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‘Regional Macroeconomic Dynamics in Britain: Investigating structural heterogeneity in transmission of shocks’

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by

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Dedication

I would like to dedicate this work to my wife, Victoria.

Preface

This thesis is a study of the macrodynamics of the British regions. It reports the existence of heterogeneity in British regional macrodynamics and furthermore demonstrates, through three related research programmes, for the first time how differences in short run and long run dynamics of the regions are related to structural factors reflecting their different industrial composition.

Part I, the preliminary chapters one to three, includes the introduction, a discussion of the structural heterogeneities of the regional economies and a discussion of the regional data, and acts to introduce and set the scene for the research that follows.

Part II comprises chapter 4, the research review of several topics required to set the scene for the research reported in chapters 5 and 6, and chapters 5 and 6. These topics covered in chapter 4 include: a review of the issues and research literature surrounding SVAR techniques; the use of VARs in the analysis of monetary transmission; a review of the literature on investigating regionally heterogeneous monetary transmission; and a survey of the literature concerning the macroeconomics of the British regions. The research presented in this part concerns itself with the analysis of shocks, supply and demand, in chapter 5, and monetary, in chapter 6, on the British regions and an investigation which accounts for the reported heterogeneous effects.

Part III comprises chapters 7, which includes the literature review for the subsequent chapter, and chapter 8 which presents the research of the heterogeneities of the British regions from a different perspective; namely that of an estimated model of the supply side, specifically the hybrid New Keynesian Phillips Curve as proposed by Gali and Gertler (1999).

Chapter 9 presents the conclusion and the contribution of the thesis which is followed by references and the many appendices which contain results and tests output not reproduced (for the purposes of expositional brevity) in the main body of the document and a key algorithm from RATS in chapter 5.

The introduction of chapter 1 lays out the motivation for this thesis, namely that monetary policy can have heterogeneous and divergent effects on the UK regions, and explains the rationale and approach taken in this thesis and that taken by the current research programme.

Chapters 2 and 3 provide a review of the UK regional economies and the issues with UK regional data respectively. Chapter 2 demonstrates clearly that the economies of the UK regions differ and provides a detailed review by various measures including growth rates, output, unemployment, employment, wages, education and in particular by industrial composition. This latter point is particularly emphasised as (as discussed) not only is it the basis for two key UK regional models (Cambridge Econometrics, Oxford Economics) it is also shown by this thesis to be a key factor in determining and accounting for the heterogeneities of dynamics reported in Part II of the thesis. It is also shown how differences in industrial composition have continued to increase over the last 20 years. Chapter 3 provides a thorough discussion of the data used and highlights the problems with the quality of the data for the UK regions that are confronted when undertaking research.

The research of this thesis applies a rationale and logic to the British regions based on several different but related strands of theory and research and chapter 4 therefore provides a comprehensive broadly based review of these relevant strands: structural VARS; differences in regional monetary transmission; and the rather small strand of literature that is devoted specifically to the UK regions.

Chapter 5 reports the results of the application of a recently published (Covers et al (2006)) structural VAR identification scheme to a study of the demand and supply shocks of the British regions. This is the first time this identification has been applied to the British regions. This study also uses recently published price series for the UK regions (Hayes (2006)). It demonstrates how regional responses to demand shocks can and do differ and that they can and do differ in the long run. It demonstrates that the pattern across the regions of the reported responses to these structural shocks is consistent with previous research and significantly also demonstrates demand shocks having a greater role in long run output variance than previously reported in the literature.

Chapter 6 reports a comprehensive study of the regional transmission of monetary shocks across the UK regions using structural VAR and SUR techniques. The contribution of this chapter is not just the thoroughness of the analysis (results from three VAR and two SUR estimations are cross referenced and robustness tests provided) but by the fact that the heterogeneities reported are related for the first time to structural measures of industrial heterogeneity of the UK regional economies.

The analysis of regional VARs strongly supports the view that sectoral heterogeneity is a key causal factor of differences of response to monetary policy shocks whilst evidence of a heterogeneous exchange rate effect is also reported. Whilst intuitive and logically sensible a relation between sectoral heterogeneity and heterogeneous responses to monetary shocks has never been demonstrated for the British regions as is done in this thesis. A brief review of sectoral sensitivities of the regions is also included. These results also support, with stylised facts similar to previous studies, the view that dissimilarities are driven mainly by sectoral not spatial factors.

Chapter 7 provides a review of both the theory and a discussion of the related research literature of the model that is the basis for the research undertaken in chapter 8: the hybrid New Keynesian Phillips Curve. This chapter relates the history of the analysis of short run inflation output dynamics from the traditional Phillips curve of the 1950s to the structurally micro founded models utilised today. It explains how the structural foundations of the hybrid NKPC ideally lend it to a study of the UK regions. Chapter 8 presents an application of the hybrid NKPC to the British regions. The model based on 'deep' structural microeconomic parameters therefore lends itself to a study of heterogeneities. This approach is innovative and has never been previously applied, despite its logic, to the regions. Significantly, data from the ONS has facilitated the use of marginal costs as the driving variable in the model. This is a key to the contribution of this research, given the importance of the role attributed to this variable by the original proponents of this model (Gali & Gertler (1999)).

From the estimated equations, evidence of a relationship between the estimates of the model's structural parameters and measures of regional industrial heterogeneity is presented. Again this is the first time this has been shown to be the case for the British regions. A consideration of the robustness of these results is also presented. This work is supplemented with a series of estimates for wage Phillips equations for the regions which display a pattern of heterogeneity consistent with the economic characteristics of the regions

The consistency between results of chapter 6 and 8 is significant. Both sets of results demonstrate a relationship to structural factors.

The final chapter, 9, outlines conclusions and the contributions to knowledge of this thesis. It has shown that: demand side shocks have heterogeneous long run effects on output across the regions; responses to monetary policy shocks vary across the regions, are accountable by structural heterogeneities, and also have different level effects across the regions; and thirdly that structural heterogeneities account for differences in short run (inflation/output) dynamics across the regions.

After all this analysis it can be concluded that heterogeneities in British regional macrodynamics whether in the short or long run are related to structural economic characteristics.

List of Abbreviations

AIC	Akaike Information Criteria
ACF	Autocorrelation Function
AR	Autoregressive
ARMA	Autoregressive, Moving Average
BEA	Bureau of Economic Analysis
BoE	Bank of England
BQ	Blanchard Quah
CR	Croner Rewards
DGP	Data Generating Process
DSGE	Dynamic Stochastic General Equilibrium
DTI	Department of Trade and Industry
DW	Durbin Watson
GDP	Gross Domestic Product
GLS	Generalised Least Squares
GMM	Generalised Methods of Moments
GVA	Gross value added
HMT	Her Majesty's Treasury
HP	Hodrick Prescott
IS	Investment Saving
LR	Likelihood Ratio
MA	Moving Average
NKPC	New Keynesian Phillips Curve
NUT	Nomenclature of Territorial Units for Statistics, (NUTS) for the French nomenclature d'unités territoriales statistiques
OLS	Ordinary Least Squares
ONS	Office of National Statistics
ROT	Rule of Thumb
SBC	Schwartz Bayesian Criteria
SIC	Standard Industrial Classification

SUR	Seemingly Unrelated Regression
SVAR	Structural Vector Auto regression
VAR	Vector Auto regression
VECM	Vector Error Correction Model

Regional Sectors (ONS, Government Office of the Regions Offices)

EA	East of England
EM	East Midlands
Ldn	London
Sco	Scotland
SE	South East
SW	South West
NE	North East (North of England)
NW	North West
Wal	Wales
WM	West Midlands
Yks	Yorkshire & Humberside

Sectoral/Industrial Disaggregates Used

Agg	Agriculture
Con	Construction
Dhc	Hotels and catering
Eh	Education and Health
Fin	Financial (and business) services
Min	Mining
Man	Manufacturing
PA	Public Administration
Trans	Transport
Util	Utilities

1 Introduction

"Monetary policy can only target the economy as a whole - it can't seek to protect individual firms or sectors, or therefore regions" - Eddie George (1999).

This acknowledgement: that monetary policy cannot deal with the interests of all regions simultaneously, underlines the need for a better understanding of the heterogeneities of the macrodynamics of the UK regions, both generally and in response to monetary policy shocks.

The debate of the appropriateness or optimality of single currency zones during and after the introduction of the Euro over spilled into a discussion of possible negative ramifications of a 'one size fits all' UK monetary policy for the UK's regions in the late 90's (Funke & Hall (1998)). This debate never particularly took hold in academic circles and literature mainly due to the lack of appropriate robust regional time series.

The UK regions are different. Of that there is little doubt. Not just by the accents of their populations, but by just about every major measurement of social and economic factors. As is outlined in depth in chapter two, they are heterogeneous in size, population and industrial make up, unemployment levels are persistently different across the regions, as are levels of educational attainment, and potential growth rates vary: estimates by the Department of Trade & Industry (HM

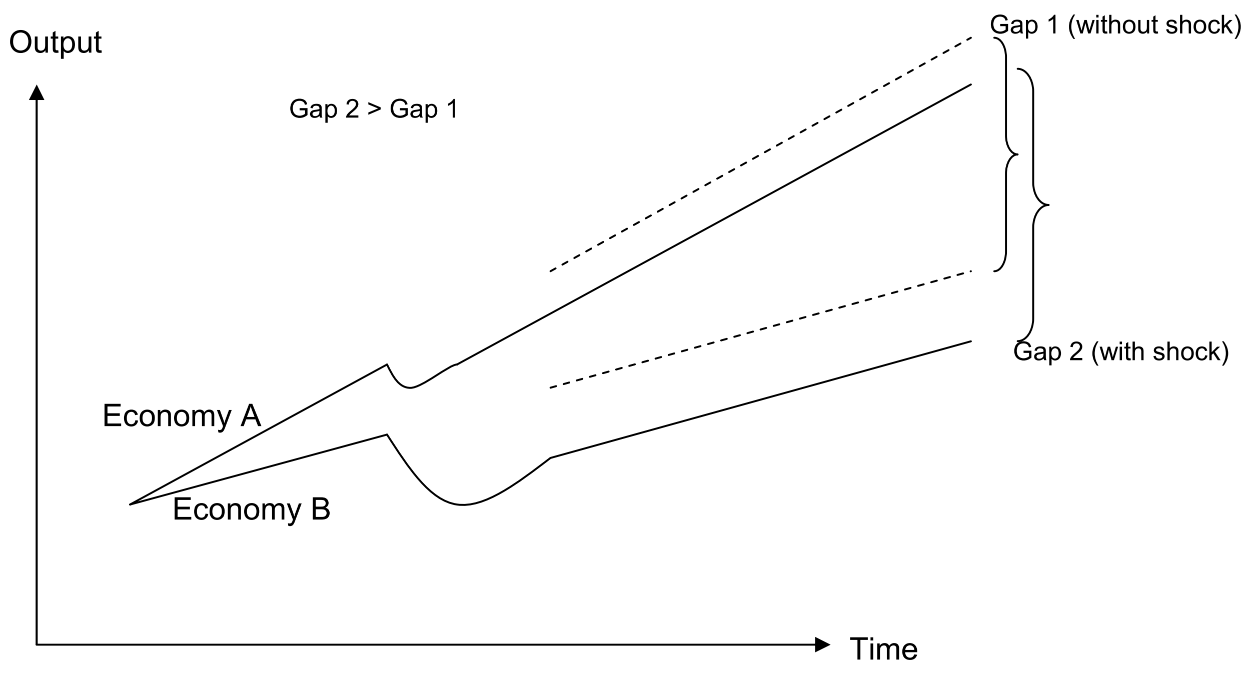
Treasury 2001) suggest 1.25% for the North East and over a percentage point higher, 2.5%, for the South East. In particular, industry mix varies significantly: in 2002 for example, manufacturing accounted for less than 9% of output in London and financial and business services nearly 50%, whereas the corresponding amounts were 22% and 22% in the North East, and continues to diverge over time (see chapter two).

The issue is how important are these differences for, and what effect do they have on, the macrodynamics of the UK regions? Is it beyond the bounds of credulity to suggest that they have no effect? To suggest that their effect is sufficiently strong to cause the different macrodynamics to contribute to a long run effect on the relative performance of the UK regions is also to stretch what is considered orthodox and would a highly ambitious hypothesis to prove. Modern monetary theory (to which this thesis is not a contribution towards: for a comprehensive review of modern theory see Walsh (2003) or Woodford (2003)) takes as its starting point the classical assumption that an economy's (any economy) natural (or long run) position is one of general equilibrium treating business cycles and dynamics as movements around this natural point. This is not an incontrovertible perspective but most contemporary small scale macroeconomic modeling builds on this assumption and the majority of investigation of dynamics of these models involves movements from this 'steady state' along a linearised solution to the model (see Cooley & Hansen (1995) or McCandless (2008)). Added to this is the issue of the neutrality of money in the long run. This position is widely accepted. Therefore any heterogeneities of response to demand shocks of the monetary kind exhibited by the regions are necessarily a short run phenomena by assumption according to orthodox theory.

This is not a propitious starting point to be in to suggest that perhaps monetary shocks could have long term – even albeit only level – heterogeneous effects on the UK regions. The line of argument that motivates this thesis goes as follows: even if all regions are in a state of near permanent equilibrium any disturbance that causes region A to move further than region B or to move away for longer before returning to equilibrium will lead to a greater loss in output or a greater level loss of output even if they both return to the same, separate rates of (assumed) trend growth. Through this effect monetary policy is able to contribute (albeit in a small manner) to the long run divergence in output of regions. This thesis sets out to show this is indeed the case.

This is conceptually outlined in figure one. Two economies are illustrated with different growth rates. Economy A having the larger growth rate is less affected (in the short run) by the shock and resumes its (long run) growth rate sooner than economy B which too resumes the same long run rate of growth than before the shock. In this scenario, the gap between the levels of output of the two economies over time is larger if a common shock is applied.

Figure 1: Illustrating how a common shock can have a level effect

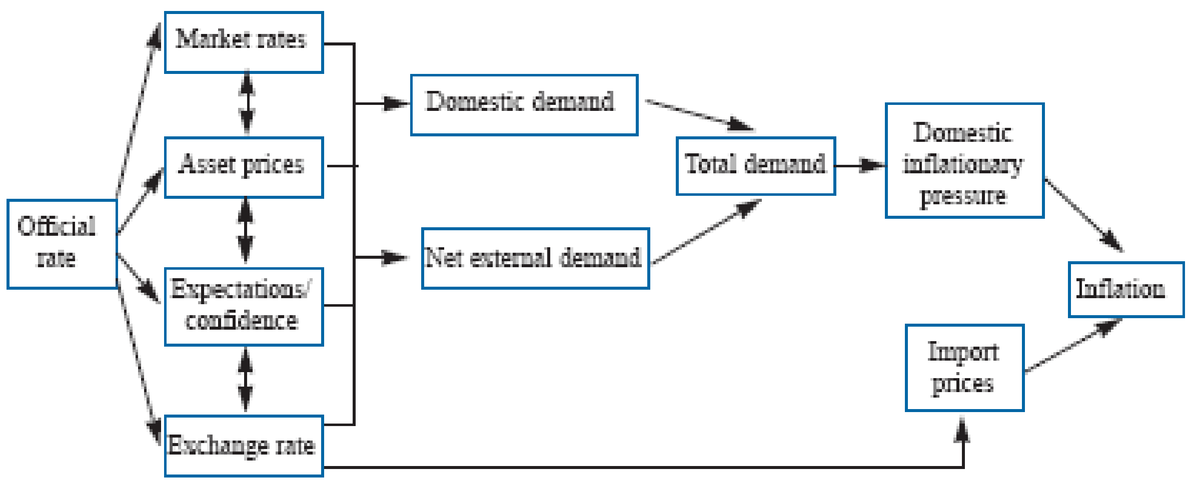


That regions can and do react differently in the short term to monetary policy shocks is widely recognised. There is now a long established literature on the subject of heterogeneous transmission of monetary policy and this body of work is reviewed in chapter 4. In the main research (and literature) has focused on those areas – the US, within the Euro zone and some EU states (notably Spain) where the data lends itself to a robust examination of the issue (again see chapter 4). In addition, the comments of Eddie George used to open this thesis hint at a concern for the uneven welfare effects on different regions of a common monetary policy. By default if a policy cannot be set in the simultaneous interests of all regions, then some regions' interests must be more equal than others even if only by accident and not design. It is not known by the author whether the Monetary Policy Committee puts any greater weight on one region's welfare over another when making its interest rate deliberations but despite extensive reading he has not found any evidence of such a thought process – a point raised by Sheila Gow (HMT (2006)). However, if one was concerned about regional inequity, some manner of consideration of the effects of monetary policy on the UK regions ought to be in place. In an ideal world the relative costs of the effects of monetary policy across the regions would be known (within reasonable bounds of certainty) so as to assist making informed policy choices.

The orthodox traditional 'ad hoc' approach (Gouvea & Sen Gupta (2007)) to central bank policy preferences treats central bankers as having a quadratic loss function whose two parameters consist of inflation variance and output variance. If aggregate output variance is deemed to be worthy of minimisation why have no concern for the distribution of this variance? Would it not be beneficial to have some understanding of where monetary policy has the greatest or least impact and if it was demonstrated that there is indeed a level effect would the concern be greater? If this was to hand would it then not be possible to apportion a weighting, based on population or some such measure, to each region's output to then be in a position to construct a UK welfare function based on a method of aggregation of each individual region? Would this not be consistent with UK government policy? Would it be practical or would it re-introduce an element of political bias into a monetary regime when it has been celebrated as having been removed? (Balls and O'Donnell, 2002).

These specific questions in the paragraph above are not questions that will be attempted to be answered by this thesis. They are to provide illustration or context to what is a policy issue and explain the motivation behind this thesis. This thesis sets out to better understand and account for the differing macrodynamics of the British regions and provide evidence to support a line of argument that monetary policy can indeed contribute to differences in the long run performance of the British regions, ie to demonstrate a level effect.

Figure 2: The Monetary Policy Committee's View of the Monetary Transmission Mechanism (source, BoE (2006))



Note: For simplicity, this figure does not show all interactions between variables, but these can be important

It is probably beneficial to first consider and discuss the general monetary transmission mechanism. The Bank of England (2006) views the transmission mechanism of its monetary policy actions (ie interest rate changes) in the manner shown above. Figure 2 above is a direct ‘cut and paste’ from the MPC’s (BoE (2006)) own explanation of the transmission mechanism. It explains how in its view a change (increase) in the interest rate works through to changes (reductions) in inflation. According to the MPC there are four key links.

1) A change in rates directly affects market rates, asset prices, expectations and confidence in the future direction of the economy and a movement in the exchange rate.
2) The change in rates affects spending, saving and investment decisions of consumers and firms. A rise in rates thus reducing spending and investment and increasing saving. Also through an increased exchange rate, import prices are reduced. These factors all have an impact on domestic demand.
3) The third link is then the relative position of overall domestic demand to domestic supply. For instance, higher levels of domestic demand leading to increased supply of labour leading to inflationary pressures.
4) The fourth link being a direct reduction in the contribution of imported goods to inflation via their lower prices due to the movement in the exchange rate.

This is, as is acknowledged by the footnote in the imported figure, an incredibly simplistic representation of the monetary transmission mechanism. It does provide a framework to understand not just the transmission mechanism itself but also the thinking of the MPC. The question is how this framework can be used to help one understand the question of a heterogeneous transmission of monetary policy across the UK regions? There are three potential sources of heterogeneity:

1) via different consumptions/savings responses of regional consumers;
2) via different investment/output responses of firms; and
3) via differential wealth effects due to asset price changes.

The main focus of research to date that has analysed heterogeneous responses of regions (both country level and continent level) to monetary policy shocks has focused on the second point above and looked to the supply side or more specifically industrial composition to account for heterogeneous responses to interest rate or monetary shocks. Whilst different consumer responses seem at first glance to be a likely source of heterogeneities, it is not a traditional route attempted[1]. The small scale structural models of demand that could be applied involve incredibly complicated non linear functions of structural parameters and it would be impossible to credibly ascertain differences in estimates across the UK

[1] Dibartolomeo et al (2004) have produced estimates for 'rule of thumb' consumers that vary across countries. They use a Bayesian Monte Carlo Full Information Liklihood technique, estimate a system of nine structural equations to produce estimates of 15 structural parameters from non linear coefficients. A very ambitious piece of work and beyond the limits set by the data available for the UK regions.

regions with the data available given that it is only available on an annual basis. Neither, until recently, as will be discussed in chapter 4, have differential wealth effects (eg Case & Shiller (2005)) (through changing asset prices) been an area that has received much attention. The three traditional routes investigated in the literature (Carlino & Defina, 1998) as to the causes of heterogeneous regional responses to monetary policy shocks are all based on the supply side of the economy:

1) an interest rate effect where the direct response (or elasticity of response) of firms of different types to higher interest rates will differ;

2) a credit effect where the differing ability across firms to borrow (due to size) is amplified; and

3) the exchange rate channel, where the response of exporting firms to a changed exchange rate is different to firms focused on domestic supply.

The orthodox approach to consider the different interest rate sensitivities or 'elasticities' of industries is to compare the sensitivities of the regions against measures of sectoral diversity, typically shares of various industries. To provide a measure of how credit constraints may vary across regions the share of small firms to proxy for a measure of credit constrained firms is used; and the share of exports by value or volume is taken to provide a variable by which the exchange rate effect can be compared. Despite the many data issues confronting the UK regional macroeconomic researcher, data is available to be able to provide a measure of these three variables and thus meaningful analysis of this type can be conducted.

Two distinct methodological approaches in modern economics are available to the macroeconomic researcher. The first and perhaps more theoretically robust method is the approach of the (structural) dynamic stochastic general equilibrium modeler. Catalysed by the work of Kydland and Prescott (1982), King and Plosser (1984) and others in the early 80s this approach is founded in micro-economics ie a model is built from the bottom up from microeconomic foundations and the economy is assumed to be in a state of general equilibrium and hence market clearing conditions are presumed to hold. These models typically comprise a single representative firm, household etc. and the model is dynamically optimised and solved.

These models initially at least were fairly simple animals, so much so that they rarely included a monetary sector. It did not take long before money was added (again see Cooley & Hanson (1995), McCandless (2008) or, for a discussion with the emphasis specifically relating to money, Walsh (2003, Chapters 1-4)) to these types of model and a certain class has become known as New Keynesian models so called because they incorporate some form of rigidity into the price or wage setting process. Over time they have become much, much more complex incorporating a whole host of different features including capital accumulation, rule of thumb producers, consumers, habit persistence (eg Gali, Gertler, Lopez-Salido (2003), Fuhrer (2000)). It is a fairly long list. The approach of the DSGE modeler is to build, solve and test their model against features of the real economic data. One of these models, the hybrid New Keynesian Phillips Curve is applied in part II of this thesis. It must be noted that it is an existing model and there is no attempt to construct any new variant of the model.

The alternative methodological approach available to the researcher is a more general reliance on time series econometrics - whereby the goal it to merely estimate and test empirical relationships amongst the key macroeconomic variables. Clearly the use of the word merely is somewhat pejorative and unintentionally so for the mathematics of leading edge econometrics is as complex if not more so than anything seen elsewhere in the economics discipline. Neither is there an absence of theory, the more theory that can be incorporated clearly the more robust are the results. However, the quest remains that of estimating empirical relationships from the data.

Whilst econometric modeling came under fairly hefty criticism during the 1970s following the breakdown of the performance of certain large scale empirical models (Favero, 2001) in use at the time, it is still a major branch of research today. Techniques were revised to take into account the criticisms of the time and led to the widespread use of the Vector Autoregressive technique which is extensively used in this thesis.

This thesis makes extensive use of this econometric methodology. It also applies a model derived from the former methodology, namely the hybrid New Keynesian Phillips curve. Having demonstrated in the research of part I that the size of the responses of the regions to monetary (in effect demand) shocks are related to supply side characteristics, part II estimates this model (the hybrid NKPC) of the supply side to see if these same supply side characteristics have similar bearings on the estimates of a supply side model. Demonstrating that they do is a key contribution of this thesis. As a body of work this thesis is therefore somewhat broad, straddling and incorporating various different areas of applied research; the structural VAR literature, the regional monetary VAR literature; the UK regional macroeconomic literature and the New Keynesian and traditional Phillips Curve literature.

The first piece of research presented in this thesis is an investigation of the responses of the UK regions to structurally identified demand and supply shocks using two separate decomposition regimes and a regional price series dataset recently published (Hayes 2005). Given the results of tests for order of integration of the price level series are somewhat ambiguous, two sets of estimates are calculated: those for the first difference of prices and another for the second difference. This does lead to a rather voluminous set of results, in particular graphs, given there are also ten regions of interest. This means that this document is rather long at around 460 pages. It was deemed that it would make the thesis easier to follow if on occasion (clearly not always) a sample of the regions' results are discussed in the main text and the remainder placed in appendices for later review.

Chapter 5 presents this work and first compares results from the two SVAR identification schemes – Blanchard and Quah ('BQ') (1992) and Covers, Enders and Hueng (2007). Significantly, this latter decomposition has never been applied to the UK regions and it is an innovation of this identification scheme that opens up the divergent effect that is of interest. Namely it relaxes the long run BQ neutrality restriction of demand shocks and thus opens up the route to differing long run level effects of shocks (ie differing cumulative responses.)

This work sets the stall for research of chapter 6 in that the first task this thesis sets out to achieve it to demonstrate show that it is possible for demand shocks to have a permanent level effect that is heterogeneous across the UK regions. Once that case is proven, as it were, the work moves onto a thorough investigation of monetary shocks on the regions and accounts for their differences by recourse to structural factors. This work is reported in chapter 7. Once again it applies the structural VAR methodology although in this instance the structural content is the result of the ordering of the variables in the VAR. The contribution of this chapter is not just the thoroughness of the analysis (results from three VAR and two SUR estimations are cross referenced) but by the fact that the heterogeneities reported are related for the first time to structural measures of the British regional economies in a manner that has been applied to other, in particular the US, economies. This analysis of regional VARs suggests sectoral heterogeneity is a key causal factor of differences of response to monetary policy shocks. Whilst intuitive and logically sensible this has never been shown to be the case for the British regions. An attempt is also made to review sectoral sensitivities of the British regions. The results do suggest, with stylised facts similar to previous studies, the view that dissimilarities are driven mainly by sectoral not spatial factors[2].

The final aspect of the research presented is a study of the short run inflation/output dynamics of the regions ie regional Phillips curves. The hybrid New Keynesian model has been chosen on account of its basis on deep seated 'structural' parameters (Gali & Gertler (1999)) as is discussed in chapter 7. It is a modern monetary model, derived from micro foundations and is of the class of DSGE macro models referred to above. It is clearly a model of the supply side and the research seeks to relate differences of the estimated regional parameters to measures of supply side differences across the regions: in short the same variables that are shown to relate to the differing dynamics demonstrated in chapter 6. A hybrid NKPC is estimated separately for each region. This approach is innovative and has never been previously attempted.

[2] A strong caveat is that the data used in this particular piece of work is particularly poor and hence the results not particularly robust.

The model itself was chosen despite its controversy for its relative simplicity. It incorporates a fairly straightforward mechanism for introducing inflation inertia into the model, that of ‘rule of thumb’ producers. This lends itself to an investigation of structural heterogeneities of the UK regions because, as was stated earlier and will be referred to throughout this thesis, data availability on the regions is poor, yet data of reasonably good quality providing various measures of the industrial characteristics of the UK regions does exist. In addition, the model is itself reasonably simple to estimate and the parameters of the econometrically estimated model whilst non-linear are rather simple non-linear functions.

This point is raised now because the obvious question is whether an investigation of heterogeneities on the demand side ought not also to be included in a body of work such as this. This approach as outlined earlier is not common and, in the view of the author, an attempt to do so using the current structural models in use is not feasible. The features such as habit persistence and rule of thumb consumers[3], that have been used to incorporate inertia on the demand side, lead to much more complicated non-linear functions of the estimated parameters on what are commonly know as Euler demand functions (Favero, (2001), Fuhrer & Rudebusch (2003), Fuhrer & Olivei (2004)) and as such it would not be possible to estimate credible differences across regional parameters with

[3] However, it is recognised that Campbell and Mankiw (1991) and Banejeree and Battini (2003) have estimated different shares of ‘rule of thumb’ consumers across the UK and US and (see note one) Dibartolomeo et al estimate shares of ROT consumers across the G7.

the data available. Whilst Dejuan (2003) has used regional data to estimate a simple form of demand in testing the permanent income hypothesis across the UK regions, this is a much simpler econometric task than attempting to recover the separate structural parameters from the models developed to incorporate rule of thumb consumers in the latest structural models of demand. As was indicated in note 1 Dibartolomeo et al (2004) estimated heterogeneous values of a rule of thumb consumers across countries but to do so required nine structural equations using Bayesian Monte Carlo Full Information Likelihood. The UK regional data is not of sufficiently quality to undertake this type of analysis. From the estimated equations, evidence of a relationship between the estimates of the model's structural parameters and measures of regional industrial heterogeneity is presented. A consideration of the robustness of these results is also presented.

What is also of significance is the consistency between the findings regarding causal factors in this research and the findings regarding causal factors in the research of chapter 6, the reaction of the regional monetary policy shock responses. In both evidence of a similar relationships between responses to monetary shocks and the regional industrial characteristics and structural estimates and the regional industrial characteristics is reported. What is of crucial importance to realise is that this research demonstrates that the same (structural supply side) factors determine not just the heterogeneities in a an demand side econometric model but also determine heterogeneities in a theoretical supply side model. As a somewhat supplemental piece of research, crude estimates of traditional wage Phillips equations for the UK regions consistent with the known facts of the regional economies are also presented in this chapter.

This thesis is set out in four parts: the first part providing the introduction to the research which includes this chapter; the second providing research of two chapters concerned with demand and monetary shocks and their accompanying research reviews; the third providing the results of the estimated regional Phillips curves with its accompanying research review. Each research chapter has been written to be semi-self contained, to form the foundation of a stand alone paper, as the first two chapters of research have already been presented separately to a conference public. Part four is the conclusion of the thesis and if followed by references and quite (necessarily) extensive appendices. These include various results that for reasons already outlined are not included in the main body discussion of the document. They also include various econometric software outputs.

Two piece of econometric software have been used to conduct the research: Eviews and RATS. RATS has been used where the methodology required a bespoke algorithm as the technique was beyond the capability of Eviews which whilst very powerful has certain limitations given it is a windows menu driven system. This included the Covers and Blanchard Quah decompositions as the

Covers algorithm incorporated the inclusion of both short run and long run restrictions which Eviews is unable to do (although strictly speaking Eviews is capable of estimating the BQ decomposition). RATS was also used for the non-linear methods and bootstrapping. Eviews was used where the estimation method was more straightforward such as in chapter 6. Eviews has also been used to produce various statistical test outputs where its windows, menu system was a useful labour saving device (compared to RATS) given there are on every occasion ten sets of regional estimates to produce. Chapter 2 contains a general description of the UK economies. This chapter is not designed to do anything more than provide a flavour of the heterogeneities of the regions and whilst it is comprehensive, it is a review nothing more, the information being easily garnered by the motivated individual. All information on the regions unless otherwise stated, has been sourced from the Office of National Statistics ('ONS').

Given the obvious data constraints, and despite its clear priority for the present UK government (HM Treasury (2001, 2002, 2003)), the volume of previous work on the UK regions is not massive. There are those, Funke & Hall (1998), Barrios et al (2002), who conclude that, despite all the evidence of actual economic heterogeneities of the UK regions, macroeconomic shocks' effects on the regions differ little. There are others such as, Fielding and Shields (2001), who disagree and clearly this thesis is in the latter camp.

The UK government itself has specifically emphasised the importance of the regional dimension to its central economic objectives and has set targets for regional convergence (again HMT, 2001, 2002, 2003, 2006). Thus far however, it has been silent on whether a mechanism of divergence exists working through the transmission of monetary policy. This thesis is based on the view that monetary policy does have heterogeneous effects across the regions (and that this is systematic and hence at some level predictable).

Chapters 5 and 6 present research based on the analysis of the transmission of shocks, monetary and demand, across the British regions. These primarily apply the structural VAR econometric techniques. Chapter 5 shows firstly that once certain restrictions have been lifted (namely the homogeneity restriction of long run neutrality of demand shocks) that demand shocks can have heterogeneous effects across the regions. Secondly, once that principle has been demonstrated, chapter 6 demonstrates that size of the differing long run (ie cumulative impulse response) of monetary shocks across the regions is related to the differing industrial characteristics of the regions.

As stated, the research presented in chapter 8 takes a different but complementary approach to this issue. It takes a small scale structural modern monetary model – the hybrid New Keynesian Phillips Curve – and explores whether the estimated parameters of this model also relate to the self same industrial characteristics. This is demonstrated to be the case and underlines the importance of these industrial characteristics (and in a manner is a mutual robustness test of the two areas of work – that the same factors relate to estimated responses of an demand side econometric model and estimated coefficients of a theoretical model of the supply side) and reinforces the need for monetary policy to take account of regional differences in the conduct of monetary policy.

This thesis makes progress towards a better understanding of the transmission of shocks across the UK regions and demonstrates that monetary policy is able to contribute to a divergence of the performance of the regional economies (even if the majority contribution in the long run is indeed determined by structural supply side factors). The general contribution of this research is to confirm the existence of regional heterogeneities in the transmission of shocks and to underline their importance by illustrating how this may indeed provide an additional source of their long term output divergence. Its key contribution is to demonstrate how the different regional responses to monetary shocks and short run inflation/output dynamics of the regions both relate to the structural composition of the underlying regional economy. These responses are systematic and if systematic most likely predictable. This ought to be of interest to monetary policy makers who have any concern about the distributional welfare effects of monetary policy.

2 A description of the UK Regional Economies[4]

The title of this chapter is erroneous. It should read 'British' not 'UK' economies for this thesis restricts analysis to the English Regions and includes Scotland and Wales but omits Northern Ireland from the analysis. This is deliberate and consistent with the much of the research on the subject as Northern Ireland for much of the period that the data is taken from and is used for analysis was experiencing what has become euphemistically known as 'the troubles' and so could not be expected to be studied under the same economic framework.

That caveat aside, the disparity of the regions' economic performance is not a recent phenomenon but over the last ten years the varying performance of the regions has never been far from the policy agenda and this government has gone as far to set performance targets (HMT (2003) for regional economic performance and in the late nineties created large new quangos (quasi non-governmental organizations), the regional development agencies, (and concurrently created a new tier of regional bureaucracy: the Government Offices of the Regions) with the express (original) remit of improving lagging regions' performance.

The subject is naturally of particular interest to commentators and think tanks alike. Some report (IPPR North (2007)) signs of a recent convergence in

[4] All data is sourced from the ONS unless otherwise stated.

economic performance. The consensus, however, (FT (2006)) suggests that the gap (in per capita output) continues to widen. This thesis is not a contribution to the debate about how to improve the long run growth characteristics of the lagging UK regions. This thesis concerns itself with differences in the dynamics of the regions brought about their heterogeneous nature, motivated by the concern that monetary policy cannot be set in the equal interests of all of the regions simultaneously, and seeks to explore, review and account for heterogeneous dynamics brought about by various economic shocks.

This chapter is a brief attempt to first describe the disparity of the regions' economies, taken the NUT definition of the regions as its unit for description. It does so in a fairly orthodox manner outlining differences in key economic areas. It does not touch on other social measures of welfare and thus does not concern itself with the more esoteric arguments of the like postulated by Layard (2006) or others. The basic description below outlines differences in standard economic measures in the areas of economic output, employment, industrial composition, income, prices and population. The diversity of size, geography and population of the UK regions whilst not say on the scale of federal states such as the US or as culturally entrenched as say Spain is significant nonetheless. Yorkshire and the Humber (referred to throughout this thesis as 'yks'[5]) mainly comprises the

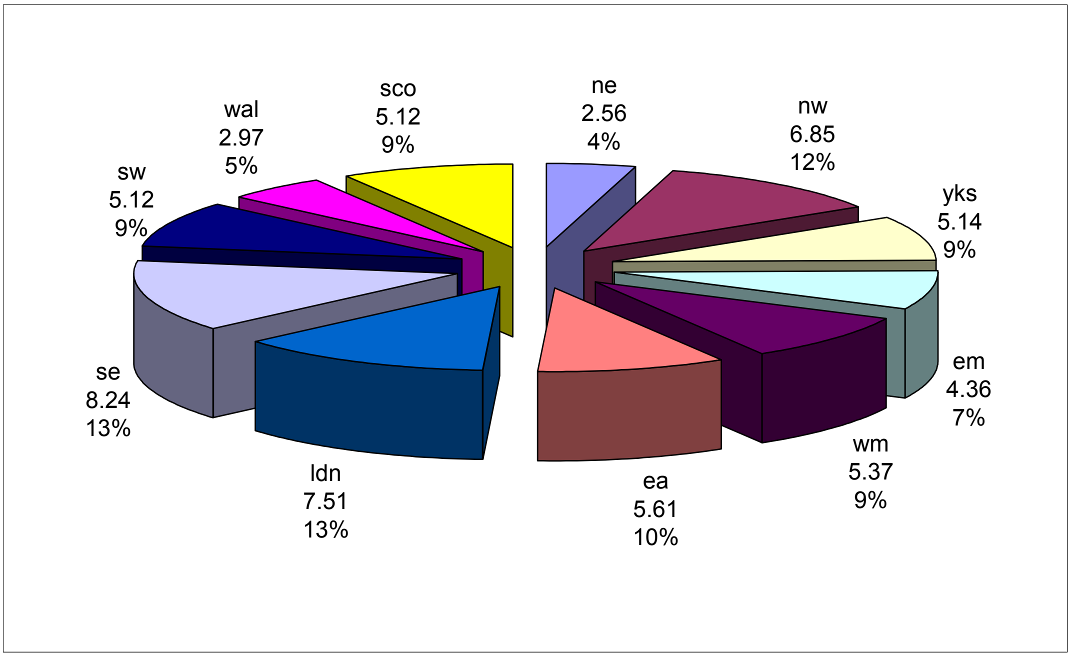
[5] throughout the regions are referred to in 'shorthand': 'ea' referring to the NUTS1 are East of England; 'em', East Midlands; 'ne', North East; 'nw', North West, 'ldn', London; 'se', South East; 'sw', South West; 'Sco', Scotland; 'wal', Wales; 'wm', West Midlands; 'yks', Yorkshire

country of Yorkshire but takes in parts of North Lincolnshire has a population greater than Scotland ('sco') yet has a land mass of less than quarter.

The East Midlands ('em') is the fourth largest English region in terms of land area, yet the second smallest in terms of population, and is over 90 per cent rural whilst half of the total population of the West Midlands ('wm'), its neighbour, live in large conurbations. The South West ('sw') has the largest land area and the lowest population density of any English region. About four-fifths of the total land area of the region is agricultural and just under a tenth urban or suburban, making the region predominantly rural in character: over half the population lives in rural areas or towns of less than 20,000 people.

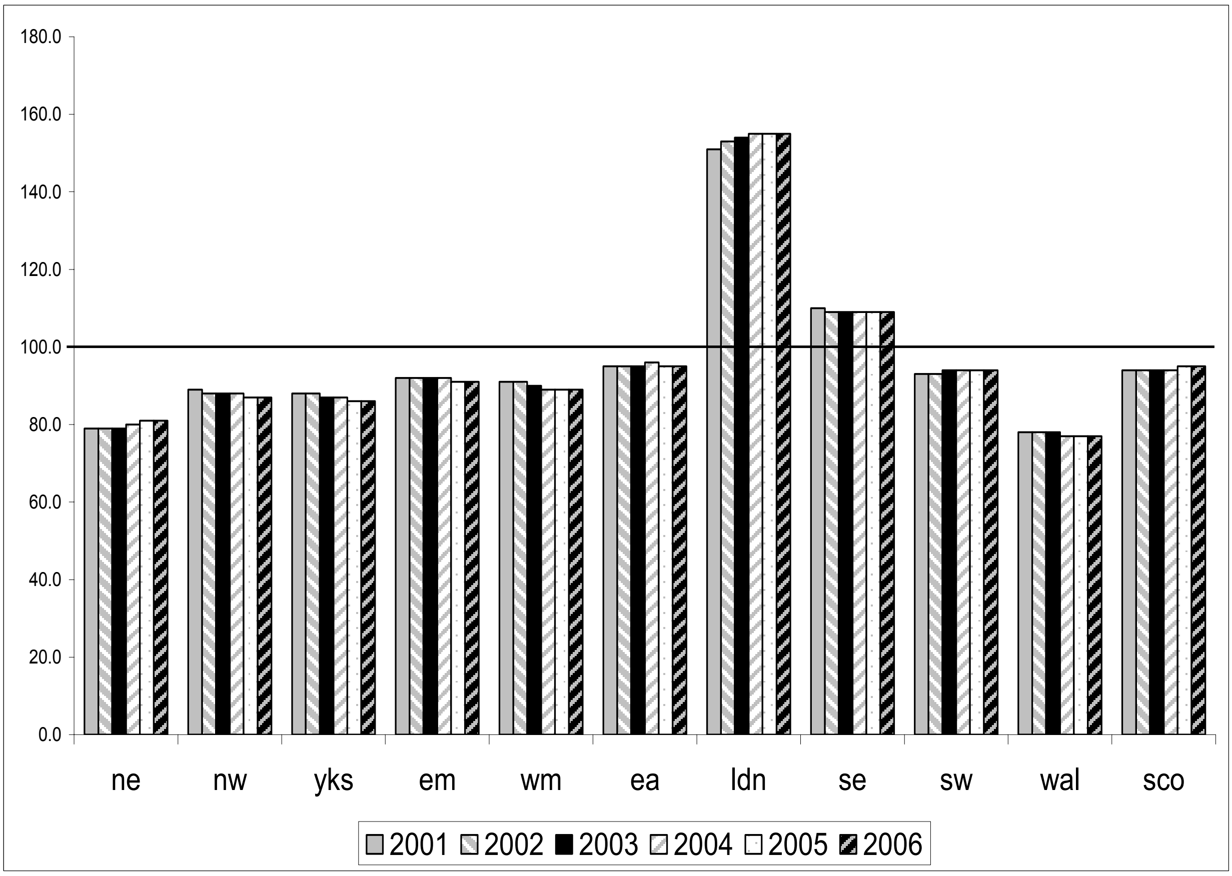
Population density is greatest in London ('ldn') and the Southeast ('se') and these two regions alone account for 25 percent of the UK population. Taken together these regions are the motor of the UK economy combining to produce over 34% of UK economic output. In terms of the traditional yardstick of economic success: output or more specifically gross value added (GVA) per head (or capita), the disparity in the relative economic strength of the regions is clear. Examining Figure 4, GVA per head (indexed for each region with the UK average = 100), shows that output in the best performing region, London at 155, is almost exactly double that of the worst, Wales at 77. Only London and the South East exhibit output greater than the UK average. There is precious little evidence from this dataset of this disparity abating with the majority of regions' relative position to the average worsening over this short time period.

Figure 3: Population shares of the UK regions
Regional populations (million) and percentage of UK total



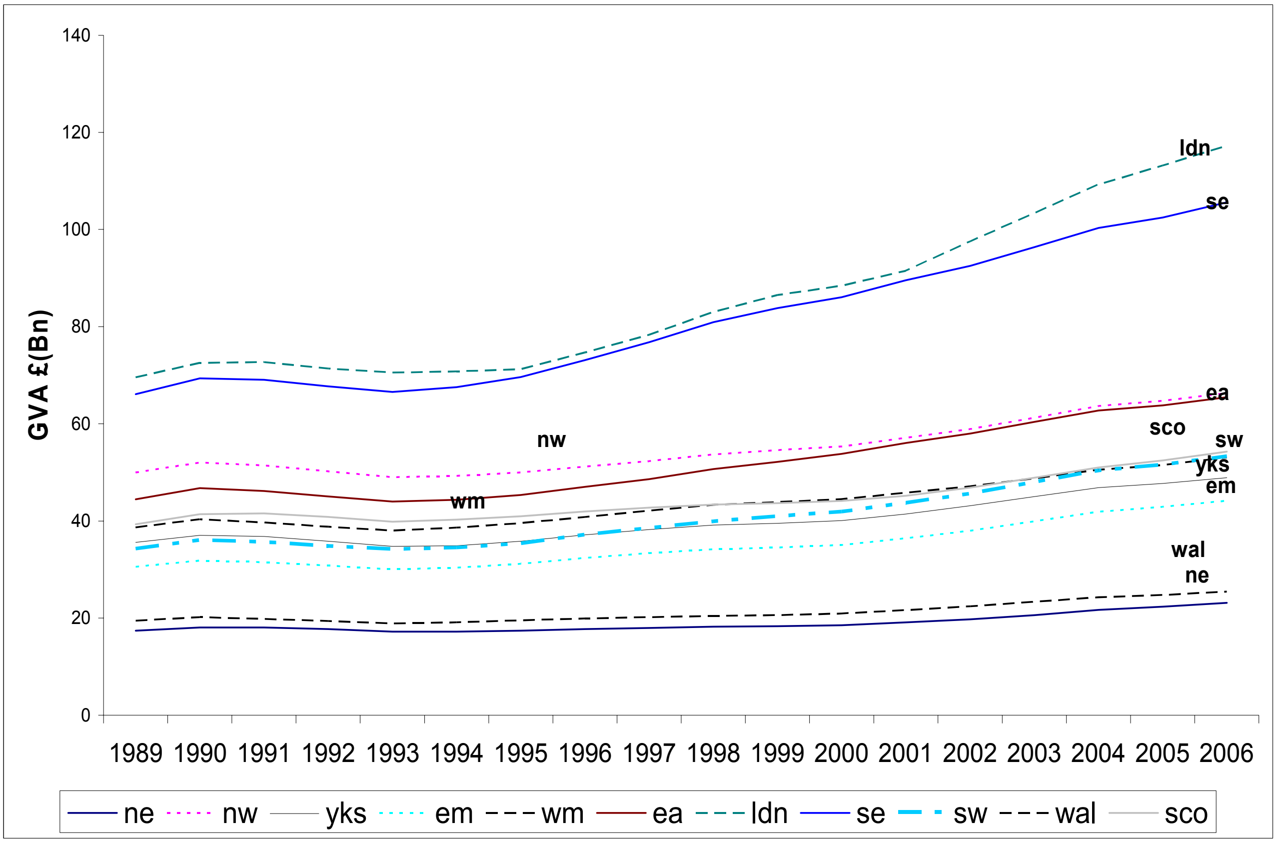
This apparent secular trend is more evident the longer the period studied. Figure 5 below plots the aggregate level of GVA for the regions over the time period 1989 to 2006 which includes the recession period of the early nineties.

Figure 4: Regional GVA/Head (indexed basis, UK average = 100)



As is fairly evident the London economy has grown significantly faster over this time period (68.5%) compared to all economies but particularly the smaller lagging economies of Wales, Northeast & Northwest which have grown between 31 and 33 percent over the same time period. In fact it can be seen that the average annualised growth rate of London is again more than twice than that for Wales and almost twice when compared to the Northeast and Northwest. The southern economies (Southeast, Southwest, East of England (which is labeled 'ea' throughout this thesis)) are closest in the wake of London and it is only these, together with the East Midlands, that have managed to produce average growth of over two percent over this period: Scotland, Yorkshire and the West Midlands all managing just one point nine percent growth.

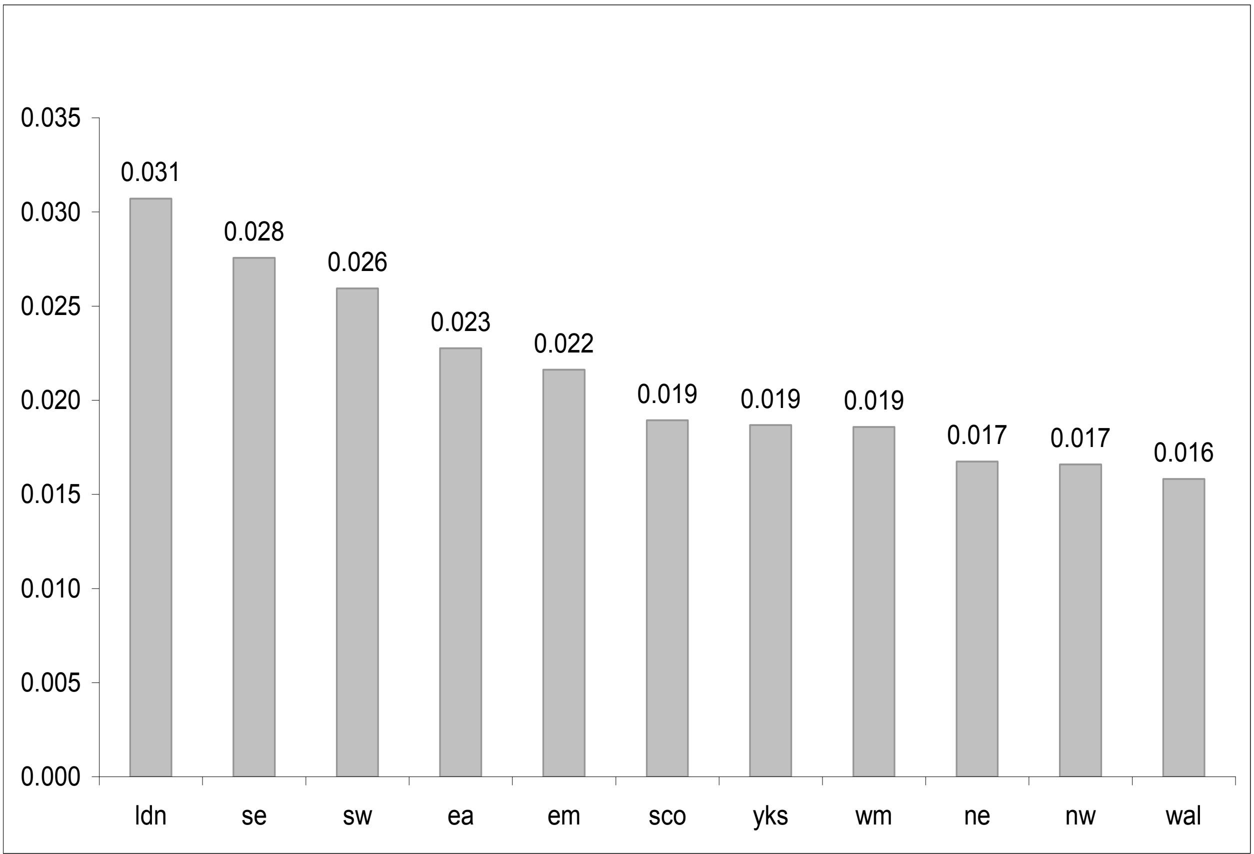
Figure 5: Regional GVA, 1989 – 2006 (1990 Prices)



This data supports the official estimated 'potential growth rates' by the DTI (2004) which vary from 1.25% in the North East to over a percentage higher for the South East at 2.5%. Another stark fact about the regional economies is their heterogeneity in industrial composition. The UK's journey to a post industrial economy is well documented but it can be seen that this journey has clearly gone further in some regions than in others. Figures 7 to 12 show the industrial composition for the regions of the North East, Yorkshire and London for the years

1982 and 2002 and figures 13 to 15 break down overall GVA growth for each region into key industrial sectors[6] (only three regions are reported here, the rest in appendix one).

Figure 6: Average GVA growth rates (%), 1989 – 2006, UK regions



Not only is industrial composition seen to vary significantly across regions; in 2002 for example, manufacturing accounted for less than 9% of output in London and financial and business services nearly 50%, whereas the corresponding amounts were 22% and 22% in the North East; the industrial structure of all of

[6] See over for the explanation of how these have been aggregated for purposes of this graphical representation.

Figure 7: Industrial Composition of NE, 1982

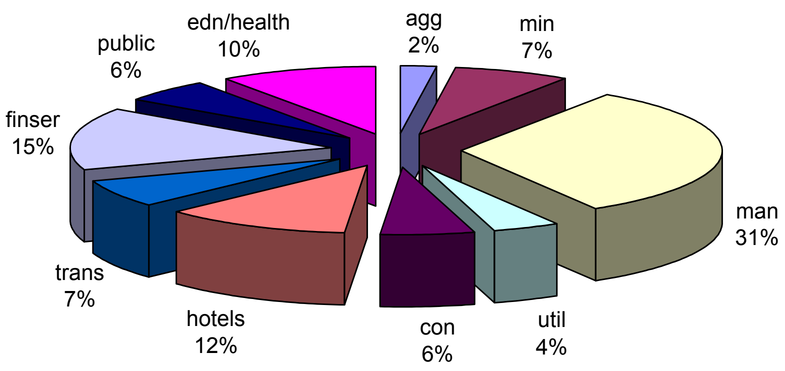


Figure 8: Industrial Composition of NE, 2002

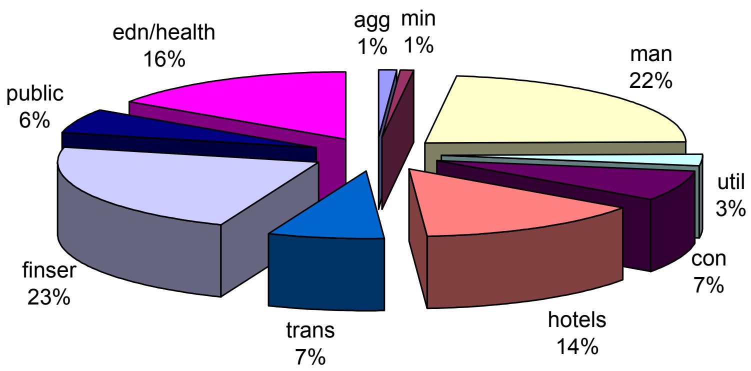


Figure 9: Industrial Composition Yks, 1982

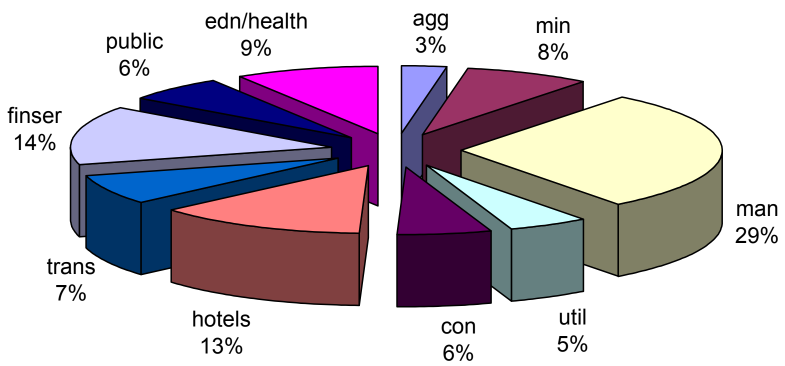


Figure 10: Industrial Composition Yks, 2002

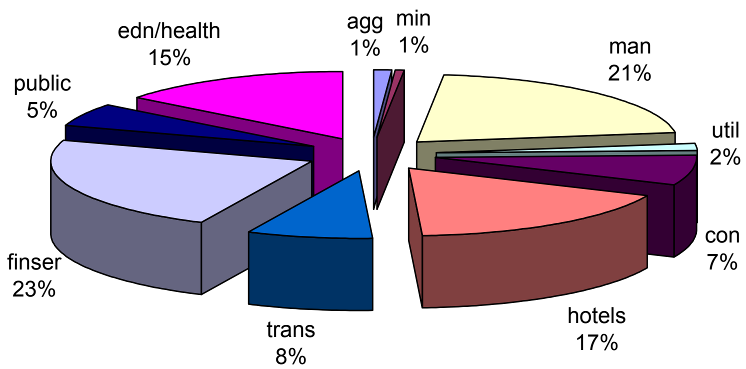


Figure 11: Industrial Composition Ldn, 1982

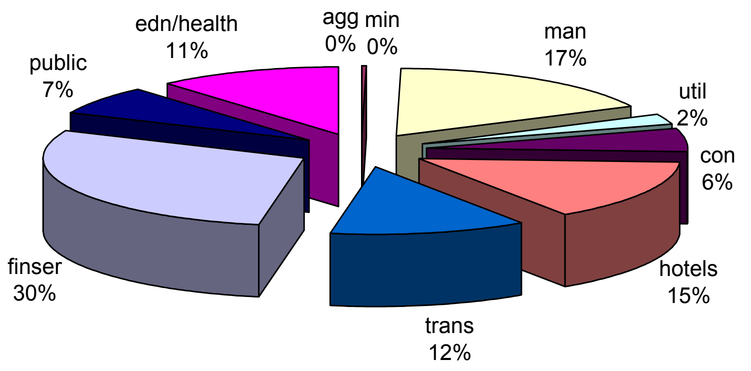


Figure 12: Industrial Composition Ldn, 2002

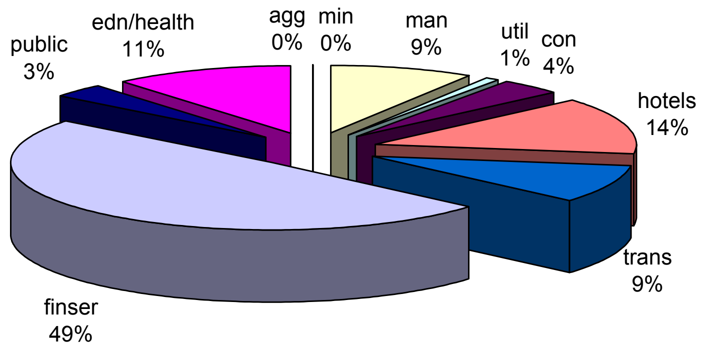


Figure 13: NE Growth (by sector) 1982 – 2002 (1990 prices, £bns)

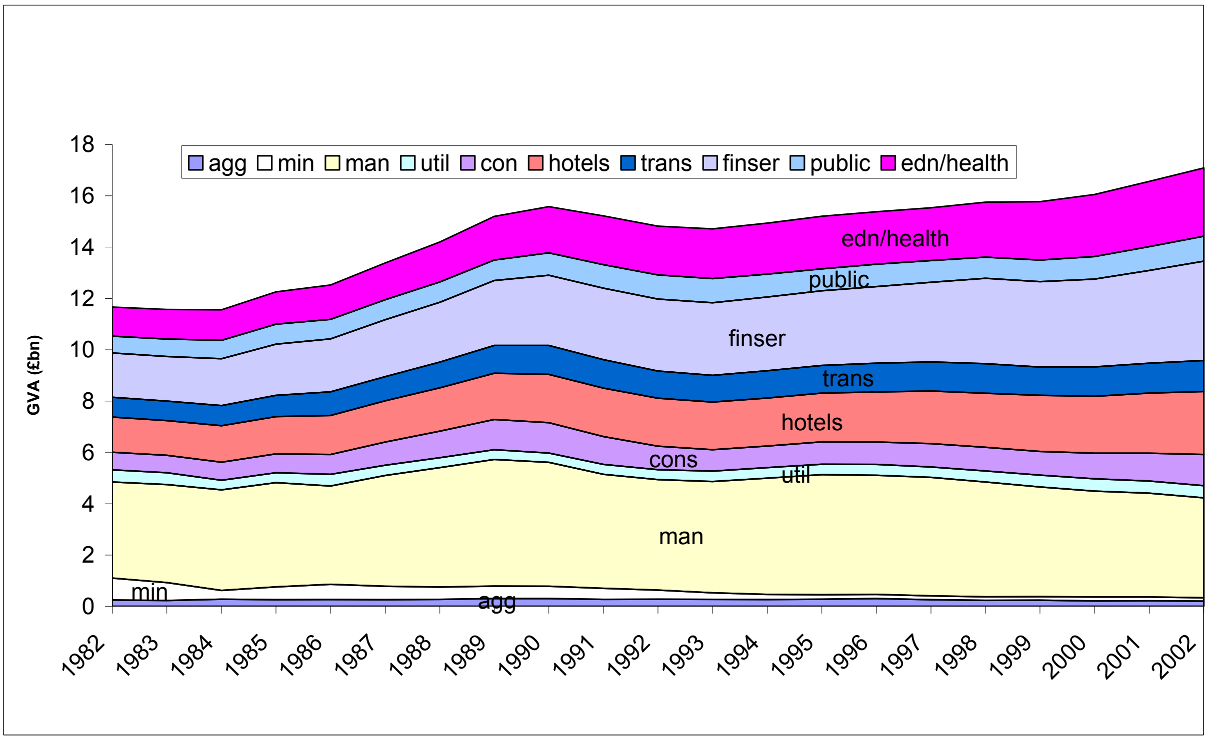


Figure 14: Yks Growth (by sector) 1982 – 2002 (1990 prices, £bns)

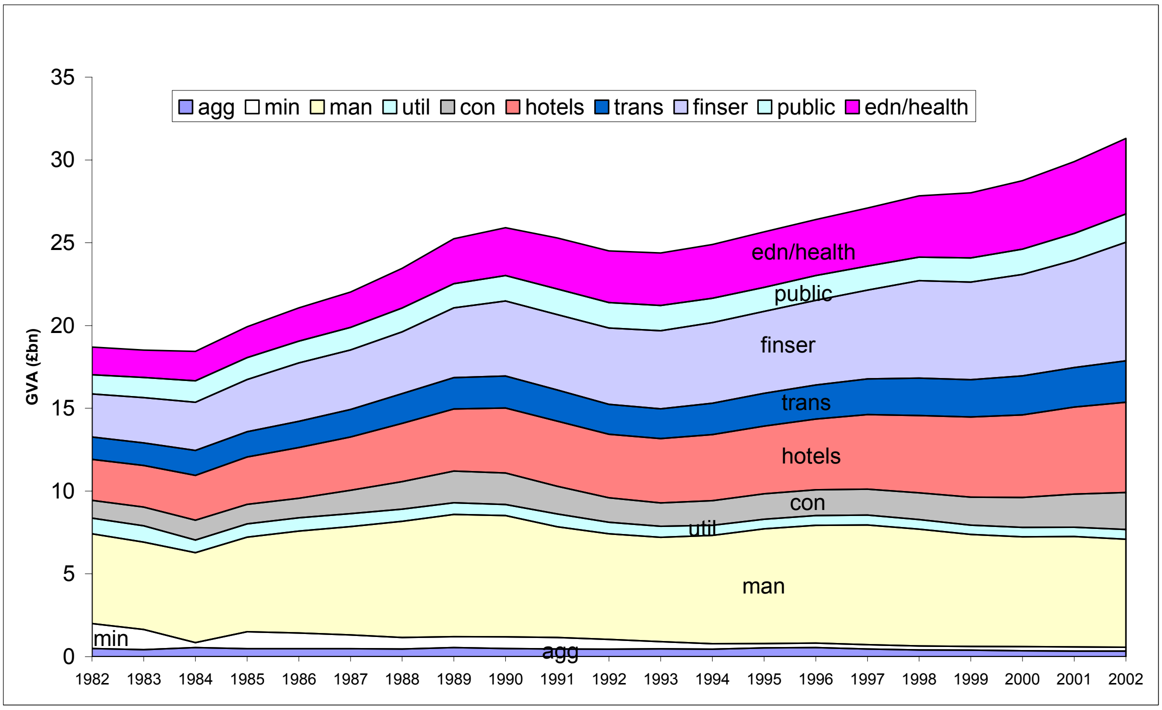
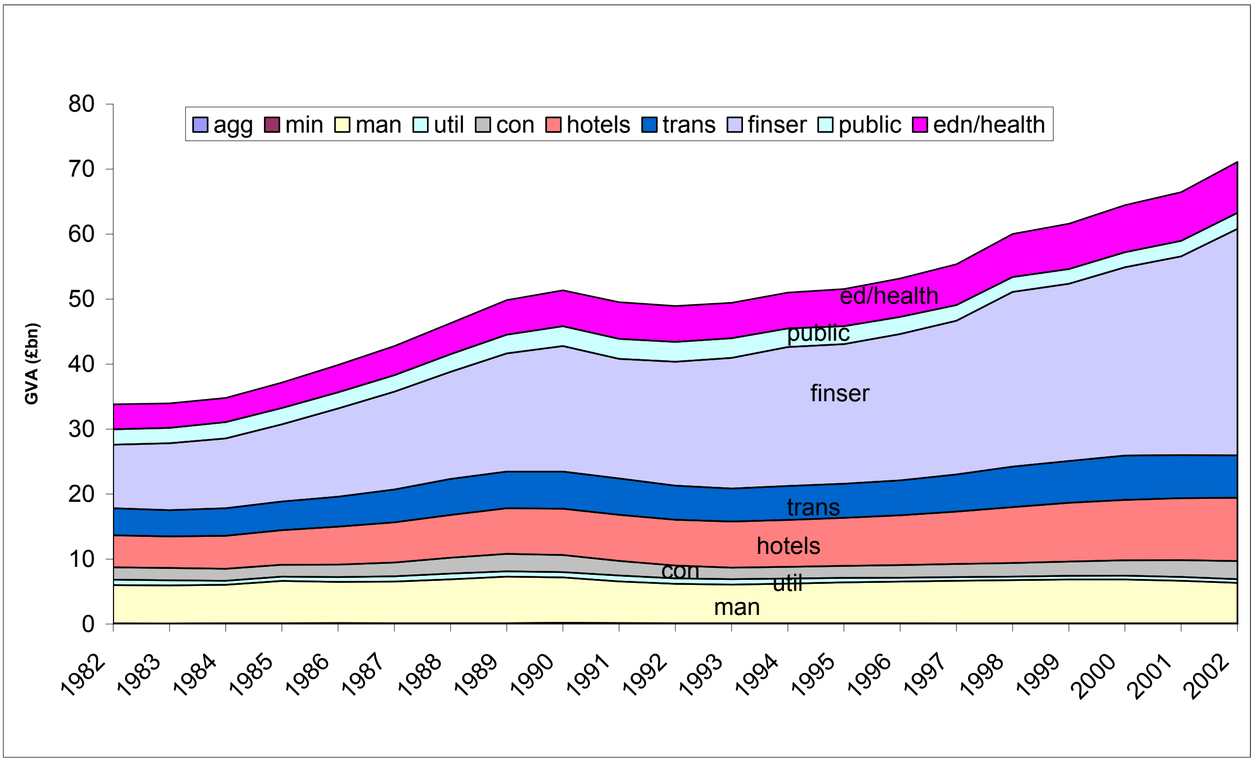


Figure 15: Ldn Growth (by sector) 1982 – 2002 (1990 prices, £bns)

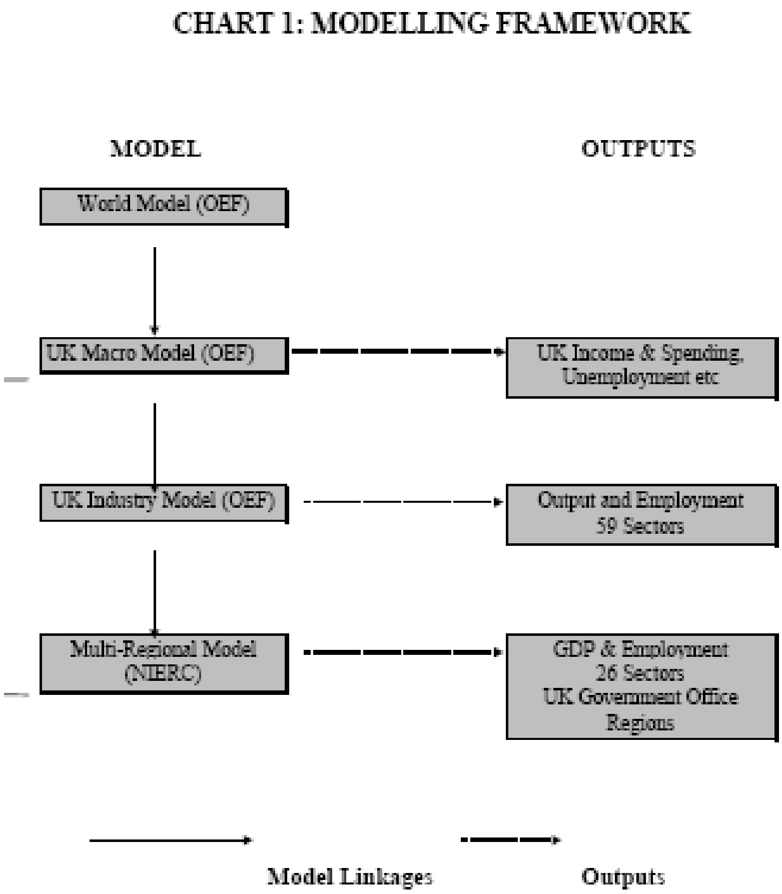


the regions can be seen to be changing over time and the relative share of traditional manufacturing industries declining and those of services, financial or otherwise, increasing for each and every region. This has clearly been fastest in London where the share of output accounted for by manufacturing has nearly halved (albeit from a much lower base) than for the Northeast and Yorkshire where the share has reduced by roughly a third.

In fact this degree of specialisation has been noted by regional macro modelers. Both the MDM-E3 regional model of Cambridge Econometrics (Cambridge Econometrics (2007)) and the NIESRC MRM model run jointly with Oxford

Economics (Oxford Economics (undated)) base much of their regional output forecasting from aggregating up individual sectoral based forecasts: the Cambridge model disaggregating the data in to 30 individual industries; the Oxford Model providing output forecasts for 23 industries and employment forecasts for 26 industries. In the case of the NIESR model these are calculated and reconciled simultaneously with a UK wide aggregate macro forecast (figure 16, (taken directly from Oxford Economics (undated))) but those of Cambridge Econometrics model are not.

Figure 16: Oxford Economics/NIESR Regional Model, Modeling Framework

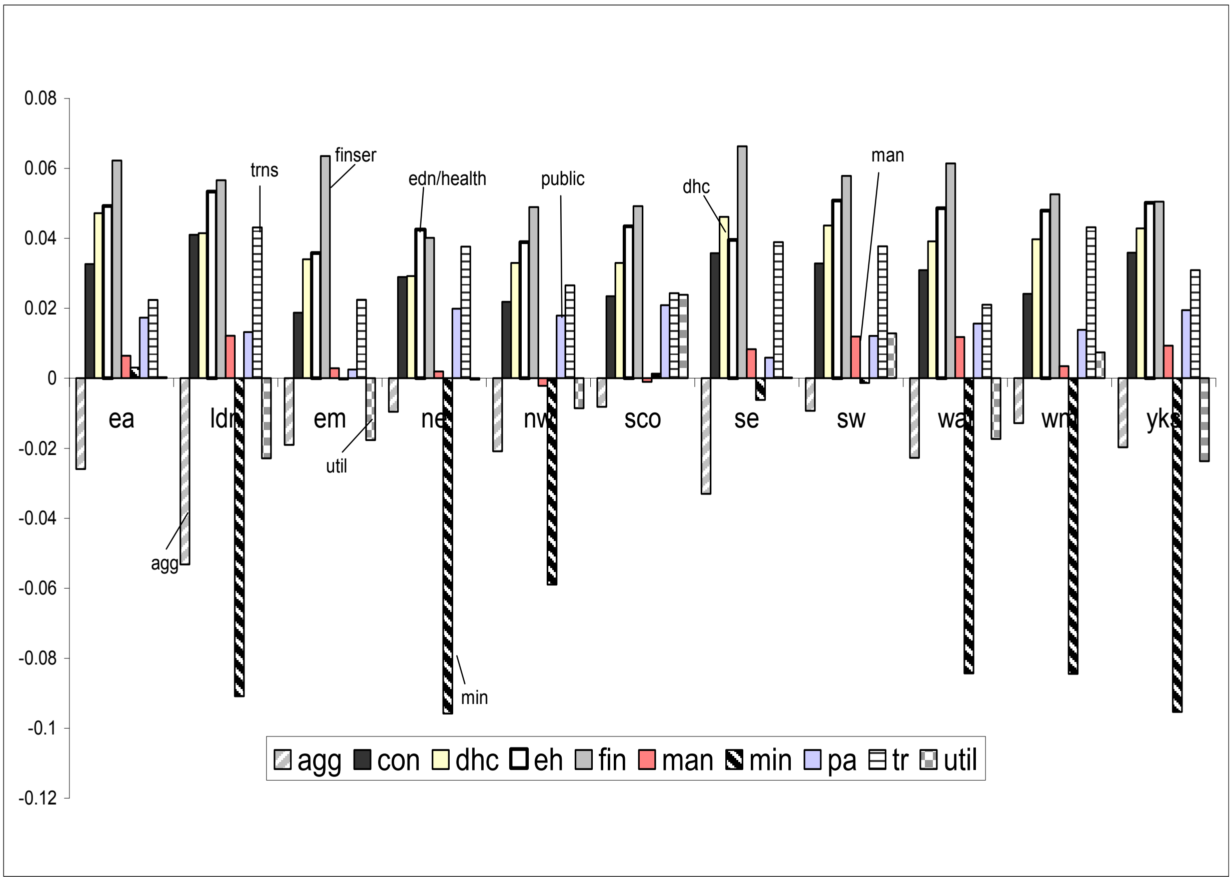


Given the nature of work of this thesis, that the regions are broken down by sectors to provide an approximation of their differences, regional data has been disaggregated into ten sectors: agriculture; mining; manufacturing; utilities; construction; hotels and catering; transport; financial (and business) services; public administration; and education and health.

As stated already, this thesis does not seek to account for the differences in structural growth rates across the regions being as that is the purview of growth theory but concerns itself with differences in the dynamics of the regions brought about their heterogeneous nature and explores heterogeneous dynamics brought about by various economic shocks.   However, it is of interest and some relevance at this point to very briefly discuss the growth rates of the different industrial sectors across the regions.

Average growth rates of sectors across the regions are displayed in figure 16. This illustrates there is a similar pattern of growth across sectors intra regions. Financial services in all regions has been the fastest growing ‘sector’ in every regional economy bar the North East and London’s growth rate is only some 50% more than the laggard regions of Wales and the North East, thus not only does it possess the largest share of the highest GVA sector but that sector is growing faster.

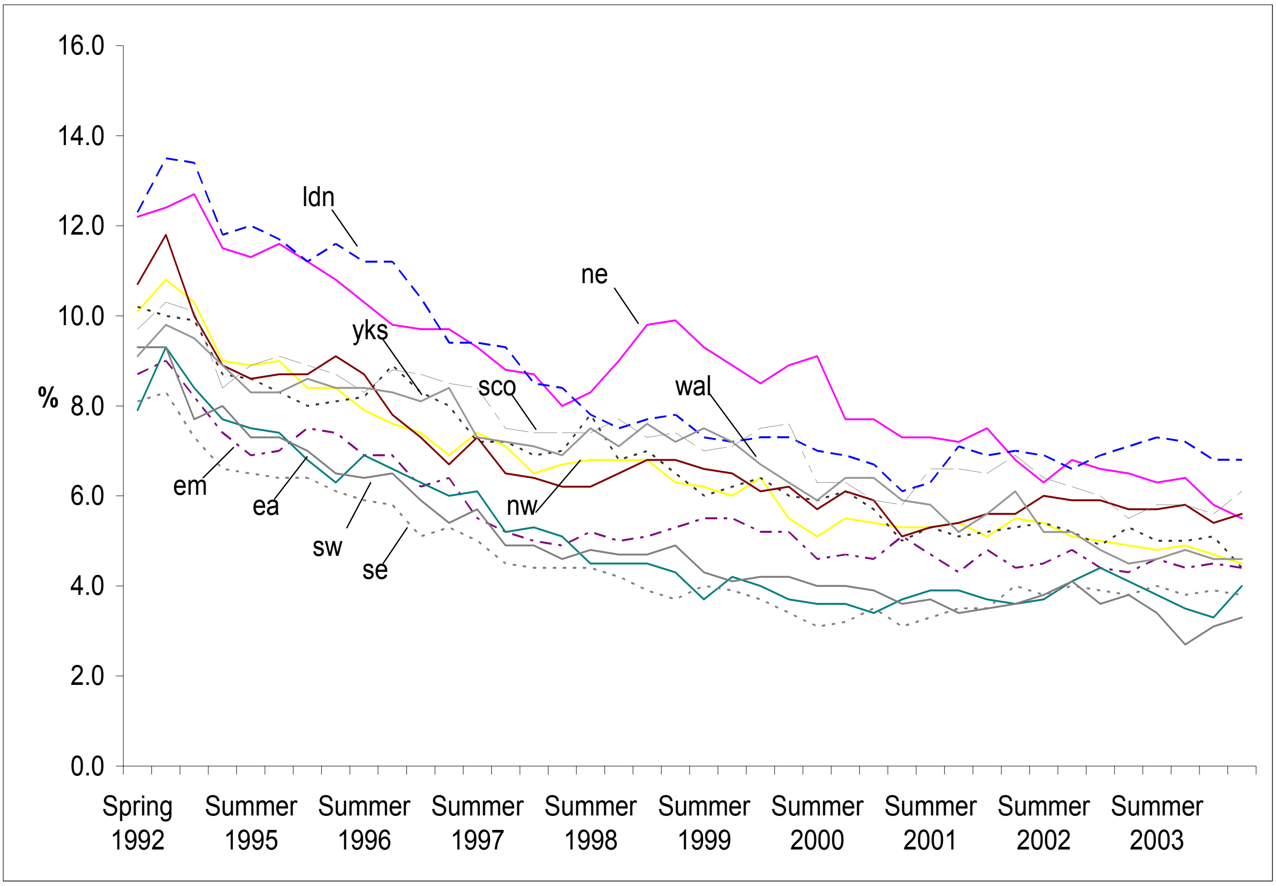
Figure 17: UK regions, average sectoral growth rates 1982 – 2002



It does seem from this evidence that aggregate regional growth rates appear to be to a certain extent a function of their sectoral composition and an interesting avenue for exploration. However, this issue is explored no further in this thesis. As said, this is not a review of regional growth. It is sufficient to state that the regions clearly display different growth characteristics and industrial composition varies significantly across the regions. The issue of heterogeneity in industrial composition of regional economies is however very important to the research when heterogeneous short and long run dynamics are accounted for.

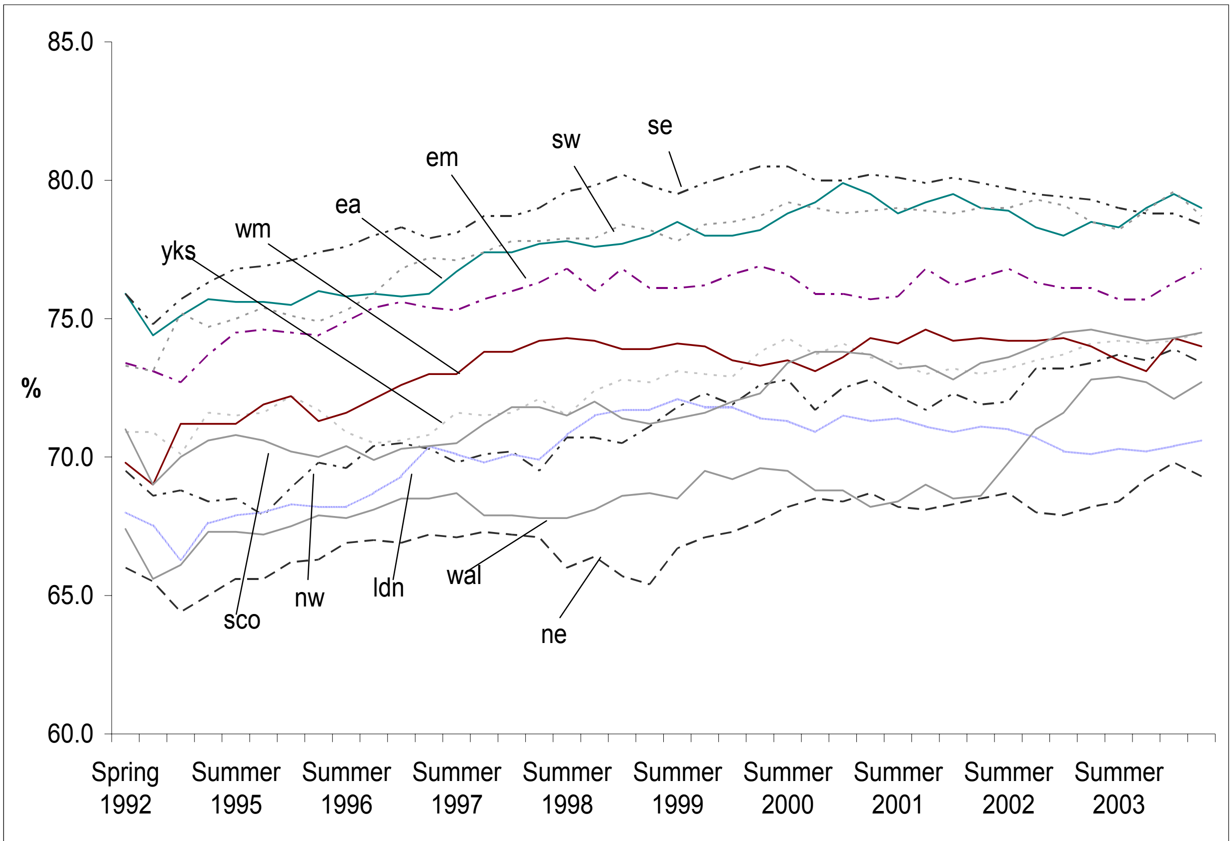
Turning attention now to regional labour markets, figure 18 below illustrates that unemployment rates persistently differ across the regions.

Figure 18: UK regions, Unemployment rates (%) 1982 – 2004



Whilst a few regions change rank order (ie the ordering based on levels), for instance at the beginning of the illustrated period (Spring 1992 to Spring 2004) the East of England has the lowest reported unemployment rate (7.9%) by the end of the period it is the Southwest (3.3%) exhibiting the lowest rate, in general regions retain their rank position and remain consistently above or below the UK average.

Figure 19: UK regional employment rates (%), 1982 -2004



It is worthwhile noting that the unemployment rates in London are counter-intuitively (at least based on intuition of the limited evidence of regional output presented to date) highest or second highest of any region throughout the period illustrated. This may suggest a certain duality in the economy. Highly productive average output from those in employment alongside higher rates of unemployment. Again this is not an issue for exploration in this thesis and it is merely noted here.

A picture of the persistently different rates of unemployment across the regions is only a partial picture. Figure 19 above shows that the pattern is repeated for employment rates. Again the regions tend to remain above or below the UK average throughout the period illustrated. The rank of regions is pretty similar (only London significantly changing its position).

The inter regional range of both employment rates and unemployment rates remain fairly constant during the illustrated period. The difference between the highest and lowest rates of unemployment reduced by only 0.9 points from 4.4 percentage points to 3.5 percentage points during the period. Similarly the decline in difference between highest employment rate and lowest employment rate reduced by only 1.2 points from 9.9 percentage points to 8.7 percentage points over the period. Both pieces of evidence supporting the view that labour market differences between the regions are fairly persistent.

There are a variety of ways to present household income and/or individual earnings data to illustrate the distribution of income across the UK regions. Two of the simplest are presented overleaf notwithstanding there are various others, more detailed. Figures 20, 21 and 22, are sufficient to illustrate the point that once again earnings (both the level and distribution) varies significantly across the regions. All three clearly show that once again the London region tops the rankings and the ordering should by now be very familiar to the reader. Similar to GVA per head (figure 4) only London, the South East and East of England possess median wages greater than the UK average and once again Wales and the North East have the lowest.

Figure 20: Median Wage (weekly) level including overtime, UK regions, 2007

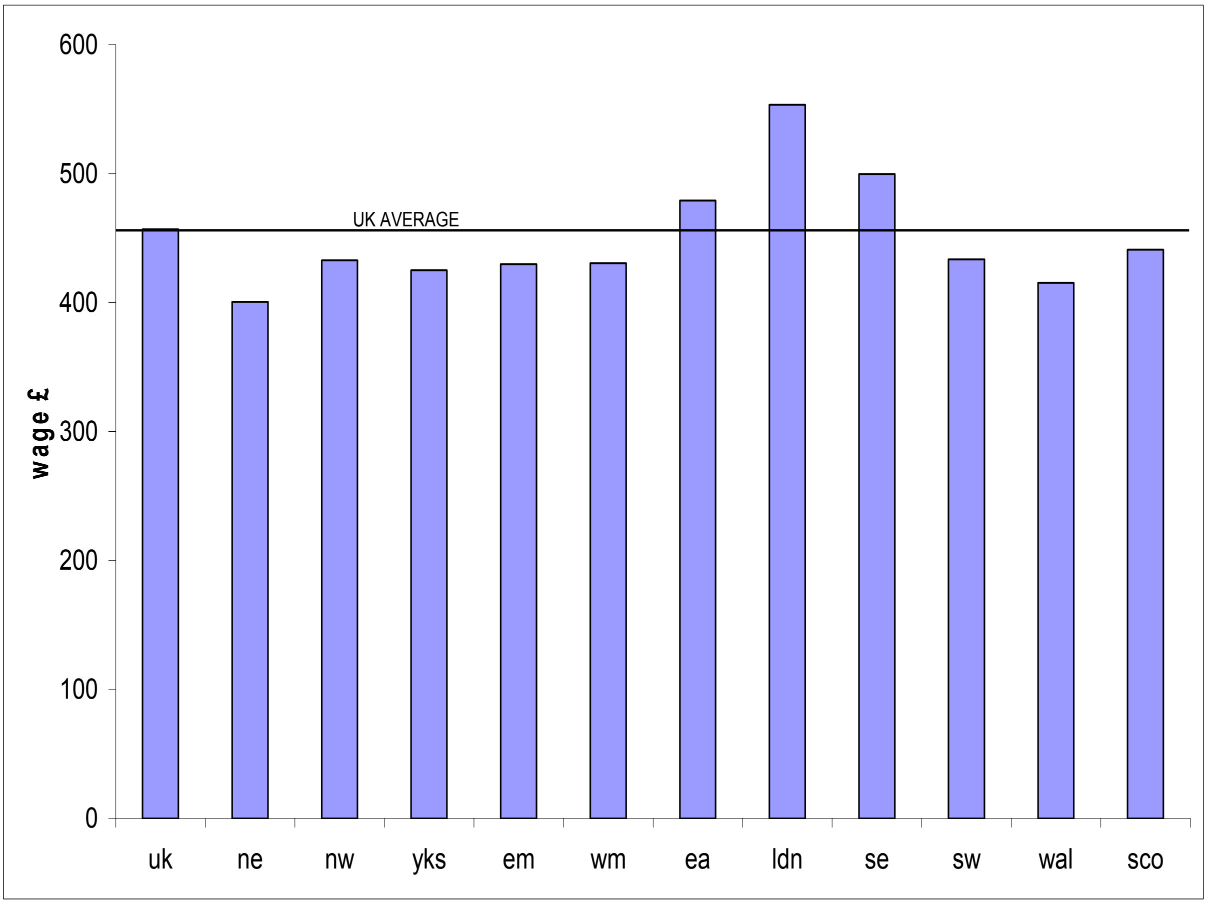
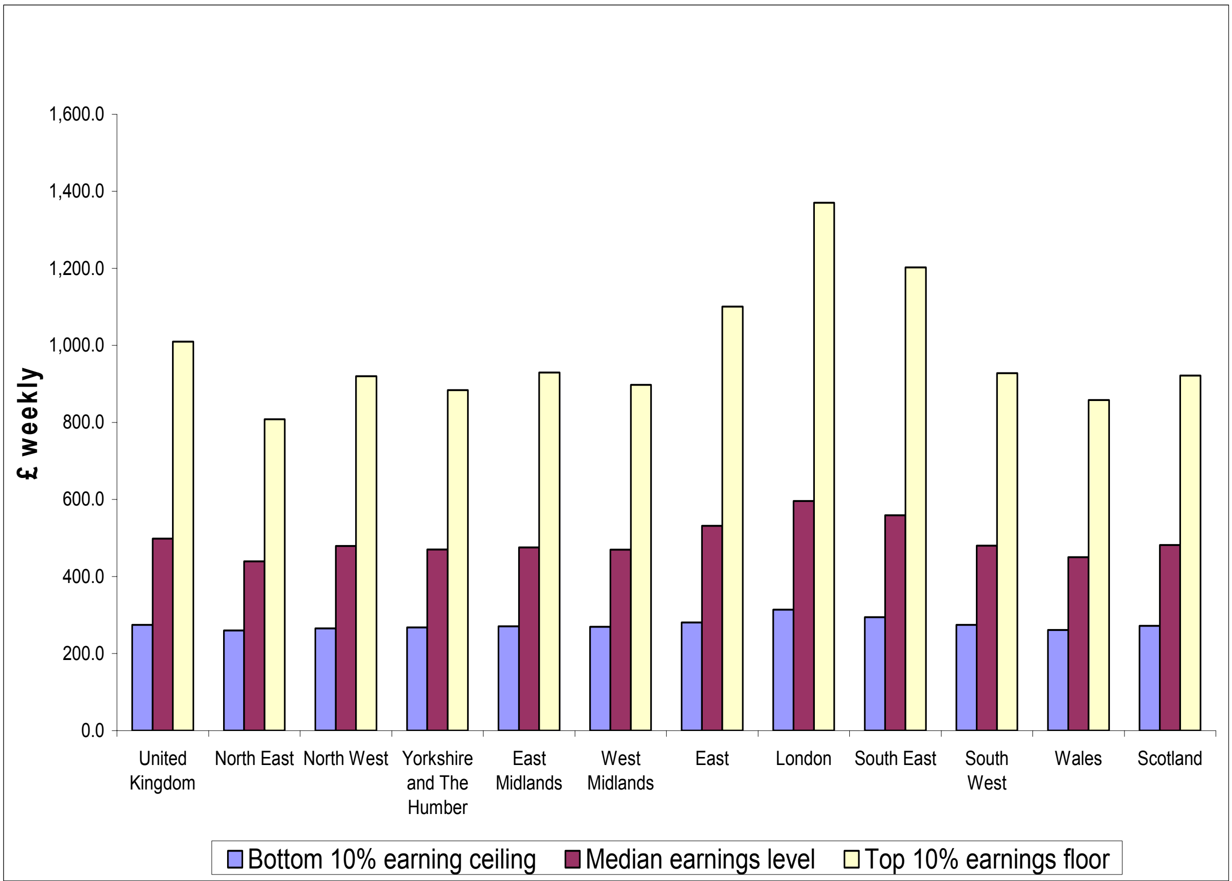
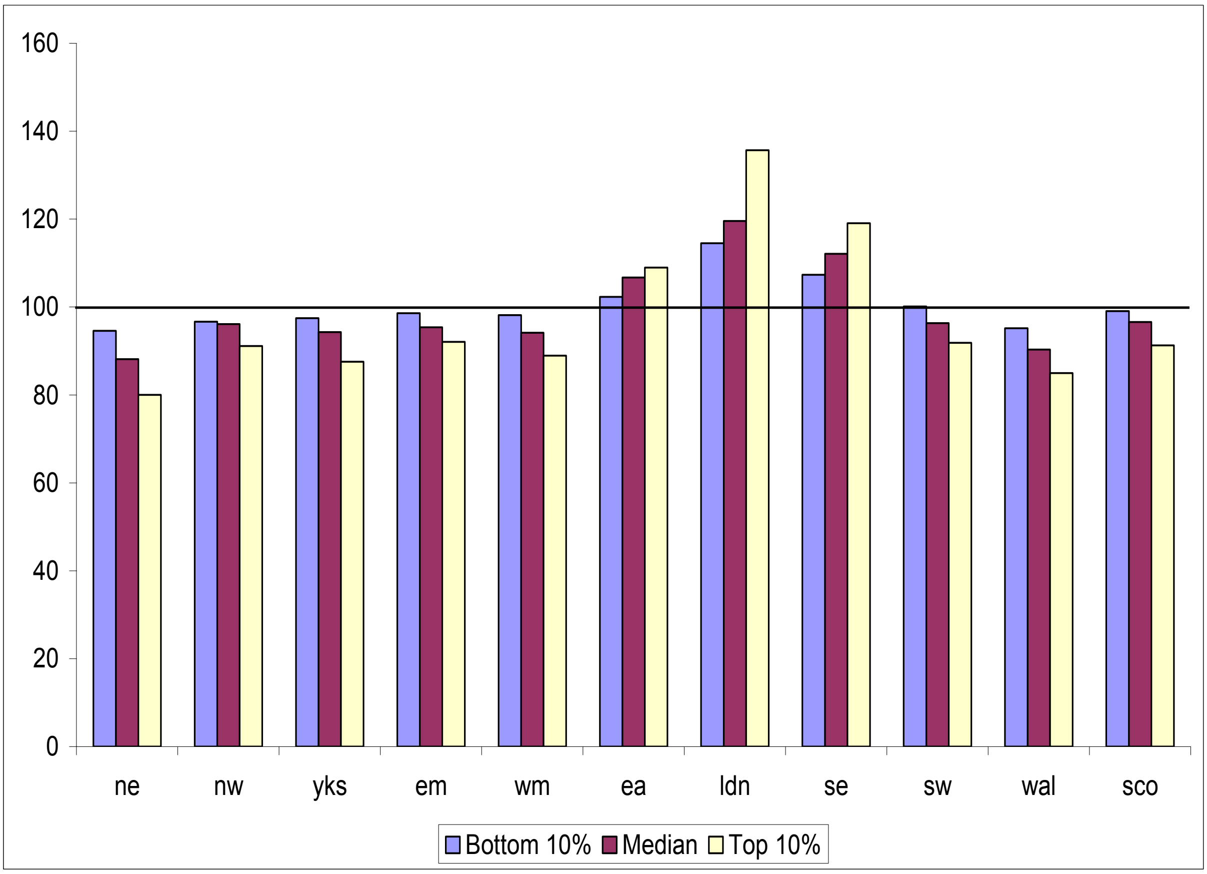


Figure 21: UK regions earnings distribution, 2007



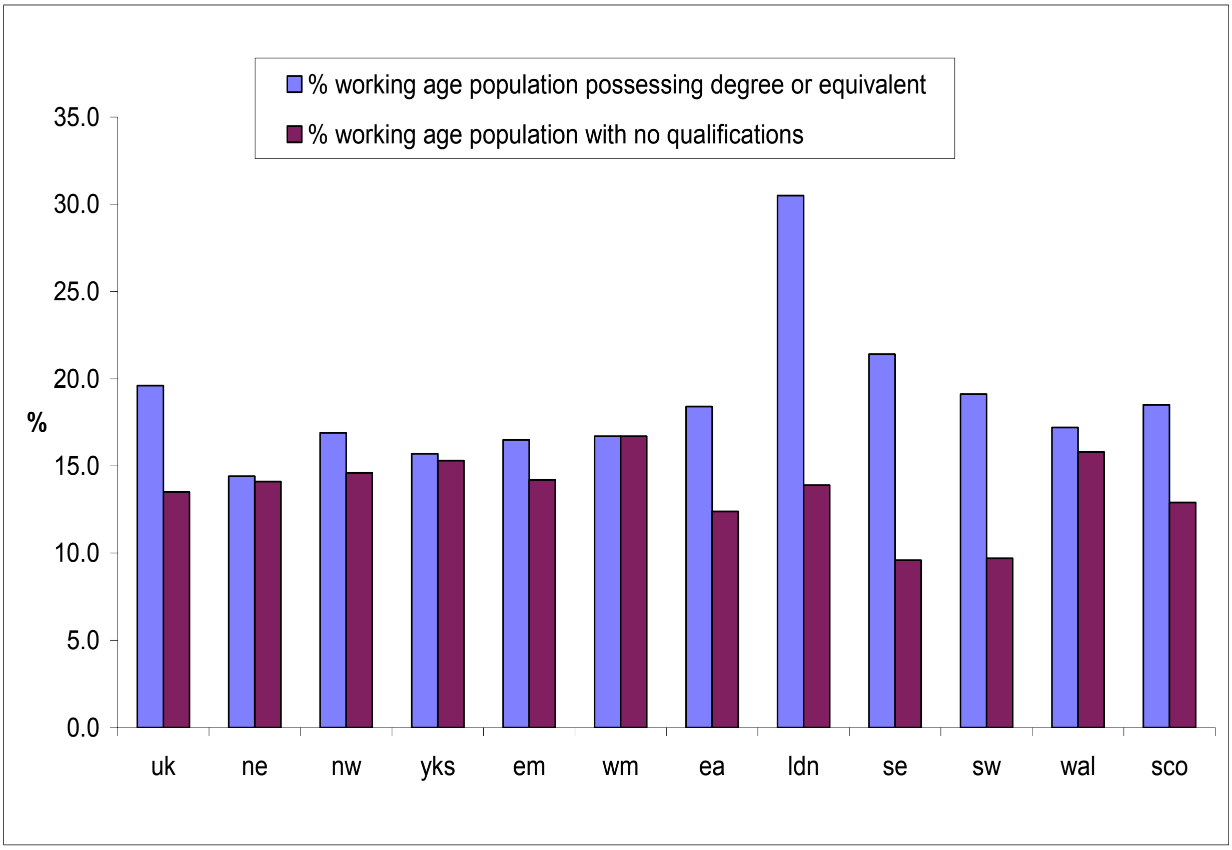
This pattern is more apparent studying figures 21 and 22. Figure 21 shows not just the median wage level (the middle bar in each case) but the ceiling of the lowest 10% of earners in each region and the floor earnings level of the highest ten percent of earners in each region in cardinal units. Figure 22 presents the same information in a slightly different manner. Here the UK average has been indexed to 100 (as was done for GVA per head). The distribution pattern can be seen to be more pronounced at higher levels illustrating that earnings differences are greatest between regions at the higher levels of the distribution.

