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Abstract

This paper examines the effects of monetary policy shocks on UK regional economic growth and dispersion in a novel Constrained Mixed Frequency Vector Autoregressive framework. Compared to a standard MFVAR, the model partially accounts for missing quarterly observations for regional growth by exploiting national growth data. Results suggest significant heterogeneity in the importance of monetary policy shocks across regions. Mortgage indebtedness is highly related to regional sensitivity to monetary policy shocks. Also, there is some evidence suggesting that regions with larger share of manufacturing output and small and medium sized firms in employment are more sensitive to monetary policy shocks.

Keywords: Regional Growth, Monetary Policy, Bayesian Analysis, VAR, Mixed Frequency Data.

JEL Classification: E01, E3, E52, C11, C32, C5.

1 Introduction

A common feature of the applied macroeconomics literature on the effects of monetary policy shocks is the assumption that the responses of heterogeneous units or regions are homogeneous. On the other hand, there have been growing strands of literature that investigate the heterogeneous effects of monetary policy shocks across groups, categorized with respect to different characterizations as income or geographical locations for a long time. In particular, the issue gained even more importance with the formation of the European Monetary Union. More recently, many questioned and criticized the expansionary monetary policies pursued by the central banks in the developed world arguing that these policies may have significant distributional effects.[1] This paper employs a novel econometric model to study the heterogeneous effects of monetary policy shocks on regional economic growth in the United Kingdom (UK). Also, it provides evidence on the role of monetary policy in driving regional economic growth dispersion relative to economy-wide demand and supply shocks across time.

Existing literature propose several reasons as to why monetary policy shocks may have heterogeneous impact on different regions. Rodríguez-Fuentes & Dow (2003) separate the arguments in the literature into two categories; the ones based on the differences between

[1]See, for instance, Coibion et al. (2012) and Mumtaz & Theophilopoulou (2015) for the distributional effects of monetary policy in the United States and the United Kingdom respectively.

the economic structures across regions and the ones that emphasize the differences in the financial structures. Within each of these two categories, there are several possible explanations. Regarding the economic structures, Carlino & DeFina (1998) argue that the sensitivity of a region to monetary policy shocks may be due to the industry mix of the given region. They call this channel as interest rate channel. In fact, Ganley & Salmon (1997) study the sensitivity of UK industries to monetary policy shocks and find notable differences across industries. Furthermore Carlino & DeFina (1998) and Owyang & Wall (2005), following Bernanke & Blinder (1988), Bernanke (1993), Gertler & Gilchrist (1993) and Oliner & Rudebusch (1995), focus on the broad credit view of monetary policy. They argue that, in the presence of informational frictions, monetary policy may have different effects on small vs big firms as their ability to borrow may be different. Regarding the differences in the financial structures across regions, following Kashyap & Stein (1995) and Kashyap & Stein (1997) the literature mainly focus on the bank lending channel as in Owyang & Wall (2005). The argument is that following a contractionary monetary policy shock bank reserves decrease and small banks find it harder to obtain funding through alternative source of finance than deposits compared to larger banks; hence they become more reluctant to lend. This implies that regions sensitivities to monetary policy shocks can be different given that they have different proportion of small vs big banks. Holmes (2000) argue that an additional channel is the mortgage indebtedness of a region.

Empirically, existing literature employ either panel data or time series Vector Autoregressive (VAR) models to study the differential effects of monetary policy. For instance, Carlino & DeFina (1998) and Owyang & Wall (2005) employ VAR models to investigate the regional effects of monetary policy shocks in the US. In the absence of quarterly regional economic output data, Arnold (2001) focus on the European countries and employ panel data models to study interest rate sensitivity of regional growth. The author argues that the sample with annual data is restrictive to use comprehensive time series models. Likewise, Holmes (2000) studies the effect of monetary policy shocks on UK regional output with a panel model, arguing that yearly data restricts using a VAR. While panel models are useful in studying the impact of exogenous shocks on an endogenous variable, they are not well-suited to study propagation of shocks within variables that drive each other dynamically, like key macroeconomic variables output and interest rates.

The first contribution of this paper is to provide evidence on the dynamic effects of monetary policy shocks on UK regional economic growth using a novel econometric model. The methodological contribution is the Constrained Mixed Frequency VAR (C-MFVAR) model that accommodates both high and low frequency variables. In comparison to the standard MFVAR model of Schorfheide & Song (2015), the modified model in here utilizes high frequency aggregate (national) data to infer about the missing high frequency disaggregate (regional) data. Using the C-MFVAR, I study the impact of monetary policy shocks on growth in UK regions, and assess the relevance of various regional characteristics in explaining regional sensitivity to monetary policy. Finally, I decompose regional growth into monetary policy, as well as economy-wide demand and supply shocks to examine their relative role in driving the observed regional growth dispersion across time.

Results indicate significant heterogeneity in the effects of monetary policy shocks on UK regional growth. I find South East, Midlands, South West, East and London to be the most sensitive regions to monetary policy shocks, whereas Northern Ireland and Yorkshire and the Humber to be the least. Results indicate that mortgage indebtedness is highly related to monetary policy sensitivity of regions, and there is also some evidence for the interest rate and broad credit channels, albeit weaker. Historical decompositions indicate that, supply shocks have been the primary source of disparities in growth across the regions. Monetary policy and demand shocks generate similar degrees of heterogeneity in regional growth, but significantly less than supply shocks. Furthermore, by means of Monte Carlo (MC) simulations, I compare the accuracy of high frequency estimates from the C-MFVAR with the standard model. Simulations indicate that C-MFVAR improves the estimates by 37.5% in terms of root mean square error (RMSE).

