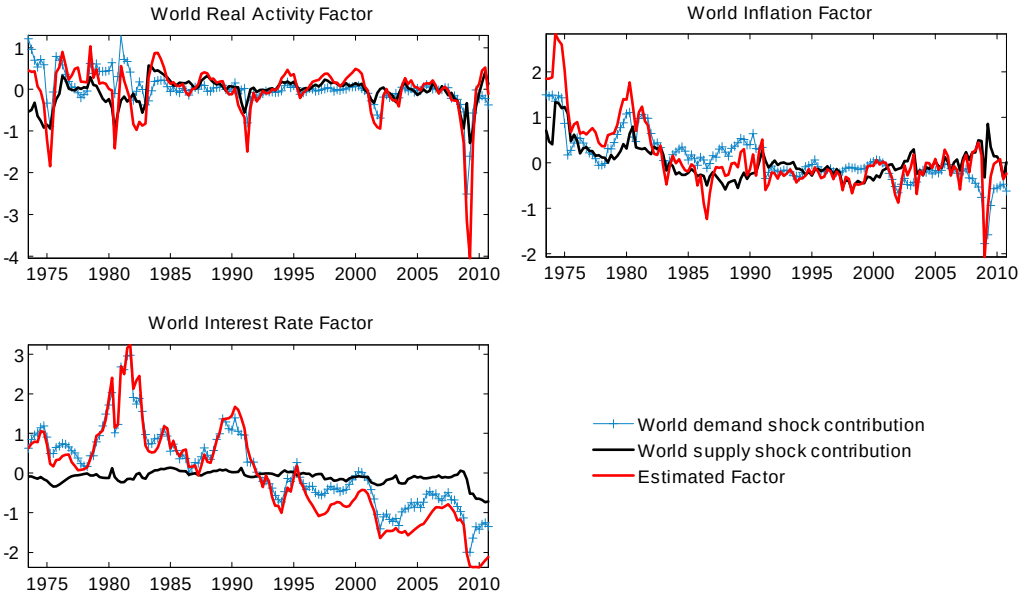

Figure 6: Historical decomposition: World Factors

Figure 6 plots the estimated historical decomposition for the world factors.[9] The red lines show the estimated factors. The remaining lines show the factor estimates under the counter-factual assumption that only the world demand or supply shocks are operational. A close co-movement between the actual and the counter-factual estimates would suggest that the shock in question makes an important contribution.

Consider the top left panel of the figure. It is interesting to note that the world real activity factor shows a downturn over the period 2007-2009 that is unprecedented over the

[8] Note that it is difficult to interpret 'monetary policy' shocks over the recent period as several countries in our data-set have been pursuing unconventional monetary policy that cannot be modelled via short-term interest rates. It is for this reason that we focus on demand and supply shocks only.

[9] Note that, the estimated world factors do not depend on domestic UK shocks by assumption and therefore their contribution is not shown in the figure. Also note that the underlying series are standardised.

sample period.[10] The world supply shock played a major part in the recessions of the mid and the late-1970s. The recession of the early 1990s was driven largely by demand shocks. These shocks also played a major part in the downturn in the early 2000s. It is interesting to see that the downturn in world real activity associated with the recent financial crisis is largely driven by aggregate demand shocks. Note, however, that over this period, these demand shocks may also reflect the impact of of unconventional monetary policy which are not captured by the identified world interest rate shock. Both world demand and supply shocks played an important part in driving the great inflation during the mid-1970s and then the early 1980s. Note that the supply shock contributed to the period of dis-inflation after the early 1980s with the demand shock prominent over the post-1990 period. The world interest rate factor is driven largely by the world demand shock over the entire sample period.