Figure 22: UK distribution of earnings, Indexed (UK = 100)



The issue of labour market heterogeneity extends to the human capital of the workforce. On just about any measure (see ONS Regional Trends 40) London and the South East exhibit a higher average skills level across the workforce. Two measures are presented in figure 23: the proportion of the workforce which possess a degree (or equivalent) qualification and the proportion of the workforce that possess none.

Figure 23: Average Workforce Educational Attainment UK Regions



The pattern is similar to those already reported for GVA and wages. Only London, the South East and East of England report rates of possession of a degree higher than the UK average and once again the gap is largest for North East. Interesting despite London having the highest unemployment rate (reported in figure 18, it ranks above (above meaning better not more than!) six other regions for the percentage of workforce possessing no qualification.

Figures 20, 21 and 22 have illustrated the differences in earning across regions. It would be interesting to know if prices are correspondingly divergent.

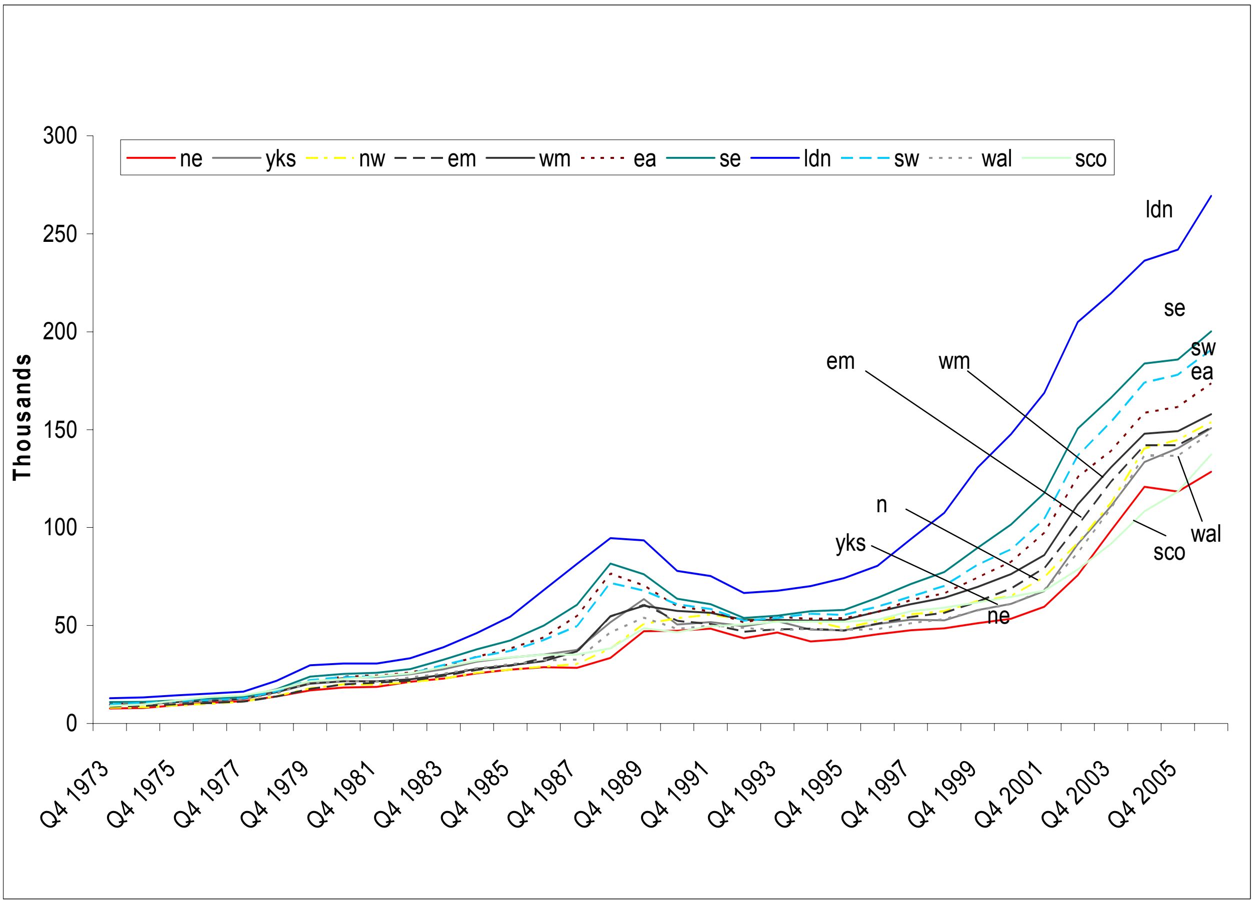
Unfortunately the UK does not publish regional price series. There are limited sources for regional prices of varying time series lengths Croner Rewards do published time series and the ONS (2005) recently calculated a snapshot comparison of price levels.

This issue is revisited in chapter three. For now it is sufficient to note that it has been the prevailing wisdom to believe that the majority of regional variation in prices (Hayes, 2005) is caused by housing costs and services; the competitive nature of the UK market being thought to be sufficiently strong to ensure differentials in traded goods such as clothes, food, fuel etc are minimised.

For illustration purposes figure 23 produces a historical plot of regional house price levels (as published by the Nationwide Building Society). As can be seen over time major divergences emerge between the regional house price levels but for retail price levels this is a more contentious subject.   The range of the regional retail price level (as calculated by Hayes (2005) after 24 years is a mere 13.8 index points (the indices are all rebased to a hundred in 1974) between 550.7 and 564.5. To provide a measure which gives more a flavour of the scale of this difference, the standard deviation is 14.68 or 2.63% of the average price level in 1996: a minor divergence over such a time period and indicating heterogeneities are small.

However, Fenwick and O'Donaghue (2003) using 1999 ONS data calculated a somewhat larger consumer price deviation. Their 'purchasing parity' calculations state that a national basket costing £100 at national average prices would cost some £106.80 in London compared with only £95.30 in the North East – a much larger discrepancy. Their calculations also suggested a greater homogeneity in price levels for products as opposed to services across the UK regions.

Figure 24: Regional House Price Levels, 1973 – 2007

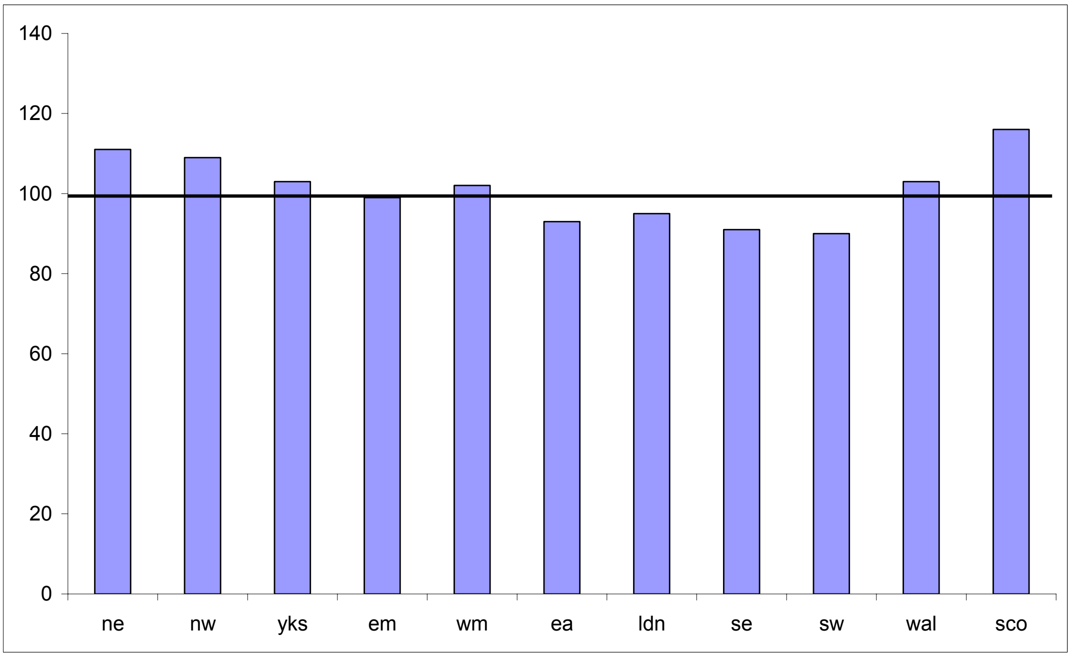


Irrespective of which view is most correct they both support the fact that the retail price level differs much less markedly across regions than does the property price level. Interestingly, the difference in property price levels has been growing at a more rapid rate in recent years.

This chapter has briefly reviewed the dissimilarity of the regional economies. It has shown the extent and persistence of the differences between the regional economies.   It has used crude measures of economic output: GVA and shown how the level and per capita amounts have diverged and are continuing to diverge across regions. It has illustrated that the differences in economic structure is pervasive; encompassing industrial composition, employment and unemployment rates, wages and skills.   It has not sought to explain these differences, merely to note them.   This thesis however, suggests that these differences ought to play some part in causing heterogeneous short and long run dynamics of the UK regions. What has been done in this chapter is to first underline the fact that these differences are real and significant and to describe them.

Finally, to reinforce this point the reader is referred to figure 25. This illustrates how the differences are also social not purely economic (whether there exists causality in either direction is again not for this thesis). It reports the standardised mortality ratios for the UK regions. In this instance, lower values (or below average) are best. The pattern however should be very familiar to the reader.

Figure 25: Regional Standardised Mortality Rates (UK Average =100)



3 Discussion of Data Used and Issues

The analysis of regional dynamics in the UK (or Britain) is seriously constrained given the lack of quarterly time series data. Flexibility is required, and necessitates the utilisation of various datasets. In the research of this thesis an attempt is always made to use the longest time series available that contains the data required for model estimation. All data used has been taken from the ONS, except the regional retail price series from Hayes (2006) and the values for real exchange rates, annual UK short term interest rates and real oil prices used in chapter 8 which have been downloaded from Eurostat.

The ONS has published data series on annual output for the UK regions from as early as 1967. This is the dataset used by Barrios et al (2002) and one that is used in chapter 6 for the estimation of monetary VARs and the reaction of regional outputs to monetary policy shocks. This dataset was obtained directly from the researchers (Marianne Sensier) and the author is grateful for this as it is no longer directly available via the ONS.

The ONS has published regional series for the time periods 1971 up to 1996 which has regional output broken down into earnings from employment, pensions, and assets. This is the dataset that is utilised in chapter 8 where the breaking down of earnings in this manner facilitates calculation of a proxy for the labour share – ie marginal costs - which is critical in estimating correctly signed coefficients on the forcing variable for inflation when estimating the New Keynesian Phillips Curve and its hybrid variant (see chapter 7 and 8).

All the time series utilised in this thesis cover the period late nineteen sixties and early to mid seventies to the mid nineties. Given the present date, the question may arise why time series covering more recent periods have not been used? The reason being that the ONS has not published the regional data on a consistent basis throughout the time period. Recent ONS data published for the regions commence around 1989 and lead up to the present day. Unfortunately the geographical classification of the regions changed between the first set of time series and the second.   Certain regions' (the North East, North West, East Anglia[7], South East) borders changed significantly and others', West Midlands, East Midlands and Yorkshire changed in a less significant manner. Therefore for time series analysis – particularly inference as to dynamics - it is impossible to construct a consistent series for these regions.

The problem is best illustrated by reference to the GDP series for East Anglia and the South East below where both series for each region have been commonly deflated using the GDP annual deflator from the ONS.

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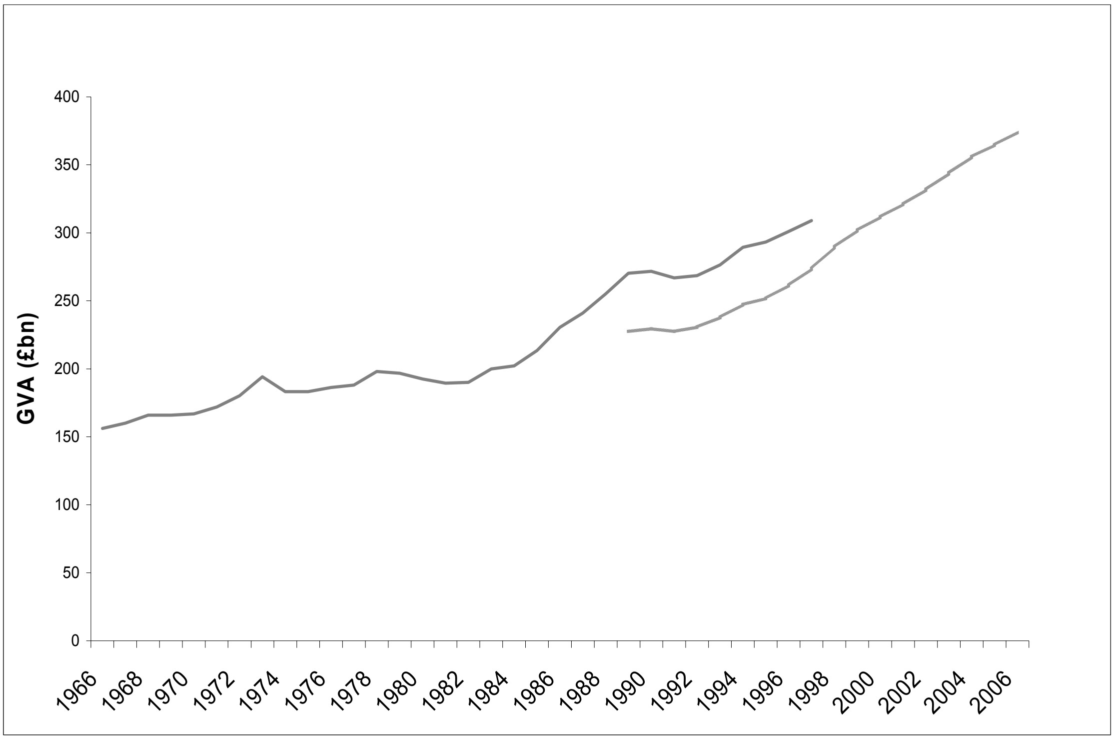
[7] Technically, East of England.

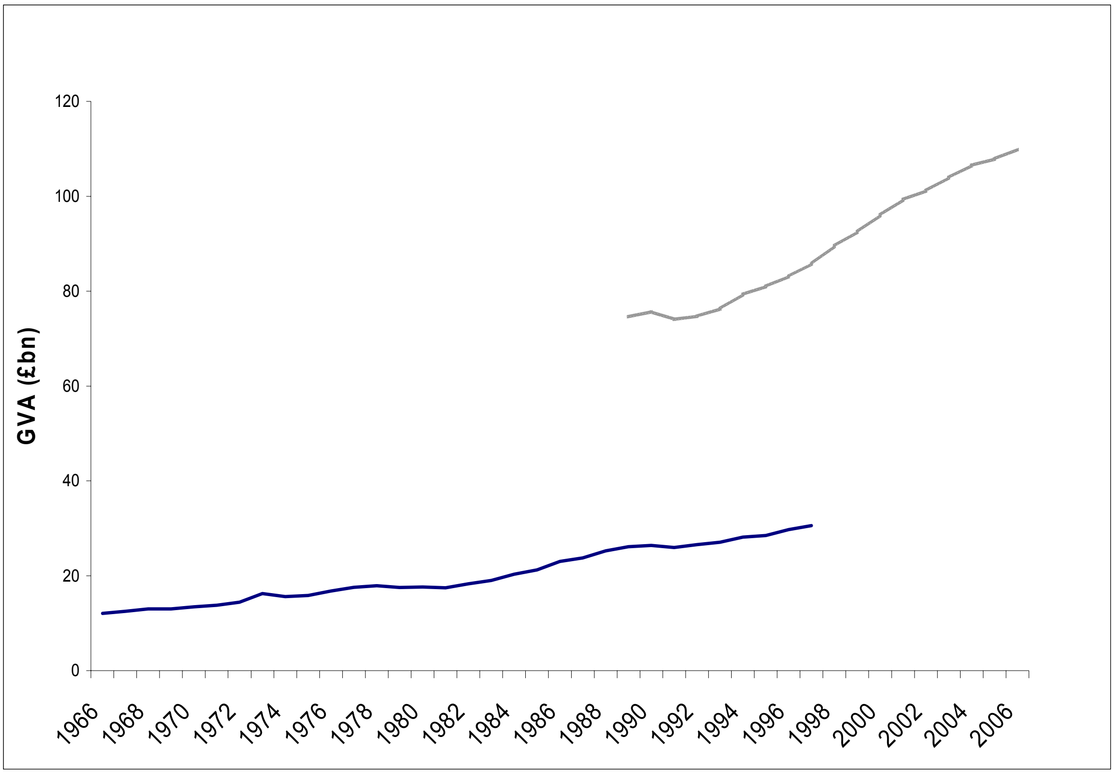
Figure 26: South East & Ldn GVA Series,1967-1996 & 1989-2006 (2006 Prices)



Whilst it can be seen that clearly the size of the change is consistent across the two regions (visually it looks different due to the relative size change in the economies– ie East Anglia increase in size by some 400% and the South East reduces in size by some 20%) it is not credible to attempt to connect the two series as they clearly represent significantly different areas.

The only point where these series have been linked was during the brief analysis of sectoral responses in chapter 8. Given that sectoral data for the regions has only been published since 1982 and, given that it is only a secondary part of the analysis, and the unavailability of other data sources there is little choice.

Figure 27: EA (East England) GVA Series,1967-1996 & 1989-2006 (2006 prices)



The preferred and key measure for regional sectoral dissimilarity throughout this thesis is the index proposed by Krugman (1991). This has been used by other researchers (Barrios et al, 2002); its advantage is that it gives a measure of the breadth of sectoral dissimilarity outside the traditional measure of share of manufacturing traditionally used (Carlino Defina, 1998).

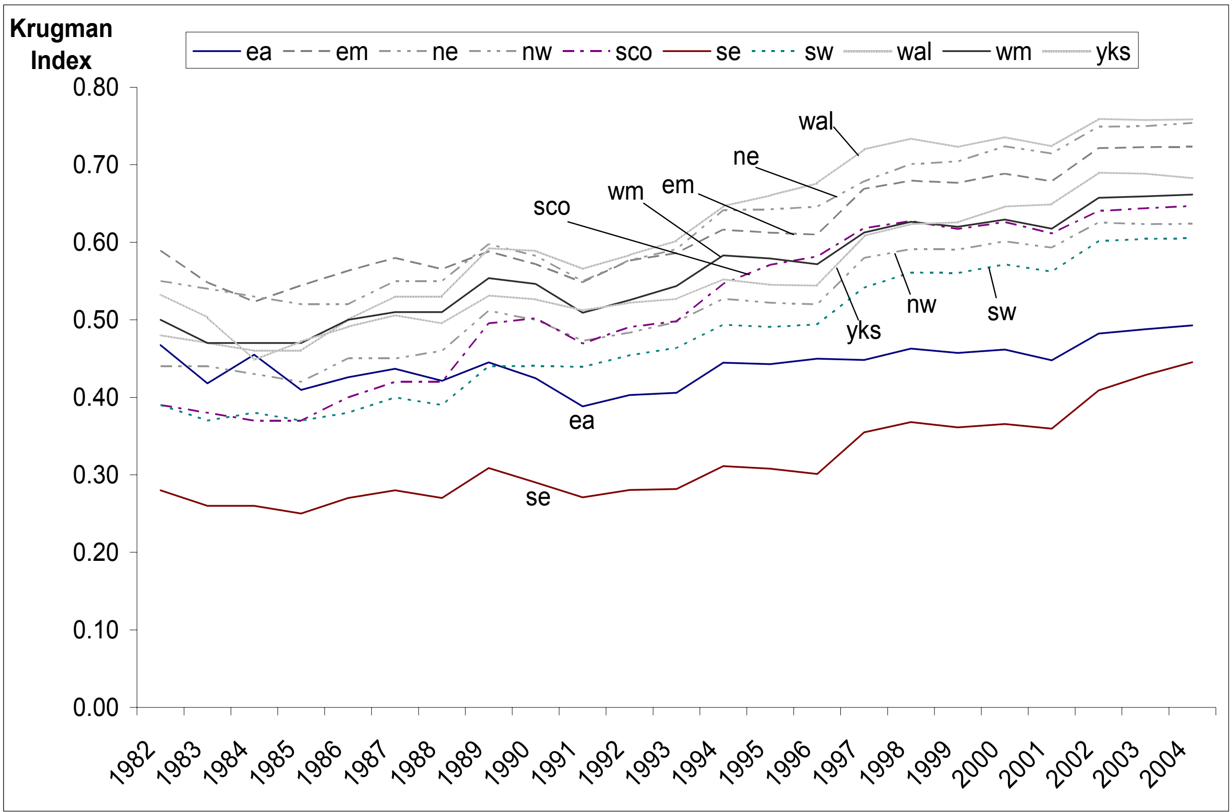
The measure is constructed thus:

$$Krugman_{jk} = \sum_{n=1}^{N} | s_{nj} - s_{nk} | \qquad (1)$$

Where s_{nj} and s_{nk} denotes the output share of sector n in regions j and k. The index ranges from zero to two, zero for identical similarity, two for perfect dissimilarity (with the caveat that if such a concept exists). As can be seen below the relative positions (according to ranking their Krugman values) of the regions has little changed over the time period. However, there is a slight step change in values around 1990 (and is likely to be caused by the change in the geographic areas referred to earlier.)

Given all the estimation periods cover the late 1960s/early 1970s to the mid 1990s the 1982 values have been chosen as the benchmark year as a) this is the central point over these time series and b) there is little change during the 1980s in relative rankings. This is important to bear in mind as these will be mainly used in rank correlation analysis and it is key to remember that this has little changed over time. No official data series exists for regional price indices although Croner Rewards has published data series on regional price baskets that have been utilised in certain UK studies on the regions (Henley 2005).

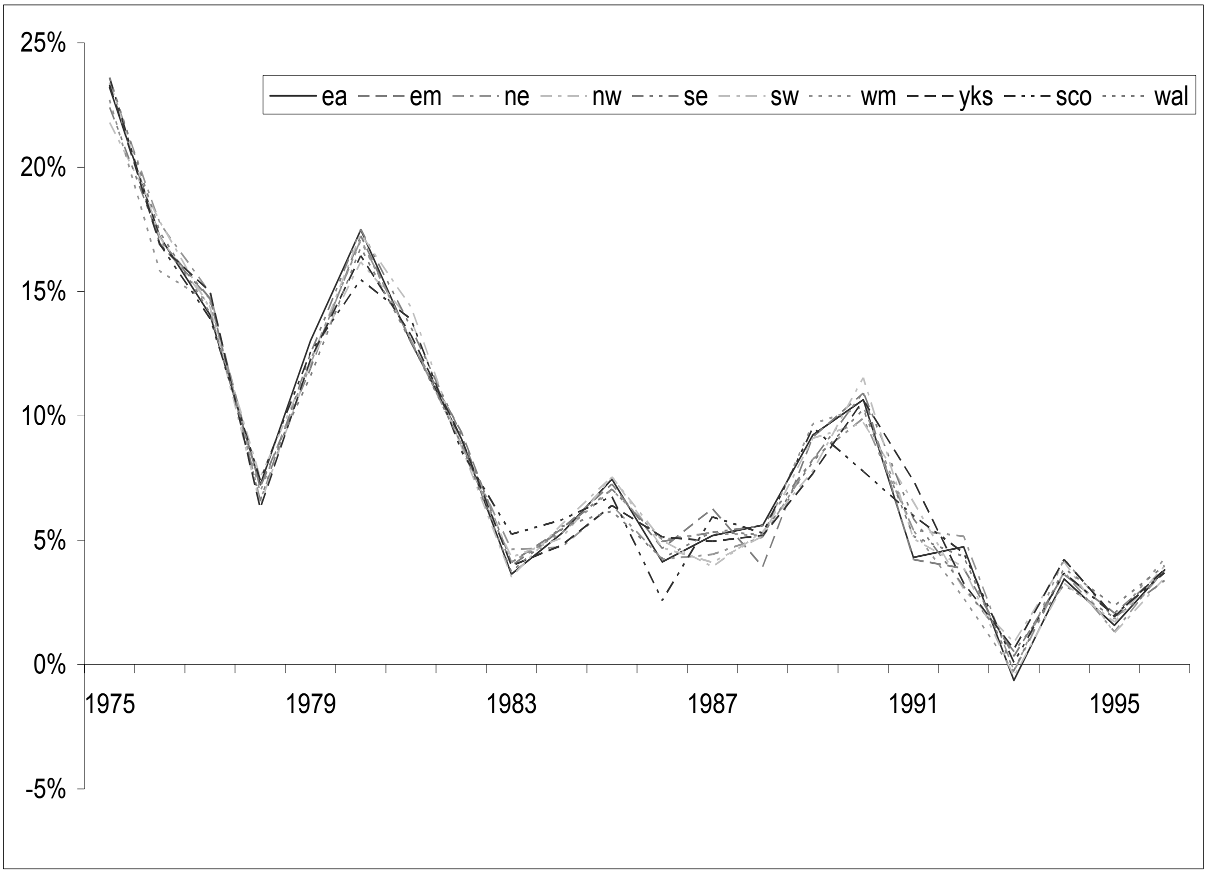
Figure 28: Calculated Krugman Indices, 1982 – 2004



Hayes (2005) has produced regional price data over the period 1976 to 1996. Citing the over dominance of housing data in previously published indices, Hayes constructs his price index by combining data from the Croner Rewards consumer expenditure survey with the national housing expenditure index and using weightings from the EFS survey. Interesting he compares each of his regional price series against the retail price index and is unable to reject the null hypothesis that each of the regional prices indices is not statistically significantly different in growth rates at the 1% level. He acknowledges that this questions the need for a regional specific price index.

Therefore in chapter 5 where this data set has been utilised the corresponding output series is similarly foreshortened to 1974.

Figure 29: Regional Inflation Series (Hayes), 1975 – 1997

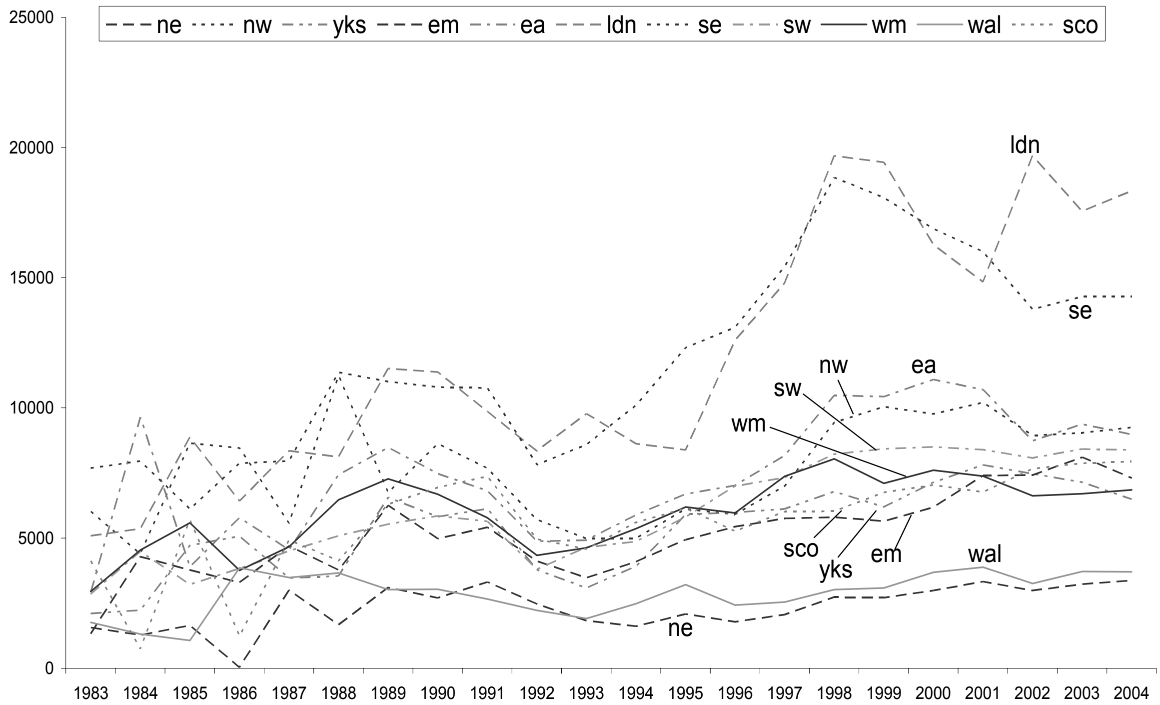


No data series exists for investment for the regions except for preliminary datasets released over the period 1998 to 2000 and this is provided on an industry basis although for a handful of industries, including manufacturing, investment data are available for a five year period. Capital expenditure has been published separately from the Annual Business Inquiry by the ONS over a six year period (1998 to 2004) although this comes with a health warning that this should not be used as a proxy for net investment.

An attempt by the author was made to construct regional investment series. Capital stock series exist for the sectors at a national level from the mid-1970s onwards as do employment level data. With allowances for depreciation and by allocating capital stock among the regions according to their share of sectoral output for any given year it is possible to construct regional investment and capital stock series. As can be seen from figure 30, the regional investment series derived via this method can be seen to be fairly heterogeneous.

The investment figures derived by this method are compared to those published by the ONS for 2000 (investment shares (of total UK investment) of the regions constructed versus actual) in figure 31. One might optimistically conclude that the constructed data is a pretty close approximation for this particularly year but one swallow does not make a summer and it the view of the author that it is beyond the realm of reasonableness to assume this is an accurate manner of deriving the series over a time period of 20 years when the express research interest is dynamics. However, his method has been used in previously published work.

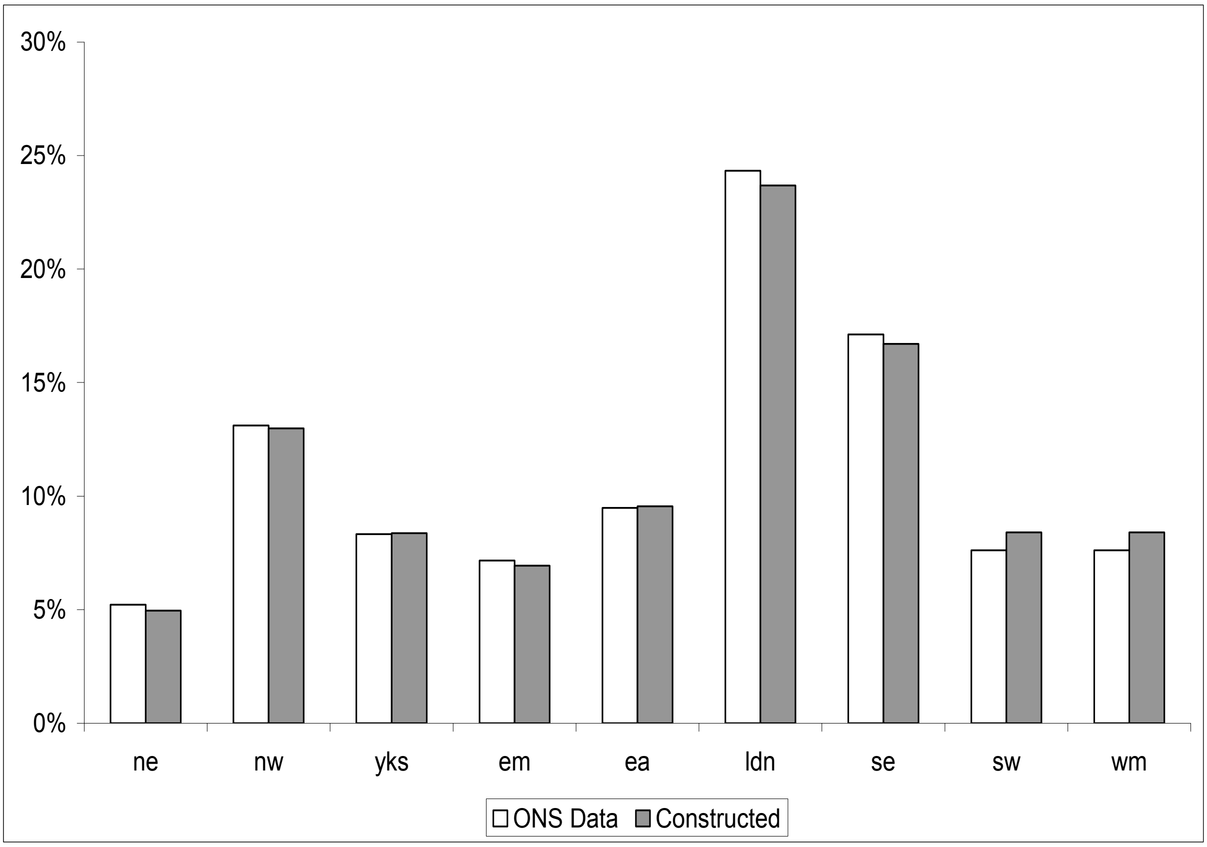
Figure 30: (Constructed) Regional investment series



Whilst unemployment data is available on a monthly basis for the regions as far back as the early 1970s, employment rates and levels are only available since the early 1990s. Wage data is not available for the regions for the time period under review, again only from the early 1990s onwards.

In short the available data is extremely limited and this limits the level and type of analysis that can be conducted in the pursuit of knowledge of regional dynamics. This is not auspicious for anyone wishing to analyse macro dynamics of the UK regions since for dynamic analysis and in particular analysis of impulse responses from VAR estimations one would prefer to have quarterly if not monthly data.

Figure 31: Comparison constructed investment shares vs ONS data (year 2000 comparison)



However, published studies that have focused on the UK regional macro dynamics including those of that of Fielding and Shields (2001) and Barrios et al (2002), Funke and Hall (1998) have encountered this issue and saw fit to be able to estimate VAR type models and investigate dynamics using annual data. A dichotomous choice is faced: use the data or do not conduct the research. Obviously the choice has been the same of previous researchers and conduct the research with the caveat that it is not ideal.

4 Research Review

Having provided a thorough review of the economies of the British regions and subsequently a broad discussion of the data constraints to be faced when researching the economies of the regions in part I, this chapter introduces part II of the thesis. It provides a review of four separate sets of literature to provide the context for the research presented in chapters 5 and 6 which are themselves studies of the transmission of demand and monetary shocks respectively through the British regions. These four literature reviews are as follows: the general SVAR literature; the literature on the use of VARs in monetary policy analysis; a review of the literature on the regional transmission mechanism; and the literature on the study of the UK regional economies. These four aspects of literature are required for the research presented in chapters 5 and 6 as no single aspect alone provides sufficient context due to the original nature of the work presented.

4.1 Structural VARs ('SVARs')

The SVAR field of research is vast and this section will not and cannot attempt to do justice to the whole panorama of work carried out under this umbrella (to give a flavour of the scale, there are over 150 citations for Jordi Gali's 1999 paper '"Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations" from the last five years alone as registered by the IDEAS website[8])

The method has been used to analyse the macroeconomic effects of aggregate supply and demand shocks (Estrella (1997), Funke (1997a,b,c), Rzigui (2007)); monetary shocks (Gail (1992), Ascari (2000), Klauson & Hayo (2002), Gomes et al (2007)); technology shocks (Gali (1999), Peersman & Straub (2004)); fiscal shocks (van Aarle et al (2003), Dungey & Fry (2007)); and exchange rate shocks (Enders & Lee (1997), Kano (2003)). What this chapter will therefore do is provide a brief overview of the breadth of the field, walk through some of the more significant contributions (and identification schemes) to the agenda, highlight some of the key works of relevance to the research presented in chapter 5 and discuss briefly criticisms of the methodology. To do this, a short technical introduction to VARs and SVARs is provided.

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[8] www.ideas.repec.org : In its own words: "The IDEAS website is the largest bibliographic database dedicated to Economics and available freely on the Internet. Over 550'000 items of research can be browsed or searched, and over 450'000 can be downloaded in full text. The site is part of a large volunteer effort to enhance the free dissemination of research in Economics."

4.1.1 SVARs a short technical introduction

The vector autoregression (VAR) methodology championed originally by Sims (1980) is a commonly used method of analysis in time series, often for forecasting but more commonly for analysing the dynamic effects of 'shocks' or disturbances to the variables in the system via a method of impulse response analysis. Every variable is treated as endogenous to the system and dependent on all other variables and lags of itself and all other variables.

Thus in its base form the VAR is an atheoretical approach to macroeconomic modeling doing away with the need for 'structural' modeling - although this can and is more often that not reintroduced with structural identification of various shocks. Their simplicity and their ease of use makes them a popular tool and has led them becoming a benchmark tool in mainstream macroeconomic analysis.

The simplest form of the VAR features two variables and one lag:

$$y_{1t} = a_{11}y_{1,t-1} + a_{12}y_{2,t-1} + e_{1t} \qquad (2)$$

$$y_{2t} = a_{21}y_{1,t-1} + a_{22}y_{2,t-1} + e_{2t} \qquad (3)$$

This can be easily written in vector form:

$$Y_t = AY_{t-1} + e_t \qquad (4)$$

VARs express variables as functions of what happened yesterday and today's shocks, but what happened yesterday depended on yesterday's shocks and what happened the day before. Therefore an alternative presentation is the Vector Moving Average Form ('VMA'):

$$Y_t = e_t + AY_{t-1} = e_t + A(e_{t-1} + AY_{t-2}) = e_t + Ae_{t-1} + A^2(e_{t-2} + AY_{t-3}) \qquad (5)$$

Or

$$Y_t = e_t + Ae_{t-1} + A^2 e_{t-2} + A^3 e_{t-3} + .. + A^t e_0 \qquad (6)$$

Equation 4 above is the reduced form of the model where the components of Y_t are dependent only on past values of themselves and the 'shocks' which when estimated are merely econometric residuals. A theoretical or 'structural' representation of this model is required which allows for contemporaneous relationships between the variables and includes 'structural' , ε_t, shocks:

$$y_{1t} = a_{12}y_{2t} + b_{11}y_{1,t-1} + b_{12}y_{2,t-1} + c_{11}\epsilon_{1t} \qquad (7)$$

$$y_{2t} = a_{21}y_{1t} + b_{21}y_{1,t-1} + b_{22}y_{2,t-1} + c_{22}\epsilon_{2t} \qquad (8)$$

Which again can be represented in matrix form:

$$AY_t = BY_{t-1} + C\epsilon_t \qquad (9)$$

Where clearly

$$A = \begin{pmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{pmatrix} \qquad (10)$$

Now the estimated reduced form model can be represented by:

$$Y_t = DY_{t-1} + e_t \qquad (11)$$

Where

$$D = A^{-1}B \ and \ e_t = A^{-1}C\epsilon_t$$

There are $3n^2 + \frac{n(n+1)}{2}$ free parameters in this model. However, estimation of the reduced form via OLS only gives information on $n^2 + \frac{n(n+1)}{2}$ parameters. Restrictions need to be made a priori to identify the model. The traditional methodology is via the Choleski matrix ie setting the A matrix to be upper or lower zero triangular.

An alternative to the above method is to identify the model by making restrictions on the long run of the effects on the endogenous variables by the structural shocks. Popularised by Blanchard & Quah (1989), the technique is a variation of the Beveridge and Nelson (1981) decomposition of output into its temporary and permanent components. Commonly shocks to output (and other variables) are attributed to supply and demand factors where demand (in line with classical theory) has no long run effect on output. Clearly then, for the identification to be valid all series need to be in stationary form. In their work Blanchard & Quah do not associate the structural variables ε_{xt} , ε_{zt}, as direct structural shocks to the endogenous variable series but as themselves exogenous variables. They are assumed to be uncorrelated with each other and of unit variance (a normalisation of convenience). Although, these structural variables are unobserved they are related to the regression residuals by the linear relationship:

$$\begin{bmatrix} e_{xt} \\ e_{zt} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_{xt} \\ \varepsilon_{zt} \end{bmatrix} \qquad (12)$$

$$\boldsymbol{e_t = C\varepsilon_t} \qquad (13)$$

Remembering, the reduced (estimated) VAR has the form:

$$y_t = D(L)y_{t-1} + e_t \qquad (11)$$

or:

$$(1\text{-}D(L)L)y_t = e_t \qquad (14)$$

The long run methodology is easiest explained with reference to the moving average representation of the VAR model. Given the variables are stationary there exists the moving average form:

$$y_t = S(L)e_t \qquad (15)$$

$$y_t = S(L)C\varepsilon_t \qquad (16)$$

where $S(L)$ is $(1\text{-}D(L)L)^{-1}$ and S the n by n matrix relating the residuals to the structural exogenous shocks. Stability clearly requires $(1\text{-}D(L)L)$ to be invertible. $(1\text{-}D(L)L)^{-1}$ is provided by estimation of the reduced form. Identification requires $(n^2 - 2)/2$ restrictions. Given normalisation conditions, this is done by assuming no long run effect of demand shocks on output or more explicitly by assuming a value of zero in the S matrix corresponding to the impact on output by whichever structural series ε_{xt} or ε_{zt} has been assumed to represent demand shocks.

4.1.2 SVARs, a literature review

The use of SVARs was catalysed by the work of Sims (1980) who criticised the (then) prevailing macroeconometric approach saying that the sheer scale of the models then in use imposed 'incredible' identifying restrictions. Initially at least Sims proposed a simple recursive identification methodology using a Choleski matrix. By the mid eighties concurrently Bernanke (1986), Blanchard & Watston (1986) and Sims (1986) proposed utilising contemporaneous restrictions on the variables implied by economically plausible theory.

In his 1986 work Sims estimated a six variable VAR of (logs of) real GNP, y, real fixed business investment, i, the GNP deflator, P, money supply as measured by M1, m, unemployment, u, and the treasury bill rate, r. He first identified the model using his traditional Choleski identification and reported that certain of the impulse response functions had unreasonable interpretations. For instance, a shock to the money supply shock had little effect on prices, output, or the interest rate. He therefore suggested a set of contemporaneous restrictions based on simple money supply and money demand functions:

$$M_s : r = f\{m_t(+), \varepsilon_{rt}\}$$

$$M_d : m_t = f\{y_t(+), p_t(+), r_t(-), \varepsilon_{mt}\}$$

(17,18)

Together with an assumption that investment innovations were autonomous and a block recursive Choleski ordering for the other variables he restricted the contemporaneous D matrix accordingly:

$$\begin{pmatrix} 1 & d_{11} & 0 & 0 & 0 & 0 \\ d_{21} & 1 & d_{23} & d_{24} & 0 & 0 \\ d_{31} & 0 & 1 & 0 & 0 & d_{36} \\ d_{41} & 0 & d_{43} & 1 & 0 & d_{46} \\ d_{51} & 0 & d_{53} & 1 & 1 & d_{56} \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} r_t \\ m_t \\ y_t \\ p_t \\ u_t \\ i_t \end{pmatrix} = \begin{pmatrix} \varepsilon_{rt} \\ \varepsilon_{mt} \\ \varepsilon_{yt} \\ \varepsilon_{pt} \\ \varepsilon_{ut} \\ \varepsilon_{it} \end{pmatrix} \qquad (19)$$

Where the left hand side of the model is the contemporaneous D matrix and the right hand side are the time t vector of structural shocks, ε_{rt}, ε_{mt}, ε_{yt}, ε_{pt}, ε_{ut}, ε_{it}, respectively to the interest rate, money, output, prices, unemployment and investment.

Similar identifications schemes such as Blanchard (1989) and Funke (1997a) attempt to replicate a 'Keynesian' style model. Funke used the following identification (recalling first from equation 9 that the structural model is represented by):

$$Ay_t = B(L)y_{t-1} + C\varepsilon_t \qquad (9)$$

Where y_t is the vector of endogenous variables, ε_t , a vector white noise error term interpreted as shocks to the structural equations where $E(\varepsilon_t)=[0]$, $E(\varepsilon_t\varepsilon_t') = \sum$ *and* $det(\sum) \neq 0$.

The reduced form is:

$y_t = D(L)y_{t-1} + e_t$ (11)

where $D(L) = A^{-1}B(L)$ and $e_t = A^{-1}C\varepsilon_t$,and the structural shocks are then related to the residuals by $A\, e_t = C\varepsilon_t$)

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & a_{42} & a_{43} & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{pmatrix} \begin{pmatrix} e_y \\ e_u \\ e_p \\ e_w \\ e_m \end{pmatrix} = \begin{pmatrix} c_{11} & 0 & 0 & 0 & 0 \\ 0 & c_{22} & 0 & 0 & 0 \\ 0 & c_{32} & c_{33} & 0 & 0 \\ 0 & c_{42} & 0 & c_{44} & 0 \\ 0 & 0 & 0 & 0 & c_{55} \end{pmatrix} \begin{pmatrix} \varepsilon_y \\ \varepsilon_u \\ \varepsilon_p \\ \varepsilon_w \\ \varepsilon_m \end{pmatrix} \qquad (20)$$

These equations he states mimic the flavour of a traditional Keynesian model. Real GDP innovations are driven by demand disturbances with the same period due to nominal rigidities; unemployment is determined by an Okun's relationship, innovations in unemployment for given output are attributed to supply shocks to reflect productivity changes. Prices are determined by their own innovation plus the supply shock. Wages are determined by a Phillips relationship in which wages depend on prices, unemployment, the supply shock and also its own shock and then money is allowed to respond to shocks or innovations in all other variables. Funke estimates the model and the coefficients in the contemporaneous matrices by the method of numerical scoring and reports impulse responses consistent with the stylised facts of theory.

This iteration of the SVAR method therefore imposes additional 'theoretical" restrictions upon a set of a priori assumptions about the ordering and contemporaneous effects of the variables. The justification for this second set of restrictions is made by reference to theories that in the words of Cooley & Dwyer (1998) ‘imply them but which as are not fully articulated in the sense that they do not operate at the level of preferences, technologies and explicit equilibrium concepts’. These types of restrictions have also been criticised as being empirically misleading by Canova (1995), Mellander et al. (1992) and Faust and Leeper (1997) and others (and this issue is returned to momentarily).

A further stage of iteration (or evolution) of the SVAR model was the development by the likes of Blanchard and Quah (1989), King et al (1991) and Shapiro and Watson (1988) of the incorporation of restrictions based on long run neutrality properties of the effects of certain shocks on the variables – ie Blanchard and Quah identifying a demand shock as having no permanent long run effect on output, this latter work in particular leading to the popular use of these restrictions.

This is the SVAR model of direct interest to this thesis. This was the model applied by Funke and Hall (1996) in their study of the UK regions and in chapter 5 the study is replicated but importantly differentiates the estimates by the use of regional price series. The model of Covers et al (2006) is also applied which is a class of model that mixes both short run restrictions described previously and long run restrictions à la Blanchard Quah. Mixing short and long run restrictions in this manner was popularised by Gali (1992). The Blanchard Quah ('BQ') restriction is first discussed in detail and the restrictions of Gali and Covers et al are then discussed.

Recalling the reduced form of the VAR model:

$$y_t = D(L)y_{t-1} + e_t \qquad (11)$$

Where now the regression residuals are related to the underlying shocks simply as $e_t = C\varepsilon_t$. Rearranging equation 11 gives:

$$(1\text{-}D(L)L)y_t = e_t \qquad (14)$$

And given that both variables are stationary the model can be represented in bivariate moving average form:

$$y_t = S(L)e_t \qquad (15)$$

$$y_t = S(L)C\varepsilon_t \qquad (16)$$

Depending on the ordering of the shocks the restriction that a demand side shock has no permanent effect on output requires that the value of the matrix term $S(L)$ or $(1\text{-}D(L)L)^{-1}$ corresponding to the (designated) demand shock on ouput to be zero. Together with the assumption of orthonormal shocks and a convenient normalisation of unit variance makes the variance/covariance matrix of the structural shocks to be the identity matrix, this fully identifies the system.

In their estimations Blanchard and Quah use the first difference of the log of real GNP and the level of unemployment. However, they note that unemployment appears to follow a trend over time and that there is also a slowdown in real growth rates during the 70s. They therefore take an ‘eclectic’ approach in that they estimate four VARs: a base case which includes a time trend for unemployment and a dummy for a structural break in output; no change in the growth rate of output but retaining the time trend in unemployment; a change in the growth rate but no time trend; and finally no trend and no break.

They report that the results are pretty similar across all four cases and their ‘stylised facts’ (from the impulse responses) to be that the time paths of demand side disturbances on both variables are ‘hump shaped’ and mirror images of each other, peaking after four quarters and then returning to original levels. Supply side disturbances have permanent effects on output and a small positive supply shock initially increases unemployment before it reduces to below its long run level after around four quarters remaining so for nearly five years.

Blanchard and Quah then move on to an analysis of the forecast error variance decomposition. They report that demand shocks account for almost all output variance in the short run (98% at a four quarter horizon) and that this decreases rapidly at the long run horizon (necessarily given the restrictions imposed on the model, supply shock contribution will asymptotically tend to 100%). They suggest it is difficult to attribute accurately in the short to medium term horizon as for this particular analysis there is some variance reported across the four sets of restrictions. Demand shocks only account for just over 50% of variance in unemployment at the short run but this increases significantly (to circa 85%) at the long run (40 quarter) period horizon.

This perspective is supported by estimates from others such as in the work of Funke (whose manner of identification was detailed in depth earlier and where demand shocks are identified as those to the output equation), Karras (1996) and Jordan and Lenz (1994). It is contradicted however, by the work of Gali (1992) who suggests supply shocks account for the majority of variance of output at all horizons. This work is of interest not just for its contrary perspective but also for the fact that it also popularises a further iteration of the SVAR identification schemes; namely that of a mixture of short and long run restrictions.   Gali (1992) constructs an empirical model (with associated identifications) to reflect a typical ISLM textbook macro model of the economy:

$$y_t = \alpha + \varepsilon_{s,t} - \sigma(i_t - E_t \Delta p_{t+1}) + \varepsilon_{is,t}$$
$$IS equation$$

$$m_t - p_t = \phi y_t - \lambda i_t + \varepsilon_{md,t}$$
$$LM equation$$

(21,22,23,24))

$$\Delta m_t = \varepsilon_{ms,t}$$
$$money \sup ply$$

$$\Delta p_t = \Delta p_{t-1} + \beta(y_t - \varepsilon_{s,t})$$
$$aggregate \sup ply$$

He allows his model to be subject to four exogenous shocks: supply, money supply, money demand and IS shocks; and thus decomposes demand into three composite shocks. His mix of short run and long run restrictions are as follows:

<u>Short run</u>

- No contemporaneous effect of money supply shocks on output
- No contemporaneous effect of money demand shocks on output
- Contemporaneous prices do not enter the money supply rule
- Contemporaneous output does not enter the money supply rule
- (contemporaneous) homogeneity in money demand

<u>Long run</u>

- No long run effects of money supply, money demand and IS shocks on output

(in fact with the normalisation of the covariance/variance matrix only three of the five short run restrictions are required to just identify the model). These restrictions are imposed through a combination of both of the two methods that have just previously been outlined. Subsequent to co-integration analysis he estimates a four variable model with two alternative schemes with a covariance stationary vector of variables being either $z \equiv [\Delta y, \Delta i, i - \Delta p, \Delta m - \Delta p]^{'} or [\Delta y, i, \Delta p \Delta m]^{'}$. He suggests qualitative results were identical. The dynamic responses reported are as predicated and stylised by the model. What is of significance is twofold: the first that it popularised the method of combining both long run and short run restrictions and the second that it suggested that supply shocks account for the majority of variance in output at business cycle frequencies in line with an RBC view of the world.

Covers et al (2006) apply this method of mixing both short run and long term shocks to modify Blanchard and Quah's original AS/AD model. They do so motivated by the belief that it is erroneous to assume zero correlation between the structural demand and supply shocks. They provide two main motives for co-movement in AS and AD. Firstly with causality from supply to demand they suggest citing the permanent income hypothesis as justification that a movement in aggregate supply will cause an increase in aggregate demand due to the increase in lifetime wealth. In addition they also propose that a monetary authority interested in price stability will attempt to increase demand to counter the downward movement in prices brought about by a supply shock. Secondly with causality running from demand to supply they cite that Keynesian assumptions of real rigidity will imply that some producers will merely increase output in response to a supply shock. They emphasise the point that in their model the BQ zero cumulative effect assumption in their model applies to a purely independent demand shock – a distinction which will become clear soon.

Covers et al's proposal is to impose a structural Lucas model over the BQ framework. Their simple Lucas ASAD model with prices and output in logs and [ε_t] representing a supply and [η_t] a demand shock:

$y^s_t = E_{t-1}y_t + \alpha(p_t - E_{t-1}p_t) + \varepsilon_t$ (25)

supply

$(y_t + p_t)^d = E_{t-1}(y_t + p_t)^d + \eta_t$ (26)

demand

$y^s_t = y^d_t$ (27)

equilibrium

can be solved for output and prices (see Appendix 2) and can be represented in matrix form as:

$$\begin{bmatrix} y_t \\ p_t \end{bmatrix} = \begin{bmatrix} E_{t-1}y_t \\ E_{t-1}p_t \end{bmatrix} + \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} \varepsilon_t \\ \eta_t \end{bmatrix} \qquad (28)$$

Assuming that the $E_{t-1}p_t$ and $E_{t-1}y_t$ are linear combination of their past values it can be seen that the bivariate moving average model implies the following relationship between the innovations and the structural shocks:

$$\begin{bmatrix} e_{yt} \\ e_{pt} \end{bmatrix} = \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} \varepsilon_t \\ \eta_t \end{bmatrix} \qquad (29)$$

And therefore the relationship between the variance/covariance matrix of the residuals of the estimated VAR and the variance/covariance matrix of the structural shocks becomes:

$$\begin{bmatrix} \text{var}(e_y) & \text{cov}(e_{yp}) \\ \text{cov}(e_y e_p) & \text{var}(e_p) \end{bmatrix} = \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} \sigma_\varepsilon^2 & \sigma_{\varepsilon\eta} \\ \sigma_{\varepsilon\eta} & \sigma_\eta^2 \end{bmatrix} \begin{bmatrix} \frac{1}{1+\alpha} & \frac{-1}{1+\alpha} \\ \frac{\alpha}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \qquad (30)$$

Given that this implies the following restrictions amongst the elements of the contemporaneous C matrix (equation 25): $c_{11}=\alpha\, c_{12}$, $c_{11}= -c_{21}$ and $c_{11}= c_{22}$ and that α, the short run slope of aggregate supply, can also be estimated.

The Blanchard Quah long run restriction implies (where the d_{nn} coefficients represent elements of D matrix of reduced form estimated VAR):

$$\alpha = \frac{-d_{12}(1)}{[1 - d_{22}(1)]} \qquad (31)$$

Given these additional restrictions the BQ restriction of zero correlation between supply and demand shocks can be dropped. The clever intuition of Covers et al is to realise that, given the shocks are now correlated, in order to conduct impulse response and variance decomposition analysis the demand and supply shocks must first be deconstructed into their pure and induced components and hence re-orthogonalise the shocks.

This is done in two alternative 'orderings'. The first to assume that causality runs from supply to demand which can be illustrated by the representation that unexpected aggregate demand is composed of a pure aggregate demand shock,

v_t, plus a movement that is induced by the supply shock, ε_t , (where ρ is the size of the induced effect or the correlation of the shocks).

$$\eta_t = \rho\varepsilon_t + v_t \qquad (32)$$

Similarly, causality from demand to supply implies the supply shock is broken down into a pure supply shock, δ_t, and induced shock (ie movement) (with gamma representing the correlation) by the demand shock, η_t :

$$\varepsilon_t = \gamma\eta_t + \delta_t \qquad (33)$$

Given these structural representations the variance/covariance matrix of the residuals can now be represented by either:

$$\begin{bmatrix} \text{var}(e_y) & \text{cov}(e_y e_p) \\ \text{cov}(e_y e_p) & \text{var}(e_p) \end{bmatrix} = \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \rho & 1 \end{bmatrix} \begin{bmatrix} \sigma_\varepsilon^2 & 0 \\ 0 & \sigma_v^2 \end{bmatrix} \begin{bmatrix} 1 & \rho \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \frac{1}{1+\alpha} & \frac{-1}{1+\alpha} \\ \frac{\alpha}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \quad (34)$$

or

$$\begin{bmatrix} \text{var}(e_y) & \text{cov}(e_y e_p) \\ \text{cov}(e_y e_p) & \text{var}(e_p) \end{bmatrix} = \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} 1 & \gamma \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \sigma_\delta^2 & 0 \\ 0 & \sigma_\eta^2 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \gamma & 1 \end{bmatrix} \begin{bmatrix} \frac{1}{1+\alpha} & \frac{-1}{1+\alpha} \\ \frac{\alpha}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \quad (35)$$

these imply that:

$$\begin{bmatrix} \frac{1+\alpha\rho}{1+\alpha}\sigma_\varepsilon & \frac{\alpha}{1+\alpha}\sigma_v \\ \frac{1(1-\rho)}{1+\alpha}\sigma_\varepsilon & \frac{1}{1+\alpha}\sigma_v \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \qquad (36)$$

And

$$\begin{bmatrix} \frac{1}{1+\alpha}\sigma_\delta & \frac{\gamma+\alpha}{1+\alpha}\sigma_\eta \\ \frac{-1}{1+\alpha}\sigma_\delta & \frac{\gamma-1}{1+\alpha}\sigma_\eta \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \qquad (37)$$

In the former all of the common movement is attributed to the supply shock which can be seen to be identical to the standard BQ model. Therefore it is of little relevance for comparative analysis. Covers et al illustrate that, in addition being able to make a point estimate for the supply curve, that this second causality demand to supply has a significant effect on both the impact effect and variance decompositions of the structural shocks. Importantly demand shocks now induce a smaller instantaneous movement in inflation and a larger movement in output (given the co-movement caused by the induced supply shock) and demand shocks account for over 80% in the long run horizon variation in output. This identification scheme is utilised together with the standard Blanchard Quah identification in chapter 5 where heterogeneities in short run and long run movements of the regions due to structural shocks are studied.

The methodology of 'structural' identification of VAR models is not immune to criticism. A general criticism is that the empirical models bear little relation to the theoretical models that are then used to interpret the results. Numerous papers during the 1990s, Faust and Leeper (1997), Cooley and Dwyer (1998) and others, raised more technical doubts about the methodology. The key criticism outlined by Faust and Leeper was that the finite order VAR is a poor representation of the data generating process (clearly the shorter the lag length of the model the poorer the representation). This is a critical point given that the identification methodology itself imposes a long run restriction (precisely at the horizon of most weakness) by construction. Therefore the model will be imprecisely estimated and this imprecision transferred to reported impulse responses and forecast error variance decompositions. The shorthand method to overcome this weakness, they suggest, is the imposition of further, over-identifying restrictions.

Secondly it is suggested that the shocks themselves (Faust and Leeper used as a benchmark for discussion the Blanchard Quah model) are aggregates of a multitude of shocks and that it is therefore theoretically unsound to suggest an interpretation of there being solely two (for example demand shocks would incorporate at the very least money demand and IS shocks as in the Gali (1992) model). This aggregation issue also undermines the assumption that there is zero correlation (or in the words of Faust and Leeper 'co-mingling') between the shocks which would invalidate any inferences at long run horizons which is the precisely the period the scheme relies upon for identification. They also illustrate that an aggregation problem also exists across the time dimension

A more recent criticism is the potential inability of a VAR to recover the structural relationship produced by a DSGE model and this has been highlighted by Giordani (2004), Chari et. al. (2005) and Benati and Suraco (2008), amongst others. It again is based on the ability of the VAR to represent the underlying DGP. The reasoning outlined by Canova (2006) is that dynamic stochastic general equilibrium models, when log-linearised around the deterministic (or stochastic) steady state, produce a VARMA DGP, where the MA component may have, at least, one large root. When a sample is short, a finite order VAR will not be able to capture the true dynamics of the structural model. In some extreme cases, and even when data is abundant, a VAR representation may not exist. However, Canova concludes ‘its empirical relevance still needs to be proved’.

4.2 Research Review: The Use of VARs in Monetary Policy Analysis

The application of VARs to monetary policy analysis is now, and has been for some, a standard technique. In its stripped down form the methodology involves estimation of a VAR which includes a monetary policy variable alongside various endogenous macroeconomic variables and to analyse the impulse responses of the endogenous variables to a monetary shock.

It is often serves as a benchmark for comparing the results of calibrated small scale (monetary) dynamic general equilibrium models where researchers have their model economy and compare the simulated responses of their derived structural models to 'stylised facts' ascertained by econometrically estimated VARs. These 'stylised facts' were best outlined in a series of papers in the 1990s by Christiano, Eichenbaum and Evans (1999). In this work they suggested that plausible models of the monetary transmission mechanism should be consistent with the following responses to a monetary shock: (i) the aggregate price level initially responds very little; (ii) interest rates initially rise, and (iii) aggregate output initially falls, with a j shaped response, with a long run zero effect of the monetary policy impulse.

Because they are extensively used in the research of chapter 6, this section discusses some of the more significant issues surrounding the methodology (and deliberately outlines problems) and then progresses to discuss the research literature specifically concerning heterogeneous regional responses to monetary policy (more often done than not by applying VARs) in the next section.

The key issues that are highlighted here are easiest to understand by a stepwise discussion of what the VAR attempts to represent. In itself the VAR is a simple econometric description of DGP of the economy. The economy itself theory suggests is a complex system of a myriad of supply, demand and equilibrium relationships. Even the most stripped down complete new Keynesian ('NK') structural model (for examples see Blanchard & Gali (2005), McCallum & Nelson (1999), Smets Wouters (2003) among others), includes at least three structural relationships: an aggregate supply curve (or NK Phillips Curve); aggregate demand (an Euler equation) and a monetary policy reaction function (a Taylor rule)[9]. The VAR therefore is an alternate representation of this economic system but it must include an identification strategy which identifies and thus represents the monetary policy reaction function if it is to be useful in analysis of monetary transmission.

The subject of analysis is the endogenous variables' reaction to an unanticipated shock to the monetary policy variable not to a change in the monetary policy variable itself. It would be a simple mistake to make from reading some of the voluminous research on the subject. This can be easily conceptualised if one properly appreciates that a monetary policy reaction function is a description of

[9] The NKPC is discussed in full in chapter seven. For a discussion of the small scale model approach see McCallum (1999) and a discussion of Taylor rules see Taylor (1999)

how a policy maker reacts to information available. The reactions of the endogenous variables to the policy maker's actions are already built into the system. It is the response to unanticipated changes in the policy variable ie structural monetary shocks that are measured by impulse response analysis – the systematic reaction is factored into the estimated coefficients in the VAR.

If there is an Achilles heel in this field of research it is that the two reactions, that to a change in the policy variable and a 'shock' to the policy variable, can sometimes seem to be treated and discussed as if they are the same thing. Notwithstanding, given the various simplifications and inherent assumptions the fact is that one may be able to proxy for the other, theoretically at least there is a distinction.

The potential flaws in these inherent assumptions form the basis of a major critique by Rudebusch (1998) of the use of VARs for monetary policy analysis. Whilst this work is often referred to as a major criticism of their use, it is the case that the main proponents of the use of VARs Christiano, Eichenbaum and Evans in their key paper (produced in several guises from 1996 onwards, the 1999 version referenced in this thesis) also specifically outline their use in the context of a critique, providing as they do a series of caveats and health warnings about their use.

One of the key issues that Rudebusch raises is that (as referred to above) the use of a VAR model necessitates a view on the policy maker's reaction function and that it is encapsulated somehow by the VAR estimation (in order for the model to represent an economic system). Given the necessity to impose restrictions on the estimated reduced system to identify the model (and thus reaction function) it is the manner of identification that is of concern. The standard technique is to identify the model through a Choleski decomposition. This necessitates a recursive assumption which is not innocuous given that it entails an assumption about not just the order in which the endogenous variables affect each other but also what information the policy maker is assumed to react to in forming decisions.

The standard methodology (Favero (2001)) is to assume the policy maker has and reacts to current information (ie time t information set) on all other variables in the system when setting the value of the policy instrument. This also necessitates an assumption that endogenous variables do not react contemporaneously to the monetary policy instrument. This is a pretty strong assumption especially when one tries to contextualise what this means with the situation in the real world. Posed as a question one needs to ask if in the real world, is it reasonable to assume that policy makers have up to date time t information at their fingertips when setting monetary policy? Macroeconomic data takes time to compile and first estimates are prone to significant revisions. On the other side of the coin, do actors (producers, buyers etc) in the economy not respond with immediate effect to changes in macroeconomic policy which are clearly visible as soon as actioned?

Nevertheless the standard assumption is a recursive ordering placing the monetary variable last. There are alternatives to the recursive assumption (notably Sims & Zha (1995), Leeper, Sims and Zha (1996)) which adopt the alternate assumptions but then the question is: it is reasonable to assume that policy makers don't attempt to ascertain current output and prices when setting values of their instrument? There is no easy answer.

An interesting question posed is what interpretation does a monetary policy shock actually have? Chari, Christiano and Eichenbaum (1997) outline the following suggestions: changes in policy makers' preferences; strategic considerations; and, the interpretation they give most significance, technical factors ie measurement errors because they lead to a violation of a key assumption of the recursive VAR methodology. Their analysis is set out below:

The monetary policy shock is identified as the disturbance term in an equation of the form:

$$P_t = f(_{-t}) + \sigma_p \varepsilon_t^s \qquad (38)$$

Where P_t is the policy instrument, $f(\,_{-t})$ the policy reaction function (or rule) based on an information set $_{-t}$, and $\sigma_p \varepsilon_t^s$ is the monetary policy shock where ε_t^s is normalised to unit variance so σ_p is the standard deviation of the policy shock.

Assume the policy maker sets the policy instrument P_t as an exact function of current and lagged observations of a macroeconomic variable set y_t. Denote time t observations on y_t and y_{t-1} as $y_t(0)$ and $y_{t-1}(1)$ respectively where:

$$y_t(0) = y_t + v_t, \quad \text{and} \quad y_{t-1}(1) = y_{t-1} + u_{t-1} \qquad (39,40)$$

So v_t represents the contemporaneous measurement error and u_{t-1} represents the measurement error from the perspective of period $t+1$. If the variables are measured perfectly with a one period delay then clearly $u_{t-1} \equiv 0$.

Now assume the policy makers set P_t by the rule:

$$P_t = \beta_0 P_{t-1} + \beta_1 y_t(0) + \beta_2 y_{t-1}(1) \qquad (41)$$

A not unreasonable rule, incorporating lagged values of the policy instrument and current and lagged values of the endogenous variables is a fairly standard Taylor rule type arrangement (see Taylor (1999)). If the policy rule is now expressed in terms of the correctly measured variables:

$$f(_{-t}) = \beta_0 P_{t-1} + \beta_1 y_t + \beta_2 y_{t-1}, \sigma_p \varepsilon_t^p = \beta_1 \nu_t + \beta_2 u_{t-1} \tag{42}$$

Thus illustrating how noise (or errors in measurement) can be interpreted as policy shocks. However, this interpretation comes with a major health warning. Under plausible assumptions this interpretation violates the very same recursive assumptions that are required to identify the monetary shock.

Perhaps this potential internal contradiction explains the robustness with which Rudebusch (1998) criticises the whole VAR approach of modeling monetary policy. He begins his abstract of his paper entitled ‘Do Measures of Monetary Policy in a VAR make sense?’ with the single word sentence: ‘No’. He attacks the methodology from several angles suggesting that there exists a body of literature which provide non-VAR structural estimates of the Federal Reserve reaction functions which have been completely ignored by monetary VAR modelers. His assertion is that the VAR funds rate equations as representation of a Federal Reserve Policy function bear no relation to those estimated by the literature. The other angle of attack is the interpretation of the recovered structural shocks from VAR estimations as monetary policy shocks. Comparing them to shocks to anticipated Federal Reserve policy (by constructing shocks from realised values of the policy variable to those anticipated by the futures market) he suggests they bear little relation to actual policy shocks.

Perhaps for this reason an alternative procedure has been suggested as measure of the dynamic response to monetary policy. Based on the recursive assumption, it follows a methodology outlined in Cover (1992). This is to first estimate the policy shocks by the fitted residuals in the OLS regression of P_t on the information set available at $_t$. The second step is to then estimate the dynamic response of a variable to the monetary policy shock by regressing the variable on the current and lagged values of the estimated policy shocks.

These criticisms though severe are not necessarily terminal according to others. Evans and Kuttner (1998) suggest reducing lag lengths and estimating models over more recent sub samples improve forecast accuracy and therefore we should not 'Throw the VAR out with the Bathwater'.

Notwithstanding these issues, the use and popularity of monetary VARs continues unabated as shall be seen in the next section which reviews some of the research of direct applied relevance to the research undertook in thesis. In more recent times researchers have sought to augment what is recognised to be a parsimonious dataset with the use of factor augmented models which seeks to include factor variables to better represent the full information set which the policy maker has to hand when setting policy instruments. Bernanke, Boivin and Elliasz (2005) amongst others have concluded that augmenting the dataset in this manner assists to identify the monetary policy transmission mechanism.

4.3 Research Review: Regional Monetary Transmission

As just outlined, despite issues and criticisms, the use of VARs in monetary policy analysis is now a fairly standard technique. In its stripped down form the methodology involves estimation of a VAR which includes a monetary policy variable alongside various endogenous macroeconomic variables and to analyse the impulse responses of the endogenous variables to a monetary shock.

This section discusses the relevant research pertaining specifically to the heterogeneous responses of the regions to a monetary policy shock. As outlined in the previous section a series of caveats regarding the methodology is outlined to reinforce the understanding, as ever, the limitations and issues when using these techniques. A last point that needs to be referred to before previous research on the issue is surveyed is the choice of monetary policy instrument. It has become fairly standard practice to utilise the interest rate as the monetary policy variable (eg Bernanke & Blinder (1992), Evans & Marshall (1998), Favero (2001)). This is consistent with the present practice of inflation targeting regimes across Europe, the UK and many other parts of the world and so is consistent with an interpretation of the equation in the VAR as being a representation of a Taylor type rule.

For periods preceding this however, central bank were not thought to actively manage monetary policy specifically utilising the interest rate in a manner consistent with a Taylor type rule. In recent times central bankers (Mervyn King (2000)) acknowledged their use as a guide to policy decisions). Other econometric practices (Bernanke & Mihov (1995)) involve identification of monetary policy rules and shocks through a mixture of rates and levels of reserves at the central bank or plain growth in money stock. However, empirical evidence of research of the mid 90s (Strongin (1995), Leeper, Sims, Zha (1996)) supports the practice of using Taylor type rules ex post as an empirical representation of monetary policy practice.

Finally, there is one further technical difficulty with interpreting shocks to the interest rate as a monetary policy shocks (Christiano, Eichenbaum, Evans ('CEE') (1999)). Generally, it is found that, counter-intuitively, the response of prices is to rise following a positive interest rate shock: a phenomenon referred to or known as the 'price puzzle'. The intuition is that if there is a variable omitted from the parsimonious VAR that acts as a leading indicator for inflation that the monetary policy maker reacts to then the VAR will be mis-specified if it is not included in the VAR. CEE (1999) show that typically a commodity price index usually solves the puzzle and for these reasons an oil price index is often included as a conditioning variable in interest rate response analysis (see Darby & Phillips (2007), Ganley & Salmon (1997)). These caveats presented the research is now reviewed below.

The studies on regional business cycles and regional monetary policy transmission have a tendency to emerge from countries such as the US, where there is a strong federal structure, or countries such as Spain (eg Barrios, de Lucio Fernández (2003)) where there is a strong regional culture (and the data to match) or inter state within the euro zone.

Little literature exists for the study of UK regional monetary transmission heterogeneities per se. Clearly data issues are strong (a point that has been recognised recently by the ONS (2007) although recognition of the issue is only a first step). There is a small tradition of analysis of supply and demand side shocks across the UK regions such as Funke and Hall (1998), Fielding and Shields (2001) (which forms part of the review of the next section and is a body of work which chapter 5 of this thesis builds upon. There is a less than a handful of works concerning UK monetary response heterogeneities.

The monetary policy transmission process can be defined as the process by which monetary policy decisions are transmitted into changes into economic growth and inflation. An interest rate change by the central bank can affect aggregate demand through a whole host of variables; the real cost of capital, the real exchange rate, income, wealth and credit effects. A short overview of the BoE's view of the monetary policy transmission process was presented in the introduction. The fact that there are various routes by which monetary policy can be transmitted through the economy gives rise to various manners in which the response of regional economies may differ if their economies also differ.

The main focus of research to date that has analysed heterogeneous responses of regions (both country level and continent level) to monetary policy shocks has looked to the supply side or more specifically industrial composition to account for heterogeneous responses to interest rate or monetary shocks. Studies concerning heterogeneities on the consumption side are not common and neither, until recently, have differential wealth effects (eg Case & Shiller (2005)) (through changing asset prices) been an area that has received much attention.

The three traditional routes investigated in the literature (Carlino & Defina, 1998) as to the causes of heterogeneous regional responses to monetary policy shocks are all based on the supply side of the economy:

1) an interest rate effect where the direct response (or elasticity of response) of firms of different types to higher interest rates will differ;

2) a credit effect where the differing ability across firms to borrow (due to size) is amplified (Gertler and Gilchrist (1994) demonstrate for US manufacturing firms that small firms respond more strongly to monetary tightening than larger firms)
; and

3) the exchange rate channel, where the response of exporting firms is different to domestic firms to a changed exchange rate.

The orthodox approach to consider the different interest rate sensitivities or 'elasticities' of industries is to compare the sensitivities of the regions against measures of sectoral diversity or typical share of various industries. To provide a measure of how credit constraints may vary across regions the share of small firms to proxy for a measure of credit constrained firms is used and the share of exports by value or volume is taken to provide a variable by which the exchange rate effect can be compared. In what is probably the most oft cited reference of recent years (and it is reasonable to say has become the bedrock upon which research on regional heterogeneous monetary response is now built), Carlino and Defina (1998), in a study of 48 states across the US, specifically explore the relationship between the maximum cumulative response to an monetary shock and industrial composition and business sizes.

This study by Carlino and Defina was based on a (structural[10]) interest rate VAR estimated from times series data from the period 1958 to 1992. This work itself built on research of the early 1990s (Bias (1992), Kashyap, Stein & Wilcox (1993)) and late 1980s on the variation in US state response to the monetary policy transmission mechanism. Their contribution was to analyse responses in a manner that allowed for feedback associated with the interrelationships between economies and also to attempt to systematically account for the

[10] In the Choleski decomposition sense.

variation in response of the states. The former point was addressed by re-aggregating blocks of regions into the major regions and include in the regression variables for individual state, block minus individual state and each other regional block. The latter by regressing the size of maximum cumulative response on four state level explanatory variables; size of state manufacturing industries, size of state manufacturing industries; and two measures of lending to small firms. They conclude that 'the size of a states response is significantly related to industry mix variables, providing evidence of an interest rate channel for monetary policy, although the state level data offer no support for recently advanced credit channel theories'.

It is the view of the author that a 'consensus' has emerged supporting the above view that industrial – or what will be referred to as 'sectoral' – effects are more likely to be the cause than 'spatial' effects. Indeed, studies revisiting the work of Carlino and Defina, Schunk (2005) go as far to suggest that the growing homogenisation of US state level industries and the declining variation in capital intensity of industries has led to a reduction in the differential impact of monetary policy since Carlino and Defina's work was first published. More recently published literature including Peersman and Smets (2002), Dedola and Lippi (2005) has built the case that sectoral effects dominate. Dedola and Lippi's analysis is based on the effects of monetary policy shocks on the industrial activity of 21 manufacturing sectors in five OECD countries including the UK. They estimate 101 VARs for each country and industry pair. Having 101 estimates for the impact of monetary policy shocks on activity they test the extent to which heterogeneity in these estimates can be explained by country and industry dummies. They report several highly significant industry dummies but are unable to reject the null that country specific effects are no different to zero. Hence they conclude there to be an 'absence of significant cross country differences in the transmission mechanism of monetary policy'.

Research from various sources tends to support this 'consensus'. Arnold and Vrugt (2002) estimate VAR models for the Netherlands for time series over 1973 to 1993 covering 11 Dutch regions and 12 sectors. They similarly conclude that the 'differential impact of monetary policy are related to the industrial composition, but not to firm size or bank size'. This paper is similar to the research presented in chapter 6 in that Arnold and Vrugt (2002) are also restricted to annual data series given similar data availability issues and similarly are constrained in their analysis by issues of losing degrees of freedom. Hayo and Uhlenbrock (1999) also publish research supporting the 'sectoral' view concluding, from a similar avenue of work on the impulse responses estimated for VARs of manufacturing and mining industries of the Länder, that 'they (the German Länder) are likely to be affected asymmetrically by monetary shocks since there are large differences in the respective 'regional industry portfolios''. Peersman and Smets's (2002) work reviews the interest rate effects on growth in output in eleven industries of seven euro area countries and again conclude there exists considerable cross industry heterogeneity and also conclude that 'this can be regarded as evidence for the conventional interest rate channel.'

For the UK a key work on sectoral sensitivities is that of Ganley and Salmon (1997) who estimated impulse responses of 24 industrial sectors' output (14 of which were sub sectors of manufacturing) to monetary policy shocks. Ganley and Salmon's work mirrors the line of investigation of others, in that it studies the response of industrial sectors to interest rate changes. Similar to Carlino and Defina they include aggregate variables in their regression with and without the relevant sector so as to interpret the individual responses under investigation as 'marginal'. They note certain stylised facts: that construction industries exhibit the largest and quickest response to an interest rate change, the manufacturing sector is similarly responsive but on a slightly lesser scale, certain industries such as mining and agriculture display an immediately positive response and for others such as utilities the responses can be characterised as ambivalent.

Their analysis illustrated a wide range of responses across the subset of 14 manufacturing sectors. They compared the maximum output response of each sector with two measures of industry characteristics: the average firm size and a measure of industry concentration. Using the Spearman rank correlation coefficient they concluded that 'there appears to be some link between industry size measures and the output responses'. From the fact that some of the industries exhibiting the largest responses have the smallest firm size they suggest that it may be the case that credit market imperfection 'may' play a role in the monetary transmission process.

The work of Darby and Phillips (2007) employs an extremely similar methodology both to Ganley and Salmon (1997) and is comparable also to the work Carlino and Defina (1998)[11]. In this work untypically an attempt is make to draw out statistically significant differences between impulse responses of different individual sectors. Darby and Phillips estimate VARs for sectors of the UK and Scotland using quarterly data that is available for the Scottish economy (but not for the English regions) since 1994. Similar to previous methods they estimate the marginal response of individual sectors – ie they include a variable for aggregate output less the sector under review. Whilst this is the only such analysis that has been conducted for a British region to date a criticism would be that this is somewhat superfluous as the reason for inclusion of the aggregate variable is to ascertain the marginal response of the sector in question vis a vis the whole economy and doing it in this manner assumes no interdependency between the rest of the UK economy and Scotland. This may seem pedantic but given this is the only work reviewed that infers statistically different responses then it seems reasonable to highlight this fact.

[11] There is a slight difference between the methodologies employed by the UK researchers and that of Carlino and Defina. Given the fact that the key output variable is non-stationary Carlino and Defina, as do many others (Arnold & Vrugt, 2004) choose to estimate their VARs in differences with inflation as a variable. Both the UK works mentioned here decide to estimate the model in log levels given co-integration tests suggesting the prescence of co-integration between the price level and output (but not the interest rate clearly). The technical literature is a little divided on the appropriate methodology to employ. If one estimates effectively a VECM model (applying the cointegration methodology) then this does restrict the models short run and hence dynamics (Favero 2001). For that reason if the object of interest is merely the short term dynamics a VAR in level is employed. The alternative is to induce stationarity (similar to SVAR methodology of Blanchard and Quah) by first differencing as is the route taken by Carlino and Defina.

A key conclusion of their work is that the Scottish economy is more sensitive to monetary policy tightening given the share of more highly interest rate sensitive sectors in Scotland is higher than for the UK economy as a whole: for the UK as a whole sectors accounting for some 52.6% of GVA were seen to have a maximum response significantly different from zero (at the ten percent level) with the corresponding share for the Scottish economy being some 73.4%.

Thus far the research reviewed has suggested that heterogeneities of industrial responses due to the direct interest rate channel have been caused by a ‘compositional effect’. That is regional economies responses differ due to their differing sectoral composition and not that the same industries in different regions react differently. The suggestion that the Scottish economy has a higher proportion of highly interest rate sensitive industries is in line with this thinking. Darby and Phillips also conclude spatial effects to be present. Based on an analysis of individual impulses responses and associated standard error bands, they report those certain (same) industries’ responses to be statistically significantly different across the UK and Scotland. They report that for financial services, Government services and electrical engineering maximum Scottish impulse responses lay outside the confidence intervals of the UK’s impulse response. They also report that certain sectors exhibit a significant response (ie statistically different from zero at the maximum response) for the UK but not Scotland: agriculture, mining and quarrying, printing and publishing, mechanical engineering and construction; and for certain industries a statistically significant response was reported for Scotland but not the UK: petroleum, chemicals, electricity and gas, and retail. From this evidence they conclude that spatial effects in addition to sectoral or compositional effects have a part to play in heterogeneous regional monetary transmission for the UK.

A further cause of heterogeneity that has been cited in the literature is the dampening effect of the exchange rate dynamics of an interest rate tightening. Darby and Phillips point to this mechanism to explain positive responses of certain sectors to monetary tightening. The view from the research literature on whether the exchange rate effect is positive or negative is not definitive. Some conclude (Ber, Blass, Yosha (2002)) that the more export intensive are firms the less they are affected by tight money, although other researchers (Hayo and Uhlenbrock (2004)) report evidence of the contrary view with justification being that exchange rate effects exacerbate the effects of monetary tightening through increased export price via an appreciating currency. It is fair also to highlight the fact that neither Peersman & Smets or Dedola & Lippi were able to find any significant evidence that 'openness' to be a factor in explaining heterogeneities in responses.

The published work above concentrates mainly on accounting for heterogeneous responses of the regions of various countries by recourse to the producer side of the economy (and in the case of Ganley and Simon is solely a comparison of sectoral responses). However, there is separate strand of work (Frantantoni &

Schuh (2003), Owyang & Wall (2006)) that seeks to account for such heterogeneities by recourse to the consumption side of the economy, specifically looking at the housing market and its potential role in accounting for differing responses of demand to interest rate changes. This could be an interesting line of research, especially given the present day macroeconomic climate; although the present orthodox opinion is that house or 'asset' values are not reliable determinants of demand (Aoki et al (2005)). Again however the constraint of data is present and that whilst housing data may be available on a quarterly basis, its potential is negated by the lack of other quarterly reported aggregates.

4.4 Research Review: the UK Regions

Remarkably little has changed since David Bell (1993) flatly asserted that regional econometric modeling to be underdeveloped in the UK in comparison to the other major industrialised countries. The data issues that were extensively discussed in chapter 3 impose quite severe constraints on the regional econometrician: the availability of only annual time series data for the main macroeconomic aggregates; the total lack of data on interregional trade; and the lack of regional price series. Despite the UK government's recent (in relative terms) acknowledgement of the issue (Allsopp Review (2004) and promises of change (Brown (2003)) and in spite of the renewed policy priority of the regions under the present (post 1997) government (Balls (2002), HMT (2003)), the unavailability of quality macroeconomic data remains a major problem area. Fundamentally for this reason research concerning the macroeconomics of the UK regions is remarkably thing on the ground.

That is not to say there is a complete absence of research about the economies of the regions. In fact there is a burgeoning programme of research devoted to the 'enterprise' agenda (Cooke (2007), Cook, Clifton & Oleaga (2005), Jayne (2005), Webber, Martin, Plumridge (2007), Hart, McGuinness (2003)). The Labour Force Survey does provide a reasonably rich vein of data that can be utilised to answer research questions with a more microeconomic focus or concerning cross regional variation to earnings distribution, unemployment or employment (Duranton & Monastiriotis (2001), (Monastiriotis (2002), Bernard et al (2004), Anyadike-Danes (2004)). Indeed, perhaps because regional labour data is of a better quality, the study of regional variations in unemployment has the longest developed tradition (Schofield (1974)).

In addition the area of variations in regional fiscal spending has received a reasonable degree of attention. (Mackay, Williams (2005), McLean & McMillan (2003)). With political devolution in Scotland and Wales and failed moves towards English regional devolution, this subject and the issues of fairness of spending levels has become an area of some debate. Mackay (2001) shows that in addition to public spending being above tax revenues for seven of the UK regions, that levels of public expenditure in Northern Ireland, Scotland, the South East and London are above what would be expected given these regions' level of prosperity. The reasons provided by Mackay going beyond what would be expected by the level of fiscal transfers and stabilizers natural to the role of the central state.

This strand of research does not specifically relate to differences in regional macrodynamics which is the main object of interest of this thesis. The relevant areas of theoretical and applied research to the research issues explored in later chapters; namely demand and monetary shocks and short run inflation output dynamics; is of a more general and broader base and was reported on in previous chapters. We have covered the general research agenda on heterogeneous regional responses to monetary shocks which included the small numbers of work specifically concerning the UK regions: the work of Darby and Phillips (2007) and Ganley and Salmon (1997) (although strictly speaking this latter work is an investigation into differences of sectoral transmission of monetary policy). Both works suggest similar differences across sectors in sensitivity to interest rate shocks.   The work of Darby and Phillips is also not strictly speaking an investigation of the regions (plural) insofar as it was a study of the Scottish economy in comparison to the UK.   That said the conclusion was that given the share of interest rate sensitive sectors in Scotland is higher than for the UK as a whole they conclude that the Scottish economy is more sensitive to monetary policy tightening and also that spatial effects in addition to sectoral effects have a part to play in heterogeneous regional monetary transmission characteristics (at least between Scotland and the UK).

In a similar vein, but using a distinctively different approach is the work of Holmes (2000). Holmes' approach was to estimate asymmetries of regional responses to monetary shocks based on estimates from an output growth equation in the manner of Karras (1996), the methodology slightly more complicated in that he estimates the following output growth equation:

Output growth:

$$\Delta y_t^j = \beta + \sum_{i=1}^{n} \kappa_i \Delta y_{t-i}^j + \sum_{i=0}^{n} \theta_i \Delta o_{t-i} + \sum_{i=1}^{n} \xi_i^+ u_{t-i}^+ + \sum_{i=1}^{n} \xi_i^- u_{t-i}^- + v_t^j \qquad (43)$$

(where y is the natural log of output in region j, o the natural log of the real price of oil (to represent supply shocks) and u^+ and u^- positive and negative shocks to monetary policy (all other terms being estimated coefficients)). This approach being consistent with the thinking on using actual monetary policy shocks in estimation practices as suggested by Rudebusch (1998).

The monetary 'shocks' have been earlier estimated as the residuals from a monetary policy equation. Whilst Karras suggested using a monetary policy equation based on money supply aggregates, Holmes actually uses a model based on an assumed Taylor rule. However, it is not reported how similar the two alternative measures of monetary shocks would have been. However, the interest rate itself per se is not in the output equation. Separately he then also estimates a model with trend inflation and thus moving his model's similarity closer to a standard VAR model. Holmes studies utilises the SUR method to analyse the coefficients on the positive and negative shocks. He first estimates a paneled model across all of the UK regions (providing 264 observations for a times series from 1971 to 1995 (as ever data being annual)) to report statistically significant coefficients on (some of) both the positive and negative monetary shock terms. He also reports evidence of asymmetric effects to monetary shocks based on the rejection of the Wald test that the coefficients are the same on the terms for the positive and negative shocks. Providing separate regional estimates of the model Holmes reports that London and the South East are the least responsive to interest rate shock. He also suggests that these two regions are so insensitive as not to react to a negative shock.

Whilst Holmes work could just as easily be justified as belonging to the review of the analysis of regional transmission of monetary policy, it provides a useful link between that body of research which more or less exclusively uses an identified monetary (interest rate) shock from a structural VAR to models more generally investigating output and price dynamics and seeking to explore heterogeneities (if any) in regional business cycles which is a small but directly relevant body of research for this thesis. Fielding and Shields (2001) is such a work of a more general investigation of regional output and price dynamics. In it they estimate a vector error correction model ('VECM') for output growth and inflation across the UK regions using annual data from 1967 to 1996. Importantly in this work they use a constructed series of regional price levels (of their own construction). Their VECM framework allows for terms representing average aggregate growth and inflation and average aggregate growth (outside of the particular region) to enter into the model. Crucially their co-integration analysis suggest that regional prices are co-integrated with the national price level but regional output series are not co-integrated with each other nor with national output hence and importantly (and significantly) shocks to output can have a permanent heterogeneous level effect across the regions. Their analysis is based on a method (somewhat analogous to VAR based cumulative impulse responses) of calculation of persistence profiles of shocks to a non stationary times series (a methodology outlined in Lee, Pesaren, Pierce (1993)).

On the subject of business cycle heterogeneities or alternatively homogeneities they also report that the correlations between the innovations to both inflation and output across the regions to be large and positive averaging 70% or greater in the case of the output growth series. This result is consistent with findings from other work such as that of Funke and Hall (1996) (as discussed below) and they suggest that, if progressed no further than an assessment of the correlation of shocks to the regions on impact, it would suggest (as also concluded by Funke and Hall) a high degree of homogeneity across the regions. However, the results from the persistence profile analysis of shocks (both region specific and aggregate) to regional output and prices lead them to the different conclusion that there does exist ‘a substantial degree of heterogeneity across English regions.

Fielding and Shields dataset incorporates the English regions without a separate measures of London and the Southeast. No economic interpretation is given (deliberately) to shocks to output growth and inflation but these results suggest a greater degree of heterogeneity in response across the regions in output to shock as against prices to shocks (ie inflation responses are more homogenous). The heterogeneity of output growth to shocks is (just) slightly more dispersed for inflation shock persistence profiles than for output shock persistence profiles but for both there is anecdotal evidence of grouping of regions: the Southeast and West Midlands displaying clearly the largest responses, followed by a middle group consisting of Yorkshire, East Midlands and the Northwest and then the South West and the North (East) being in the third group with the smallest response. It is interesting to note this somewhat different ordering than that implied (he did not comment) by the results of Holmes in his estimation of interest rate responses.

Funke and Hall's (1998) work is a straightforward replication of the Blanchard and Quah (1989) (long run restriction of supply shocks having no permanent effect on output) methodology outlined in chapter eight estimated on bivariate series of regional output growth and a common (UK) inflation series. Their findings are unambiguous. They report little evidence of heterogeneity in the dynamics of the regions, their impulse response (instantaneous and cumulative) provides little to suggest significant differences and they report a very high degree of correlation (of pairwise regional series with London and the Southeast) between supply shocks (average 0.92) and a high correlation of demand shocks (0.68). Test of Granger causality between the various series show no evidence of Granger causality for supply shocks and only slight evidence for London and the Southeast demand shocks to Granger cause demand shocks for (some of) the other regions.

Funke and Hall's conclusion therefore is at odds with that of Holmes and Fielding and Shields, the latter pair suggesting that 'an effective and equitable macroeconomic policy in the country (UK) will require an understanding of the economic structure underlying the regional heterogeneity that we have uncovered' and intriguingly, whilst neither of these latter two works attempted to order or rank the relative orderings of the responses per se, the evidence they did suggest was that London and the South East was either the most responsive (Fielding and Shields) or least (Holmes) to shocks.

The slightly more recent research of Barrios et al (2002) provides an analysis not of the effects of shocks but simple an analysis of the cross correlation of regional time series of output innovations. These innovations were calculated simply as the differences between the output series and an HP filtered series for regional data from 1967 to 1996 heterogeneously deflated using regional time series constructed by Fielding and Shields. They report an average pairwise correlation for UK regional series to be 0.69.   This is itself not a particularly startling or profound contribution but it is used to support a conclusion of heterogeneity in UK regional business cycles. They also show how the pairwise (between London and each other region) correlations across regions differ and have differed slightly in value over time but that the relative ordering of values (or rankings) have not.

However, this work is also of interest because of its attempt to explain pairwise correlations (and indirectly the differences in pairwise correlation) by recourse to regressing the correlation values on a number of explanatory variables. For the UK regions especially some of these measures are somewhat crude but sought to proxy for geographic proximity, size, trade etc and significantly a measure of the sectoral dissimilarity: the Krugman index referred to in chapter 3 which is also utilised in this research. This work was billed as a comparison of UK and EU business cycles and therefore the intra UK or UK region/UK region business cycle analysis is only a small portion of the research presented but is one of few works to explore factors causing regional heterogeneity. Ironically for all this, reported explanatory power of their chosen regressors for the UK regions is low and the sign on the Krugman explanatory variable reported by Barrios et al is wrongly signed according to theory.

This then constitutes the most relevant research literature on the macrodynamics of the UK regions. It is not large, it comprises only a handful of papers. The work of Funke and Hall (1998), Barrios et al (2002) and Fielding and Shields (2001) on the investigation of output and price dynamics on the one hand and on the other the work of Holmes (2000), Darby and Phillips (2007) and Ganley and Salmon (1997) on the investigation of dynamics subsequent to monetary shocks (although strictly speaking this last work is sectoral not regional) on the other.

This is not a huge foundation on which to build. As was said at the outset of this section there are other lines of investigation. These include the exploration of: regional variation in unemployment levels (Cook (1999), Evans & McCormick (1994), Erdem & Glyn (2001); convergence in growth rates or productivity of the regions over time (McGuinness & Sheehan (1999), Harris & Trainor (1997), Evans & Pentacost (1998), Henley (2005); and cross regional variation in house prices and any resultant effects on regional economies (Cook (2006), Cook & Thomas (2003), Carruth & Henley (1993)).

The work on unemployment is blessed by the fact that this time series alone for the regions is available on a frequency better than annual basis. Whilst the data reviewed in the chapter describing the UK regions in this thesis (chapter 3) suggested regional unemployment dispersion had changed little over time, Evans and McCormick's work is based on the premise that it narrowed over the course of the 1980s and is a contributory factor to their suggestion that the Southeast became more interest rate sensitive (a finding at odds with Holmes) than the other regions over that period. Erdem & Glynn's view of regional unemployment heterogeneities is more consistent with the view is that they have remained constant over the 1990s and they cite the greater level of unskilled unemployment (and firstly greater levels of unskilled) in the northern regions to be the key cause. Cook (1999) conducts statistical tests to ascertain the deepness and steepness of detrended (via HP filter) regional unemployment series. His results suggest that whilst there is common cyclical asymmetry in the deepness (level) of unemployment across the regions there is heterogeneity in the steepness (speed of adjustment) across the regions although he indicated no pattern to this reported heterogeneity..