The paper is organized as follows; Section 2 presents the C-MFVAR, estimation, MC exercise; Section 3 depicts the data; Section 4 discusses the results; Section 5 concludes.

2 Empirical Methodology

2.1 The Constrained MFVAR Model

Similar to Schorfheide & Song (2015), to model the dynamic interaction between economy-wide real and nominal shocks and regional economic growth, below presented C-MFVAR model has been specified,

$$Z_{rt} = c + \sum_{p=1}^{L} B_{rp} Z_{rt-p} + u_{rt}, \qquad u_{rt} \sim N(0, A_r^{-1} \Sigma_r A_r^{-1\prime}) \tag{1}$$

where $Z_t = [y_t^{ex}; p_t; r_t; y_t^r]'$, which includes quarterly year-over-year (yoy) UK-ex-region-r growth ($y_t^{ex} = y_t^{uk} - w_{rt} y_t^r$), yoy core inflation ($p$), tbill rate ($r$), unobserved quarterly yoy regional real economic growth (y_t^r), $L = 4$, w_{rt} is the share of regional output in the national economy at time t for regions $r = 1, ..., 12$.[2]

Since regional output data is yearly, y_t^r is observed only in the last quarter (Q4) in each year, with intra-year quarters (Q1, Q2, Q3) missing. Hence, there are two unobserved high frequency variables in Q1, Q2 and Q3 in each year; y_t^{ex} and y^r. Notice that, although quarterly UK growth (y_t^{uk}) is observed in all quarters, UK-ex-region-r growth y_t^{ex} is unknown in Q1, Q2 and Q3, since y^r is unobserved in these quarters. In line with these considerations, the observation equation of the model has been specified as,

$$X_{rt} = M_{rt} Z_{rt}$$

$$\begin{aligned}
\begin{bmatrix} y_t^{uk} \\ p_t \\ r_t \end{bmatrix} &= \begin{bmatrix} 1-w_{rt} & 0 & 0 & w_{rt} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} y_t^{ex} \\ p_t \\ r_t \\ y_t^r \end{bmatrix} \quad \text{if } t = Q1, Q2, Q3 \\
\begin{bmatrix} y_t^{ex} \\ p_t \\ r_t \\ y_t^r \end{bmatrix} &= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} y_t^{ex} \\ p_t \\ r_t \\ y_t^r \end{bmatrix} \quad \text{if } t = Q4
\end{aligned} \tag{2}$$

Equation 1 in companion form and Equation 2 represent the transition and the measurement equations for the C-MFVAR. The novelty in the above specification is that the C-MFVAR embodies an aggregation constraint for y_t^{ex} and y_t^r. Through this constraint

[2] Since the share of regional output in the aggregate economy does not demonstrate much high frequency variation, the weights are calculated from interpolated data and kept the same throughout the estimation.

the model both incorporates relevant high frequency intra-year variations at the existing national growth data, and also takes into account the uncertainty about the intra-year regional growth and hence intra-year UK-ex-region growth.

The identification of structural demand, supply and monetary policy shocks have been achieved by imposing sign restrictions on the contemporaneous impact of shocks. Furthermore, in order to distinguish between regional and economy-wide shocks, instantaneous impact of regional shocks is assumed not to affect other variables, similar to Carlino & DeFina (1998). These restrictions together imply a mixture of short run exclusion and sign restrictions, as in Rubio-Ramirez et al. (2010).[3] Also, the restrictions on the national economic growth are imposed on the economic-size-weighted averages of the responses of y_t^{ex} and y_t^r. The sign restrictions are outlined in Table 1. Following Benati (2008) and Baumeister & Benati (2013), demand shocks are assumed to increase output, inflation and interest rates; supply shocks are assumed to lower growth and increase inflation; and monetary policy shocks are assumed to increase interest rates, lower growth and inflation.

Table 1: Sign Restrictions

	Response		
Shock	y	p	r
Demand	$>$	$>$	$>$
Supply	$<$	$>$	?
Monetary Policy	$<$	$<$	$>$

The C-MFVAR model has been estimated for 12 UK regions. Markov Chain Monte Carlo (MCMC), Gibbs Sampling techniques are employed for the estimation, similar to Schorfheide & Song (2015).[4] For the coefficients matrices, minnesota priors are used following Bańbura et al. (2007) and Bańbura et al. (2010) with the interpolated data. Given the priors and initial conditions, Gibbs sampling steps involve drawing respectively, coefficient matrices, variance covariance matrix, missing observations following Carter & Kohn (1994). Gibbs steps are repeated 100000 times with 90000 as burn in.