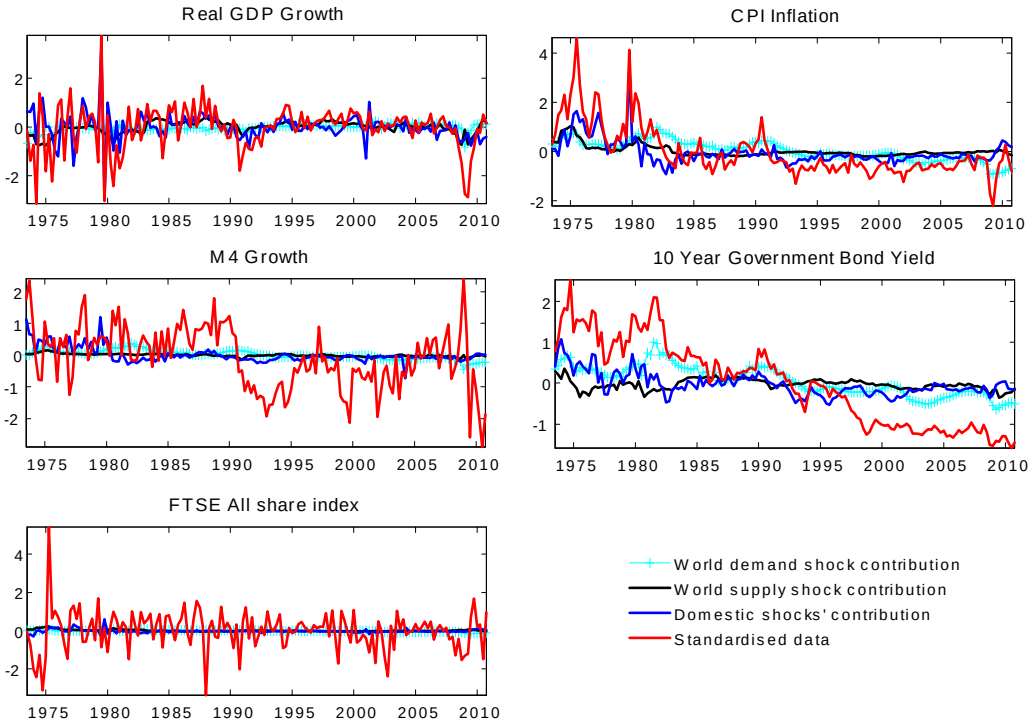

Figure 7: The contribution of structural shocks to key UK data series

Figure 7 plots the historical decomposition for some key UK data series. Alongside the standardised data series, the figure plots the estimated value of the series under the assumption that only world demand, world supply and domestic shocks (which are left

[10] However, it is worth pointing out the caveat that the factor estimates over 2007-2009 are subject to end point filter uncertainty.

unidentified and shown together for clarity) respectively are non-zero. World supply and demand shocks play a part in driving UK real GDP in the mid-1970s and the early 1980s. It is interesting to observe that the period of steady GDP growth after the recession of the early 1980s saw a significant positive contribution from world supply shocks indicating that the UK benefited from positive international developments over that period. World supply shocks contributed to the recession of the early 1990s. International shocks play an important role during the recent recession in 2008/2009 with both world supply and demand shocks contributing to the GDP downturn. Our results thus indicate that without the adverse impact of international shocks, the downturn in UK GDP growth would have been milder. While domestic shocks played an important part in driving inflation during the 1970s and the early 1980s, our results suggest an important role for world supply and demand shocks during this period. Note, however, that the disinflation period of the early 1980s is largely dominated by domestic shocks. However, world demand shocks made a contribution to inflation over the post-1990 period. World demand shocks were also an important contributor to the long term UK government bond yield over the entire sample period, with a negative contribution over the last two decades. In contrast, the international shocks appear to have had a more limited impact on UK money growth and share price growth.

Overall, these results suggest that international shocks played an important part in driving key UK macroeconomic variables. In particular, international shocks played an important role for GDP and inflation, with their contribution especially relevant during the recent crisis period.

4 Conclusions

This paper has studied the international transmission of structural shocks in an open economy FAVAR model applied to the U.K. Unlike previous contributions, we use data on 17 countries and 558 variables, covering prices, economic activity and monetary indicators, to model the interaction between the foreign and domestic blocks of the VAR. In addition, we allow the relationships embodied in this model to change over time by incorporating time-varying coefficients and stochastic volatility within the FAVAR framework.

We find that the recent recession has been characterised by a common drop in real activity in the industrialised world that has surpassed the recessions of the 1970s. This drop in world real activity appears to be driven largely by the identified world demand shock. This shock makes an important contribution to the drop in UK GDP over the recent crisis period. A foreign interest rate shock is estimated to have substantially different effects on the UK in the period after 1990. In particular, the response of the domestic economy in the period before 1990 resembles a classic beggar-thy-neighbor scenario, with decreases in foreign money supply resulting in an increase in U.K. real activity. In contrast, the post-1990 period is characterized with negative response of U.K. real activity to this shock.

In this study, we have identified changes to the international transmission of shocks around 1990 which corresponds to significant changes to UK's monetary policy framework and coincides with changes in the statistical methodology used in the UK. Future research could therefore be directed towards understanding the interactions between these changes and the international transmission mechanism.

References

Bai, J. and S. Ng (2002, January). Determining the number of factors in approximate factor models. *Econometrica 70*(1), 191–221.

Benati, L. (2006). UK monetary regimes and macroeconomic stylised facts. Bank of England Working Paper 290, Bank of England.

Betts, C. and M. B. Devereux (1999). The international effects of monetary and fiscal policy in a two country model. In G. Calvo, R. Dornbusch, and M. Obstfeld (Eds.), *Essays in Honor of Robert A. Mundell*. MIT Press.

Boivin, J. and M. P. Giannoni (2006, October). Has monetary policy become more effective? *The Review of Economics and Statistics 88*(3), 445–62.

Campa, J. M. and L. S. Goldberg (2005, December). Exchange rate pass-through into import prices. *The Review of Economics and Statistics 87*(4), 679–90.