A straightforward summary of the work on convergence ((McGuinness & Sheehan (1999), Harris & Trainor (1997), Evans & Pentacost (1998), Henley (2005)) is that the regions have not and are not converging in either the alpha or beta sense[12]. This short remark may do little justice to the volume and extent of the work but encapsulates it nevertheless. The work of Cook (2006) and Cook and Thomas (2003) use two methods to investigate the possibility of a ripple effect from the South East to other regions. The first is non-parametric testing of increased volatility of prices vis a vis the other regions and the second is a standard business cycle dating technique of dating the peak as larger than the subsequent two quarters whilst also being as least as large as any value in the preceding or subsequent two years. These results imply house price movements of the English regions lag those of the Southeast. Cook (2006) extends the analysis of the cyclical analysis of house prices utilising (he suggests) higher power statistical tests to confirm these previous findings and also to report asymmetries in house price movements: namely that peaks are larger than subsequent troughs.

The housing market feels intuitively fertile territory to assist the analysis of economic heterogeneities of the regions. Indeed given that regional housing

[12] see Barro & Sala-I-Martin (1992) for an explanation of these terms

data is available on a quarterly basis as far back as the early 1970s it would be of enormous benefit if there was common consensus on the relationship between the housing market and real demand and output. However, this is not the case and utilising the data in such a manner would first necessitate an investigation of the linkage at a national level (eg Aoki 2005) which is a different research question. Notwithstanding this lack of consensus, Carruth and Henley (1993) report a positive relationship between increasing housing wealth and consumer spending using a regional fixed effects panel and by testing for common coefficient values across SUR estimates suggest that this effect is strongest in the South East, although they stress that their results 'should be treated with caution due to the short time span of the regional data.'

An interesting panel application of UK regional data has been made by Dejuan (2003) who confirms the permanent income hypothesis across the UK regions but no study of heterogeneity is attempted. As a penultimate point, there is one further work to which reference needs to be made because its title suggest that it will reveals a great deal of direct relevance to the work: 'The Regional Transmission of UK Monetary Policy': Dow & Montagnolia (2007). Despite the promising nature of the title, this (published) paper provides very little in the way of empirical analysis merely being an interesting discursive exposition of how monetary policy transmission may differ across the regions. It provides an interesting (if textbook) explanation of how credit conditions may differ across two regions of the same economy. It also explains how different short run wage dynamics (ie Phillips curves) across the regions would make monetary policy transmission less homogenously efficient and then calculates coefficients of Phillips curve relationships based on a mere eight data points. It also constructs and compares an ‘expected credit supply’ curve for the UK and Scotland based on CBI survey data (again from a series of rather short length).

Additionally, it suggests that given that house prices in London and the South East lead the rest of the UK regions and that UK interest rate policy is set to choke off housing demand in the South East (their assertion) this would lead to a) a greater house price differential that would otherwise be the case and b) that it would lead to a choke off in natural demand of the regions and lead to a lower level of output in the long run than would otherwise be the case. The authors provide no empirical evidence to support this intuitively appealing notion. Indeed, it would be very difficult as this author has the same view and thought long and hard about how one would be able to prove or disprove this without success!

Finally, reference is made to the work of Bell, Nickell & Quintini (2000) which takes the short run analysis ‘back to the beginning’ as discussed in chapter seven by estimating a UK regional wage curves based on a panel data technique using the regional series for the panels. This research (as stated in chapter 7) takes wage dynamics back into the realms of the microeconomic and whilst regional variation is highlighted in passing there is little in this work of relevance to the analysis in this thesis.

This section provided the context of the current state of play of research on the macrodynamics of the UK regions. It is not a particularly large body of research, assumedly for the reason suggested at the beginning of this section (ie data issues). An attempt has been made to provide a broad review of the works of relevance to the thesis and to that event research has been referenced where there is perhaps only a small direct relevance to the work of this thesis (and often the point of most direct relevance is that the research has been conducted on the UK regions or using regional data). The subject of the macrodynamics of the UK regions is somewhat dormant at this present moment in time, although many of the macroeconomic issues that underpin the possibility for heterogeneities of regional dynamics remain as pertinent and present as ever.

5 Effects of Demand and Supply Shocks on the UK Regions

The last section of the previous chapter outlined various aspects of research into the UK regions. The literature whilst not vast contains various studies of UK regional macrodynamics and what there is tends to the support of homogeneity of macrodynamics. The work of Barrios et al (2002) citing an average correlation of shocks to UK regional cycles to be 0.69 and mainly from this fact conclude little heterogeneity in UK regional business cycles. This chapter also referred to the work of Funke and Hall (1998) who implemented the standard Blanchard Quah decomposition for regional output series (differenced) and a national price series (differenced). Again they conclude there to be little in the way of heterogeneity citing high levels of structural shock correlations. Contrary to this Fielding and Shields (2001) estimated a VECM model of regional output and regional prices of their own construction. Their conclusion is in contrast to the two works previously mentioned. They report ‘substantial heterogeneity in the response of regional GDP to shocks’. In fact they report a pattern of heterogeneity across the regions strikingly similar to that reported later in this chapter.

The work of this chapter builds upon the work of Fielding and Shields and Funke and Hall in particular. It first replicates the Blanchard Quah decomposition utilised by Funke and Hall but importantly uses regional price series published by

Hayes (2006) in place of a common national deflator. It then compares and contrasts these results using an alternative (Covers) decomposition[13].
The rationale is simple: the Blanchard Quah decomposition (putting aside the general criticisms of the SVAR methodology) restricts the long run effects of identified supply shocks to be zero. This decomposition therefore in effect imposes homogeneity across the regions by its very construction. It is therefore unsurprising that estimations using this methodology and a common price series would lead to a conclusion of there being little evidence of heterogeneity.

The Covers decomposition relaxes this 'homogeneity restriction' of the Blanchard Quah methodology. It does so by first imposing a short run restriction which represents a simple Lucas model of aggregate supply which then over identifies the standard model and thus facilitates the relaxing of the zero long run restriction on the identified supply shocks. This is key because by doing so it opens up the possibility of co-movement between supply curves and demand shocks and vice versa. Once this possibility is allowed for then it becomes a methodology that can be utilised for the exploration of heterogeneities of dynamics of the UK regions because they have been allowed for by construction.

The intuition is straightforward. This methodology allows for the co-movement of AS and AD curves. This co-movement would be similar across regions if their

[13] An alternative option to analysis of demand and supply shocks in a bivariate setting would be also to incorporate a monetary variable. However, the lack of an appropriate tri-variate model of just prices, output and money for application to a VAR framework, together with data constraints of the regions precludes this approach. An attempt to replicate Gali's (1992) ISLM model proved impossible to correctly idenfity with this dataset.

dynamics were similar but different if heterogeneities exist. The motivation for this thesis is that the regions are indeed sufficiently different for external shocks to have differing effects across the regions and using this methodology we show this to be the case: in short the results from this chapter will demonstrate demand shocks to have heterogeneous effects across regions. The contribution of this chapter is to apply the Blanchard Quah decomposition to the UK regions using recently published regional price series and to then illustrate, using the Covers decomposition, a significant degree of heterogeneity in the responses of the regions to shocks and thus illustrate that demand shocks can account for the variance in output of the regions over the long run.

5.1 Covers Identification

The derivation of the Covers decomposition is repeated below. Covers et al's proposal is to impose a structural Lucas model over the BQ framework. Their simple Lucas ASAD model with prices and output in logs and [ε_t] representing a supply and [η_t] a demand shock is:

$$y^s_t = E_{t-1}y_t + \alpha(p_t - E_{t-1}p_t) + \varepsilon_t \qquad (25)$$

supply

$$(y_t + p_t)^d = E_{t-1}(y_t + p_t)^d + \eta_t \qquad (26)$$

demand

$$y^s_t = y^d_t \qquad (27)$$

equilibrium

this can be solved for output and prices and can be represented in matrix form (see Appendix 2) as:

$$\begin{bmatrix} y_t \\ p_t \end{bmatrix} = \begin{bmatrix} E_{t-1} y_t \\ E_{t-1} p_t \end{bmatrix} + \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} \varepsilon_t \\ \eta_t \end{bmatrix} \qquad (28)$$

Assuming that the $E_{t-1}p_t$ and $E_{t-1}y_t$ are linear combination of their past values the bivariate moving average model implies the following relationship between the innovations and the structural shocks:

$$\begin{bmatrix} e_{yt} \\ e_{pt} \end{bmatrix} = \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} \varepsilon_t \\ \eta_t \end{bmatrix} \qquad (29)$$

And therefore the relationship between the variance/covariance matrix of the residuals of the estimated VAR and the variance/covariance matrix of the structural shocks becomes:

$$\begin{bmatrix} \mathrm{var}(e_y) & \mathrm{cov}(e_{yp}) \\ \mathrm{cov}(e_y e_p) & \mathrm{var}(e_p) \end{bmatrix} = \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} \sigma_\varepsilon^2 & \sigma_{\varepsilon\eta} \\ \sigma_{\varepsilon\eta} & \sigma_\eta^2 \end{bmatrix} \begin{bmatrix} \frac{1}{1+\alpha} & \frac{-1}{1+\alpha} \\ \frac{\alpha}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \qquad (30)$$

Given that this implies the following restrictions amongst the elements of the contemporaneous C matrix (see equation 25): $c_{11}=\alpha\ c_{12},\ c_{11}= -c_{21}$ and $c_{11}= c_{22}$ and that α, the short run slope of aggregate supply, can also be estimated.

The Blanchard Quah long run restriction implies (where the d_{nn} coefficients represent elements of D matrix of reduced form estimated VAR):

$$\alpha = \frac{-d_{12}(1)}{[1 - d_{22}(1)]} \qquad (31)$$

Given these additional restrictions the BQ restrictions of zero correlation between supply and demand shocks can be dropped.

The clever intuition of Covers et al is to realise that, given the shocks are now correlated, in order to conduct impulse response and variance decomposition analysis the demand and supply shocks must first be deconstructed into their pure and induced components and hence re-orthogonalise the shocks. This is done in two alternative 'orderings'. The first to assume that causality runs from supply to demand which can be illustrated by the representation that unexpected aggregate demand is composed of a pure aggregate demand shock, v_t, plus a movement that is induced by the supply shock (where ρ is the size of the induced effect or the correlation of the shocks).

$$\eta_t = \rho\varepsilon_t + v_t \qquad (32)$$

Similarly, causality from demand to supply implies movement in supply is broken down into a pure, δ_t, and induced movement (with γ representing the correlation):

$$\varepsilon_t = \gamma\eta_t + \delta_t \qquad (33)$$

Given these structural representations the variance/covariance matrix of the residuals can now be represented by either:

$$\begin{bmatrix} \text{var}(e_y) & \text{cov}(e_y e_p) \\ \text{cov}(e_y e_p) & \text{var}(e_p) \end{bmatrix} = \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \rho & 1 \end{bmatrix} \begin{bmatrix} \sigma_\varepsilon^2 & 0 \\ 0 & \sigma_v^2 \end{bmatrix} \begin{bmatrix} 1 & \rho \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \frac{1}{1+\alpha} & \frac{-1}{1+\alpha} \\ \frac{\alpha}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \quad (34)$$

or

$$\begin{bmatrix} \text{var}(e_y) & \text{cov}(e_y e_p) \\ \text{cov}(e_y e_p) & \text{var}(e_p) \end{bmatrix} = \begin{bmatrix} \frac{1}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{-1}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} 1 & \gamma \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \sigma_\delta^2 & 0 \\ 0 & \sigma_\eta^2 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \gamma & 1 \end{bmatrix} \begin{bmatrix} \frac{1}{1+\alpha} & \frac{-1}{1+\alpha} \\ \frac{\alpha}{1+\alpha} & \frac{1}{1+\alpha} \end{bmatrix} \quad (35)$$

these imply that:

$$\begin{bmatrix} \frac{1+\alpha\rho}{1+\alpha}\sigma_\varepsilon & \frac{\alpha}{1+\alpha}\sigma_V \\ \frac{1(1-\rho)}{1+\alpha}\sigma_\varepsilon & \frac{1}{1+\alpha}\sigma_V \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \qquad (36)$$

And

$$\begin{bmatrix} \frac{1}{1+\alpha}\sigma_\delta & \frac{\gamma+\alpha}{1+\alpha}\sigma_\eta \\ \frac{-1}{1+\alpha}\sigma_\delta & \frac{\gamma-1}{1+\alpha}\sigma_\eta \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \qquad (37)$$

In the former all of the common movement is attributed to the supply shock which can be seen to be identical to the standard BQ model. Therefore it is of little relevance for comparative analysis.

The Covers algorithm (written in RATS[14]) used for this chapter is attached in appendix 16 which was written by the author. Verification of its correctness was achieved by estimating results for the same US data used by Covers et al in their 2006 paper.

[14] As was stated in chapter 1 two software packages for estimation have been used in the work of this thesis. The majority of the simpler work has been conducted using Eviews but Estima's RATs has been used where a more complicated methodology necessitates its use. In this chapter the majority of the estimation has been conducted utilising RATS as the Covers methodology imposes a mixture of short and long run restrictions which is impossible in Eviews. However, the majority of tests were conducted using Eviews. Its windows format making the task of producing estimates/test statistics of 10 regions/regressions much less laborious.

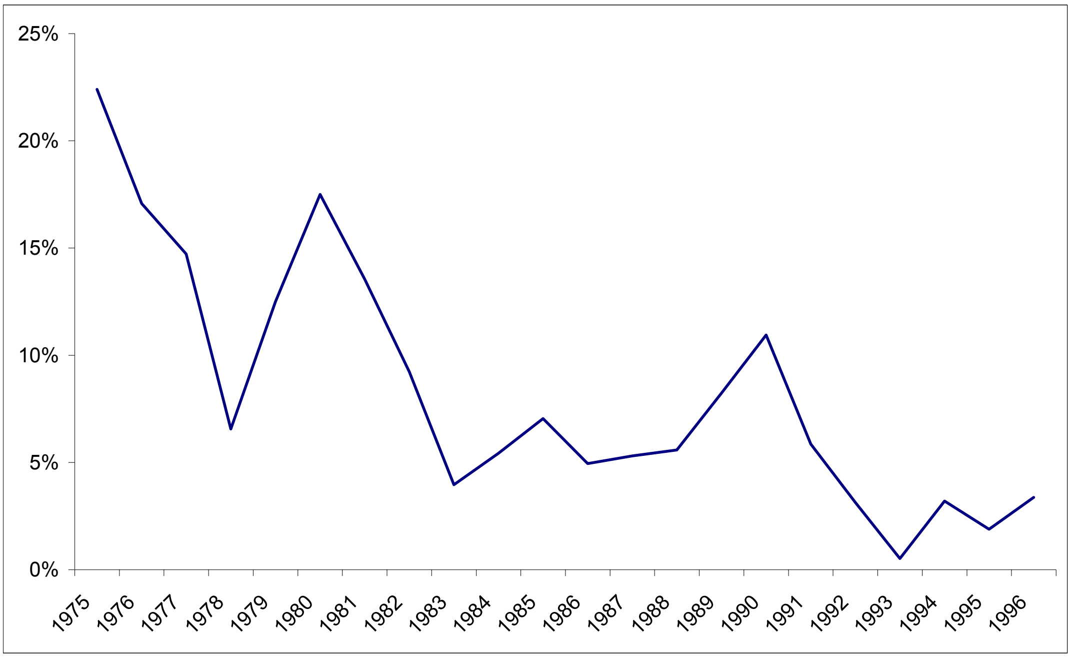
5.2 Data

Fielding and Shields estimated their VECM model of output and prices using regional consumer price series and regional output data deflated using these series. Funke and Hall used a common price series and their regional output series were similarly commonly deflated. In the research of this chapter the regional price series of Hayes (2006) which was constructed over the period 1975 to 1996 is used (and hence this is the length of time series we have available for estimation) and the regional output series have been heterogeneously deflated accordingly.

The properties of the data are first checked. An (expected) absence of co-integration between regional price and output series is reported by both the Johansen Trace and Rank tests for all of the series save the North West. Given this is an isolated case this is discounted.   For exposition and brevity purposes, the formal test results are presented in appendix 3. Tests for unit roots are also conducted since, for both of the identifications that are applied, stationarity is required of the data. Unsurprisingly, tests (reported in appendix 4) indicate a unit root in levels of both sets of series.

A significant point now arises. There still exists some debate as to whether price series are integrated of order one or two (Byrne et al (2007)). The time period for the data series starts from a period of historically high UK inflation (annual rates mid twenties) to historic lows (low single digits). A cursory visual inspection of the South East inflation (price level differenced) data series below suggests that a unit root may still be present in the data.

Figure 32: Inflation (SE) 1975-1997



Therefore each differenced price series is tested for a further unit root. The augmented Dickey-Fuller test is used. An issue arises as to whether to include exogenous regressors or trends in unit root tests (see Hamilton 1994). For completeness for the different regional price series the results of the general case and that including a constant are presented. As can be seen from the results presented in appendix 4 for no series can the null of a unit root at the five percent level for the case including a constant be rejected. In addition, for certain series (Southeast, Southwest, Wales and West Midlands) this is also the case for the results of the general case and for the case with a constant the null cannot be rejected at the 10% level.

This poses a question as to which is the appropriate level of differencing. The question is answered by conducting the estimations across both identification schemes across all regions with both sets of series (for the purposes of presentation results for the first differenced price series are labeled ‘P1’, results for the second differenced price series ‘P2’). Whilst this provides a rather large quantity of results, it is in a manner a robustness check, and, as will be seen, the conclusions drawn are the same for both cases.

The final test for the model is that of lag length. The Schwartz criterion suggests a lag length of six is appropriate, which for a VAR for annual series is very surprising. Given that the inverse roots for this lag length lie outside the unit circle (ie the model has explosive roots) this is clearly erroneous. The Schwartz criterion also indicates a preference for four lags over two lags. However, estimation using four lags leads to mis-identified impulse responses. A Lagrange Multiplier test suggests a preference for two lags for almost all of the regions (SE and SW excepted). On this basis, given the previous issues with the other lag lengths discussed and that two lags is ordinarily deemed appropriate for annual time series (Enders (2001)), a rule of thumb being twice the value of the reciprocal of interval, a lag length of two is chosen. The formal test results are presented in appendix 5.

5.3 Results from the Blanchard Quah Decomposition

The responses of each region under the standard (BQ) model whilst differing in size conform to the orthodox expectation that of demand and supply shocks: both having a positive effect on output, demand shocks having a positive effect on prices and supply shocks having a negative effect on prices. The cumulative response of output to demand and prices to supply are zero in the long run and accounts for the peak/trough-positive/negative wave like impulse responses.

Even though separate regional price series have been used it is difficult to discern grounds for concluding there are significant heterogeneities in the dynamics of the regions. Figures 33 to 36, 37 to 40 and 41 to 44 provide a full set (instantaneous and cumulative, P1 and P2) of impulse responses for the South East, Yorkshire and the North East respectively (the complete set of responses is provided in appendix 6, why three, and these three, regions have been chosen for illustration purposes will become evident shortly). There is little to immediately distinguish between each set of regional impulses. Size and scale of responses are similar across each region.

The SVAR scheme facilitates the recovery of series of structural shocks for each regional series. The correlations between each series are produced in tables 1 through 4. These shows that each structural series is highly correlated with each other, slightly more for demand shocks than supply shocks – the average correlation for P1 and P2 recovered supply shocks being 0.60 and 0.67

respectively and the average correlation for P1 and P2 demand shocks being 0.74 and 0.81 respectively. This provides support for the view that the shocks hit each region more or less concurrently. Whilst there is some suggestion this is less so for supply shocks than demand shocks, the correlations are still high and therefore does not provide much in the way of a 'compelling case' for heterogeneity in business cycles

Granger Causality tests in tables 5 and 6 support this intuition. There is little evidence to suggest anything other than the conclusion that shocks are common to all regions. Left at this, the fact that there is little heterogeneity in response (a supposition made from an analysis of the impulse responses) would lead to the same conclusion (based on these results) made by Funke and Hall and Barrios et al that there is little heterogeneity in regional dynamics. However, the Covers identification is now employed leading to significantly different conclusions.

The following impulse and cumulative impulse response functions are presented with four responses per graph; output (y) response to a supply shock; output (y) response to a demand shock; the difference price level series (i) to a supply shock; and the differenced price level series (i) to a demand shock. Whilst two sets of results are presented: price level differenced once (P1) and price level differenced twice (P2); the key in all cases uses the label (i) for both price series and the level of differencing of the price series is noted in the title of the figure.

Figure 33: P1: South East Impulse BQ Decomposition

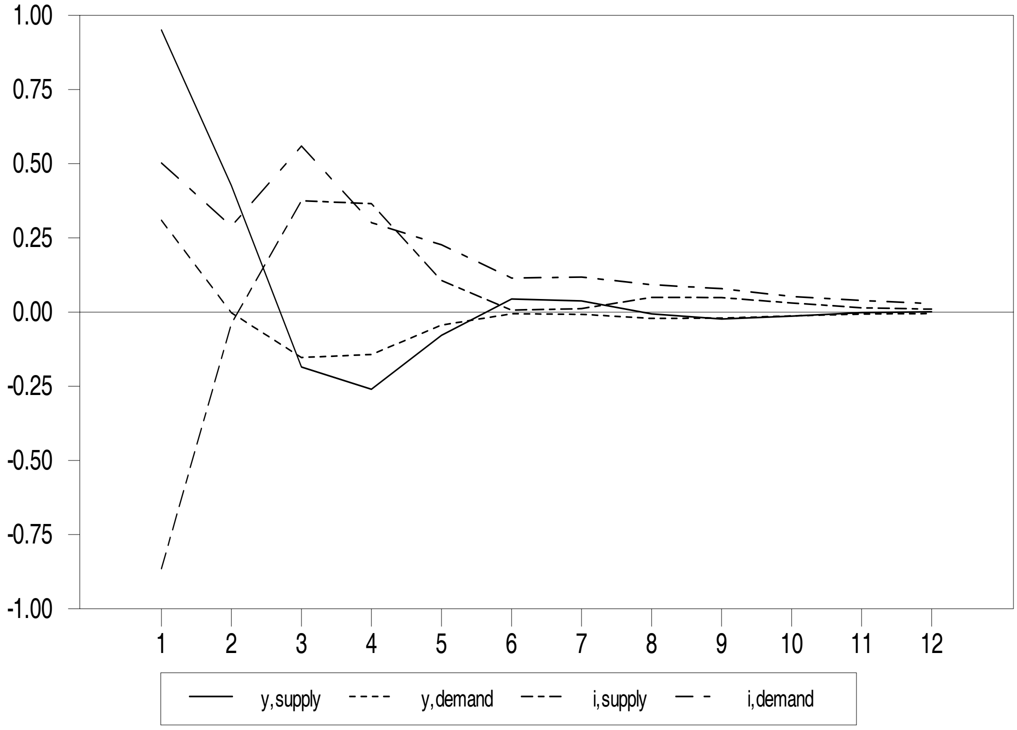


Figure 34: P2: South East Impulse BQ Decomposition

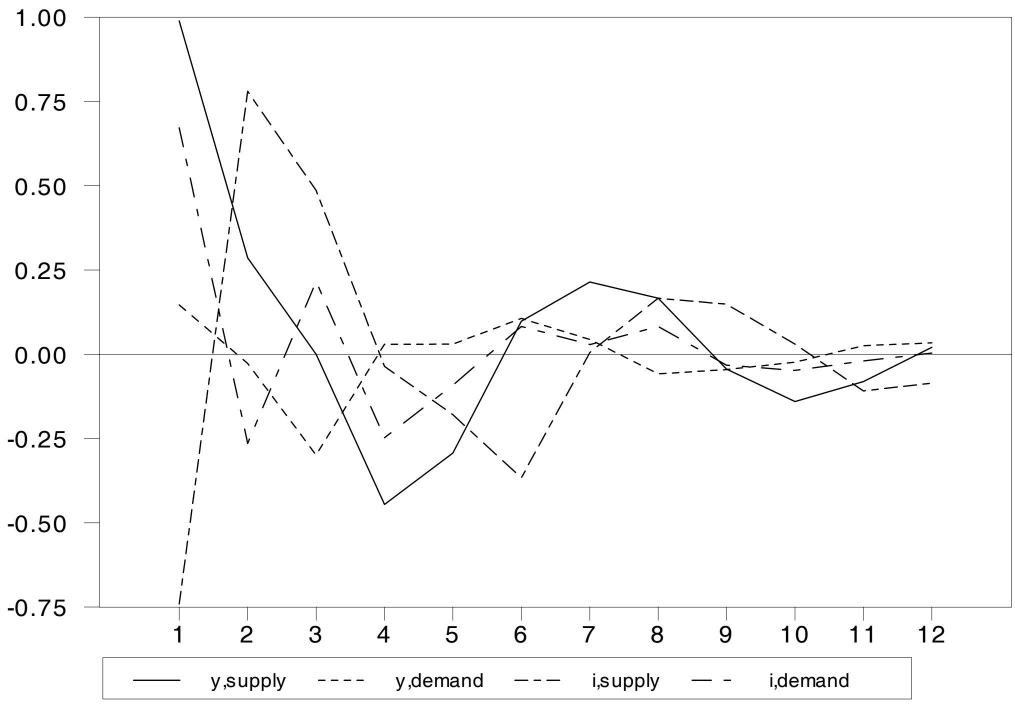


Figure 35: P1: South East Cumulative BQ Decomposition

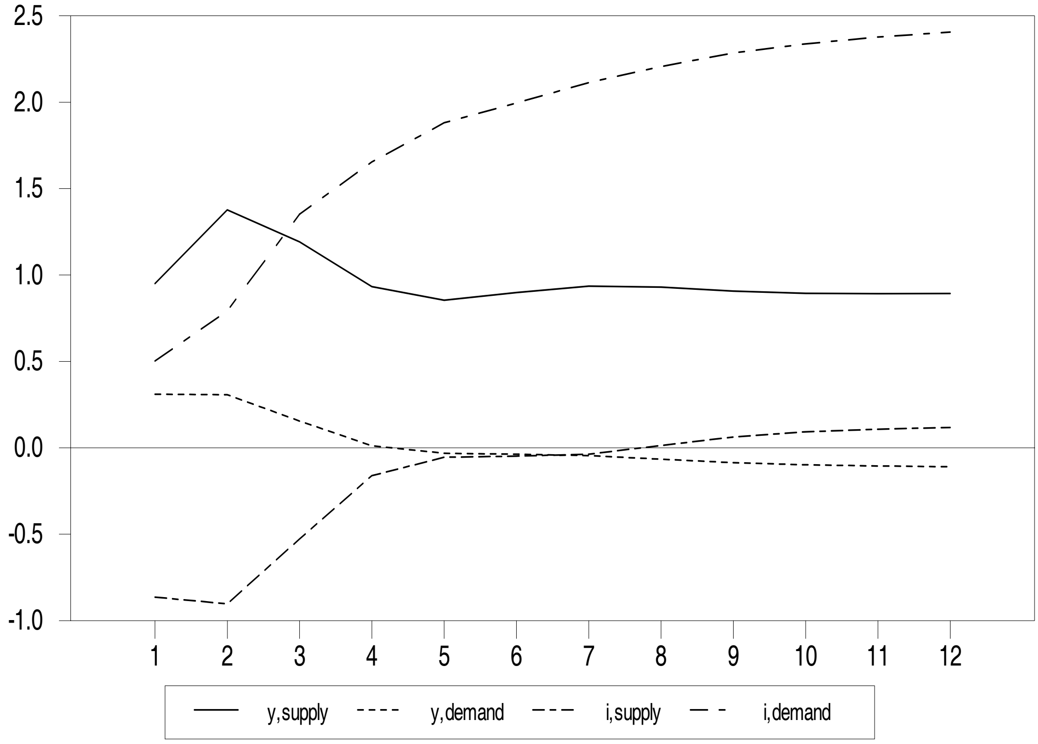


Figure 36: P2: South East Cumulative BQ Decomposition

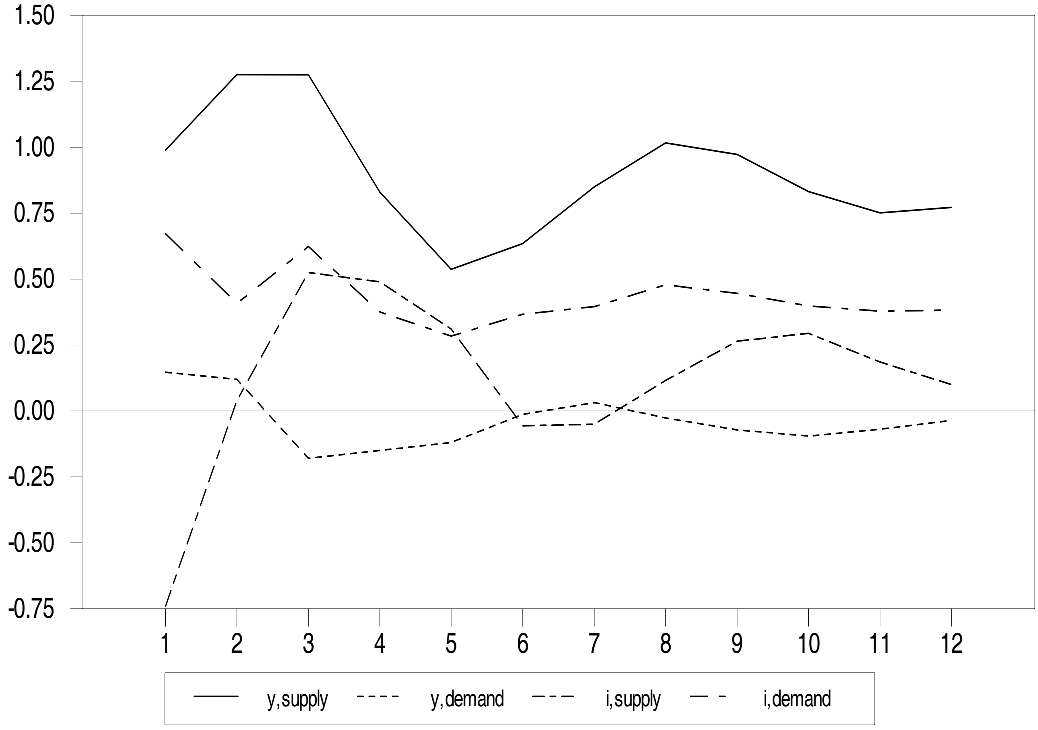


Figure 37: P1: Yorkshire Impulse BQ Decomposition

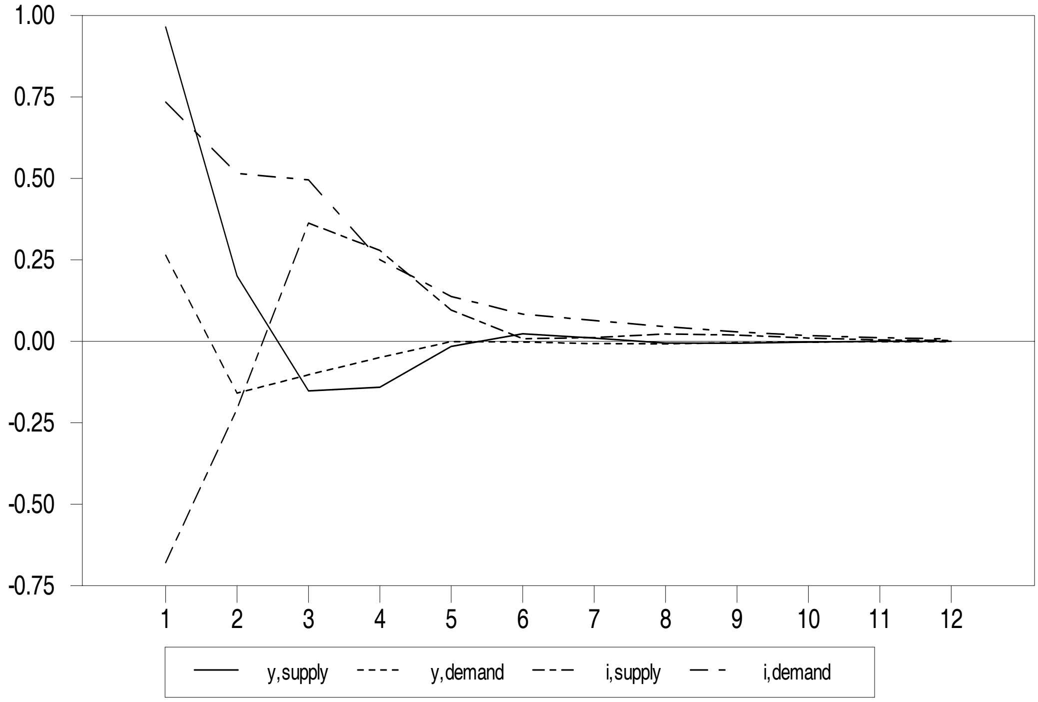


Figure 38: P2: YKS BQ Decomposition Impulse

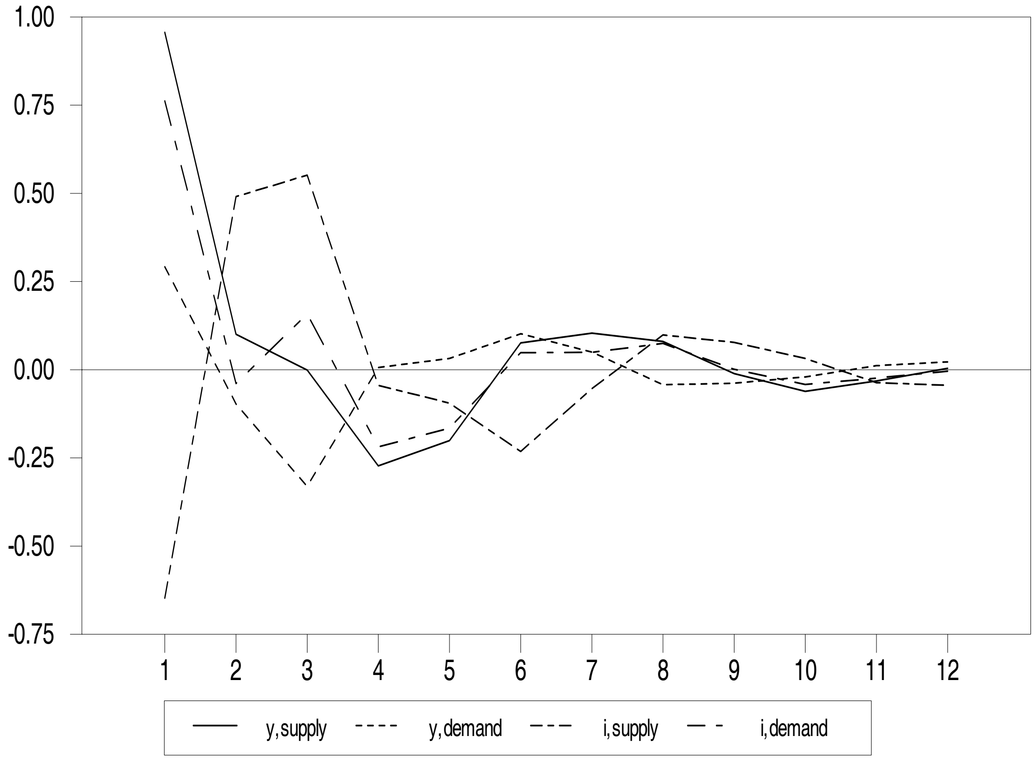


Figure 39: P1: Yorkshire Cumulative BQ Decomposition

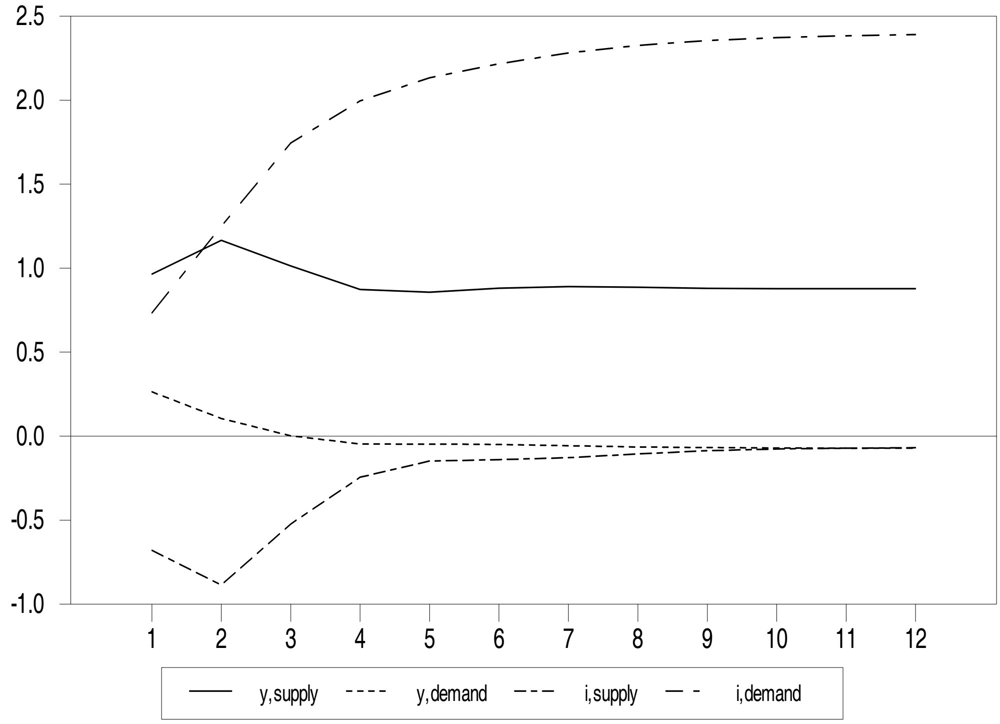


Figure 40: P2: YKS BQ Decomposition Cumulative

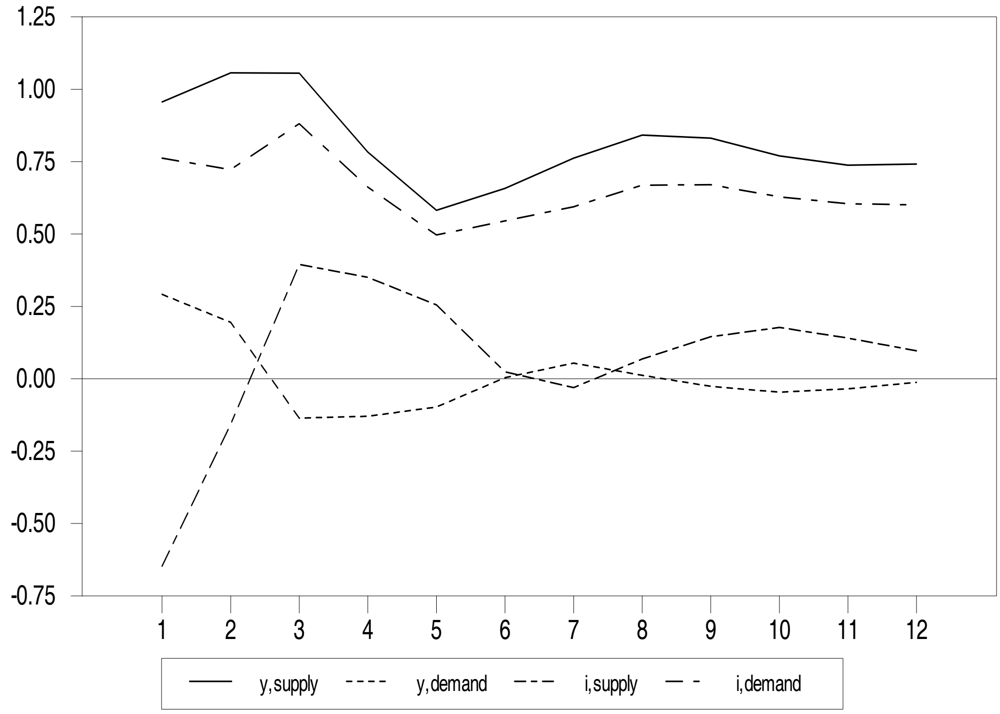


Figure 41 P1: NE BQ Decomposition Impulse

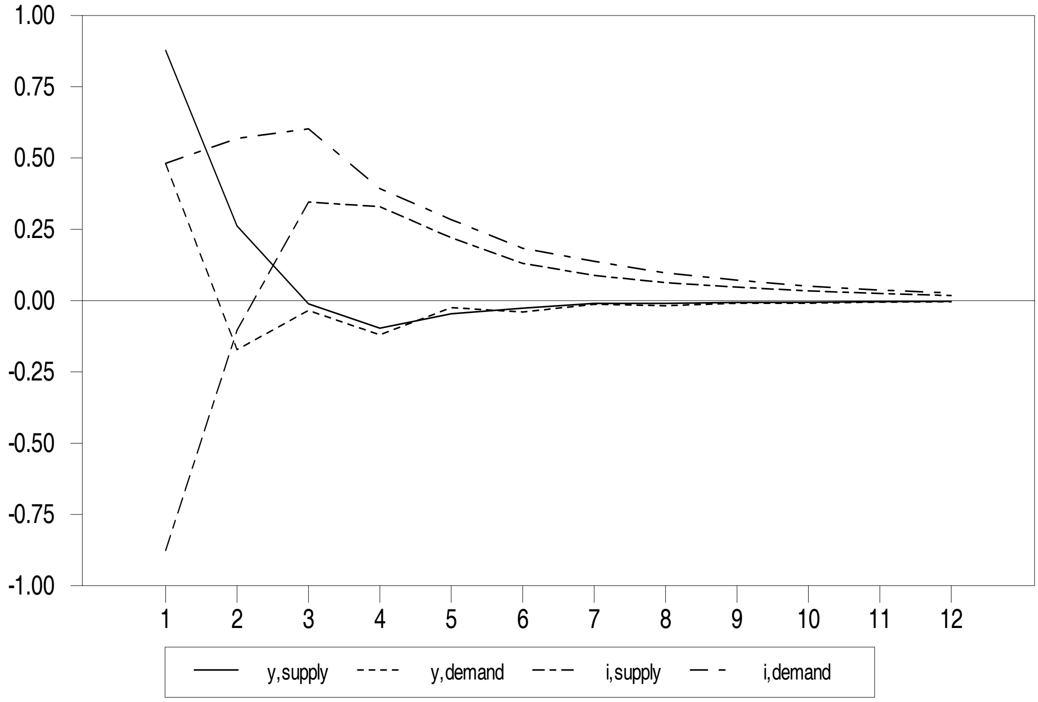


Figure 42: P2: NE BQ Decomposition Impulse

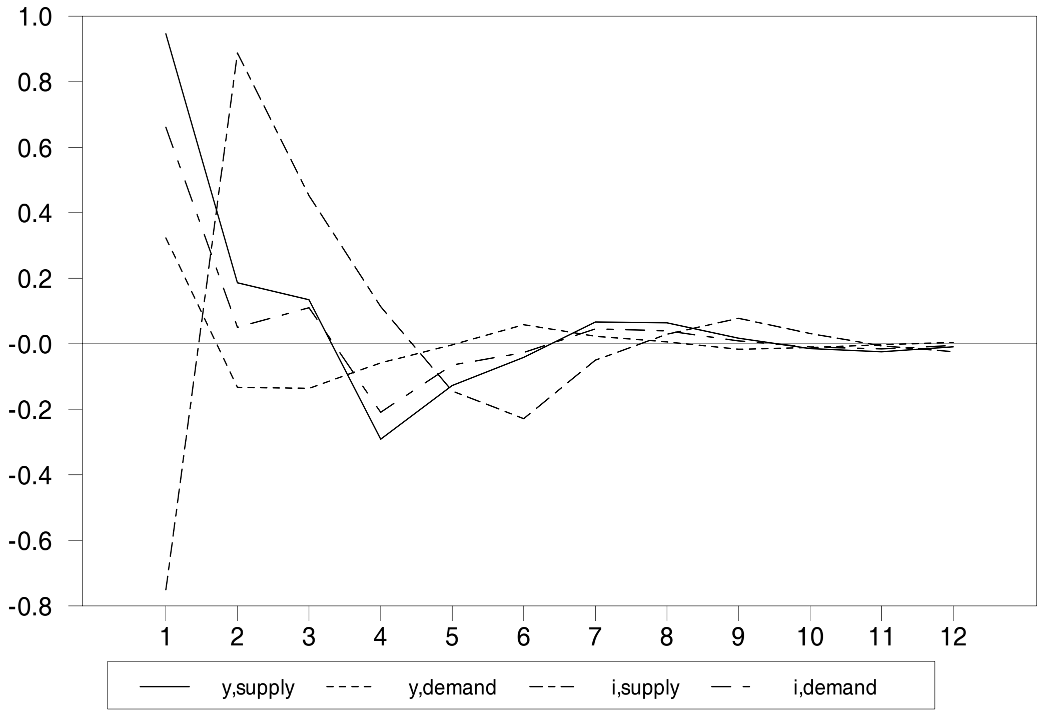


Figure 43: P1: NE BQ Decomposition Cumulative

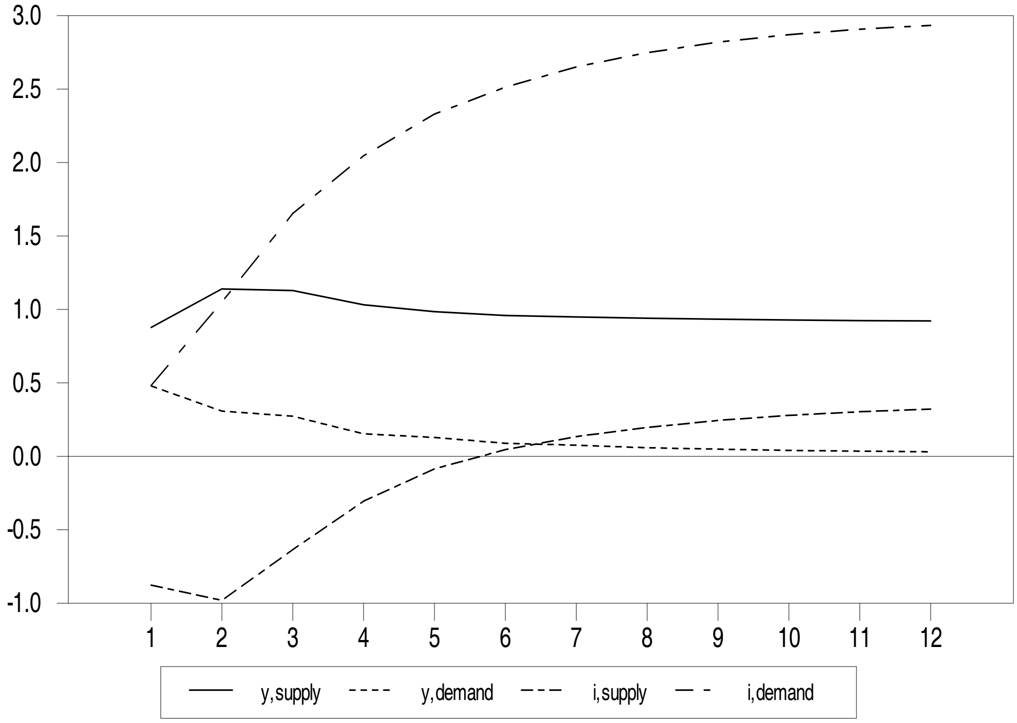


Figure 44: P2: NE BQ Decomposition Cumulative

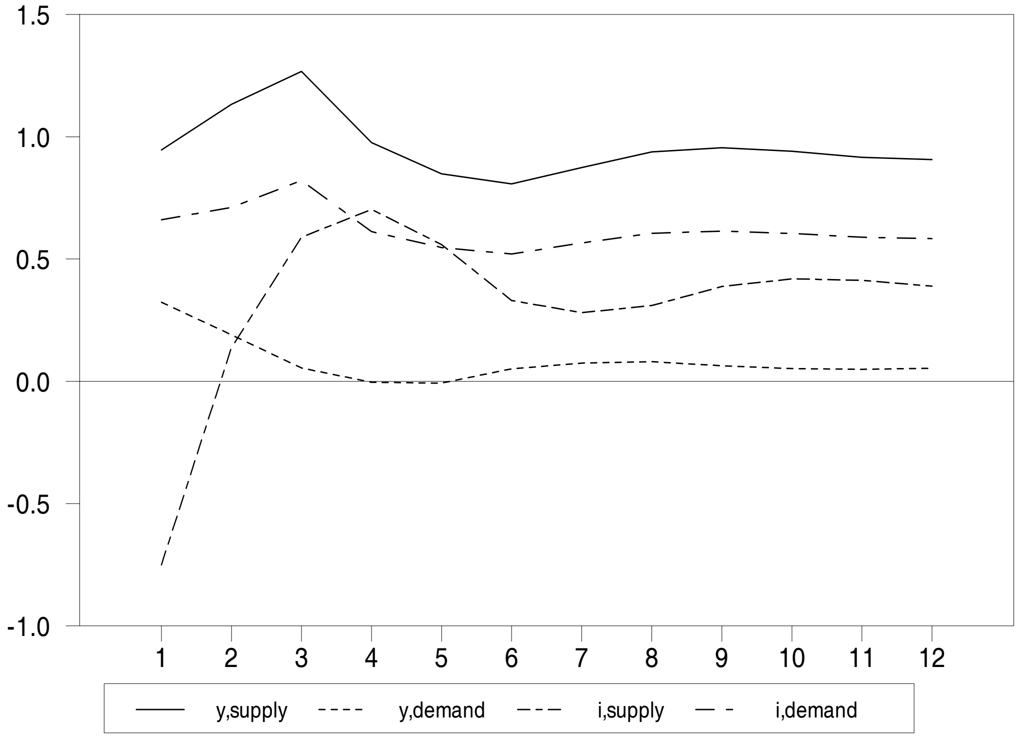


Table 1: P1 BQ Supply Shock Correlations

	EA	EM	NE	NW	SCO	SE	SW	WAL	WM	YKS
EA	1.00	0.42	0.43	0.57	0.27	0.43	0.48	0.38	0.29	0.39
EM	0.42	1.00	0.88	0.65	0.27	0.39	0.73	0.80	0.40	0.92
NE	0.43	0.88	1.00	0.66	0.39	0.51	0.80	0.70	0.38	0.80
NW	0.57	0.65	0.66	1.00	0.73	0.82	0.52	0.64	0.80	0.70
SCO	0.27	0.27	0.39	0.73	1.00	0.72	0.42	0.39	0.77	0.46
SE	0.43	0.39	0.51	0.82	0.72	1.00	0.32	0.26	0.68	0.45
SW	0.48	0.73	0.80	0.52	0.42	0.32	1.00	0.75	0.20	0.76
WAL	0.38	0.80	0.70	0.64	0.39	0.26	0.75	1.00	0.36	0.86
WM	0.29	0.40	0.38	0.80	0.77	0.68	0.20	0.36	1.00	0.47
YKS	0.39	0.92	0.80	0.70	0.46	0.45	0.76	0.86	0.47	1.00
									Avge	***0.60***

Table 2: P1 BQ Demand Correlations

	EA	EM	NE	NW	SCO	SE	SW	WAL	WM	YKS
EA	1.00	0.82	0.88	0.75	0.54	0.72	0.84	0.79	0.63	0.73
EM	0.82	1.00	0.86	0.82	0.29	0.77	0.91	0.92	0.58	0.84
NE	0.88	0.86	1.00	0.78	0.48	0.81	0.91	0.81	0.66	0.82
NW	0.75	0.82	0.78	1.00	0.45	0.85	0.87	0.84	0.68	0.91
SCO	0.54	0.29	0.48	0.45	1.00	0.30	0.56	0.37	0.75	0.26
SE	0.72	0.77	0.81	0.85	0.30	1.00	0.78	0.69	0.62	0.81
SW	0.84	0.91	0.91	0.87	0.56	0.78	1.00	0.86	0.73	0.89
WAL	0.79	0.92	0.81	0.84	0.37	0.69	0.86	1.00	0.50	0.84
WM	0.63	0.58	0.66	0.68	0.75	0.62	0.73	0.50	1.00	0.52
YKS	0.73	0.84	0.82	0.91	0.26	0.81	0.89	0.84	0.52	1.00
									Avge	***0.74***

Table 3: P2 BQ Supply Shock Correlations

	EA	EM	NE	NW	SCO	SE	SW	WAL	WM	YKS
EA	1.00	0.48	0.46	0.48	0.41	0.42	0.61	0.52	0.32	0.41
EM	0.48	1.00	0.90	0.72	0.65	0.45	0.80	0.84	0.60	0.91
NE	0.46	0.90	1.00	0.61	0.72	0.48	0.84	0.78	0.44	0.78
NW	0.48	0.72	0.61	1.00	0.50	0.85	0.71	0.60	0.80	0.74
SCO	0.41	0.65	0.72	0.50	1.00	0.52	0.73	0.63	0.51	0.72
SE	0.42	0.45	0.48	0.85	0.52	1.00	0.61	0.36	0.67	0.53
SW	0.61	0.80	0.84	0.71	0.73	0.61	1.00	0.82	0.57	0.80
WAL	0.52	0.84	0.78	0.60	0.63	0.36	0.82	1.00	0.47	0.85
WM	0.32	0.60	0.44	0.80	0.51	0.67	0.57	0.47	1.00	0.71
YKS	0.41	0.91	0.78	0.74	0.72	0.53	0.80	0.85	0.71	1.00
									Avge	***0.67***

Table 4: P2 BQ Demand Correlations

	EA	EM	NE	NW	SCO	SE	SW	WAL	WM	YKS
EA	1.00	0.79	0.82	0.67	0.68	0.66	0.76	0.70	0.68	0.69
EM	0.79	1.00	0.88	0.75	0.68	0.75	0.92	0.89	0.72	0.83
NE	0.82	0.88	1.00	0.81	0.77	0.82	0.91	0.79	0.80	0.88
NW	0.67	0.75	0.81	1.00	0.81	0.85	0.85	0.83	0.89	0.90
SCO	0.68	0.68	0.77	0.81	1.00	0.80	0.72	0.74	0.84	0.70
SE	0.66	0.75	0.82	0.85	0.80	1.00	0.77	0.66	0.83	0.79
SW	0.76	0.92	0.91	0.85	0.72	0.77	1.00	0.87	0.81	0.92
WAL	0.70	0.89	0.79	0.83	0.74	0.66	0.87	1.00	0.75	0.86
WM	0.68	0.72	0.80	0.89	0.84	0.83	0.81	0.75	1.00	0.85
YKS	0.69	0.83	0.88	0.90	0.70	0.79	0.92	0.86	0.85	1.00
									Avge	***0.81***

Table 5: Granger Causality (marginal significance) Supply and Demand Shocks P1

Supply Region	BQ SE to R	R to SE	Demand Region	BQ SE to R	R to SE
EA	0.524	0.558	EA	0.003	0.051
EM	0.043	0.033	EM	0.734	0.236
NW	0.235	0.275	NW	0.990	0.079
Sco	0.582	0.741	Sco	0.190	0.429
SW	0.093	0.101	SW	0.779	0.158
Wal	0.065	0.163	Wal	0.778	0.318
WM	0.053	0.154	WM	0.965	0.285
Yks	0.005	0.094	Yks	0.698	0.085
NE	0.020	0.056	NE	0.159	0.161

Table 6: Granger Causality (marginal significance) Supply and Demand Shocks P2

Supply Region	BQ SE to R	R to SE	Demand Region	BQ SE to R	R to SE
EA	0.524	0.558	EA	0.003	0.051
EM	0.043	0.033	EM	0.734	0.236
NW	0.235	0.275	NW	0.990	0.079
Sco	0.582	0.741	Sco	0.190	0.429
SW	0.093	0.101	SW	0.779	0.158
Wal	0.065	0.163	Wal	0.778	0.318
WM	0.053	0.154	WM	0.965	0.285
Yks	0.005	0.094	Yks	0.698	0.085
NE	0.020	0.056	NE	0.159	0.161

5.4 Covers Results

As discussed extensively the Covers identification relaxes this 'imposed homogeneity' restriction of zero cumulative effect of demand shocks allowing there to be a co-movement in supply with demand shocks (and vice versa). This then opens up an avenue for heterogeneities in dynamics to occur via the degree of co-movement differing across the regions.

The estimation results are presented in several forms and for both the P1 and P2 regimes: a complete set of parameters for all of the structural parameters for the Covers identification for each region are estimated; the impulse (instantaneous and cumulative) responses for each region are reported and a full (12 year horizon) set of variance decompositions of output and prices to supply and demand shocks for both the Covers and BQ decompositions are reported. Again for purposes of space only the full complement of results for three regions is presented within this chapter. Each region being representative of the three different 'groups' that are implied by the results (this point becomes evident shortly). The full set of results for all the regions are presented in appendix 6.

What will be illustrated through the presentation of these results is that the Covers decomposition results in a large degree of heterogeneity displayed across UK regions, particularly to a demand shock, the variable of interest.

The complete set of parameter estimates for the South East, North East and Yorkshire regions are presented in tables 7 to 12 are now outlined and discussed. These tables show estimates of the structural parameters for the base results and the two alternative orderings. The first row presents the base results before re-orthogonalisation of the structural shocks. The second row reports the results for the recursive ordering, supply to demand. As was shown this leads to a model identical by a factor to the standard BQ model which attributes all common movements of the AS and AD curves to the supply shock. This is represented by equation 32 (as was also shown previously):

$$\eta_t = \rho\varepsilon_t + \nu_t \qquad (32)$$

In row two of each table thus there are two new parameter estimates, ρ, the degree of induced movement of demand by supply shocks and σ_ν^2, the variance of the 'independent' demand shock. Table 7 (South East) and table 8 (Yorkshire) show the results for the P1 regime. The variance of the independent demand shock account for 56% and 72% of the variance of the total demand shocks, σ_η^2, in the cases of the South East and Yorkshire respectively. Or put another way 44% of the variance of demand for the South East and 28% of the variance of demand for Yorkshire can be attributed to supply shocks.

Table 10 (South East) and table 11 (Yorkshire) outline the results for the P2 regime. It can be seen that now the variance of the independent demand shocks account for 58% (South East) and 72% (Yorkshire) of the variance of the total demand shocks, σ_η^2. Or again 42% of the variance of demand for the South East and 12% of the variance of demand for Yorkshire can be attributed to supply shocks.

Row three represents the recursive ordering of interest, namely that demand shocks are prior to supply (ie that supply movements are induced by demand shocks – ie the route whereby a permanent effect on output can be caused by demand shocks).

This is represented by :

$$\varepsilon_t = \gamma\eta_t + \delta_t \qquad (33)$$

and causality from demand to supply implies movement in supply is broken down into a pure, δ_t, and induced movement (with γ representing the correlation).

Table 7: Full set Covers Parameter Estimates, SE, P1

Model	α	σ^2_{ε}	$\sigma^2_{\varepsilon\eta}$	σ^2_{η}	σ^2_{υ}	ρ	σ^2_{δ}	γ
Basic AS/AD	1.19	23.38	7.93	6.14				
Causality: supply to demand	1.19	23.38			3.45	0.34		
Causality: demand to supply	1.19			6.14			13.15	1.29

Table 8: Full set Covers Parameter Estimates, Yks, P1

Model	α	σ^2_{ε}	$\sigma^2_{\varepsilon\eta}$	σ^2_{η}	σ^2_{υ}	ρ	σ^2_{δ}	γ
Basic AS/AD	0.51	14.77	5.93	8.57				
Causality: supply to demand	0.51	14.77			6.19	.40		
Causality: demand to supply	0.51			8.57			10.66	.69

Table 9: Full set Covers Parameter Estimates, SE, Yks, NE, P1

Model	α	σ^2_{ε}	$\sigma^2_{\varepsilon\eta}$	σ^2_{η}	σ^2_{υ}	ρ	σ^2_{δ}	γ
Basic AS/AD	0.91	16.01	-0.69	5.29				
Causality: supply to demand	0.91	16.01			5.26	-0.04		
Causality: demand to supply	0.91			5.29			15.92	-0.13

α=sensitivity of aggregate supply to an unexpected change in inflation
σ^2_{ε}= variance of total structural shock to aggregate supply
$\sigma^2_{\varepsilon\eta}$= covariance between total structural shocks to aggregate supply and demand
σ^2_{η} = variance of total structural shock to aggregate demand
σ^2_{υ} = variance of independent structural shock to aggregate demand
ρ = effect of shock to aggregate demand on total shock to aggregate supply (causality supply to demand shock)
σ^2_{δ}= variance of independent structural shock to aggregate supply
γ = effect of shock to aggregate supply on total shock to aggregate demand (causality demand to supply shock)

Table 10: Full set Covers Parameter Estimates, SE, P2

Model	α	σ^2_{ε}	$\sigma^2_{\varepsilon\eta}$	σ^2_{η}	σ^2_{υ}	ρ	σ^2_{δ}	γ
Basic AS/AD	0.33	11.74	5.09	5.31				
Causality: supply to demand	0.33	11.74			3.10	0.43		
Causality: demand to supply	0.33			5.31			6.86	0.96

Table 11: Full set Covers Parameter Estimates, Yks, P2

Model	α	σ^2_{ε}	$\sigma^2_{\varepsilon\eta}$	σ^2_{η}	σ^2_{υ}	ρ	σ^2_{δ}	γ
Basic AS/AD	0.42	12.28	3.72	9.38				
Causality: supply to demand	0.42	12.28			8.26	0.30		
Causality: demand to supply	0.42			9.38			10.80	0.40

Table 12: Full set Covers Parameter Estimates, NE, P2

Model	α	σ^2_{ε}	$\sigma^2_{\varepsilon\eta}$	σ^2_{η}	σ^2_{υ}	ρ	σ^2_{δ}	γ
Basic AS/AD	0.37	7.94	-0.22	6.49				
Causality: supply to demand	0.37	7.94			6.49	-0.03		
Causality: demand to supply	0.37			6.49			7.93	-0.03

α=sensitivity of aggregate supply to an unexpected change in inflation
σ^2_{ε}= variance of total structural shock to aggregate supply
$\sigma^2_{\varepsilon\eta}$= covariance between total structural shocks to aggregate supply and demand
σ^2_{η} = variance of total structural shock to aggregate demand
σ^2_{υ} = variance of independent structural shock to aggregate demand
ρ = effect of shock to aggregate demand on total shock to aggregate supply (causality supply to demand shock)
σ^2_{δ}= variance of independent structural shock to aggregate supply
γ = effect of shock to aggregate supply on total shock to aggregate demand (causality demand to supply shock)

Therefore on row three there are two further parameters of interest to report ie , γ, (the variable of key interest) the degree of induced movement of demand by supply shocks and σ_{δ}^{2}, the variance of the 'independent' supply shock.

Whilst the complete set of all parameter estimates for all regions is contained in tables 7 through 12 and appendix 7, table 13 provides a summary of the key parameters of interest for all the regions as an explanation of why three particular regions are being utilised for a discussion of the results.

In table 13 three 'groups' of regions emerge: the first (Group I: South East, West Midlands and the North West) where the magnitudes of the induced movements (ie sizes of ρ and γ) are greatest; the second (Group II: Wales, Scotland, Yorkshire, East Midlands and the South West) where the magnitudes are of a size to suggest a 'middling' ordering; and the final group (Group III: North East and East Anglia) where the induced effects are negligible. This implied ordering is almost identical to that of Fielding and Shields who, unlike Funke and Hall and Barrios et al, report the existence of heterogeneity in movement of output of the regions in responses to shocks.

Table 13: Full set of Alpha, Rho, Gamma Estimates (both price series)

	P1	α	ρ	γ	P2	α	ρ	γ
SE		1.19	0.34	1.29		0.33	0.43	0.96
WM		1.14	0.25	1.14		0.36	0.34	0.97
NW		1.45	0.28	0.99		0.53	0.36	0.91
Yks		0.51	0.40	0.69		0.42	0.30	0.40
Wal		0.48	0.41	0.66		0.15	0.56	0.57
Scotland		n/a	n/a	n/a		0.25	0.27	0.42
EM		0.46	0.27	0.47		0.34	0.20	0.26
EA		1.13	0.02	0.07		0.57	-0.07	-0.13
SW		0.64	-0.03	-0.07		0.35	0.14	0.24
NE		0.92	-0.04	-0.13		0.37	-0.03	-0.03

It should be clear to the reader why three regions have been chosen – one region from each ‘group’ - for illustration purposes. This facilitates ease of discussion and presentation especially when now discussing impulse responses and variance decomposition

Figures 52 to 63 show the Covers decomposition (demand to supply causality) impulse response and the cumulative response functions for each of these regions for 1 percent structural shocks. Both the P1 and P2 regime results are illustrated. A discussion of these illuminates the implications of the Covers identification. (Again the response functions for the rest of the regions are provided in appendices). As already demonstrated, the responses of each region under the standard (BQ) model whilst differing a little in size conform to the orthodox expectation which is that demand and supply shocks both have a positive effect on output, demand shocks have a positive effect on prices and supply shocks have a negative effect on prices. The cumulative response of output to demand (and prices to supply) is zero in the long run as would be anticipated given the imposed neutrality restriction.

The main point of interest is the demand movements[15]. Taking Yorkshire for illustration, figures 56 and 57 (P1 and P2 regimes respectively) it can be seen that a demand shock now has a greater instantaneous effect on output and lesser effect on prices. This is consistent with the results reported by Cover et al (2007) and can be explained with reference to the co-movement of supply induced by the demand shock. The positive shift in supply amplifies the original movement in output so a greater response is to be expected. Similarly this shift in supply dampens down the price movement and hence the lesser response.

Comparing how the impulse responses differ across the three illustrative regions it can be seen how the size of gamma (ie the degree of co-movement of supply with demand) relates to the relative movements. The South East, with the highest value, quite clearly demonstrates the most significant shift. For the P1 regime (figure 52) , the instantaneous output movement of a demand shock is now some four times than under the Blanchard (figure 33) Quah decomposition. Indeed the instantaneous output movement to a demand shock is now nearly double that of the instantaneous output movement to a supply shock whereas under the BQ decomposition output to supply was around three times that of that under a demand shock.

[15] As indicated earlier the Covers identification of supply to demand causality is identical to the standard BQ model (by a factor) and so the impulse responses (and variance decompositions) are not reported. With causality from demand to supply the supply responses differ only in magnitude since a supply shock causes no other movement (and the normalisations of shocks used for the calculation of impulses differ).

The relative changes under the P2 regime (figure 53) are similar. Whereas under the BQ decomposition (figure 34) the instantaneous output response to a supply shock was largest again with the Cover decomposition this is no longer the case: the instantaneous output movement is now greatest in response to a demand shock and the movement is some three times larger in the Cover decomposition than was the case in the BQ decomposition. The relative instantaneous movement for prices is reversed. In the P2 regime (figure 53) in response to a demand shock the instantaneous movement of prices is very small compared to the movement under the standard BQ decomposition (figure 34). Under the P1 regime for this particular case only, the initial movement of prices is negative. This point is deliberately raised to be addressed as it points to a possibility that the model is misidentified in this case.

Figure 45: P1: SE Impulse Cover Decomposition Demand to Supply Causality

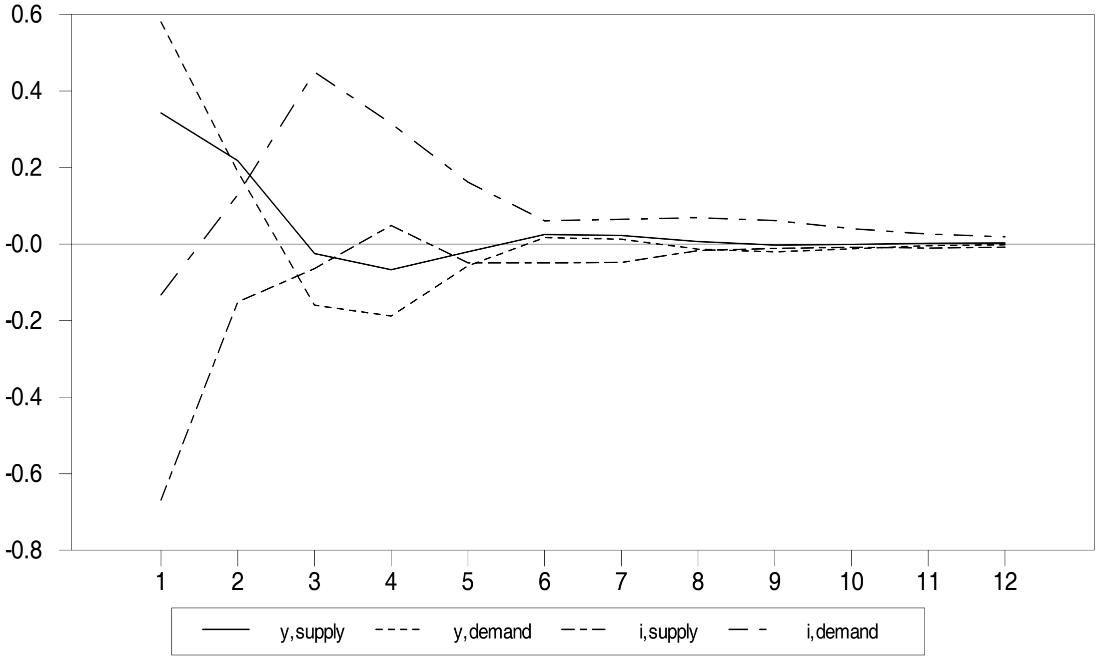


Figure 46: P2: SE Impulse Cover Decomposition Demand to Supply Causality

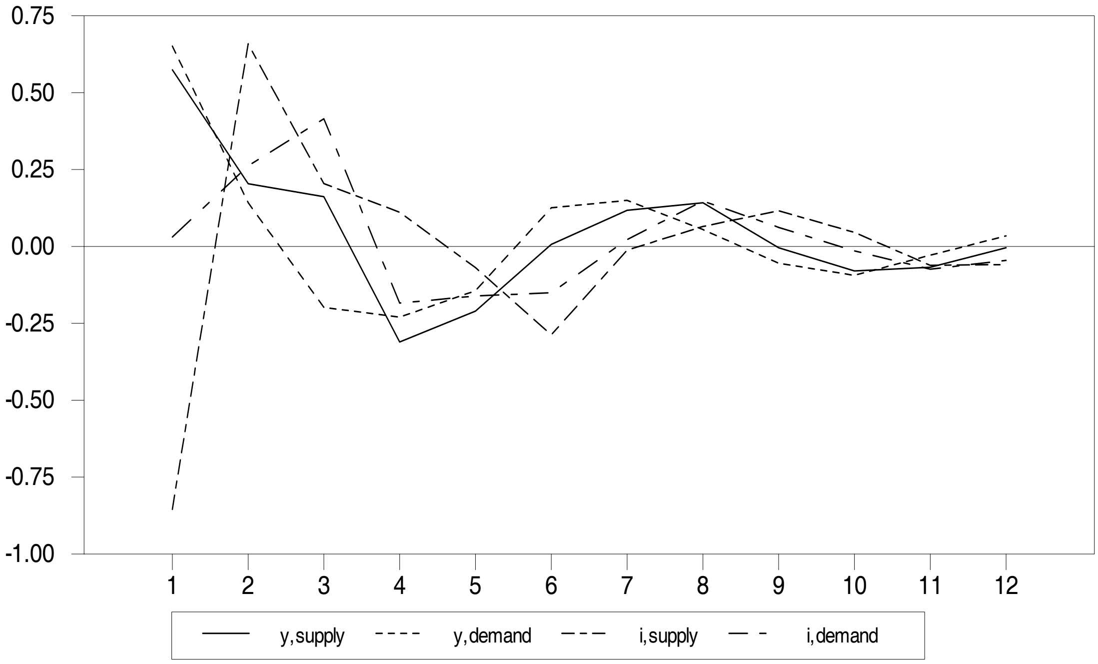


Figure 47: P1: SE Cumulative Cover Decomposition Demand to Supply Causality

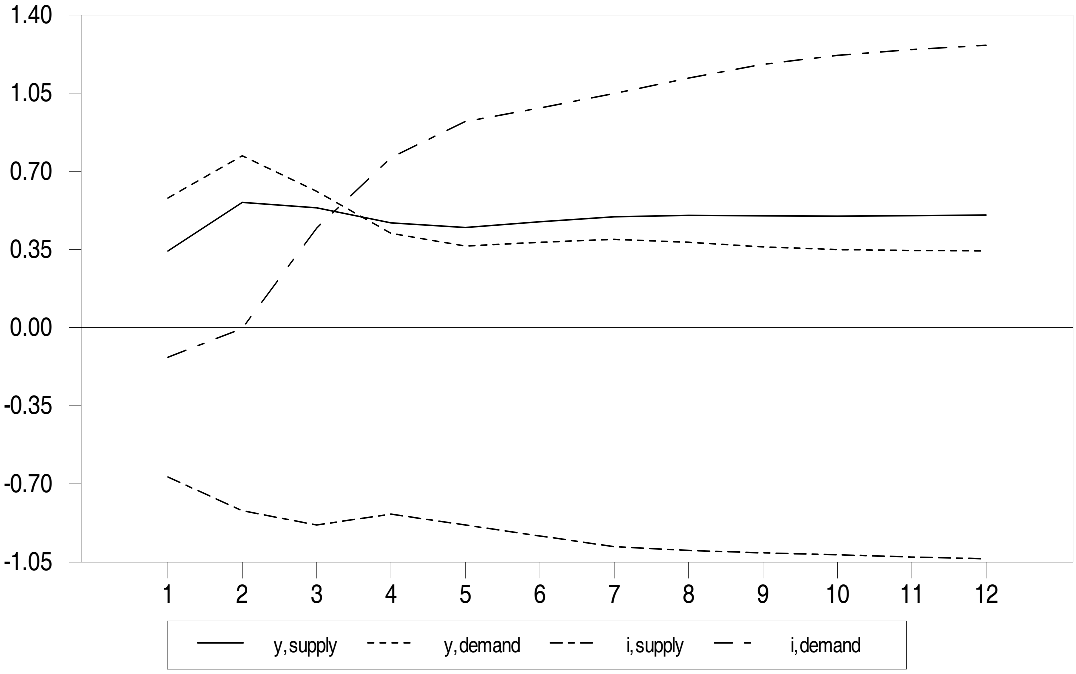


Figure 48: P2: SE Cumulative Cover Decomposition Demand to Supply Causality

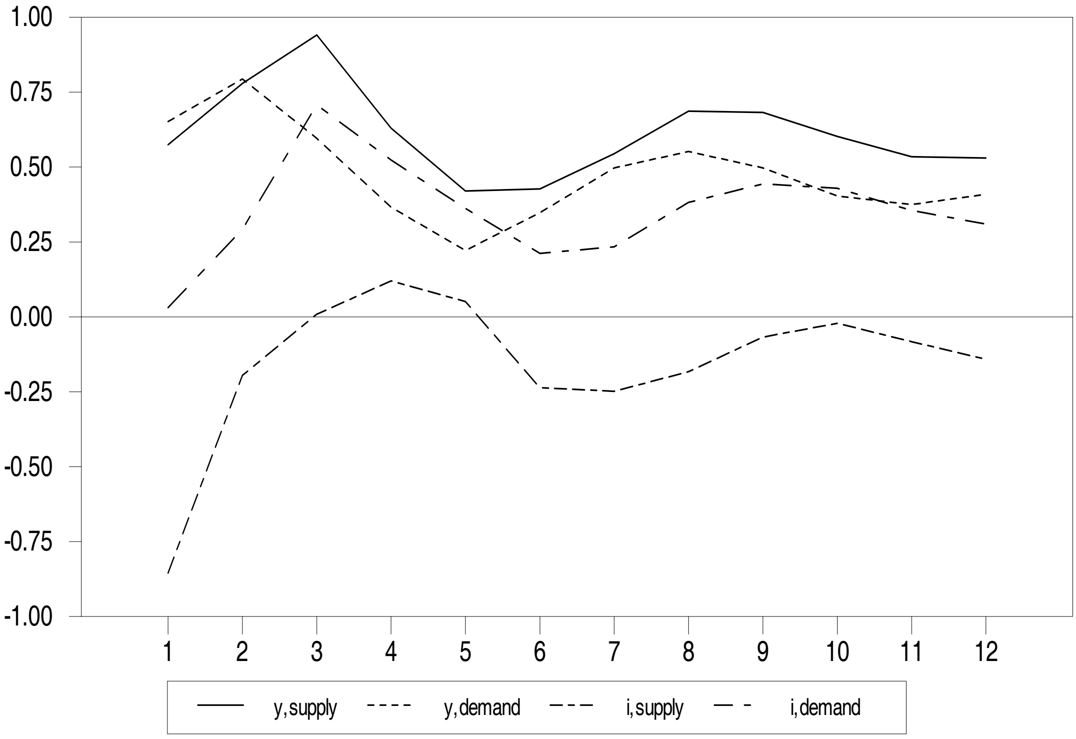


Figure 49: P1: Yorkshire Impulse Cover Decomposition Demand to Supply Causality

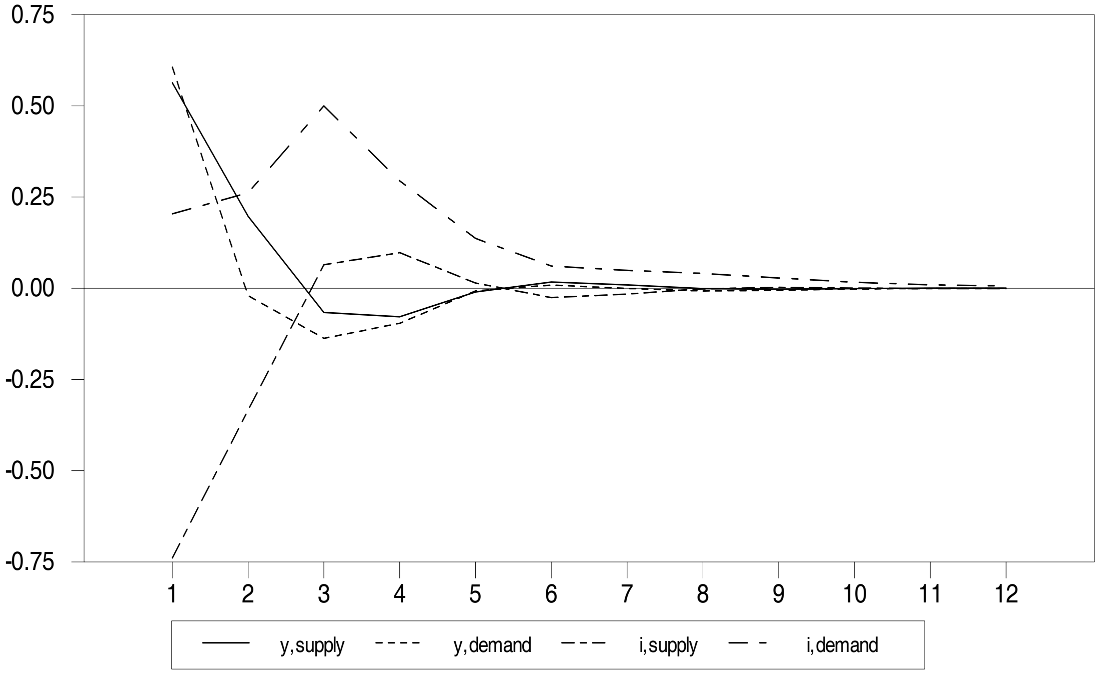


Figure 50: P2: Yorkshire Impulse Cover Decomposition Demand to Supply Causality

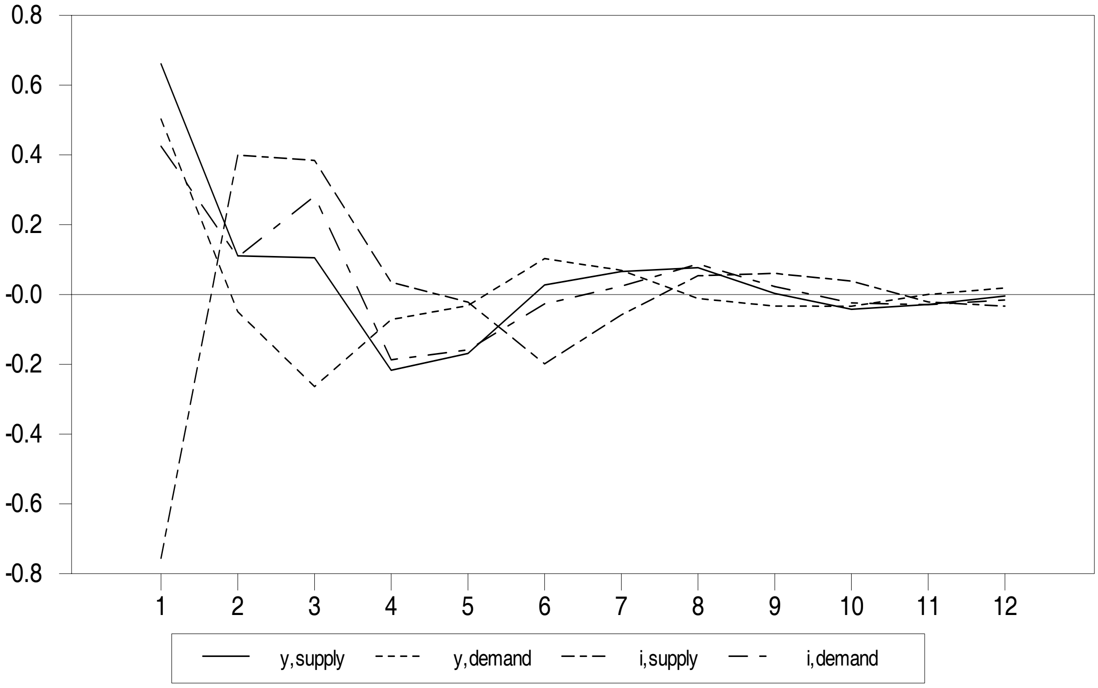


Figure 51: P1: Yorkshire Cumulative Cover Decomposition Demand to Supply Causality

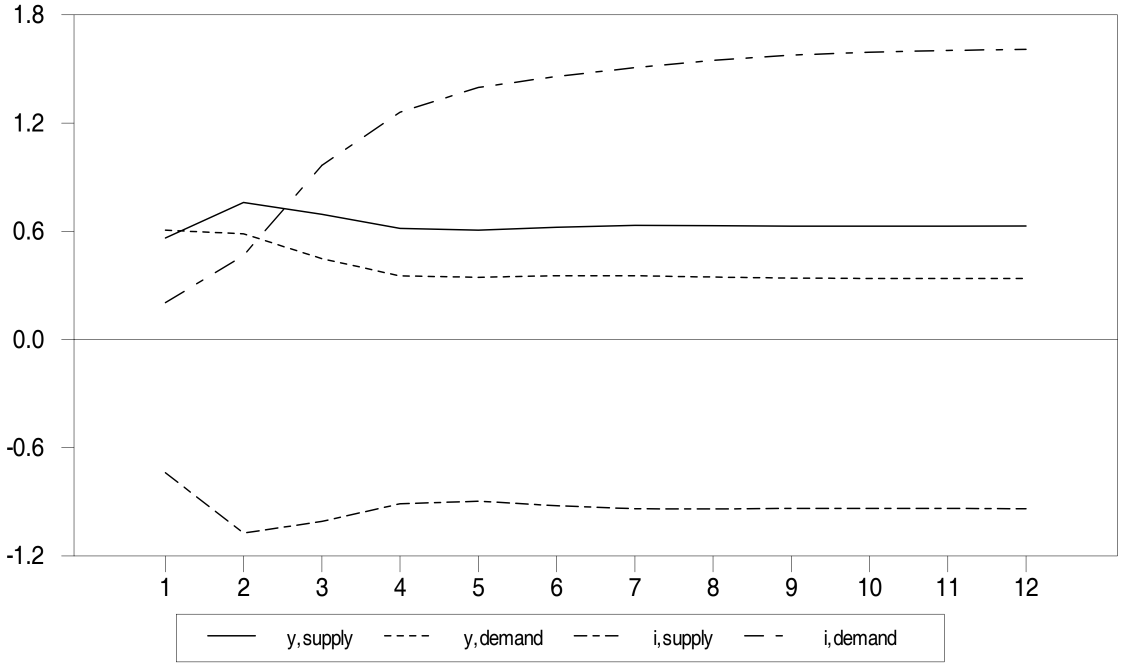


Figure 52: P2: Yorkshire Cumulative Cover Decomposition Demand to Supply Causality

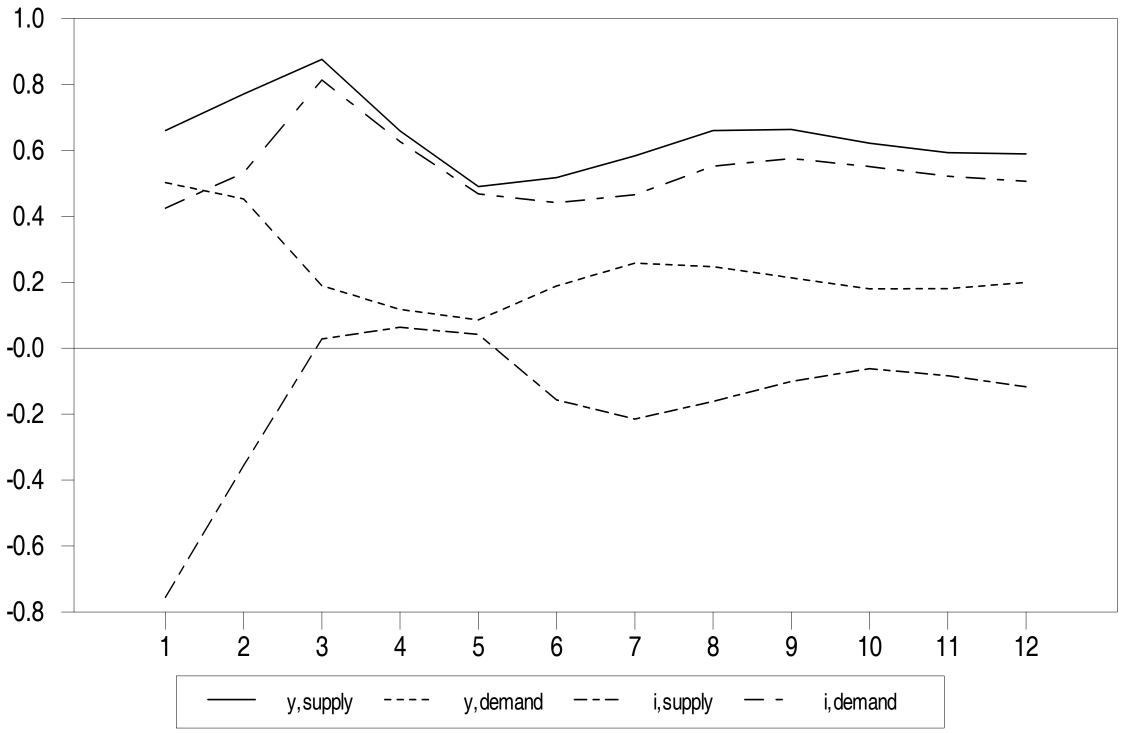


Figure 53: P1: NE Impulse Cover Decomposition Demand to Supply Causality

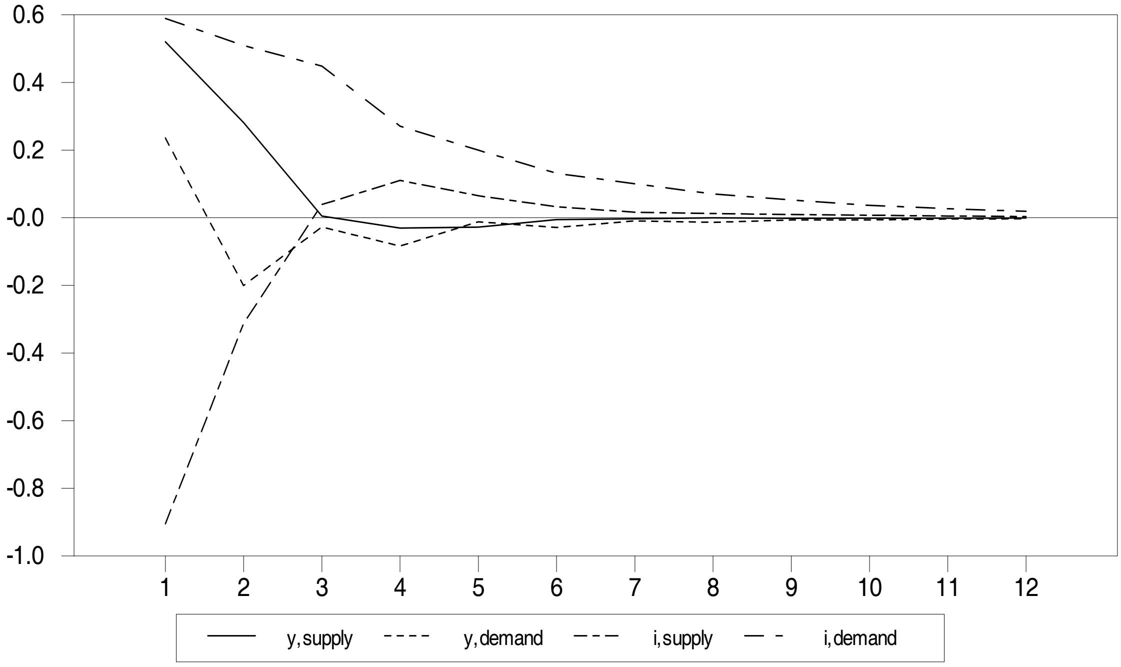


Figure 54: P2: NE Impulse Cover Decomposition Demand to Supply Causality

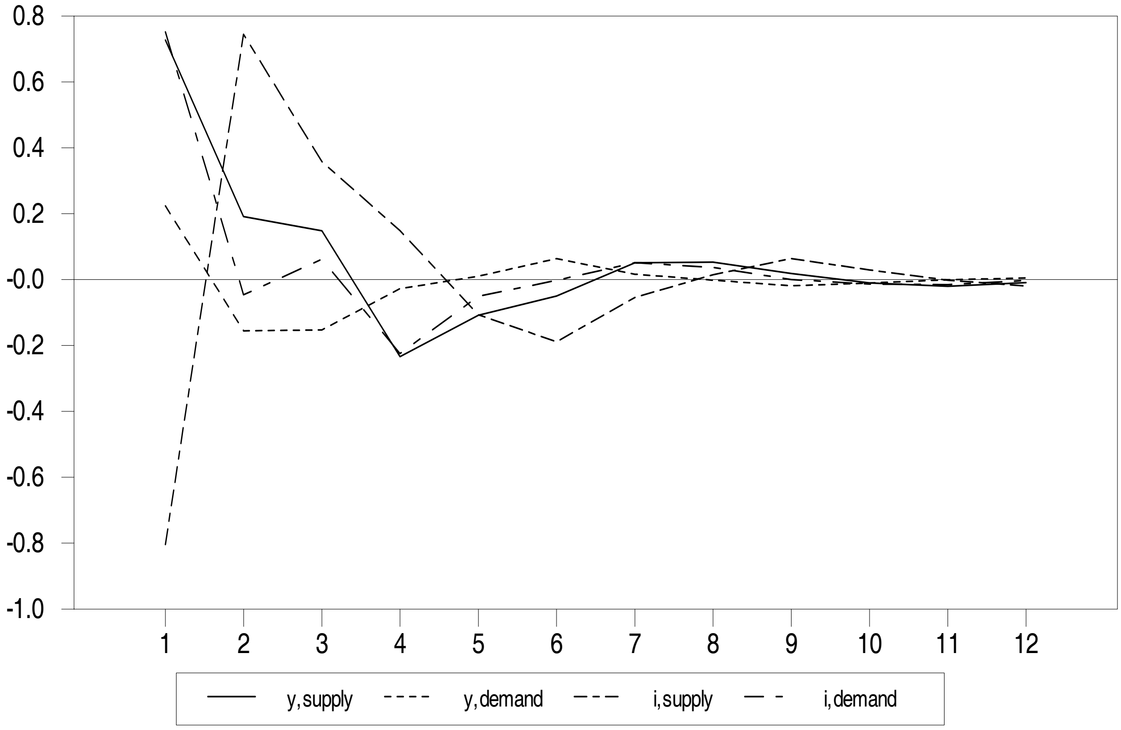


Figure 55: P1: NE Cumulative Cover Decomposition Demand to Supply Causality

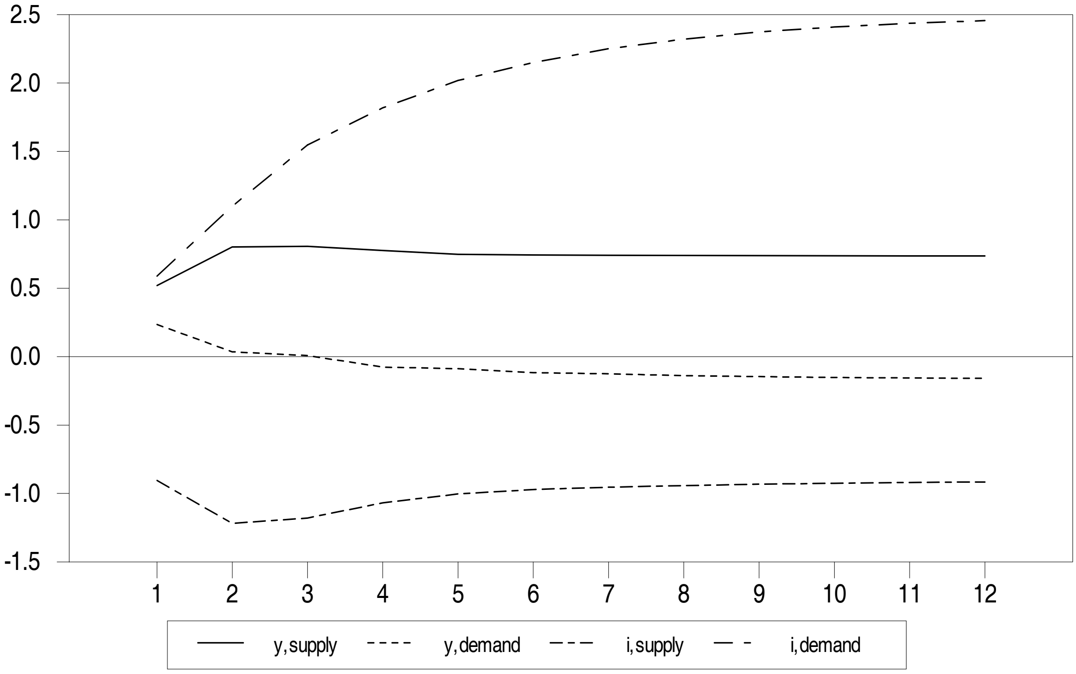
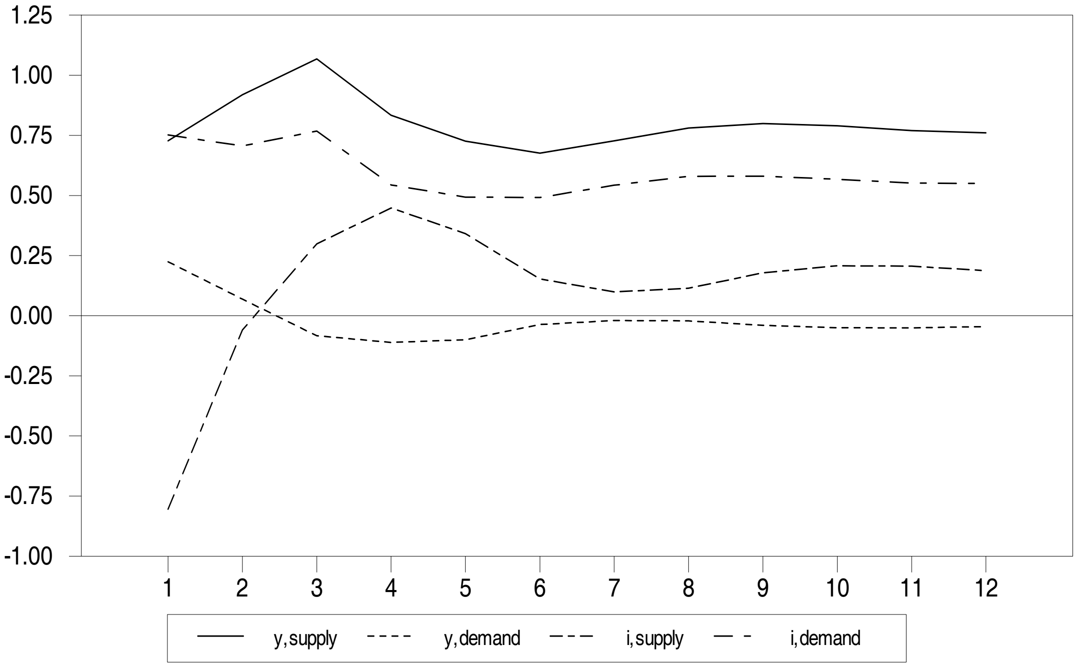


Figure 56: P2: NE Cumulative Cover Decomposition Demand to Supply Causality



There are two probable explanations. The first recalls that it was the South East where using the LR statistic a lag length of four was indicated. For the other regions the LR statistic suggested a lag length of two and a common 2 lag estimation was chosen for comparative purposes. The second recalls that this regime has differenced price just once. Recalling that unit roots tests suggested the probability (for this particular choice of time) that prices were integrated of order two to induce stationarity (the model is only identified if the variables are in stationary form) this result may indicate misidentification is due to a lack of stationarity in the price series. If that was the case then the complete set of results from the P1 regime ought to be disregarded. However, this is not done and they have been reproduced as the similarity of relative results across regimes in the author's view reinforces the conclusions made.