2.2 Monte Carlo Experiment

Notice that the empirical strategy presented in the previous subsection involves estimating the C-MFVAR model for 12 regions separately. An alternative would have been to estimate a single model with all 12 regions included. Observation equations for this Large-C-MFVAR model would have the representation below,

$$\begin{aligned}
\begin{bmatrix} y_t^{uk} \\ p_t \\ r_t \end{bmatrix} &= \begin{bmatrix} w_{1t} & ... & w_{12t} & 0 & 0 \\ 0 & ... & 0 & 1 & 0 \\ 0 & ... & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \overline{y}_t^r \\ p_t \\ r_t \end{bmatrix} \quad \text{if } t = Q1, Q2, Q3 \\
\begin{bmatrix} \overline{y}_t^r \\ p_t \\ r_t \end{bmatrix} &= \begin{bmatrix} I_{12} & 0_{12} & 0 \\ 0_{12} & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \overline{y}_t^r \\ p_t \\ r_t \end{bmatrix} \quad \text{if } t = Q4
\end{aligned} \tag{3}$$

[3] Codes provided by Binning (2013) have been employed for identification.
[4] Matlab codes written by the author have been used for the estimation.

where $\overline{y}_t^r = [y_t^1; y_t^2; ...; y_t^{12}]'$. In this case, the weighted sum of intra-year unobserved growth in 12 regions is constrained to be equal to the observed UK growth. Hence, unlike the smaller model presented in the previous subsection, this larger model includes all regions rather than having a specific region of interest and having rest of the regions included via UK-ex-region y_t^{ex} variable. The standard unconstrained MFVAR would have the representation as,

$$\begin{aligned} \begin{bmatrix} p_t \\ r_t \end{bmatrix} &= \begin{bmatrix} 0 & ... & 0 & 1 & 0 \\ 0 & ... & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \overline{y}_t^r \\ p_t \\ r_t \end{bmatrix} \quad \text{if } t = Q1, Q2, Q3 \\ \begin{bmatrix} \overline{y}_t^r \\ p_t \\ r_t \end{bmatrix} &= \begin{bmatrix} I_{12} & 0_{12} & 0 \\ 0_{12} & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \overline{y}_t^r \\ p_t \\ r_t \end{bmatrix} \quad \text{if } t = Q4 \end{aligned} \tag{4}$$

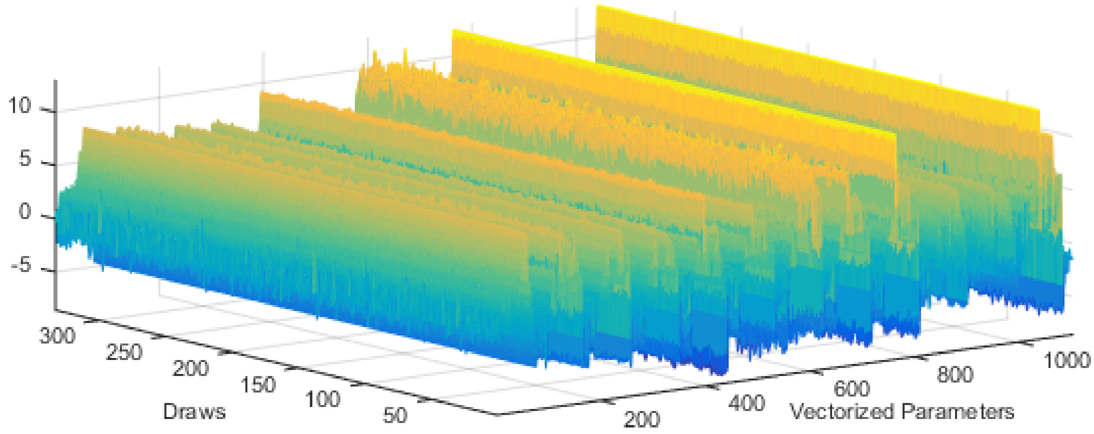
This paper favours estimating parsimonious smaller models rather than estimating a single large model for three reasons. Firstly, VAR models are subject to the proliferation of parameters problem as the number of variables increase. So, the efficient strategy is to estimate separate models for different regions. This becomes even more evident when the question of interest is not the inter-regional dependencies, but the interaction between nation-wide shocks and individual regions as in here. Second reason is, Monte Carlo simulations presented below indicate that C-MFVAR beats the Large-C-MFVAR in terms of the RMSEs. The final concern is the identification of demand shocks in the large model. In the larger model, there are 12 regions of which the residuals are at best noisy signals of the economy-wide demand shocks. In contrast, in the smaller model y_t^{ex} reduced form residuals have a natural interpretation as economy-wide variations since the idiosyncratic regional shocks are averaged out.

Objective of the Monte Carlo experiment has been to assess whether the small C-MFVAR provides more accurate estimates than a standard unconditional MFVAR and Large-C-MFVAR in the context of this paper. A VAR with 12 regional growth and 2 additional variables have been used as the data generating process (DGP); and the parameters of the DGP have been randomly drawn or set as below similar to Mandalinci & Mumtaz (2015).

$$\begin{aligned} B &\sim \left\{ \begin{array}{ll} N(0.5, 0.2) & \text{for } 1^{st} \text{ Own Lag} \\ N(0, 0.02) & \text{for } 1^{st} \text{ Lags of Other Regions} \\ N(0, 0.05) & \text{for } 1^{st} \text{ Lags of National Variables} \\ N(0, 0.01) & \text{for } 2^{nd} \text{ Lags of Other Regions} \\ N(0, 0.02) & \text{for } 2^{nd} \text{ Lags of National Variables} \end{array} \right\}, \\ c &\sim \left\{ \begin{array}{ll} N(1, 0.05) & \text{for Growth Variables} \\ N(0, 0.05) & \text{for Other Variables} \end{array} \right\}, \qquad \Sigma = I_{15}, \\ A^{-1} &\sim \left\{ \begin{array}{ll} N(+/-0.4, 0.4) & \text{for Sign Constrained National Vars.} \\ N(+/-0.4, 0.1) + N(0, 0.4) & \text{for Regional Variables} \\ N(0, 0.4) & \text{for Sign Unconstr. National Vars.} \\ 0 & \text{for Responses to Regional Shocks} \end{array} \right\}. \end{aligned}$$