Carter, C. K. and R. Kohn (1994). On Gibbs sampling for state space models. *Biometrika 81*(3), 541–53).

Castelnuovo, E. and P. Surico (2005). The price puzzle: fact or artefact? Technical report.

Clarida, R., J. Galí, and M. Gertler (2000, February). Monetary policy rules and macroeconomic stability: evidence and some theory. *The Quarterly Journal of Economics 115*(1), 147–80.

Cogley, T. and T. Sargent (2002). Evolving post-world war II US inflation dynamics. In B. S. Bernanke and K. Rogoff (Eds.), *NBER Macroeconomics Annual 2001*. MIT Press.

Cogley, T. and T. J. Sargent (2005, April). Drift and volatilities: monetary policies and outcomes in the post WWII US. *Review of Economic Dynamics 8*(2), 262–302.

Cushman, D. O. and T. Zha (1997). Identifying monetary policy in a small open economy under flexible exchange rates. *Journal of Monetary Economics 39*, 433–48.

Del Negro, M. and C. Otrok (2008). Dynamic factor models with time-varying parameters: measuring changes in international business cycles. *Federal Reserve Bank of New York Staff Reports*.

Eichenbaum, M. and C. L. Evans (1995, November). Some empirical evidence on the effects of shocks to monetary policy on exchange rates. *The Quarterly Journal of Economics 110*(4), 975–1,009.

Faust, J. and J. H. Rogers (2003, October). Monetary policy's role in exchange rate behavior. *Journal of Monetary Economics 50*(7), 1,403–24.

Gambetti, L., E. Pappa, and F. Canova (2008, 03). The structural dynamics of US output and inflation: what explains the changes? *Journal of Money, Credit and Banking 40*(2-3), 369–88.

Grilli, V. and N. Roubini (1995, October). Liquidity and exchange rates: puzzling evidence from the G-7 countries. Working Paper 95-17, New York University, Leonard N. Stern School of Business, Department of Economics.

Hansen, L. P. and T. J. Sargent (1991). Two problems in interpreting vector autoregressions. In R. E. Lucas and T. J. Sargent (Eds.), *Rational Expectations Econometrics*. Westview: Boulder.

Jacquier, E., N. G. Polson, and P. E. Rossi (1994, October). Bayesian analysis of stochastic volatility models. *Journal of Business and Economic Statistics 12*(4), 371–89.

Kim, C. J. and C. R. Nelson (1998). *State-space models with regime-switching: classical and Gibbs-sampling approaches with applications*. MIT Press.

Kim, C. J. and C. R. Nelson (1999, November). Has the US economy become more stable? A Bayesian approach based on a Markov-switching model of the business cycle. *The Review of Economics and Statistics 81*(4), 608–16.

Kim, S. (2001, October). International transmission of US monetary policy shocks: evidence from VAR's. *Journal of Monetary Economics 48*(2), 339–72.

Kose, M. A., C. Otrok, and C. H. Whiteman (2003, September). International business cycles: world, region, and country-specific factors. *American Economic Review 93*(4), 1,216–239.

Lippi, M. and L. Reichlin (1994). Var analysis, nonfundamental representations, blaschke matrices. *Journal of Econometrics 63*(1), 307–325.

McConnell, M. M. and G. Perez-Quiros (2000, December). Output fluctuations in the United States: what has changed since the early 1980's? *American Economic Review 90*(5), 1,464–76.

Mumtaz, H., O. Oomen, and J. Wang (2006). Exchange rate pass-through into uk import prices. Technical report.

Mumtaz, H., S. Simonelli, and P. Surico (2011, January). International comovements, business cycle and inflation: a historical perspective. *Review of Economic Dynamics 14*(1), 176–198.

Mumtaz, H. and P. Surico (2009, 02). The transmission of international shocks: a factor-augmented VAR approach. *Journal of Money, Credit and Banking 41*(s1), 71–100.

Murchison, S. (2009). Exchange rate pass-through and monetary policy: How strong is the link? Technical report.

Nelson, E. (2001). Uk monetary policy 1972-97: a guide using taylor rules. Technical report.

Primiceri, G. E. (2005, July). Time varying structural vector autoregressions and monetary policy. *Review of Economic Studies 72*(3), 821–52.

Rogoff, K. S. (2003). Globalization and global disinflation. *Proceedings*, 77–112.

Rubio-Ramirez, J. F., D. Waggoner, and T. Zha (2006). Markov-switching structural vector autoregressions: theory and application. Computing in Economics and Finance 2006 69, Society for Computational Economics.

Sekine, T. (2006, March). Time-varying exchange rate pass-through: experiences of some industrial countries. BIS Working Papers 202, Bank for International Settlements.

Sims, C. A. and T. Zha (2006, March). Were there regime switches in US monetary policy? *American Economic Review 96*(1), 54–81.

4.1 Appendix: MCMC convergence diagnostics