The value of γ reported for the South East under the P1 regime (greater than 1) this suggests a more than 1 for 1 movement in supply. Another interpretation would be that such a movement in supply leads to the effect from the supply shock dominating the instantaneous inflation movement and hence causes the initial (small) negative movement.

For the representative of the middling group, Yorkshire, it can be seen that the size of the relative shifts are somewhat lessened when compared to those of the South East. This is to be anticipated, Yorkshire having a value for gamma at just over a half of that for reported for the SE under the P1 regime and less than a half of that of the SE under the P2 regime.

Figure 56 illustrates the impulse response function for Yorkshire under the P1 regime. Again it can be seen that the relative sizes of the instantaneous output response to a demand shock and supply shock have changed when compared to the original BQ decomposition – ie that now the instantaneous output movement to a demand shock is larger than the instantaneous output response to a supply shock. Figure 57 illustrates that this relative reversal does not quite occur under the P2 regime. This is to be anticipated, the value of gamma (the size of the induced co-movement of supply with demand) was estimated to be 0.42 whereas under the P1 regime it was estimated to be 0.69. Nevertheless the absolute change in instantaneous response is still significant, being an increase of 80% over the movement under the BQ decomposition.

The instantaneous movement in price to a demand shock is also changed significantly, halving under the P2 regime and dropping by some two thirds under the P1 regime (when compared to the original BQ movements). These movements clearly demonstrating the relation of the relative size of the shifts across these two regions to the reported values of gamma (the degree of co-movement of supply with demand shocks).

With the North East having a value of gamma under both regimes not too different from zero it is understandable that there is little relative change in instantaneous responses between the two decompositions.

This therefore clearly illustrates a route whereby demand shocks have a greater significance in effecting output movements than under the BQ identification. Significantly it opens up the route that was discussed in the introduction for demand shocks to have permanent effects. As can be seen from figure 54 or 55 for the South East the cumulative response of output is now non-negative. This is also the case for Yorkshire (where the response is (slightly) less) but not for the North East where no co-movement has been induced.

The increased role for demand shocks can be better illustrated with a review of the variance decompositions: tables 14 to 19 (for the rest of the regions these are reported in the appendices). In the case of the South East under the standard BQ decomposition demand shocks have a marginal contribution in the short term and supply shocks account for over around 90% of output variance at the twelve year horizon for both the P1 and P2 regimes (table 14). This accords with previous research such as Gali (1994) who attributes the majority of long run output variance to supply shocks.

Table 14: SE Variance Decomposition Output (P1 & P2)

P1	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.90	0.10	0.26	0.74
2	0.92	0.08	0.31	0.69
3	0.90	0.10	0.29	0.71
4	0.89	0.11	0.28	0.72
5	0.89	0.11	0.28	0.72
6	0.89	0.11	0.28	0.72
7	0.89	0.11	0.28	0.72
8	0.89	0.11	0.28	0.72
9	0.89	0.11	0.28	0.72
10	0.89	0.11	0.28	0.72
11	0.89	0.11	0.28	0.72
12	0.89	0.11	0.28	0.72

P2	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.98	0.02	0.44	0.56
2	0.98	0.02	0.46	0.54
3	0.90	0.10	0.45	0.55
4	0.92	0.08	0.48	0.52
5	0.92	0.08	0.49	0.51
6	0.92	0.08	0.48	0.52
7	0.92	0.08	0.48	0.52
8	0.92	0.08	0.49	0.51
9	0.92	0.08	0.49	0.51
10	0.92	0.08	0.49	0.51
11	0.92	0.08	0.49	0.51
12	0.92	0.08	0.49	0.51

Table 15: Yks Variance Decomposition Output (P1 & P2)

P1	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.93	0.07	0.46	0.54
2	0.91	0.09	0.49	0.51
3	0.90	0.10	0.48	0.52
4	0.90	0.10	0.48	0.52
5	0.90	0.10	0.48	0.52
6	0.90	0.10	0.48	0.52
7	0.90	0.10	0.48	0.52
8	0.90	0.10	0.48	0.52
9	0.90	0.10	0.48	0.52
10	0.90	0.10	0.48	0.52
11	0.90	0.10	0.48	0.52
12	0.90	0.10	0.48	0.52

P2	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.91	0.09	0.63	0.37
2	0.91	0.09	0.64	0.36
3	0.82	0.18	0.59	0.41
4	0.83	0.17	0.61	0.39
5	0.84	0.16	0.62	0.38
6	0.83	0.17	0.61	0.39
7	0.83	0.17	0.61	0.39
8	0.83	0.17	0.61	0.39
9	0.83	0.17	0.61	0.39
10	0.83	0.17	0.61	0.39
11	0.83	0.17	0.61	0.39
12	0.83	0.17	0.61	0.39

Table 16: NE Variance Decomposition Output (P1 & P2)

P1	BQ		Cov	
	Ysup	**Ydem**	**Ysup**	**Ydem**
1	0.77	0.23	0.83	0.17
2	0.76	0.24	0.79	0.21
3	0.76	0.24	0.78	0.22
4	0.75	0.25	0.77	0.23
5	0.75	0.25	0.77	0.23
6	0.75	0.25	0.77	0.23
7	0.75	0.25	0.77	0.23
8	0.75	0.25	0.77	0.23
9	0.75	0.25	0.77	0.23
10	0.75	0.25	0.77	0.23
11	0.75	0.25	0.77	0.23
12	0.75	0.25	0.77	0.23

P2	BQ		Cov	
	Ysup	**Ydem**	**Ysup**	**Ydem**
1	0.90	0.10	0.91	0.09
2	0.88	0.12	0.88	0.12
3	0.87	0.13	0.86	0.14
4	0.88	0.12	0.87	0.13
5	0.88	0.12	0.87	0.13
6	0.88	0.12	0.86	0.14
7	0.88	0.12	0.87	0.13
8	0.88	0.12	0.87	0.13
9	0.88	0.12	0.87	0.13
10	0.88	0.12	0.87	0.13
11	0.88	0.12	0.87	0.13
12	0.88	0.12	0.87	0.13

Table 17: SE Variance Decomposition Prices (P1 & P2)

P1	BQ		Cov	
	Psup	**Pdem**	**Psup**	**Pdem**
1	0.75	0.25	0.96	0.04
2	0.69	0.31	0.93	0.07
3	0.58	0.42	0.67	0.33
4	0.58	0.42	0.59	0.41
5	0.57	0.43	0.57	0.43
6	0.56	0.44	0.57	0.43
7	0.56	0.44	0.57	0.43
8	0.56	0.44	0.56	0.44
9	0.55	0.45	0.56	0.44
10	0.55	0.45	0.56	0.44
11	0.55	0.45	0.56	0.44
12	0.55	0.45	0.56	0.44

P2	BQ		Cov	
	Psup	**Pdem**	**Psup**	**Pdem**
1	0.55	0.45	1.00	0.00
2	0.69	0.31	0.94	0.06
3	0.71	0.29	0.83	0.17
4	0.69	0.31	0.82	0.18
5	0.69	0.31	0.80	0.20
6	0.71	0.29	0.80	0.20
7	0.71	0.29	0.80	0.20
8	0.71	0.29	0.79	0.21
9	0.71	0.29	0.79	0.21
10	0.71	0.29	0.79	0.21
11	0.71	0.29	0.79	0.21
12	0.71	0.29	0.79	0.21

Table 18: Yks Variance Decomposition Prices (P1 & P2)

P1	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.46	0.54	0.93	0.07
2	0.39	0.61	0.86	0.14
3	0.38	0.62	0.65	0.35
4	0.39	0.61	0.6	0.4
5	0.39	0.61	0.59	0.41
6	0.39	0.61	0.59	0.41
7	0.39	0.61	0.59	0.41
8	0.39	0.61	0.59	0.41
9	0.39	0.61	0.59	0.41
10	0.39	0.61	0.59	0.41
11	0.39	0.61	0.59	0.41
12	0.39	0.61	0.59	0.41

P2	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.42	0.58	0.76	0.24
2	0.53	0.47	0.79	0.21
3	0.61	0.39	0.76	0.24
4	0.60	0.40	0.74	0.26
5	0.59	0.41	0.73	0.27
6	0.60	0.40	0.73	0.27
7	0.60	0.40	0.73	0.27
8	0.60	0.40	0.73	0.27
9	0.60	0.40	0.73	0.27
10	0.60	0.40	0.73	0.27
11	0.60	0.40	0.73	0.27
12	0.60	0.40	0.73	0.27

Table 19: NE Variance Decomposition Prices (P1 & P2)

P1	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.77	0.23	0.7	0.3
2	0.58	0.42	0.6	0.4
3	0.49	0.51	0.53	0.47
4	0.48	0.52	0.51	0.49
5	0.48	0.52	0.5	0.5
6	0.47	0.53	0.5	0.5
7	0.47	0.53	0.5	0.5
8	0.47	0.53	0.5	0.5
9	0.47	0.53	0.49	0.51
10	0.47	0.53	0.49	0.51
11	0.47	0.53	0.49	0.51
12	0.47	0.53	0.49	0.51

P2	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.56	0.44	0.53	0.47
2	0.75	0.25	0.68	0.32
3	0.78	0.22	0.70	0.30
4	0.76	0.24	0.69	0.31
5	0.76	0.24	0.69	0.31
6	0.77	0.23	0.69	0.31
7	0.77	0.23	0.69	0.31
8	0.77	0.23	0.69	0.31
9	0.77	0.23	0.69	0.31
10	0.77	0.23	0.69	0.31
11	0.77	0.23	0.69	0.31
12	0.77	0.23	0.69	0.31

Demand shocks have a greater contribution to price variance and account for 45% of variance of prices at the twelve year horizon in the P1 regime and just under a third, at 29%, in the P2 regime.

The contrast with the Cover's decomposition is stark. For the South East demand shocks now account for some 72% of output variance at the long run horizon in the P1 regime (table 14) and 49% of output in the P1 regime. Consistent with the impulse responses of prices reported previously (where the instantaneous price response to a demand shock was reduced) demand shock contribution to price variance is significantly diminished (table 17) at the short run horizon where the effects for the first two periods is somewhat negligible.

The contrast with the variance decompositions of Yorkshire and the North East is instructive and also easily intuitive. In the case of Yorkshire (table 15) again demand has a greater role to play in output variations at the long run horizon but the increase somewhat less than was the case for the South East. Demand accounts for circa 52% and 39% of output variance at the long run horizon for the P1 and P2 regimes respectively compared to 72% and 51% in the case of the South East. Again explained by the lesser estimated values of the co-movement parameter, gamma. The contribution of demand to price variance is diminished not just at the short run horizon but also now at the long run horizon where they now account for 41% and 27% of price variance (table 18). This is a larger drop from the corresponding BQ estimates than demonstrated for the South East although the original levels in the BQ case were somewhat higher. For the North East there is little change in variance decomposition across the two identification schemes (tables 16 and 19) as would be expected given the values reported for its co-movement coefficient are little different from zero.

Finally, referring back to the point estimates row three in tables 7 to 12 it can be seen in the P2 regime the size of the independent structural supply shock variance is some 58%, 87% and more or less 100% of the total supply shock variance for the South East, Yorkshire and the North East respectively. This implies the remainder is accounted for by variance induced by structural demand shocks ie demand shocks are accounting for the variance of 42% 13% and zero percent of supply shock variance – ie induced movements. For the P1 regime the relative size of the independent supply shock to the total supply shock variance is 56%, 72 % and more or less 100% for the South East, Yorkshire and the North East respectively. Again the effects are dampened by the additional differencing. It is significant that the results under the P1 regime are of a similar scale reported in Cover's paper where the contributions of demand shocks were able to account for some 80% in output variance in the long term.

Table 20: P1 Cover Supply Shock Correlations

	EA	EM	NE	NW	SCO	SE	SW	WAL	WM	YKS
EA	1.00	0.41	0.41	0.65	0.51	0.53	0.46	0.40	0.50	0.44
EM	0.41	1.00	0.86	0.70	0.57	0.49	0.78	0.82	0.58	0.92
NE	0.41	0.86	1.00	0.73	0.69	0.64	0.79	0.67	0.58	0.82
NW	0.65	0.70	0.73	1.00	0.77	0.83	0.60	0.71	0.89	0.79
SCO	0.51	0.57	0.69	0.77	1.00	0.78	0.66	0.62	0.73	0.69
SE	0.53	0.49	0.64	0.83	0.78	1.00	0.36	0.37	0.79	0.56
SW	0.46	0.78	0.79	0.60	0.66	0.36	1.00	0.78	0.40	0.78
WAL	0.40	0.82	0.67	0.71	0.62	0.37	0.78	1.00	0.55	0.85
WM	0.50	0.58	0.58	0.89	0.73	0.79	0.40	0.55	1.00	0.69
YKS	0.44	0.92	0.82	0.79	0.69	0.56	0.78	0.85	0.69	1.00
									Avge	**0.68**

Table 21: P1 Cover Demand Correlations

	EA	EM	NE	NW	SCO	SE	SW	WAL	WM	YKS
EA	1.00	0.86	0.82	0.61	n/a	0.38	0.81	0.84	0.48	0.80
EM	0.86	1.00	0.86	0.79	n/a	0.66	0.90	0.92	0.64	0.83
NE	0.82	0.86	1.00	0.61	n/a	0.52	0.90	0.79	0.47	0.85
NW	0.61	0.79	0.61	1.00	n/a	0.84	0.76	0.83	0.84	0.87
SCO	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SE	0.38	0.66	0.52	0.84	n/a	1.00	0.66	0.66	0.81	0.74
SW	0.81	0.90	0.90	0.76	n/a	0.66	1.00	0.83	0.56	0.89
WAL	0.84	0.92	0.79	0.83	n/a	0.66	0.83	1.00	0.65	0.85
WM	0.48	0.64	0.47	0.84	n/a	0.81	0.56	0.65	1.00	0.72
YKS	0.80	0.83	0.85	0.87	n/a	0.74	0.89	0.85	0.72	1.00
									Avge	**0.77**

Table 22: P1 Cover Supply Shock Correlations

	EA	EM	NE	NW	SCO	SE	SW	WAL	WM	YKS
EA	1.00	0.34	0.29	0.39	0.23	0.26	0.50	0.17	0.28	0.37
EM	0.34	1.00	0.85	0.65	0.58	0.37	0.79	0.48	0.91	0.83
NE	0.29	0.85	1.00	0.50	0.63	0.37	0.77	0.32	0.74	0.65
NW	0.39	0.65	0.50	1.00	0.56	0.84	0.77	0.88	0.72	0.68
SCO	0.23	0.58	0.63	0.56	1.00	0.57	0.69	0.47	0.70	0.57
SE	0.26	0.37	0.37	0.84	0.57	1.00	0.53	0.76	0.47	0.33
SW	0.50	0.79	0.77	0.77	0.69	0.53	1.00	0.57	0.82	0.82
WAL	0.17	0.48	0.32	0.88	0.47	0.76	0.57	1.00	0.65	0.50
WM	0.28	0.91	0.74	0.72	0.70	0.47	0.82	0.65	1.00	0.87
YKS	0.37	0.83	0.65	0.68	0.57	0.33	0.82	0.50	0.87	1.00
									Avge	**0.62**

Table 23: P2 Cover Demand Correlations

	EA	EM	NE	NW	SCO	SE	SW	WAL	WM	YKS
EA	1.00	0.77	0.74	0.54	0.72	0.48	0.74	0.76	0.50	0.69
EM	0.77	1.00	0.86	0.69	0.73	0.79	0.93	0.90	0.66	0.83
NE	0.74	0.86	1.00	0.66	0.79	0.71	0.90	0.80	0.60	0.86
NW	0.54	0.69	0.66	1.00	0.69	0.87	0.78	0.77	0.79	0.90
SCO	0.72	0.73	0.79	0.69	1.00	0.64	0.78	0.77	0.75	0.72
SE	0.48	0.79	0.71	0.87	0.64	1.00	0.83	0.79	0.80	0.87
SW	0.74	0.93	0.90	0.78	0.78	0.83	1.00	0.87	0.72	0.91
WAL	0.76	0.90	0.80	0.77	0.77	0.79	0.87	1.00	0.70	0.87
WM	0.50	0.66	0.60	0.79	0.75	0.80	0.72	0.70	1.00	0.75
YKS	0.69	0.83	0.86	0.90	0.72	0.87	0.91	0.87	0.75	1.00
									Avge	**0.78**

Above a ‘triangular’ case has been presented for demand shocks having an increased role in output movements under the Cover decomposition. Once the ‘homogenous’ restriction of the BQ decomposition is relaxed and co-movements between supply and demand are allowed for these results demonstrate how demand shocks as evidenced by: impulse response analysis; variance decomposition analysis; and structural shock variance accounting; do account for a much greater share of output movements. Separately and significantly for this thesis, the effect is heterogeneous across regions.

As a confirmation that it is the heterogeneous reaction to shocks and not different timing of shocks hitting the regions the correlations of the structural estimates of demand and supply shocks (tables 20 to 23) and Granger causality tests (tables 24 and 25) are produced. These show if anything that the correlations of shocks is higher and the absence of evidence of granger causality to be greater than under the standard BQ model.

Table 24: Granger Causality (marginal significance) Supply and Demand Shocks (Cover decomposition) P1

Supply Region	Cover SE to R	R to SE	Demand Region	Cover SE to R	R to SE
EA	0.473	0.981	EA	0.692	0.829
EM	0.047	0.084	EM	0.322	0.670
NW	0.496	0.140	NW	0.230	0.836
Sco	0.107	0.660	Sco	0.721	0.185
SW	0.167	0.112	SW	0.225	0.539
Wal	0.210	0.147	Wal	0.114	0.643
WM	0.213	0.030	WM	0.796	0.770
Yks	0.027	0.107	Yks	0.197	0.886
NE	0.109	0.078	NE	0.451	0.420

Table 25: Granger Causality (marginal significance) Supply and Demand Shocks (Cover decomposition) P2

Supply Region	Cover SE to R	R to SE	Demand Region	Cover SE to R	R to SE
EA	0.473	0.981	EA	0.692	0.829
EM	0.047	0.084	EM	0.322	0.670
NW	0.496	0.140	NW	0.230	0.836
Sco	0.107	0.660	Sco	0.721	0.185
SW	0.167	0.112	SW	0.225	0.539
Wal	0.210	0.147	Wal	0.114	0.643
WM	0.213	0.030	WM	0.796	0.770
Yks	0.027	0.107	Yks	0.197	0.886
NE	0.109	0.078	NE	0.451	0.420

5.5 Constructing Demand and Supply Curves from Cumulative Responses

An alternative presentation (as outlined by Funke and Hall) of the movement in the output / price space as suggested by the cumulative impulse response functions is presented as an interesting illustration of the different implications of the two decompositions.

Intuitively speaking a supply shock results in a movement along (down) the demand curve and similarly a demand shock results in a movement along (up) the short run aggregate supply curve. Therefore a plot of the cumulative impulse response of prices versus output subsequent to a demand (supply) shock provides a crude representation of the dynamics in the prices/output space and thus provides a visual representation of the supply (demand) curve.

For pedagogical purposes this is best first explained by reference to a simple model of aggregate demand and aggregate supply. Figures 45 and 46 explain the dynamics as suggested by the results from the Blanchard Quah decomposition.

As is seen in figure 57, the effect of a demand shock is a movement along the short run aggregate supply curve followed by a movement back along the aggregate demand curve to return to the long run (vertical) aggregate supply curve (A→B→C). In the case of an aggregate supply shock the movement is

Figure 57: Effect of a Demand Shock (BQ decomposition)

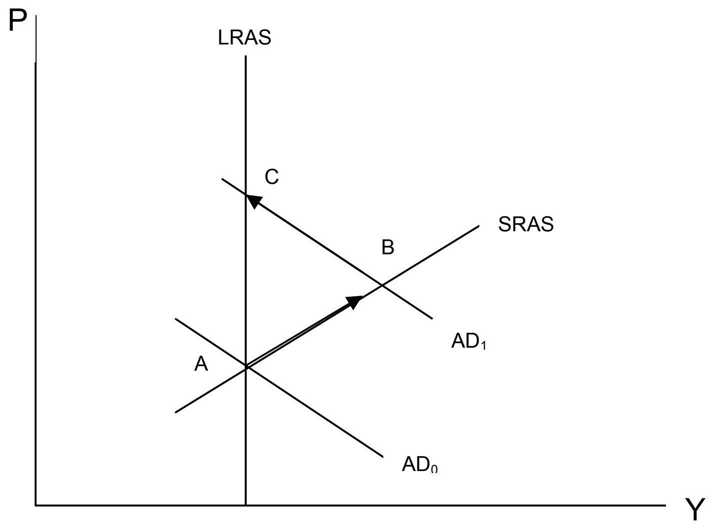
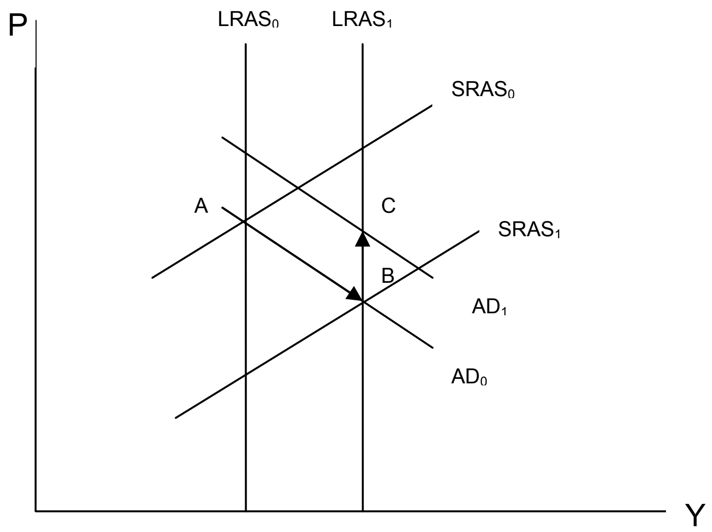
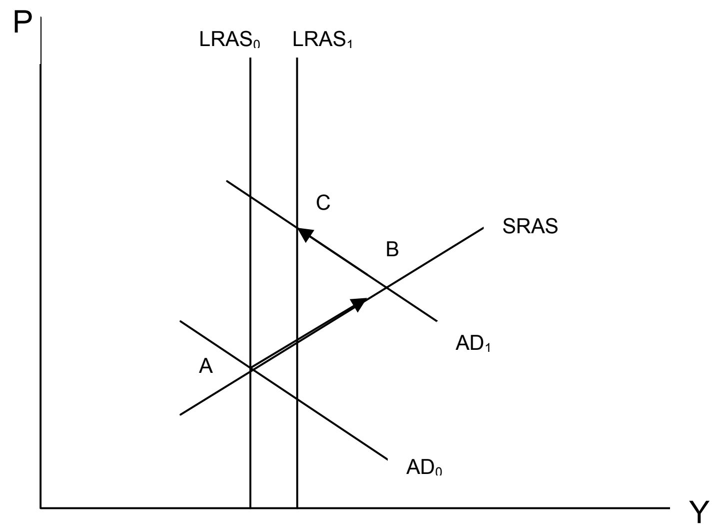


Figure 58: Effect of a Supply Shock (BQ decomposition)



along the aggregate demand curve to the new long run aggregate supply curve. The second stage is a movement up the new long run aggregate supply curve caused by a subsequent shift in aggregate demand which can negate to some or a complete extent the price fall induced by the supply shift (A→B→C) (figure 58).

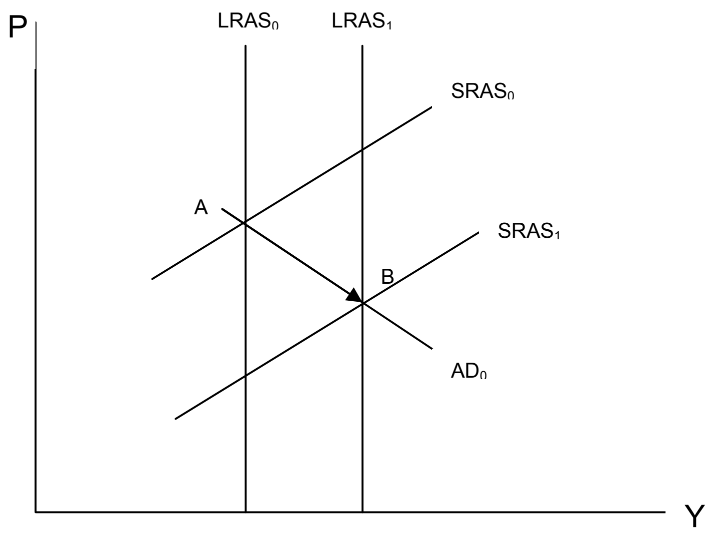
Figure 59: Effect of a Demand Shock (Covers decomposition)



For the Covers decomposition (the case of demand to supply causality only is outlined as this is the causality of interest to the analysis) figure 59 outlines the effect of a demand shock. Again there is movement along the short run aggregate supply curve. However, the subsequent movement back along the aggregate demand curve is less as the long run aggregate supply curve has been allowed to shift in response to the demand shock.

The case for a supply shock in the case of the Covers decomposition is simple (figure 60), a straight movement down the aggregate demand curve to the new long run aggregate supply. By construction causality has been completely attributed as running from demand to supply and hence rules out a co-movement of the demand curve induced by the supply shock.

Figure 60: Effect of a Supply Shock (Covers decomposition)



As can be seen from figures 61 to 63[16] below, the movements subsequent to a demand and supply shock trace out the movements described above.

In each case following a supply shock a movement down the demand curve occurs followed by in the case of the BQ decomposition a movement up the new long run aggregate supply curve.

Following a demand shock in the case of the traditional BQ decomposition the movement back along the aggregate demand curve to the long run aggregate

[16] These three regions have been chosen for a comparative purposes to illustrate three different 'cases' as evidenced by the estimated results.

Figure 61: South East, ASAD Curves

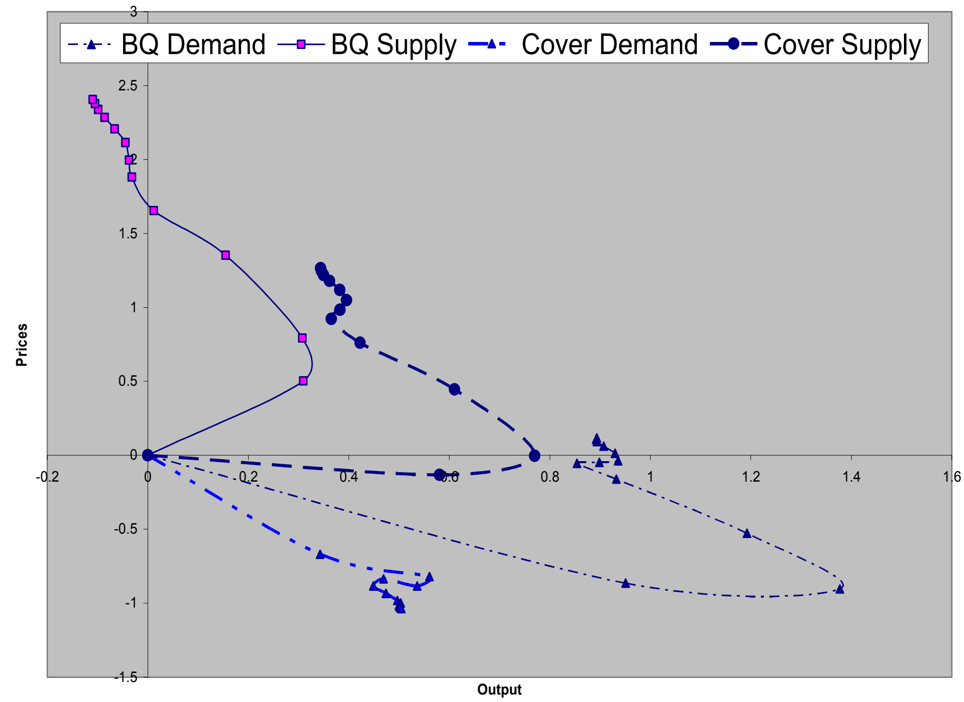


Figure 62: North East, ASAD Curves

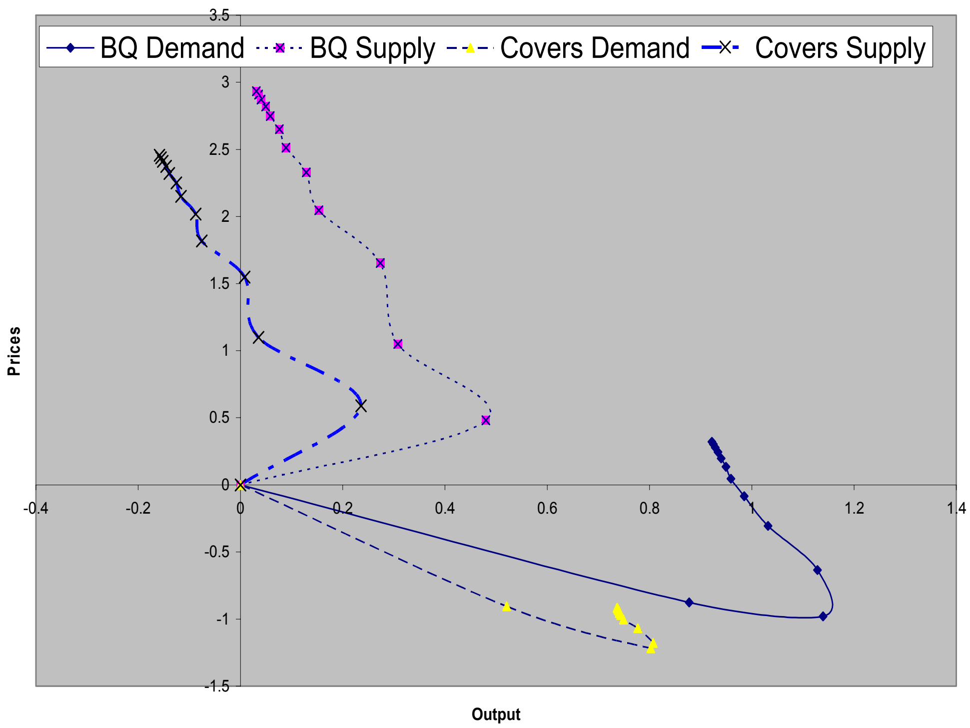
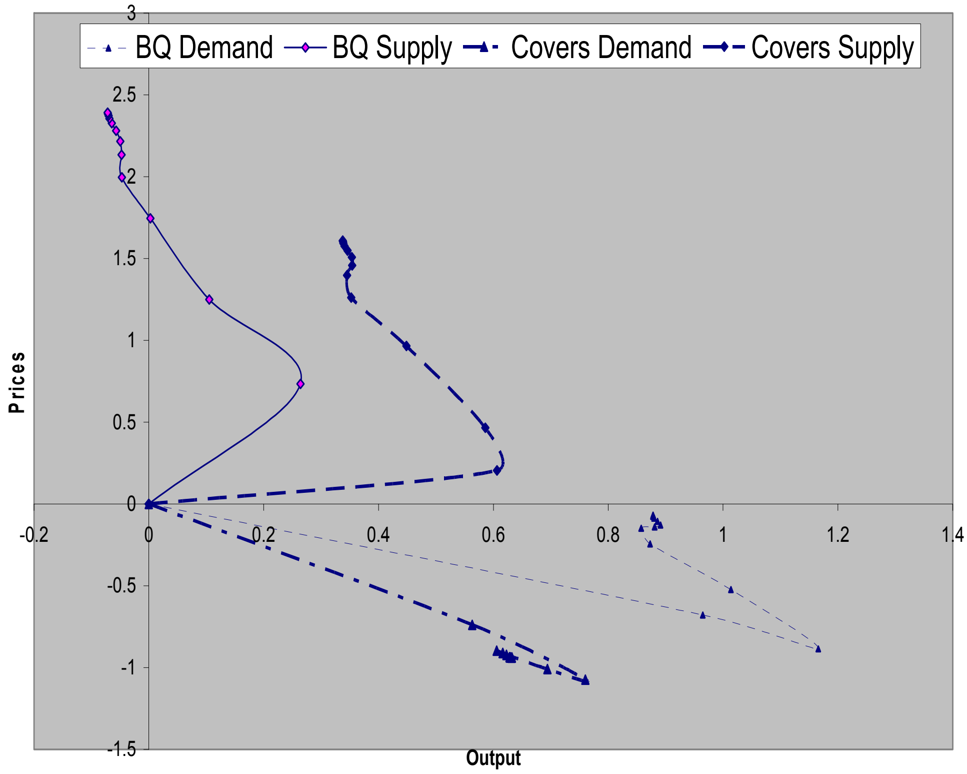


Figure 63: Yks ASAD Curves



supply curve can be seen illustrating that the demand shock has no long run effect on output. However, in the case of Covers as can be seen in both the Yorkshire and South East cases, this movement back along the aggregate demand curve is 'choked off' by the induced movement in the long run aggregate supply curve. It should be noted that this is not the case for the North East. This is because the results reported earlier indicate no (or close to zero) induced co-movement in the aggregate supply curve from the estimates for the North East.

5.6 Conclusion

The key contribution of the research of this chapter has been to demonstrate firstly that demand side shocks can have heterogeneous effects on the regions and secondly how this effect varies across the regions. Once the homogeneity restriction has been lifted it can be seen that demand side shocks can contribute to heterogeneity by the differing size of the induced co movement of supply by the demand side shock. It was clearly shown that all the evidence from both decompositions was that both demand and supply shocks hit the regions simultaneously and differences in dynamics was caused by the responses of the regions to the same shock.

This co movement is key. It demonstrates that this effect is not merely a short run phenomenon as can be seen from the cumulative response functions under the Covers decomposition. The co-movement induces a movement in supply and hence is a permanent effect. This implication is not innocuous as it opens up the avenue for demand shocks to have a long run effect on the output performance of the regions through the cumulative increased supply response from a series of demand side shocks or vice versa.

The intuition for this long run effect is backed up by the variance decomposition analysis. The results clearly showed that under the Covers 'co-movement' decomposition the long run share of output variance accounted for by demand shocks increased significantly: by up to 80%. This was further supported by the 'structural shock accounting' whereby it was shown that with the demand shock could be accountable for up to 45% of the supply movement variance.

This is the 'triangular' case has been presented for demand shocks having an increased role in output movements under the Cover decomposition.

The second component of the contribution of this chapter of research is that it has been demonstrated that this co-movement varies across the regions. For both regimes a clear ordering of the regions is evident.   It is clear that there is are three 'groups' of regions: the first (Group I: South East, West Midlands and the Northwest) where the magnitudes of the induced movements are greatest; a second (Group II: Wales, Scotland, Yorkshire[17], East Midlands and the South West) where the magnitudes tended to be banded in a middling range; and a final group (Group III: North East and East Anglia) where the effects are very small or negligible: this ordering or grouping being consistent with those reported by Fielding and Shields.

These results therefore demonstrate that the regional variation in reaction to shocks can have a long term impact on the divergence in the level of output of the UK regions and therefore of interest to policy makers.

[17] although in the case of Scotland this is for one regime only, in the case of the P1 regime, the model was not correctly identified.

6 Monetary VARs for the UK regions

This chapter analyses the UK regions' responses to monetary policy shocks. It uses the standard VAR methodology outlined in chapter four, namely utilisation of the impulse response function to a 'structural' monetary policy shock. The structural shocks are identified by Choleski decomposition.

The model is estimated in differences to be consistent with the key reference in this field (that of Carlino and Defina, 1998). Several variants of the VAR are estimated for each region. These variants include different placing of the interest rate variable and inclusion or otherwise of an aggregate output variable. Also estimated by SUR is a series of individual regional output equations. The set of regressors is pared down to provide a 'structural' model of the kind estimated by Holmes (2000). These latter two sets of results being utilised for robustness checks.

The results point to a consistent pattern in the regional variation in responses. It needs to be acknowledged that it is extremely difficult to credibly attempt to ascertain statistical significant differences between the impulse responses: it is the exception rather than the rule to attempt to justify reporting of statistically significant different impulse responses. Indeed Carlino and Defina did not attempt something so ambitious and, as was stated in chapter 4, only Darby and Phillips have attempted to report such statistically significant heterogeneities.

Instead, the chapter then produces the results of an investigation into the causes of variance of the impulse responses and provides a systematic account for these variations using a series of measures of regional industrial heterogeneity. This has never been provided for the UK regions.

The three common routes to account for differing industrial responses to a monetary policy shock are the direct interest rate effect, the credit effect and the exchange rate effect. The interest rate effect is the direct or elasticity of response to an interest rate change where is it assumed the magnitude of response across different sectors of the economy differs. The credit effect assumes an increasing degree of credit constraint the smaller the size of firm and the exchange rate effect measures the size of the increased response to a monetary shock due to the subsequent currency appreciation. Three variables are used to provide a measure of the differences in industrial structure, share of small firms and export orientation of the regional economies are used.

The analysis will show that sectoral heterogeneity is a key causal factor of differences through the different interest rate sensitivities of the sectors – and also show that there is some evidence in support of an exchange rate effect

Robustness analysis of the results of the VAR methodology is provided and discussed.

Finally, a crude attempt is made to provide an analysis of the regional sectors with the caveat that the data constraints are severe. In this scenario, it is even more unrealistic to attempt to ascertain statistically significant differences. Instead it is only possible to provide 'stylised facts', patterns of differing sensitivity to interest rate shocks appear homogenous within sectors, which show themselves similar to Ganley & Salmon's (1997) previous study. Utilising a panel of the 'regions by sector' and a separate 'sectors by region' panel, the analysis then supports the view that dissimilarities are driven by sectoral not spatial factors, ie there is little evidence at this level for heterogeneities of same sectors across regions.

This research of this chapter therefore presents a 'story'. It presents the evidence that sectoral make up contributes to the differing response of the regions to monetary impulses and then presents evidence that sectors do differ in response to monetary impulses but not by region. This is what is illustrated with the data to hand. It does so to a level not attempted previously for the UK regions, provides for the first time statistically robust (to the level allowed by the data) evidence to support sectoral factors being the likeliest determinants of heterogeneities.

The significance of these results for policymakers is that if the degree and scale of heterogeneity is to a reasonable extent predictable then it has implications for interest rate policies, as it can be determined which regions will react the strongest (and why) to monetary policy (as was discussed in chapter 6, whilst the analysis is of reactions to ‘shocks’ this is in many ways a proxy for reactions to monetary policy movements themselves). Given the discussions surrounding a UK ‘Regional Welfare’ function in the introduction, knowing to a degree the extent of the scale of differing response is the first stage in its construction.

6.1 Methodological Issues

In this chapter a series of results of estimations of the response of the UK regions to monetary policy shocks is presented. Chapter 4 provided both a review of the relevant published research regarding previous estimation of monetary VARs for regions for both the UK and elsewhere and a discussion and explanation of some of the issues surrounding the methodology itself.

Of key relevance to this chapter is the work of Carlino & Defina (1998), Ganley & Salmon (1996), Darby & Phillips (2007) and Holmes (2000). This chapter now outlines some of the methodological differences between these works and relates this methodology of this research to them.

The first, Carlino and Defina, is a seminal (and most oft quoted) piece of research on heterogeneous regional responses to monetary policy shocks. As was previously outlined, Carlino and Defina, estimate 'structural[18]' VARS for 48 states across the US. As referred to in chapter 4, there is debate as to the appropriate methodology for analysis the dynamics of VARs. Carlino and Defina chose to estimate and analyse the cumulative response function of their model estimated in first differenced form.

Stationarity tests for the data series (appendix 10) indicated the presence of unit roots in levels. The model was estimated in differences. The differenced form of the VAR model was chosen for four reasons: a) differencing is the standard method for removal of unit roots b) it is a more typical form of the 'structural' literature ie it is the form for the 'BQ type' structural VARs c) it more reflects an actual underlying data generating process and d) it means the results are a direct analogue of the work of Carlino and Defina.

However, if co-integration is present, it is perfectly feasible to conduct impulse response analysis from an estimated Vector Error Correction Model. Favero (2001) suggest that if one is only interested in the dynamic relationship between variables that leaving the stochastic trend in place is best (ie estimating the model in levels) as imposing a VECM framework may lead to imposition of an incorrect co-integrating parameter and skew the short run dynamics which is the object of interest. Therefore as an alternative to VARs in differences, unrestricted VARs in levels can be estimated by researchers.

[18] 'structural' in the sense that the Choleski matrix is used, shocks are assumed to be orthonormal and a choice is required of the relevant ordering, not in the sense of short run or long run BQ type restrictions discussed in chapter 4.

Both Ganley and Salmon and Darby and Phillips have estimated an unrestricted VAR model citing concerns regarding co-integration as justification. Their choice as to which version of the model to estimate is thus slightly different to that of this research and Carlino and Defina. A point that needs to be borne in mind when comparing differences in impulse responses of the different research. Additionally, this research, like that of Carlino and Defina, takes the cumulative response as the primary function of interest, unlike Ganley & Salmon and Darby and Phillips who take the impulse response function.

A further point to discuss is the ordering of the monetary instrument variable[19]. Again the UK authors (Darby & Phillips, Ganley & Salmon) take a contrary position to Carlino and Defina in that they place the interest rate variable first in their VAR. Carlino and Defina place the interest rate variable last as per convention in monetary VARs but as discussed in chapter 4 the ordering is of some contention given it defines which variables can contemporaneously effect another. To overcome any ambiguity, estimates for both sets of orderings are presented in the early parts of the chapter and, as shall be seen, there is little effect on the relative ordering of the responses and significance of the results. On the rare occasion where just one set of estimates have been provided, the standard practice of ordering the rate last is reverted to.

[19] Pesaran and Shin (1998) have proposed an alternative to orthogonalisation of the shocks, namely the Generalised Impulse Response which is invariant to the ordering of the shocks. However, as recognised in their work, there are 'substantial differences in the results of the two approaches' and it is also desired to maintain comparability with previous studies with the results presented in this chapter, this alternative approach is not employed.

The vector form for estimation therefore is :

$$X_{r,t} = (\Delta g_{r,t}, \Delta G_t, \pi_t, \Delta ex_t, i_t) \qquad (44)$$

if the methodology of Carlino and Defina is followed.

(where G is UK output, g regional output, i interest rate, ex real exchange rate and π inflation.)

and

$$X_{r,t} = (i_t, \Delta G \ , \pi_t, \Delta ex_t, \Delta g_{r,t}) \qquad (45)$$

if the methodology of Ganley and Salmon is followed.

As can be seen from above, also included in the variable set is an aggregate output variable which represents that of the UK minus the region of interest under study. This is analogous to Carlino and Defina who disaggregate the state of interest, its BEA group minus output in that state, and output in all other BEA states into separate variables. There is no analogy to the US BEA classification for the UK and any grouping would suggest a priori a degree of knowledge of conformity or otherwise of regional 'blocs' that is not known for the UK (and co-incidentally is one of the purposes of the research). Both Darby & Phillips and Ganley & Salmon include the aggregate output variable but this does not exclude the region/sector of interest.

The precise nature of these contemporaneous effects requires some thought. Ideally there would be a known pattern of transmission of shocks through the UK. As has already been oft stated in this thesis that there is not a vast amount of material published on the subject and that there is no definitive prevailing view as to what this may be. The evidence there is from Granger Causality tests (see Funke and Hall (1998), Fielding and Shields (2001) and from the results produced in chapter 5) points to shocks hitting regions pretty much simultaneously. This does then pose the question whether the inclusion of an aggregate variable adds anything of interest to the dynamics or indeed is necessary and/or there is anything to be gained from its inclusion. Erring on the side of caution it is included and, as shall be seen, a conclusion is reached on this matter during estimation. It should again be noted, the ordering is slightly different in both cases, Carlino and Defina place the State output variable first followed by the aggregate output variable, Darby & Phillips place aggregate output before the sector of interest.

Also applied in this work is the methodology of Holmes. This uses an entirely different methodology that was described earlier in chapter 4. In short ‘monetary shocks’ are estimated from an a priori monetary policy reaction function and then incorporated into an output equation which is then estimated by the SUR methodology. The model for the ‘Holmes’ output model estimated is:

$$\Delta y_t^j = \beta + \sum_{i=1}^{n} \kappa_i \Delta y_{t-i}^j + \sum_{i=0}^{n} \theta_i \Delta o_{t-i} + \sum_{i=1}^{n} \xi_i u_{t-i} + v_t^j \qquad (46)$$

Where y is the natural log of output in region j, o the natural log of the real price of oil (to represent supply shocks) and u shocks to monetary policy (all other terms being estimated coefficients) which are the residual of an estimated monetary policy rule (a simple Taylor type function of inflation and the output gap). The version used is referred to in more detail later in this chapter. This methodology is utilised in two ways: 1) in to check robustness of VAR estimates 2) in the manner of Holmes as an output growth equation in its own right .

The methodology used by Darby and Phillips to check for robustness of the VAR estimates is to estimate via SUR a set of regional output equations. The Holmes equation is used in this manner in this work, however, separately also estimated in this work are similarly sets of individual regional equations with the regressors the same as the VAR minus the aggregate output variable. These two models are both estimated by SUR as the time series is not of sufficient length to provide sufficient degrees of freedom to be able to estimate these as VAR systems.

To summarise, in addition to estimates of two sets of regional VARs including an aggregate variable for both options for the interest rate ordering (last and first) a set of VARs without this aggregate variable for comparison is also estimated (referred to as the ‘plain vanilla’ model). Also a set of SUR estimates of the individual regional output equations (concurrently estimating the monetary policy function) are produced as is a set of Holmes output equations. This provides a set of results for the purposes of checking robustness. Two different panel estimates of the Holmes model are also estimated using standard panel techniques.

6.2 Data

For this estimation the longest continuous time series available is utilised which is from 1967 to 1996. Tests indicate the presence of unit roots in the levels of prices and output but no co-integration (see appendices 9 and 10 for test output). Tests for lag length are definitively unambiguous and a lag length of two is chosen. As just discussed, the model is estimated in differenced form following the methodology of Carlino & Defina. However, for comparison the model was first estimated/tested in level form. In levels tests show that the model has potentially one explosive root (ie the polynomial in the lag operator has one inverse root outside the unit circle (see appendix 11)) and it was a simple decision to drop any further working with this version of the model. The model in differences is stable.

The model's impulse response functions were first checked to first ensure it is consistent with the stylised facts of Christiano, Eichenbaum and Evans (see chapter 4) of 'at least interest rates rising, output falling and a slight (fall/rise) in the price level'.

Figures 64 and 65 provide the impulse responses for the model using UK aggregate GDP as the output variable. As can be seen for both version of this VAR model the responses are broadly consistent with the stylised facts. There is a slight ‘price puzzle’ (initial increase) in the inflation response to an interest rate shock despite the inclusion of real oil prices as a conditioning variable and this is slightly larger for the interest first ordering. Inflation is seen to fall following an exchange rate rise (imported good becoming cheaper) and whilst there is only the slightest of movements subsequent to an inflationary shock it is of the correct sign (negative) in both cases. Response to interest rate shocks of the exchange rate is positive as would be expected.

From this analysis either model would be consistent with the stylised facts and given this dataset appropriate for the conduct of monetary policy analysis (with all the caveats that critics suggest borne in mind) with perhaps the interest rate first ordering having the slight edge due to its slightly smaller ‘prize puzzle’.

Figure 64: UK series, Full set of Impulse Responses, Choleski Decomposition, and Interest Rate Ordered First

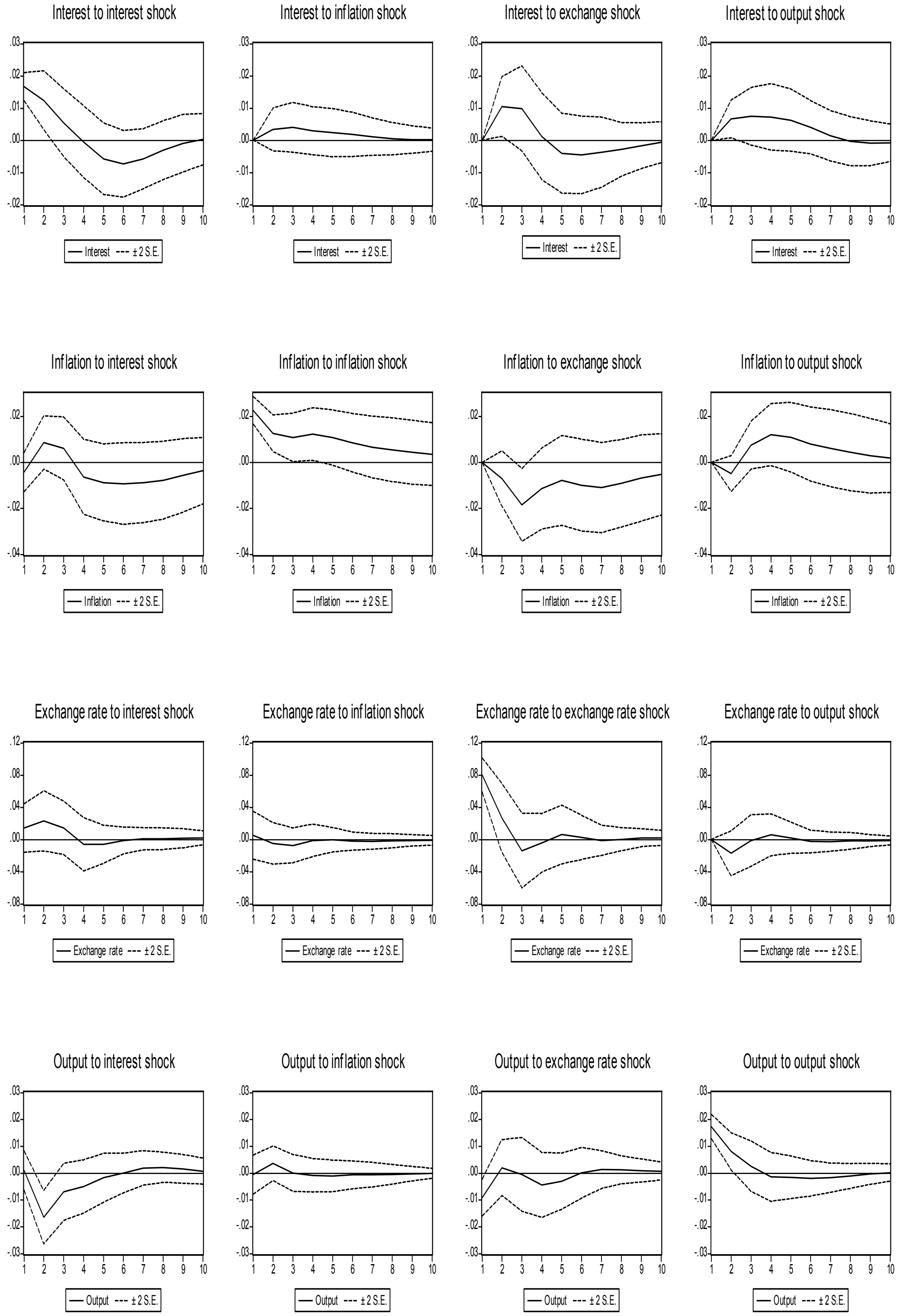
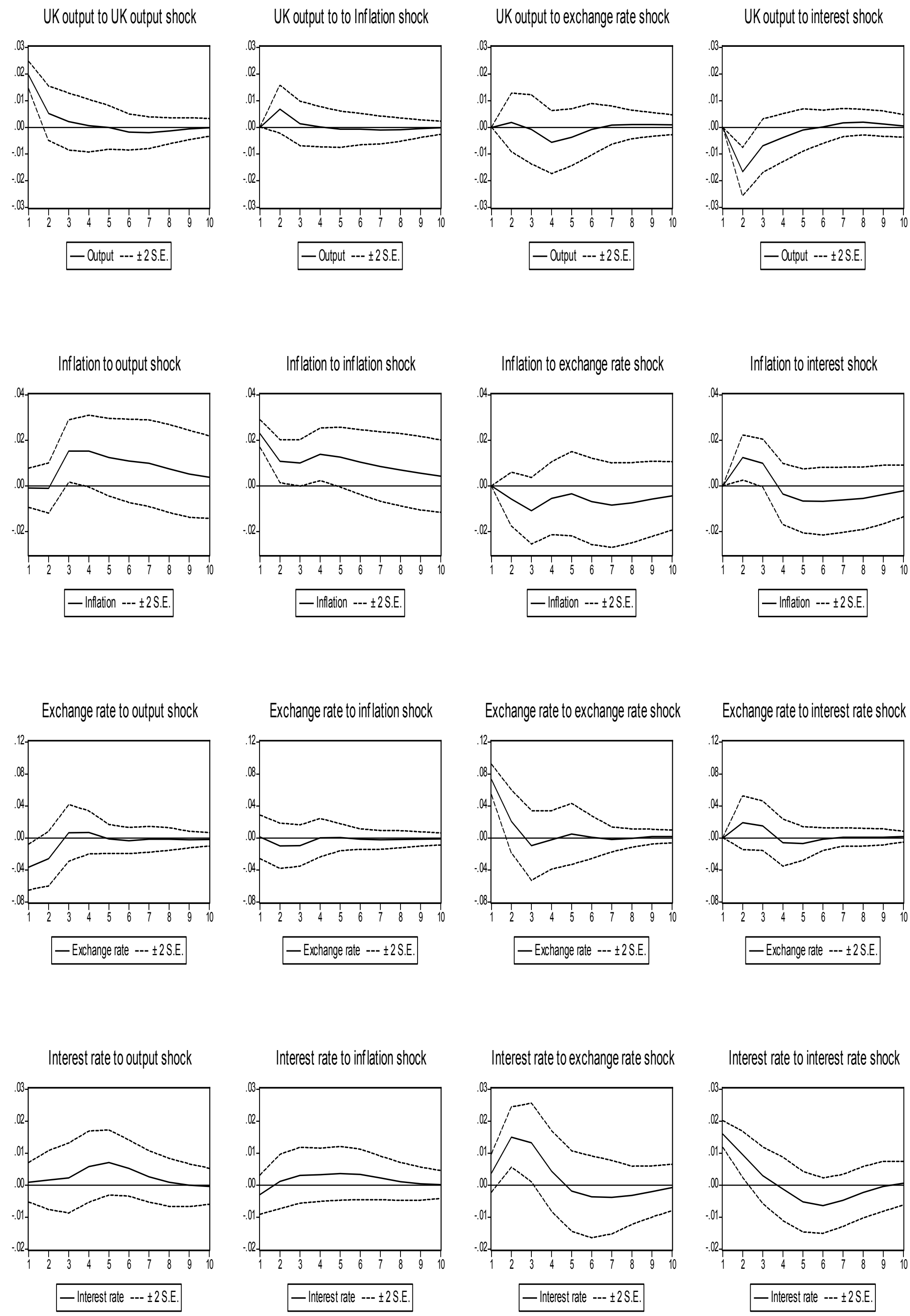


Figure 65: UK series, Full set of Impulse Responses, Choleski Decomposition, and Interest Rate Ordered Last



6.3 Responses

The individual impulse responses for each region have been reproduced and are presented in figure 66 (interest rate ordering first). They are consistent with the stylised facts (ie CEE (1999)) as they all display the expected negative response to an interest rate shock. Maximum negative response is typically after two periods which is anticipated period for impulse responses with annual data (Arnold & Vrugt (2002).

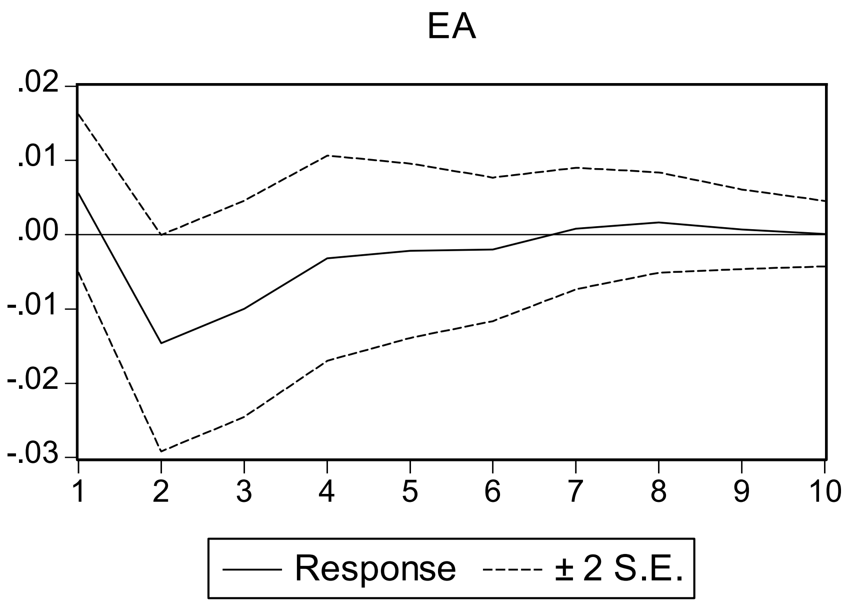
Whilst it can easily be seen there are some differences in magnitude of the maximum responses, it would be optimistic to hope to infer any meaningful differences across the UK regions from individual analysis of these responses separately but they are all reproduced individually so that a comparison can be made and the similarity seen with the responses to a unit shock in the 'structural shocks'/Holmes model which are presented later in this chapter in figure 84.

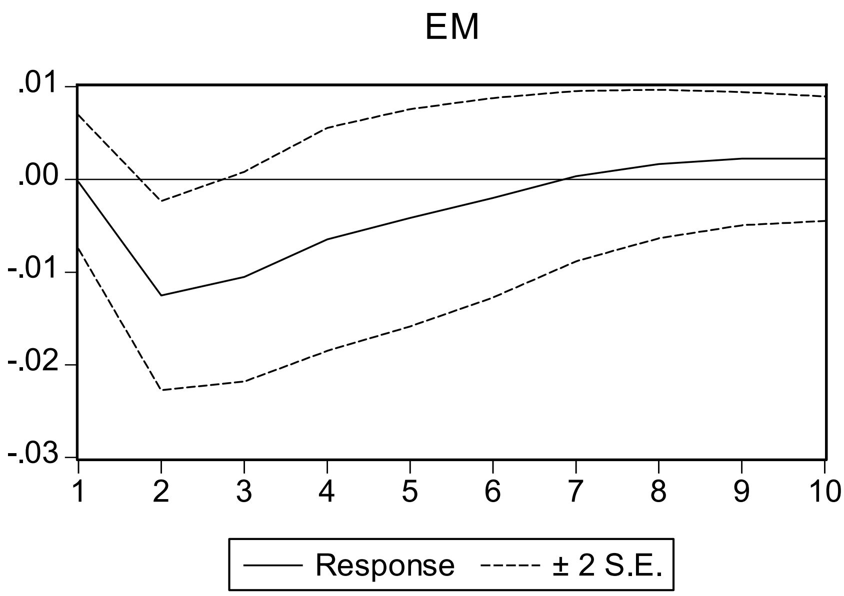
The work of Darby and Phillips founded its conclusions that the sectoral responses of certain sectors in Scotland and the UK are different based on the observation that their calculated impulse responses for a Scottish sector may lie outside (albeit temporarily) for that of the same sector in the UK.

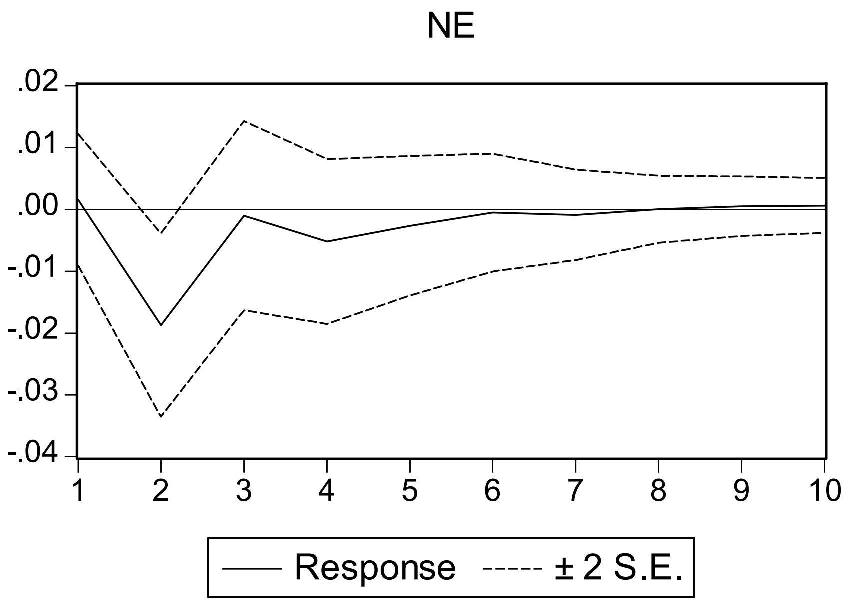
For the regions this can also be shown to be the case. Figure 67 shows that is the case for the SW and the NW in period two. Both the response and the standard errors of the SW are outside that (including the standard error) of the NW.

However, figures 68 and 69 show the responses for the NE and SE and also the EM and Scotland and show no evidence of statistical differences in the pairwise comparison of these responses (there is little to be gained in producing every pairwise combination of regions). It is easily seen that an attempt to imply statistically different responses of the regions by this method would not be credible. Therefore a different route is utilised to attempt infer statistical differences which is returned to later in this chapter. It should be highlighted that Darby and Phillips have the benefit of quarterly data for their analysis. However, it should also be pointed out that later in this chapter results will be reported which support a different conclusion to their work.

Figure 66: Full set (separate) Regional Impulse Responses (output to interest)



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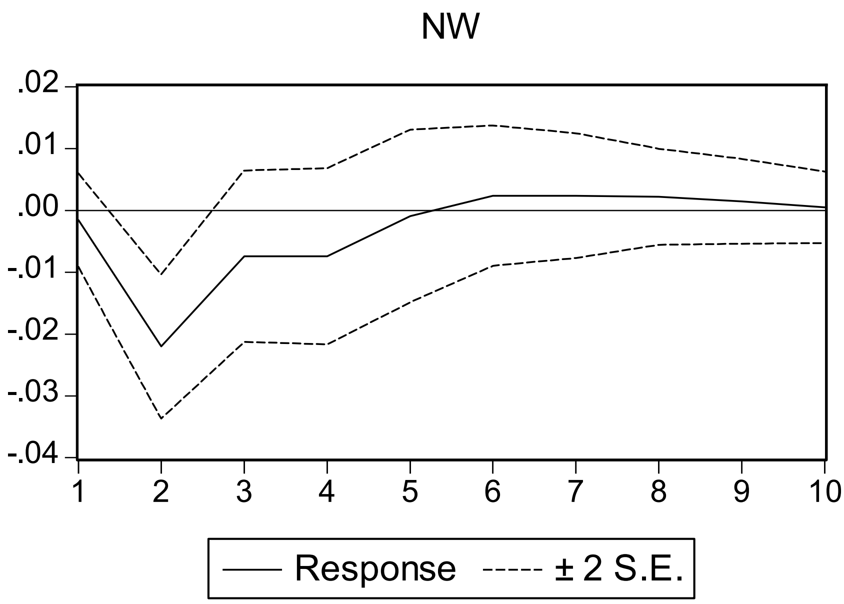
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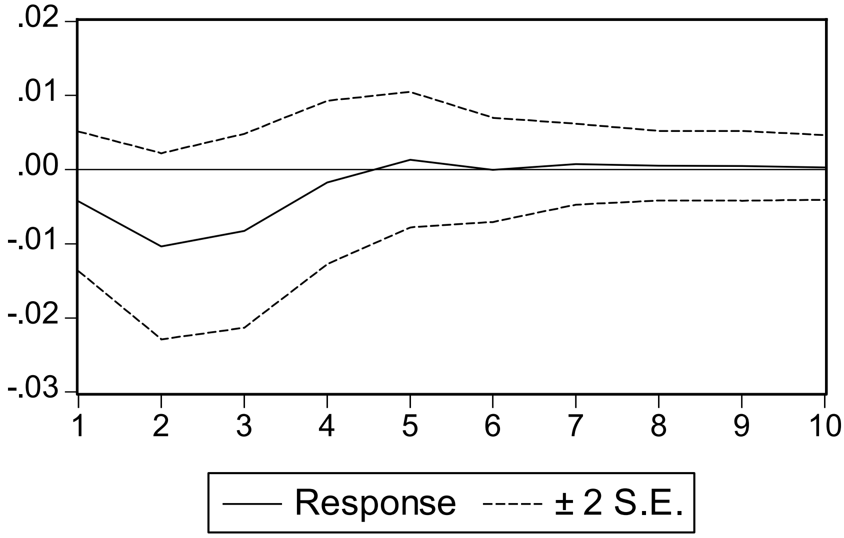
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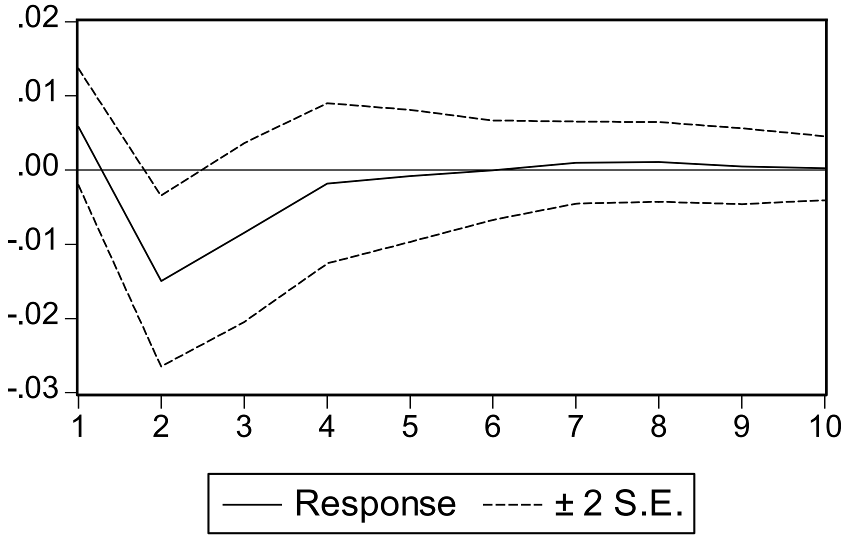
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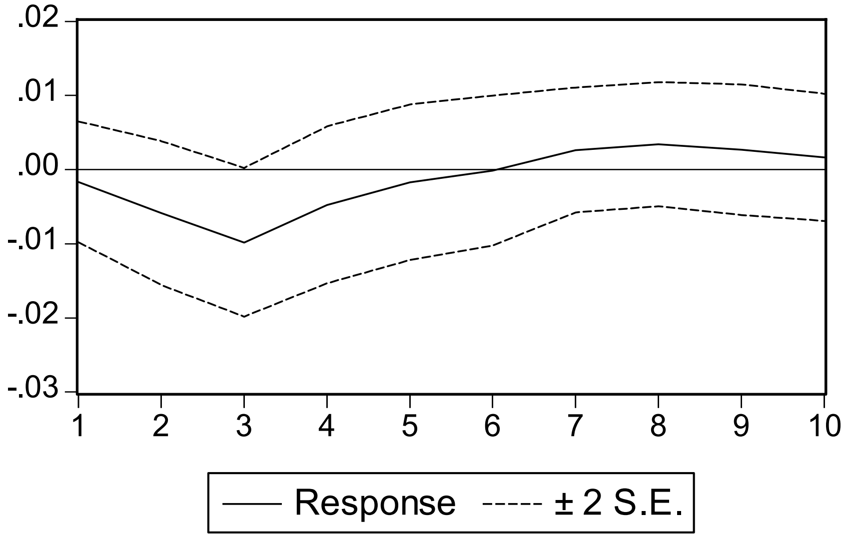
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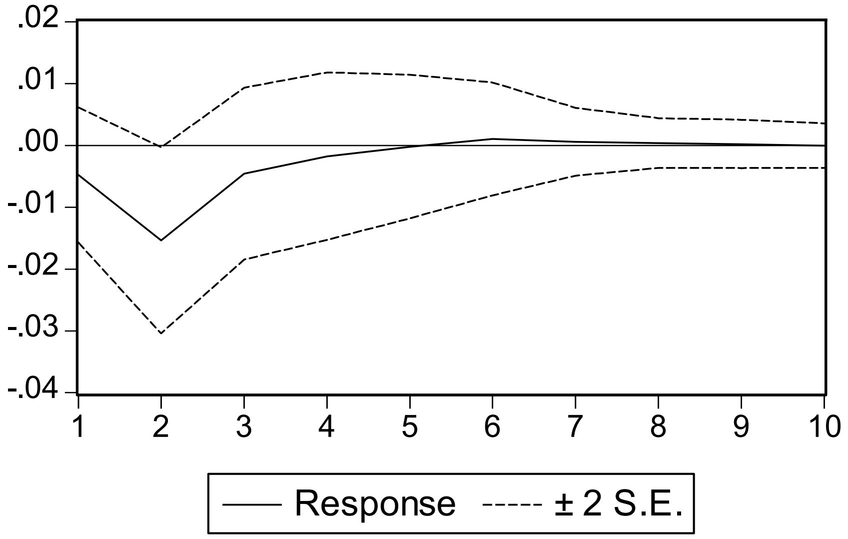
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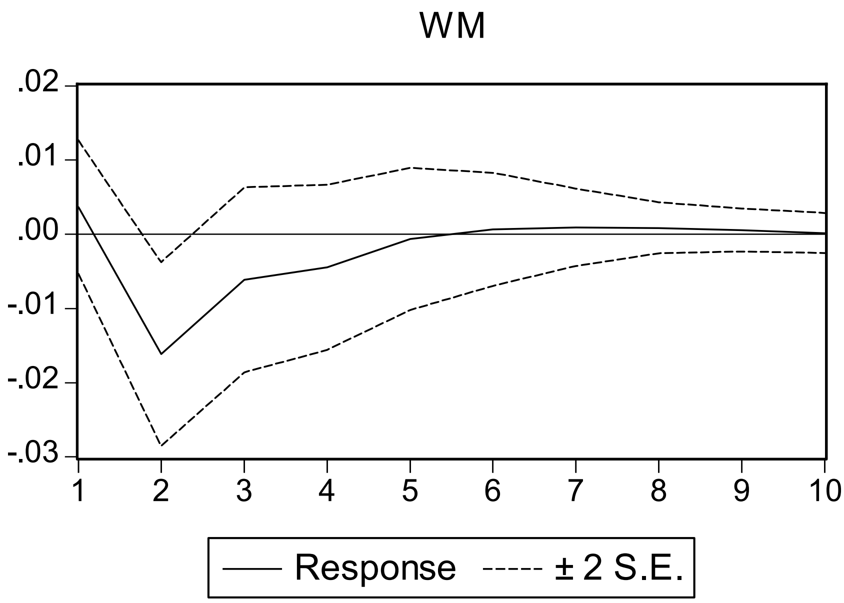
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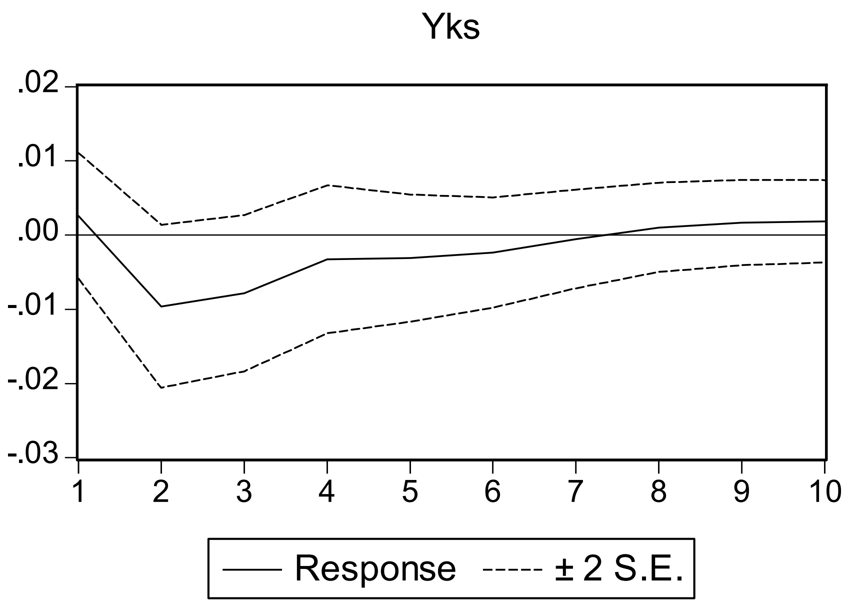
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Figure 67: Pairwise comparison of Impulse Responses with Standard Error Bands, NW & SW

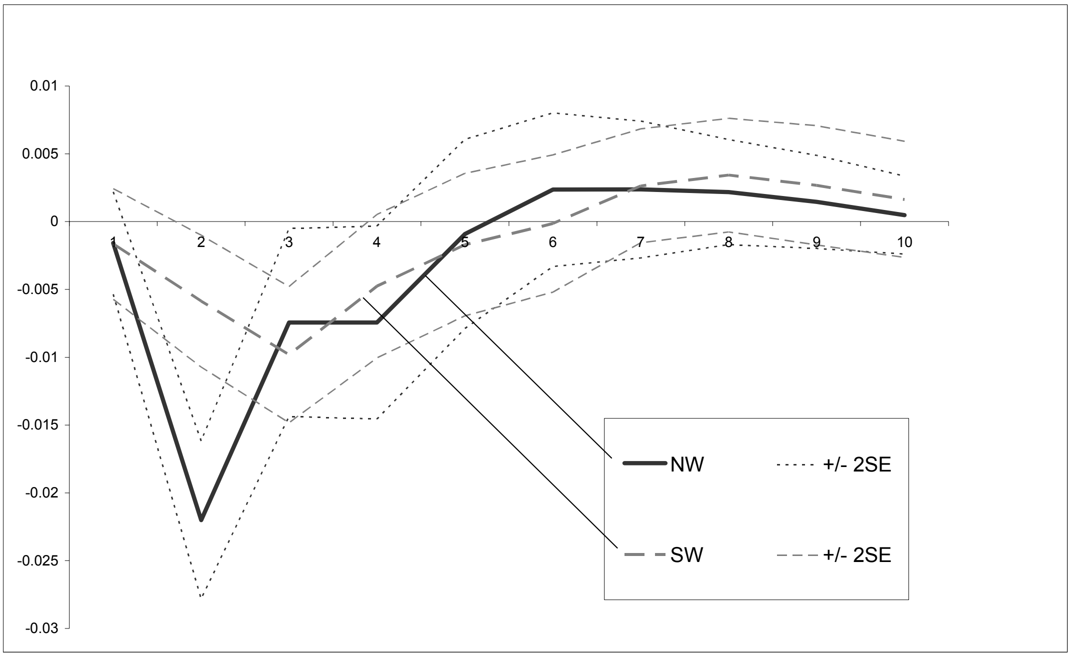


Figure 68: Pairwise comparison of Impulse Responses with Standard Error Bands, NE & SE

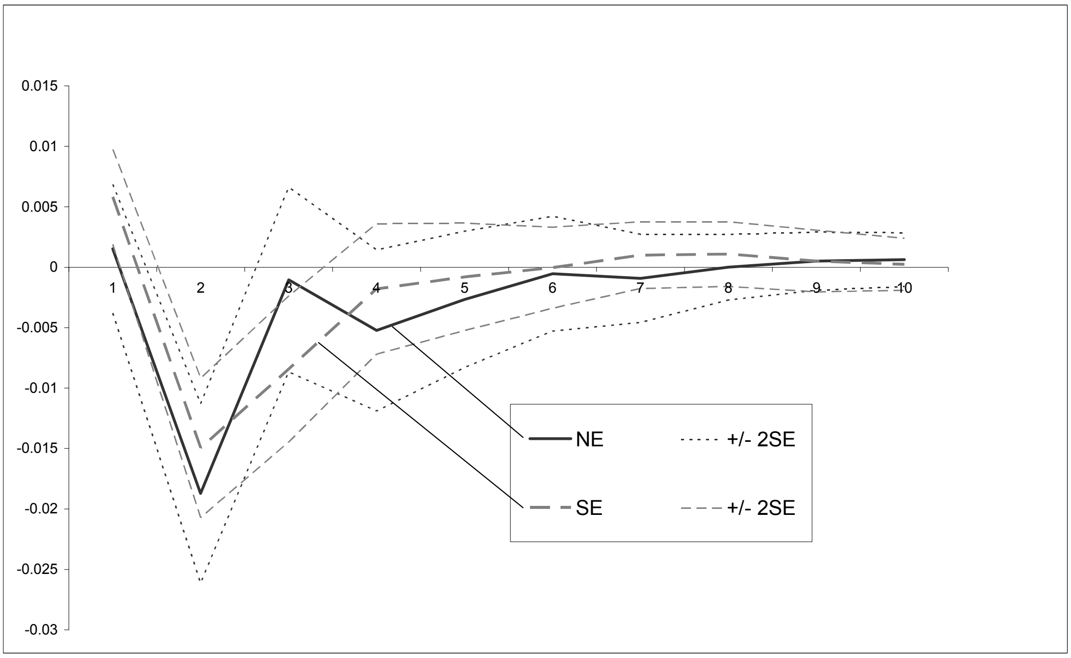
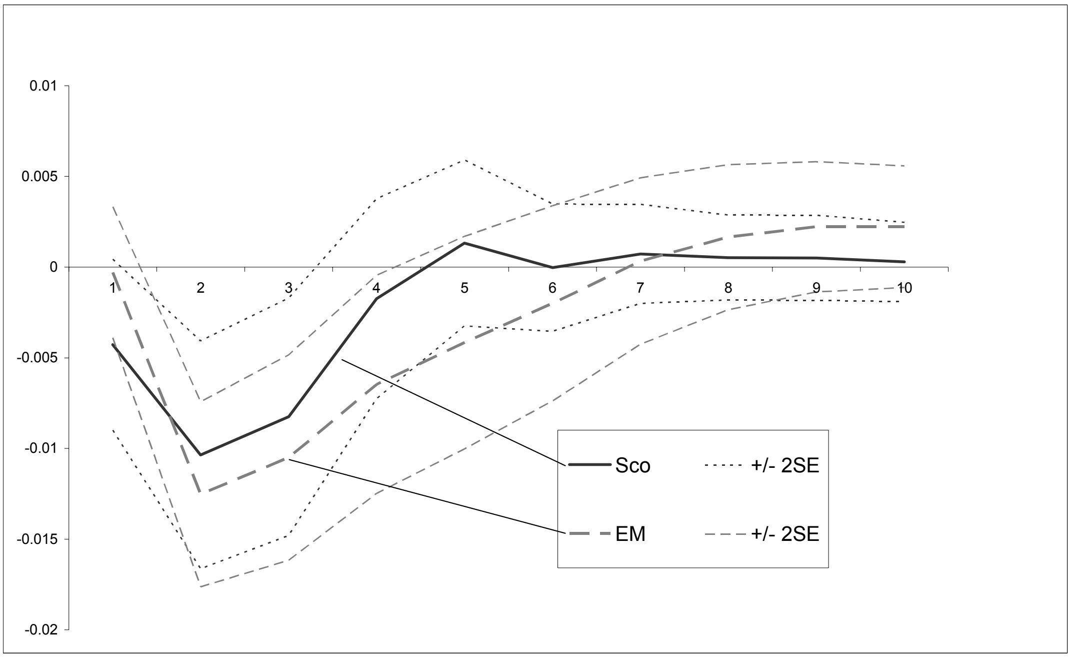


Figure 69: Pairwise comparison of Impulse Responses with Standard Error Bands, Sco & EM



6.4 Comparison of sets of responses

Rather than working with the responses individually, figures 70 to 77 illustrate the full set of regional impulse and cumulative responses for all four models estimated: the two VARs models which include an aggregate output variable, the 'plain vanilla', which neglects to include the aggregate variable, and the SUR version of the model. The questions to hand at this stage of the research agenda is to investigate whether there is a pattern to the heterogeneities and whether any such reported heterogeneities can be explained by structural factors as in Carlino and Defina's work for the US states and whether they are significant.

It needs to be first decided whether any version of the four models: the SUR estimated model of individual regional output equations (with simultaneous estimation of the interest rate function); the two VARs which include an aggregate (UK output minus the region of interest variable) with the interest rate in two alternative orderings (first and last) and the 'plain vanilla' VAR which does not include the aggregate variable (and places the interest rate last): is more appropriate to use for analysis and from which to draw conclusions. The size and orderings (1 to 10, smallest 1) of maximum impulse and cumulative responses of the regions are produced below in tables 26 and 27.