Experiment design has been done to mimic the case considered in this paper. Namely, number of observations have been set to 100; regions to 12; number of observed variables to 2; and the lag length to 4. The elements of the contemporaneous impact matrix A have

Figure 1: MCMC Convergence: Recursive Means of Regional Growth



been set according to the identifying assumptions discussed in the previous section. A point to note is that, responses of regions to nation-wide shocks are set in two steps. First, the mean response has been sampled, and individual regions' responses have been set to this value plus noise. Also, note that there are 15 shocks in the DGP, out of which demand shocks affect all regional growth series. This is because reduced form growth series' residuals are assumed to reflect noisy signals of economy-wide demand shocks, in addition to other economy wide shocks. Once the parameters have been generated/set, they are fixed while 100 simulations have been performed later by first generating structural errors and then variables. In each simulation, first 100 observations have been discarded to remove the impact of initial conditions. Models have been estimated with the generated data for each simulation with 5000 gibbs replications out of which 4000 as burn in, and rmse values are calculated and stored to assess the accuracy of the intra-year estimates of the missing regional growth series.

Table 2: Monte Carlo Experiment: RMSEs

		RMSE Ratios	
Model	RMSE	MFVAR	Large-C-MFVAR
MFVAR	1.907		
Large-C-MFVAR	1.511	0.792	
C-MFVAR	1.193	0.625	0.789

Table 2 reports the rmse values from three competing models in the first column, and the rmse ratios in the last two columns. Large-C-MFVAR beats the standard MFVAR by over 20% in terms of the rmses. Examining the rmse ratios for C-MFVAR vs Large C-MFVAR model, the estimates from the C-MFVAR beat the estimates from the Large C-MFVAR by 21%. C-MFVAR beat a standard MFVAR by 37.5% in terms of the rmses.

3 Dataset

The regional activity measure is the gross value added (GVA) for 12 UK NUTS 1 (Nomenclature of Territorial Units for Statistics) regions. The list of regions is presented in Table 3. The data is obtained from Datastream, Office for National Statistics (ONS) and Eurostat. Regional unemployment data is from Datastream and ONS.

Figure 2: Estimated Regional Growth

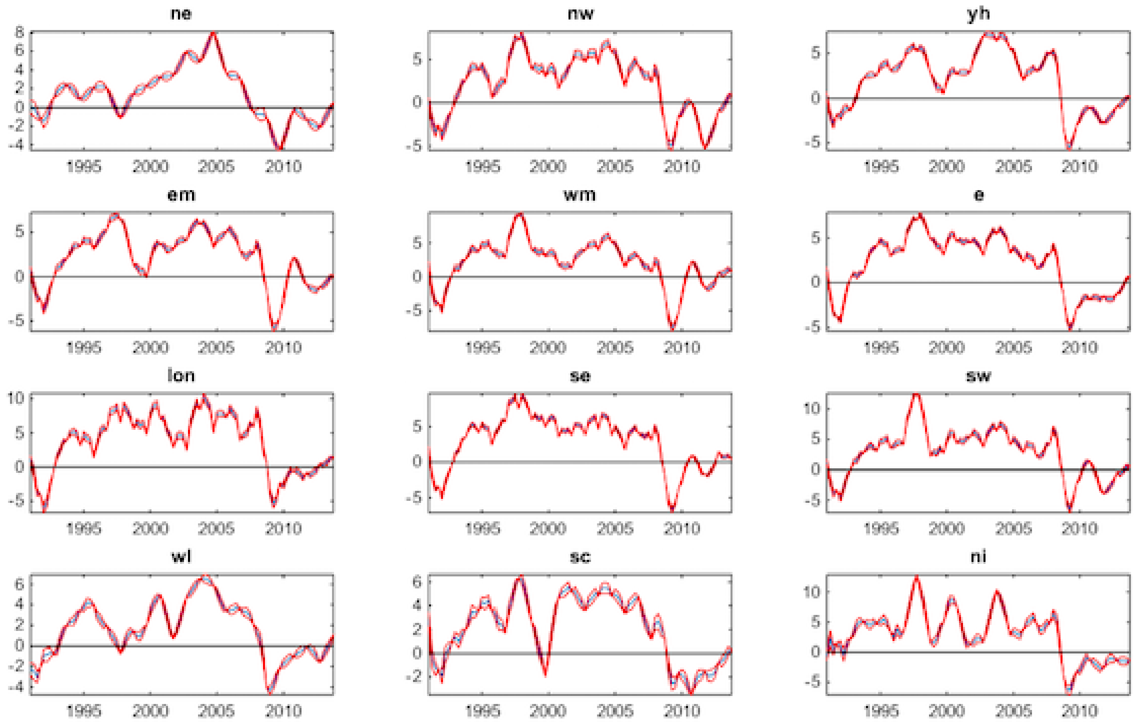


Table 3: List of NUTS 1 Regions of UK

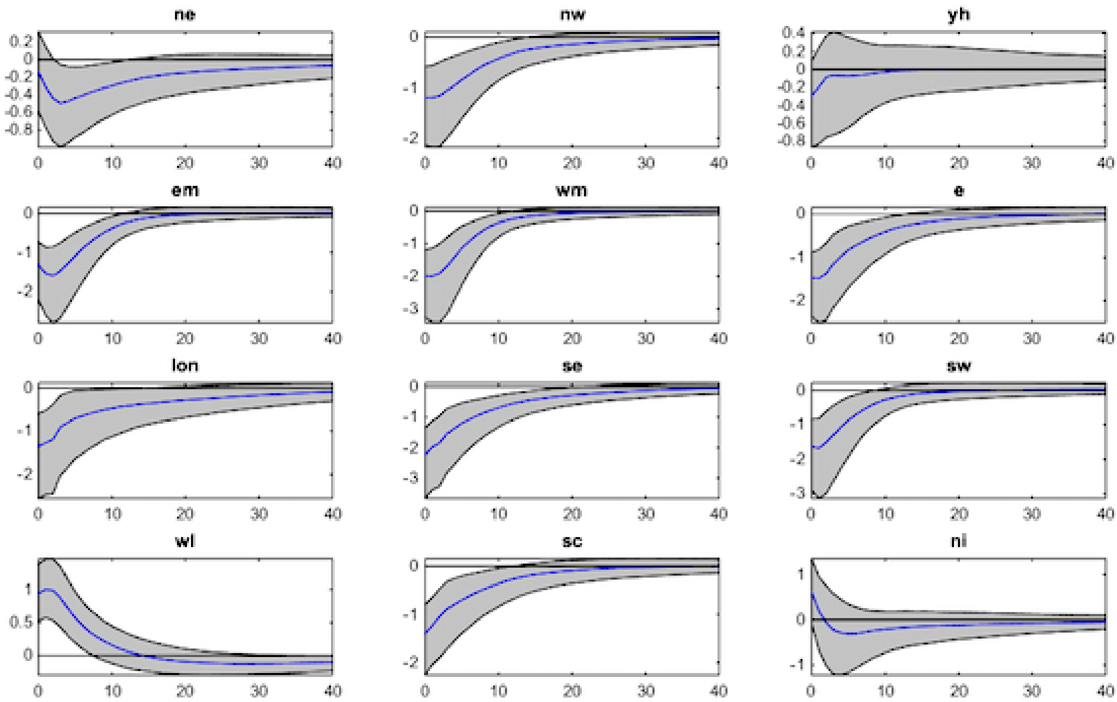
North East England (ne)	Greater London (lon)
North West England (nw)	South East England (se)
Yorkshire and the Humber (yh)	South West England (sw)
East Midlands (em)	Wales (wl)
West Midlands (wm)	Scotland (sc)
East of England (e)	Northern Ireland (ni)

The data for UK aggregate variables are all obtained from Datastream. The original source of the quarterly UK GVA and CPI index is ONS. When the national GVA does not equal total regional GVA data, the measurement error is corrected on the national data assuming the error is equally spread over the intra year quarters. Nominal effective exchange rate data is originally from the International Monetary Fund (IMF) International Financial Statistics (IFS), whereas the nominal exchange rate data is from the European Central Bank. Interest rate data is UK t-bill rate which is obtained from ONS, complemented with IMF-IFS. The data for small and medium sized enterprises, manufacturing are from ONS, Datastream (ONS) and Datastream (Barclays/Woolwich Mortgage Affordability Index) respectively. The sample period for the benchmark model is 1990Q1 - 2013Q4. Yearly percentage changes are used for GVA and Inflation measures. Growth measures reflect real growth. Growth and inflation variables are seasonally adjusted.

4 Results

In order to judge whether the MCMC algorithm converged or not, Figure 1 presents the recursive means of the gibbs draws for the vectorized regional growth series. Recursive

Figure 3: IRFs: Response of Regional Growth to a Monetary Policy Shock



means do not depict any shifts, and variations seem to be around steady means, indicating convergence. Figure 2 presents the estimated regional growth series with their 32%-68% quantiles. Overall, there seems to be significant heterogeneity in the dynamics of economic growth across twelve regions over time. For instance, in the aftermath of the global financial crisis, the rebound in growth in Northern Ireland, Scotland and East of England had been less stronger compared to London, East and West Midlands.

Figure 3 presents the IRFs for regional growth following a contractionary 100 basis points monetary policy shock. The figure portray notable differences in the responses across regions. West Midlands, South East and West are the most sensitive regions, whereas Yorkshire and the Humber, North East being the least to monetary policy shocks contemporaneously. Figure 4 presents 8 quarter (Q) cumulated responses across regions.[5] The most effected regions in 8Q are South East, Midlands and South West, followed by East, North West and London. Regarding the signs of the responses, almost all is negative as expected. At the national level, the cumulative effect of a unit monetary shock stabilizes slowly in 5 years and reduces growth by around 3%-3.5% cumulatively.[6]

As mentioned earlier, there are various channels through which monetary policy shocks may result in heterogeneous impact on growth in different regions. By comparing the responses of regions to monetary policy shocks with regional characteristics that reflect these channels, it is possible to infer the importance of different channels in the UK. However, the limited number of cross-sections/regions precludes a statistical inference, for instance a cross-sectional regression. For that reason, a qualitative analysis has been carried out by comparing the most sensitive regions with regions that are top-ranked in characteristics that reflect different channels.