Figure 70: VAR (interest order first) Regional Impulse Responses

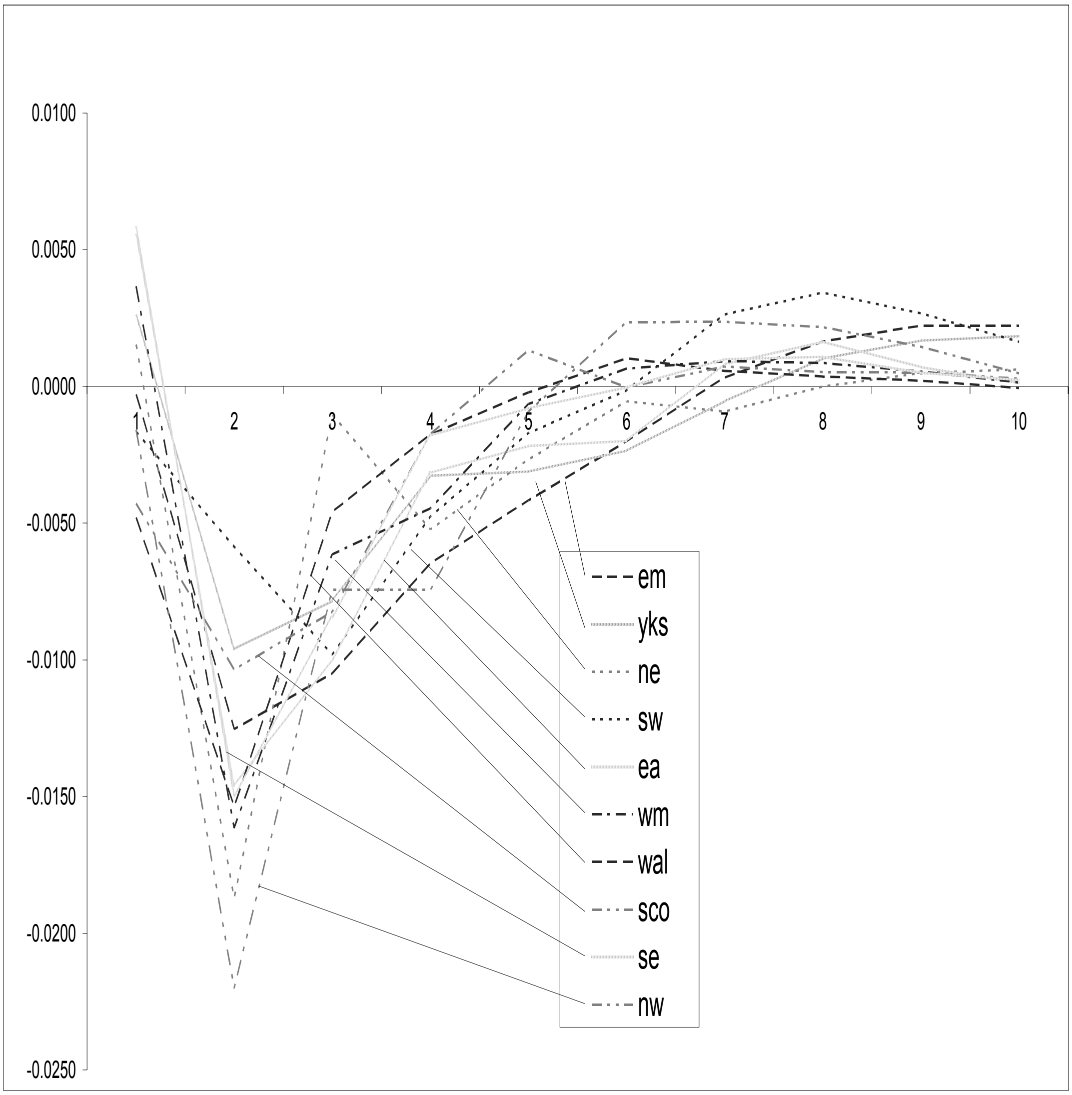


Figure 71: VAR (interest order last) Regional Impulse Responses

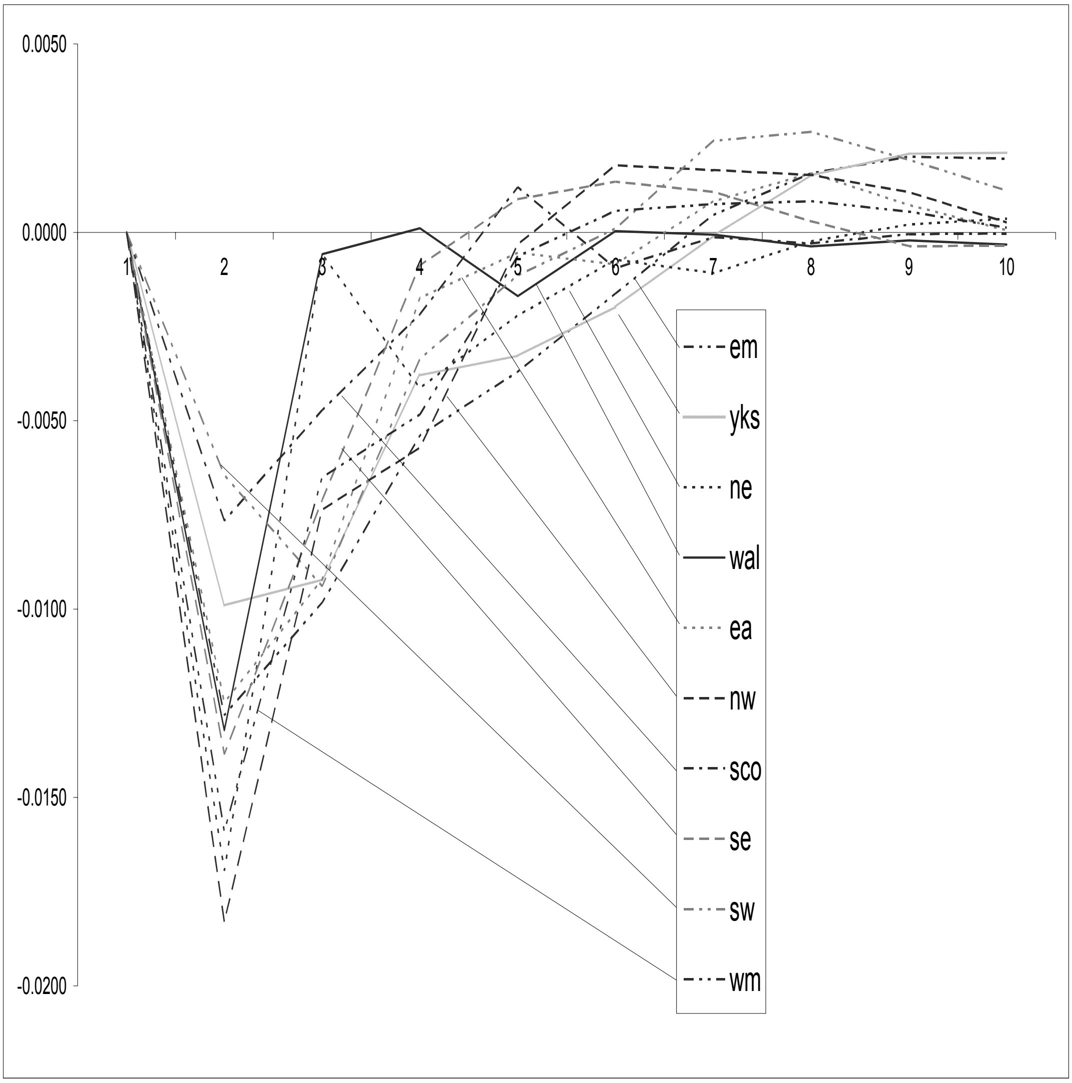


Figure 72: SUR Impulse Responses

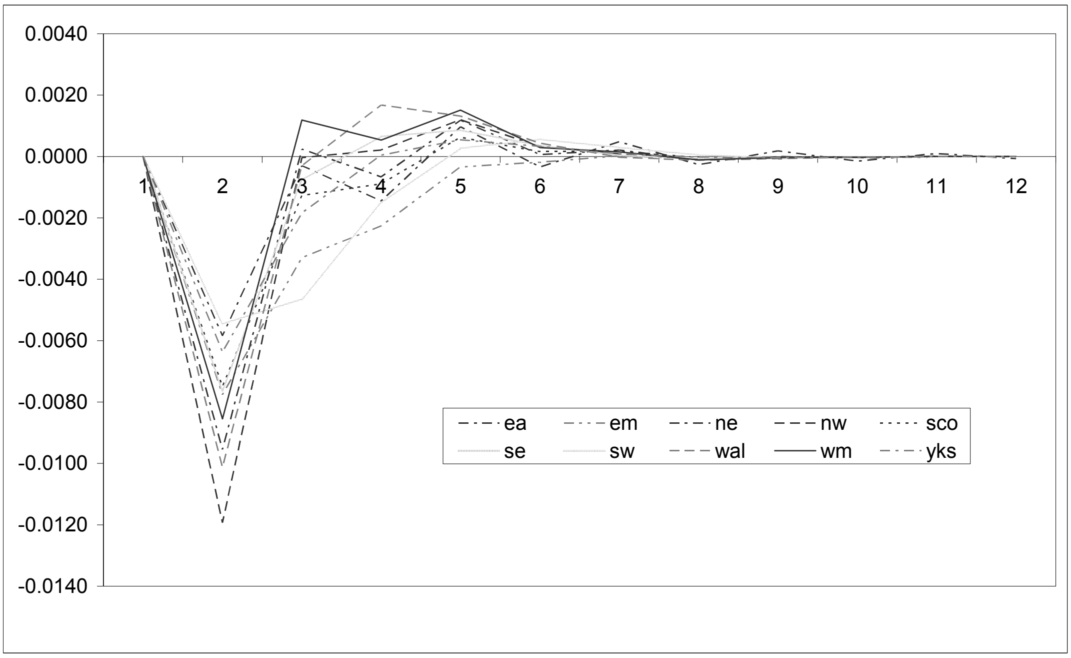


Figure 73: 'Plain Vanilla' Impulse Responses

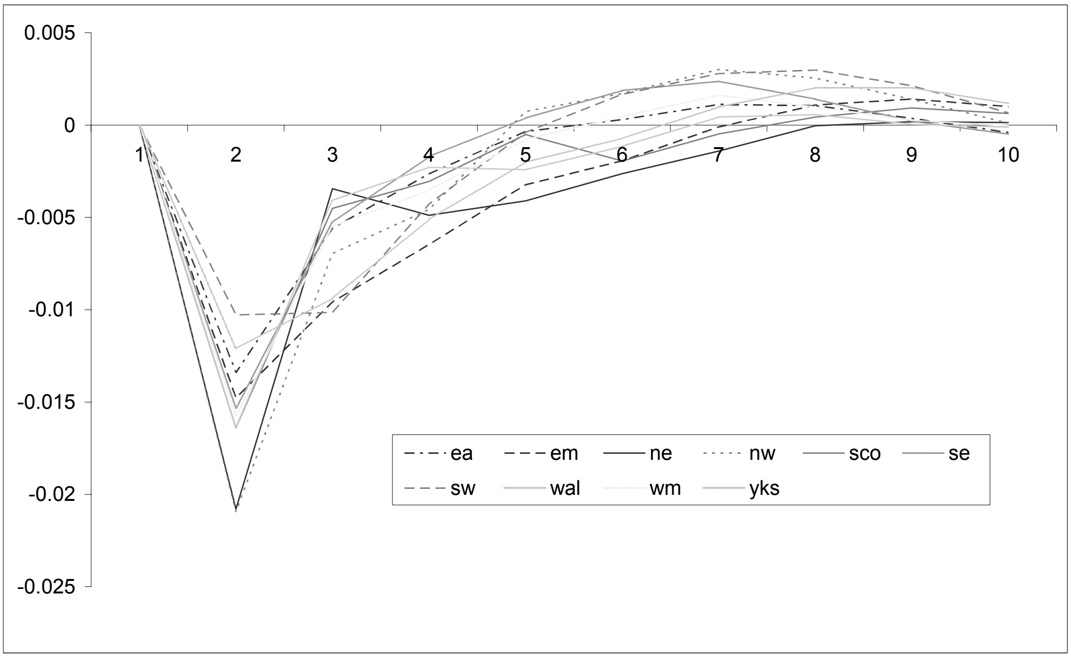


Figure 74: VAR (interest order first) Regional Cumulative Responses

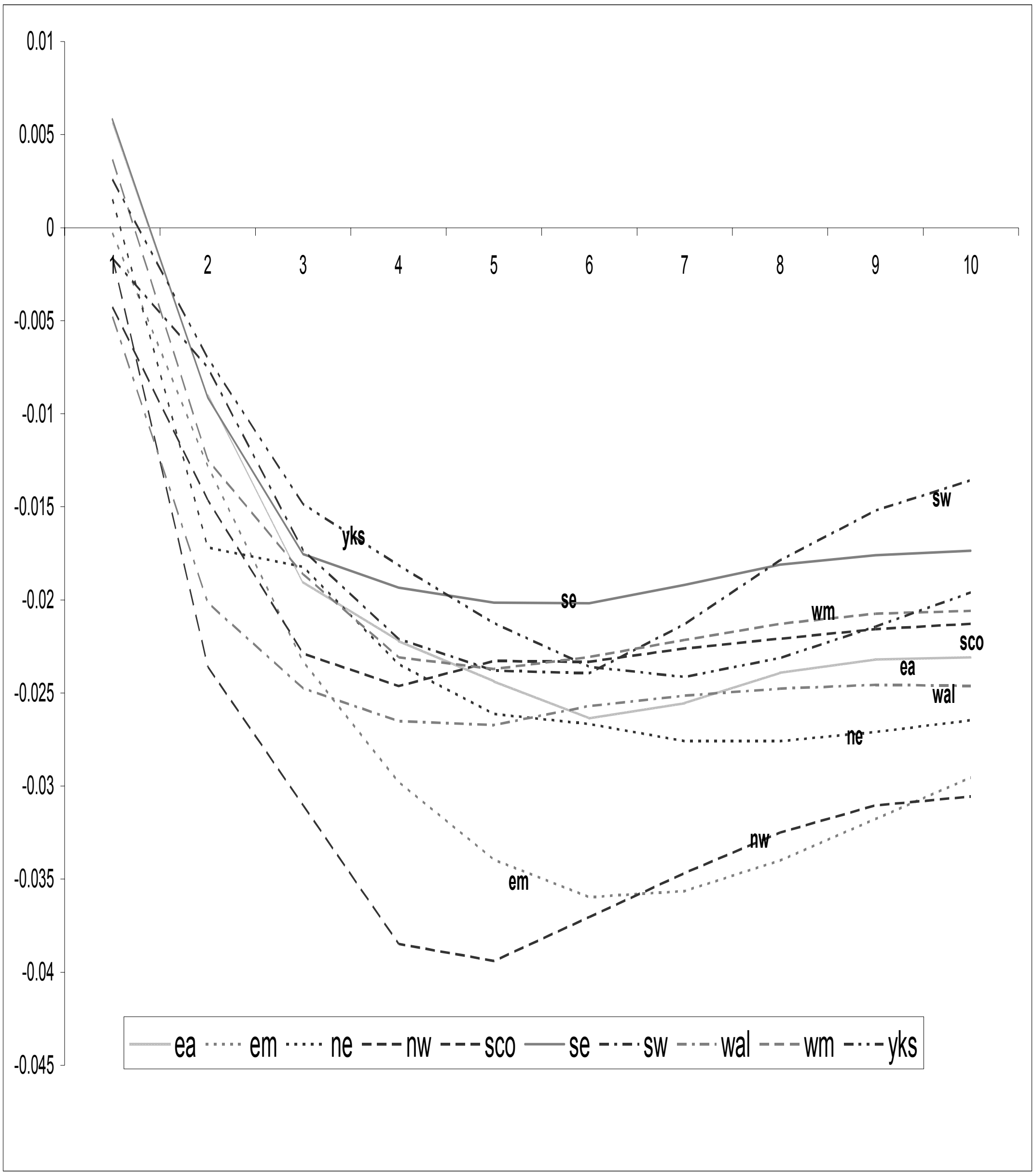


Figure 75: VAR (interest order last) Regional Cumulative Responses

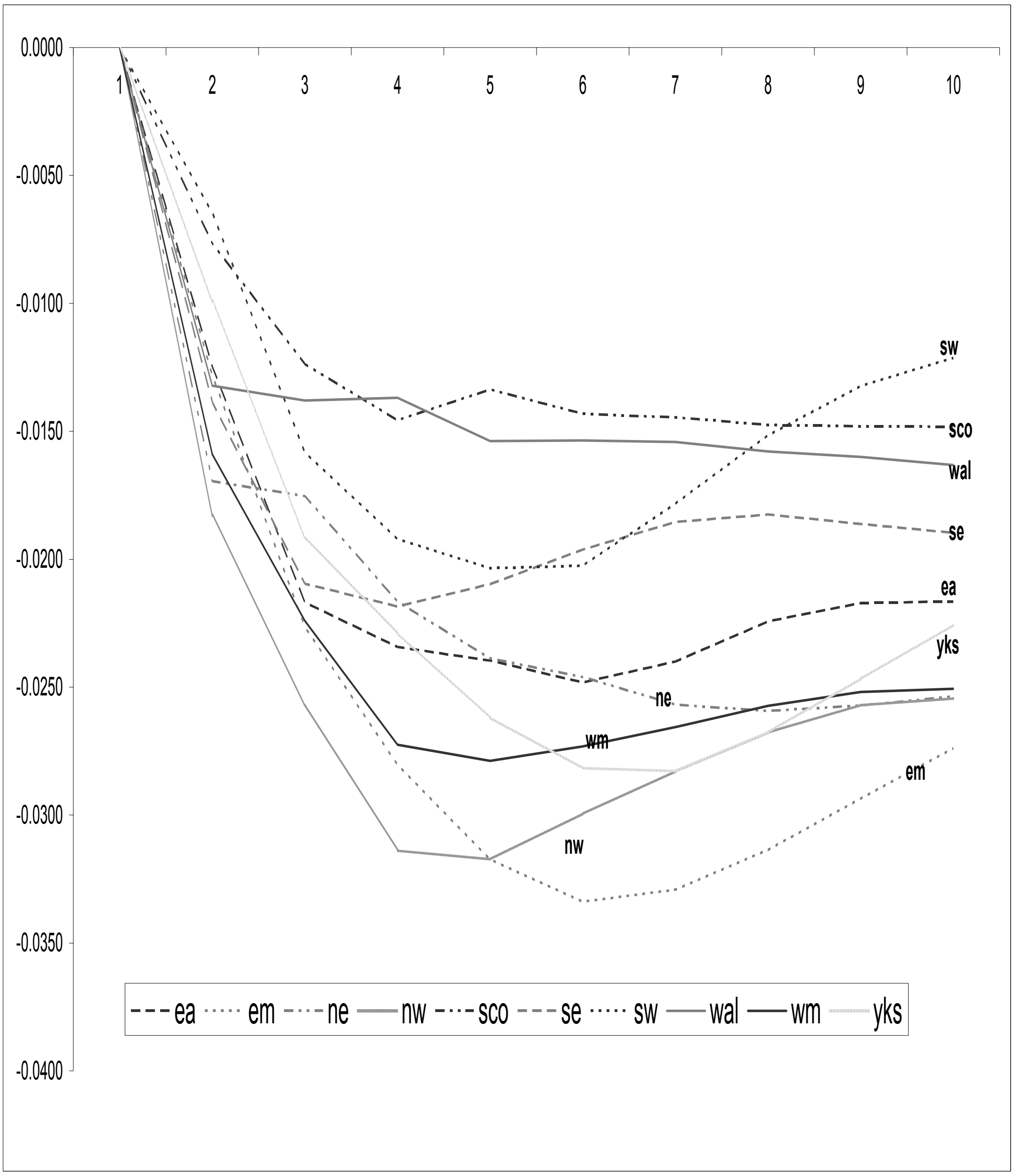


Figure 76: SUR Cumulative Responses

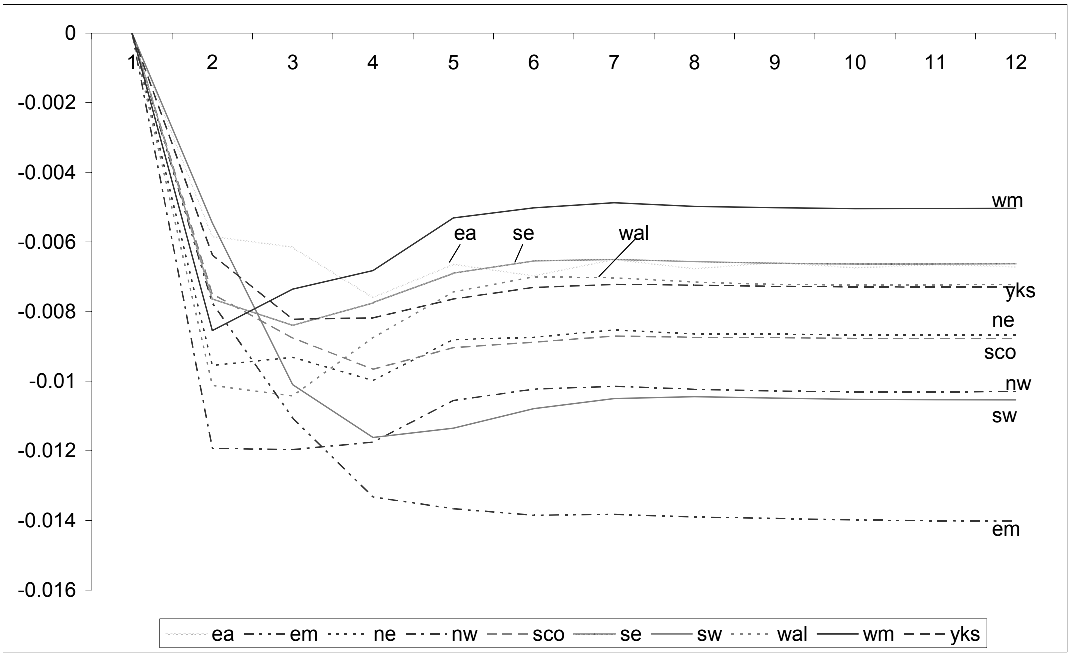


Figure 77: 'Plain Vanilla' Cumulative Responses

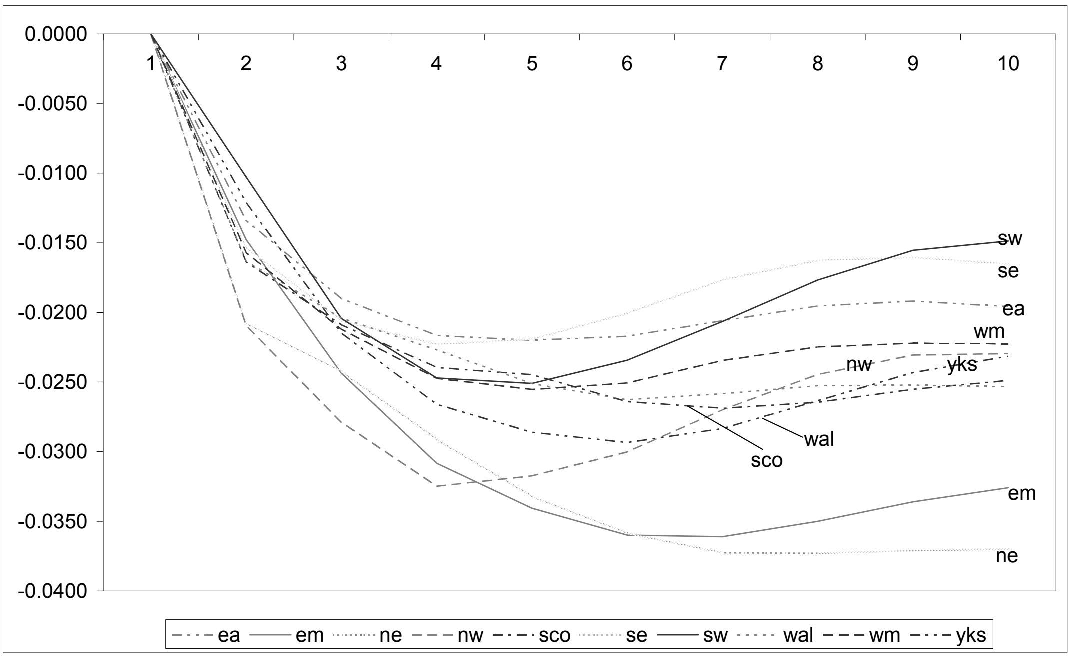


Table 26: (Ordered) Maximum Impulse Responses VARx3 and SUR results

	sur	surrank	varvanilla	vanilla rank	varilast	varilast rank	varifirst	varifirst rank
ea	-0.0080	2	-0.0134	3	-0.0125	4	-0.0146	5
em	-0.0107	6	-0.0148	4	-0.0128	5	-0.0125	4
ne	-0.0129	8	-0.0208	9	-0.0170	9	-0.0187	9
nw	-0.0163	10	-0.0210	10	-0.0183	10	-0.0220	10
sco	-0.0100	4	-0.0164	8	-0.0077	2	-0.0104	3
se	-0.0103	5	-0.0153	5	-0.0139	7	-0.0149	6
sw	-0.0075	1	-0.0103	1	-0.0064	1	-0.0059	1
wal	-0.0136	9	-0.0163	7	-0.0132	6	-0.0154	7
wm	-0.0116	7	-0.0157	6	-0.0159	8	-0.0161	8
yks	-0.0088	3	-0.0121	2	-0.0099	3	-0.0096	2

Table 27: (Ordered) Maximum Cumulative Responses VARx3 and SUR results

	sur	surrank	varvanilla	vanilla rank	varilast	varilast rank	varifirst	varifirst rank
ea	-0.0179	3	-0.0196	3	-0.0231	6	-0.0217	5
em	-0.0383	10	-0.0326	9	-0.0295	9	-0.0274	10
ne	-0.0248	6	-0.0370	10	-0.0265	8	-0.0254	8
nw	-0.0288	8	-0.0230	5	-0.0306	10	-0.0254	9
sco	-0.0255	7	-0.0249	7	-0.0213	5	-0.0148	2
se	-0.0177	2	-0.0165	2	-0.0174	2	-0.0190	4
sw	-0.0289	9	-0.0149	1	-0.0136	1	-0.0121	1
wal	-0.0231	5	-0.0253	8	-0.0246	7	-0.0163	3
wm	-0.0137	1	-0.0223	4	-0.0206	4	-0.0251	7
yks	-0.0193	4	-0.0231	6	-0.0196	3	-0.0226	6

The first point to note is that there are obvious similarities across the impulse responses. The Southwest displays the smallest response across each set of results, the Northwest the largest. Wales, the North East and the West Midlands display one of the larger responses across all sets of results. Similarly EA and (surprisingly perhaps) Yorkshire consistently exhibit one of the smaller responses. The South East (perhaps intuitively surprising) exhibits a middling response across all four sets. Scotland (which Darby and Phillips concluded was more interest rate sensitive than the UK) exhibits one of the smaller responses across three sets of results (the exception being the ‘plain vanilla’ set). This is clearly at odds with their findings. It is the view of the author that this is perhaps due to an overlooked weakness in their methodology in that, whilst they include aggregate output variables in their sectoral VARS, they estimate Scottish and UK VARS *separately* and the data for each is from separate sources.

The range of the regional estimates for the impulse responses are: SUR, 0.088; plain vanilla, 0.0107; interest last, 0.0119; and interest first, 0.161. Clearly the interest rate first variable displays the maximum range and this is intuitive given the ordering as the shock has more variables and can immediately work through to the output variable. The SUR estimates range being some half of this. The situation is not the same for the cumulative responses. The range now being: 0.0246, SUR; 0.0221, plain vanilla; 0.017, interest last; and 0.0153 interest last. This again is intuitive. There two VARS including the aggregate output variable are analogously (as explained) ‘marginal’ responses and so one would expect less dispersion over time.

Ignoring the issue of statistical significance of the relative size of the responses (where it has already been argued it is difficult to provide evidence for given the constraints in the dataset), these ranges demonstrate the potential of the scale of the heterogeneities caused by interest rate shocks. The North West’s impulse response is double the size of the South West for the SUR and plain vanilla response and nearly three times and more than three times the size of the South West response for the interest rate last and first VARs respectively. The picture for the cumulative responses is similar where the cumulative response of the region exhibiting the largest response is between two and three times the smallest response in every case.

Vis a vis the different results for Scotland compared to Darby & Phillips, the inclusion of an aggregate variable is to allow for contemporaneous effects transmitted from the aggregate to the sectoral (or in the case regional economy). By not including an aggregate variable for UK output in the Scottish sectoral results there this effect could be ‘missing’. This would then leave their results more analogous to the ‘plain vanilla’ estimations and it is perhaps the reason that in this set of results Scotland does indeed display one of the larger responses.

The similarities (or otherwise) of the relative orderings of the regions across model results is easiest seen by reviewing the Spearman rank correlations. The pairwise correlations are produced in table 28 (impulse responses) and 29 (cumulative responses).

Table 28: Spearman Rank Correlations Impulse Responses

	SUR	Vanilla	Int last	Int first
SUR	1.000	0.830	0.855	0.867
Vanilla	0.830	1.000	0.709	0.794
Int last	0.855	0.709	1.000	0.964
Int first	0.867	0.794	0.964	1.000

Table 29: Spearman Rank Correlations Cumulative Responses

	SUR	Vanilla	Int last	Int first
SUR	1.000	0.321	0.115	0.394
Vanilla	0.321	1.000	0.467	0.685
Int last	0.115	0.467	1.000	0.697
Int first	0.394	0.685	0.697	1.000

Clearly similarity of the responses across the models is unquestionable. The average rank correlation is some 0.84 and there is precious difference between the two 'aggregate variable included' VARs with a rank correlation of 0.964. The SUR estimates display most similarity with these VAR estimates and the least similarity is exhibited between the plain Vanilla model and the aggregate interest rate last VAR but still high with a rank correlation of 0.709.

However, this is not the case for cumulative responses. The SUR cumulative responses rank correlations with the other models drops significantly to a very weak 0.115 lowest rank with the interest rate last variable. The drop in correlation is to be expected and the cumulative responses facilitate more opportunity for divergence. The SURs lack of correlation at first sight may give cause for concern. However, this is easily understandable and explainable. The SUR model does not incorporate feedback effects amongst the other variables so that after two period there is little change in the response unlike the VAR case where interactive effects continue to feed through into the response. In simple terms the SUR responses are nothing much more than the one and two period step responses to an interest rate shock. Therefore the longer term (ie

post two period) dynamics are not particularly robust when compared to the other models. However, the correlation of the plain vanilla results are also much weaker than in the case of the impulse responses. Again the logic is the same, there clearly are feedback effects between the aggregate variable and the output variable of interest that are lost which are important for the study of the cumulative dynamics. From this therefore it is deemed that inclusion of the aggregate variable does provide additional information important to the analysis of the cumulative responses (less so if one restricts the analysis to impulse).
The final question is which, if any, of the two ‘aggregate variable included’ VARs is more appropriate for the analysis.

There are two schools of thought. Using the interest last ordering is preferable because it is the standard methodology. It was also the choice of Carlino and Defina (and Carlino and Defina’s method of analysis of the differing regional responses is to be repeated). Intuitively it is hard to argue for inclusion of immediate contemporaneous effects of the policy instrument variable.
The other is the slight edge the interest rate first ordering has from analysis of the stylised facts of the aggregate VAR discussed previously in this chapter. Also the slightly increased dispersion of its responses allow for a little easier analysis. Finally, this is the ordering that has been used by the two groups of UK researchers that have been extensively discussed. As it is not clear cut, the analysis proceeds using results from both orderings.

6.5 Explanatory variables

Having illustrated that the variations in cumulative response across the two interest rate orderings are reasonably similar the next stage is to seek to account for these variations. The options are somewhat limited. With fear of repetition, Carlino and Defina estimated a regression of the cumulative impact on variables which provided a measure of structural differences of the regional economies. To reflect industrial composition directly they include share of statewide GVA accounted for by manufacturing and extractive industries. To provide a measure of effect of differing credit constraints across firms and thus proxy for the credit channel thy used a measure of percentage share of small businesses and share of firms having small bank loans (with and without a holding company). Missing from the analysis that follows here (due to lack of degrees of freedom), they also included a regression with dummy variables for each state to account for state specific effects.

They report that their regression results were significant (overall) at the 1% level of significance accounting for between 42% and 47% of variation (R squared values) in cumulative responses. Values on coefficients for manufacturing and extractive industries were significant at the 1% level in models without state dummies and at the 5% and 10% level with dummies (no other coefficients on the other explanatory variables were significant.

Figure 78: Plot of Cumulative Responses vs Krugman Index

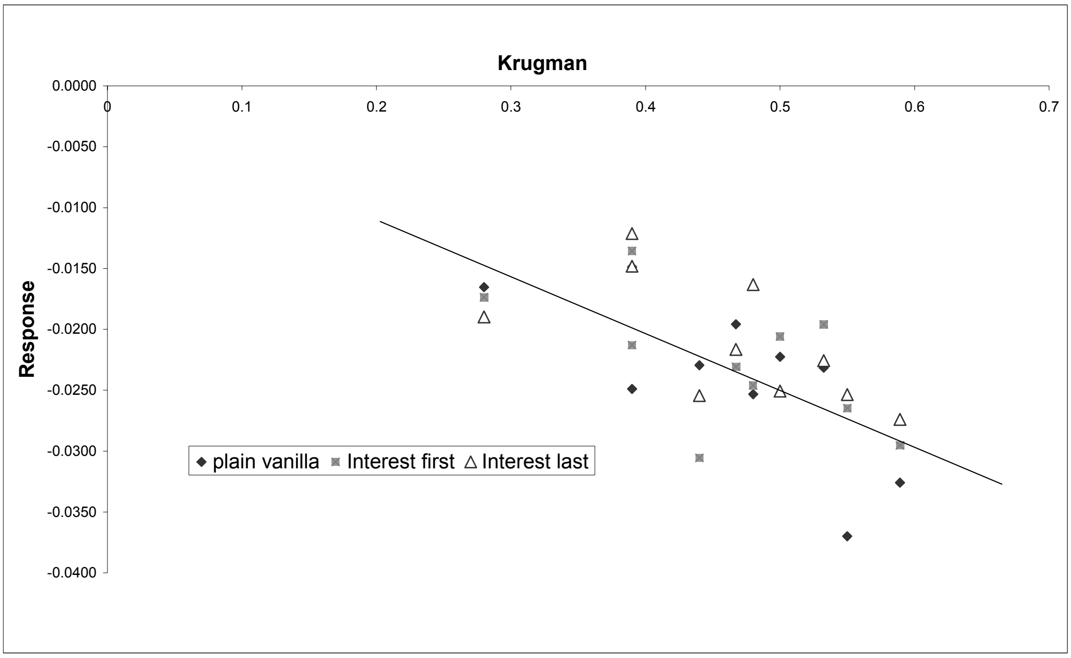


Figure 79: Plot of Cumulative Responses vs Export Share

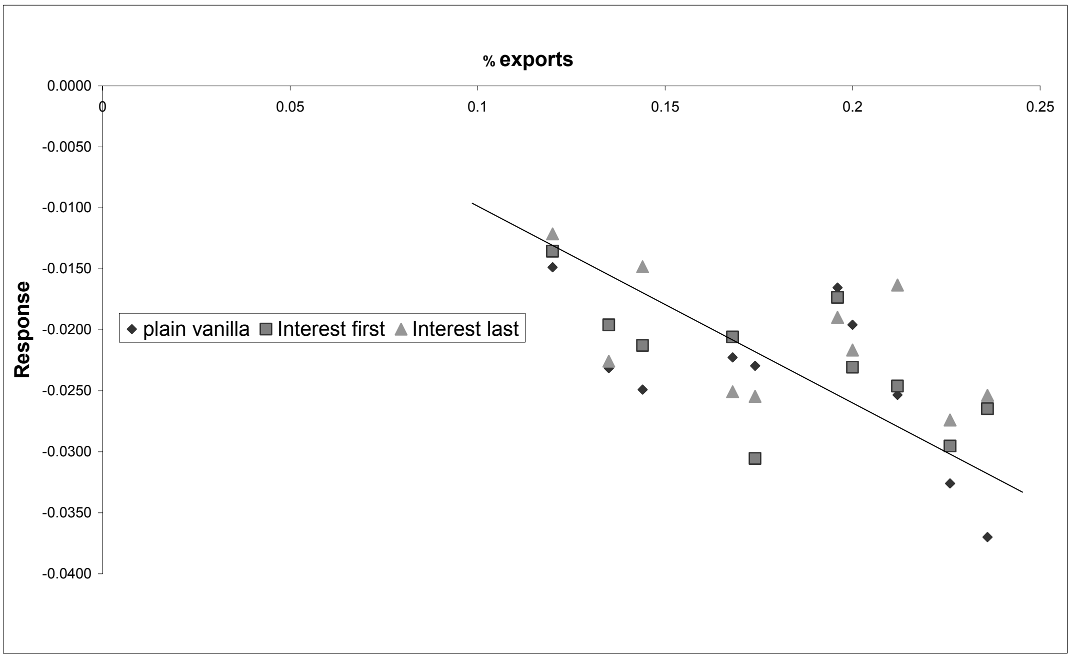
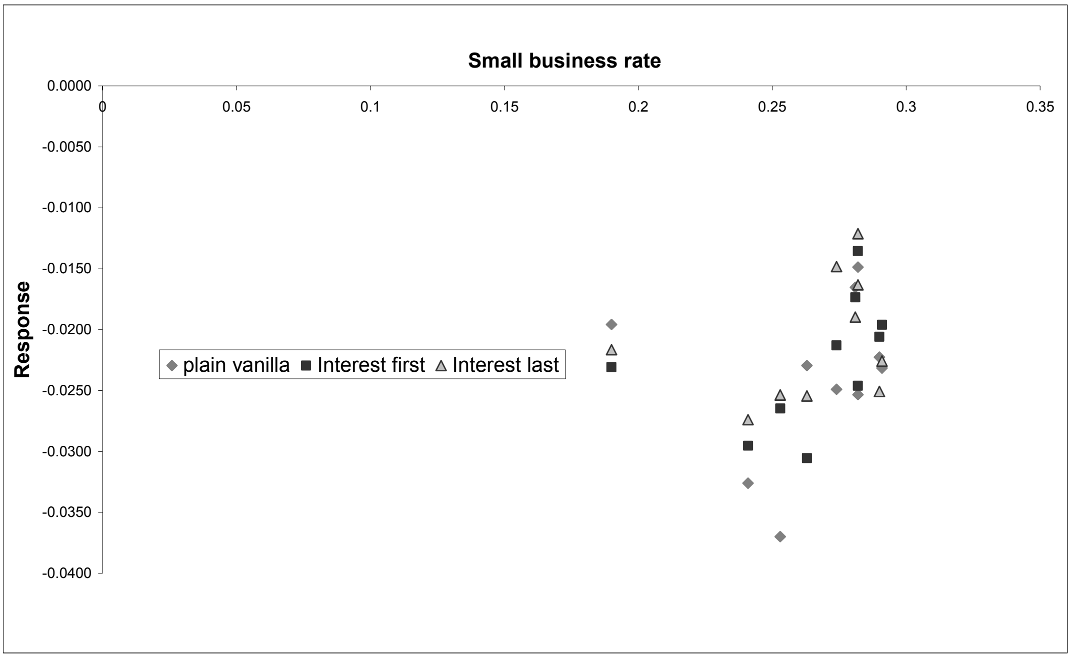


Figure 80: Plot of Cumulative Responses vs Small Business Rates



It is fortunate that there are similar measures available across the UK regions. It is possible to review the relationship between the cumulative response and the Krugman index[20], a measure of industrial heterogeneity[21], which should provide an indication of the effect of the differing sectoral interest rate sensitivity. The channel effects and export / exchange rate effects can be represented by using the percentage of small businesses (less than 250 employees) per thousand firms and the value of regional GVA accounted for by export value respective.

The first of these values was calculated (see chapter 3) the other two variables were sourced from ONS: Employment and Labour Market Trends 07. The values used are below in table 30.

Table 30: Regional Values of Krugman Index, Export Share and Small Business Rate

	Krugman (82 value)	Exports (% regional GVA 04)	Small business rate 2004
ea	0.467	0.200	0.190
em	0.589	0.226	0.241
ne	0.550	0.236	0.253
nw	0.440	0.174	0.263
sco	0.390	0.144	0.274
se	0.280	0.196	0.281
sw	0.390	0.120	0.282
wal	0.480	0.212	0.282
wm	0.500	0.168	0.290
yks	0.532	0.135	0.291

---

[20] As outlined in chapter three, the measure is constructed as $Krugman_{jk} = \sum_{n=1}^{N} | s_{nj} - s_{nk} |$

Where s_{nj} and s_{nk} denotes the output share of sector n in regions j and k. The index ranges from zero to two. Zero for identical similarity. Two for perfect dissimilarity (with the caveat that if such a concept exists).

[21] The Krugman Index was used because it provides a measure of overall econonomic sectoral dissimilarity than purely a one industry measure of manufacturing or extractive industries.

As is evident from figures 78 to 80 there seems to be a clear relationship between at least the first two of the three variables where an increasing value of the Krugman Index (ie a greater dissimilarity in sectoral composition) and an increasing share of exports leads to a greater long run cumulative impact of an interest rate shock.

A glance at the correlations between the variables in table 31 supports this view.

Table 31: Simple correlations with Explanatory Variables

	interest first	interest last	plain vanilla
krugman	-0.5732	-0.6438	-0.7397
exports	-0.6434	-0.5309	-0.6434
share small business	0.4116	0.3053	0.181

To verify this apparent relationship two methods are utilised. First the Spearman Rank correlation is calculated between the rank of the cumulative response and the rank of the variable respectively (where the values calculated for the 'plain vanilla' responses are included for comparison). These indeed confirm a statistically significant relationship between the first of these three variables (table 32)

Table 32: Spearman Rank Correlations with 'Explanatory' Variables

	int first	int last	Plain vanilla
krug	0.466667	0.684848	0.672727
exports	0.684848	0.515152	0.612121
small biz	0.187879	0.018182	0.381818

Table 33: Regression of Responses on all 'explanatory' Variables

All observations				
Variable	Coefficient	std err	t-stat	Prob.
C	0.002615	0.009514	0.274801	0.7856
KRUG	-0.03194	0.009481	-3.36824	0.0024
EXPORTS	-0.06102	0.023763	-2.56777	0.0163
SMALLBIZ	0.002515	0.028327	0.088776	0.9299
R-squared	0.556156		F-stat	10.85973*
			*jointly sig at 1% level	
Vanilla Observations				
Variable	Coefficient	std err	t-stat	Prob.
C	-0.00286	0.01744	-0.16387	0.8752
KRUG	-0.0466	0.017379	-2.68146	0.0365
EXPORTS	-0.05728	0.043557	-1.31502	0.2365
SMALLBIZ	0.040936	0.051922	0.788411	0.4605
R-squared	0.733307		F-stat	5.499253*
			*jointly sig at 5% level	
Interest first Observations				
Variable	Coefficient	std err	t-stat	Prob.
C	0.012918	0.016861	0.766111	0.4727
KRUG	-0.01876	0.016803	-1.11645	0.3069
EXPORTS	-0.08487	0.042112	-2.0154	0.0905
SMALLBIZ	-0.04361	0.0502	-0.86878	0.4184
R-squared	0.59976		F-stat	2.996997*
			*not jointly significant at 10% level	
Interest last Observations				
Variable	Coefficient	std err	t-stat	Prob.
C	-0.00222	0.018108	-0.12238	0.9066
KRUG	-0.03045	0.018045	-1.68716	0.1425
EXPORTS	-0.0409	0.045226	-0.90435	0.4007
SMALLBIZ	0.010221	0.053912	0.189579	0.8559
R-squared	0.51718		F-stat	2.142326*
			*not jointly significant at 10% level	

Table 34: Regression of Responses on Krugman and Exports

All Observations

Variable	Coefficient	std err	t-stat	Prob.
C	0.003354	0.004508	0.743982	0.4633
KRUG	-0.03172	0.008988	-3.52887	0.0015
EXPORTS	-0.06198	0.02074	-2.98851	0.0059
R-squared	0.556022		F-stat	16.90691*
			*jointly sig at 1% level	

Vanilla Observations

Variable	Coefficient	std err	t-stat	Prob.
C	0.009183	0.008189	1.121328	0.2991
KRUG	-0.04305	0.016326	-2.63704	0.0336
EXPORTS	-0.07298	0.037673	-1.93729	0.0939
			F-stat	8.391724*
			*jointly sig at 5% level	

Interest first Observations

Variable	Coefficient	std err	t-stat	Prob.
C	8.94E-05	0.007997	0.011179	0.9914
KRUG	-0.02254	0.015943	-1.41384	0.2003
EXPORTS	-0.06814	0.036788	-1.85224	0.1064
R-squared	0.549411		F-stat	4.26761*
			*jointly significant at 10% level	

Interest last Observations

Variable	Coefficient	std err	t-stat	Prob.
C	0.00079	0.008119	0.097342	0.9252
KRUG	-0.02956	0.016185	-1.82635	0.1105
EXPORTS	-0.04482	0.037347	-1.20014	0.2691
R-squared	0.514287		F-stat	3.705907*
			*jointly significant at 10% level	

The next route is that of regression. There is obviously first the concern that there are so few observations (ten observations for each variable – ie 10 regions). However, with such a small observation set any relationship would need to be strong to display evidence of statistical significance. Given the sample size is so small, the regression results significance is quite compelling (tables 33 and 34). The regression is first estimated with all three explanatory variables. Given that the coefficient on the small business rate is insignificant across all estimations this term is dropped and the regression is estimated with just the two variables; Krugman index and export percentage.

Each regression is estimated for both interest rate orderings and again the plain vanilla results are included. In addition, given the small sample size a first regression to be estimated is one across all three sets of results simultaneously. This is defensible by recourse to the argument that it is effectively paneling three sets of results to gain greater statistical accuracy. Where one stands on whether this is a fair or foul method there is no doubt the results provide strong evidence support to the conclusion that the variables strongly and significantly effect the level of cumulative response of a region to a monetary policy shock.

Whilst this might perhaps prematurely allude to the conclusion to be drawn, this is supported by a careful reading of the rest of the results. For each of the two variable regressions the explanatory variables are jointly significant at the 10%

level and for the plain vanilla responses at the 5% level. Indeed for the three variable cases the vanilla results are still significant at the 5% level. That the vanilla results exhibit the most statistical significance is to be expected. These results have not had the contemporaneous influence of the aggregate variable removed (see earlier discussion) and so the cumulative responses are larger in absolute terms as is the spread of responses across the regions (some 50% larger).

Whilst for the ‘aggregate output variable included’ regressions there is only one occasion where there is a statistically significant value for a coefficient (on exports in the three variable regression, interest rate first) there are several that are nearly significant at the 10% level in the two variable case. The R squared values for all of the regressions is greater that 0.50 which is reasonable given there are only ten data points to Carlino and Defina’s 48. Whilst the value of the constant is only weakly estimated its removal leads to the coefficient on Krugman becoming significant in every single regression and whilst one may disagree about whether pooling each set of results (ie this was a ‘quasi’ panel given that there was only have one set of explanatory variables they are the same for each regressand) the statistical significance is still of note.

The rank ordering across the four methods of the impulse response and across the VAR responses for the cumulative responses show clear evidence for there being consistent heterogeneities of responses across the regions. The correlations, rank correlations and to a lesser extent the regression results also provide (in the author's view) pretty compelling evidence for the differences across regions being systematic. This statistical evidence supports the view that sectoral dissimilarity (and thus differing interest rate sensitivities) is a cause of heterogeneous responses to interest rate shocks. This is the first time that an attempt has been made to account for estimated heterogeneities of regional responses and the only evidence provided to date to show that, similar to US regions, EU states and regions, the UK regions' responses to interest rate shocks is determined by their industrial composition.

This differing sectoral sensitivities to interest rate shocks will now be explored further but first the robustness checks of the VAR responses is presented.

6.6 Robustness checks

As outlined in chapter 4, a common test for 'robustness' of VAR estimates is the comparison of VAR estimates with the simulated response of output growth equations in the style of Karras (1996). The output growth equation chosen is of the form:

$$\Delta y_t^j = \beta + \sum_{i=1}^{n} \kappa_i \Delta y_{t-i}^j + \sum_{i=0}^{n} \theta_i \Delta o_{t-i} + \sum_{i=1}^{n} \xi_i u_{t-i} + v_t^j \qquad (44)$$

which is essentially the same model used by Holmes in a test for asymmetry in regional responses to monetary shocks. The difference being is that Holmes used two variables for shocks, a series for positive shocks and another for negative shocks: his object of interest being to test for asymmetries in responses. Here two lags of output and shocks are included and the contemporaneous value of the oil price (as in Holmes).

Hence for easy reference this equation has generally been referred to as either the structural shock model or 'Holmes' equation. A variant often used is to regress output growth on all the variables in the original VAR and pare down the model (as outlined by CEE (1998) and Darby & Phillips (2007)). The Holmes equation in the form outlined above has been chosen here.

The monetary structural shocks (see Figure 81) are first determined by estimating a monetary policy function of a standard form. A Taylor type rule based on the lags of inflation, the output gap (estimated via deviations of UK aggregate output from an HP trend), the exchange rate and a lag of the interest rate itself was estimated (given the general consensus is that central banks tend to prefer interest rate smoothing to sudden policy shifts (McCallum 1998)).

Figure 83 compares the maximum impulse responses of the VAR method to the maximum movement under Holmes (clearly units will be different). The clear positive correlation together with a Spearman Rank correlation of some 0.70 and 0.81 between the ranked responses of the Holmes and interest rate first and last VAR results respectively corroborate the robustness of the VAR estimates the VAR estimates are indeed robust. Table 35 produces the coefficient estimates of the 'Holmes' SUR structural equation. As is immediately obvious, the majority of the relevant structural shock coefficients are estimated with a high degree of accuracy given the restriction to annual data. Only the coefficient on the Southwest is not statistically significant at any standard level (ie 10%, 5% or 1%) and four out of the remaining nine coefficients are significant at the 1% level.

Figure 81: Estimated Monetary Shocks from 'Taylor' Regression

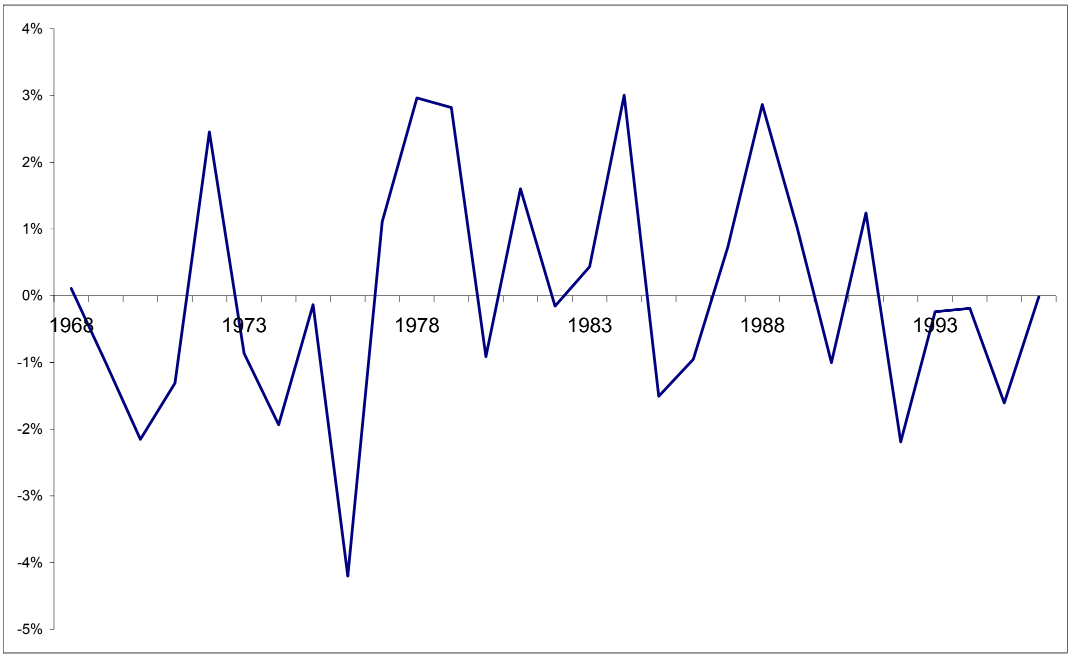


Figure 82: Interest Rate and Estimated Monetary Shocks

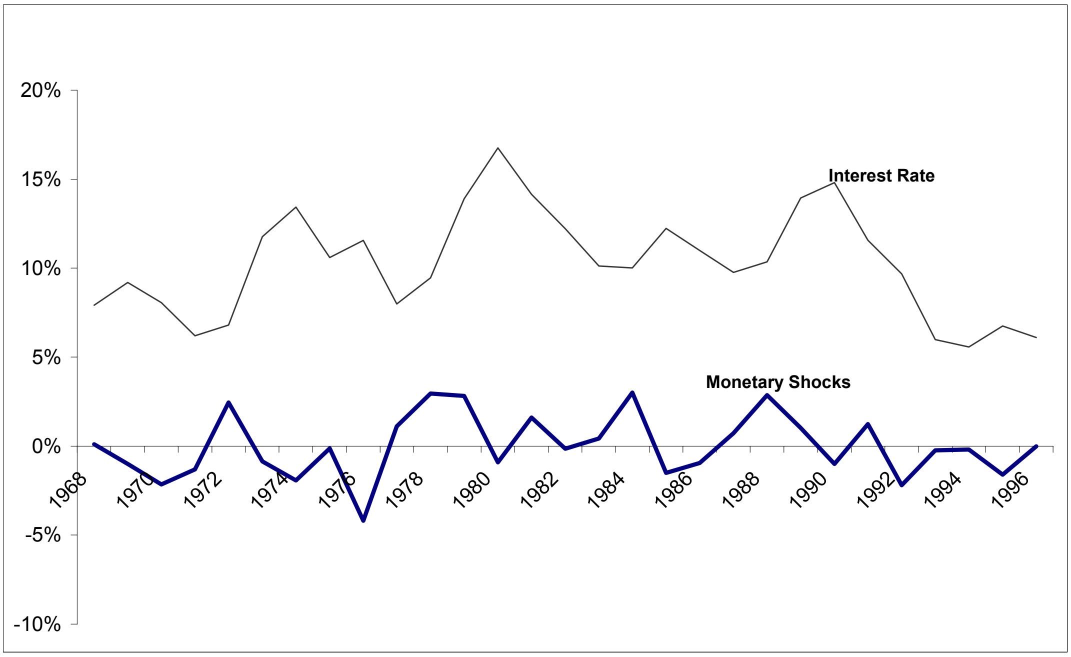
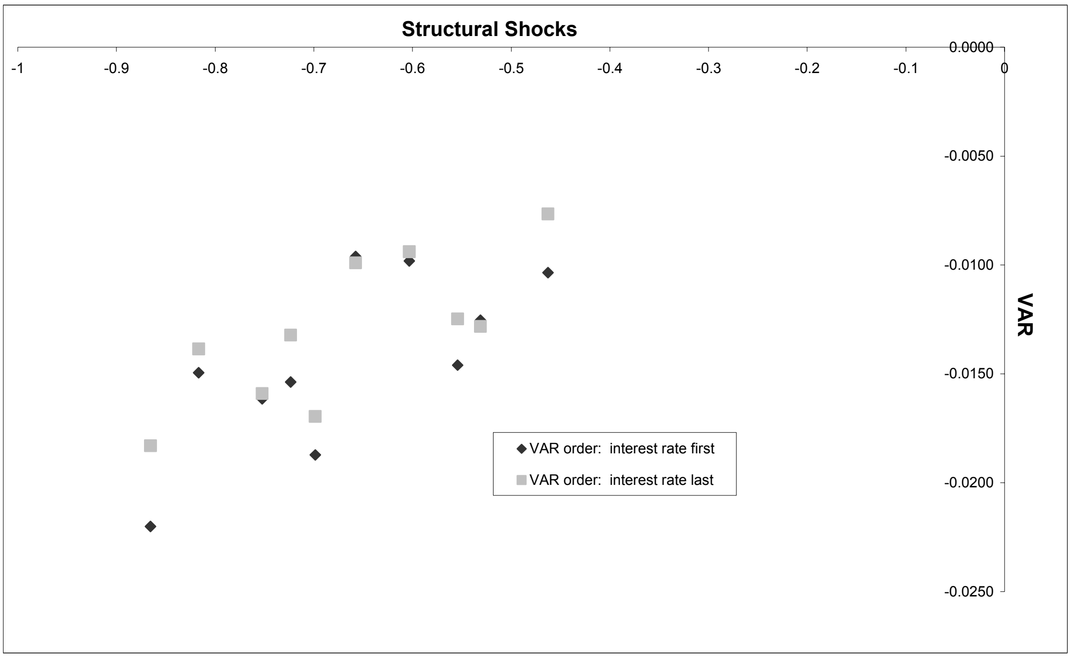


Figure 83: VAR Impulse Responses vs Structural Estimate Responses



This therefore now provides evidence of statistically significant responses. A test for whether these coefficients are statistically similar or not now provides the evidence of whether the responses are statistically significantly different.

For the simple Wald Test of cross equation restriction that the coefficients of ξ_1 are the same the chi squared statistic of the null that each coefficient is equal to each other is reported as 28.1594 with nine degrees of freedom, a clear rejection with a critical value of 21.666 at the 1% level of significance. The research has now shown that the regional responses are statistically different in addition to being systematic and related to the structural differences in the economies.

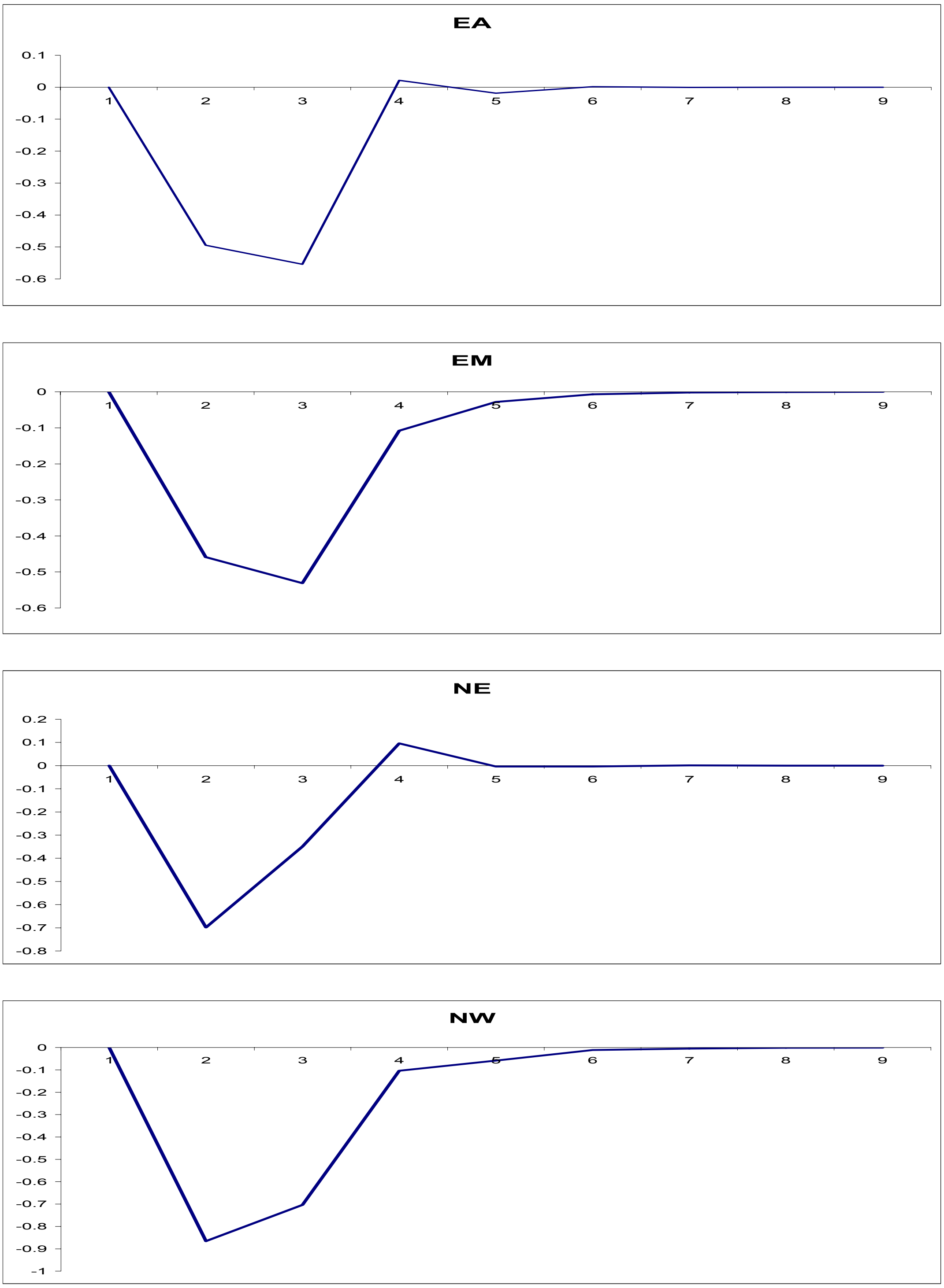
A rank correlation test of the Holmes test with the explanatory variables used previously is inappropriate since this was an exploration of determinants of cumulative response. However, with a mind to the fact that the shocks in this equation are indeed structural insofar as they have been identified and estimated from a monetary reaction function the rank correlation with the value of gamma – the structural degree of co-movement in supply to demand estimated in chapter 5 - value is high, providing support for joint confidence in the both sets of 'structural' estimates, at 0.782.

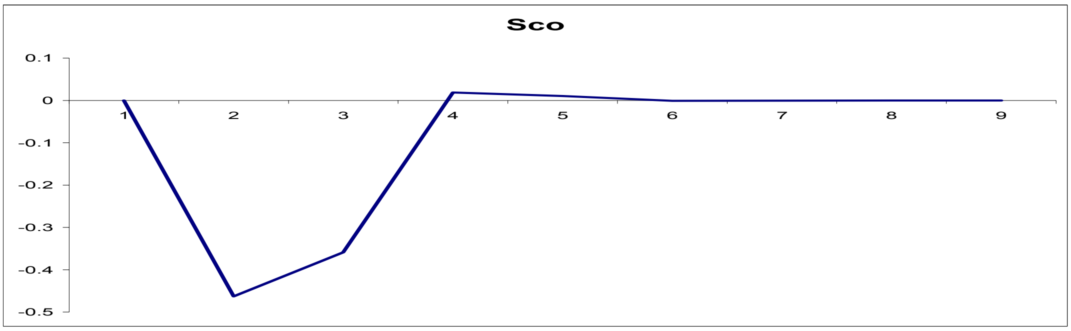
Table 35: ‘Holmes’ SUR Estimates

	EA		t stat	EM		t stat	NE		t stat	NW		t stat	Sco		t stat
β	0.038	***	5.481	0.026	***	5.650	0.026	***	4.182	0.022	***	4.945	0.027	***	4.471
se	0.007			0.005			0.006			0.005			0.006		
κ1	-0.063		-0.509	0.202	**	1.970	-0.170	*	-1.649	0.089		1.242	-0.001		-0.015
se	0.123			0.103			0.103			0.072			0.096		
κ2	-0.010		-0.088	-0.056		-0.588	-0.120		-1.188	-0.046		-0.842	-0.118		-1.232
se	0.110			0.095			0.101			0.055			0.096		
θ	-0.049	***	-3.273	-0.019	*	-1.699	-0.036	**	-2.113	-0.058	***	-4.811	-0.027	*	-1.707
se	0.015			0.011			0.017			0.012			0.016		
ξ1	-0.498	*	-1.875	-0.466	**	-2.377	-0.729	**	-2.380	-0.872	***	-4.006	-0.506	*	-1.790
se	0.265			0.196			0.306			0.218			0.283		
ξ2	-0.580	**	-1.959	-0.425	*	-1.920	-0.451		-1.324	-0.606	**	-2.460	-0.347		-1.126
se	0.296			0.221			0.340			0.246			0.309		
	*,**,*** indicates significance at the 10, 5, 1% level respectively														

	SE		t stat	SW		t stat	Wal		t stat	WM		t stat	Yks		t stat
β	0.022	***	5.264	0.031	***	5.464	0.024	***	4.309	0.016	***	3.587	0.021	***	4.771
se	0.004			0.006			0.006			0.004			0.004		
κ1	0.309	***	3.821	0.287	**	2.462	0.155		1.557	0.281	**	3.094	0.189	**	2.183
se	0.081			0.117			0.100			0.091			0.087		
κ2	0.017		0.238	-0.195	*	-1.741	-0.027		-0.310	0.102		1.313	-0.038		-0.480
se	0.070			0.112			0.088			0.078			0.078		
θ	-0.062	***	-5.587	-0.019		-1.533	-0.056	***	-3.730	-0.050	***	-4.117	-0.037	**	-3.221
se	0.011			0.012			0.015			0.012			0.012		
ξ1	-0.621	***	-3.106	-0.340		-1.524	-0.726	***	-2.682	-0.757	***	-3.414	-0.371	*	-1.771
se	0.200			0.223			0.271			0.222			0.210		
ξ2	-0.596	***	-2.650	-0.503	*	-2.055	-0.375		-1.235	-0.412		-1.613	-0.581	**	-2.514
se	0.225			0.245			0.304			0.256			0.231		
	*,**,*** indicates significance at the 10, 5, 1% level respectively														

Figure 84: Regional 'Structural' Responses




Sco
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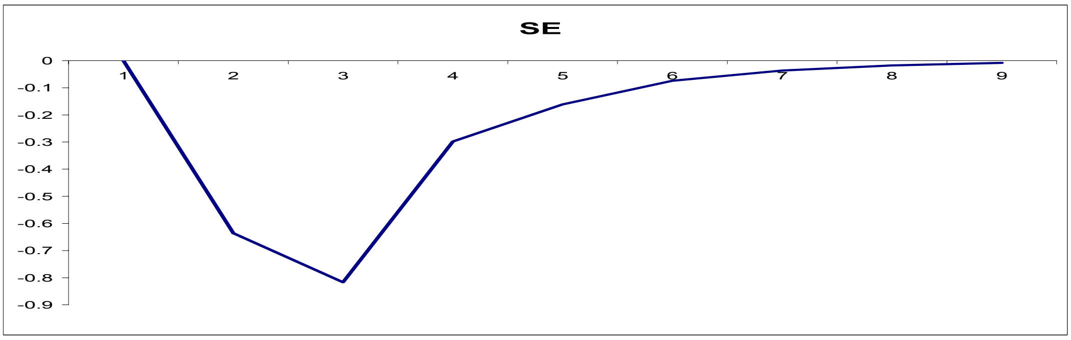
SE
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-0.2
-0.3
-0.4
-0.5
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-0.7
-0.8
-0.9
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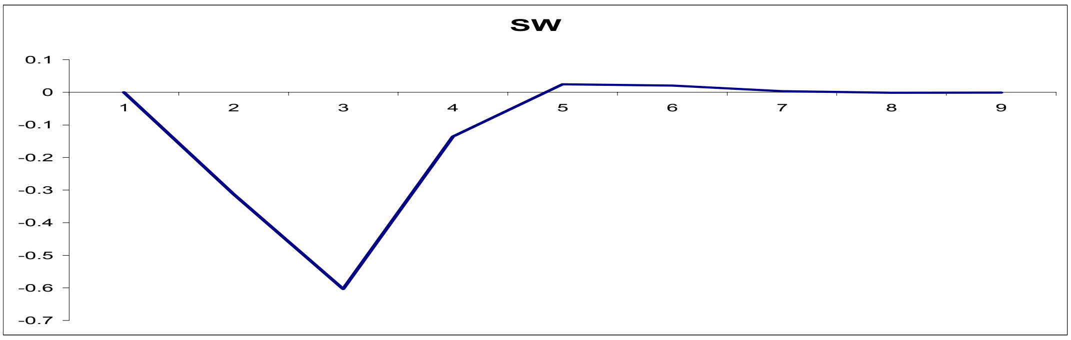
SW
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0
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-0.2
-0.3
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-0.6
-0.7
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2
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4
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6
7
8
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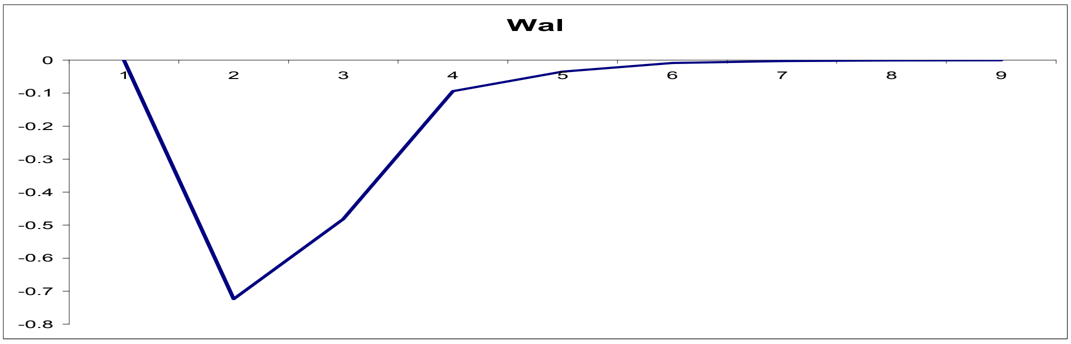
Wal
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-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
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3
4
5
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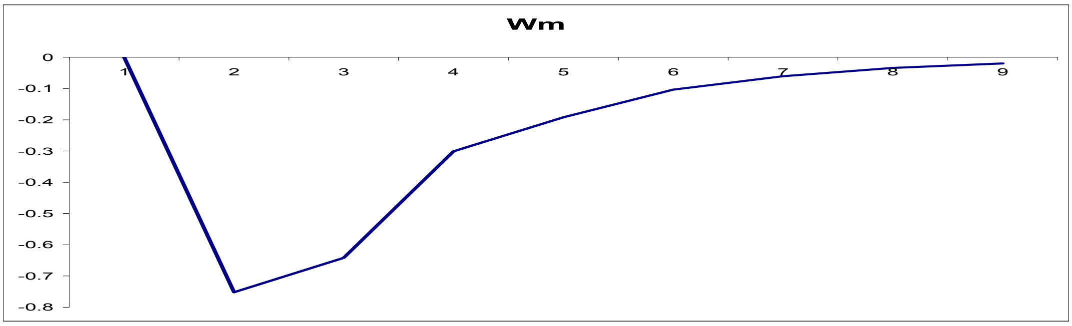
Wm
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-0.5
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-0.8
1
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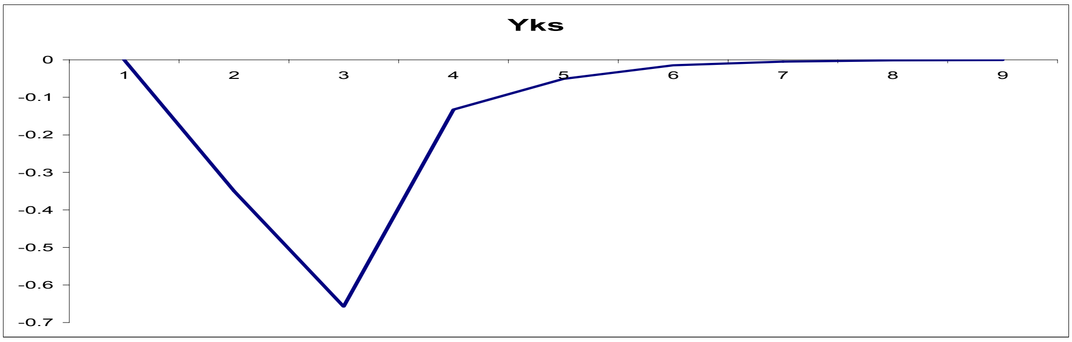
Yks
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
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6.7 Regional Sectors

Finally, the key finding of the research of this chapter has been to show that the differing reactions to shocks across the regions can be shown to be accountable by industrial sectoral factors: namely as a result of differing industrial composition of the regions. This accords with evidence suggested by Carlino and Defina (1998) and Dedoli and Lippa (2005) and others and this work has provided evidence in support of this being the case for the UK regions for the first time.

However, Darby & Phillips, researchers who have been mentioned frequently, have suggested that differing responses of the same sector across regions also has a part to play, ie that ‘spatial’ effects are also important. Notwithstanding the slight issues with the methodology that were raised earlier in this chapter, the question is whether similar analysis be conducted for the UK regions given the major data issues present? As dummies to account for spatial effects could not be included in the regressions due to a lack of degrees of freedom, this is a pertinent question.

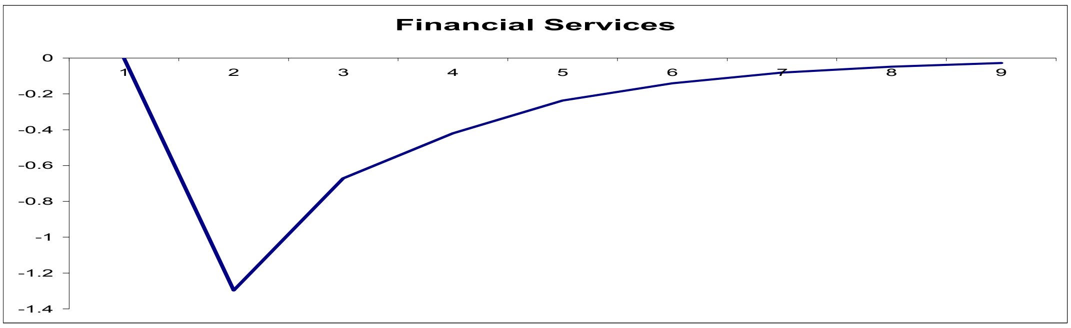
Regional sectoral output series for the UK regions have been constructed as described and explained in chapter 3. This data does have major weaknesses. Apart from its annual nature and its short length (no more than 20 years) it is a composite of two separate series (see chapter 3). It will not be possible draw robust conclusions, particularly on dynamics, from such series.

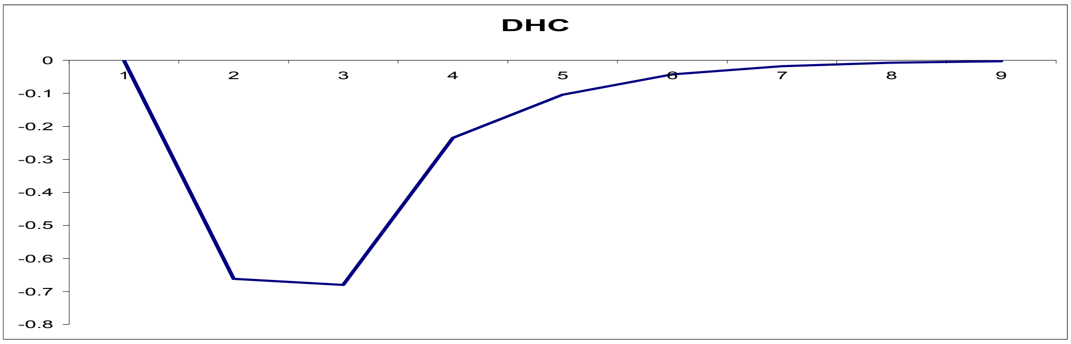
However, 2 lag VARs have been estimated for each regional sector series (and a few of these are reproduced and discussed in appendix fourteen). These show that the same sector across each region display similar *looking* impulse responses to each other. They also show that the differences across sectors are similar looking in nature to the ‘stylised facts’ of Ganley and Salmon (1996). The use of italics is deliberate. It is not possible to infer differences in response in the manner outlined earlier. All impulses lay well within what are rather large confidence bands. Also estimated and produced here are the structural responses (ie calculated by the ‘Holmes’ method) reproduced in figure 85 which again share remarkably similar characteristics to the Ganley and Salmon results: sufficient to provide enough confidence to utilise to test a line of logic below.

Despite data constraints a line of logic is proposed to test whether differences in responses between sectors across regions is likely to be a major contributor to heterogeneous responses in the manner already shown for sectoral dissimilarity. The data series are paneled in two alternative manners. The first is to panel the sectors of the economy by regions, ie financial services ea, financial services, em, financial services, wm, etc, etc. The second is to panel the regions by the sectors of the economy, ie em financial services, em manufacturing, em education and health etc.

Now the Holmes equation is estimated using monetary shocks from a paneled estimation of the Taylor reaction function the statistical properties of the results (which are outlined in tables 36 and 37) are compared and contrasted. Clearly the statistical robustness of the 'sectors by regions' panel is vastly superior to anything yet produced, yet the 'regions by sector' panel is not. This surely is due to the fact that the sectors by region is a panel of similarity whereas the regions by sectors is a panel of heterogeneity. The Wald test of the restriction that all of the coefficients on the period one shock term are equal is not rejected by the 'regions by sector' panel' with a Chi squared value of 10.74776 with nine degrees of freedom and is massively rejected by the sectors by region panel with a Chi squared value of 158.2936 (again with nine degrees of freedom).

Figure 85: Sectoral 'Structural' Responses

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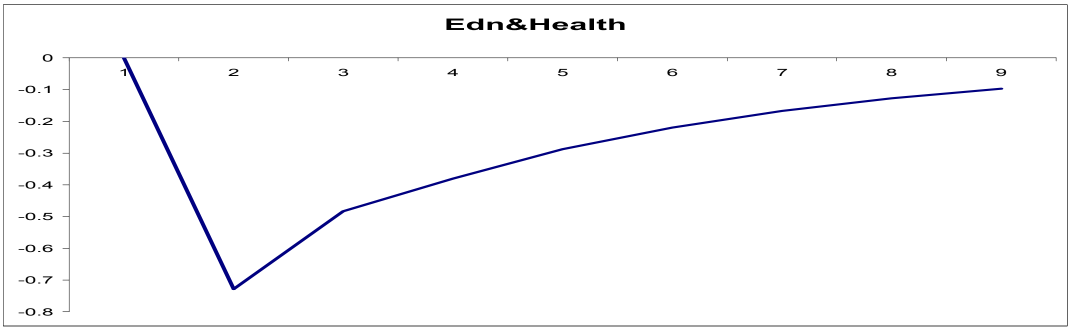
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
1 2 3 4 5 6 7 8 9


Man
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
1 2 3 4 5 6 7 8 9


Edn&Health
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-0.5
-0.6
-0.7
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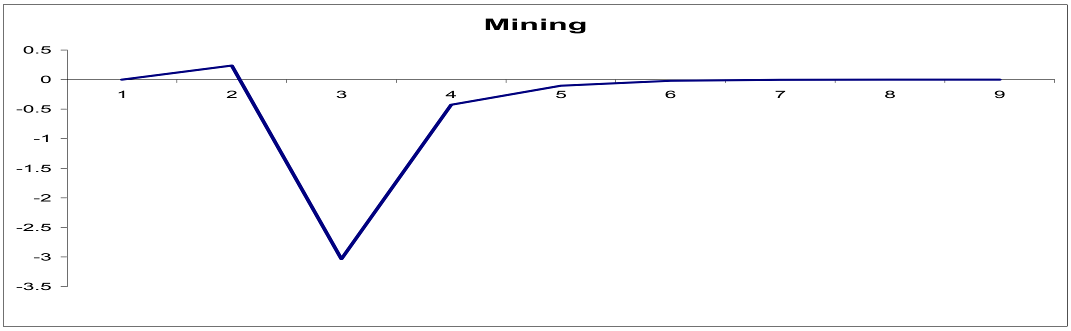
1 2 3 4 5 6 7 8 9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-2
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-3
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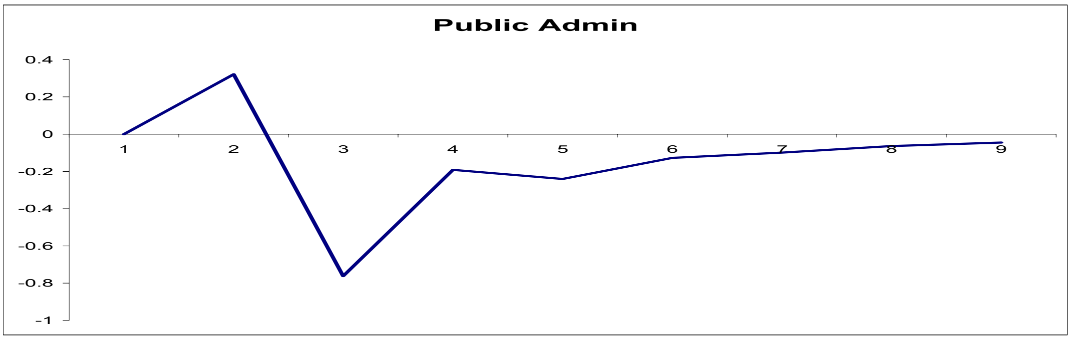
1 2 3 4 5 6 7 8 9


Public Admin
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0
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-1
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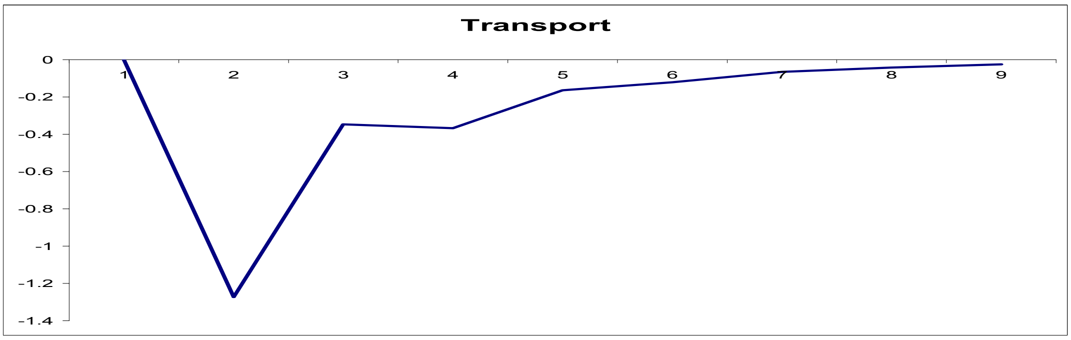
Transport
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-0.4
-0.6
-0.8
-1
-1.2
-1.4
1
2
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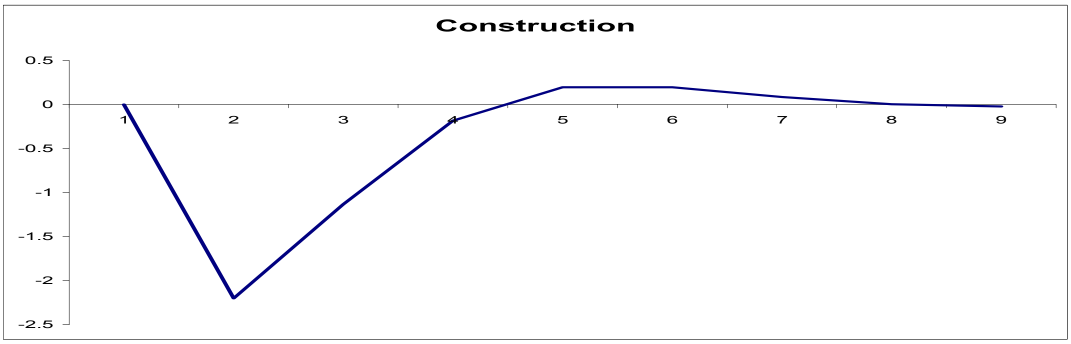
8
9


Construction
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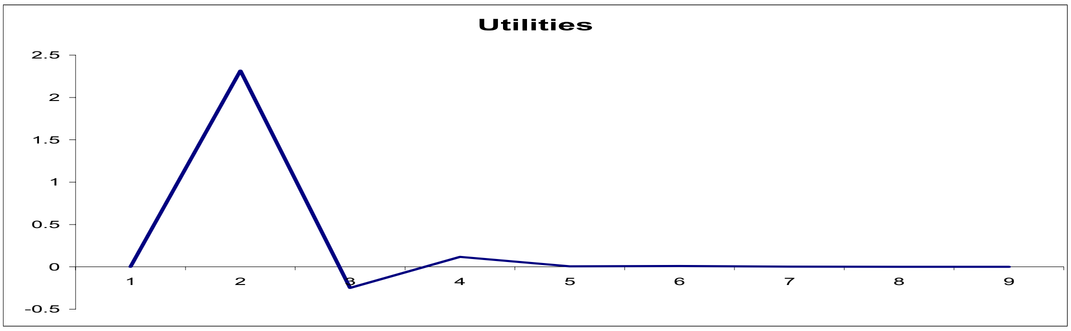
0
-0.5
-1
-1.5
-2
-2.5
1
2
3
4
5
6
7
8
9


Utilities
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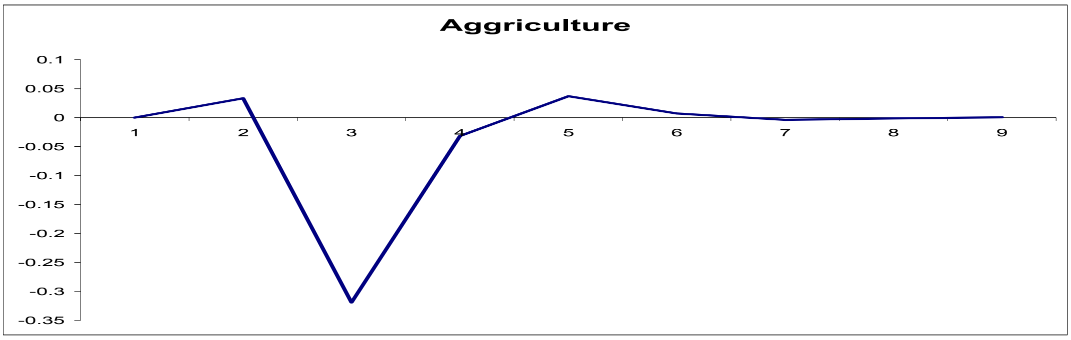
2
1.5
1
0.5
0
-0.5
1
2
3
4
5
6
7
8
9



The deductive logic is simple: the similarity between the sectors across the regions is driving the statistically accuracy of the paneled estimation. The opposite is the case for the regions by sector panel. All of the previous tests indicated statistically different regional responses to monetary shocks. Yet, the regional output is disaggregated by sector and then re-aggregated by paneling the dissimilarity of sectors is sufficient to snuff out this statistically different response across the region[22]. The line of logic suggests therefore that the dissimilarity within sectors across regions is unlikely to be significant (as paneling would not produce the improved statistical significance illustrated in table 36) and therefore an unlikely source of the cause of dissimilarity of regional responses to monetary shocks: in short evidence not in favour of spatial effects.

[22] An attempt was made to estimate each sector by separate regional sectoral output equations by SUR with a view using the Wald test for coefficient restrictions but the statistical robustness of the estimates was not sufficient to draw plausibly confident conclusions.

Table 36: 'Holmes' SUR Sector Estimates

	man		t-stat	dhc		t-stat	fin		t-stat	eh		t-stat	min		t-stat
β	-0.003		-1.357	0.000		-0.164	0.001		0.286	0.002		1.042	0.001		0.158
se	0.002			0.001			0.002			0.002			0.008		
κ1	0.542	***	10.148	0.295	***	5.632	0.272	***	4.294	0.593	***	9.491	0.141	***	3.283
se	0.053			0.052			0.063			0.063			0.043		
κ2	-0.110	**	-2.184	0.052		0.956	0.183	***	2.818	0.129	**	1.944	0.015		0.468
	0.050			0.054			0.065			0.066			0.032		
θ	-0.034	***	-2.773	-0.031	***	-4.265	-0.065	***	-5.577	-0.041	***	-4.398	0.133	***	3.750
se	0.012			0.007			0.012			0.009			0.035		
ξ1	-1.131	***	-5.537	-0.662	***	-5.072	-1.296	***	-6.450	-0.728	***	-4.285	0.236		0.384
se	0.204			0.131			0.201			0.170			0.614		
ξ2	0.965	***	5.721	-0.485	***	-4.908	-0.319	**	-2.040	-0.051		-0.430	-3.068	***	-6.189
se	0.169			0.099			0.157			0.119			0.496		

*,**,*** indicates significance at the 10, 5, 1% level respectively

	pa		t-stat	trns		t-stat	util		t-stat	agg		t-stat	cons		t-stat
β	-0.001		-0.381	-0.001		-0.558	0.001		0.282	-0.001		-0.163	0.004		1.149
se	0.002			0.002			0.004			0.007			0.003		
κ1	0.348	***	6.648	0.233	***	3.995	0.215	***	3.532	0.086	**	1.827	0.726	***	12.257
se	0.052			0.058			0.061			0.047			0.059		
κ2	0.229	***	4.108	0.225	***	3.792	0.074		1.565	-0.124	***	-2.754	-0.290	***	-5.575
se	0.056			0.059			0.047			0.045			0.052		
θ	0.088	***	10.063	-0.058	***	-5.376	0.009		0.477	0.023		0.719	-0.052	***	-3.377
se	0.009			0.011			0.020			0.033			0.015		
ξ1	0.322	**	2.151	-1.273	***	-6.499	2.316	***	6.932	0.033		0.062	-2.202	***	-7.389
se	0.150			0.196			0.334			0.539			0.298		
ξ2	-0.874	***	-7.242	-0.050		-0.329	-0.746	**	-2.478	-0.322		-0.749	0.464	**	1.975
se	0.121			0.151			0.301			0.430			0.235		

*,**,*** indicates significance at the 10, 5, 1% level respectively

Wald Test of Cross Equation Restrictions of Equal Coefficients on Shock Term

Wald Test:
System: SYS01

Test Statistic	Value	df	Probability
Chi-square	158.2936	9	0.0000

Table 37: 'Holmes' SUR Regional Estimates

	EA		t-stat	EM		t-stat	NE		t-stat	NW		t-stat	Sco		t-stat
β	-0.001		-0.266	-0.002		-0.438	0.000		0.100	0.001		0.324	0.000		0.092
se	0.004			0.005			0.004			0.004			0.004		
κ_1	0.223	***	5.273	0.103	***	3.494	0.270	***	6.577	0.284	***	6.266	0.051		1.115
se	0.042			0.029			0.041			0.045			0.046		
κ_2	0.035		1.068	0.017		0.736	-0.020		-0.607	-0.098		-2.343	0.105	***	2.660
se	0.033			0.023			0.033			0.042			0.040		
θ	-0.019		-0.951	0.026		1.174	0.008		0.403	-0.005		-0.233	0.000		0.014
se	0.020			0.022			0.020			0.021			0.020		
ξ_1	-0.838	**	-2.390	-0.161		-0.423	-0.322		-0.950	-0.622	*	-1.706	-0.307		-0.907
se	0.351			0.379			0.339			0.364			0.339		
ξ_2	-0.444		-1.570	-0.612		-2.012	-0.752	***	-2.753	-0.701	**	-2.383	-0.378		-1.398
se	0.283			0.304			0.273			0.294			0.270		

*,**,*** indicates significance at the 10, 5, 1% level respectively

	SE		t-stat	SW		t-stat	Wal		t-stat	WM		t-stat	Yks		t-stat
β	0.000		0.018	0.002		0.501	0.003		0.759	0.000		0.095	0.000		0.058
se	0.004			0.004			0.004			0.004			0.004		
κ_1	0.194	***	4.640	0.250	***	8.090	0.309	***	6.030	0.285	***	9.524	0.098	***	3.424
se	0.042			0.031			0.051			0.030			0.029		
κ_2	-0.017		-0.447	-0.074	**	-2.912	-0.029		-0.618	-0.020		-0.875	0.054	**	2.469
se	0.038			0.026			0.047			0.023			0.022		
θ	0.003		0.122	-0.021		-0.968	-0.009		-0.466	-0.003		-0.180	0.015		0.727
se	0.021			0.021			0.019			0.019			0.021		
ξ_1	-0.359		-1.004	-0.532		-1.457	-0.496		-1.544	-0.391		-1.232	-0.507		-1.406
se	0.358			0.365			0.321			0.317			0.361		
ξ_2	-0.213		-0.742	-0.257		-0.877	-0.397		-1.538	-0.551	**	-2.159	-0.820	**	-2.828
se	0.286			0.293			0.258			0.255			0.290		

*,**,*** indicates significance at the 10, 5, 1% level respectively

Wald Test of Cross Equation Restrictions of Equal Coefficients on Shock Term

Wald Test:
System: SYS01

Test Statistic	Value	df	Probability
Chi-square	10.74776	9	0.2934

6. 8 Conclusion

The results presented in this chapter have reviewed the different responses to a monetary shock of the UK regions. This response has been estimated via three versions of a VAR model and SUR estimates of two systems of output equations and it has been shown that these estimates are robust and statistically similar across methodologies.

The differing responses of the regions have been shown to be statistically different using Wald tests of cross restrictions for the Holmes estimates – something that has not been evidenced prior to this. In addition it has been demonstrated how the heterogeneities of the regional responses can be accounted for by heterogeneities in industrial composition of the regions. In particular evidence has been provided that in particular sectoral dissimilarity contributes to the differing responses (via the varying interest rate sensitivities of the sectoral composition) and also to some support to an exchange rate effect which again varies according to the regions' degree of export orientation of its economy.

A line of logic shown that dissimilarities of the same sectors across regions are an unlikely source of heterogeneities has also been demonstrated.

The evidence is pretty unambiguous. Differing industrial composition – ie sectoral factors – is the strongest candidate to explain differing responses to interest rate changes. The public policy consequences are clear. It has also been accepted that regions must respond differently to interest rate shocks but little has been provided to date by way of evidence to explain or account for these differences. As the review in chapter 4 showed over the question 'by how much and why?' there has been little consensus. This research contributes part of the answer to that question. It has provided evidence of statistically significant systematic differences and supported a relation between these and industrial composition.

Finally in this chapter a point made by Darby & Phillips (2007) is reproduced in totality:

"In principle, if the estimated impacts of monetary policy shocks are found to be similar for the same sectors in both the whole of the UK and Scotland this could justify the use of UK wide estimates of the impact of monetary policy changes to infer a full set of regional impacts based upon the available data on the sectoral composition of regional activity and. However, to the extent that differential impacts are found for the same sectors based upon the Scottish and UK data, there would appear to be region specific factors at play, and such inference would be less feasible. The level of sectoral aggregation is also an issue here. Attribution of differential effects in the manner described above assumes that sectoral characteristics are similar across regions but there are likely to be particular cases where this assumption is questionable."

The results of this thesis dispute this. Based on the evidence, sectoral factors do seem to have a strong contribution to heterogeneity and are strong enough to provide a sufficient cause for their use as a first approximation to infer a 'full set of regional impacts'.

Returning to the argument of a regional welfare loss function discussed in the introduction, if a first approximation to regional impacts can be constructed then the public policy consequences for a central banker looking to minimise a welfare loss function that includes output variance are clear. A better idea of output variance can be constructed for each region which when aggregated can give a better approximation of the distribution of UK welfare loss and thus provide more informed policy choices.

7 NKPC Theory & Research Review

Chapters 5 and 6 have presented research based on the analysis of the transmission of shocks, monetary and demand, across the British regions. These have primarily applied the structural VAR econometric techniques. Chapter 5 showed firstly that once certain restriction have been lifted (namely the homogeneity restriction of long run neutrality of demand shocks) that demand shocks can have heterogeneous effects across the regions. Secondly, once that principle had been demonstrated, chapter 6 demonstrated that size of the differing long run (ie cumulative impulse response) of monetary shocks across the regions was related to the differing industrial characteristics of the regions.

The research presented in the next chapter takes a different but complementary approach to this issue. It takes a small scale structural modern monetary model – the hybrid New Keynesian Phillips Curve – and explores whether the estimated parameters of this model also relate to the self same industrial characteristics. If this was demonstrated to be the case it would firstly underline the importance of these industrial characteristics (and in a manner be a mutual robustness test of the two areas of work) and would reinforce the need for monetary policy to take account of regional differences in the conduct of monetary policy. For this would demonstrate that the models that inform monetary policy, such as the NKPC provide different implications for the inflation generating process (and hence policy) depending from which part of the economy their parameters are derived.

The attraction of the hybrid NKPC is that it is a model of the supply side is that it is based on structural parameters, itself grounded in microeconomic theory (which shall be explained fully in this chapter). Given the economies of the regions differ markedly in their industrial structure, logic dictates that regional estimates of the structural parameters of the model ought also to differ. This chapter provides the background and context for this model.

The results presented in chapter 8 are based on utilisation of the Hybrid New Keynesian Phillips Curve (NKPC). This is a modern macroeconomic model of aggregate supply introduced by Gali and Gertler (1999); a structural micro founded model that owes much to the real business cycle strand of research (see Cooley and Hansen (1995) for an early review of these models or McCandless (2008) for a modern expositional text) than to say the unemployment disequilibrium models attributed to the spirit of Keynes' original analysis (Layard et al (1991) is an excellent text providing a thorough exploration of the subject on disequilibrium unemployment). The version of the hybrid NKPC used is part of the solution to what is in effect a RBC model with price rigidities (although other versions of the model incorporate wage as well as or in addition to these (Amato & Laubach (2001)) and describes inflation as a function of expectations of inflation, lagged inflation and a measure of marginal costs in the economy.

7.1 History of the Phillips Curve (inflation/output dynamics)

The hybrid NKPC bears little resemblance to the original Phillips curve, itself a simple empirical relationship between money wages and unemployment first published in 1958. This describes a simple empirical negative relationship between inflation (in the first instance wage, subsequent research found a similar relationship held for price inflation) and the unemployment level. This chapter provides a brief account of both versions of Phillips curve, their relation to each other, their relevance to this thesis and a little of their history and use. Both versions remain a part of mainstream economics today providing as they do a structural and non-structural account of short run inflation dynamics. This chapter will be reviewing some of the literature and issues surrounding these models and concepts associated with both Phillips curves. It also provides a derivation of the NKPC and a thorough review of the range of estimates that have been published by many researchers working in this field.

This chapter will therefore provide a full conceptual background for the final set of reported results (chapter 8) and also act as an introduction to the concept of short run macrodynamics (the methodology of their empirical estimation with VAR models has already been introduced. Chapter 4 provided a general review of the applied VAR research material published in this field).

At the time according to Friedman (1968) the Phillips curve was seen by many to be ‘the long run structural equation which provided the missing equation the then Keynesian system needed’. Algebraically:

$$\Delta w_t = f(UN_{t-1}) \qquad (47)$$

Where Δw_t is the change in wage rate in period *t* and UN_{t-1} the unemployment rate in period t_{-1}.

Phillips’ work (1958) which was an empirical study of wages and unemployment in the in the British economy between 1861 and 1957 (absenting the periods of world wars and the Great Depression) and suggested an inverse relationship between wage inflation and unemployment. Phillips’ analysis can be interpreted as being essentially an application of demand and supply. When demand is high (unemployment low) the price of a good (in this case wages) rises and therefore higher inflation ensues. Samuelson and Solow (1960) coined the phrase ‘Phillips Curve’ when they published similar findings for the US. At the time, as can be inferred from the Friedman quote above, the relationship’s status was immediately assured implying as it did a predictable trade off between unemployment and inflation and thus its use as a policy tool was almost immediate.

Almost immediately, and separately, Friedman and Phelps (1968, 1967), illustrated that there was no such trade off and suggested that workers only cared for the real wage and therefore the relationship between wages and unemployment needed to take into account changes in prices ie:

$$\Delta w_t - \Delta p_t = f(UN_{t-1}) \qquad (48)$$

where Δp_t is the change in period t price level ie the inflation rate.

Given the relationship is derived to explain the change in the nominal wage rate agreed upon by workers and firms based on prevailing conditions and the next period inflation is unknown expectations of inflation must be taken. Thus the expectations augmented Phillips curve becomes:

$$\Delta w_t = f(UN_{t-1}) + E_{t-1}\Delta p_t \qquad (49)$$

So long as workers and firms form expectations rationally a policy maker cannot exploit any short run trade off between unemployment and inflation (any attempt to do so would only lead to a wage price spiral) and hence the long run Phillips curve must be vertical. The natural progression of this model is that the level of unemployment at this point will ensure stable inflation of any value thus it is known as the non-accelerating inflation rate of unemployment or NAIRU, also commonly though erroneously called the natural rate of unemployment.

As predicated by the Friedman and Phelps the Phillips curve empirical relationship broke down just at the time policy makers began its use in earnest. Subsequent to the supply shocks of the late sixties and early seventies the world witnessed a period of concurrent high inflation and high unemployment: contrary to what the Phillips curve would predict but consistent with the augmented approach. This led to a parting of the ways of macroeconomic schools: 'Keynesians' continuing to adapt the model to take into account the vertical long run natural rate and other exogenous factors such as supply shock to produce a consensus model described by Gordon (1997) as the 'triangle' model; the 'neo-classicals' following the Lucas critique (1976) sought to build micro-founded general equilibrium models of the economy where inflation was not endogenously modelled in early forms of the models. This line of research would later become known as real business cycle analysis (so called because the early models would seek to account for fluctuations in the model being caused by 'real' or technology shocks (Kydland & Prescott (1982), King & Plosser (1984)) and the development of these models ultimately leads back to the NKPC (returned to momentarily).

Gordon labels the traditional interpretation 'triangle' because in it inflation depends on three factors: 'inertia, demand and supply'. This generic model can be represented by the following equation:

$$\pi_t = a(L)\pi_{t-1} + b(L)D_t + c(L)z_t + e_t \qquad (50)$$

Inertia is represented by lagged rate of π_{t-1}. The term D_t equates to an index of excess demand, where D_t = 0 indicates an absence of excess demand clearly. z_t is a vector of supply shocks and $a(L)$, $b(L)$ and *c(L)* are polynomials in the lag operator. As is standard practice e_t is assumed to be an uncorrelated error term.

Variables that can act as proxies for the index of excess demand D_t include the output gap and the unemployment gap. The subject of the modern theoretical concept of the output gap will be returned to later in this chapter as it is the issue of some debate (Neiss & Nelson (2002), Nelson & Nikolov (2003)). Traditionally in empirical estimation it is taken to be the difference between output and its potential, 'natural' or trend rate. The trend is often taken to be an HP filtered version of the series which is assumed to remove business cycle fluctuations. The unemployment gap is taken to be the difference between unemployment and its 'natural' rate and it is via this route that a mechanism is retained for unemployment to influence future inflation.

Variations of this model have proven remarkably resilient and reliable over time and academics continue to stress its relevance as providing a model of a relationship between inflation and the NAIRU (Staiger, Stock and Watson (1997) and continue to press for its inclusion as 'one of many' models to inform monetary policy decision and the programme of research into estimating the

NAIRU continues unabated (Berger (2008), Battini & Greenslade (2003), McMorrow & Roeger (2000), Apel & Jansen (1999), Greenslade, Pierse & Saleheen (2003), Fabiani & Mestre (2001)). It is an irony that Staiger, Stock and Watson represent a plot of the annual change in inflation and annual unemployment rate change to suggest that the original Phillips relationship continued to exist between 1962 and 1995.

The concept of this modern version of the Phillips curve therefore suggests that short run inflation dynamics ie any short run relation between unemployment movements and inflation movements, remain exactly that, ie transitory. Accurate estimation of the model rests heavily on being able to ascertain the NAIRU. This rate of unemployment also moves over time (Gordon, (1997)) complicating matters somewhat.

The view that this modern version of the traditional Phillips curve remains valid and useful for policy analysis is not shared by all. Various researchers (Atkeson & Ohanian (2001), Niskanen (2002), Reichel (2004)) among others have all suggested that either Phillips curve does not exist in the manner described and/or that estimates of inflation based on models including NAIRU are ‘no better than a naïve forecast’. For the UK the conclusion of Haldane & Quah (1999) that the appearance of a traditional type Phillips relationship between unemployment and inflation (for post 1980 data) is nothing more than a confirmation of the acknowledgement by policymakers that no such trade off exists. In the words of Reichel (2004) ‘as a policy guideline it is totally useless.’

Nonetheless it remains in use by policymakers (Llaudes, 2005) and more recently a strand of research has developed around a variant of the traditional model: the wage curve where level of real wages as function of unemployment is modeled rather than the wage change as function of unemployment and is typically estimated cross chapter rather than time series (see Blanchflower and Oswald 2006). In the main this general dissatisfaction with the traditional Phillips Curve model[23] led researchers to seek an alternative specification of inflation generating process - which returns the discussion to developments in the RBC literature.

23 As a matter of interest traditional versions of the Phillips curves for the UK regions have also been estimated. The results are produced in chapter 8.

7.2 The New Keynesian Phillips Curve

The NKPC builds on models that originally came from a strand of research that can be tagged as the ‘RBC school’. The RBC school sought to base their models completely on microeconomic foundations so that their models would be invariant to policy markers decisions, in other words immune to the Lucas critique. Hence the tag ‘structural’ since these models are based on a microeconomic structure determined by representative agents’ (firms and consumers) preferences and optimising decisions not, as in the case of the original Phillips curve, an empirical relationship which would, as history showed, change depending on policy makers’ actions. The original RBC models (Kydland & Prescott (1982)) did not concern themselves with modeling money or inflation driven as they were by a view that ‘real’ shocks such as technology are the primary causes of variations in output at business cycle frequencies (Gali 1999). However, for the purposes of monetary policy analysis and decision making a relationship linking inflation in the short run to a measure of aggregate real activity was still required. This led to money (and by extension inflation) being appended to the RBC models (for a textbook review of early methods see Walsh (2003)). Separately there exists from the late 1970s and early 1980s (Fischer (1977), Taylor (1980), Calvo (1983)) a body of work that sought to build models of inflation by incorporating staggered wage and price setting of forward looking agents. Bringing these two strands together is what has become known as the

New Keynesian Economics literature[24] which latterly has taken to mean to refer to any version of the hybrid New Keynesian Phillips Curve (the term ‘NKPC’ in this thesis is taken to refer to the hybrid model as it is this form that has become the de facto standard and reference is made to the original model (perhaps somewhat confusingly) as the standard NKPC unless explicitly stated otherwise) and generally refers to the inflation generating equation of the linearised solution of a small scale, structural dynamically optimised general equilibrium model which incorporates some form of wage or price rigidity by recourse to a staggered wage or price setting mechanism[25].

Notwithstanding, issues surrounding its estimation and validity (which is discussed later in this chapter) the NKPC has become a standard workhorse model. The complete model is accompanied usually by an estimated Euler demand (again a log linear approximation to a dynamically optimised model) equation and closed usually with a linear Taylor monetary policy reaction function (see Walsh (2003), Woodford (2003), McCallum (1997)). For reasons which will be underlined shortly it is this model which is used to explore whether there exist differences in the short run dynamics of the UK regions and more significantly whether these can be accounted for by recourse to structural factors.

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[24] The term New Keynesian Phillips Curves is still sometimes used by researchers (eg Driver & Wren Lewis 1999) to refer to models that incorporate a staggered wage or price setting mechanism (the phrase generally being coined by the publications of the books edited by Mankiw & Romer, New Keynesian Economics Vol I & II (1991)) however it more recent years the term is generally used to refer to the dynamically optimized variant (which obviously includes a staggered wage or price setting mechanism.)

[25] There are other mechanisms utlised to incorporate intertia into the system eg habit persistence (Furher, 2000)

Roberts (1995) shows that the NKPC can be derived from a number of different models of price rigidity although the most common practice assumes assuming a Calvo (1983) pricing mechanism - whilst this is the predominant form of the model there are still research programmes which incorporate Rotemburg (1982) or even Taylor (1980) pricing mechanisms into the model. The Calvo model has achieved this first preference due to its tractability however its choice is by no means innocuous – as Khan (2004) shows the choice of Calvo or Rotemburg pricing leads to quite different results for the interaction of competition effects and short run inflationary pressures. Woodford (2003) provides the most mathematically grounded derivation. Outlined below is a simpler derivation which follows the exposition provided by Gali (2008). This derives the NKPC as a solution to the firm's pricing decision. It can be shown (Walsh (2003)) that the same form of the NKPC will be derived as part of the solution to a complete general equilibrium model which involves household optimisation and full market clearing. Following this method would illustrate that the solution of the household optimisation problem to describe the conditions of aggregate demand[26]. Solving the complete version of the model is not necessary here. An accurate derivation of the NKPC can be illustrated by reference to the optimising pricing decisions of suppliers.

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[26] As has been referred to in the introduction and numerous other occasions, there is a signficant separate research literature which focuses on many alernative mechanisms for incorporating rigidities into a complete DSGE model, rule of thumb consumers, habit persistance, capital accumulation to name a few which have implications for final form of the demand side of a complete model. The choice of this form of the model is that it provides an easy to work with model which reflects supply side differences in firm characteristics which lends itself to an application to a study of the differences across the UK regional economies.