[5] Since growth is yoy, 8Q cumulated IRFs are calculated by summing 0Q, 4Q and 8Q IRFs.

[6] GVA weighted national IRFs are not presented to conserve space, but they are available upon request.

Figure 4: IRFs: 8Q Cumulated Impact of a Monetary Policy Shock on Regional Growth

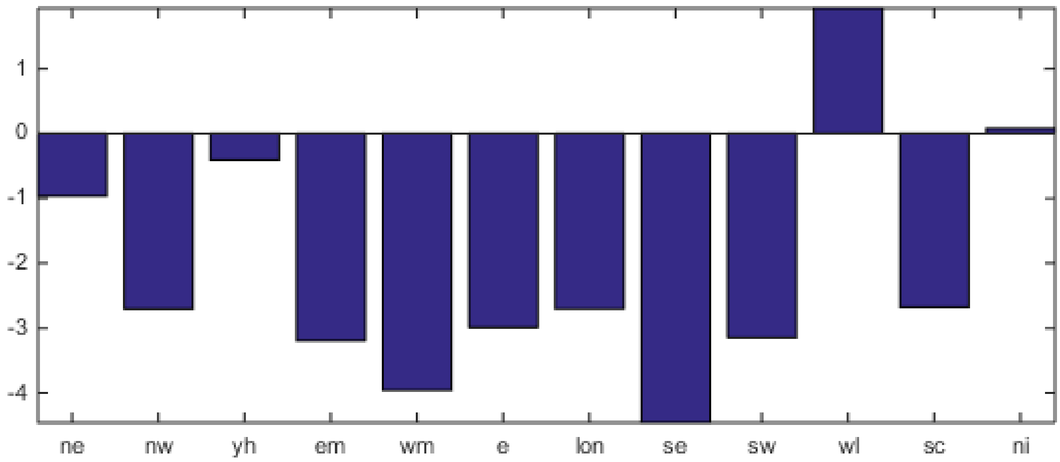


Table 4 presents the most sensitive regions with respect to 8Q cumulated IRFs in the first row.[7] Rest of the columns indicates whether a region in the respective row is among the top-7-ranking region in terms of the regional characteristic represented by the respective column; and if so its ranking. Following the literature, percentage of regional employment in small and medium sized enterprises (SME) is assumed to be an indicator for the broad credit channel.[8] The share of total manufacturing GVA of a region is considered to be an indicator of the interest rate channel, since manufacturing has been found to be a very sensitive sector to interest rates.[9] Finally, Holmes (2000) argues that regions with higher mortgage indebtedness and in which mortgage payments constitute larger shares of income can be affected more by monetary policy shocks. Hence, the last variable included in the table is mortgage affordability, which represents the proportion of total net household income that corresponds to mortgage payments in a given region.[10]

Table 4: Monetary Policy Sensitivity of Regions and Regional Characteristics

Regions	SMEs Share	Manufact. Share	Mortgage Affordabl.
South East (1st)			**2nd**
West Midlands (2nd)	6th	**3rd**	4th
East Midlands (3rd)		**1st**	6th
South West (4th)	**3rd**		**3rd**
North West (6th)	5th	**2nd**	5th
London (7th)			**1st**

Starting with the interest rate and broad credit channels, 3 out of 6 sensitive regions appear to be also among the regions in which the share of SME employment and manufacturing output is the highest. South East and London are not included for any of the indicators. In contrary, Table 4 suggests an interesting pattern in the monetary policy

[7] East ranks as the 5th sensitive region, but it is not reported, because there is no mortgage affordability data. In terms of the other indicators, East do not rank in the top 6 in neither of them.

[8] A firm is considered to be an SME if the number of employees is less than 250.

[9] See for instance Carlino & DeFina (1998) and Owyang & Wall (2005) for discussion of these indicators.

[10] Note that the indicator values are as of 2003, since 2003 is approximately in the middle of the sample period and data for all indicators are available for this date.

sensitivity of the regions. All of the sensitive regions presented in the Table are also the top 6 regions in which the mortgage affordability is the lowest. Out of these regions South East is the most monetary policy sensitive region and also the second region in which it is most difficult to afford a mortgage. Another interesting finding is, all of the 6 regions appear as among the top 3 regions for at least one indicator. The cells that correspond to top 3 are highlighted in bold. Namely, South East and London are among the top 3 for mortgage affordability; Midlands and North West for manufacturing share; and South West for SMEs share. Overall results suggest that mortgage affordability of a region is highly related to the degree of sensitivity of a region to monetary policy shocks; whereas there is also some evidence for the interest rate and broad credit channels.

To examine the contribution of economy-wide demand, supply and monetary policy shocks on regional growth dispersion, Historical Decomposition (HD) of regional growth series are carried out. Then, cross-sectional standard deviation of contributions of different economy-wide shocks are calculated for each quarter, and plotted in Figure 5. The intuition behing this exercise is that cross-sectional standard deviations of the historical contribution of shocks is an indicator for the amount of dispersion a given structural shock generates across the regions at a given time. Hence, by examining the relative values of standard deviations for different shocks, it is possible to infer about the relative contribution of shocks in generating regional growth differentials. Furthermore, by plotting the cross sectional standard deviations one can also infer about the contribution ot regional dispersion over time.

An interesting observation from Figure 5 is that the contribution of shocks to regional dispersion has not been constant over time, but notably time-varying. For instance, even though the role of supply shocks had been subdued before, the main driver of regional heterogeneity in the aftermath of the global financial crisis has been supply shocks. A similar time-variation is also present for the role of demand shocks, as it had a notable contribution at the peak of the crisis albeit smaller than supply shocks. To put into perspective, total contribution of demand and monetary shocks has been in general less than supply shocks in this period. Monetary Policy shocks seem to have had a large role in regional growth dispersion only before 1995 and during 2002-03.

On average across time, mean of the cross sectional deviations for the contribution of shocks had been .31, .65 and .31 for demand, supply and monetary policy shocks respectively. This indicates that supply shocks had been the dominant source behind observed disparities in regional economic growth in the UK. Demand and monetary policy shocks have caused similar degrees of dispersion, but significantly less than supply shocks.

4.1 Robustness Checks

To check whether the results obtained in the benchmark model are robust with respect to model specification, a number of alternative models have been estimated. First model (Model 1) reduces the number of lags to 2. Second model (Model 2) reduces the tightness of the priors on the coefficients. In the third model (Model 3), benchmark model variables are augmented with regional unemployment. Fourth model (Model 4) incorporates nominal effective exchange rates (neer).[11] In the last model (Model 5), the sample period is restricted to 1990-2007, which excludes the crisis period.

[11] Models 3 and 4 are estimated with a single lag, given that the number of parameters to estimate increases significantly otherwise.

Figure 5: Cross-sectional Std Dev of Historical Contribution of Shocks to Regional Growth

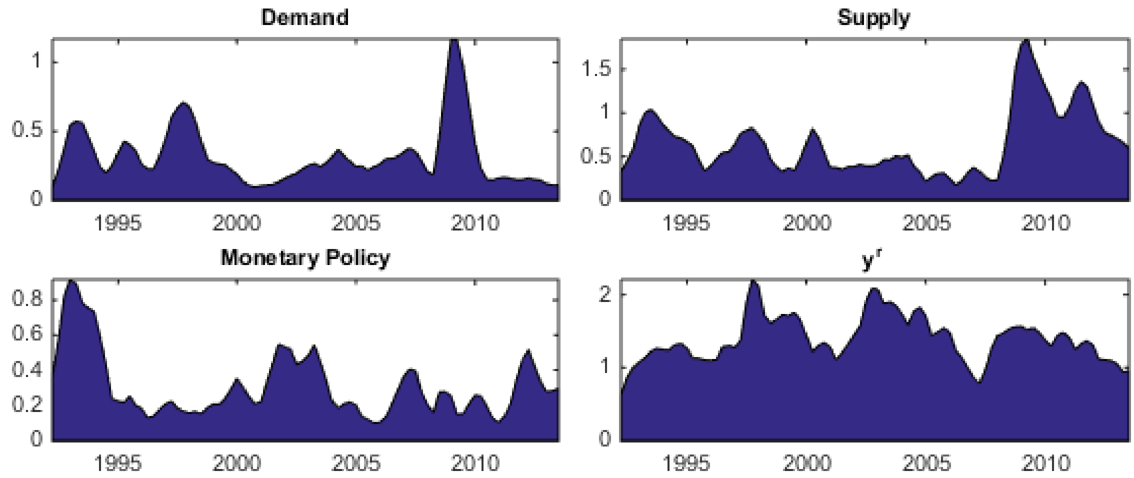


Table 5: Correlation of Estimated Regional Growth Series with Benchmark Model

Model 1	Model 2	Model 3	Model 4	Model 5
0.999	0.996	0.969	0.988	0.995

Entries are the mean correlations for 12 estimated regional growth series with the benchmark model.

Table 5 reports the correlation of estimated regional growth series under the benchmark model vs alternative models.[12] One can see that the correlations of estimated factors are above 96% in all model specifications. Furthermore, the relative degrees of sensitivities across regions are very similar for 8Q cumulative impact of monetary policy shocks under different specifications.[13] Lastly, Table 6 reports the mean of cross sectional standard deviations for historical contribution of shocks in models considered. Similar to the benchmark case, supply shocks appear as the most important driver of regional growth dispersion, whereas demand and monetary policy shocks have similar degrees of importance in the majority of the models considered. Overall, results obtained under the benchmark model are robust with respect to changes in model specification.

Table 6: Mean of Cross-Sectional Std. Dev.'s For Historical Contribution of Shocks

Shock	Bench	Model 1	Model 2	Model 3	Model 4	Model 5
Demand	0.31	0.30	0.33	0.56	0.27	0.29
Supply	0.50	0.48	0.49	0.60	0.67	0.58
Monetary Policy	0.31	0.29	0.33	0.37	0.18	0.31

5 Conclusion

There are several contributions of this paper to the existing literature. Methodologically, it presents a Constrained Mixed Frequency VAR model that exploits the high frequency variations in observed aggregate data (national growth) to infer about the unobserved

[12] Given that alternative models have different sample periods, results presented in Tables 5 and 6 are calculated using the common sample period of 1992-2007.