The following assumptions are made to describe fully the supply side of the economy:

- There exists a continuum of firms, indexed by $i \in [0,1]$
- Each firm produces a differentiated good
- Each firm possesses an identical production technology

  $$Y_i(i) = A_t N_t(i)$$

- Probability of a firm resetting its price in any given period is $(1 - \theta)$ which is independent across firms (Calvo (1983)) and independent of the rate of inflation
- Theta the index of price stickiness is described by $\theta \in [0,1]$
- Hence the Implied average price duration is: $\frac{1}{1-\theta}$

We assume that firms have a random probability of resetting their price in any one period. Therefore (as above) the fraction of firms able to reset their price in any one period is $(1 - \theta)$. When firms set their price they assume the price may be fixed for many periods and they set a log-price, z_t , that minimises the following loss function:

$$L(z_t) = \sum_{k=0}^{\infty} (\theta\beta)^k E_t (z_t - p_{t+k}^*)^2 \qquad (51)$$

Where β , the subjective discount factor is between zero and one, p^*_{t+k} , is the log of the optimal reset price if there were no price rigidity. The quadratic function is an approximation to a general profit function which represents losses because the firm may be stuck with the set price z_t. The infinite sum represents the consideration of all future periods and the discounting by $(\theta\beta)^k$ gives an expected loss function (ie by the probability that the firm is unable to reset its price).

The solution for the optimal reset price is simple, each term featuring the choice variable is differentiated with respect to z_t and gives:

$$L'(z_t) = 2\sum_{k=0}^{\infty}(\theta\beta)^k E_t(z_t - p^*_{t+k}) = 0 \qquad (52)$$

Separating out terms:

$$\left[\sum_{k=0}^{\infty}(\theta\beta)^k\right] z_t = \sum_{k=0}^{\infty}(\theta\beta)^k E_t p^*_{t+k} \qquad (53)$$

Algebraic manipulation provides the solution:

$$z_t = (1-\theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_t p^*_{t+k} \qquad (54)$$

If we assume under monopolistic competition that without frictions the firm's optimal pricing strategy would be to set prices as a fixed mark up over marginal cost:

$$p^* = \mu + mc_t \quad (55)$$

The optimal reset price can be written as:

$$z_t = (1-\theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_t(\mu + mc_{t+k}) \quad (56)$$

In a Calvo economy the aggregate price level is just a weighted average of last period's price level and the new reset price:

$$p_t = \theta p_{t-1} + (1-\theta)z_t \quad (57)$$

Rearranging gives:

$$z_t = \frac{1}{1-\theta}(p_t - \theta p_{t-1}) \quad (58)$$

The recursive form of equation 56 can be written:

$$z_t = \theta\beta E_t z_{t+1} + (1-\theta\beta)(\mu + mc_t) \quad (59)$$

Substituting 58 into the above and rearranging gives the NKPC:

$$\pi_t = \beta E\pi_{t+1} + \frac{(1-\theta)(1-\theta\beta)}{\theta}(\mu + mc_t - p_t) \quad (60)$$

Inflation depends on next period's inflation rate and the gap between the frictionless price level, $\mu + mc_t$, and the current price level or put another way inflation depends positively on real marginal cost, $mc_t - p_t$. If for simplicity, we denote the deviation of real marginal cost from the price level as $-\mu$, then we can use the term for deviation of real marginal costs from steady state values as:

$$\widehat{mc}_t = \mu + mc_t - p_t \qquad (66)$$

And the NKPC simplifies to:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \lambda\widehat{mc}_t \qquad (67, \text{NKPC})$$

Where

$$\lambda \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta} \qquad (68)$$

This form (NKPC) above is often referred to as the 'reduced' form of the model involving as it does estimation of two coefficients. Inferences for the values of the deep parameters (given by λ) then have to be made.

The key differences between the NKPC and the traditional Phillips curve is that inflation has now become a forward looking variable and dependent on all expected future values of marginal costs. A measure of the output gap is absent. In their estimation of the model Gali and Gerlter (1999) use the log as the labour share as a proxy for marginal costs. To explain first how this value can be justified as a measure the marginal cost term one needs to assume a Cobb-Douglas production function where output, Y_t, is given by:

$$Y_t = A_t K_t^{\alpha_k} N_t^{\alpha_n} \quad (69)$$

Real marginal cost is then given by the ratio of the wage rate to the marginal product of labour ie $MC_t = (W_t/P_t)/(\delta Y_t/\delta N_t)$. Hence given (69), marginal cost is given by:

$$MC_t = S/\alpha_n \quad (70)$$

Where S is given by W_tN_t/P_tY_t , the labour income share or real unit labour costs. Assuming steady state, and representing deviations from steady state by lower case letter this becomes:

$$mc_t = s_t \quad (71)$$

Any relationship between marginal cost and the output gap thus is dependent on a log linear (monotonic) relationship between the two. Rudd & Whelan (2005) argue that the Gali & Gertler's use of the log of the labour share as an empirical measure of real marginal cost is flawed as, they suggest, this measure is rather an indication of average costs. They also argue against the use of marginal costs in theory. Nevertheless Gali and Gertler's argument in support of the use of this measure found support amongst later empirical researchers.

One of the key implications for policy makers is that this specification makes disinflations costless in terms of lost output (if monetary policy is perfectly credible – ie that expected inflation equals the target rate). (McCallum and Nelson (1998) & Svensson (1997) provide a good reference for a discussion of appropriate conduct of monetary policy vis a vis models of inflation). Whilst theoretically derived from the micro foundations, early econometric estimations failed to convincingly support the case for the adoption of completely forward looking model for inflation (Fuhrer (1997), Roberts (1995, 1997, 1998).

Gali and Gertler's (1999) development of the hybrid model to include a lagged inflation term was therefore a response to the inability of the standard NKPC model to match the data. By again deriving from 'micro foundations' each term on the three regressors can be presented as non linear functions of structural parameters.   Their model is of the form (the derivation is outlined overleaf):

$$\pi_t = \alpha_1 E_t \pi_{t+1} + \alpha_2 \pi_{t-1} + \lambda mc_t \qquad (72)$$

where

$$\lambda = (1 - \omega)(1 - \theta)(1 - \beta\theta)\phi^{-1} \;, \quad \alpha_1 = \beta\theta\phi^{-1} \;, \quad \alpha_2 = \omega\phi^{-1} \qquad (73,74,75)$$

and

$$ø = \theta + \omega\ [1 - \theta(1 - \beta)] \qquad (76)$$

with β the discount factor, θ being the degree of price rigidity ie fixed price duration and ω the share of rule of thumb producers. These last two parameters are what lends this model to a study of regional heterogeneities: by logic they should differ across industries and if so they should across differ across regions of different industrial composition.

Outlined below is G&G's original (1999) derivation of the hybrid model. The key difference between the hybrid and the standard version of the model is that there is now only a share of firms that optimise in the manner described before, ie adopting forward looking behaviour, this share is denoted $(1-\omega)$, the remaining producers, ω, are backward looking and simply adopt a rule of thumb that is based on the history of the aggregate price level.[27]

The aggregate price level evolves according to:

$$p_t = \theta p_{t-1} + (1-\theta)\,\bar{\tilde{p}}_t^{*} \qquad (77)$$

where $\bar{\tilde{p}}_t^{*}$ is an index for prices newly set in period t.

[27] Again the reader is reminded that this is not the only methodology that has been adopted to incorporate persistence in to NKPC.

Letting p_t^f and p_t^b denote the price set by a forward (optimising) and backward (rule of thumb) producer respectively, then the index for newly set prices is simply:

$$\bar{p}_t^{\sim *} = (1-\omega) p_t^f + \omega p_t^b \qquad (78)$$

Forward looking firms obviously behave as per the standard Calvo model. Therefore, p_t^f can be expressed as:

$$p_t^f = (1-\beta\theta)\sum(\beta\theta)^k E_t\{mc_{t+k}^n\} \qquad (79)$$

Given assumptions made about the features of the rule of thumb (in steady state the rule is consistent with optimal behaviour and price in period *t* depends only on information available at *t-1*) p_t^b is proposed as:

$$p_t^b = \bar{p}_{t-1}^{*} + \pi_{t-1} \qquad (80)$$

Combining equations 78,79 and 80 gives the hybrid NKPC:

$$\pi_t = \alpha_f E_t\{\pi_{t+1}\} + \alpha_b \pi_{t-1} + \lambda mc_t \qquad (72)$$

where the coefficients of each term can be represented as non-linear functions of the 'structural' parameters (as was shown previously):

$$\lambda \equiv (1-\omega)(1-\theta)(1-\beta\theta)^{-1}$$

$$\alpha_f \equiv \beta\theta\phi^{-1} \qquad (73,74,75)$$

$$\alpha_b \equiv \omega\phi^{-1}$$

And

$$\phi \equiv \theta + \omega[1-\theta(1-\beta)] \qquad (76)$$

where (as a reminder) ω is the degree of backwardness or the share of the rule of thumb producers, θ is the degree of price stickiness (ie one minus θ is the probability of the optimising firm resetting its price in the Calvo model) and β is simply the subjective discount factor. In recent paragraphs the word 'structural' has been enclosed by quote marks. That is because that whilst θ and ω are in one sense structural in that they represent micro behaviour of firms in the model, in another they are merely ad hoc parameters introduced to enable the model to replicate inertia in the inflation process (and therefore somewhat arbitrary). However, these are the major parameters of interest and ones that will be used to infer differences across regions as if they differ across industries; they ought to differ across regions whose industrial composition differs markedly.

7.3 Estimating the NKPC, Method

Given that the NKPC can be seen to be a linearised solution (that is a partial solution, ie to the representative firm's optimisation problem) to a dynamically optimised model, it is estimated by the generalized method of moments technique. This use of GMM enables researchers to estimate the following orthogonality condition:

$$E_{t-1}\{(\pi_t - \lambda mc - \alpha_f \pi_{t+1} - \alpha_b \pi_{t-1}) z_{t-1}\} = 0 \qquad (81)$$

Where z_{t-1} is a vector of instruments uncorrelated with the error term.

Because of their easy applicability to the Euler equations for first order conditions the method of generalised methods of moments has become the technique of choice for many researchers when estimating NKPCs and other dynamic equations.

The method of moments is an estimation technique which suggests that the unknown parameters should be estimated by matching population (or theoretical moments) which are functions of the unknown parameters with the appropriate sample moments. The first step then is to define properly the moment conditions. In dynamic estimation, the moment condition can be easily represented by Euler first order conditions. Imposing rational expectations ensures that the expectational error term cannot be predicted by information available at time t_{-1} and creates the orthogonality conditions. For the hybrid NKPC this can be represented by equation 81.

Where z_{t-1} is a vector of instruments uncorrelated with the error term. In practice a wide choice of instruments is available but in practice more often lags of the same variables are used. Johnson and Dinardo (1997) show that given $E(Z'\varepsilon) = 0$ the GMM estimator can be represented as:

$$\text{Min } ((1/n) [\boldsymbol{Z}'(\boldsymbol{y} - \boldsymbol{X}\hat{\beta})]' . \boldsymbol{W_n} . (1/n)[(\boldsymbol{y} - \boldsymbol{X}\hat{\beta})]) \quad (82)$$

$\textit{wrt } \hat{\beta}$

where $\boldsymbol{Z}$ is $(n \text{ x } L)$, $\boldsymbol{X}$ is $(n \text{ x } k)$, $\boldsymbol{W_n}$ is an $(L \text{ x } L)$ weighting matrix and $L>k$. A candidate for the weighting matrix is the asymptotic variance matrix of the moment condition $[var(1/n)\ (\boldsymbol{Z}'\varepsilon)]^{-1}$. Provided observations are independent the White estimate of this is (Johnson and Dinardo (1997)):

$$\mathbf{W_n} = ((1/n^2)\ \Sigma_i\ z_i\ z_i^{'} r_i^2\ )^{-1} \quad (83)$$

Where z_i are the columns of $\boldsymbol{Z}$.

Hansen's procedure is to first estimate $\hat{\beta}$ using ordinary 2SLS which is equivalent to using $(\boldsymbol{Z}\boldsymbol{Z}')^{-1}$ for . $\boldsymbol{W_n}$ This can then be used to compute a value of

$\boldsymbol{W_n}$ according to equation (83) above which can then be used in the minimisation problem (82) above.

Given that GMM and 2SLS are equivalent with homoscedastic errors the GMM estimator and the 2SLS estimator are the same when the model is exactly identified. If however, L>k then the estimator $\hat{\beta}_{GMM}$ is over-identified and then the minimand become a test statistic for the validity of the restrictions. The null is that the restrictions are valid.

$$\textbf{\textit{Test}}_{GMM} = ([\boldsymbol{Z'(y - X}\hat{\beta}_{\boldsymbol{GMM}})]' \, . \, ((1/n^2) \, \Sigma_i \, z_i \, z_i' r_i^2)^{-1} \, . \, [(\boldsymbol{y - X}\hat{\beta}_{\boldsymbol{GMM}})]) \quad (84)$$

This Hansen statistic is distributed as a χ^2 distribution with L-k degrees of freedom. Johnson and Dinardo (1997) state that the statistic takes the very simple form nR^2

Where n is simply the number of observations and the R^2 the uncentred R^2 from a regression of the instruments on the fitted values from the first stage regression. If the instrumental variables are indeed orthogonal to the residuals the R^2 from the regression will be low and the null that the over-identifying restrictions are valid is not rejected.

However, GMM is a large sample estimator and as will be noted below this has led to a questioning of the degree of bias in reported estimates.

Additionally, summarising recent work in the area Khalaf & Kichian (2004) cast doubt on the reliability of instrumental variable (IV)-based inferences which together casts serious doubts on the reliability of standard inference based on GMM. They suggest that weak instruments leads to an over rejection of the null hypothesis.

7.5 Estimating the NKPC, Research Review

As already stated, one of the key attractions of both the standard and hybrid NKPC models, and indeed the reason why the hybrid model is utilised in the research presented in chapter 8, is that they have strong micro foundations reflecting preferences of firms so that their parameters are constant or at least invariant to policy actions and thus the model overcomes the Lucas critique (although a recent research agenda is an investigation of whether these parameters are indeed invariant across time - see Barkbu et al (2005) Kim, Osborn and Zhang (2007)). As previously outlined, the advantage of the structural foundations is that the coefficients of the estimated reduced form model are interpreted as non-linear functions of deep structural parameters reflecting preferences of producers in a microeconomically founded model.

The first stage of G&Gs original work (1999) concerns estimates of the standard NKPC and using a measure of marginal cost as the driving variable rather than the output gap as had been hitherto used in the previous New Keynesian tradition. Using a measure of the output gap they reported severe difficultly with rectifying the model empirically. In short they estimate a wrongly signed coefficient on the output gap for the forward looking NKPC. However, they reported a positive coefficient when using a lagged output gap.

Their use of marginal cost as a proxy of the output gap is done with the following two justifications: that it can be reconciled with a theoretically expected mark up in a model with monopolistic demand, and in a dynamically optimised solution can be treated as a forward looking variable, in addition to this any relationship between output gap and marginal cost can be treated as log linear. Hence they justify using unit labour costs to provide a reasonable approximation of marginal cost. As has been explained previously, this relationship is also very much dependent on the choice of the (Cobb Douglas) production function.

In the second stage of this work, G&G's derive and estimate the hybrid model: one that now includes a lagged term of inflation. Whilst remembering that the coefficients on the model are non-linear functions of the structural parameters they publish estimates for US data for backward and forward coefficients of the hybrid model (once derived) of between 0.25 and 0.38 and 0.68 and 0.59 respectively.

Subsequent to their original paper G&G published a second major work (2001). In this 'European' paper they report even greater dominance of the forward term for EU data with estimates between 0.689 and 0.82 alongside further results for the US consistent with their original work. They repeat the methodology as before - GMM non-linear instrument variables and citing evidence of serial correlation of the error terms they use a Newey-West correction. Data is sourced from Fagan & Mestre (2001). The instruments used are five lags of inflation, two lags of the real marginal costs, detrended output, and wage inflation as instruments. For the pure NKPC using marginal costs they report values for the discount factor of 0.914 (against 0.924) and lambda (the coefficient on the marginal cost/output gap term) of only 0.088 (se 0.041) (against 0.250 (se 0.118)). Once again using the output gap they report incorrectly signed coefficients. They conclude that 'across all specifications forward looking behaviour remains dominant' and 'when tested explicitly against an alternative that allows for a fraction of price setters to be backward looking, the structural estimates suggest that this fraction, while statistically significant, is not quantitatively important.' Henceforth a modern macroeconomic workhorse[28] was born.

The results from these two papers, which have spawned a whole new research agenda in addition to launching a new inflation dynamics model, come under widespread criticism on three methodological fronts: the use GMM of estimation being susceptible to small sample error; their method of normalisation of the

[28] The hybrid NKPC model with three variables; expected inflation, lagged inflation and marginal costs.

moment condition[29] (Sondergaard 2003); and their choice of instruments: those used are four lags of inflation, labor income share, interest rates spread, output gap, wage inflation, commodity price inflation. To say that there is some controversy surrounding the model is perhaps to understate the matter but given its status as a modern workhorse of macroeconomic policy the quantity of such is quite staggering. A host of leading researchers, Linde (2005), Roberts (2005), Rudd and Whelan (2005), Bardsen (2002), Tillman (2005), Soderlind et al (2005) have refuted either its estimates and hence its validity or criticised the estimation methodology employed or both. Indeed the volume of criticism is such that in 2005 Gali, Gertler and Lopez Salido felt moved to publish a rebuttal.

Rudd and Whelan's (2005) key criticism of G&G estimates is that the use of instrument variables can lead to forward looking behaviour to be inferred when there is none – that is an error can occur if instruments are used that should be in the inflation formation equation and thus whose explanatory power biases the forward looking parameter estimate. A common theme of the criticisms is to point to misspecification in the hybrid NKPC and highlight the fact that better 'fits' of the data results from models which nest it. Barsdsen et al (2004) suggest that given the outcomes from encompassing tests 'economists should not accept the NKPCM too readily'. Many researchers make similar points regarding the validity of instruments as a significant problem.

[29] Since the moment condition itself has non-linear structural parameters estimation first requires normalisation of some of these. G&G report results for two normalisations techniques. With the hybrid curve – restricting the coefficient on inflation to unity they suggest the degree of backward looking firms to be around a quarter but they get a higher estimate with the second normalisation technique.

There is also some debate as to whether or not G&G's assertion that inclusion of marginal cost as the driving variable is fundamental. Their description of its use in their empirical work is 'a virtue'. Not all researchers share this view that use of marginal cost is so critical. Neiss and Nelson (2002) incorporate a theory based measure of output gap and Batini et al (2000) were happy to continue to use detrended output. That said, the majority of researchers make an attempt to mimic marginal cost as the driving variable and utilise time series (the log of the labour share) that act as reasonable proxies for this measure. A lesser criticism is to merely dispute the size of relative coefficients. Using survey evidence of expectations rather than future inflation as the expected variable Henzel and Wollmershaeuser (2006) report that the backward looking behaviour is more relevant for countries in their sample (which includes the UK): a finding is repeated by Bjornstad & Nymoen (2008) in a panel estimation of 20 OECD countries.

However, the purpose of this research presented in this thesis is not to contribute to this debate above but to apply the model to the UK regions and in this respect it important to note there are as many researchers who support G&G original work as not. Many, including Paloviita (2005), Sbordone (2002), have readily published estimates in favour of a forward dominated hybrid curve. Balakrishanan and Lopez Salido (2002) reported estimates between 0.657 and 0.953 for the forward term: Gulyas and Starz (2006) state that 'future inflation plays a predominant role in explaining inflation dynamics' reporting coefficient estimates of between 0.72 to 0.84; Jondeau & Bihan (2005) state that forward looking dominates for US and UK but lagged behaviour is more important for EU; and Rumler (2007) found that logically Germany had the highest dominance of forward looking behaviour – logical given the credibility of its central bank.

Controversy aside, the hybrid NKPC has become a workhorse of macroeconomic modeling - the modern toolkit comprising this equation, together with an Euler demand equation and a Taylor rule to complete the macroeconomic model – and its acceptance is such that the research agenda moves on.

This purpose of the research produced in chapter 8 is to apply the hybrid NKPC to the UK regions to explore the potential of the model to account for heterogeneities of regional dynamics. In the spirit of Angeloni et al (2006) who in a review of microdata across several euro zone states suggest that 'evidence of heterogeneity and of asymmetries in price setting suggest the need to consider models with several sectors'. In fact the research agenda is quite developed on the investigation of heterogeneities of inflation persistence across sectors (Alissimo et al (2006)) and has led to a hefty programme of work across Europe investigating sectoral pricing behaviour (Jonker et al (2004), Loupias & Ricard (2004), Alvarez & Hernando (2004)).

Ironically then, rarely, if at all, are attempts made to account for the causes of the differences in estimates of the structural parameters in regional studies. This is somewhat anomalous given the incorporation of structural parameters in the model ideally lends itself to analysis of this nature. Massidda (2005) comes closest to the spirit of the research in chapter 8 where she produces estimates of the NKPC across different Italian manufacturing sectors. Given this point and Angeloni et al’s assertion applying the model to account for heterogeneities in short run dynamics of the UK regions is a logical, rational application of the model.

Lastly but by no means least, reference is made of the choice whether or not to estimate an ‘open economy’ version of the NKPC in the research presented. The original version of the model does not distinguish between closed and open economies. Whilst the US is often considered not to be considered as a small open economy, G&Gs estimates the same model for the US, Germany and other EU states with no compunction to make this distinction.

However, there is the criticism that a theoretically robust model ought to include intermediate imported inputs as another variable on the basis that the marginal cost term in the (closed AKA original) model does not account for (different) changes in the price of imported factors of production. Incorporating this into a theoretical model does make the mathematics somewhat more complicated but the net result is merely a different term for the coefficient on marginal costs against the closed (sic) economy version.

Neiss and Nelson's (2002) argue against the need for the modeling of intermediate inputs citing evidence from the survey by Staiger, Stock and Watson (2001) that the exchange rate is rarely a good predictor of future inflation. There also seems to be a lack of consensus as to whether the inclusion of the open economy term leads to significant variation in the results of the model. For example, Leith and Malley (2002) find that the estimates of the two versions of the model have no statistically significant difference. Rumler (2007) strongly finds in its favour and, whilst they themselves do not remark upon it specifically, the open economy term (a representation of GDP in world prices) in Battini et al's (2000) study of UK inflation only becomes significant when restricting the sum of the coefficients of forward and backward looking terms for inflation to unity – a restriction which itself is rejected! For the remaining four (out of six) regressions in their paper the coefficient was not only small but insignificant and often changed signs.

On balance and given the easier nature of estimating the closed model it was decided there is little to be gained by attempting to include an open economy term in the estimation of regional UK equations

8 Estimated Phillips Curves: New Keynesian (Hybrid) and Traditional For the UK Regions

This chapter presents the results of an investigation as to whether the short run relationship between prices (inflation) and output (or employment), ie Phillips curves, differs across the UK regions, whether it is possible to make inferences from differences in the estimated coefficient values of the estimated Phillips curves across the regions, and what, if any, may be the implications of the industrial structures of the regions in these. The majority of the chapter pertains to the presentation of the results of the hybrid NKPC model. It again uses an annual dataset, given data issues (see chapter 3), as has been done in previous chapters.

The focus on the hybrid NKPC model is due to the possibility of there being differences in the estimated regional structural coefficients given the structural formulation of the model. The results suggest that this is so and evidence is presented that these inferred differences relate to regional characteristics in a similar manner to chapter 6.

The smaller latter half of the chapter presents estimates of a traditional price unemployment Phillips curve given the availability of a quarterly time series for unemployment for the regions back to the mid 1970s. The model allows for estimates of regional NAIRUs and employment flexibility to be made: the results being consistent with the economic characteristics of the regional economies.

Chapter 4 contained a review of research pertinent to the UK regional agenda with specific relevance to monetary, supply and demand shock or business cycle analysis. There is precious little in the way of research published regarding UK regional Phillips curves.

Schofield (1974) is a dated piece of work and there is a small body (Cook (1999)) of work discussing non-linearities of unemployment across the regions but aside from that the proposed methodology – to attempt to estimate separate regional Phillips curves, New Keynesian and Wage Phillips, undertaken in this chapter is a contribution of this research.

8.1 Data

The longest time series available for the regions that includes values for the labour income share is that of the annual data series for regional GDP and labour income share covering the period 1971 to 1996. This latter variable is key as it provides a measure of marginal costs and thus facilitates replication of the approach of Gali and Gertler (G&G) in the estimation of regional hybrid NKPCs for the UK regions.

The use of marginal costs is an important distinction made by G&G. Theoretical derivations imply that future inflation is a discounted stream of expected future marginal costs. If a measure of the output gap is used in empirical estimation then a log linear approximation of the relationship between output gap and marginal cost is assumed ie:

$$mc_t = \kappa x_t \qquad (86)$$

where κ is the output elasticity of x, marginal cost.

The issue being that the NKPC implies inflation leads the output gap yet G&G show the opposite is exhibited in the (quarterly) data. The consequence is that this leads to an incorrectly signed coefficient on the output gap when estimated empirically.

Their investigation of the cyclical behaviour of marginal cost is key to their explanation of why the use of marginal cost is fundamental to a correctly signed coefficient in estimation of the model. Figure 86 reproduces the values of marginal costs (log labour share (proxying theory) percentage deviations in (steady state) values) and values for the output gap (percentage deviations from an HP trend) for the data series used in this work. Clearly the cyclical behaviour of the two series differs, with the output gap leading marginal costs. This is the same as was suggested by Gali and Gertler.

G&G presented tabulations of cross correlations between the output gap and inflation, output gap and marginal costs (or labour share) and marginal costs and inflation which illustrated that the output gap leads inflation as it does marginal cost and there is a strong contemporaneous relationship between inflation and marginal costs. Figures 87 through 89 display the cross correlations for the dataset used in this work which, although not as tidily given the data's annual nature, displays the same relationships between the co-movements in the variables, underlining the importance of the use of marginal cost and explaining and emphasising its role in producing the correctly signed coefficient on the driving variable in the results presented in this chapter.

A slightly longer series exists (from 1967 to the same date (1996)) which was used for the estimation of responses to monetary shocks in chapter 6 but this does not include consistent estimates of this variable which is key to the ability to include marginal cost (fundamental to the ability to produce statistically significant estimates for the forcing variable) in the regression.

There is no theoretical justification to stipulate what frequency data is best applicable to the model and G&G themselves highlight that prior to their work the only research that had managed to produce robust estimates of the NKPC was based on annual data (a point repeated by Bjornstad and Nymoen (2008) in their panel estimates of OECD NKPCs based on annual data).

For the estimation of traditional (price unemployment) regional Phillips curves quarterly unemployment (rates not levels) which have been produced consistently since 1971 for certain regions, 1974 for all regions, are available and have been used. Thus traditional price Phillips curve of the type suggested by Flaschel et al (2004) (which is discussed in more detail later in this chapter) has been estimated.

Figure 86: Change in Marginal Costs vs Output Gap (SE), 71 – 97

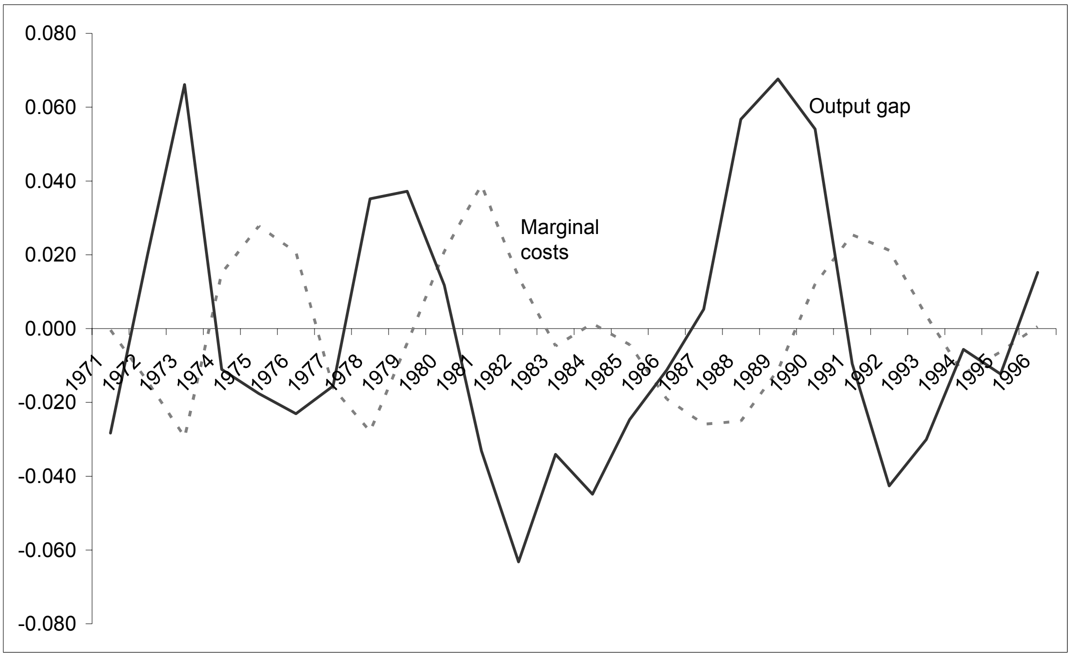


Figure 87: Cross Correlations, Output gap, Inflation

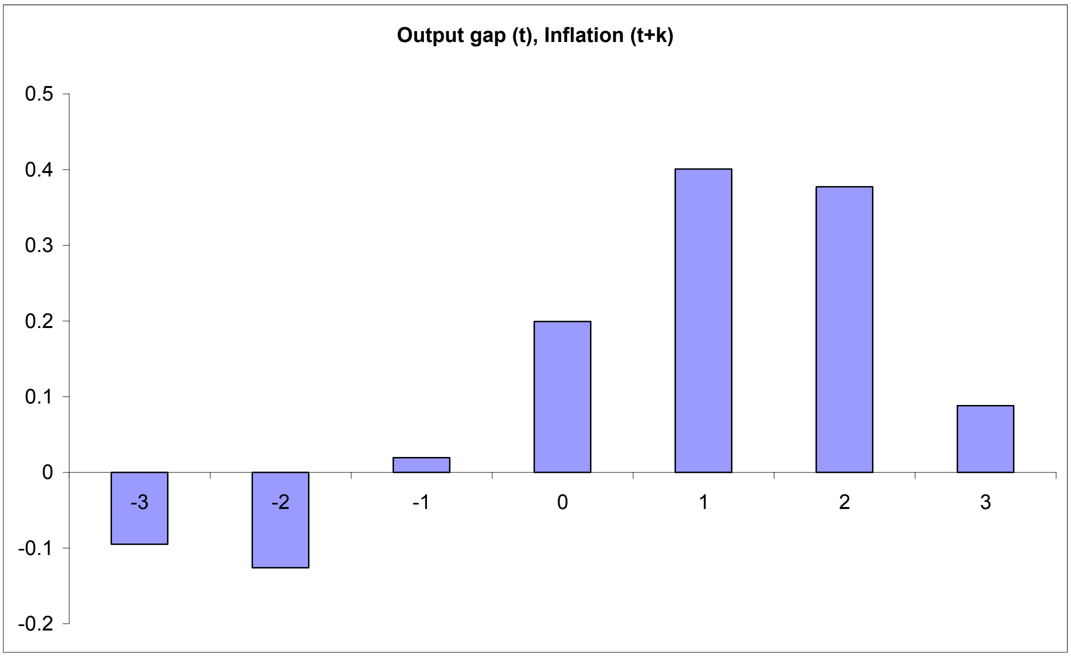


Figure 88: Cross Correlations, Output gap, Marginal Cost

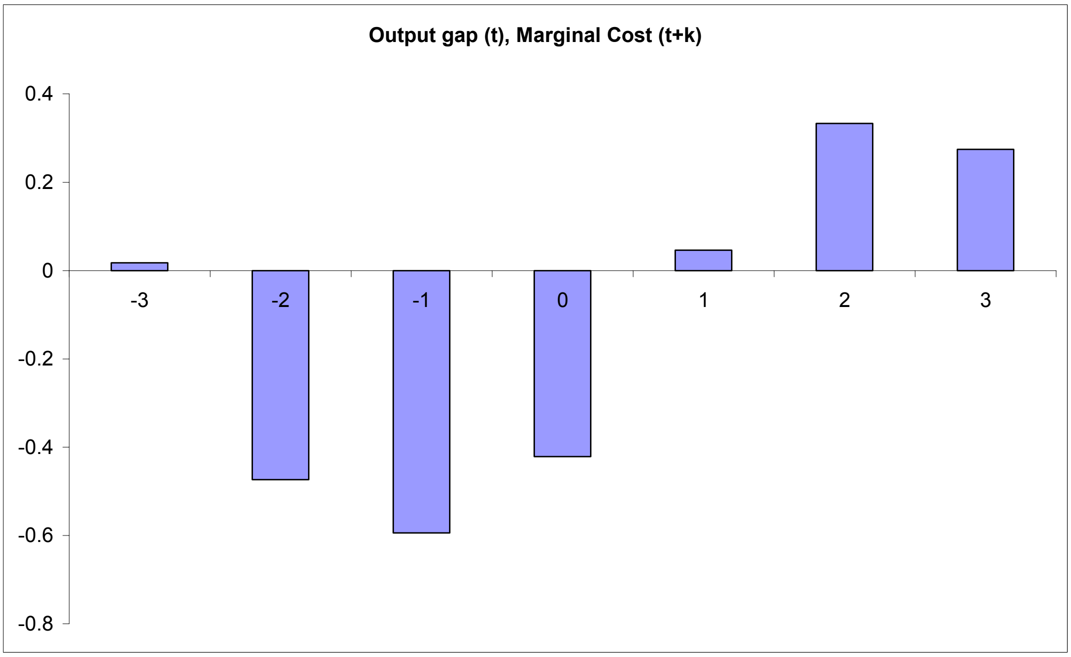
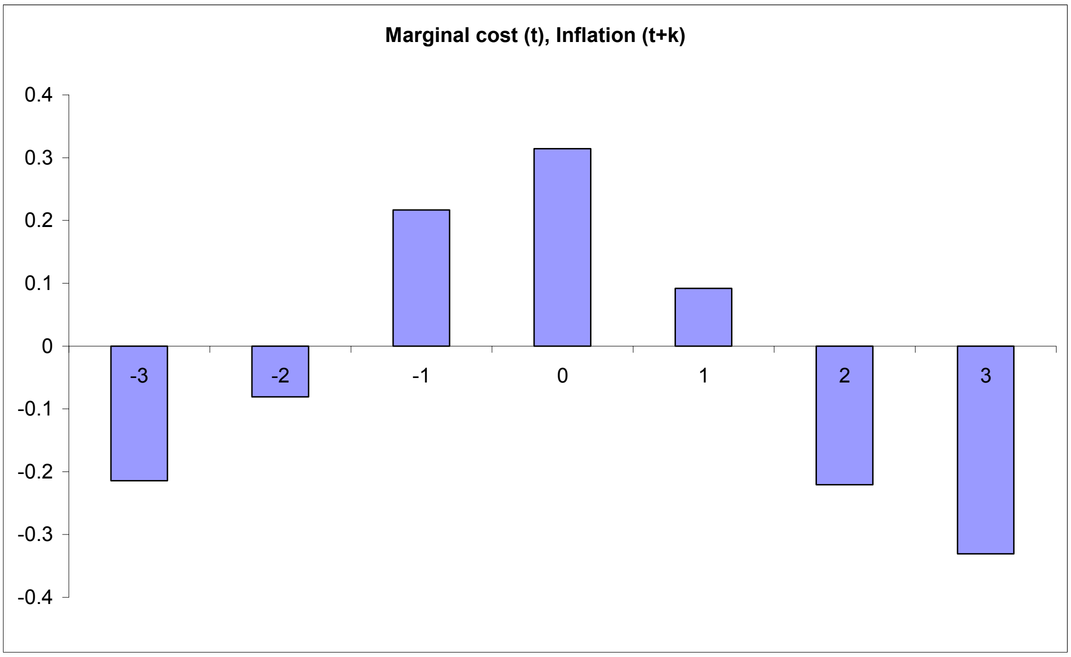


Figure 89: Cross Correlations, Marginal Cost, Inflation



8.2 NKPC Estimates

The first model of inflation estimated in this chapter is the NKPC or more specifically the hybrid version of the NKPC. As outlined in chapter 7, both of these models can be seen to be linear approximations of small scale DGSE structural models of the economy. The hybrid variant being postulated primarily as a result of the fact that the standard version being unable to replicate inflation inertia introduces structural parameters that are of key interest and usefulness: these parameter being (in the model of G&G at least) the share of producers in the economy who set prices according to a ‘rule of thumb’ and the frequency of price setting. This model was discussed and derived in chapter 7.

Whilst a criticism of the theoretical underpinnings of the hybrid model is that these parameters themselves are merely ad hoc and therefore somewhat underline the supposed theoretical rigour of the model, once they have been incorporated into the model they are of more than passing interest. Logically if these parameters are of the ‘deep structural’ nature then they ought to vary across economies reflecting different habits, preferences and structures. If that is the case the line of argument is that it is logical and reasonable to expect parameters of this type to vary across the UK regions. Chapter 2 described a set of regional economies that, although linked by a common language, geography, and currency, varied in their industrial, output, income, price and employment characteristics, variables that ought to determine structural parameters.

Very rarely are attempts made to account for the causes of the differences in estimates of the structural parameters in regional studies. This is somewhat anomalous given the incorporation of structural parameters in the model ideally lends itself to analysis of this nature and that quite recent research on causes of inflation persistence across euro zone states (Angeloni et al (2006)) underlines this very point - 'evidence of heterogeneity and of asymmetries in price setting suggest the need to consider models with several sectors'. The notion that different sectors can have different implications on inflation dynamics is well developed (Alverez et al 2006) and has led to major programme of research into sectoral pricing behaviour (Jonker et al (2004), Loupias & Ricard (2004), Alvarez & Hernando (2004).

The point being that each sector has different structural characteristics and this line of thought has been pursued by Massidda (2005) who has produced different NKPC estimates for different Italian manufacturing sectors. Given the regions of the UK different so markedly in sectoral make up then this should have implications for regionally estimated values of the NKPC model. This then is what is investigated in this chapter and is indeed a novel approach to regional modeling. In short, the two key parameters of the (supply side) hybrid NKPC model are ω, the degree of rule of thumb behaviour, and θ, the fixed price duration. These should vary across industries and by logic should vary across regions whose industrial composition differs.

This thesis is motivated by the belief that the macroeconomic dynamics of the British regions must be different on account of their differing structures and monetary policy therefore needs to be informed and to better understand these differences. The first part of this chapter produces the estimates the hybrid new Keynesian Phillips curve for each of the British regions. This is a significant contribution in its own right, the first attempt to apply the model in this manner to the British regions not only to provide separate estimates of the empirical or reduced hybrid NK model for each but significantly to provide separate estimates of the regional structural parameters.

Extending the analysis to explore the suggestion that heterogeneities exist across sectors, evidence is produced to account for the variance in the reported key structural parameters by the differing nature of the industrial composition of the British regions. As in chapter 6 three measures are used to gauge industrial dissimilarity between the regions: the Krugman index (explained in chapter 3); export share by value of regional output and the percentage of small businesses per region.

The results support the view that there exist differences in the short run inflation/output dynamics. Significantly, evidence of a relationship between the regional structural parameter estimates and various measures of industrial heterogeneity is reported. This is reproduced both graphically and quantitatively.

These results support the view that heterogeneities in regional macrodynamics are driven by sectoral factors. The robustness of the results is tested by estimating the model across several sets of instrument variables (given the GMM technique is utilised) and robustness of the model is tested by comparing the estimated model against two alternative models of inflation: a version of Gordon's triangle model and a simple univariate autoregressive model. These tests suggest that both the model and results are indeed robust.

8.3 NKPC Empirical Methodology

Estimating the model using the method of non-linear least squares facilitates estimation of the parameters of the structural form directly. The reduced form is also estimated separately using the generalised methods of moments (non linear least squares being a specific case of the general method) with the same instruments. The model was estimated in RATS.

The use of GMM facilitates estimate the following orthogonality condition[5]:

$$E_{t-1}\{(\pi_t - \lambda mc - \alpha_f \pi_{t+1} - \alpha_b \pi_{t-1})\, \mathbf{z}_{t-1}\} = 0 \qquad (81)$$

Where $\mathbf{z}_{t-1}$ is a vector of instruments uncorrelated with the error term.

As was discussed in chapter 7, the coefficients of these terms can be expressed as nonlinear functions of the structural parameters:

$$\lambda \equiv (1-\omega)(1-\theta)(1-\beta\theta)^{-1}$$

$$\alpha_f \equiv \beta\theta\phi^{-1} \qquad (73,74,75)$$

$$\alpha_b \equiv \omega\phi^{-1}$$

And

$$\phi \equiv \theta + \omega[1-\theta(1-\beta)] \qquad (76)$$

Where theta is the fixed price duration, omega the share of rule of thumb producers and beta the discount factor.

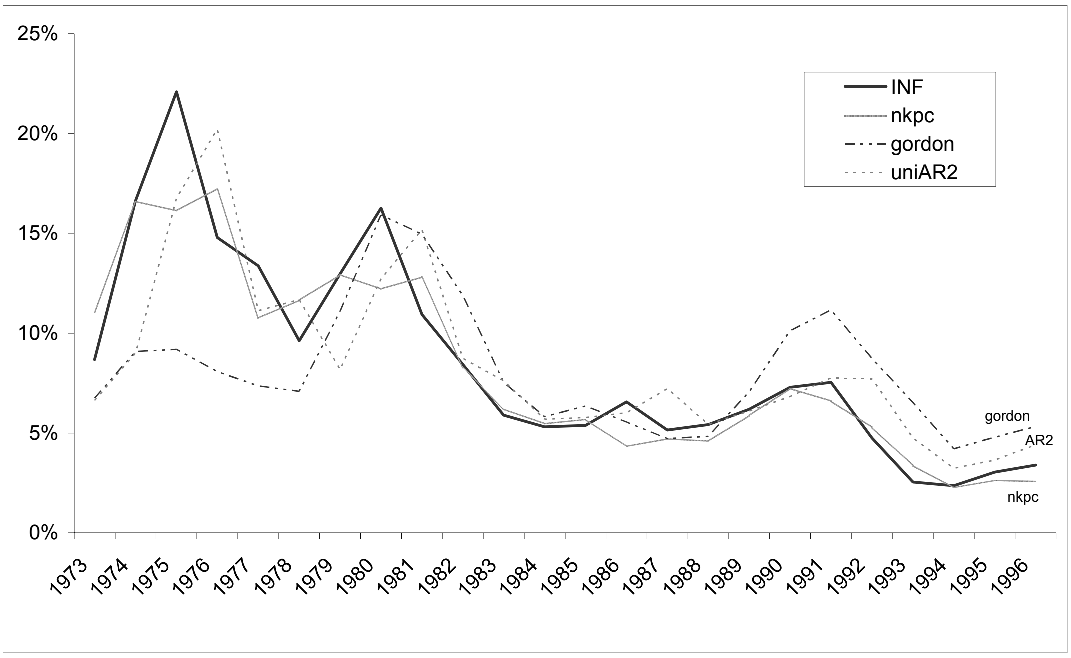
Imposing rationale expectations implies that any variable dated prior to t will be orthogonal to the error term at time t. For the first set of estimations two lags of marginal cost for the region, inflation, the interest rate and the real exchange rate are used. The second and third sets of instruments used are extended to include lags of average UK marginal costs and lags of an ad hoc (HP detrended) measure of the output gap respectively.

The Hausman (p stat) test is used to check validity of the instrument set. It has been borne in mind that care has to be taken to limit the number of instruments used given the length of the time series and the fact that annual as opposed to quarterly data incorporated in most studies is used. The results indicate that the reported values are somewhat sensitive to the choice of the instrument set. This is discussed later.

8.4 Testing the NKPC Model

The first 'test' of the model is to ascertain goodness of fit with the actual dataset. It is an oft repeated criticism that alternative models provide a better fit than the NKPC. The estimated NKPC model is compared and contrasted to two alternatives: a simple univariate autoregressive model; and a 'Gordon' type model of inflation incorporating lags of the inflation rate, supply shocks and demand (represented by deviations in unemployment from an HP trend) shocks. Given the constraints inherent in the short nature of the dataset, the lags in each model have been restricted to a maximum of two.

Figure 90: Plots of Inflation vs Alternative 'Fitted' Measures (SE)



A visual presentation of the three fitted models together with the actual series for the SE data is presented in figure 90. Aside from the obvious and understandable inability of the Gordon model to account for the surge in inflation at the beginning of the chosen time series, it still remains the worst fitting model being unable to replicate the volatility of inflation over this period. The comparison of the fit of the series post 1976 is perhaps a more valid test and this clearly illustrates the NKPC providing a better fit of the inflation process with the Gordon model having a tendency to overshoot the actual series. For this test, for this dataset at least the NKPC provides a good and reasonable fit of the inflation process – overcoming one of its key criticisms.

The table of statistics describing the fit of each individual regional series is produced in table 38 and the figures displaying the fit for each region included in appendix 14. For each reason the fit by R^2 or SSR is clearly superior to both the AR2 and Gordon models of inflation with R^2 values ranging from 0.7849 to 0.8187 for the NKPC as opposed to 0.6682 (there is only one value obviously) for the AR2 series and between 0.7427 and 0.7877 for the Gordon model. These values do include the pre 1976 values for the Gordon model where the given the nature of the model (purely backward looking) and the early spike in inflation in this period it provided a poor fit for the actual series. However, these values taken together with the Gordon model tending to overshoot the actual series as it trended downwards during the 1980s and 1990s do contradict the criticism that the NKPC does not provide a good fit of the data.

Figures 91 and 92 allow an easy comparison of the dispersion of the regional fitted Gordon and NKPC series. As is evident from these the NKPC fitted series display a much greater degree of homogeneity across regional estimates supporting confidence in the general form of the model.

Table 39 presents the J stat tests for validity of instruments. The instruments used were: the second lag of inflation, two lags of the short term interest rate, two lags of marginal costs and the real exchange rate. As can be seen there are one or two indications of the presence of autocorrelation in certain series estimates, as represented by slightly high reported DW values of 2.878 for the EM series and 2.545 for the NE series. However, the remaining series report DW series in a range of 2.027 to 2.415 which is acceptable. Extending the instrument set did little to reduce these higher values confirming the view that there is some autocorrelation present. However, given the short time series it was not considered prudent to extend the instrument lags to greater than two.

For all instruments sets for all regions the null of valid instruments was clearly not rejected and there does not appear to be an appreciable gain in statistical confidence in the validity of instruments by increasing the variables included in the set.

Figure 91: Plots of Regional 'Fitted' Gordon Model of Inflation

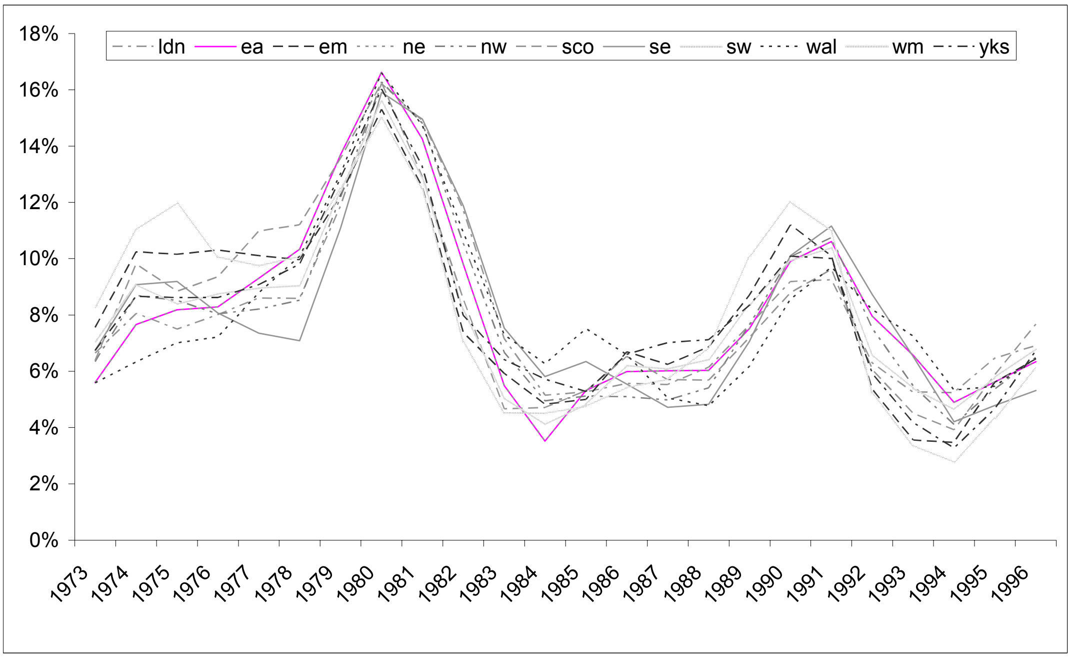


Figure 92: Plots of Regional 'Fitted' NKPC Model of Inflation

Table 38: 'Goodness of fit' statistics for all models inflation, all Regions

	ea				em		
	uniAR2	gordon	nkpc		uniAR2	gordon	nkpc
R-squared	0.6682	0.7664	0.8187		0.6682	0.7877	0.7944
Adjusted R-squared	0.6380	0.6885	0.8015		0.6380	0.7170	0.7748
Sum squared resid	0.0212	0.0150	0.0109		0.0212	0.0136	0.0124
	ne				nw		
	uniAR2	gordon	nkpc		uniAR2	gordon	nkpc
R-squared	0.6682	0.7756	0.8146		0.6682	0.7755	0.7881
Adjusted R-squared	0.6380	0.7008	0.7969		0.6380	0.7006	0.7680
Sum squared resid	0.0212	0.0144	0.0112		0.0212	0.0144	0.0128
	sco				se		
	uniAR2	gordon	nkpc		uniAR2	gordon	nkpc
R-squared	0.6682	0.7806	0.7942		0.6682	0.7837	0.8103
Adjusted R-squared	0.6380	0.7075	0.7746		0.6380	0.7116	0.7923
Sum squared resid	0.0212	0.0140	0.0124		0.0212	0.0139	0.0115
	sw				wal		
	uniAR2	gordon	nkpc		uniAR2	gordon	nkpc
R-squared	0.6682	0.8169	0.8092		0.6682	0.7427	0.7968
Adjusted R-squared	0.6380	0.7559	0.7910		0.6380	0.6570	0.7774
Sum squared resid	0.0212	0.0117	0.0115		0.0212	0.0165	0.0123
	wm				yks		
	uniAR2	gordon	nkpc		uniAR2	gordon	nkpc
R-squared	0.6682	0.7681	0.8018		0.6682	0.7709	0.7849
Adjusted R-squared	0.6380	0.6908	0.7829		0.6380	0.6945	0.7644
Sum squared resid	0.0212	0.0149	0.0120		0.0212	0.0286	0.0512

Table 39: J stats for alternative instruments, all Regions

		ea	em	ne	nw	sco
Inst set 1	J-Stat(5)	4.553	4.994	4.402	2.185	3.337
	Sig Level of J	0.473	0.417	0.493	0.823	0.648
	DW Stat	2.047	2.878	2.545	2.175	2.027
Inst set 2	J-Stat(7)	5.187	5.818	4.790	3.270	10.827
	Sig Level of J	0.637	0.561	0.686	0.859	0.146
	DW Stat	2.102	2.603	2.571	2.284	1.842
Inst set 3	J-Stat(7)	8.394	5.177	5.361	5.142	6.622
	Sig Level of J	0.299	0.638	0.616	0.643	0.469
	DW Stat	2.731	2.714	2.649	2.563	1.911
		se	sw	wal	wm	yks
Inst set 1	J-Stat(5)	3.701	2.621	3.019	2.705	2.044
	Sig Level of J	0.593	0.758	0.697	0.745	0.843
	DW Stat	2.415	2.302	2.365	2.285	2.295
Inst set 2	J-Stat(7)	10.473	3.646	7.781	5.843	6.339
	Sig Level of J	0.163	0.819	0.352	0.558	0.501
	DW Stat	2.328	2.271	2.238	2.423	2.559
Inst set 3	J-Stat(7)	6.559	2.858	8.804	4.431	2.721
	Sig Level of J	0.476	0.898	0.267	0.729	0.910
	DW Stat	2.655	2.344	1.992	2.381	2.364

8.5 NKPC Formal Results

Simple GMM of the reduced form produces estimates that lay within the range of previously reported results for the UK economy in general. In table 40, coefficient values on the forward looking term for inflation between 0.6367 (East Midlands) and 0.8155 (South West) and coefficients on the backward term of between 0.3523 (North East) and 0.1871 (South West) are reported.

Clearly the statistical significance of the forward looking term is higher than that estimated for the backward term (t stats between five and just under seven for the forward looking term against just under two (insignificant at the five percent level) and just over three for the backward term). The greater statistical significance of the forward term is a common finding amongst the research literature (see chapter 7).

Table 40: Regional Estimates of Reduced form of NKPC

	Reduced estimates								
	lambda	*se*	*tstat*	πforward	*se*	*tstat*	πback	*se*	*tstat*
ne	0.5802	0.255	2.2757	0.7379	0.1131	6.5249	0.2653	0.0917	2.8928
yks	0.784	0.2764	2.8365	0.7961	0.1565	5.0869	0.2128	0.1302	1.6339
se	1.1056	0.28	3.948	0.768	0.1387	5.5362	0.2349	0.1164	2.0178
em	0.8802	0.3424	2.571	0.6367	0.1001	6.3625	0.3523	0.0835	4.2164
sco	0.5824	0.2425	2.4015	0.7599	0.1105	6.8738	0.2375	0.0881	2.6975
ea	1.0211	0.3006	3.3972	0.7607	0.1382	5.5051	0.2235	0.1142	1.9566
sw	1.0969	0.2794	3.9257	0.8155	0.1319	6.184	0.1871	0.1145	1.635
wm	0.6855	0.2388	2.87	0.7093	0.1038	6.8334	0.2773	0.086	3.2268
nw	0.7607	0.2044	3.7215	0.7574	0.1301	5.8219	0.2283	0.1076	2.1222
wal	0.4603	0.2467	1.8655	0.7625	0.1349	5.6541	0.2516	0.117	2.1504

Significantly the use of labour share as the marginal cost variable results in a positive and statistically significant value on the coefficient of this term. As was clearly underlined in the introduction, the use of marginal cost was a key tenet of G&G's original work and this particular result was given significant prominence and cited as an important contribution of their work. The coefficients on this term are rarely significant amongst published research and commonly if not always of the wrong sign (G&G) supporting the view that not only is the inclusion of marginal cost as the forcing variable important from a theoretical standpoint it also is of key empirical significance.

Results from this dataset using a measure of the output gap also encountered difficulties in producing a correctly signed significant coefficient on this term. Two sets of results with the output gap replacing the marginal cost term for an estimated UK NKPC are provided in appendix 13.

The method of non-linear least squares facilitates the estimation of the structural parameters directly. The estimates for the three instrument sets are presented in tables 41, 42 and 43. An ordered comparison of regional omega and theta estimates are presented in table 44.

Table 41: Direct Estimates of the structural parameters ω, θ, β of the hybrid NKPC

	hybridnkpc structural								
	beta	*se*	*tstat*	*omega*	*se*	*tstat*	*theta*	*se*	*tstat*
ea	0.9675	0.0679	14.2518	0.0718	0.0495	1.4499	0.3114	0.03	10.3897
em	0.9968	0.0557	17.899	0.1951	0.0609	3.2032	0.3341	0.0775	4.3114
ne	1.0249	0.0589	17.3979	0.1889	0.0797	2.3688	0.4145	0.0782	5.2999
nw	0.972	0.0661	14.6979	0.104	0.061	1.7038	0.3653	0.0323	11.2967
sco	0.9756	0.06	16.2687	0.1391	0.0577	2.4101	0.4127	0.0538	7.6667
se	1.0108	0.071	14.2348	0.0989	0.0586	1.6869	0.2974	0.0334	8.8909
sw	1.0068	0.0462	21.7945	0.053	0.0504	1.0507	0.3145	0.0252	12.4852
wal	1.0407	0.072	14.4571	0.1651	0.0942	1.7528	0.4353	0.0787	5.5326
wm	0.9722	0.0582	16.7165	0.1285	0.0549	2.3414	0.3624	0.0345	10.5096
yks	0.9795	0.0631	15.5287	0.1135	0.0618	1.8382	0.3548	0.0497	7.143

Table 42: Structural estimates: second instrument set

	hybridnkpc structural data - instrument set 2								
	beta	se	tstat	omega	se	tstat	theta	se	tstat
ea	0.948697	0.058177	16.30702	0.086777	0.040085	2.16483	0.317041679	0.028731	11.03473
em	1.007083	0.069804	14.42726	0.277944	0.076197	3.64771	0.475428554	0.121545	3.91154
ne	1.018266	0.05716	17.81442	0.211105	0.084054	2.51153	0.433741923	0.088118	4.92231
nw	0.992842	0.063731	15.57855	0.121538	0.060915	1.9952	0.369604117	0.033724	10.95962
sco	0.838792	0.06072	13.8142	0.25855	0.103648	2.4945	0.656207002	0.177437	3.69825
se	0.851908	0.039061	21.80995	0.172853	0.02559	6.75479	0.347621024	0.028058	12.38959
sw	1.004774	0.0449	22.37795	0.045489	0.043307	1.05039	0.330688202	0.021047	15.71176
wal	0.993897	0.078001	12.74093	0.134524	0.091288	1.47363	0.38279	0.053178	7.19827
wm	1.01341	0.055836	18.14979	0.16496	0.054107	3.04878	0.326722753	0.030065	10.86716
yks	1.014873	0.074243	13.66962	0.264135	0.131269	2.01217	0.485483486	0.138132	3.51464

Table 43: structural estimates: third instrument set

	hybridnkpc structural data - instrument set 3								
	beta	*se*	*tstat*	*omega*	*se*	*tstat*	*theta*	*se*	*tstat*
ea	0.99539	0.060254	16.51999	0.189759	0.048747	3.89276	0.362458552	0.034837	10.40445
em	0.979393	0.06225	15.73312	0.162195	0.043278	3.74775	0.278402835	0.032703	8.51295
ne	1.028579	0.054859	18.74957	0.231784	0.051342	4.5145	0.411011206	0.061691	6.66246
nw	0.947925	0.057443	16.502	0.19588	0.04971	3.94048	0.383707082	0.040601	9.45067
sco	0.941291	0.049571	18.9889	0.118141	0.041311	2.85984	0.41805923	0.041977	9.95916
se	0.995696	0.067624	14.72409	0.29715	0.067436	4.4064	0.467314365	0.081691	5.7205
sw	1.013708	0.043763	23.16352	0.060885	0.048939	1.2441	0.310037706	0.023968	12.93572
wal	0.900592	0.060315	14.93151	0.192791	0.096714	1.99342	0.64051272	0.128699	4.97682
wm	1.005891	0.049204	20.44341	0.147986	0.051518	2.87252	0.351078948	0.040286	8.71469
yks	0.991404	0.060425	16.40721	0.124376	0.064429	1.93041	0.362643003	0.045274	8.01004

The direct estimates of theta (the average fixed price duration) lay within the range of 0.2974 to 0.4353: an implied price duration of 1.42 to 1.78 periods respectively. Given the data is of annual frequency this implies a fixed price duration of 16 to 20 months. Whilst the reporting of values easily within the bounds of credibility justifies the model in some respects, these could be interpreted as being a little on the high side when compared to survey evidence. However, it is within the bounds of the range of reported estimates produced in estimates of the hybrid NKPC model (Angeloni et al (2006)) and as such quite acceptable.

Estimates of omega (the degree of backward looking behaviour) range from 0.0530 to 0.1951 with standard errors in the range of 0.0495 to 0.0942. All of these estimates are significant at the ten percent level but only four are so at the five percent level. Estimation with a different (second) instrument set yields a complete set of coefficients significant at the five percent level.

There is no theory that points in the direction of one choice of instruments over any other. A priori assumptions have been made over the first instrument set – these being a parsimonious set acting as the closest analogy to G&G's original estimation. An increase in statistical confidence in the estimates of omega is gained by the extension of the instrument set to include lags of the aggregate marginal cost value. However, this comes at a cost of the statistical confidence of the estimated relationships between theta and omega and the explanatory variables. It is a trade off over which set of instruments to be the most appropriate.

The estimates of beta (the subjective discount factor) also all lay within reasonable bounds in the range of previously published research. Two of the estimates are reported of just over unity but acceptable given standard error bands of some 0.06 to 0.07 and if anything points to a weakness (acknowledged throughout) in the dataset used (the alternate to disregard these two particular estimates would be a valid option and does not materially affect the conclusions of the analysis that follows) given that a valid criticism of the quality and robustness of these results will always be that they are based on a relatively short series.

An analysis of table 44 illustrates an ordering that follows a reasonable logical basis. Remembering that larger values of omega imply a higher proportion of backward looking firms and that higher values of theta a longer fixed price duration it can be seen that there is a consistent pattern where, for want of a better label, ‘southern’ economies possess lower values of both omega and theta than ‘northern’ economies thus suggesting a greater proportion of forward looking firms and more frequent price changes. The ordering of both of these variables suggests a greater degree of flexibility and less cause of inflation inertia to be present in ‘southern’ economies. This is a significant result in its own right.

The results for the last instrument set do not conform so fully to this pattern but having included lags of the ad hoc output gap a probable reason is that this lack of consistency being put down to a poor choice of instrument (ie the output gap) variable.

Table 44: Estimates and Ordered Estimated Omega and Theta Parameters, All Regions

Ranked Omega and Theta *Inst set 1*				*Inst set2*			
	omega		*theta*		*omega*		*theta*
sw	0.053	se	0.2974	sw	0.045489	ea	0.317042
ea	0.0718	ea	0.3114	ea	0.086777	wm	0.326723
se	0.0989	sw	0.3145	nw	0.121538	sw	0.330688
nw	0.104	em	0.3341	wal	0.13452	se	0.347621
yks	0.1135	yks	0.3548	wm	0.16496	nw	0.369604
wm	0.1285	wm	0.3624	se	0.172853	wal	0.38279
sco	0.1391	nw	0.3653	ne	0.211105	ne	0.433742
wal	0.1651	sco	0.4127	sco	0.25855	em	0.475429
ne	0.1889	ne	0.4145	yks	0.264135	yks	0.485483
em	0.1951	wal	0.4353	em	0.277944	sco	0.656207

Inst set 3			
	omega		*theta*
sw	0.060885	em	0.278403
sco	0.118141	sw	0.310038
yks	0.124376	wm	0.351079
wm	0.147986	ea	0.362459
em	0.162195	yks	0.362643
ea	0.189759	nw	0.383707
wal	0.192791	ne	0.411011
nw	0.19588	sco	0.418059
ne	0.231784	se	0.467314
se	0.29715	wal	0.640513

As stated above some of the coefficient estimates for omega the first instrument set were significant only at the 10% level and not at the 5% level. Use of the second and third instrument set did increase the statistical significance of the estimates of the omega parameter as would be expected with an increased instrument set.

This method also facilitates presentation of direct estimates of the structurally derived terms for the reduced model which are presented in table 45. Again the coefficient on the marginal cost term (lambda) is positive and whilst of a different order to that of G&G's original estimates this is merely due to differences in units (given the use of different time periods).

The range of estimates across the regions ranges from 0.4274 to 1.2069 with the higher estimates produced for Southern regions supporting an intuition that marginal costs in (what are considered to be 'lead' regions of the UK) these regions have a greater forcing effect on UK inflation that those of the North.

Table 45: Structurally derived estimates of the coefficients on the inflation terms

	hybridnkpc structural				
	1/1-theta	*thi*	*lambda*	*forward*	*back*
ne	1.7079	0.6053	0.4513	0.7018	0.3121
ea	1.4521	0.3824	1.168	0.7877	0.1877
em	1.5016	0.5289	0.676	0.6296	0.3688
nw	1.5757	0.4683	0.7831	0.7584	0.2221
sco	1.7027	0.5504	0.5487	0.7315	0.2527
se	1.4232	0.3966	1.1167	0.758	0.2493
sw	1.4588	0.3676	1.2069	0.8614	0.1442
wal	1.771	0.6033	0.4274	0.7509	0.2736
wm	1.5684	0.4896	0.7351	0.7197	0.2624
yks	1.5499	0.4675	0.7981	0.7434	0.2428

8.6 Accounting for differences in regional NKPCs

This section explores whether the apparent pattern of differences in structural parameters that have been estimated for the UK regions, both for omega, theta and the reduced empirical forward/backward inflation terms and the size of the inflation forcing variable, marginal cost, hitherto identified and remarked upon can be explained by recourse to structural factors: in short, given the fact that the UK regions economies possess quite different sectoral and structural characteristics, can it be shown that the values of theta and omega vary in a systematic manner across the regions as a logical consequence of this?

The first step is to plot estimates of regional values of omega and theta against the three measures of industrial heterogeneity used in previously: the Krugman Index (a measure of dissimilarity of industrial composition); the percentage exports to GDP of a region; and small business rate (as defined by the ONS).

There is evidence of a relationship between omega and various structural factors. The share of backward looking price setters increases with greater exports. This is intuitive given the less relevance of domestic inflation for exporters. The share increases with an increasing value of the Krugman index and the share of small businesses. This is again intuitive and suggests that a clear relationship between structural make up of the regional economy and the structural parameter omega exists.

Figure 93: Inst set 1, Omega plotted against Krugman index

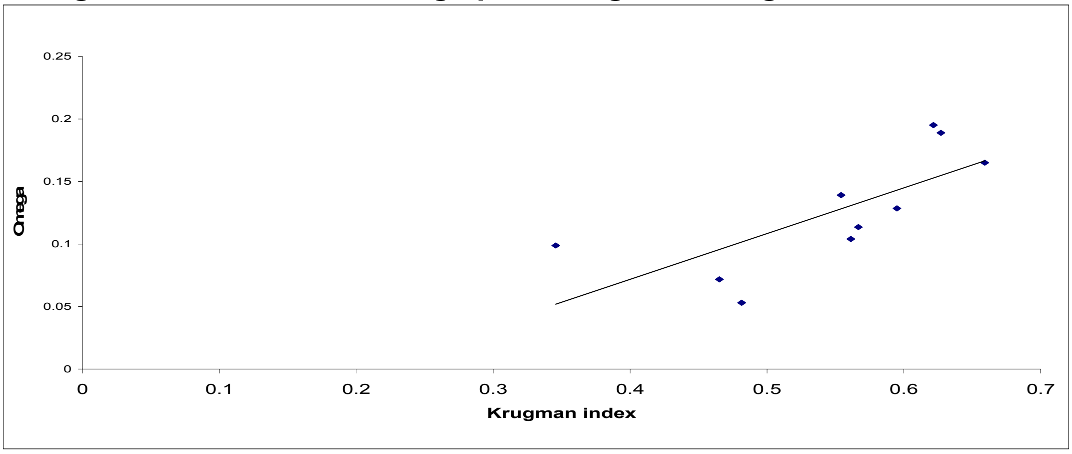


Figure 94: Inst set 1, Omega plotted against Exports

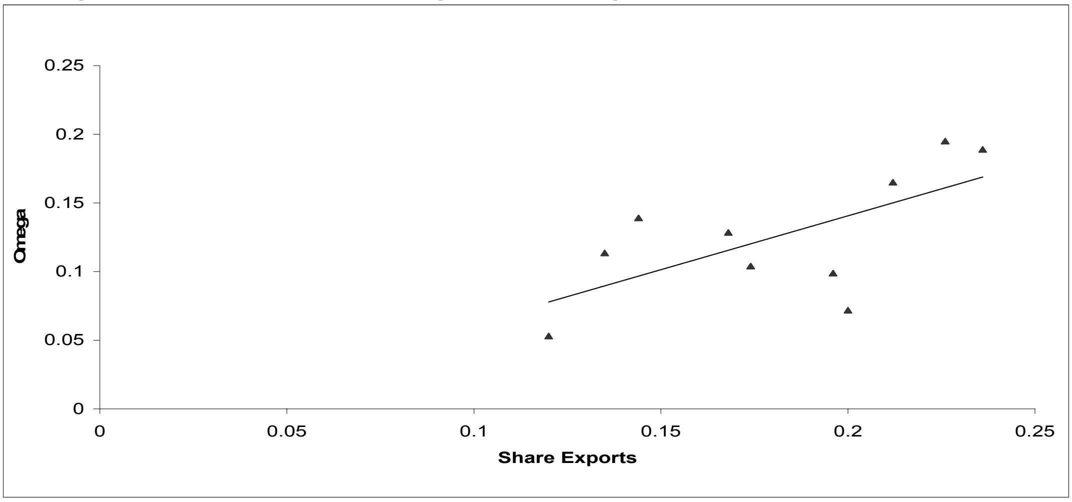


Figure 95: Inst set 1, Omega plotted against Small Business Rate

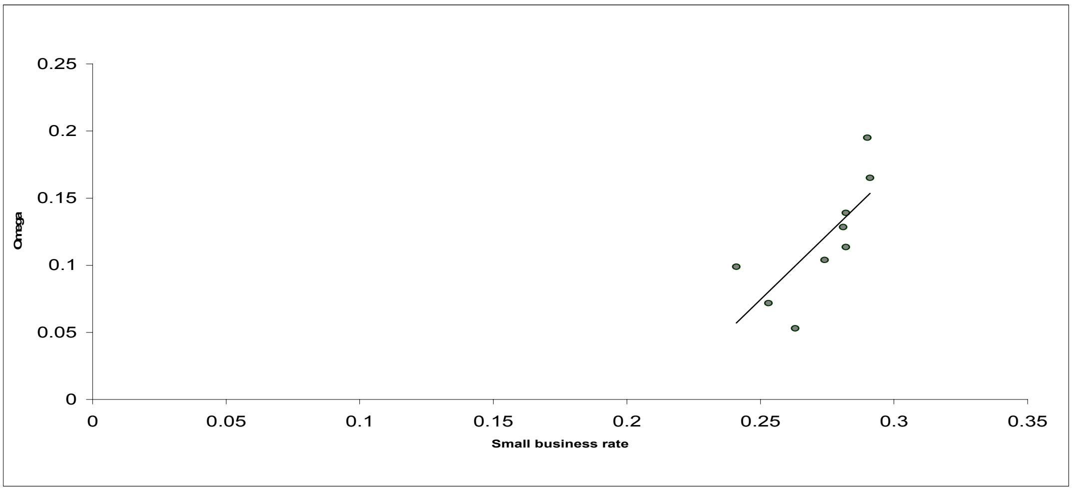


Figure 96: Inst set 1, Theta plotted against Krugman Index variables

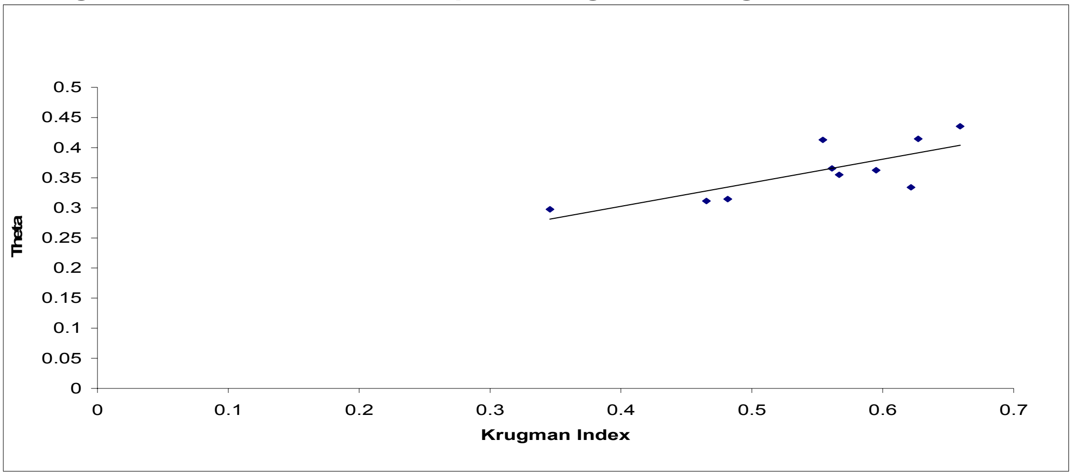


Figure 97: Inst set 1, Theta plotted against Exports

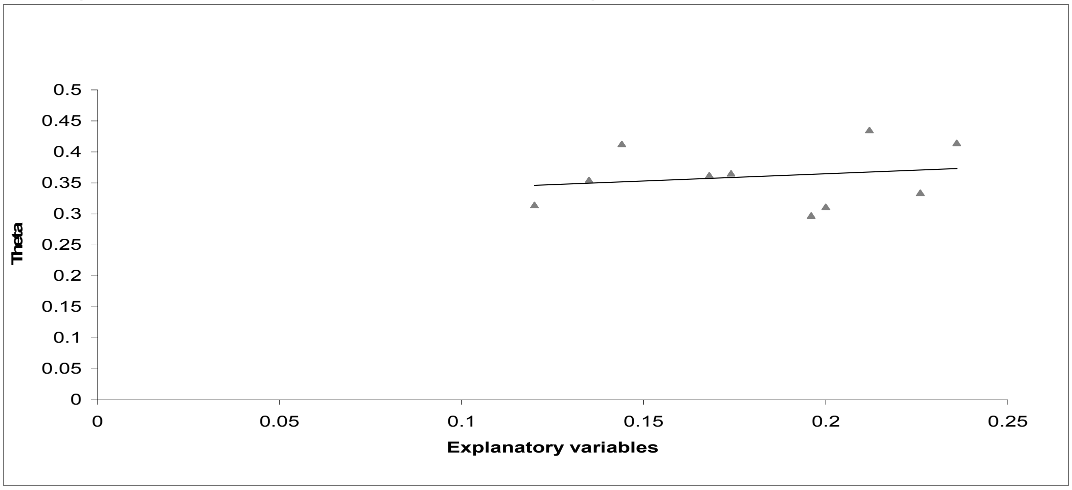


Figure 98: Inst set 1, Theta plotted against Small Business Rate

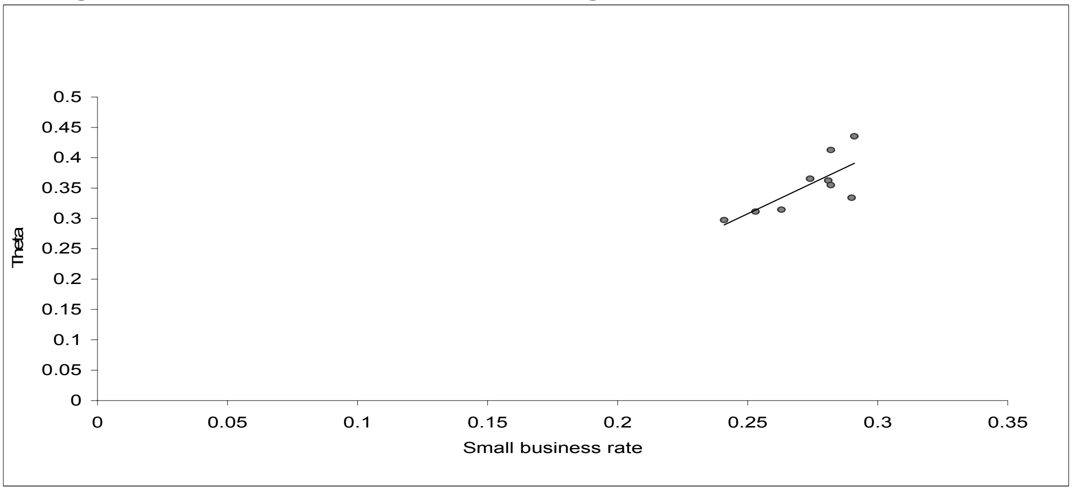


Table 46: Inst set 1, ω regressed on explanatory variables

Variable	Coefficient	Std. Error	t-stat	Prob.
C	0.0125	0.0262	0.4756	0.6488
Product 3 parameters	4.0636	0.9515	4.2708	0.0037*
R-squared		0.7227		
F-statistic		18.2401		
Prob(F-statistic)		0.003697*		
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Product 3 parameters	4.4929	0.2861	15.7041	
R-squared	0.7137			
			* significant at 1%	

Table 47: Inst set 1, θ regressed on explanatory variable

Variable	Coefficient	Std. Error	t-stat	Prob.
C	0.2005	0.0520	3.8562	0.0062
Product 2 parameters	1.0348	0.3423	3.0235	0.0193*
R-squared		0.5663		
F-statistic		9.1417		
Prob(F-statistic)		0.0193		
Variable	**Coefficient**	**Std. Error**	**t-stat**	**Prob.**
C	0.2857	0.0446	6.4049	0.0004
Product 3 parameters	2.6210	1.6176	1.6203	0.1492
R-squared		0.2728		
F-statistic		2.6254		
Prob(F-statistic)		0.1492		
			* significant at 5%	

Table 48: Inst set 2, ω regressed on explanatory variables

Variable	Coefficient	Std. Error	t-stat	Prob.
C	0.0440	0.0985	0.4468	0.6707
Product 3 parameters	5.3406	3.8694	1.3802	0.2167
R-squared		0.2410		
F-statistic		1.9050		
Prob(F-statistic)		0.2167		
	Coefficient	Std. Error	t-stat	Prob.
Product 3 parameters	6.9931	1.0702	6.5346	0.0003
R-squared	0.2157			

Table 49: Inst set 2, θ regressed on explanatory variable

Variable	Coefficient	Std. Error	t-stat	Prob.
C	0.1709	0.1986	0.8606	0.4225
Product 2 parameters	1.6957	1.3587	1.2480	0.2585
R-squared		0.2061		
F-statistic		1.5576		
Prob(F-statistic)		0.2585		
	Coefficient	Std. Error	t-stat	Prob.
Product 2 parameters	2.8407	0.27014	10.515	0.0001
R-squared	0.1081			

Table 50: Spearman and Standard Correlations between Structural Parameters and 'Explanatory' Variables, Instrument Set 1

	Spearman Correlations		Std Correlations	
	omega	theta	omega	theta
Krugman rank	0.830	0.770	0.726	0.768
Share exports (%)	0.600	0.236	0.656	0.195
Small business rate	0.879	0.782	0.750	0.752

A similar relationship is apparent for theta. The greater the share of exports, the greater the share of small businesses and the larger the value of the Krugman index, the larger is the value of theta and hence the lower is the frequency that prices are changed. Again these are intuitive. Table 50 reports both standard correlations and Spearman Rank correlations for instrument set one. Clearly there is a statistically significant relationship between the value of the Krugman Index and both the values of omega and theta. The same is true for the small business rate. Whilst a fairly high correlation is reported for the values of omega and the share of exports only weak signs of correlation exist between theta and the share of exports.

Tables 46 through 49 present a more formal test of the relationship between the explanatory variables and the values of omega and theta for instrument sets one and two. The tables report a regression on a nonlinear parameter and/or a constant. There are two choices of parameter, the first being the product of all three explanatory variables, the second being the product of the Krugman Index and the small business rate as the correlation between the share of exports and theta was low.

The results support the simple analysis. Those for the first instrument set are clearly stronger. The coefficient on the three variable non-linear parameter are significant at the one percent level even when a constant is included as is the joint significance of the constant and this variable. The explanatory power of the regression is very high: a value of R^2 of over 0.7 in each case. For theta, the coefficient on the three variable parameter is no longer statistically significant. However, when this is reduced to a product of two variables it becomes significant at the five percent level.

The results for the second instrument set are not as compelling. A statistically significant coefficient is reported only when the constant is not included in the regression and the values of R^2 are disappointing. However, this instrument set was chosen only to increase the statistical confidence of the original theta estimates and has resulted in this loss of explanatory power.

Whilst the caveat has to be provided these are regressions based on a very small dataset the statistically strength of the results is impressive.

The point is not to attempt to justify a proven form of a defined relationship but to illustrate that the New Keynesian ‘structural’ parameters can clearly be expressed as a function of these explanatory ‘structural’ variables. That said, the results above clearly point to a relationship between the estimated structural parameters and ‘structural’ values from actual data and provides evidence of the values of omega and theta being more than just arbitrary values. Together with the fact that these values vary in a manner consistent with intuition across the regions (see table 44 and 50) provides very compelling evidence not just how the relationship between output and inflation (as suggested by the NKPC) varies across the UK regions but also provides strong evidence of why based on structural parameters.

8.7 Bootstrapping

Given the concerns about the statistical significance of the estimates of the share of rule of thumb producers a bootstrap analysis was conducted as an attempt to ascertain whether any greater confidence in the statistical significance of the estimates (see appendix 15 for the methodology, the algorithm was written in RATS) was gained. For each of the regional bootstraps it is clear there is confidence that the estimates are drawn from a distribution centred around the point estimates.

The drawback is that distributions are presented that are similar to each other which undermines the case that the point estimates themselves are of significant statistical difference. Ironically the standard errors of the bootstrap sample are now somewhat larger.

This is unsurprising given the annual nature of the time series available. The distributions (with the methodology) are presented in appendix 15 for completeness.

8.8 Welfare losses

With a structural model to hand it is possible to construct a welfare theoretic expression for the loss function. Standard period loss welfare loss functions assume merely that a central banker aims to minimise the value of an ad hoc function which is a quadratic in the terms of inflation and output loss with relative weights on each term according to the preferences of the central banker (see Walsh, 2005).

Woodford (2003) shows that a function of this kind can be derived from a second-order Taylor expansion of the utility function[30], and that optimal monetary policy can therefore be properly regarded as welfare-maximizing.

The explicit welfare theoretic quadratic function derived from the micro foundations of the hybrid model can be shown to be:

$$L_t = \pi^2 + \lambda_x x_t^2 + \lambda_{\Delta\pi}(\pi_t - \pi_{t-1})^2 \qquad (87)$$

where x is marginal cost, π inflation, and the λ terms are non-linear functions of structural parameters.

[30] Clearly the final function will be dependent on the utility function used. The loss function used here is as described by Gouvea & Sen Gupta (2007) which takes account of the effect of the rule of thumb behaviour of producers on policy makers actions.

Gouvea & Sen Gupta (2007) illustrate that the coefficient of interest, λ_x, is of the following form:

$$\lambda_X = \frac{\rho(1-\omega)(1-\theta)(1-\beta\theta)(\sigma+\eta)}{(\theta+\omega[1-\theta(1-\beta)])(1+\eta\rho)} \qquad (88)$$

and

$$\lambda_{\Delta\pi} = \frac{\omega}{\theta(1-\omega)} \qquad (89)$$

Where and β, θ and ω are, as has been defined throughout, the subjective discount factor, degree of price inertia, and share of rule of thumb producers respectively. Additionally, σ is the inverse elasticity of substitution, η is the elasticity of labour and ρ is the price elasticity of demand.

This welfare function provides an illustration of the differing implications for welfare of the regions of UK monetary policy that these 'structural' estimates imply. The weights on the marginal cost and inflation rate change terms of the welfare theoretic loss function are calculated in accord with the estimates from the instrument set 1 regressions above (the coefficient on the inflation term is unity in the loss function and hence common to all) to ascertain whether there are any implications for welfare of the results. The calibrated values of σ η and ρ as 0.157, 0.473 and 7.88 are taken respectively from Amato and Laubach (2001) and have been used for estimated results presented below.

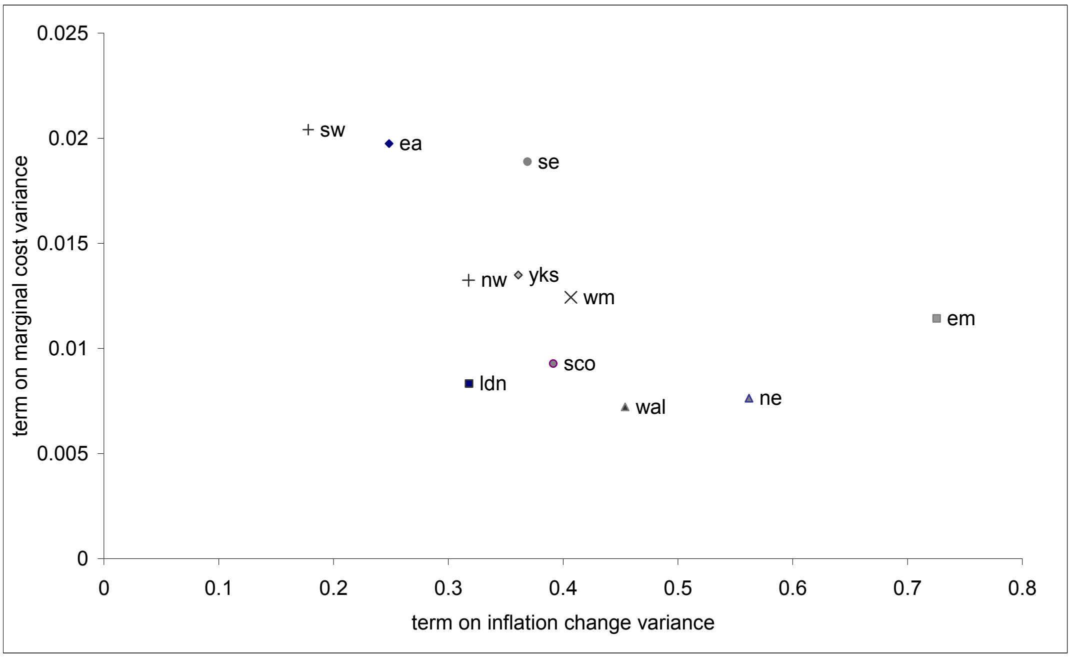
Table 51: Values of coefficients on terms on welfare theoretic loss function

	ea	EM	ne	nw	sco	se	SW	Wales	WM	YKS
coefficient on squared marginal cost term	0.0195	0.0115	0.0079	0.0131	0.0092	0.0191	0.0206	0.0076	0.0123	0.0134
coefficient on squared lagged inflation term	0.2484	0.7254	0.5619	0.3176	0.3915	0.3689	0.1779	0.4541	0.4068	0.3610

As can be better seen from diagrammatic presentation there appears to be a trade off between a larger coefficient on weight on the marginal cost term and the size of the coefficient on the inflation term. The difference in magnitude of the coefficients on the two terms is predictable and consistent with previous published estimates as outlined in Gouvea & Sen Gupta (2007).

It is evident that higher weights on the change in inflation term are commonly on the northern and midlands economies whereas greater values on the marginal cost term for are commonly on 'southern' economies (table 51, figure 99). This is an interesting result, if robust it would suggest that inflation stabilisation provides greater relative welfare benefits to the northern regions and that stabilising output variance favours the southern regions.

Figure 99: Welfare weights: marginal cost variance vs inflation change variance



The sole objective of UK monetary policy is inflation stabilisation. These results suggest that this policy favours the welfare of the north above the south: a finding somewhat perhaps at odds with 'prevailing intuition'. However, this may be less so when one considers that the estimates have shown that there exists a greater degree of 'backward looking' producers and a greater fixed price duration as evidenced by the values of omega and theta in these 'northern' regions (see table 51). Given this greater degree of inertia in prices displayed by the north the lost output through 'disinflations' would be greater. This would therefore point to maximising inflation 'stability' as being in these regions' best interests as this would reduce the likelihood of welfare losses due to future policy actions.

8.9 Wage Phillips Curves

As was referred to in chapter 7 the NKPC is not without controversy and the traditional model is still championed by many: 'Although the New Keynesian Phillips Curve has many virtues, it also has one striking vice. It is completely at odds with the facts' Mankiw (2001).

Therefore in this last subchapter estimates of a traditional 'expectations augmented' wage price (and unemployment) Phillips curve are presented. The wage price model utilised by Flaschel et al (2004) is estimated. However, there is one major flaw in this attempt: whilst unemployment data for the regions dates back as far as the early seventies and is provided on a quarterly basis no such data series exists for any other variable. Therefore we use a common wage series in the estimation of this Phillips curve. It was shown in chapter 2 that wages differ markedly across the regions and this is a significant flaw. However, the purpose is to investigate regional dynamic heterogeneities and the objective is pursued to ascertain whether even with this methodology any useful information can be gleaned.

The model estimated is that of Flaschel et al (2004). Whilst this work was specifically an investigation into the concurrent dual estimation of wage/wage and wage/price Phillips curves a similar attempt here with only one wage series would provide no information on regional differences and would be a redundant exercise. Flaschel's model itself is based on Fair's (2000) derivation of a proportional control model and is of the following form:

$$\Delta w = a_0 - a_1 U^l_{t-1} + a_2 \Delta p + a_3 \Delta p_a + a_4 dyn + \varepsilon_t \qquad (90)$$

Where Δw is the quarterly change in the log of the wage, U^l_{t-1} the last period's unemployment level (in logs), Δp the quarterly change in the log of the price level, Δp_a the annual change in the log of the price level and dyn the quarterly change in labour productivity.

The only interest in this model is to further the empirical investigation of potential heterogeneities of the UK regions. The estimates of the NKPC have demonstrated that supply side factors – ie heterogeneities in industrial composition – do contribute to heterogeneous dynamics. This version of the wage Phillips curve will illustrate that similar heterogeneities exist across the labour markets of the regions.

The coefficients in the model can be seen to be indicative of the degree of flexibility in the wage market, where a_1 can be seen to represent the degree of wage flexibility in the face of demand (unemployment) pressures ie the slope of the wage Phillips curve, and the NAIRU can be inferred as being $-a_0/a_1$. There the interest in the model ends. The single equation model is estimated for the regions using a common wage series for the express purpose of inferring differences on the basis that if any are evident they would be more so if individual regional wage series were available for estimation purposes. The fact that interest in this model is limited only to empirics, specifically in the value of two coefficients is fortunate as it was not possible to produce estimates of the form of the equation above where the coefficient on *dyn,* the quarterly change in labour productivity, is of the correct sign. It was found to be necessary to lag this term to produce non-negative values on its coefficient and even then these were not shown to be statistically significant.

Given this relaxing of the strict adherence to the exact functional form, four separate empirical formulations of the model were estimated:

Equation 1 $\Delta w = f(constant,\ U^{l}_{t-1},\ \Delta p_{a},\ dyn_{t-1});$

Equation 2 $\Delta w = f(constant,\ U^{l}_{t-1},\ \Delta p_{\ t-1},\ \Delta p_{a},\ dyn_{\ t-1});$

Equation 3 $\Delta w = f(constant,\ U^{l}_{t-1},\ \Delta p_{a\ t-1},\ dyn_{t-1});$ and

Equation 4 $\Delta w = f(constant,\ U^{l}_{t-1},\ \Delta p,\ \Delta p_{a},)$

Following *dyn* the term on quarterly inflation was found to be the least significant, the only equation which reported consistently significant values of the coefficient of this term being equation four which drops the inclusion of dyn altogether. The full sets of results for each of the four versions of the empirical model are outlined in tables 52 to 55

Table 52: Regional Wage Phillips Curve Estimates, Equation 1

	ea	t stat		em	t stat		ne	t stat		nw	t stat	
C	0.0094	2.5462	**	0.0101	2.2782	**	0.0078	1.3384	*	0.0080	1.7215	*
se	0.0037			0.0044			0.0058			0.0047		
UEA(-1)	-0.0062	-2.8685	***	-0.0057	-2.4509	**	-0.0034	-1.3688	*	-0.0041	-1.8222	*
se	0.0022			0.0023			0.0025			0.0023		
DPA	0.2228	10.3431	***	0.2219	10.0450	***	0.2324	10.6420	***	0.2329	10.8570	***
se	0.0215			0.0221			0.0218			0.0214		
DYN(-1)	0.0427	0.2960		0.0144	0.0995		-0.0172	-0.1180		-0.0027	-0.0186	
se	0.1443			0.1443			0.1458			0.1455		
R2	0.5376			0.5297			0.5144			0.5199		
AdjR2	0.5265			0.5185			0.5028			0.5084		
SE regn	0.0120			0.0121			0.0123			0.0122		
SS res	0.0181			0.0184			0.0190			0.0187		
F stat	48.4388			46.9366			44.1410			45.1194		
DW stat	1.4731			1.4735			1.4541			1.4594		

	sco	t stat		se	t stat		sw	t stat		wal	t stat	
C	0.0065	1.2717		0.0073	2.3296	**	0.0060	1.7656	*	0.0082	1.7038	*
se	0.0051			0.0031			0.0034			0.0048		
UEA(-1)	-0.0032	-1.3145		-0.0055	-2.7883	***	-0.0040	-2.0365	**	-0.0042	-1.7941	*
se	0.0025			0.0020			0.0020			0.0023		
DPA	0.2349	10.9008	***	0.2272	10.6876	***	0.2383	11.2845	***	0.2336	10.9157	***
se	0.0215			0.0213			0.0211			0.0214		
DYN(-1)	-0.0172	-0.1175		0.0431	0.2980		0.0125	0.0860		0.0002	0.0011	
se	0.1460			0.1448			0.1459			0.1459		
R2	0.5139			0.5360			0.5230			0.5195		
AdjR2	0.5022			0.5249			0.5115			0.5080		
SE regn	0.0123			0.0120			0.0122			0.0123		
SS res	0.0190			0.0181			0.0186			0.0188		
F stat	44.0424			48.1320			45.6786			45.0509		
DW stat	1.4530			1.4762			1.4605			1.4559		

C	wm	t stat		yks	t stat
se	0.0126	2.6957	*	0.0096	1.9388
UEA(-1)	0.0047			0.0049	
se	-0.0065	-2.8753	**	-0.0048	-2.0410
DPA	0.0022			0.0024	
se	0.2190	9.9951	***	0.2233	9.9339
DYN(-1)	0.0219			0.0225	
se	0.0296	0.2064		0.0001	0.0009
	0.1435			0.1450	
R2					
AdjR2	0.5377			0.5230	
SE regn	0.5266			0.5116	
SS res	0.0120			0.0122	
F stat	0.0181			0.0186	
DW stat	48.4652			45.6912	
	1.4813			1.4623	

* significant at 10% level
** significant at 5% level
*** significant at 1% level

Table 53: Regional Wage Phillips Curve Estimates, Equation 2

	ea	t stat		em	t stat		ne	t stat		nw	t stat	
C	0.009	2.539	**	0.010	2.281	**	0.008	1.333		0.008	1.711	*
se	0.004			0.004			0.006			0.005		
UEA(-1)	-0.006	-2.915	***	-0.006	-2.497	**	-0.003	-1.394		-0.004	-1.851	*
se	0.002			0.002			0.002			0.002		
DP(-1)	0.190	1.445		0.189	1.428		0.184	1.363		0.185	1.379	
se	0.131			0.133			0.135			0.134		
DPA	0.176	4.502	***	0.175	4.416	***	0.187	4.692	***	0.187	4.745	***
se	0.039			0.040			0.040			0.039		
DYN(-1)	0.083	0.569		0.055	0.373		0.021	0.145		0.036	0.246	
se	0.146			0.146			0.148			0.148		
R2	0.545			0.537			0.522			0.527		
SE regn	0.012			0.012			0.012			0.012		
SS res	0.018			0.018			0.019			0.018		
F stat	37.17			36.01			-5.81			34.56		
DW stat	1.401			1.403			1.388			1.392		
	sco	t stat		se	t stat		sw	t stat		wal	t stat	
C	0.006	1.254		0.007	2.308	**	0.006	1.736	*	0.008	1.690	*
se	0.005			0.003			0.003			0.005		
UEA(-1)	-0.003	-1.331		-0.006	-2.830	***	-0.004	-2.062	**	-0.004	-1.818	*
se	0.002			0.002			0.002			0.002		
DP(-1)	0.182	1.353		0.189	1.434		0.185	1.381		0.184	1.372	
se	0.135			0.132			0.134			0.134		
DPA	0.190	4.785	***	0.180	4.640	***	0.193	4.926	***	0.188	4.773	***
se	0.040			0.039			0.039			0.039		
DYN(-1)	0.021	0.142		0.083	0.568		0.052	0.348		0.039	0.263	
se	0.148			0.147			0.148			0.148		
R2	0.521			0.544			0.530			0.527		
SE regn	0.012			0.012			0.012			0.012		
SS res	0.019			0.018			0.018			0.018		
F stat	33.71			36.92			34.98			34.50		
DW stat	1.387			1.405			1.392			1.388		
	wm	t stat		yks								
C	0.013	2.707	***	0.010	1.939	*						
se	0.005			0.005								
UEA(-1)	-0.007	-2.927	***	-0.005	-2.078	**						
se	0.002			0.002								
DP(-1)	0.191	1.457		0.187	1.399							
se	0.131			0.134								
DPA	0.171	4.367	***	0.177	4.422	***						
se	0.039			0.040								
DYN(-1)	0.070	0.484		0.040	0.270							
se	0.146			0.147								
R2	0.545			0.530								
SE regn	0.012			0.012								
SS res	0.018			0.018								
F stat	37.21			35.02								
DW stat	1.410			1.394								

Table 54: Regional Wage Phillips Curve Estimates, Equation 3

	ea	t stat		em	t stat		ne	t stat		nw	t stat	
C	0.007	2.089	**	0.008	1.854	*	0.006	1.101		0.006	1.423	
se	0.004			0.004			0.006			0.005		
UEA(-1)	-0.006	-2.955	***	-0.005	-2.480	**	-0.004	-1.487		-0.004	-1.968	*
se	0.002			0.002			0.002			0.002		
DPA(1)	0.250	11.978	***	0.250	11.637	***	0.262	12.438	***	0.261	12.697	**
se	0.021			0.021			0.021			0.021		
DYN(-1)	0.149	1.106		0.123	0.911		0.102	0.746		0.114	0.837	
se	0.135			0.135			0.137			0.136		
R2	0.613			0.606			0.594			0.599		
SE regn	0.011			0.012			0.012			0.012		
SS res	0.016			0.017			0.017			0.017		
F stat	66.12			64.04			60.86			62.20		
DW stat	1.587			1.579			1.551			1.563		
	sco	t stat		se	t stat		sw	t stat		wal	t stat	
C	0.005	1.049		0.005	1.796	*	0.005	1.421		0.007	1.439	
se	0.005			0.003			0.003			0.005		
UEA(-1)	-0.004	-1.499		-0.005	-2.890	***	-0.004	-2.326	**	-0.004	-1.960	**
se	0.002			0.002			0.002			0.002		
DPA(1)	0.264	12.780	***	0.255	12.427	***	0.267	13.293	***	0.262	12.767	***
se	0.021			0.020			0.020			0.021		
DYN(-1)	0.103	0.755		0.152	1.125		0.132	0.967		0.118	0.862	
se	0.137			0.135			0.136			0.136		
R2	0.594			0.612			0.604			0.599		
SE regn	0.012			0.011			0.012			0.012		
SS res	0.017			0.016			0.017			0.017		
F stat	60.89			65.81			63.44			62.18		
DW stat	1.551			1.590			1.573			1.559		
C	wm	t stat		yks	t stat							
se	0.010	2.282	**	0.007	1.546							
UEA(-1)	0.005			0.005								
se	-0.006	-2.888	***	-0.005	-2.055	**						
DPA(1)	0.002			0.002								
se	0.247	11.531	***	0.252	11.538	***						
DYN(-1)	0.021			0.022								
se	0.133	0.992		0.113	0.828							
	0.134			0.136								
R2												
SE regn	0.603			0.590	* 10%							
SS res	0.011			0.012	** 5%							
F stat	0.016			0.017	*** 1%							
DW stat	65.80			62.48								
	1.591			1.562								

Table 55: Regional Wage Phillip Curve Estimates, Equation 4

	ea	t stat		em	t stat		ne	t stat		nw	t stat	
C	0.009	2.388	**	0.009	2.117	**	0.007	1.203		0.007	1.583	
se	0.004			0.004			0.006			0.005		
UEA(-1)	-0.006	-2.687	***	-0.005	-2.297	**	-0.003	-1.267		-0.004	-1.709	*
se	0.002			0.002			0.002			0.002		
DP	0.228	1.967	*	0.235	2.012	**	0.251	2.122	**	0.246	2.088	**
se	0.116			0.117			0.118			0.118		
DPA	0.168	4.878	***	0.166	4.765	***	0.173	4.908	***	0.174	4.984	***
se	0.035			0.035			0.035			0.035		
R2	0.551			0.544			0.531			0.536		
SE regn	0.012			0.012			0.012			0.012		
SS res	0.018			0.018			0.018			0.018		
F stat	51.16			49.80			47.22			48.15		
DW stat	1.666			1.653			1.625			1.636		

	sco	t stat		se	t stat		sw	t stat	
C	0.006	1.134		0.007	2.207	**	0.005	1.642	*
se	0.005			0.003			0.003		
UEA(-1)	-0.003	-1.212		-0.005	-2.617	***	-0.004	-1.912	*
se	0.002			0.002			0.002		
DP	0.251	2.124	**	0.231	1.988	**	0.243	2.068	**
se	0.118			0.116			0.117		
DPA	0.175	4.982	***	0.172	4.981	***	0.180	5.154	***
se	0.035			0.034			0.035		
R2	0.531			0.550			0.539		
SE regn	0.012			0.012			0.012		
SS res	0.018			0.018			0.018		
F stat	47.13			50.90			48.66		
DW stat	1.624			1.671			1.645		

	wal	t stat		wm	t stat		yks	t stat	
C	0.007	1.548		0.012	2.507	**	0.009	1.779	*
se	0.005			0.005			0.005		
UEA(-1)	-0.004	-1.663	*	-0.006	-2.688	***	-0.004	-1.902	*
se	0.002			0.002			0.002		
DP	0.245	2.074	**	0.226	1.947	*	0.241	2.052	**
se	0.118			0.116			0.118		
DPA	0.175	5.013	***	0.166	4.785	***	0.167	4.724	***
se	0.035			0.035			0.035		
R2	0.536			0.551			0.539	significant	
SE regn	0.012			0.012			0.012	** 5%	
SS res	0.018			0.018			0.018	*** 1%	
F stat	48.04			51.17			48.63		
DW stat	1.633			1.663			1.637		

Irrespective of which model is analysed the story is the same. The results from these estimations all result in an ordering consistent with the facts of the levels of unemployment across the UK regions.

Table 56: Estimates of Wage Phillips Curve Slope & NAIRU, UK Regions

	equation one wagephillips		nairu %
wm	-0.00646	se	3.77
ea	-0.00618	sw	4.43
em	-0.00569	ea	4.55
se	-0.00552	em	5.85
yks	-0.00481	wm	7.07
wal	-0.00417	nw	7.08
nw	-0.0041	wal	7.12
sw	-0.004	yks	7.30
ne	-0.00341	sco	7.45
sco	-0.00325	ne	9.74

	equation two wagephillips		nairu %
wm	-0.00655	se	3.65
ea	-0.00625	sw	4.25
em	-0.00578	ea	4.43
se	-0.00558	em	5.67
yks	-0.00488	nw	6.79
wal	-0.00422	wal	6.83
nw	-0.00415	wm	6.88
sw	-0.00404	yks	7.05
ne	-0.00346	sco	7.07
sco	-0.00328	ne	9.26

	equation three wagephillips		nairu %
wm	-0.00615	se	2.75
ea	-0.00603	sw	2.93
em	-0.00548	ea	3.45
se	-0.00543	em	4.27
yks	-0.00462	sco	4.37
wal	-0.00434	nw	4.60
sw	-0.00432	wal	4.69
nw	-0.0042	yks	4.97
ne	-0.00354	wm	5.41
sco	-0.00353	ne	5.74

	equation four wagephillips		nairu %
wm	-0.00591	se	3.89
ea	-0.00562	sw	4.43
em	-0.00522	ea	4.69
se	-0.00503	em	5.85
yks	-0.00439	nw	6.91
wal	-0.00378	wal	6.98
nw	-0.00376	sco	7.03
sw	-0.00365	wm	7.19
ne	-0.00309	yks	7.19
sco	-0.00293	ne	9.21

Clearly the issue of a time varying NAIRU has been ignored – given the inherent flaw in the approach of using a common wage series – it would be difficult to justify attempt more than the simple analysis which is presented.

However, this is also strength, given the limitations of what is attempted the conclusions drawn from the table 56 above can be viewed with a certain degree of confidence. Clearly the range of estimates of NAIRU may not be accurate to a sufficient degree but they are in the correct ball park and the relative sizes and positions of regional NAIRU do reflect that of the actualité in the UK. The relative sizes of the estimates of the wage Phillips slope should therefore be similarly respected. It can be concluded from this evidence that those regions of SE, EA, Wm and EM have the most flexible labour markets and those of Sco, NE, NW and the SW clearly the least. This is common to each model estimation and a finding of some significance in its own right.

8.10 Conclusion

This chapter has outlined and discussed regional estimations of two types of Phillips curves.

The NKPC has been the key model of interest, primarily because it is the modern variant but importantly due to its structural foundations it leads to structural parameters of interest that logical ought to vary economy by economy. As Angeloni et al (2006) highlighted sectoral dissimilarity is a ripe source for differing levels of inflation inertia and dynamics.

Once it had been shown that the NKPC provided a robust model of the data series to hand (compared to other estimated models) and the instrument choice valid and robust a comparison of the directly estimated parameters of interest – the degree of rule of thumb producers and the fixed price duration – across the regions was able to be made.

Significantly given the data constraints of the whole of this thesis, it was possible to mimic the original estimation methodology of G&G and use a direct measure of marginal cost for each individual region. Similar to this work this led to successful estimation of correctly signed and significant coefficients on the driving variable. It was also able to be shown, through graphical illustration of cross correlations of the relevant time series, and again replicating the conclusions of G&G why through the differing co-movements of the data, marginal cost is fundamental to a correctly estimated NKPC model.

The estimates of structural parameters were then shown to clearly relate to real structural factors of the regional economies. These relationships were shown to be intuitive, logical, and statistically relevant and to vary across the regions in a manner consistent with actual reality. This chapter then has outlined significantly how and why the NKPC varies across the UK regions in a systematic and logical manner.

Finally, to support these findings wage price Phillips curves were estimated for the regions using a common wage set. The implied results for regional NAIRUS were again consistent with real life experience and the degree and direction of wage price flexibility fully consistent with the actual labour markets of the regions.

This chapter has shown that the inflation/output dynamics across the UK regions varies according to industrial composition and that those economies of the 'south' tend to display greater product market flexibility in terms of frequency of price setting and a lesser proportion of rule of thumb producers than those of the 'north'. The chapter has also shown how similarly those economies of the south (in addition to their expected lower NAIRUs) also exhibit a greater degree of labour market flexibility as implied by estimates of slope of the wage Phillips curves. All of this being a contribution to knowledge of the UK regions.

9 Summary, Contribution & Conclusions

This thesis began with the following quote:

"Monetary policy can only target the economy as a whole - it can't seek to protect individual firms or sectors, or therefore regions" - Eddie George (1999).

It was stated at the outset that this was an acknowledgement that it was understood that despite the UK having the benefit of a currency union for several hundred years it was still not possible to set monetary policy to be set in the equal interests of all of the regions simultaneously. The motivation for this thesis was driven by the view that monetary policy ought at least to take into account the variance of regional output (and implicitly welfare) during the conduct of monetary policy. The other motivation for this thesis was a belief that the short run dynamics of the regions surely had some effect on their heterogeneous performance in the long run. Policy makers ought at least to have some understanding of the heterogeneous nature of the responses of the regions to their policy actions if only for them to have a greater awareness of the implications of their actions.

9.1 Summary

This thesis has made progress towards a better understanding of the transmission of shocks across the British regions and has demonstrated that monetary policy is able to contribute to a divergence of the performance of the regional economies (even if the majority contribution in the long run is indeed determined by structural supply side factors). The consensus of the available research prior to this thesis can be broadly classed as being of two minds. The first that heterogeneities in business cycle characteristics and/or dynamics were limited and given that supply and demand shocks to the regional economies clearly hit each region more or less concurrently any differences in transmission of monetary policy were of minor consequence – this is a view encapsulated by the work of Funke and Hall (1998) and Barrios et al (2002).

The second camp – which shall be attributed to Fielding and Shields (2001) – being of the opinion that heterogeneities are not 'limited' and that they do have significant effects on the differing performance of the UK regions economies over the long term. This latter view backed up by a limited volume of research providing evidence of some dynamic heterogeneities across the regions. This agenda, however, has not been pursued with the vigour than perhaps it might, given the oft cited and well recognised data availability issues for the UK regions. Despite words of encouragement from the UK Government (Allsopp (2004)) little has changed in the fifteen years since David Bell (1993) flatly asserted that regional econometric modeling to be underdeveloped in the UK vis a vis the other industrialised countries.

This therefore was the climate in which this work was commenced. The goal was to investigate a policy issue that some questioned its significance, others including the ex Bank of England Governor implicitly recognise its existence and relevance but has had to be set aside through lack of appropriate data tools. This work is ambitious given the constraints of the data issues prevailing. Chapter 3 outlines in detail the problems faced by the UK regional macro researcher. What it does is to apply methods and logic previously not brought to bear on the question of regional dynamics.

The thesis first outlined the nature of the differences between the regional economies, differences in economic characteristics, differences in output, employment, income etc. This was to provide context to the issues at hand but also to provide an understanding to the motivation that despite these regional economies having been part of the same country and currency for hundreds of years there was sufficient diversity to justify the belief that their dynamic responses to events of whatever nature be it supply, demand, monetary shocks would clearly be different.

The next stage of this thesis was to provide sufficient context for the research itself. The stage of preparation of introduction to the research was a discussion of five sets of theoretical and applied research. A body of work concerning itself with the short run relationship between output and inflation, namely the Phillips and New Keynesian Phillips Curves; the use of SVARs in applied modeling; that concerning itself with the use of VARs for monetary policy analysis; the research previously conducted on the subject of heterogeneous responses to monetary shocks; and finally the body of research existing concerning itself with the studies of the UK regions. Collectively this is a broad field and the research, theory and literature reviews provided in chapters 4 and 7 were designed to provide sufficient overview to understand the application of the research of this thesis to the issue of the UK regions.

Given the data constraints it has more than ever been necessary to seek methods and logic that that had not previously been applied to explore the question to hand.

The research presented encompassed three strands of work. The first a review of the effect of supply and demands side shocks across the UK regions. This first replicated the work (but importantly with a dataset of regional prices rather than a homogenous price series) of Funke and Hall to decompose regional output à la the Blanchard Quah structural VAR methodology. It then undertook to apply a different (Covers et al) methodology which critically allowed for co-movements in demand between supply and demand curves.

The second body of work then undertook to explore the heterogeneous dynamics of responses to monetary policy shocks using standard VAR techniques. Whilst some researchers (Darby and Phillips) have explored this subject using the Scottish economy as a proxy for the rest of the UK regions and others have explored the subject having taken a slightly different tack (Holmes) none have investigated the subject as thoroughly as has been outlined in chapter 6 with the cross referencing and checking of results over so many variants of methodology. Certainly none have attempted to explore the causes of the variance in the dynamics in the way presented here and this research provides evidence on why the response to a monetary policy shock differs across the British for the first time.

The third body of work presents an account of short run inflation output dynamics of the British regions – it provides regional estimates Phillips curves both hybrid New Keynesian and wage Phillips. The application and estimation of the NKPC, which, as discussed, is inherently logical if the search is for structural causes to heterogeneous dynamics (given its inclusion of structural parameters), has never been attempted for the British regions.

Chapters 5 and 6 have presented research based on the analysis of the transmission of shocks, monetary and demand, across the British regions. These primarily applied the structural VAR econometric techniques. Chapter 5 showed firstly that once certain restriction have been lifted (namely the homogeneity restriction of long run neutrality of demand shocks) that demand shocks can have heterogeneous effects across the regions. Secondly, once that principle had been demonstrated, chapter 6 demonstrated that size of the differing long run (ie cumulative impulse response) of monetary shocks across the regions was related to the differing industrial characteristics of the regions.

The research presented in the chapter 8 took a different but complementary approach to this issue. It took a small scale structural modern monetary model – the hybrid New Keynesian Phillips Curve – and explored whether the estimated parameters of this model also related to the self same industrial characteristics. This was demonstrated to be the case and underlines the importance of these industrial characteristics (and in a manner was a mutual robustness test of the two areas of work – that the same factors related to estimated responses of an econometric model of the demand side and estimated coefficients of a theoretical model of the supply side) and reinforces the need for monetary policy to take account of regional differences in the conduct of monetary policy. This demonstrated that the models that inform monetary policy, such as the NKPC, provide different implications for the inflation generating process and hence policy depending from which part of the economy their parameters are derived.

9.2 Contribution

The first chapter of research first applies the traditional Blanchard Quah SVAR identification to the regions and does so for the first time utilising regional price series. The price series used have only recently been published by Hayes. It then applied the Covers identification scheme (itself again only recently published) to UK regional data for the first time.

The application of a combination of new data and a new identification scheme to the issue of regional responses to demand and supply shocks is a key contribution of this body of research.

The application of the Covers identification is significant. It was argued that application of the Blanchard Quah scheme itself imposes a 'homogeneity restriction' by its very construction and so is of little use if one's object of interest is heterogeneities of the regions. This research illustrates that demand side shocks can have differential effects on the regions and importantly that these can have long run level effects. How this comes about is by a co-movement of supply with demand.

The implications of this are profound. This opens up the avenue by which demand (ie monetary demand) shocks could contribute to level differences between the regional economies. Even if the effects are small in comparison to say the contribution of structural growth characteristics it should not be overlooked. The contribution of this work is to illustrate that this effect's existence and importantly to show how this differs across the regions.

The results illustrate a clear ordering of the UK regional responses to structural shocks into three groups of regions: Group I: South East, West Midlands and the Northwest, where the magnitudes movements are greatest; Group II: Wales, Scotland, Yorkshire, East Midlands and the South West where the magnitudes are similarly of 'middling' size and Group III: North East and East Anglia, where the effects are very small or negligible. It was also demonstrated how the contribution of demand shocks to variation in output over the long run increased as a result of this co-movement and that this contribution varied across the regions in the manner implied by the ordering above. This demonstrates further that demand shocks could have a long term impact on the divergence in the level of output of the UK regions. The illustration of this mechanism and thus the evidence that demand shocks could play a part in long run divergence of the level of output of the regions is the major contribution of the first body of research of this thesis.

The second body of work was a major review of the differences responses to a monetary shock of the UK regions. The research stands out in its thoroughness of its investigation of the issue. It cross references results from three VAR models and two SUR models and demonstrates first that the estimates produced are robust and statistically similar across methodologies. It demonstrates that the differing responses to monetary policy shocks of the UK regions are indeed statistically significantly different: a result that is a contribution in its own right. This work also contributed to the knowledge of regional dynamics by showing that the size of the relative responses of the UK regions is systematic. Most significantly, it demonstrates that the heterogeneities of the regional responses are accounted for by heterogeneities in industrial composition of the regions. Whilst this has been attempted and shown for EU countries and US states this has never been attempted nor proven for the UK regions and is the major contribution of the work of this chapter.

In particular evidence was provided that it is in particular sectoral dissimilarity that contributes to the differing responses – ie it is the compositional make up of a regional economy that it is key and through demonstrating a line of logic shown that dissimilarities of the same sectors across regions is an unlikely source of heterogeneities - and provided evidence of an heterogeneous exchange rate effect across the UK regions. This is a key contribution of this dissertation. Measuring and accounting for differences in the regional responses to monetary policy shocks has never been done in this manner and that it has been shown that the regions response is predicated on their industrial composition is clearly of significance.

The contribution of the third body of research is to provide estimates of hybrid NK curves for the British regions for the first time. These results clearly demonstrate heterogeneity of the short run macrodynamics of the British regions. The application of the NKPC to provide a separate estimate for each British regions provided clear evidence of heterogeneous dynamics and significantly again demonstrate a relationship between the variance of the macro-dynamics of the British regions and the structural composition of the British regions. The relationship between the estimated structural parameters of the separate regional NKPCs supported the conclusions drawn from the research into regional responses to monetary shocks: that heterogeneous dynamics of the British regions are driven by 'sectoral' factors. Providing two 'bodies of evidence' from two separate methodologies in support of this view is a significant contribution of this research. The statistical methods employed would counter against this being nothing more than a chance finding.

In general it was demonstrated that the degree of inflation inertia across the British regions varies according to industrial composition and that those economies of the 'south' tend to display greater product market flexibility in terms of frequency of price setting and a lesser proportion of rule of thumb producers than those of the 'north'. The contribution of this was to demonstrate that there is a clear, rationale pattern to the heterogeneities of the regional economies. It was also demonstrated in this third body of research how similarly those economies of the south (in addition to their expected lower NAIRUs) also exhibit a greater degree of labour market flexibility as implied by estimates of slope of the wage Phillips curves.

The general contribution of this research is to confirm the existence of regional macro dynamic heterogeneities and to underline their importance by illustrating firstly how this may indeed provide an additional source of their long term output divergence. Its key contribution has been to demonstrate how their differing dynamics both to monetary shocks and their short run inflation/output dynamics relate to the structural composition of the underlying regional economy. These responses are therefore systematic and if systematic are most likely predictable.

9.3 Conclusions

The question to date has more been whether regions react differently not but by how much or why. This research makes it clear that the regions are heterogeneous and their responses to monetary and other demand shocks differ. It has produced compelling evidence to contribute to the answer to the quantitative question, providing evidence for consistent ordering of effects and strong relationships between size of effects and structural composition of the regions.

The work in a certain manner provided a triangulated case. In the first case it provides evidence to show that demand side shocks can and do have long run heterogeneous effects: that demand shocks (and thus monetary shocks) can and do have consequence for the heterogeneous performances of the British regions. The second aspect of the case, once the importance of demand shocks had been confirmed, was to show that the effect of monetary demand shocks also differed across the regions and to account for this heterogeneity.

The heterogeneity was shown to readily accountable by structural characteristics of a similar nature to those heterogeneities among US and EU regions by previous researchers. Heterogeneities were also confirmed in the short run dynamics of the regions. Tellingly these heterogeneities and factors that were shown to be able to account for these heterogeneities were consistent across both bodies of work.

The case is thus: demand shocks do have heterogeneous (and long run) effects on the UK regions; the effects of monetary (demand) shocks vary across the regions in a systematic and accountable manner; the short run dynamics of the regions share the pattern and causes of heterogeneities. This research lays a foundation to guide appropriate modeling and forecasting of future regional responses to monetary policy actions.

If policymakers are concerned about the variance of output across the UK regions then this thesis provides an interesting point of view about which regions are most adversely affected by such variance. Counter intuitively the results in chapter 8 suggested that those economies with most to gain in terms of output stabilisation were the likes of the South East and South West where given the relative prosperity of these regions one may have tended to the view that those of say the North East or North West have most to gain. This notion however is consistent with the findings of the chapter 5 which illustrated that demand side shocks had a greater contribution to output variance for the South East. Clearly minimising demand (ie monetary) shocks in this case would contribute most to output stability of the South East and supports the conclusions drawn in the third leg of the research.

These conclusions suggest that a framework could exist to build a model of a welfare function built on regional lines. Given what has been illustrated with regards to regional responses to monetary shocks and the differing implications for output and hence welfare variance across the regions it should be possible to view this welfare function in dynamic terms. This would be a very useful policy tool and would ensure that whilst it is clearly not possible to set monetary policy in the equal interests of all regions simultaneously, policy could be guided by a more informed notion of regional welfare as distinct components of aggregate welfare.

The key contribution of this thesis has been to demonstrate the point that monetary policy can contribute to the divergent performance of the British regions. It first demonstrated that demand shocks can contribute to a differing level effect of regional output and that the variance of output attributed to demand shocks differs across the regions; it then demonstrated that the size of the cumulative effect of monetary shocks differs in a systematic manner across the regions – related to their industrial composition – and that whilst no statistical differences in cumulative responses could be demonstrated given the data, through Wald cross restrictions on a panel estimation, impulse responses were shown to be statistically significantly different. Finally by way almost of a robustness check of this 'systematic' finding, it approached the issue from another angle, demonstrating that the size of estimated 'structural' coefficients of a supply side model were related in the same manner to industrial factors as had been demonstrated to be the case for monetary shocks.

With the data constraints on the UK regions, there is little further that this research can go presently. This thesis has demonstrated that monetary transmission characteristics appear to be related to the underlying structure of the regional economy. Something it has to be said that has not been demonstrated previously. However, it has not proven the case. It has demonstrated that demand shocks and monetary shocks can and do have different level effects on output of the regional economies but without much better quality data these effects cannot be quantified sufficiently. In the paragraph before last we outlined a concept for calculating aggregate welfare of the UK economy built up from the regional unit. With a more in-depth and certain knowledge of the different dynamic characteristics monetary policy could be conducted with different weights ascribed to different regions if it were considered necessary and desirable rather than taking a simple aggregate average approach as presently. To get to this level of knowledge and certainty would be an interesting and exciting policy area for further research. However, with the ever present data constraint this is never likely to be pursued.

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Appendix 1: Industrial Decompostion of Regions (EM, EA, SE, SW, WM, NW, Wal, Sco)

Figure 100: Industrial Decomposition EM, 1982

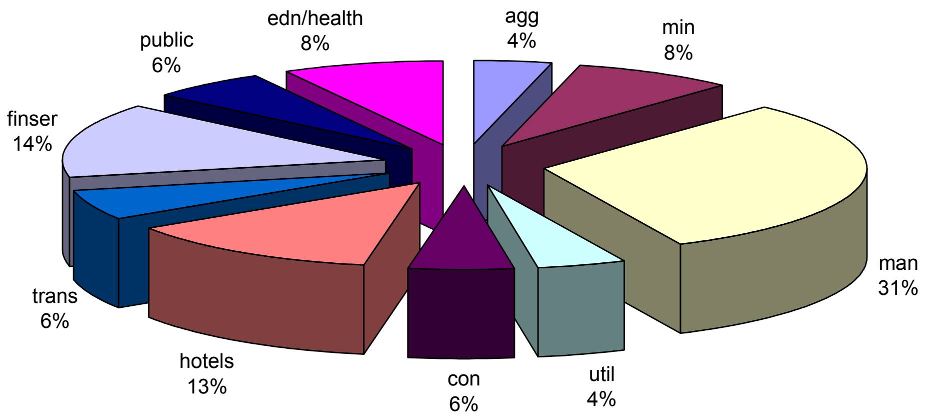


Figure 101: Industrial Decomposition EM, 2002

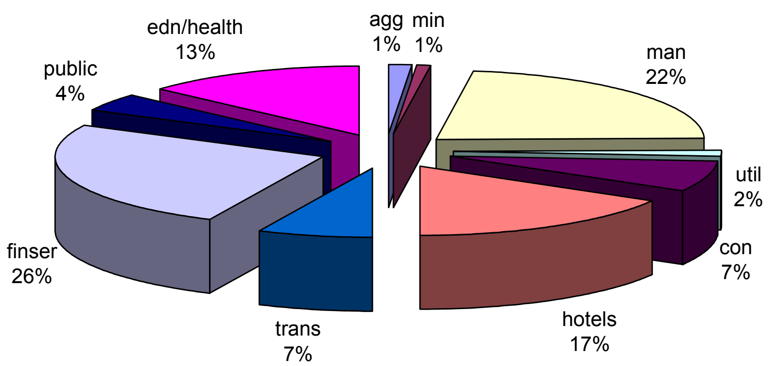


Figure 102: Industrial Decomposition EA, 1982

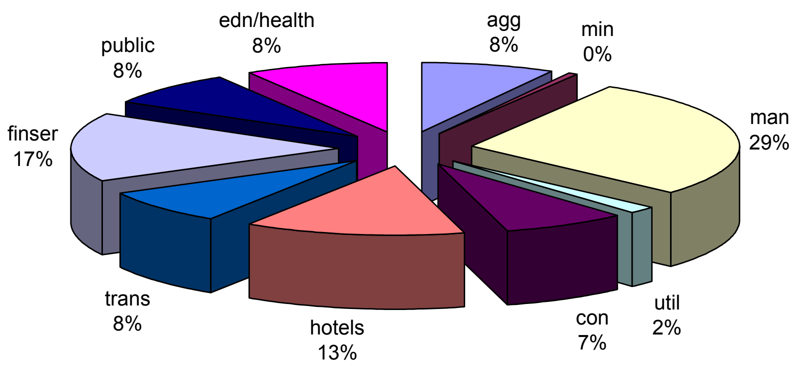


Figure 103: Industrial Decomposition EA, 2002

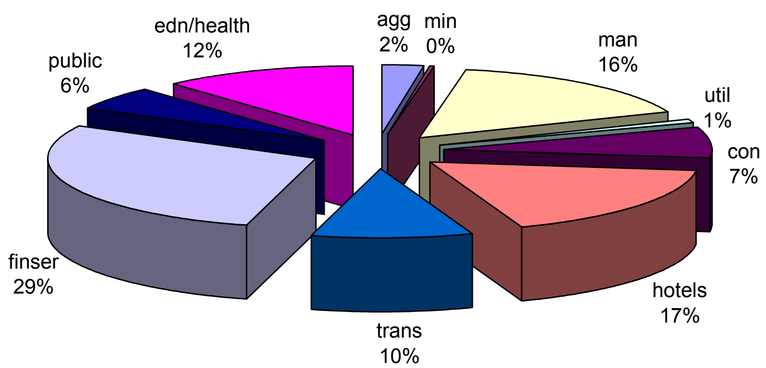


Figure 104: Industrial Decomposition SE, 1982

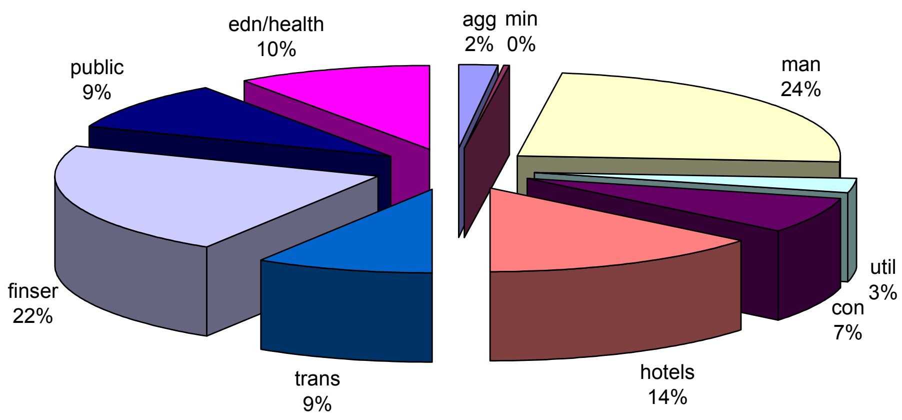


Figure 105: Industrial Decomposition SE, 2002

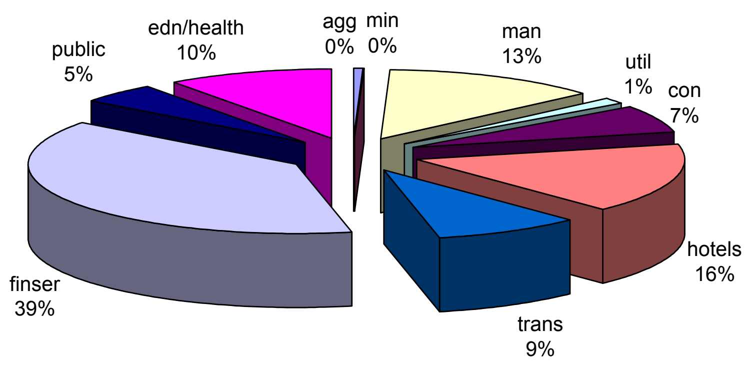


Figure 106: Industrial Decomposition SW, 2002

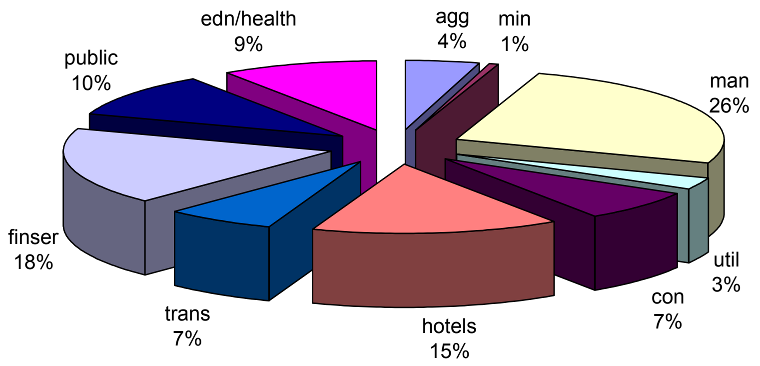


Figure 107: Industrial Decomposition SW, 2002

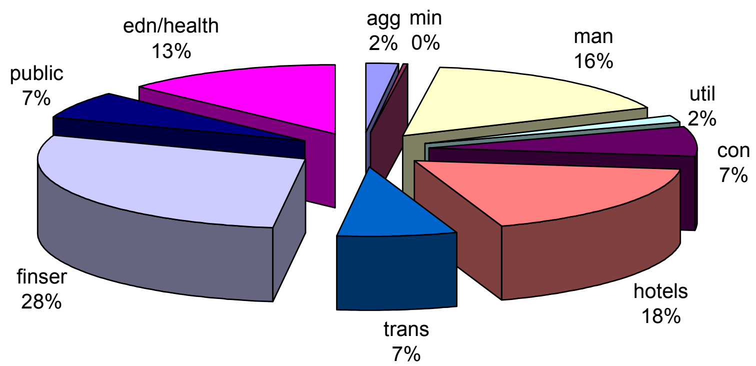


Figure 108: Industrial Decomposition WM, 1982 & 2002

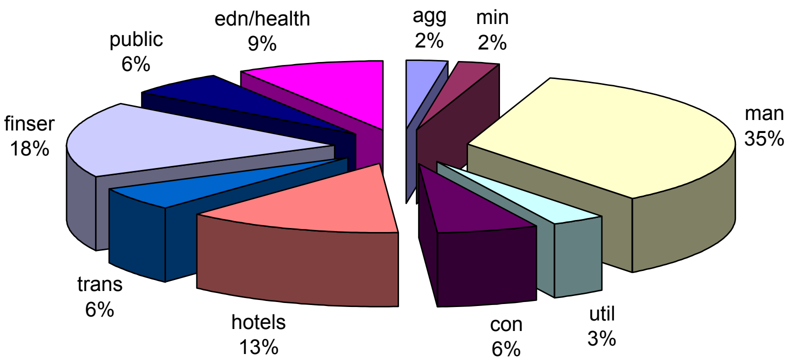


Figure 109: Industrial Decomposition WM, 1982 & 2002

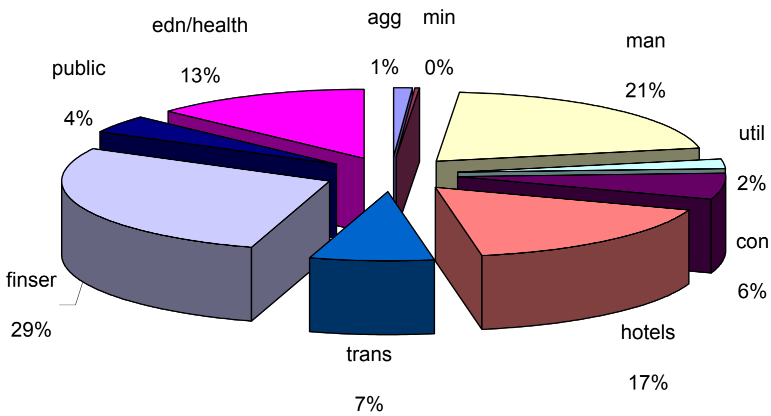


Figure 110: Industrial Decomposition NW, 1982

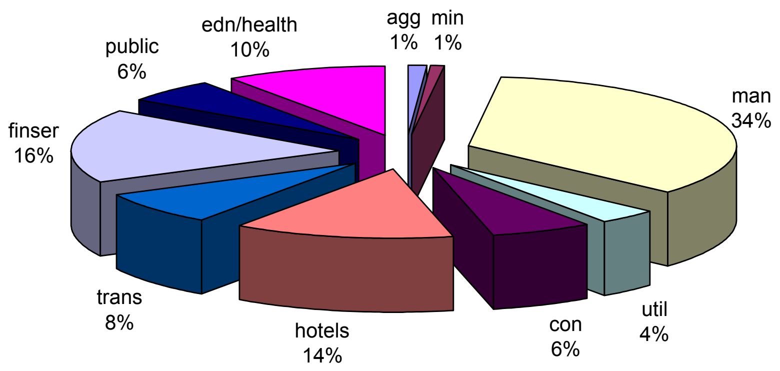


Figure 111: Industrial Decomposition NW, 1982

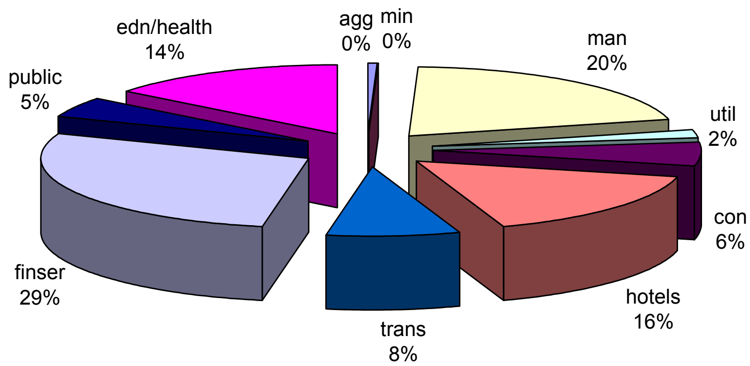


Figure 112: Industrial Decomposition Wal, 1982

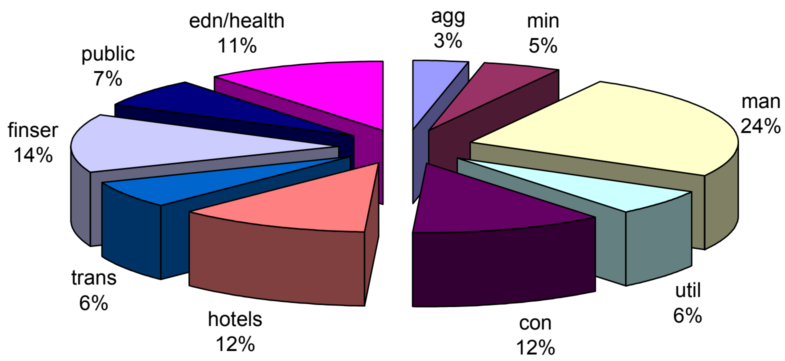


Figure 113: Industrial Decomposition Wal, 1982

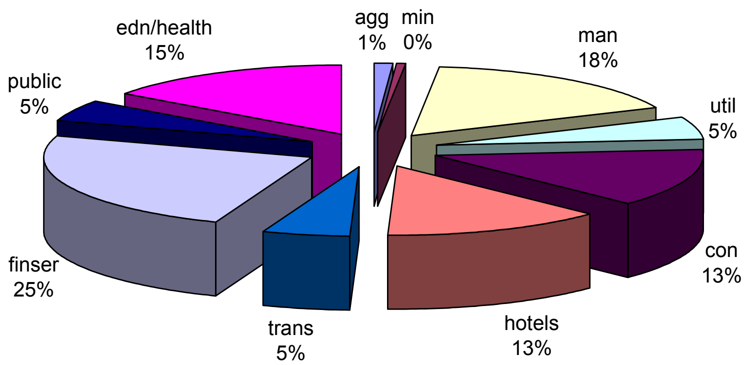


Figure 114: Industrial Decomposition Sco, 1982

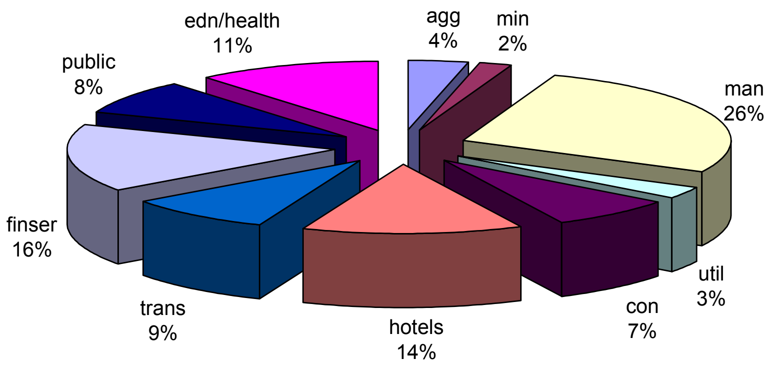
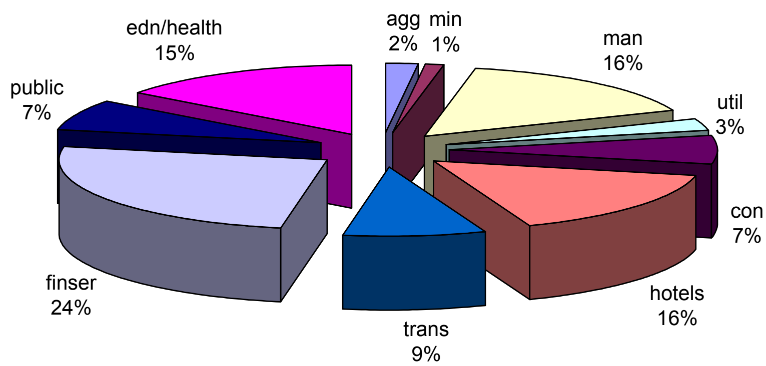


Figure 115: Industrial Decomposition Sco, 1982



Appendix 2: Solving for output and price level

Simple AS AD model

$$y^s_t = E_{t-1}y_t + \alpha(p_t - E_{t-1}p_t) + \varepsilon_t \qquad (189)$$

supply

$$(y_t + p_t)^d = E_{t-1}(y_t + p_t)^d + \eta_t \qquad (190)$$

demand

$$y^s_t = y^d_t \qquad (191)$$

equilibrium

Needs to be solved for output and prices

From (190)

$$p_t - E_{t-1}p_t = E_{t-1}y_t - y_t + \eta_t$$

Insert into (189)

$$y_t = E_{t-1}y_t + \alpha(E_{t-1}y_t - y_t + \eta_t) + \varepsilon_t$$

Solve for y_t

$$y_t = E_{t-1} + \frac{\alpha}{1+\alpha}\eta_t + \frac{1}{1+\alpha}\varepsilon_t$$

From (190)

$$y_t - E_{t-1}y_t = E_{t-1}p_t - p_t + \eta_t$$

Insert into (189)

$$E_{t-1}p_t - p + \eta_t = \alpha(p_t - E_{t-1}p_t) + \varepsilon_t$$

Rearrange and solve for p_t

$$p_t = E_{t-1}p_t + \frac{1}{1+\alpha}\eta_t - \frac{1}{1+\alpha}\varepsilon_t$$

Appendix 3: Co-integration tests (chapter 5)

Co-integration tests (Johansen Trace Tests)

Johansen Trace Tests

	Number Cointegrating Equations	Eigenvalue	Trace Stat	0.05 Critical Value	Probability
EA	None	0.338303	9.153180	15.49471	0.3514
	At most 1	0.022658	0.481282	3.841466	0.4878
EM	None	0.320562	8.276286	15.49471	0.4363
	At most 1	0.007590	0.159997	3.841466	0.6892
NE	None	0.380157	10.13438	15.49471	0.2705
	At most 1	0.004292	0.090320	3.841466	0.7638
NW	None *	0.538379	16.42134	15.49471	0.0362
	At most 1	0.008917	0.188094	3.841466	0.6645
Sco	None	0.195757	4.587740	15.49471	0.8509
	At most 1	0.000610	0.012816	3.841466	0.9097
SE	None	0.369990	9.715253	15.49471	0.3033
	At most 1	0.000611	0.012842	3.841466	0.9096
SW	None	0.359186	9.891248	15.49471	0.2892
	At most 1	0.025661	0.545924	3.841466	0.4600
Wal	None	0.457346	12.93995	15.49471	0.1170
	At most 1	0.004893	0.103014	3.841466	0.7482
WM	None	0.290271	7.201953	15.49471	0.5543
	At most 1	7.87E-05	0.001652	3.841466	0.9653
YKS	None *	0.540034	16.51820	15.49471	0.0350
	At most 1	0.009928	0.209532	3.841466	0.6471

Appendix 4: Unit Root Tests (chapter 5)

ADF tests, Lag Length: 0 (Automatic based on SIC, MAXLAG=4
Null hypothesis: series has a unit root

	t-Statistic	Prob.			t-Statistic	Prob.
EA GDP	3.170098	0.9990	EA Price		1.510427	0.9628
EA ΔPrice	-2.413985	0.0185	EA Δprice + constant		-2.808917	0.0740
				1% level	-3.788030	
				5% level	-3.012363	
				10% level	-2.646119	
EM GDP	2.582937	0.9961	EM Price		1.584167	0.9677
EM ΔPrice	-2.461044	0.0166	EM Δprice + constant		-2.902302	0.0619
				1% level	-3.788030	
				5% level	-3.012363	
				10% level	-2.646119	
NE GDP	2.817526	0.9977	NE Price		1.483527	0.9609
NE ΔPrice	-2.508326	0.0149	NE Δprice + constant		-2.826403	0.0716
				1% level	-3.788030	
				5% level	-3.012363	
				10% level	-2.646119	
NW GDP	1.870569	0.9818	NW Price		1.603341	0.9688
NW ΔPrice	-2.403996	0.0189	NW Δprice + constant		-2.876666	0.0651
				1% level	-3.788030	
				5% level	-3.012363	
				10% level	-2.646119	
Sco GDP	3.464105	0.9995	Sco Price		1.619945	0.9698
Sco ΔPrice	-2.627534	0.0113	Sco Δprice + constant		-3.011413	0.0501
				1% level	-3.788030	
				5% level	-3.012363	
				10% level	-2.646119	
SE GDP	1.425207	0.9565	SE Price		1.380801	0.9528
SE ΔPrice			SE Δprice + constant		-2.295192	0.1828
	-1.799308	0.0691		1% level	-3.808546	
				5% level	-3.020686	
				10% level	-2.650413	

	t-Statistic	Prob.			t-Statistic	Prob.
SW GDP	1.809938	0.9792	SW Price		1.673946	0.9728
SW ΔPrice	-1.919344	0.0542	SW Δprice + constant		-2.469066	0.1373
				1% level	-3.808546	
				5% level	-3.020686	
				10% level	-2.650413	
Wal GDP	1.268130	0.9425	Wal Price		1.607456	0.9691
Wal ΔPrice	-1.926407	0.0535	Wal Δprice + constant		-2.423808	0.1481
				1% level	-3.808546	
				5% level	-3.020686	
				10% level	-2.650413	
WM GDP	0.978110	0.9069	WM Price		1.603341	0.9688
WM ΔPrice	-1.709271	0.0824	WM Δprice + constant		-2.207212	0.2098
				1% level	-3.808546	
				5% level	-3.020686	
				10% level	-2.650413	
Yks GDP	1.439233	0.9576	Yks Price			
Yks ΔPrice	-1.816149	0.0668	Yks Δprice + constant		1.596260	0.9684
	-2.685718			1% level	-2.363263	0.1638
	-1.959071			5% level	-3.808546	
	-1.607456			10% level	-3.020686	
					-2.650413	

Appendix 5: Lag length Tests (chapter 5)

Table 57: Sims Lagrange Multiplier (X^2) tests and SBC statistics

Region	P1 X^{2*}	SBC lag2	SBC lag4	P2 X^{2*}	SBC lag2	SBC lag4
EA	13.24	94.29	80.47	80.04	93.74	80.31
EM	6.62	88.98	91.08	12.01	91.98	81.41
NE	9.71	88.98	83.63	13.41	92.96	78.7
NW	12.94	88.22	76.08	16.42**	87.67	68.19
SE	21.25**	83.12	53.86	24.47**	86.9	50.18
SW	22.86**	101.76	67.13	25.49**	88.82	49.95
WM	13.44	88.79	75.52	13.32	88.43	75.46
Yks	11.05	99.58	90.25	14.22	103.88	85.25
Sco	13.44	76.46	64.06	15.46	80.29	61.51
Wal	4.08	99.05	104.77	10.82	105.88	96.4