[13] Available upon request.

disaggregate data (regional growth). The model is particularly useful in analysing dependencies or propagation of shocks at a sub-national level, when high frequency national data is available but sub-national, say regional, data is not. Monte Carlo simulations suggest that the estimates obtained with the C-MFVAR beat a standard MFVAR by 37.5% in terms of RMSEs.

Secondly, this paper presents evidence on the dynamic heterogeneous impact of monetary policy shocks on regional growth in the UK. Impulse responses indicate that monetary policy shocks generate significant dispersion in economic growth across UK regions. The most sensitive regions to monetary policy shocks are South East, Midlands, South West, East and London. Regarding the channels through which monetary policy shocks result in heterogeneous effects on UK regional growth, I find that mortgage indebtedness of a region is highly correlated to regional sensitivity. This supports the view that monetary policy has significant impact on economic activity by influencing the amount of mortgage payments relative to household income. Additionally, I also find some evidence of interest rate and broad credit channels of monetary policy, as results suggest that regional monetary policy sensitivity increases as the intensity of manufacturing and the share of small and medium enterprises in regional employment increase.

Finally, I study the relative role of monetary policy, demand and supply shocks in driving regional growth heterogeneity over time via Historical Decompositions. Over the period of 1990-2013, supply shocks had been the dominant driver of inter-regional differences in economic growth. Furthermore, role of supply shocks have increased notably in the aftermath of the global financial crisis. In contrast, demand and monetary policy shocks have contributed towards regional growth disparities in similar degrees, albeit much lower than supply shocks.

References

Arnold, I. (2001). The regional effects of monetary policy in europe. *Journal of Economic Integration*, (pp. 399–420).

Bańbura, M., Giannone, D., & Reichlin, L. (2007). Bayesian vars with large panels. CEPR Discussion Paper No. DP6326, Centre for Economic Policy Research.

Bańbura, M., Giannone, D., & Reichlin, L. (2010). Large bayesian vector auto regressions. *Journal of Applied Econometrics*, *25*(1), 71–92.

Baumeister, C., & Benati, L. (2013). Unconventional monetary policy and the great recession: Estimating the macroeconomic effects of a spread compression at the zero lower bound. *International Journal of Central Banking*, *9*(2), 165–212.

Benati, L. (2008). The "Great Moderation" in the United Kingdom. *Journal of Money, Credit and Banking*, *40*(1), pp. 121–147.

Bernanke, B. (1993). Credit in the macroeconomy. *Quarterly Review-Federal Reserve Bank of New York*, *18*, 50–50.

Bernanke, B., & Blinder, A. (1988). Credit, money, and aggregate demand. Working Paper 2534, National Bureau of Economic Research.

Binning, A. (2013). Underidentified svar models: A framework for combining short and long-run restrictions with sign-restrictions. Working Papers 14, Norges Bank.

Carlino, G., & DeFina, R. (1998). The differential regional effects of monetary policy. *Review of Economics and Statistics*, *80*(4), 572–587.

Carter, C. K., & Kohn, R. (1994). On gibbs sampling for state space models. *Biometrika*, *81*(3), 541–553.

Coibion, O., Gorodnichenko, Y., Kueng, L., & Silvia, J. (2012). Innocent bystanders? monetary policy and inequality in the us. Tech. rep., National Bureau of Economic Research.

Ganley, J., & Salmon, C. (1997). The Industrial Impact of Monetary Policy Shocks: Some Stylised Facts. Bank of England working papers 68, Bank of England.

Gertler, M., & Gilchrist, S. (1993). The role of credit market imperfections in the monetary transmission mechanism: arguments and evidence. *The Scandinavian Journal of Economics*, (pp. 43–64).

Holmes, M. (2000). Monetary shocks and the asymmetric adjustment of uk regional output. *Environment and Planning C: Government and Policy*, *18*(6), 667–680.

Kashyap, A., & Stein, J. (1995). The impact of monetary policy on bank balance sheets. In *Carnegie-Rochester Conference Series on Public Policy*, vol. 42, (pp. 151–195). Elsevier.

Kashyap, A., & Stein, J. (1997). The role of banks in monetary policy: A survey with implications for the european monetary union. *Economic Perspectives-Federal Reserve Bank of Chicago*, *21*, 2–18.

Mandalinci, Z., & Mumtaz, H. (2015). Global economic divergence and porfolio capital flows to emerging markets. Working papers, Queen Mary University of London, School of Economics and Finance.

Mumtaz, H., & Theophilopoulou, A. (2015). Monetary policy and inequality in the uk. Working Papers 752, Queen Mary University of London, School of Economics and Finance.

Oliner, S., & Rudebusch, G. (1995). Is there a bank lending channel for monetary policy? *Economic Review-Federal Reserve Bank of San Francisco*, (2), 1–20.

Owyang, M., & Wall, H. (2005). Structural breaks and regional disparities in the transmission of monetary policy. Working Paper Series 2003-008C, Federal Reserve Bank of St. Louis.

Rodríguez-Fuentes, C., & Dow, S. (2003). Emu and the regional impact of monetary policy. *Regional Studies*, *37*(9), 969–980.

Rubio-Ramirez, J. F., Waggoner, D. F., & Zha, T. (2010). Structural vector autoregressions: Theory of identification and algorithms for inference. *The Review of Economic Studies*, *77*(2), 665–696.

Schorfheide, F., & Song, D. (2015). Real-time forecasting with a mixed-frequency var. *Journal of Business & Economic Statistics*, *33*(3).

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