* critical value for 8 degrees of freedom 15.507

** reject null of 2 lags at 5% confidence level

Appendix 6: BQ & Cover Decompostions Rest of Regions

Figure 116: P1: EA BQ Decomposition Impulse

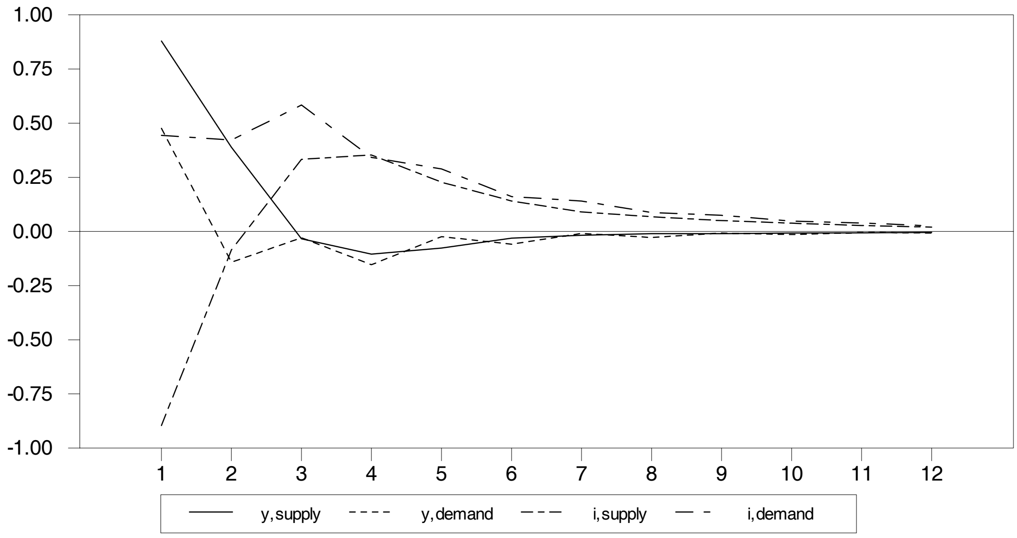


Figure 117: P1: EA Cover Decomposition Impulse

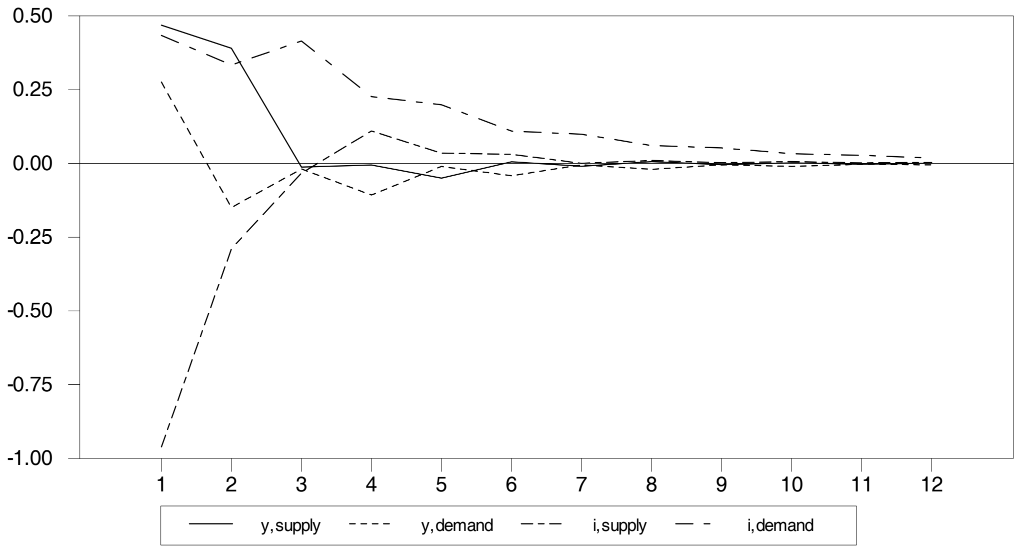


Figure 118: P1 EA BQ Decomposition Cumulative

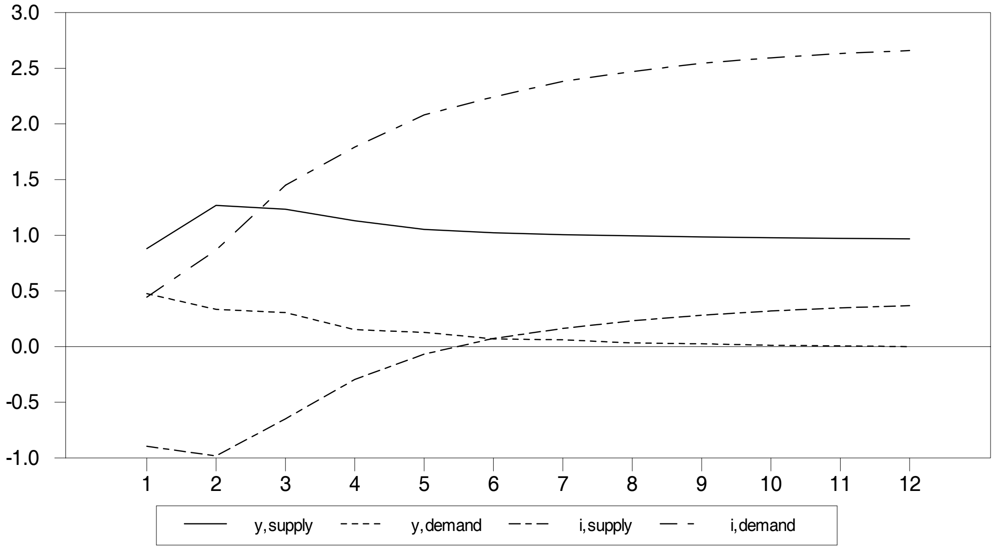


Figure 119: P1: EA Cover Decomposition Cumulative

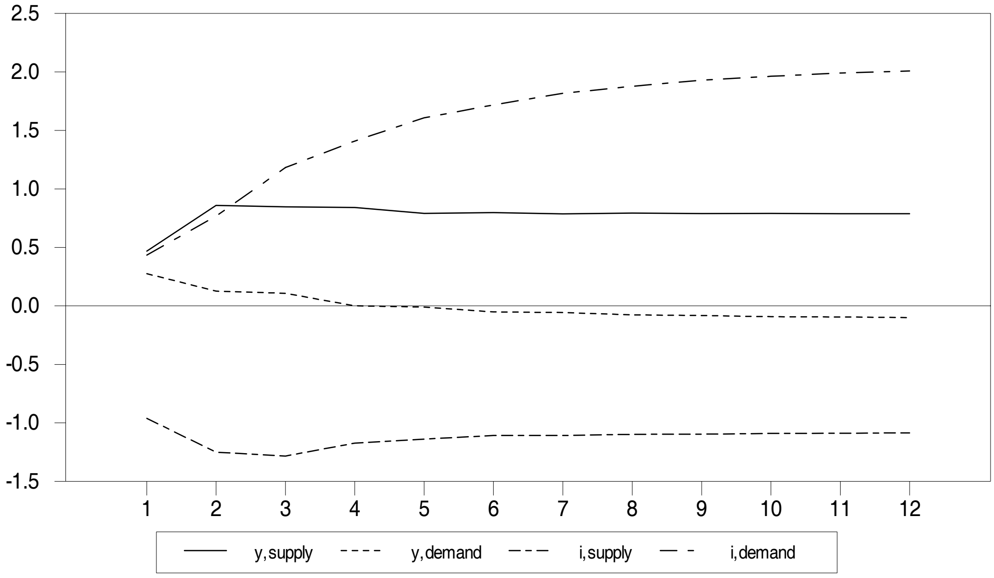


Figure 120: P2: EA BQ Decomposition Impulse response

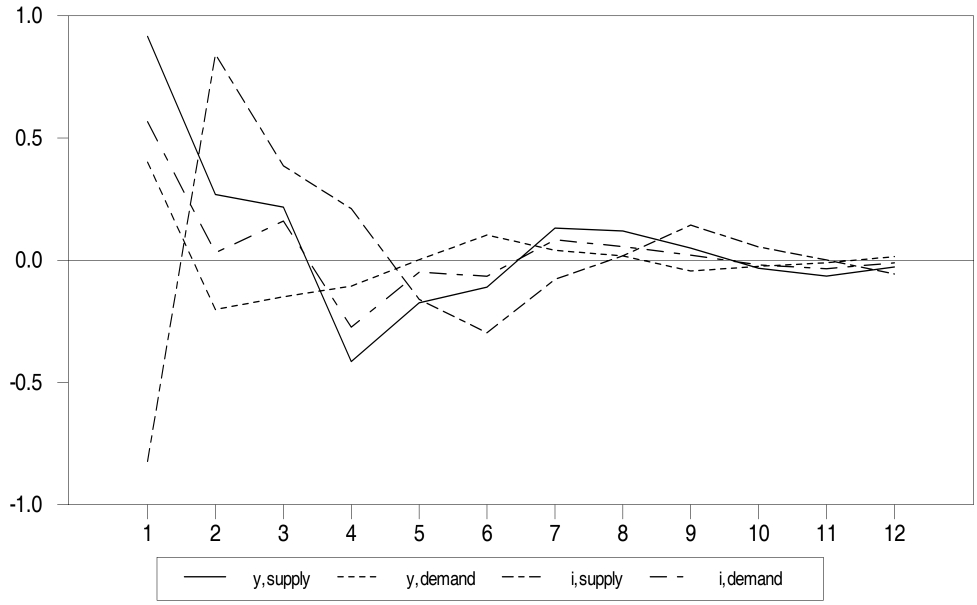


Figure 121: P2: EA Cover Demand to Supply Causality Impulse Response

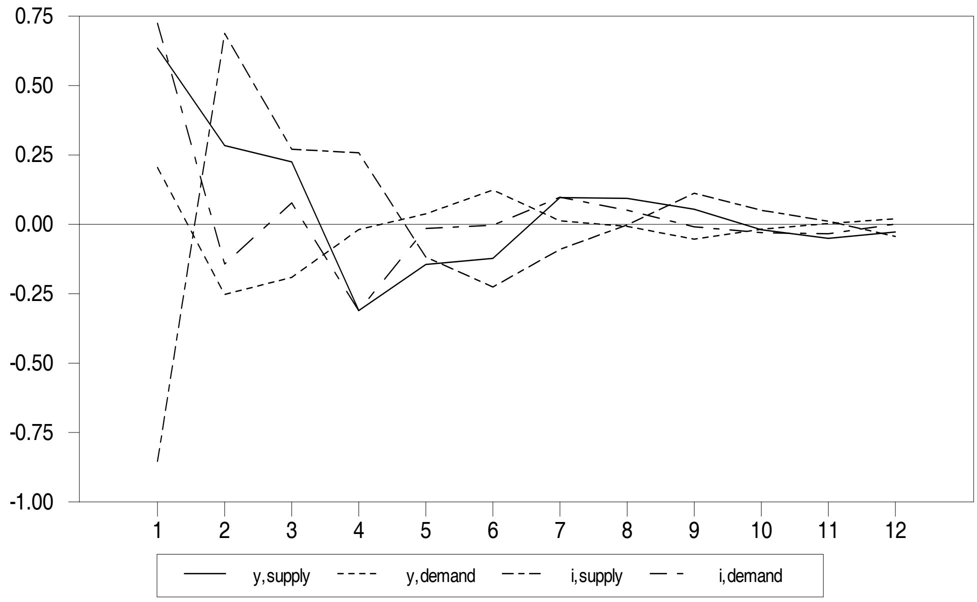


Figure 122: P2: EA BQ Decomposition Cumulative

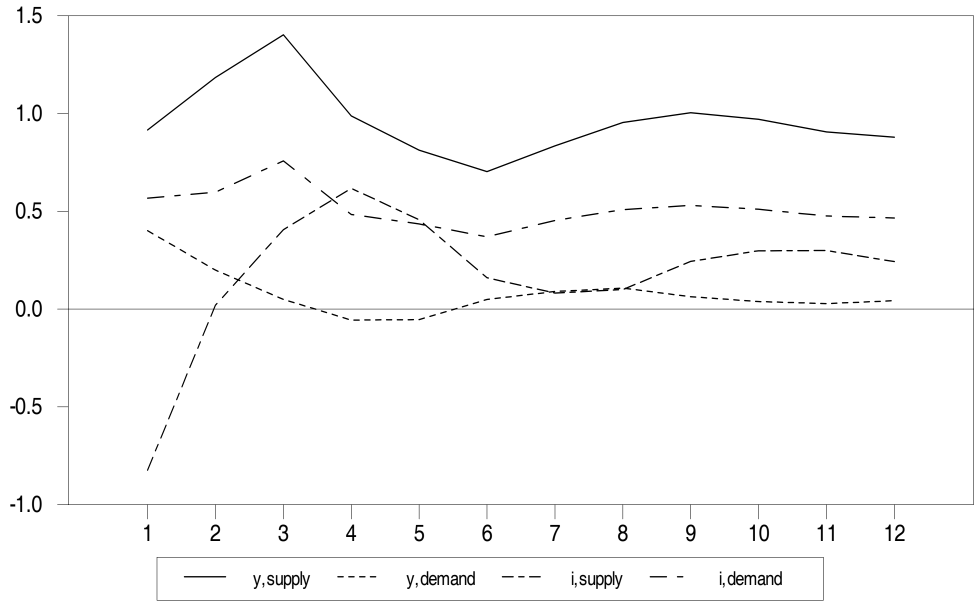


Figure 123: P2: EA Cover Decomposition Cumulative

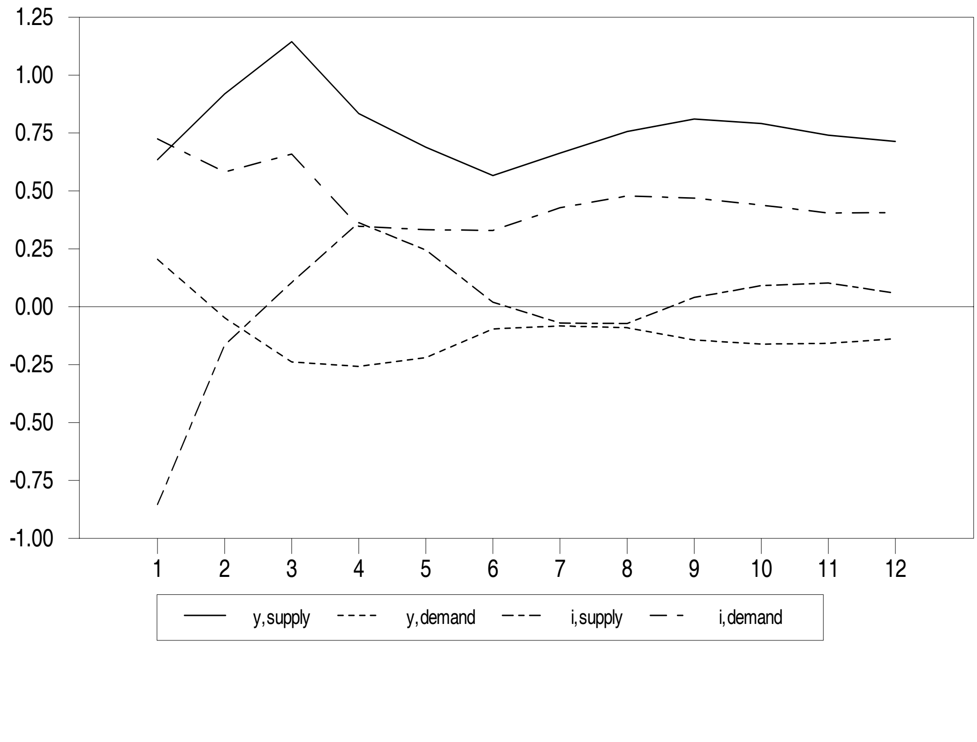


Figure 124: P1: EM BQ Decomposition Impulse response

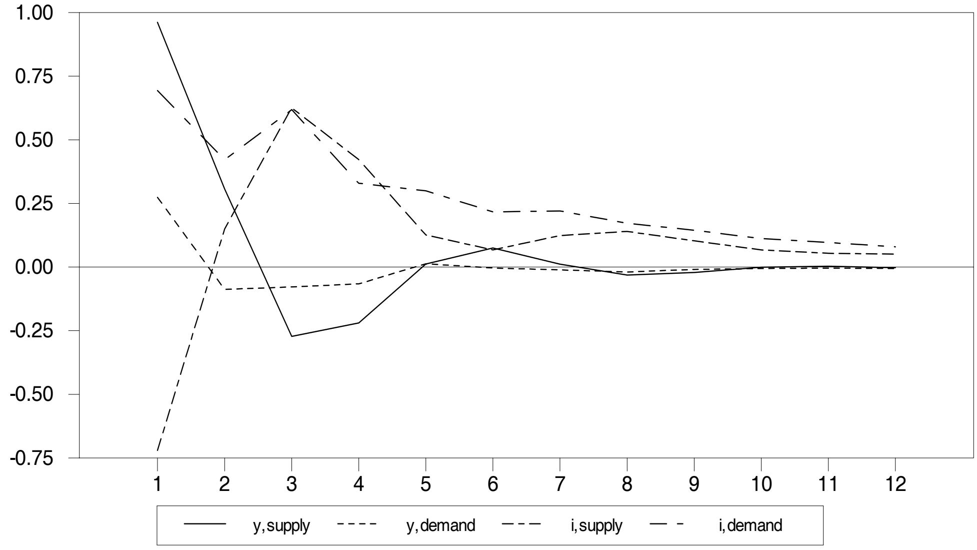


Figure 125: P1: EM Cover Demand to Supply Causality Impulse Response

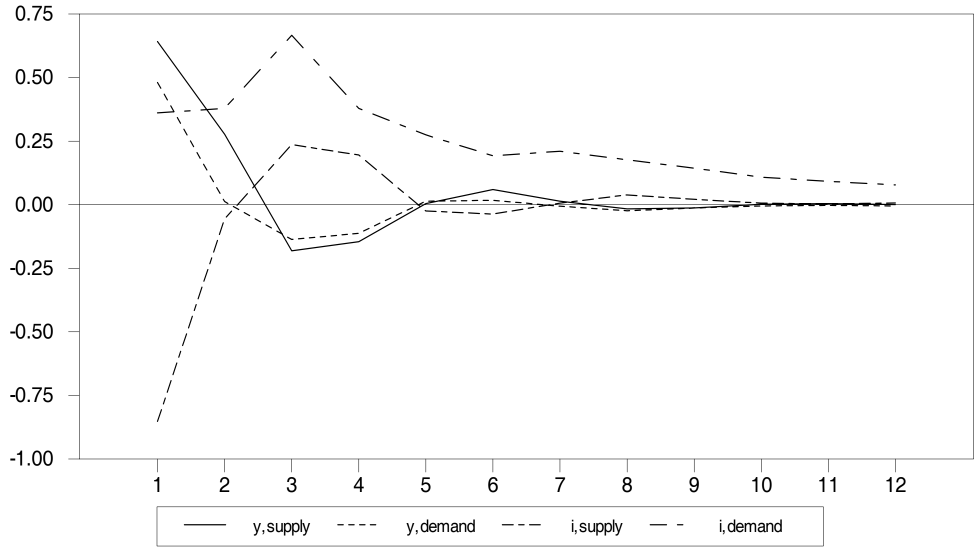


Figure 126: P1: EM BQ Decomposition Cumulative

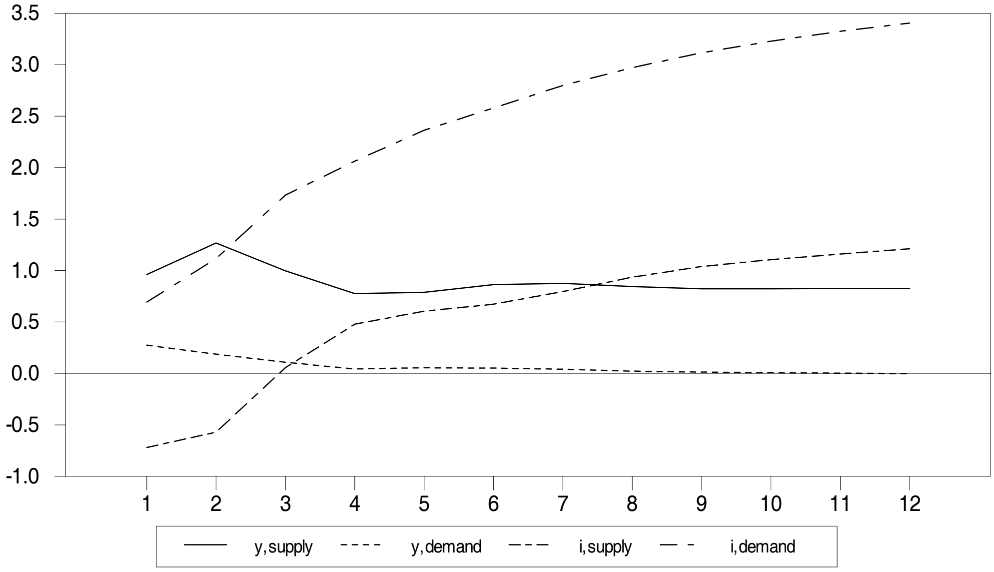


Figure 127: P1: EM Cover Decomposition Cumulative

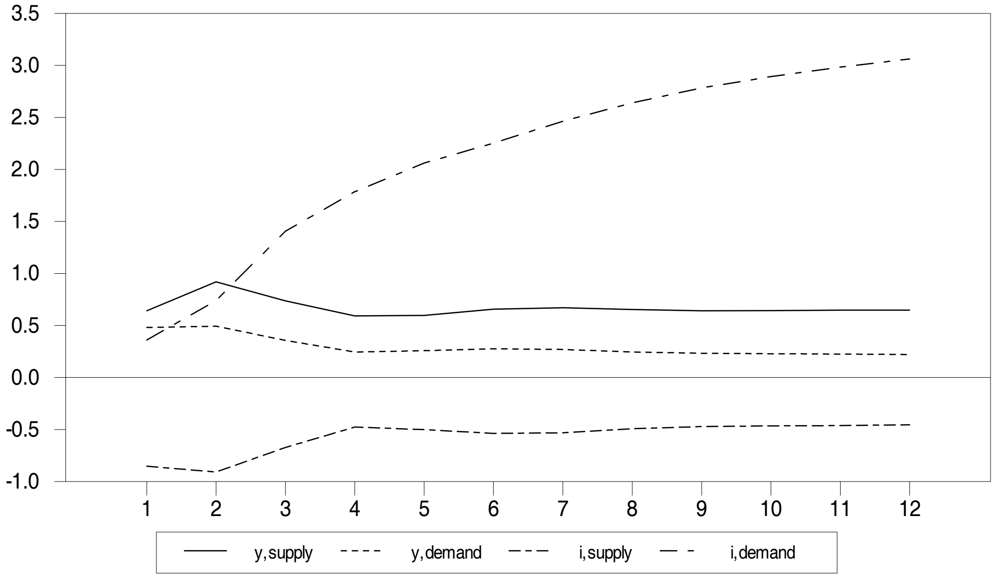


Figure 128: P2: EM BQ Decomposition Impulse

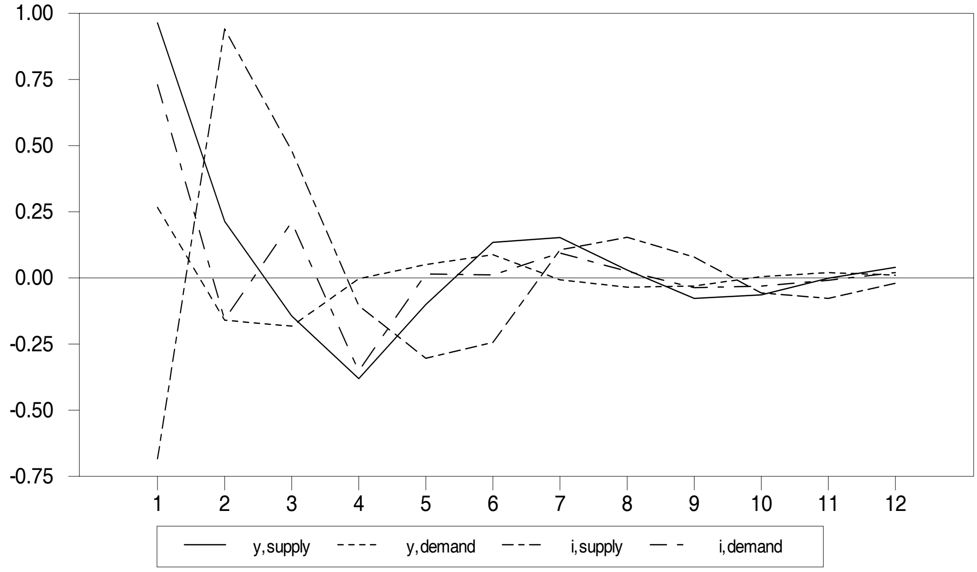


Figure 129: P2: EM Cover Decomposition Impulse

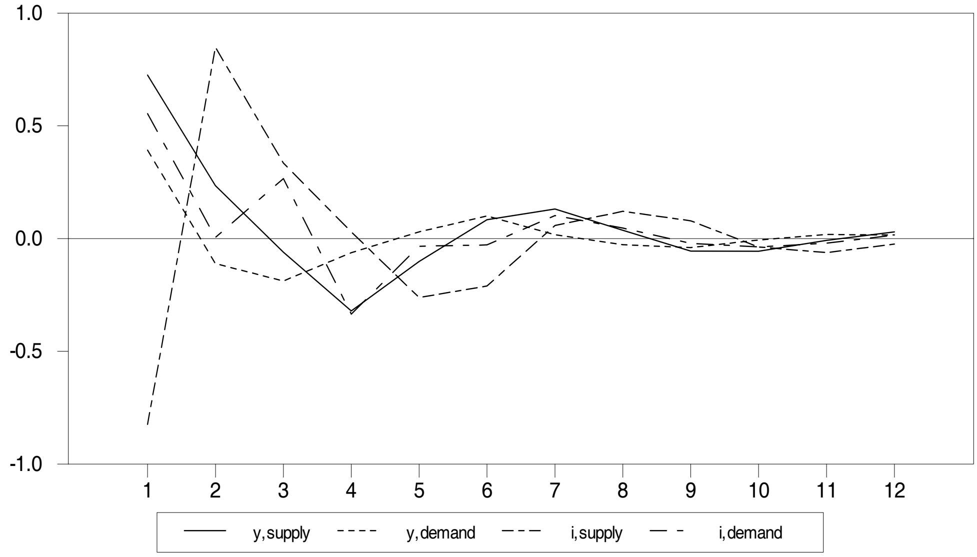


Figure 130: P2: EM BQ Decomposition Cumulative

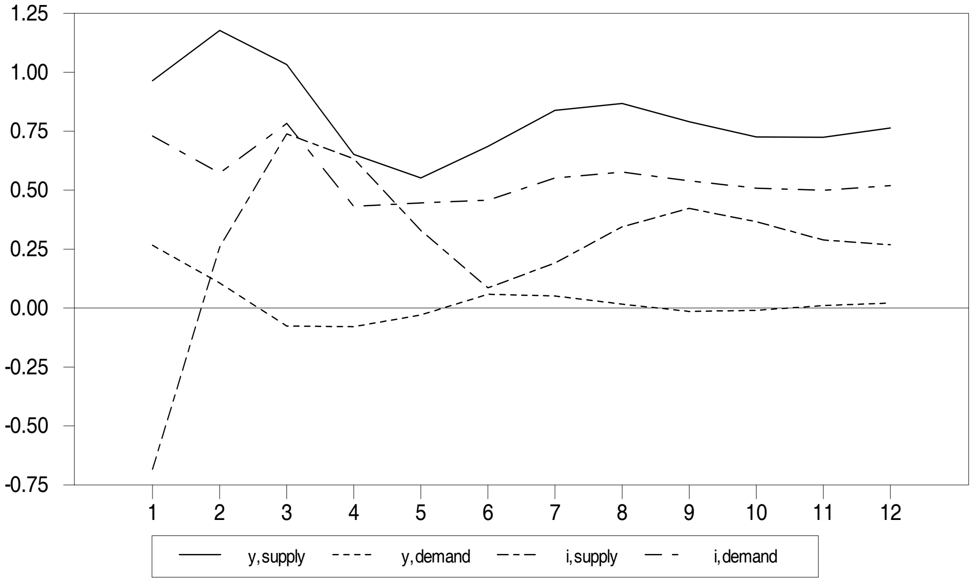


Figure 131: P2: EM Cover Decomposition Cumulative

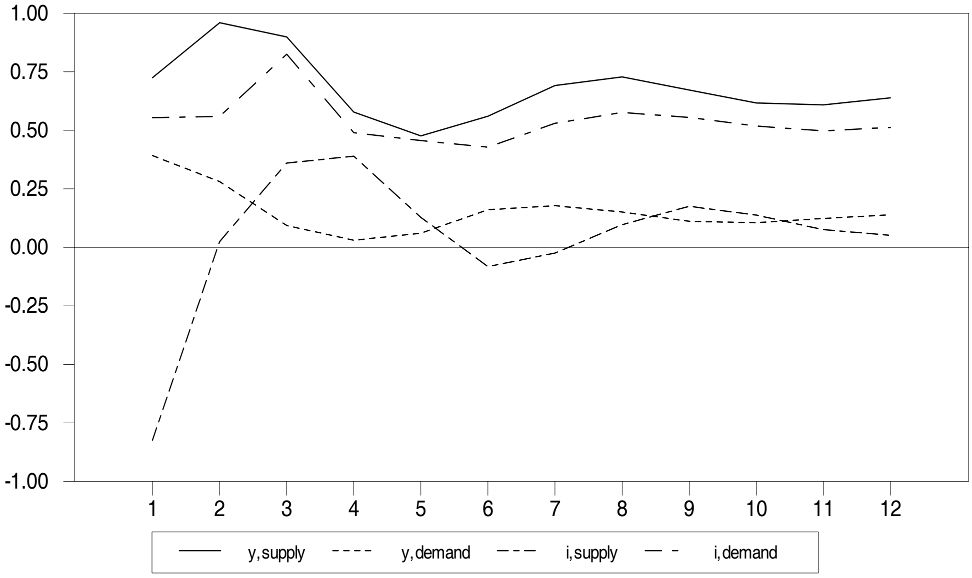


Figure 132: P1: NW BQ Decomposition Impulse

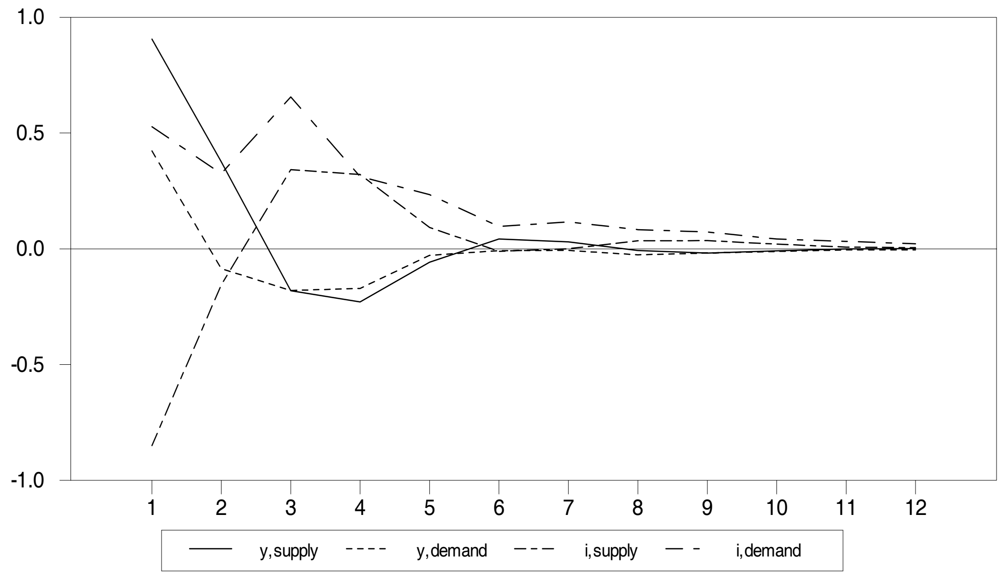


Figure 133: P1: NW Cover Decomposition Impulse

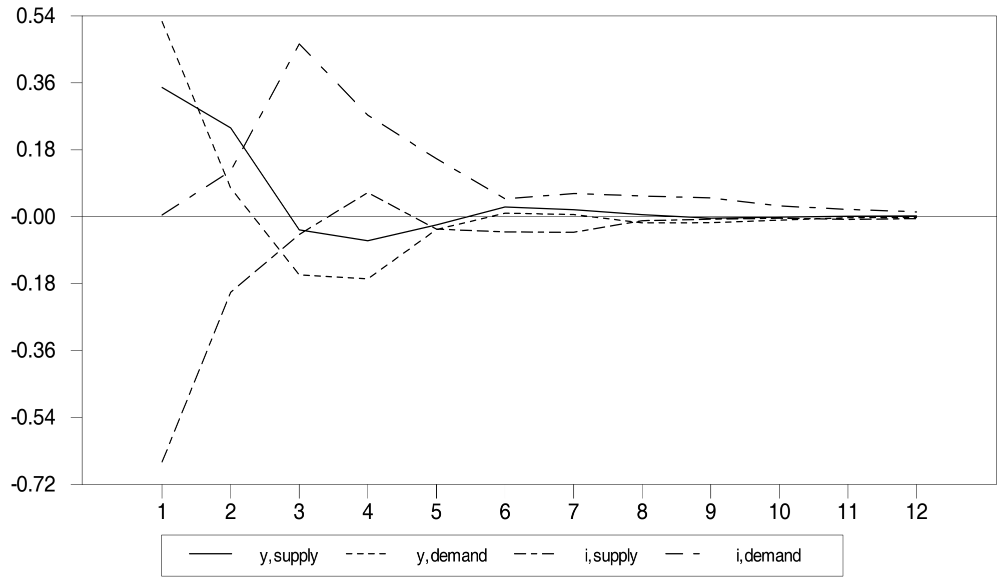


Figure 134: P1: NW BQ Decomposition Cumulative

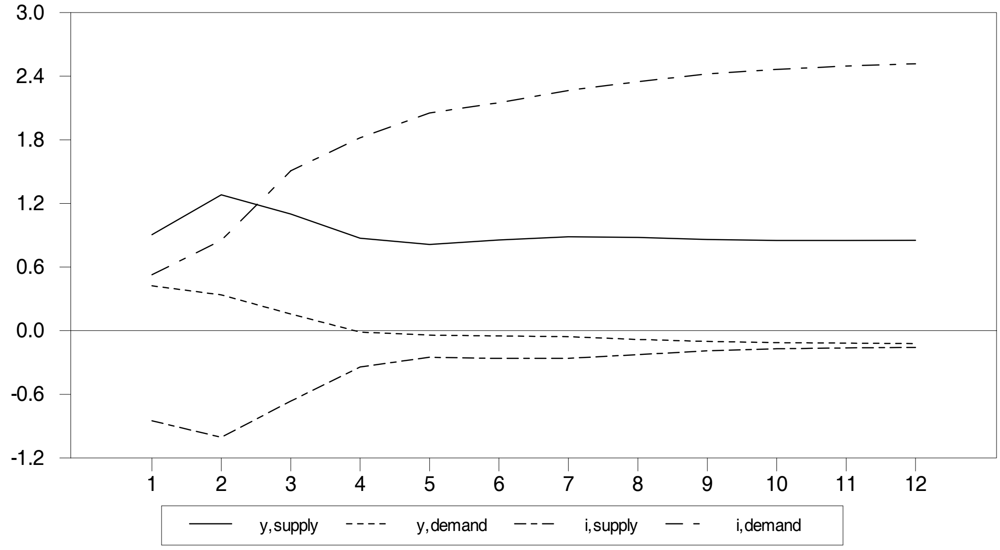


Figure 135: P1: NW Cover Decomposition Cumulative

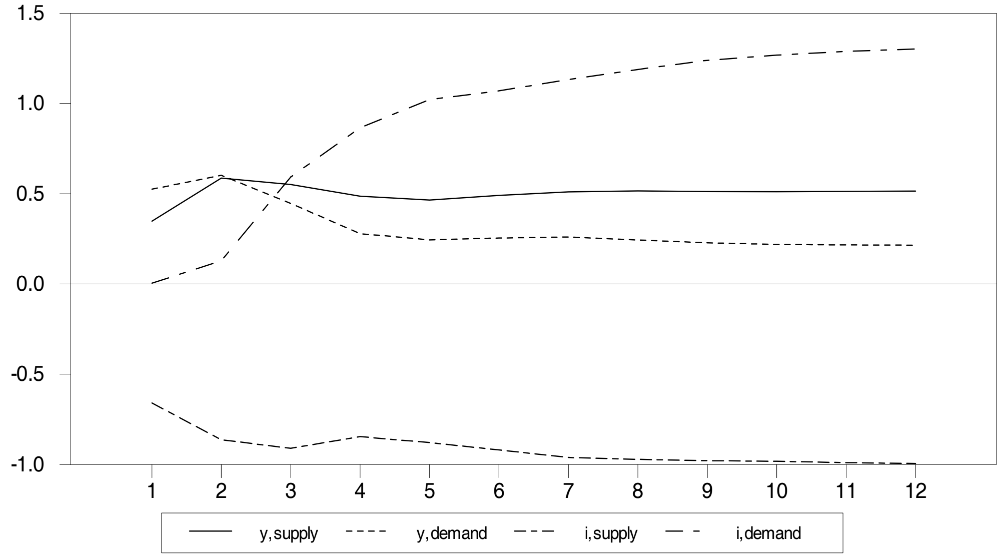


Figure 136: P2: NW BQ Decomposition Impulse

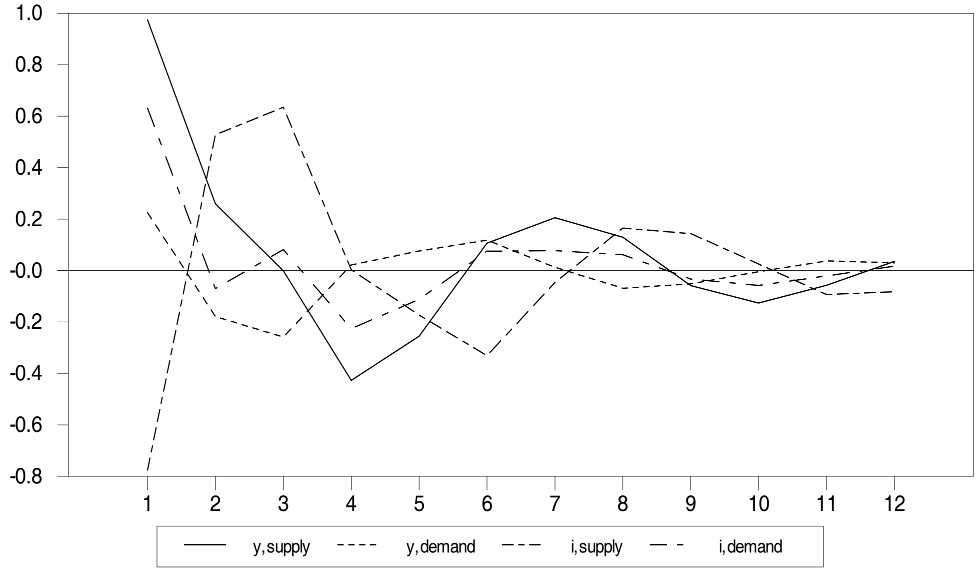


Figure 137: P2: NW Covers Decomposition Impulse

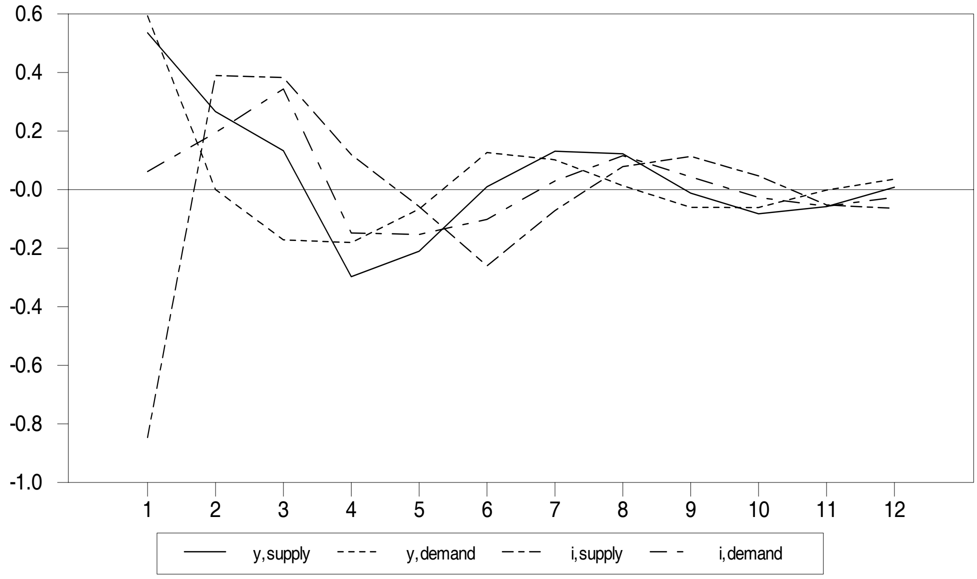


Figure 138: P2: NW BQ Decomposition Cumulative

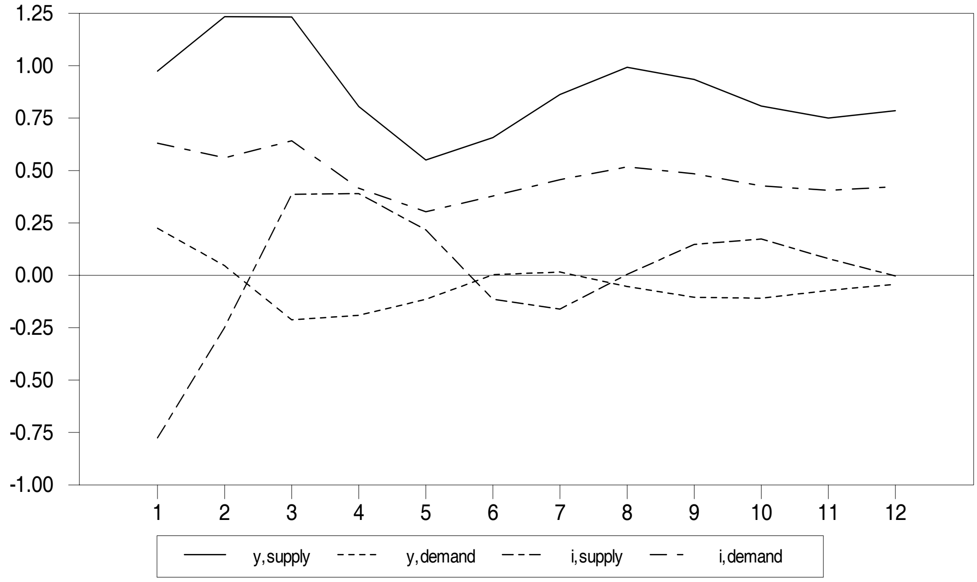


Figure 139: P2: NW Covers Decomposition Cumulative

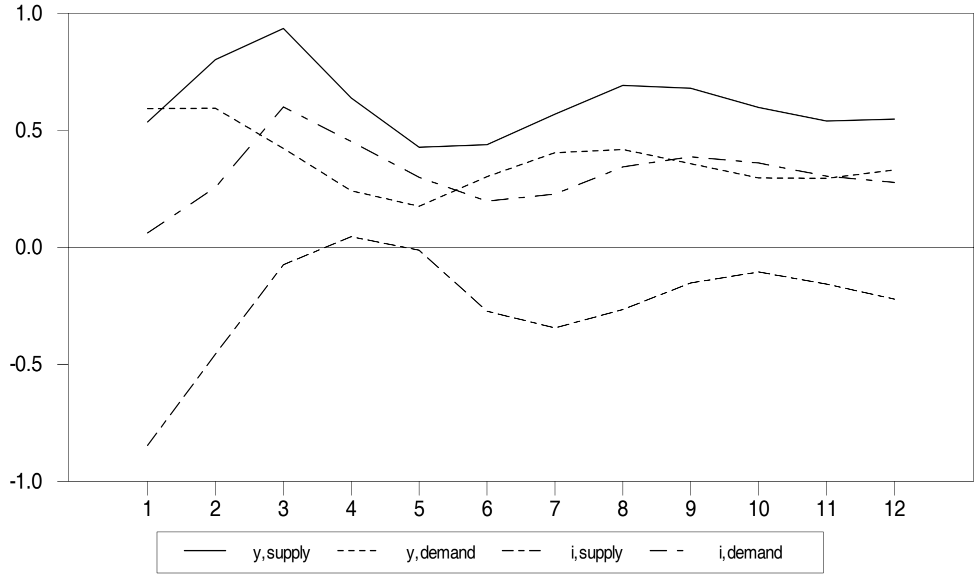


Figure 140: P1: Sco BQ Decomposition Impulse

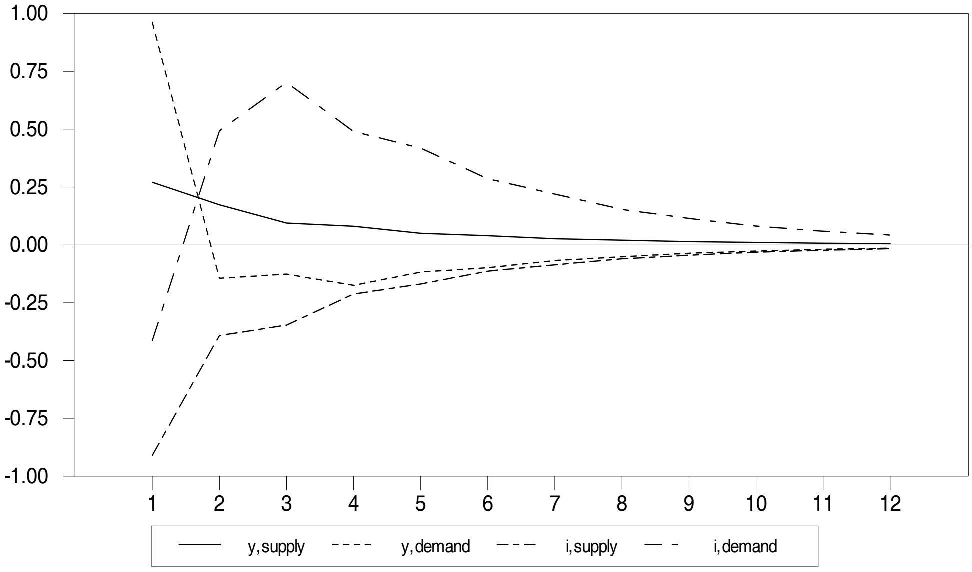


Figure 141: P1: Sco Covers Decomposition Impulse

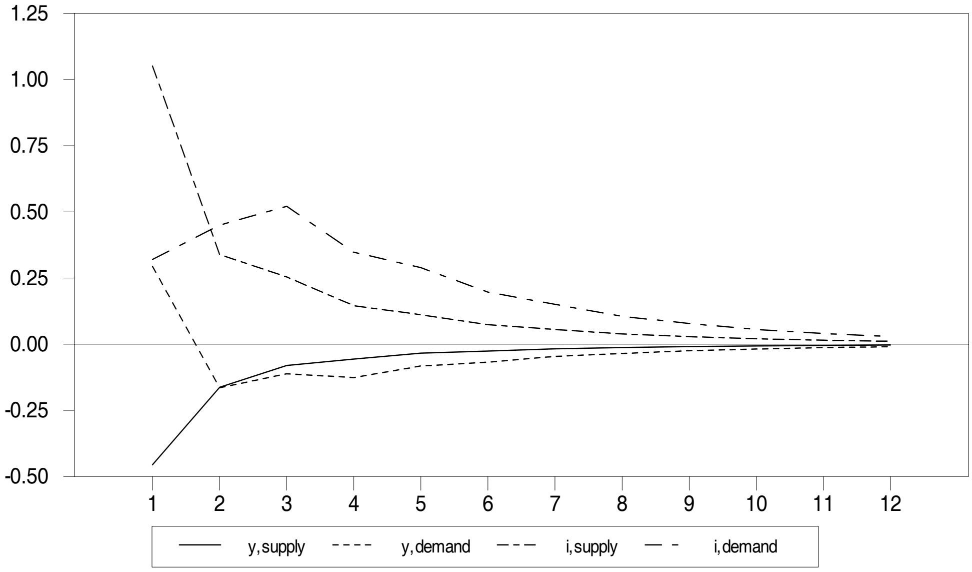


Figure 142: P1: Sco BQ Decomposition Cumulative

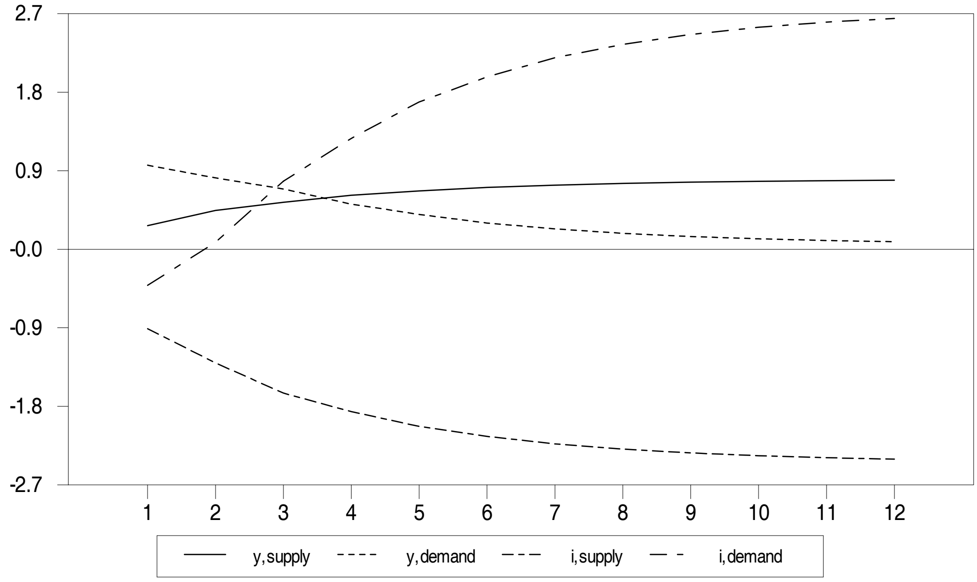


Figure 143: P1: Sco Covers Decomposition Cumulative

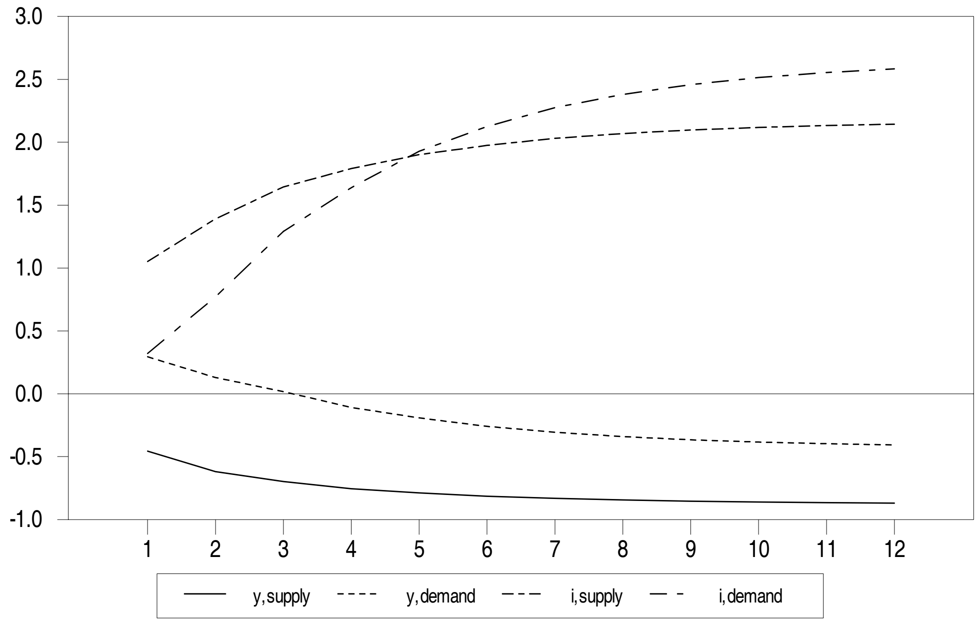


Figure 144: P2: Scotland BQ Decomposition Impulse

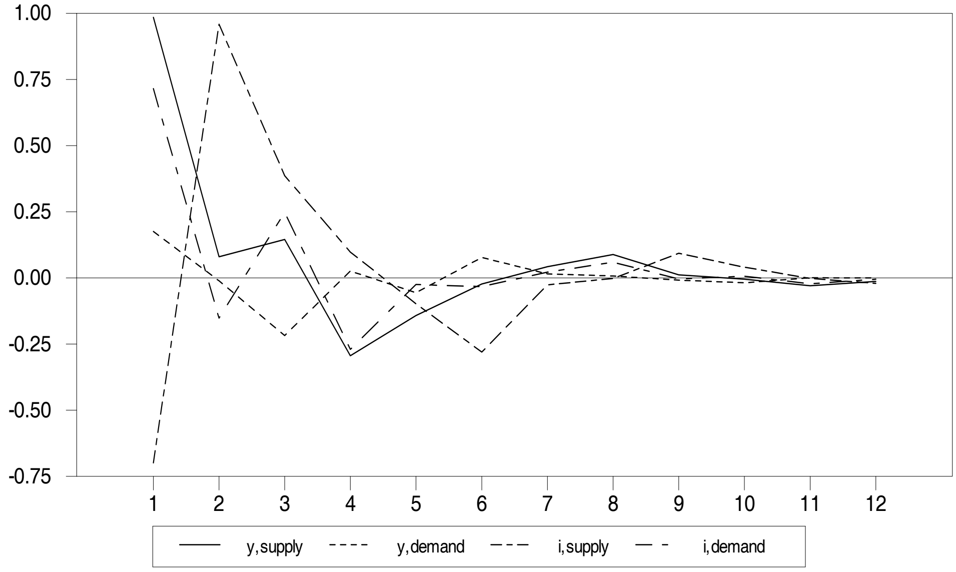


Figure 145: P2: Scotland Covers Decomposition Impulse

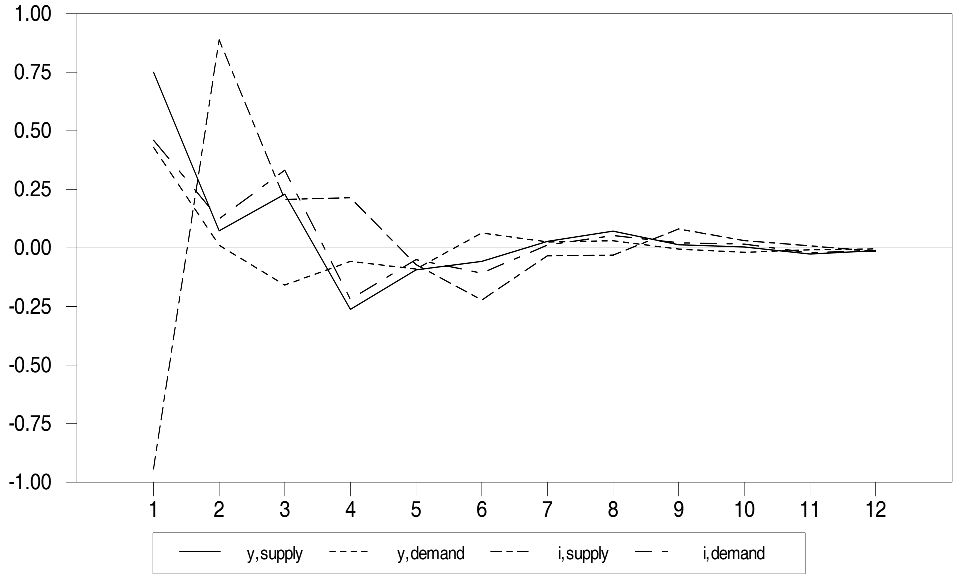


Figure 146: P2: Scotland BQ Composition Cumulative

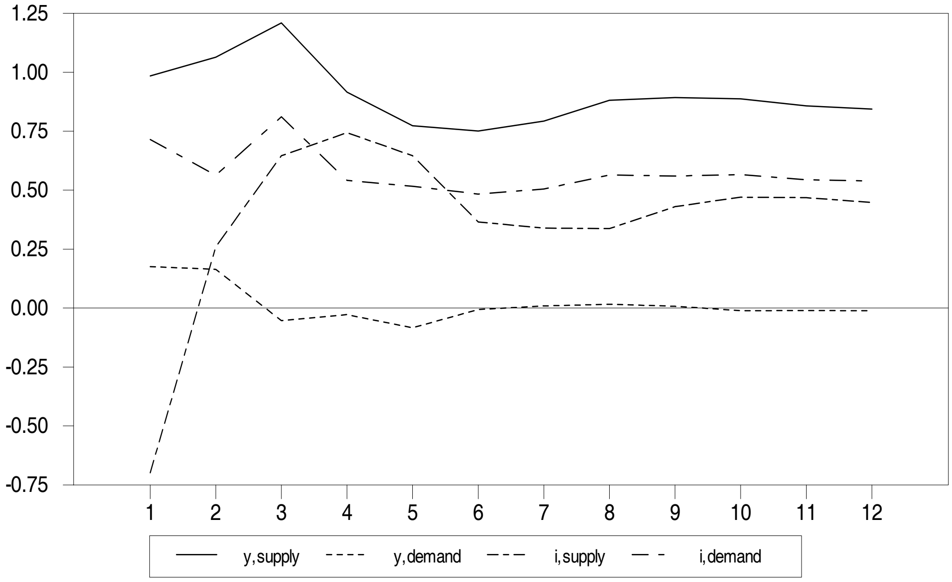


Figure 147: P2: Scotland Covers Decomposition Cumulative

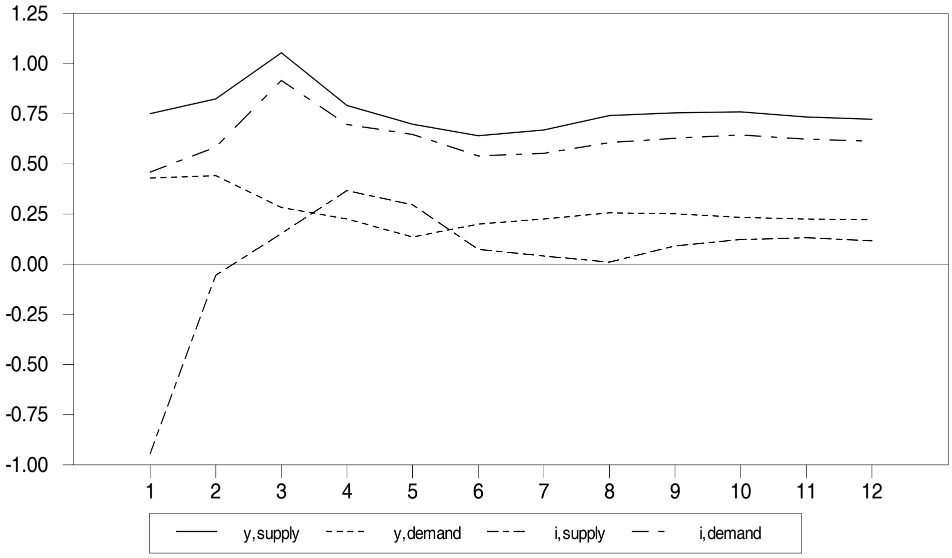


Figure 148: P1: SW BQ Decomposition Impulse

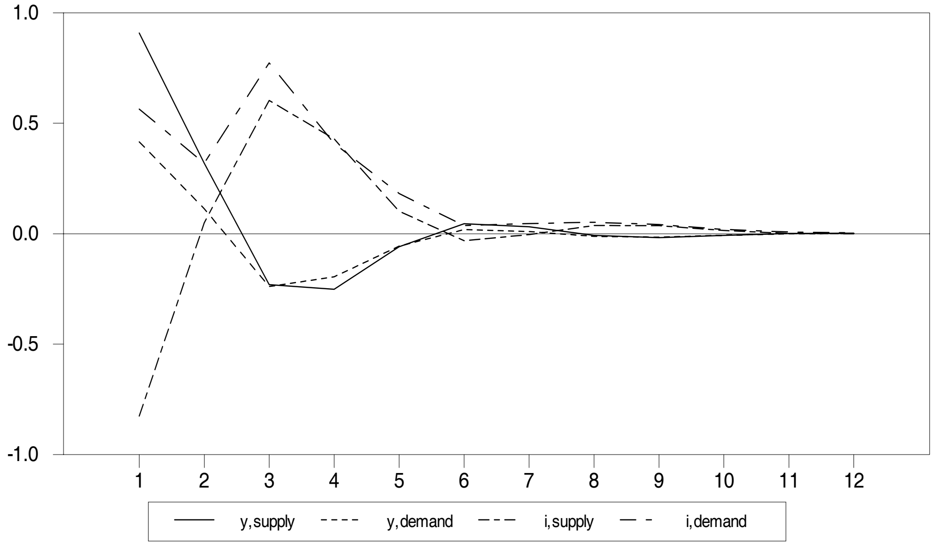


Figure 149: P1: SW Covers Decomposition Impulse

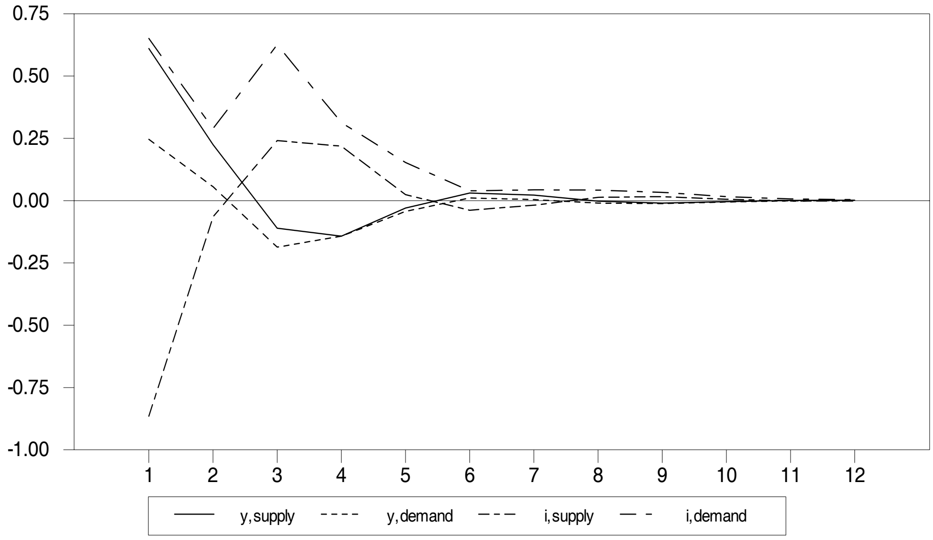


Figure 150: P1: SW BQ Composition Cumulative

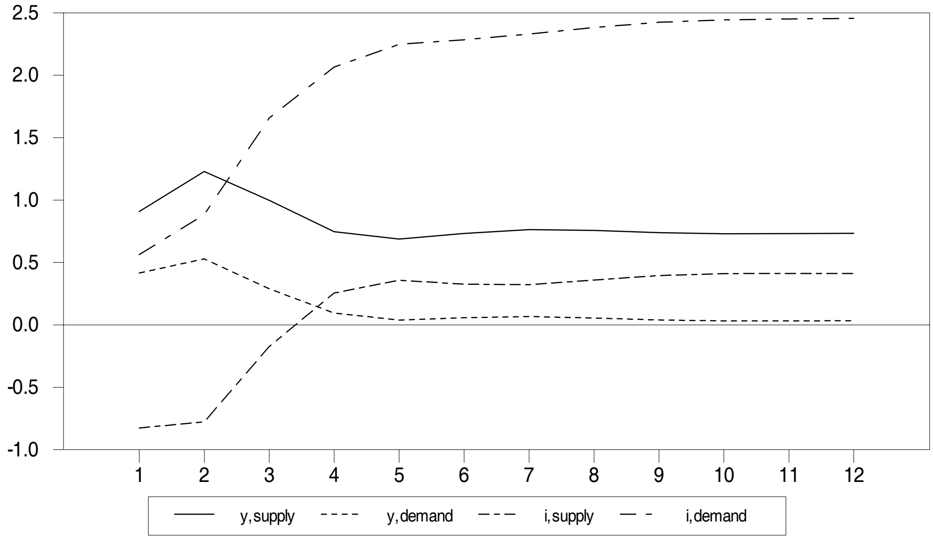


Figure 151: P1: SW Covers Decomposition Cumulative

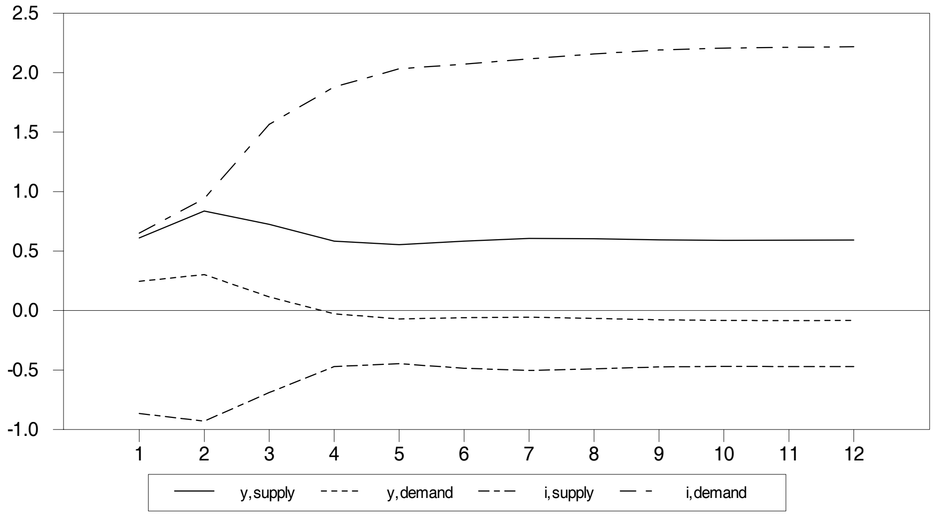


Figure 152: P2: SW BQ Decomposition Impulse

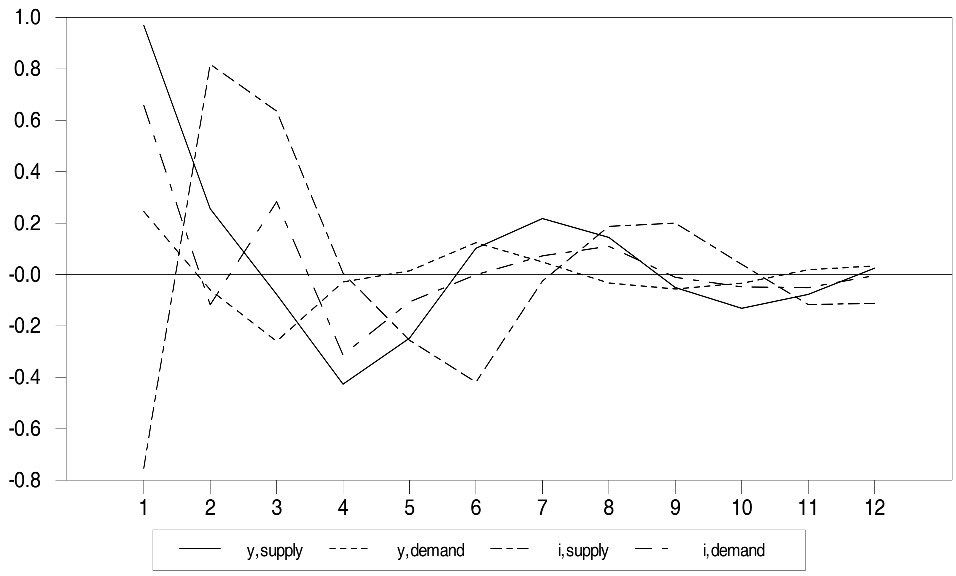


Figure 153: P2: SW Covers Decomposition Impulse

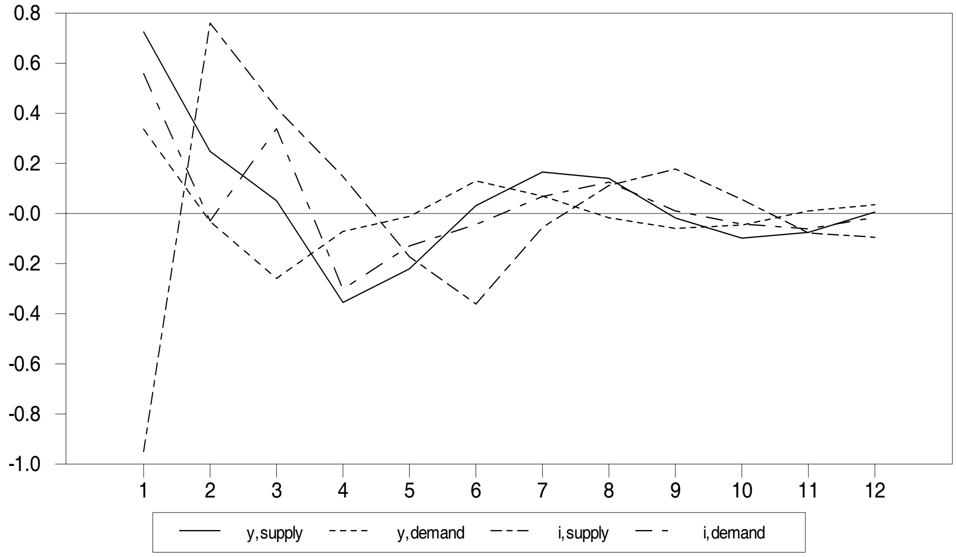


Figure 154: P2: SW BQ Decomposition Cumulative

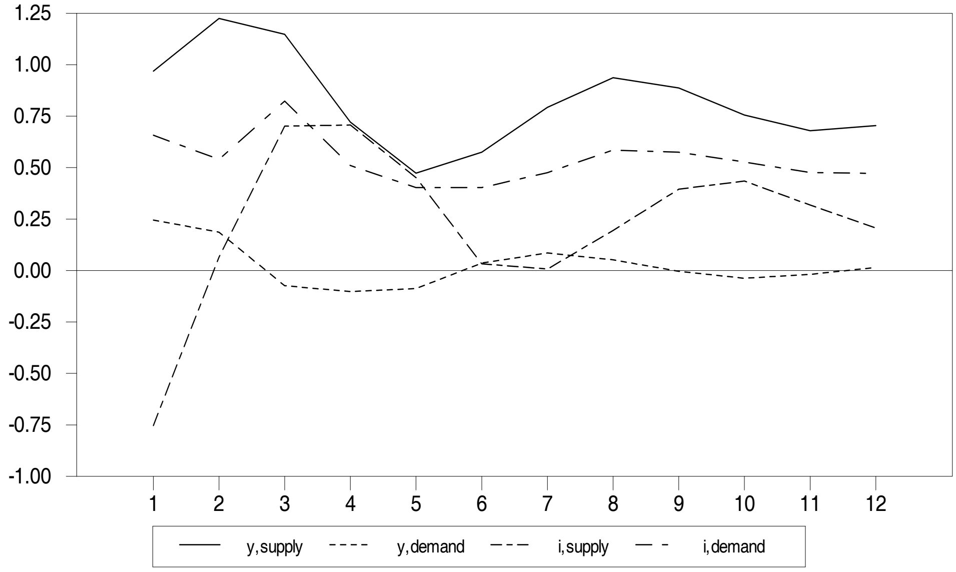


Figure 155: P2: SW Covers Decomposition Cumulative

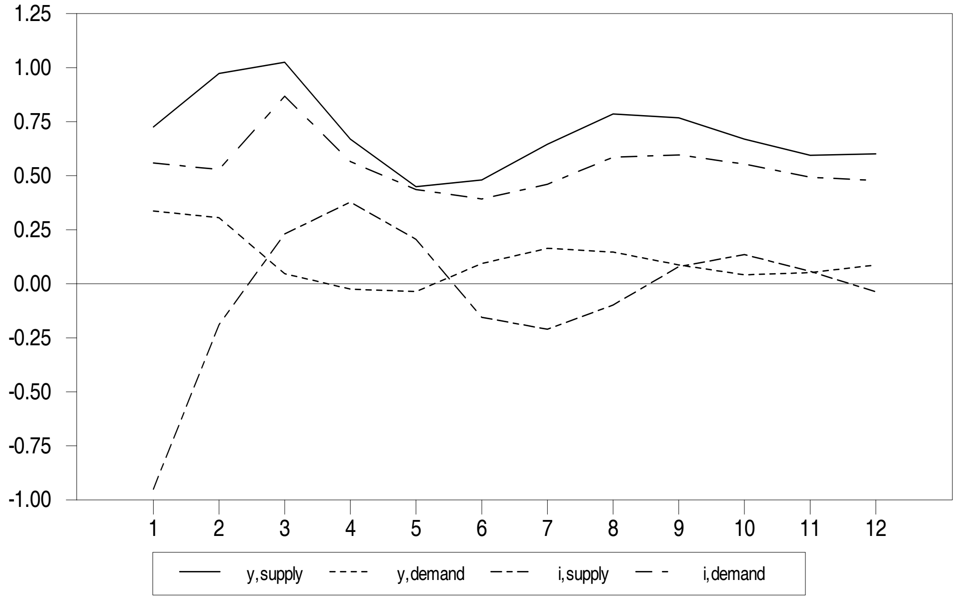


Figure 156: P1: Wales BQ Decomposition Impulse

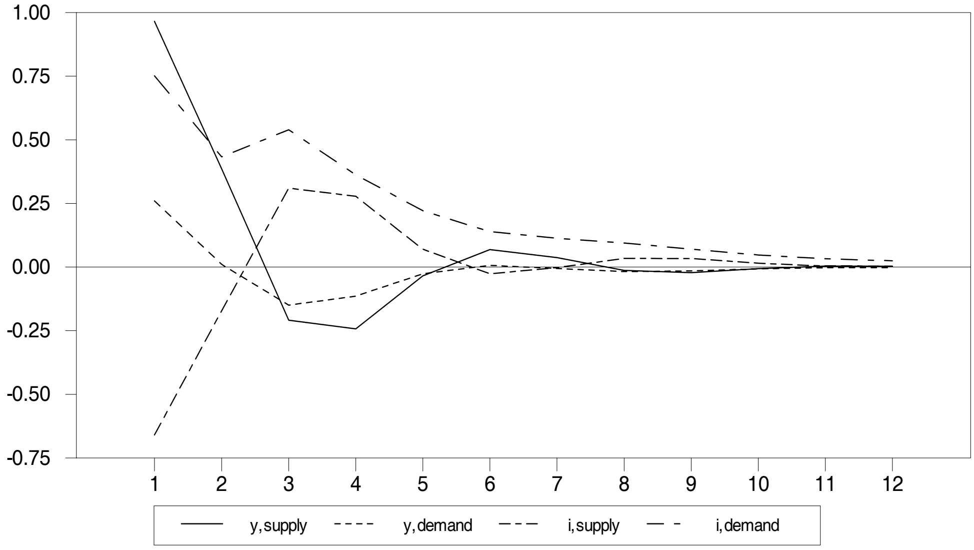


Figure 157: P1: Wales Covers Decomposition Impulse

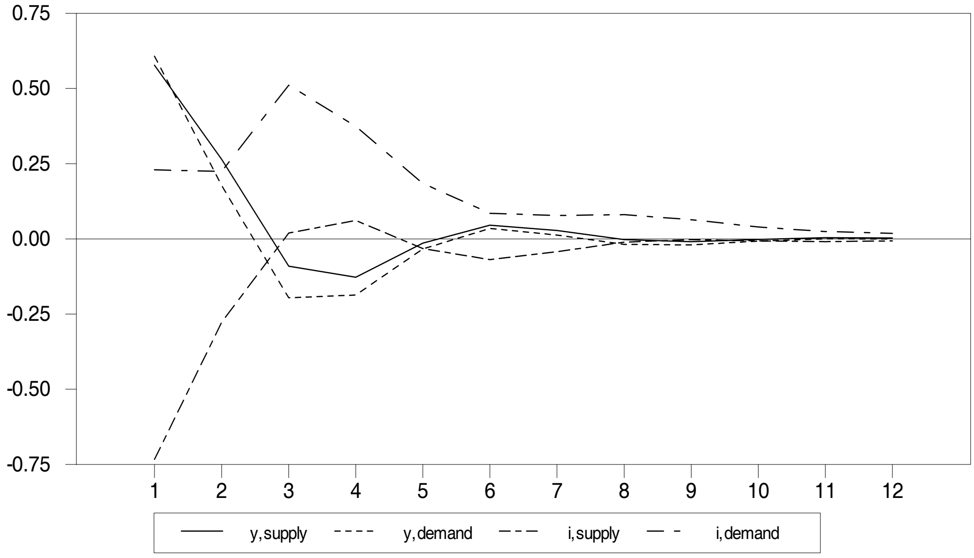


Figure 158: P1: Wales BQ Decomposition Cumulative

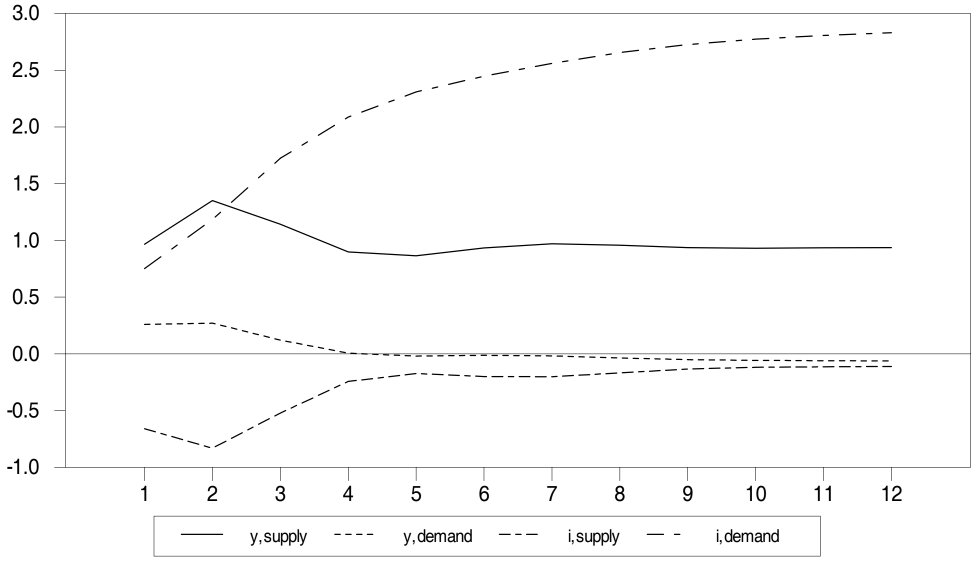


Figure 159: P1: Wales Covers Decomposition Cumulative

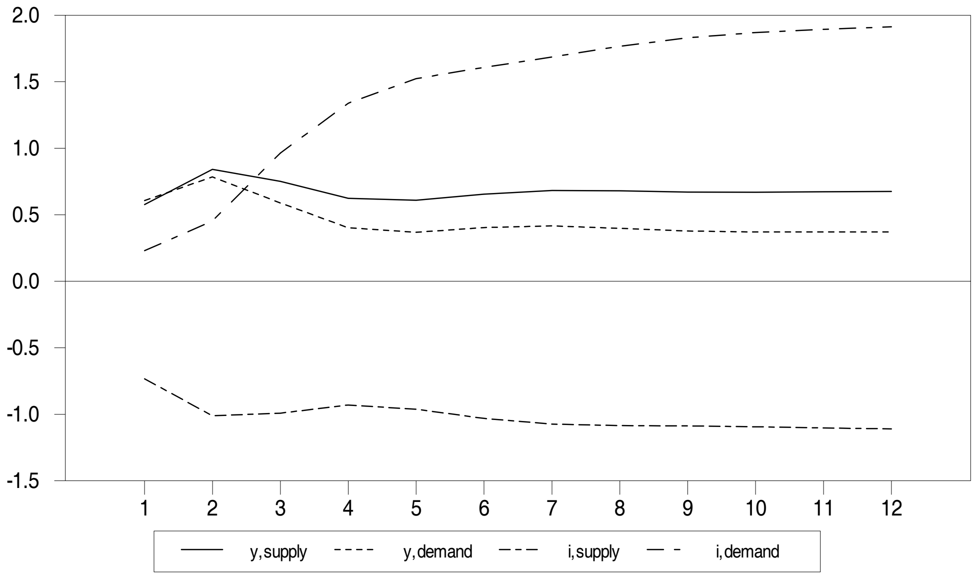


Figure 160: P2: Wales BQ Decomposition Impulse

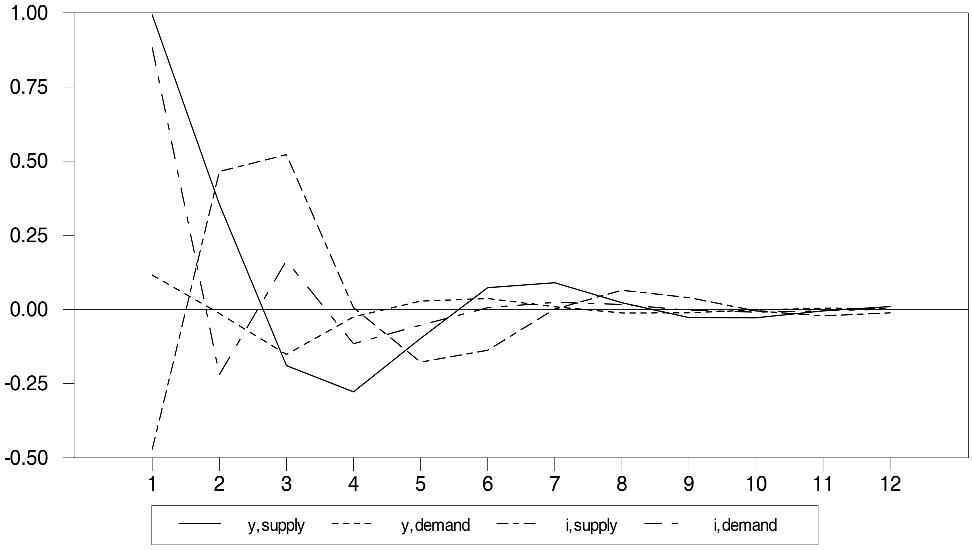


Figure 161: P2: Wales Covers Decomposition Impulse

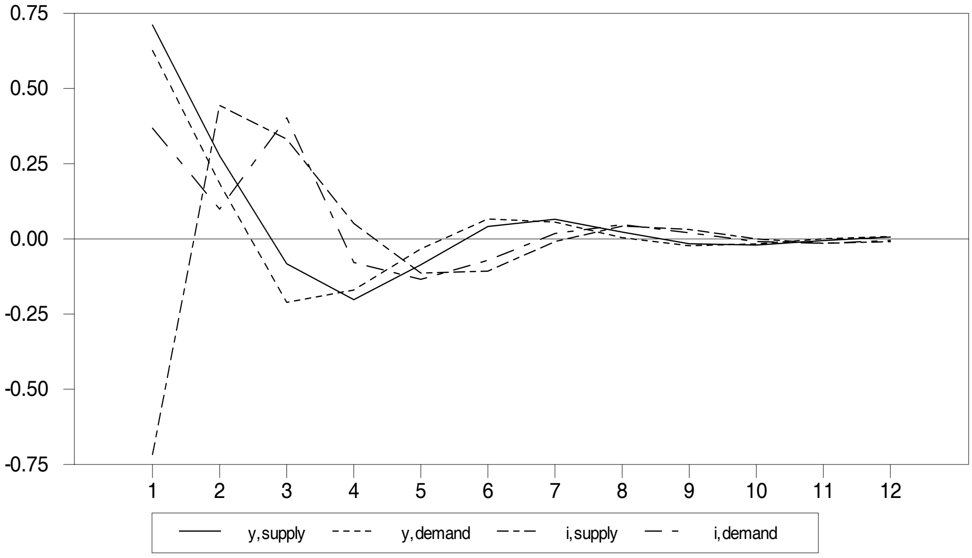


Figure 162: P2: Wales BQ Decomposition Cumulative

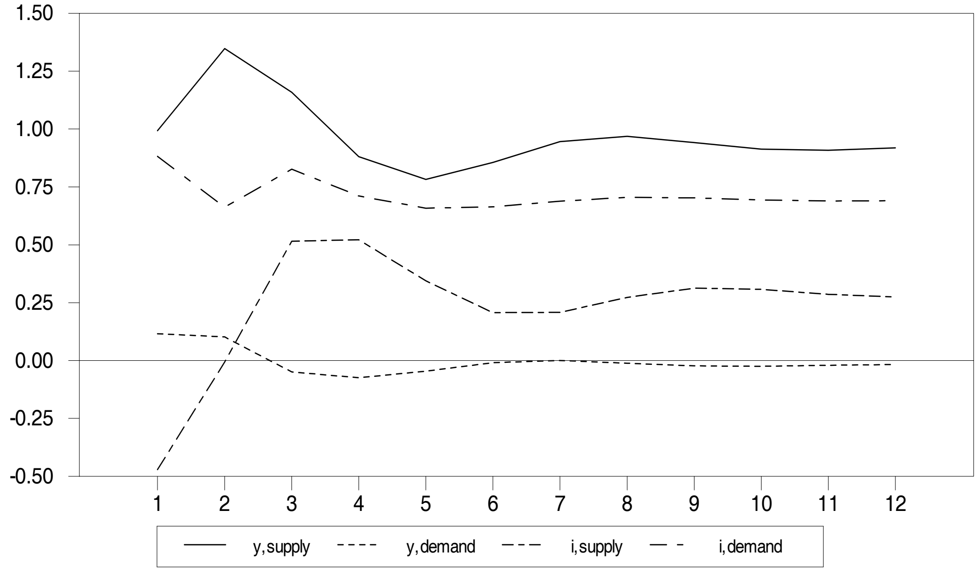


Figure 163: P2: Wales Covers Decomposition Cumulative

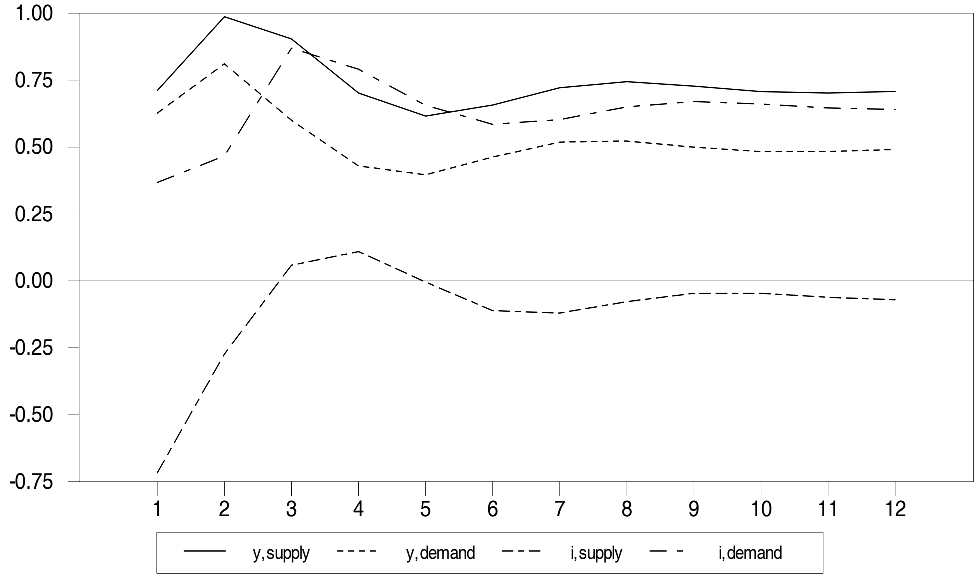


Figure 164: P1: WM BQ Decomposition Impulse

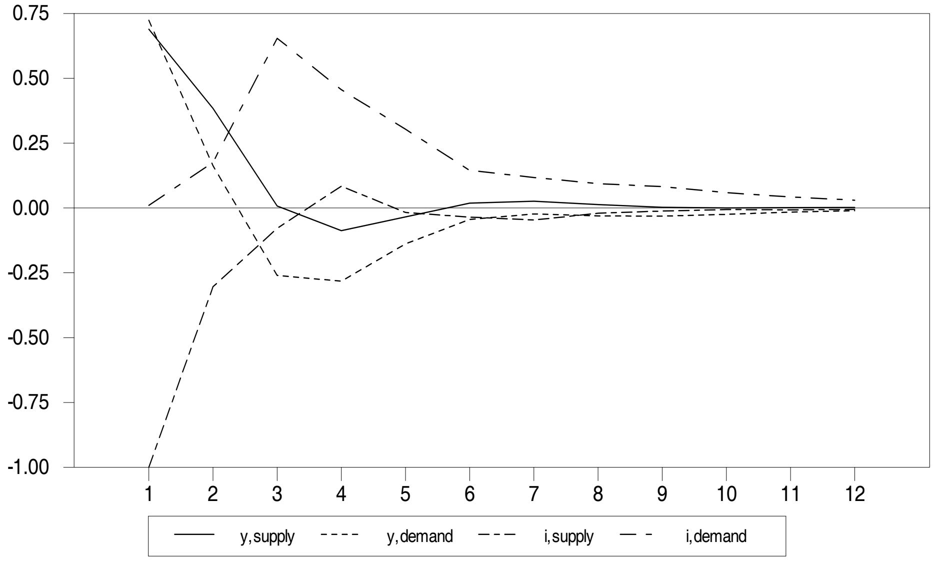


Figure 165: P1: WM Covers Decomposition Impulse

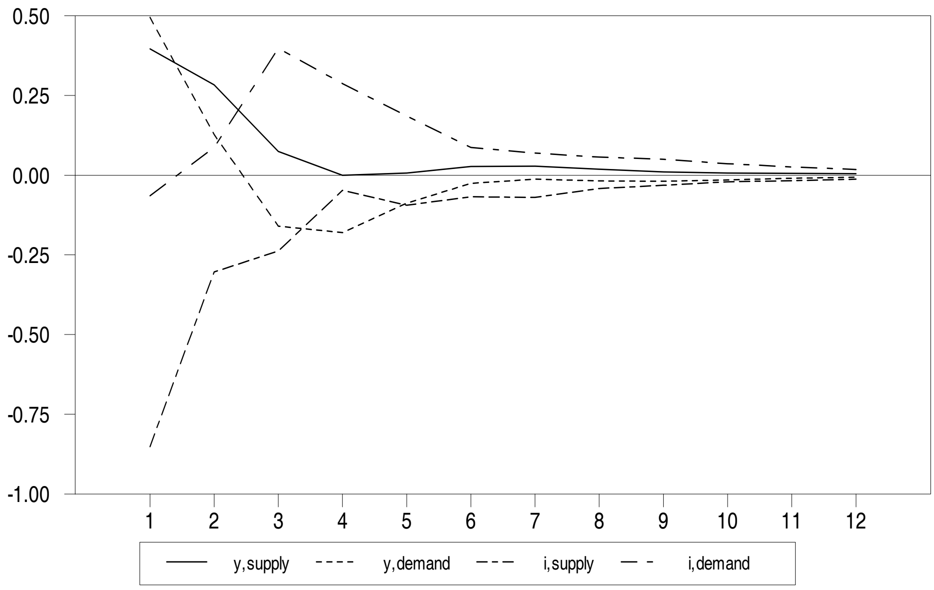


Figure 166: P1: WM BQ Decomposition Cumulative

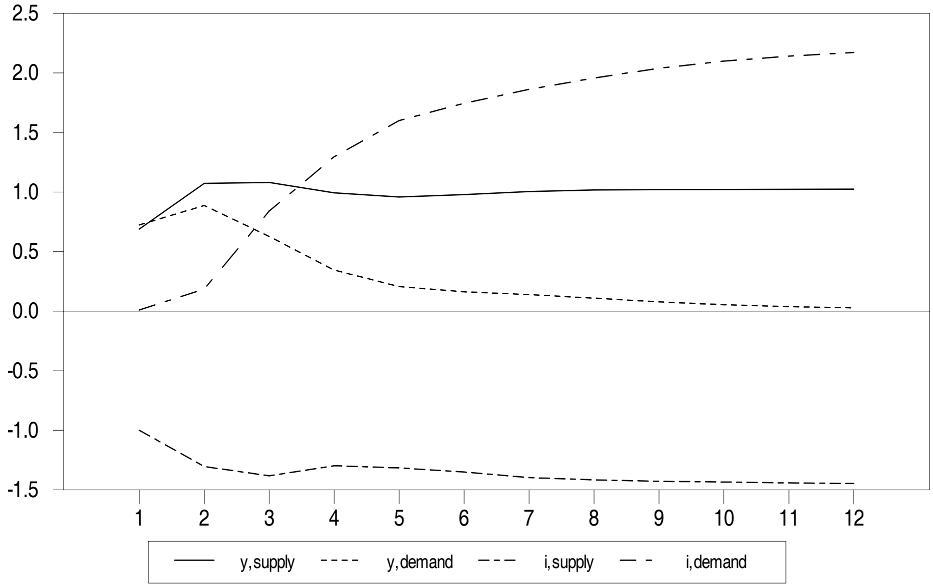


Figure 167: P1: WMCovers Decomposition Cumulative

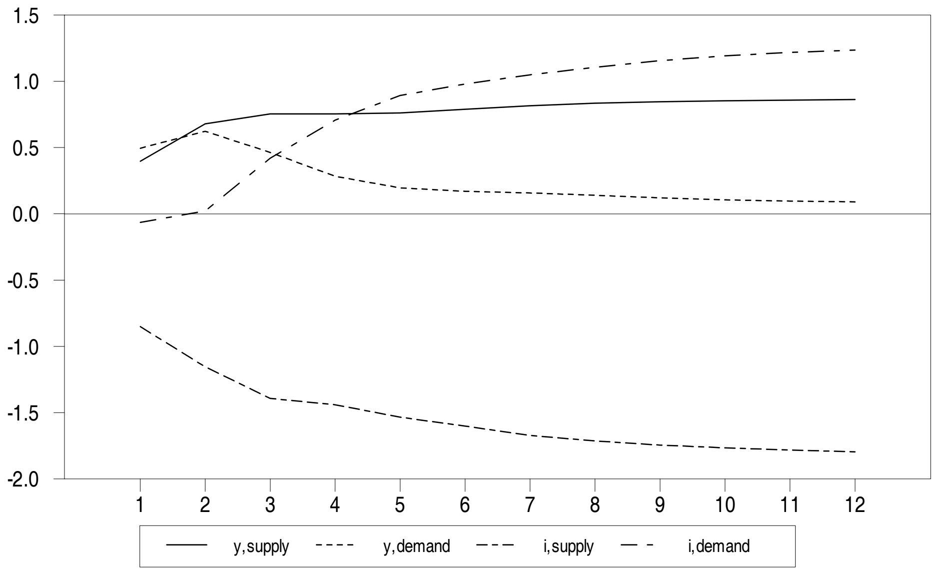


Figure 168: P2: WM BQ Decomposition Impulse

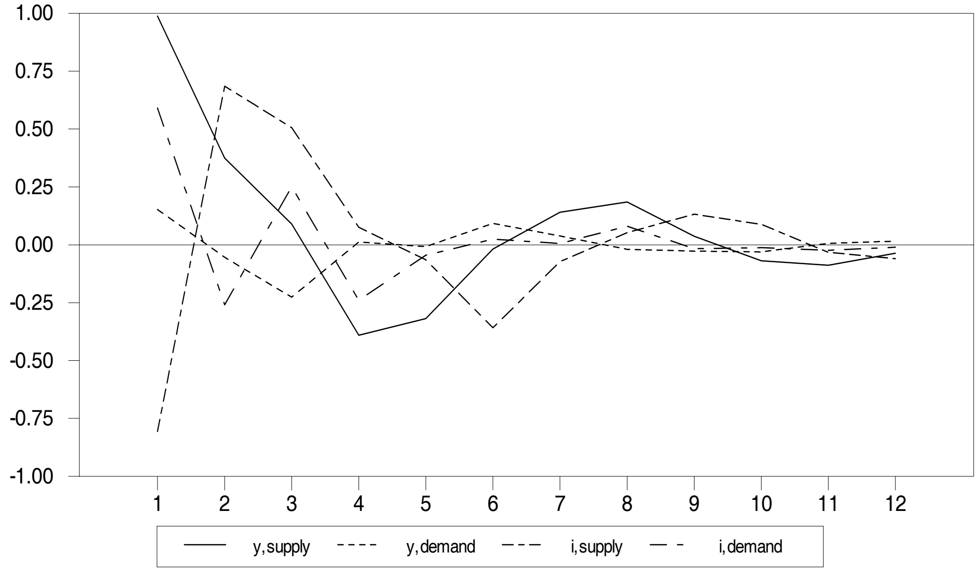


Figure 169: P2: WM Covers Decomposition Impulse

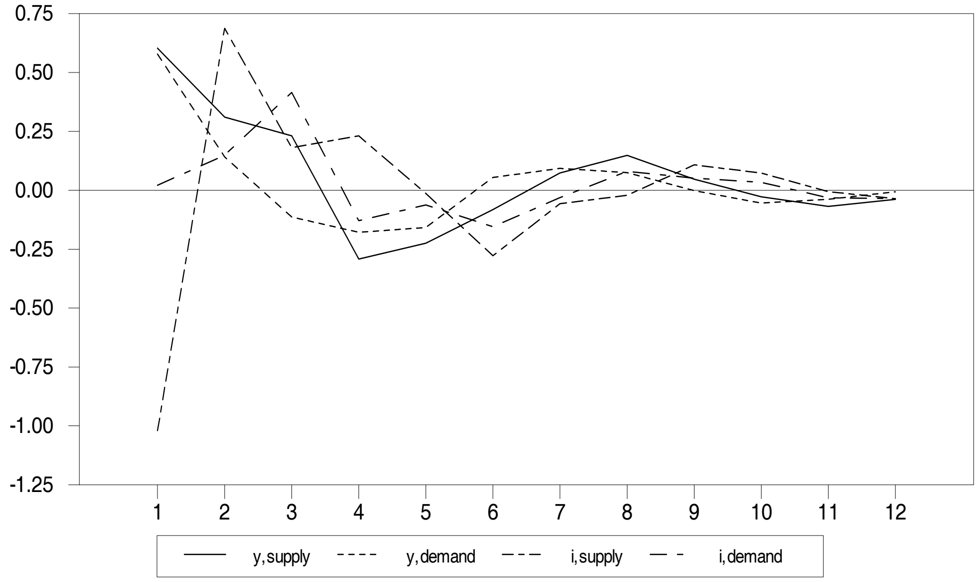


Figure 170: P2: WM BQ Decomposition Cumulative

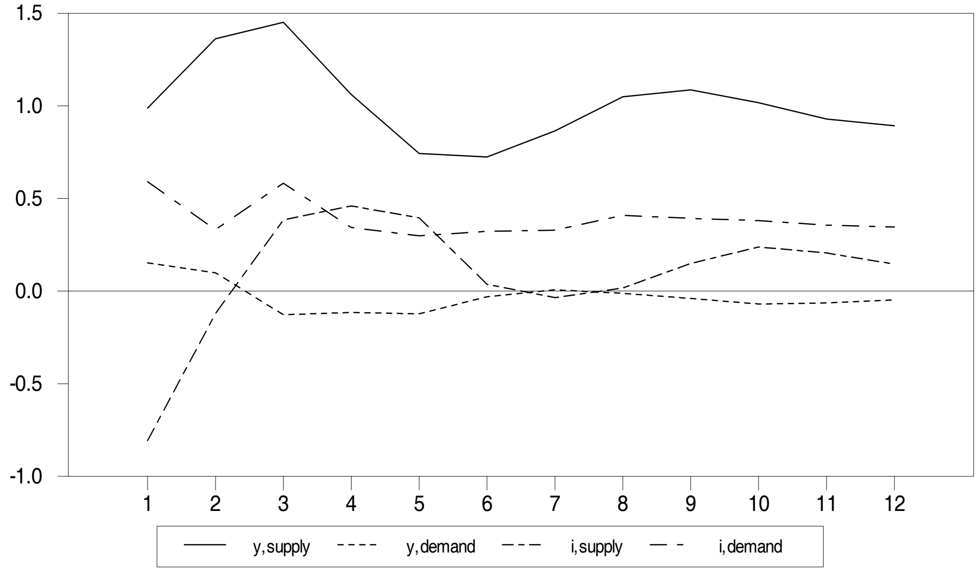
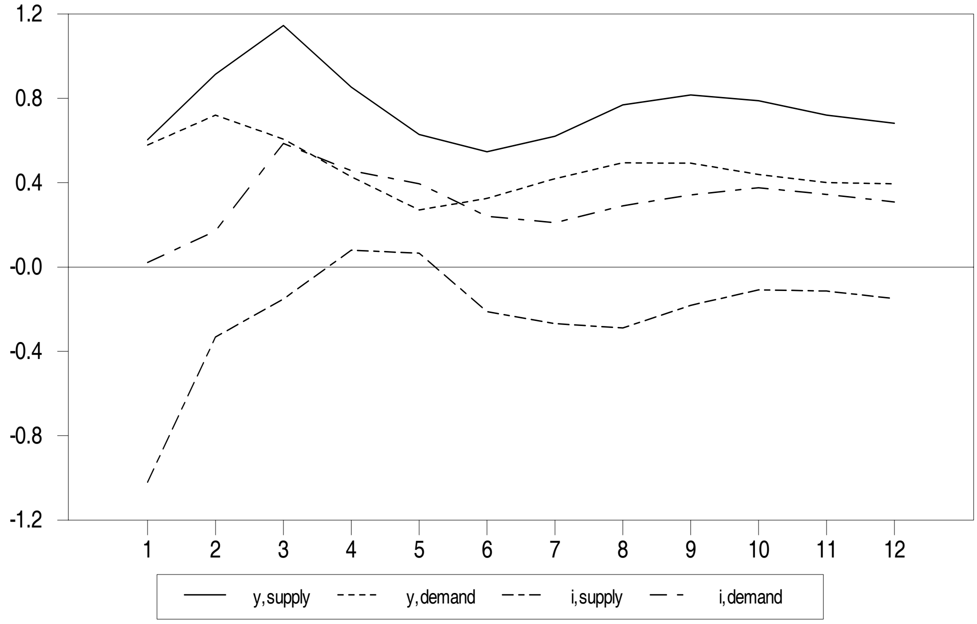


Figure 171: P2: WM Covers Decomposition Cumulative



Appendix 7: Covers Parameter Tables, Rest of Regions

Table 58: Covers P1 East Anglia

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	1.13	24.14	0.42	5.73				
Causality: supply to demand	1.13	24.14			5.72	0.02		
Causality: demand to supply	1.13			5.73			24.11	0.07

Table 59: Covers P1 East Midlands

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	0.45	9.91	2.66	5.62				
Causality: supply to demand	0.45	9.91			4.96	0.27		
Causality: demand to supply	0.45			5.62			8.65	0.47

Table 60: Covers P1 North West

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	1.45	25.60	7.04	7.12				
Causality: supply to demand	1.45	25.60			5.18	0.28		
Causality: demand to supply	1.45			7.12			18.64	0.99

α=sensitivity of aggregate supply to an unexpected change in inflation
σ^2_ε= variance of total structural shock to aggregate supply
$\sigma^2_{\varepsilon\eta}$= covariance between total structural shocks to aggregate supply and demand
σ^2_η = variance of total structural shock to aggregate demand
σ^2_υ = variance of independent structural shock to aggregate demand
ρ = effect of shock to aggregate demand on total shock to aggregate supply (causality supply to demand shock)
σ^2_δ= variance of independent structural shock to aggregate supply
γ = effect of shock to aggregate supply on total shock to aggregate demand (causality demand to supply shock)

Table 61: Covers P1 South West

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	0.63	15.56	-0.50	7.75				
Causality: supply to demand	0.63	15.56			7.73	-0.03		
Causality: demand to supply	0.63			7.75			15.52	-0.06

Table 62: Covers P1 Wales

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	0.48	13.73	5.62	8.51				
Causality: supply to demand	0.48	13.73			6.21	0.41		
Causality: demand to supply	0.48			8.51			10.02	0.6

Table 63: Covers P1 West Midlands

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	1.14	25.85	6.37	5.59				
Causality: supply to demand	1.14	25.85			4.03	0.25		
Causality: demand to supply	1.14			5.59			18.60	1.13

α=sensitivity of aggregate supply to an unexpected change in inflation
σ^2_ε= variance of total structural shock to aggregate supply
$\sigma^2_{\varepsilon\eta}$= covariance between total structural shocks to aggregate supply and demand
σ^2_η = variance of total structural shock to aggregate demand
σ^2_υ = variance of independent structural shock to aggregate demand
ρ = effect of shock to aggregate demand on total shock to aggregate supply (causality supply to demand shock)
σ^2_δ= variance of independent structural shock to aggregate supply
γ = effect of shock to aggregate supply on total shock to aggregate demand (causality demand to supply shock)

Table 64: Covers P2 East Anglia

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	0.52	11.49	-0.86	6.36				
Causality: supply to demand	0.52	11.79			6.30	-0.07		
Causality: demand to supply	0.52			6.36			11.38	-0.13

Table 65: Covers P2 East Midlands

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	0.34	8.13	1.60	6.29				
Causality: supply to demand	0.34	8.13			5.98	0.20		
Causality: demand to supply	0.34			6.29			7.72	0.26

Table 66: Covers North West

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	0.53	13.66	4.95	5.46				
Causality: supply to demand	0.53	13.66			3.67	0.36		
Causality: demand to supply	0.53			5.46			9.18	0.91

α=sensitivity of aggregate supply to an unexpected change in inflation
σ^2_ε= variance of total structural shock to aggregate supply
$\sigma^2_{\varepsilon\eta}$= covariance between total structural shocks to aggregate supply and demand
σ^2_η = variance of total structural shock to aggregate demand
σ^2_υ = variance of independent structural shock to aggregate demand
ρ = effect of shock to aggregate demand on total shock to aggregate supply (causality supply to demand shock)
σ^2_δ= variance of independent structural shock to aggregate supply
γ = effect of shock to aggregate supply on total shock to aggregate demand (causality demand to supply shock)

Table 67: Covers P2 Scotland

Model	α	σ^2_{ε}	$\sigma^2_{\varepsilon\eta}$	σ^2_{η}	σ^2_{υ}	ρ	σ^2_{δ}	γ
Basic AS/AD	0.25	6.38	1.71	4.04				
Causality: supply to demand	0.25	6.38			3.58	0.27		
Causality: demand to supply	0.25			4.04			5.66	0.42

Table 68: Covers P2 South West

Model	α	σ^2_{ε}	$\sigma^2_{\varepsilon\eta}$	σ^2_{η}	σ^2_{υ}	ρ	σ^2_{δ}	γ
Basic AS/AD	0.35	8.62	1.22	5.02				
Causality: supply to demand	0.35	8.62			4.85	0.14		
Causality: demand to supply	0.35			5.02			8.32	0.24

Table 69: Covers P2 Wales

Model	α	σ^2_{ε}	$\sigma^2_{\varepsilon\eta}$	σ^2_{η}	σ^2_{υ}	ρ	σ^2_{δ}	γ
Basic AS/AD	0.16	10.61	5.99	10.42				
Causality: supply to demand	0.16	10.61			7.04	0.56		
Causality: demand to supply	0.16			10.42			7.16	0.57

α=sensitivity of aggregate supply to an unexpected change in inflation
σ^2_{ε}= variance of total structural shock to aggregate supply
$\sigma^2_{\varepsilon\eta}$= covariance between total structural shocks to aggregate supply and demand
σ^2_{η} = variance of total structural shock to aggregate demand
σ^2_{υ} = variance of independent structural shock to aggregate demand
ρ = effect of shock to aggregate demand on total shock to aggregate supply (causality supply to demand shock)
σ^2_{δ}= variance of independent structural shock to aggregate supply
γ = effect of shock to aggregate supply on total shock to aggregate demand (causality demand to supply shock)

Table 70: Covers P2 West Midlands

Model	α	σ^2_ε	$\sigma^2_{\varepsilon\eta}$	σ^2_η	σ^2_υ	ρ	σ^2_δ	γ
Basic AS/AD	0.36	13.25	4.49	4.63				
Causality: supply to demand	0.36	13.25			3.11	0.34		
Causality: demand to supply	0.36			4.63			8.89	0.97

α=sensitivity of aggregate supply to an unexpected change in inflation
σ^2_ε= variance of total structural shock to aggregate supply
$\sigma^2_{\varepsilon\eta}$= covariance between total structural shocks to aggregate supply and demand
σ^2_η = variance of total structural shock to aggregate demand
σ^2_υ = variance of independent structural shock to aggregate demand
ρ = effect of shock to aggregate demand on total shock to aggregate supply (causality supply to demand shock)
σ^2_δ= variance of independent structural shock to aggregate supply
γ = effect of shock to aggregate supply on total shock to aggregate demand (causality demand to supply shock)

Appendix 8: Vardecompositons, Rest of Regions

Table 71: EA Vardecomp P1

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.77	0.23	0.74	0.26
2	0.79	0.21	0.79	0.21
3	0.79	0.21	0.79	0.21
4	0.78	0.22	0.77	0.23
5	0.78	0.22	0.77	0.23
6	0.77	0.23	0.77	0.23
7	0.77	0.23	0.77	0.23
8	0.77	0.23	0.77	0.23
9	0.77	0.23	0.77	0.23
10	0.77	0.23	0.77	0.23
11	0.77	0.23	0.77	0.23
12	0.77	0.23	0.77	0.23

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.80	0.20	0.83	0.17
2	0.68	0.32	0.77	0.23
3	0.56	0.44	0.68	0.32
4	0.56	0.44	0.66	0.34
5	0.54	0.46	0.64	0.36
6	0.54	0.46	0.64	0.36
7	0.54	0.46	0.64	0.36
8	0.54	0.46	0.63	0.37
9	0.54	0.46	0.63	0.37
10	0.54	0.46	0.63	0.37
11	0.54	0.46	0.63	0.37
12	0.54	0.46	0.63	0.37

Table 72: EM Vardecomp P1

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.92	0.08	0.64	0.36
2	0.92	0.08	0.68	0.32
3	0.92	0.08	0.68	0.32
4	0.92	0.08	0.67	0.33
5	0.92	0.08	0.67	0.33
6	0.92	0.08	0.67	0.33
7	0.92	0.08	0.67	0.33
8	0.92	0.08	0.67	0.33
9	0.92	0.08	0.67	0.33
10	0.92	0.08	0.67	0.33
11	0.92	0.08	0.67	0.33
12	0.92	0.08	0.67	0.33

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.52	0.48	0.85	0.15
2	0.45	0.55	0.73	0.27
3	0.47	0.53	0.52	0.48
4	0.49	0.51	0.49	0.51
5	0.48	0.52	0.47	0.53
6	0.47	0.53	0.46	0.54
7	0.46	0.54	0.45	0.55
8	0.46	0.54	0.44	0.56
9	0.46	0.54	0.44	0.56
10	0.46	0.54	0.43	0.57
11	0.46	0.54	0.43	0.57
12	0.46	0.54	0.43	0.57

Table 73: NW Vardecomp P1

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.82	0.18	0.31	0.69
2	0.84	0.16	0.39	0.61
3	0.82	0.18	0.37	0.63
4	0.81	0.19	0.35	0.65
5	0.81	0.19	0.35	0.65
6	0.81	0.19	0.36	0.64
7	0.81	0.19	0.36	0.64
8	0.81	0.19	0.36	0.64
9	0.81	0.19	0.36	0.64
10	0.81	0.19	0.36	0.64
11	0.81	0.19	0.36	0.64
12	0.81	0.19	0.36	0.64

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.72	0.28	1.00	0.00
2	0.66	0.34	0.97	0.03
3	0.51	0.49	0.67	0.33
4	0.51	0.49	0.61	0.39
5	0.50	0.50	0.59	0.41
6	0.50	0.50	0.59	0.41
7	0.50	0.50	0.59	0.41
8	0.50	0.50	0.59	0.41
9	0.49	0.51	0.59	0.41
10	0.49	0.51	0.59	0.41
11	0.49	0.51	0.59	0.41
12	0.49	0.51	0.59	0.41

Table 74: SW Vardecomp P1

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.83	0.17	0.86	0.14
2	0.83	0.17	0.87	0.13
3	0.80	0.20	0.82	0.18
4	0.79	0.21	0.79	0.21
5	0.79	0.21	0.79	0.21
6	0.79	0.21	0.79	0.21
7	0.79	0.21	0.79	0.21
8	0.79	0.21	0.79	0.21
9	0.79	0.21	0.79	0.21
10	0.79	0.21	0.79	0.21
11	0.79	0.21	0.79	0.21
12	0.79	0.21	0.79	0.21

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.68	0.32	0.64	0.36
2	0.62	0.38	0.60	0.40
3	0.51	0.49	0.47	0.53
4	0.51	0.49	0.46	0.54
5	0.50	0.50	0.46	0.54
6	0.50	0.50	0.46	0.54
7	0.50	0.50	0.46	0.54
8	0.50	0.50	0.46	0.54
9	0.50	0.50	0.46	0.54
10	0.50	0.50	0.46	0.54
11	0.50	0.50	0.46	0.54
12	0.50	0.50	0.46	0.54

Table 75: Wal Vardecomp P1

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.93	0.07	0.48	0.52
2	0.94	0.06	0.50	0.50
3	0.93	0.07	0.48	0.52
4	0.92	0.08	0.47	0.53
5	0.92	0.08	0.47	0.53
6	0.92	0.08	0.47	0.53
7	0.92	0.08	0.48	0.52
8	0.92	0.08	0.48	0.52
9	0.92	0.08	0.47	0.53
10	0.92	0.08	0.47	0.53
11	0.92	0.08	0.47	0.53
12	0.92	0.08	0.47	0.53

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.44	0.56	0.91	0.09
2	0.38	0.62	0.86	0.14
3	0.35	0.65	0.63	0.37
4	0.35	0.65	0.55	0.45
5	0.34	0.66	0.54	0.46
6	0.34	0.66	0.53	0.47
7	0.34	0.66	0.53	0.47
8	0.34	0.66	0.53	0.47
9	0.34	0.66	0.53	0.47
10	0.34	0.66	0.53	0.47
11	0.34	0.66	0.53	0.47
12	0.34	0.66	0.53	0.47

Table 76: WM Vardecomp P1

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.48	0.52	0.39	0.61
2	0.53	0.47	0.48	0.52
3	0.50	0.50	0.46	0.54
4	0.47	0.53	0.43	0.57
5	0.47	0.53	0.43	0.57
6	0.47	0.53	0.43	0.57
7	0.47	0.53	0.43	0.57
8	0.47	0.53	0.43	0.57
9	0.47	0.53	0.43	0.57
10	0.47	0.53	0.43	0.57
11	0.47	0.53	0.43	0.57
12	0.47	0.53	0.43	0.57

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	1.00	0.00	0.99	0.01
2	0.97	0.03	0.99	0.01
3	0.71	0.29	0.84	0.16
4	0.62	0.38	0.78	0.22
5	0.59	0.41	0.76	0.24
6	0.59	0.41	0.75	0.25
7	0.58	0.42	0.75	0.25
8	0.58	0.42	0.75	0.25
9	0.58	0.42	0.75	0.25
10	0.58	0.42	0.75	0.25
11	0.58	0.42	0.75	0.25
12	0.58	0.42	0.75	0.25

Table 77: EA Vardecomp P2

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.84	0.16	0.91	0.09
2	0.82	0.18	0.82	0.18
3	0.81	0.19	0.79	0.21
4	0.83	0.17	0.82	0.18
5	0.83	0.17	0.82	0.18
6	0.83	0.17	0.81	0.19
7	0.83	0.17	0.81	0.19
8	0.83	0.17	0.81	0.19
9	0.83	0.17	0.81	0.19
10	0.83	0.17	0.81	0.19
11	0.83	0.17	0.81	0.19
12	0.83	0.17	0.81	0.19

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.68	0.32	0.58	0.42
2	0.81	0.19	0.69	0.31
3	0.82	0.18	0.70	0.30
4	0.79	0.21	0.67	0.33
5	0.79	0.21	0.68	0.32
6	0.80	0.20	0.68	0.32
7	0.80	0.20	0.68	0.32
8	0.79	0.21	0.68	0.32
9	0.80	0.20	0.68	0.32
10	0.80	0.20	0.68	0.32
11	0.80	0.20	0.68	0.32
12	0.80	0.20	0.68	0.32

Table 78: EM Vardecomp P2

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.93	0.07	0.77	0.23
2	0.91	0.09	0.78	0.22
3	0.88	0.12	0.74	0.26
4	0.90	0.10	0.77	0.23
5	0.90	0.10	0.77	0.23
6	0.89	0.11	0.76	0.24
7	0.89	0.11	0.77	0.23
8	0.89	0.11	0.77	0.23
9	0.89	0.11	0.77	0.23
10	0.89	0.11	0.77	0.23
11	0.89	0.11	0.77	0.23
12	0.89	0.11	0.77	0.23

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.47	0.53	0.69	0.31
2	0.71	0.29	0.82	0.18
3	0.72	0.28	0.80	0.20
4	0.69	0.31	0.76	0.24
5	0.70	0.30	0.76	0.24
6	0.71	0.29	0.77	0.23
7	0.71	0.29	0.76	0.24
8	0.71	0.29	0.77	0.23
9	0.71	0.29	0.77	0.23
10	0.71	0.29	0.77	0.23
11	0.71	0.29	0.77	0.23
12	0.71	0.29	0.77	0.23

Table 79: NW Vardecomp P2

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.95	0.05	0.45	0.55
2	0.92	0.08	0.50	0.50
3	0.87	0.13	0.50	0.50
4	0.89	0.11	0.53	0.47
5	0.89	0.11	0.55	0.45
6	0.88	0.12	0.54	0.46
7	0.89	0.11	0.54	0.46
8	0.88	0.12	0.55	0.45
9	0.88	0.12	0.55	0.45
10	0.88	0.12	0.55	0.45
11	0.88	0.12	0.55	0.45
12	0.88	0.12	0.55	0.45

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.60	0.40	0.99	0.01
2	0.69	0.31	0.95	0.05
3	0.76	0.24	0.86	0.14
4	0.74	0.26	0.85	0.15
5	0.74	0.26	0.83	0.17
6	0.75	0.25	0.84	0.16
7	0.75	0.25	0.84	0.16
8	0.75	0.25	0.83	0.17
9	0.75	0.25	0.83	0.17
10	0.75	0.25	0.83	0.17
11	0.75	0.25	0.83	0.17
12	0.75	0.25	0.83	0.17

Table 80: Sco Vardecomp P2

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.97	0.03	0.75	0.25
2	0.97	0.03	0.75	0.25
3	0.93	0.07	0.75	0.25
4	0.93	0.07	0.76	0.24
5	0.93	0.07	0.76	0.24
6	0.93	0.07	0.76	0.24
7	0.93	0.07	0.76	0.24
8	0.93	0.07	0.76	0.24
9	0.93	0.07	0.76	0.24
10	0.93	0.07	0.76	0.24
11	0.93	0.07	0.76	0.24
12	0.93	0.07	0.76	0.24

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.49	0.51	0.81	0.19
2	0.72	0.28	0.88	0.12
3	0.72	0.28	0.84	0.16
4	0.70	0.30	0.82	0.18
5	0.70	0.30	0.82	0.18
6	0.71	0.29	0.82	0.18
7	0.71	0.29	0.82	0.18
8	0.71	0.29	0.82	0.18
9	0.71	0.29	0.82	0.18
10	0.71	0.29	0.82	0.18
11	0.71	0.29	0.82	0.18
12	0.71	0.29	0.82	0.18

Table 81: SW Vardecomp P2

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.94	0.06	0.82	0.18
2	0.94	0.06	0.84	0.16
3	0.89	0.11	0.76	0.24
4	0.90	0.10	0.79	0.21
5	0.90	0.10	0.80	0.20
6	0.90	0.10	0.79	0.21
7	0.90	0.10	0.79	0.21
8	0.90	0.10	0.80	0.20
9	0.90	0.10	0.79	0.21
10	0.90	0.10	0.79	0.21
11	0.90	0.10	0.79	0.21
12	0.90	0.10	0.79	0.21

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.57	0.43	0.74	0.26
2	0.73	0.27	0.83	0.17
3	0.76	0.24	0.80	0.20
4	0.72	0.28	0.76	0.24
5	0.73	0.27	0.76	0.24
6	0.75	0.25	0.77	0.23
7	0.75	0.25	0.77	0.23
8	0.75	0.25	0.77	0.23
9	0.75	0.25	0.77	0.23
10	0.75	0.25	0.77	0.23
11	0.75	0.25	0.77	0.23
12	0.75	0.25	0.77	0.23

Table 82: Wal Vardecomp P2

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.99	0.01	0.56	0.44
2	0.99	0.01	0.58	0.42
3	0.97	0.03	0.56	0.44
4	0.97	0.03	0.56	0.44
5	0.97	0.03	0.56	0.44
6	0.97	0.03	0.56	0.44
7	0.97	0.03	0.56	0.44
8	0.97	0.03	0.56	0.44
9	0.97	0.03	0.56	0.44
10	0.97	0.03	0.56	0.44
11	0.97	0.03	0.56	0.44
12	0.97	0.03	0.56	0.44

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.22	0.78	0.79	0.21
2	0.35	0.65	0.83	0.17
3	0.45	0.55	0.73	0.27
4	0.45	0.55	0.72	0.28
5	0.46	0.54	0.72	0.28
6	0.47	0.53	0.72	0.28
7	0.47	0.53	0.72	0.28
8	0.47	0.53	0.71	0.29
9	0.47	0.53	0.71	0.29
10	0.47	0.53	0.71	0.29
11	0.47	0.53	0.71	0.29
12	0.47	0.53	0.71	0.29

Table 83: WM Vardecomp P2

	BQ		Cov	
	Ysup	Ydem	Ysup	Ydem
1	0.98	0.02	0.52	0.48
2	0.98	0.02	0.56	0.44
3	0.94	0.06	0.58	0.42
4	0.94	0.06	0.60	0.40
5	0.95	0.05	0.61	0.39
6	0.94	0.06	0.61	0.39
7	0.94	0.06	0.60	0.40
8	0.94	0.06	0.61	0.39
9	0.94	0.06	0.61	0.39
10	0.94	0.06	0.61	0.39
11	0.94	0.06	0.61	0.39
12	0.94	0.06	0.61	0.39

	BQ		Cov	
	Psup	Pdem	Psup	Pdem
1	0.65	0.35	1.00	0.00
2	0.73	0.27	0.99	0.01
3	0.74	0.26	0.89	0.11
4	0.72	0.28	0.88	0.12
5	0.72	0.28	0.88	0.12
6	0.74	0.26	0.88	0.12
7	0.74	0.26	0.87	0.13
8	0.74	0.26	0.87	0.13
9	0.74	0.26	0.87	0.13
10	0.74	0.26	0.87	0.13
11	0.74	0.26	0.87	0.13
12	0.74	0.26	0.87	0.13

Appendix 9 Co-integration test (chapter 6):

Johansen Trace Tests

	Number Cointegrating Equations	Eigenvalue	Trace Stat	0.05 Critical Value	Probability
UK	None	0.225597	9.280286	15.49471	0.3401
	At most 1	0.052265	1.610398	3.841466	0.2044

Appendix 10: Unit Root Test (chapter 6)

ADF tests, Lag Length: 6 (Automatic based on SIC, MAXLAG=9
Null hypothesis: series has a unit root

	t-Statistic	Prob.			t-Statistic	Prob.
UK Price	0.688152	0.8596	UK GDP		2.504905	0.9960
EA ΔPrice	-2.413985	0.0185	EA Δprice + constant		-2.808917	0.0740

Appendix 11: VAR in Levels Stability tests (Eviews output)

Table 84: Roots of Characteristic Polynomial UK Aggregate Data

Roots of Characteristic Polynomial
Endogenous variables: STNOM INF LEXRT LUK
Exogenous variables: C LBRENT
Lag specification: 1 2
Date: 06/19/08 Time: 23:38

Root	Modulus
1.026350	1.026350
0.438801 - 0.711064i	0.835559
0.438801 + 0.711064i	0.835559
-0.174148 - 0.750880i	0.770810
-0.174148 + 0.750880i	0.770810
0.618231 - 0.073453i	0.622579
0.618231 + 0.073453i	0.622579
0.356637	0.356637

Warning: At least one root outside the unit circle.
VAR does not satisfy the stability condition.

Figure 172: VAR Roots UK Aggregate Data

Inverse Roots of AR Characteristic Polynomial

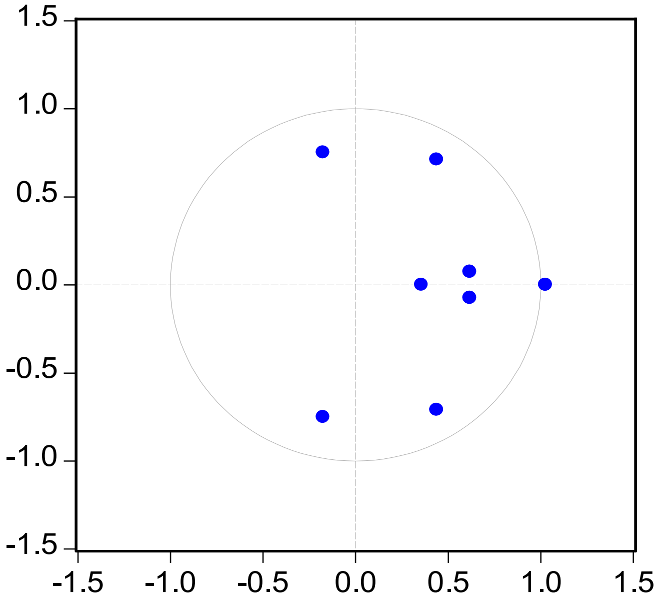


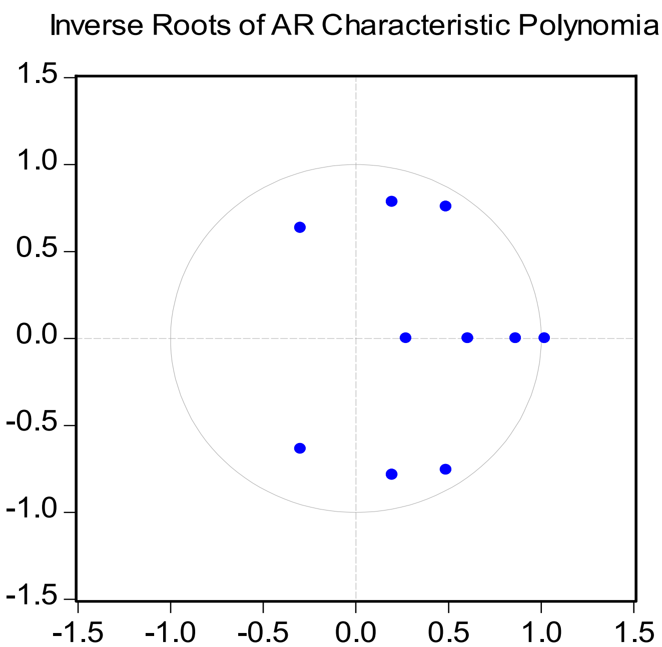
Table 85: Roots of Characteristic Polynomial SE Aggregate Data

Roots of Characteristic Polynomial
Endogenous variables: LUKNOSE LSE INF LEXRT STNOM
Exogenous variables: C LBRENT
Lag specification: 1 2
Date: 06/18/08 Time: 21:26

Root	Modulus
1.020775	1.020775
0.488346 - 0.756061i	0.900061
0.488346 + 0.756061i	0.900061
0.863830	0.863830
0.195940 - 0.784611i	0.808707
0.195940 + 0.784611i	0.808707
-0.297334 - 0.635671i	0.701772
-0.297334 + 0.635671i	0.701772
0.604738	0.604738
0.272350	0.272350

Warning: At least one root outside the unit circle.
VAR does not satisfy the stability condition.

Figure 173: VAR Roots SE Data



Appendix 12: VARs, Regional Sectors

Here we present cumulative responses to interest rate changes for the regional sectors. A visual inspection gives us sufficient guide to draw reference to some stylised facts regarding the differences between the impulse responses across the sectors.

The response of the agricultural sector stands out in that is exhibits a positive response to an interest rate shock. A similar result exists for the mining sector as well as the public sector. Utilities display a very marginal positive response. This is consistent with previous findings (Ganley and Salmon). The pattern of responses is sufficiently similar across the two interest rate orderings to draw roughly the same conclusions (and again that order 2 is larger is as expected and explained previously).

Table4 presents the average maximum response for the interest rate first ordering. The construction sector exhibits the largest and speediest negative response over 50% greater magnitude of the next sector manufacturing. Transport whilst slightly larger in average maximum magnitude exhibits a slightly slower decline than these two sectors. Both the financial services sector and hotels and catering sectors exhibit a slight rise before their more gradual (compared to construction and manufacturing) declines with the average magnitude of the financial and business services sectors being a little more than twice hotels and catering (although half that of manufacturing.)

Table 86: Cumulative max response of sectors and ordering

order 1		order 2	
con	-0.05164	con	-0.08849
tr	-0.03689	man	-0.0499
man	-0.0331	tr	-0.02751
fin	-0.01865	dhc	-0.02083
dhc	-0.00954	fin	-0.01087
util	0.006437	pa	0.004874
pa	0.018345	agg	0.01701
agg	0.019017	util	0.02553
min	0.042219	min	0.052839

The table also presents the summary results of the alternative ordering, interest rate first. Notably, negative responses are somewhat larger, positive responses slightly less. The key significance is the similarity. Again construction is by far and away the largest response, this occasion nearly twice that of manufacturing which is turn is around two thirds greater than transport and twice hotels and catering. The response of the financial services sector is now nearly half that of hotels and catering and a quarter of manufacturing.   These clear diverging sectoral responses clearly then support the prior evidence presented in this paper that the size of regional responses have a clear relationship with industrial composition.

These ‘stylised facts’ can be inferred from the estimations for the regional sectors. It is not possible to infer statistical differences across sector with these results – ie responses where responses with standard errors are statistically different (but then this is not a route often attempted) – nor infer differences between regions across sectors. It is however, fairly evident that these results support a view that each ‘group’ of regional sectors exhibit rather similar or ‘stylised’ response. Neither does any particular regional sector stand out as a potential candidate as having a different characteristic response. The results for seven sectors below, for just the one ordering, interest rate last, are presented.

Figure 174: Construction

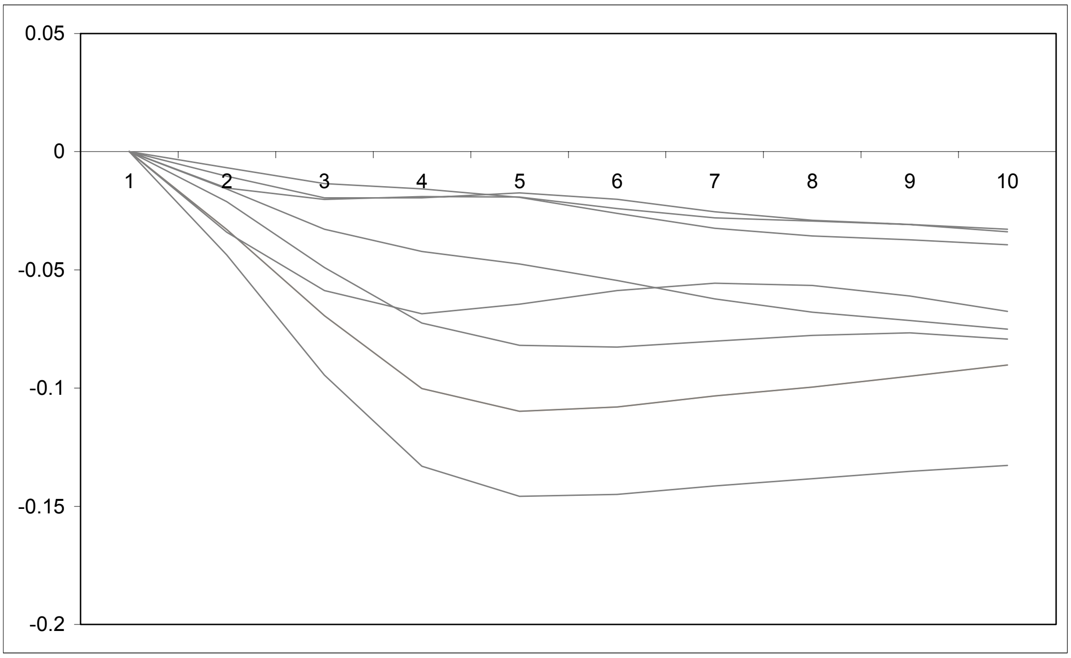


Figure 175: Hotels and Catering

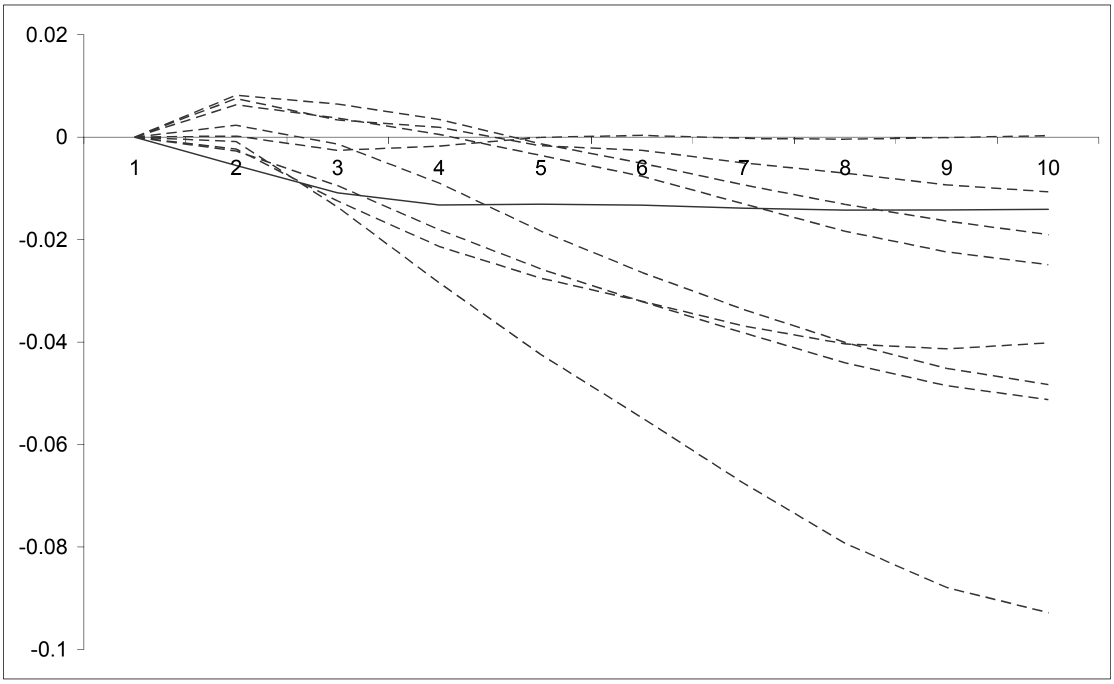


Figure 176: Financial Services

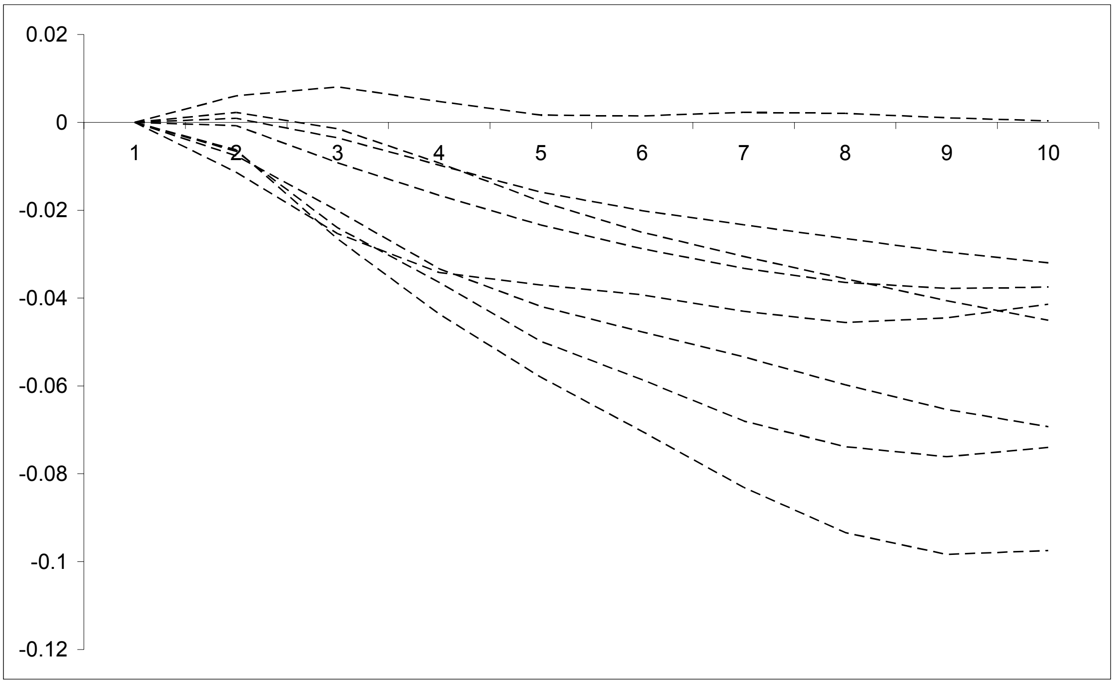


Figure 177: Mining

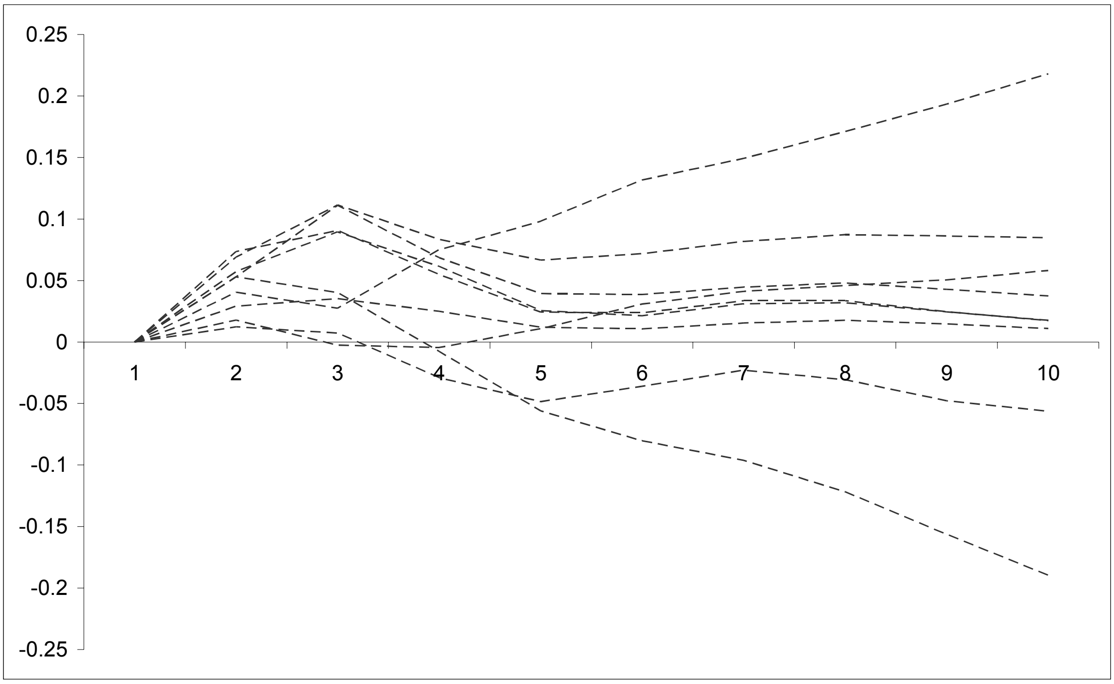


Figure 178: Manufacturing

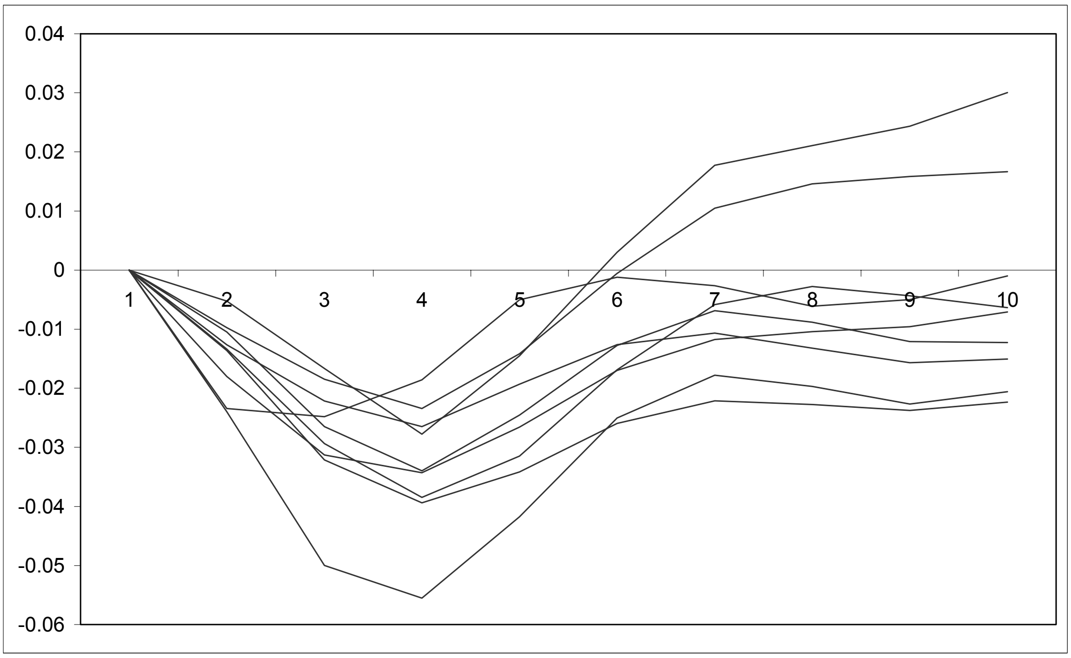
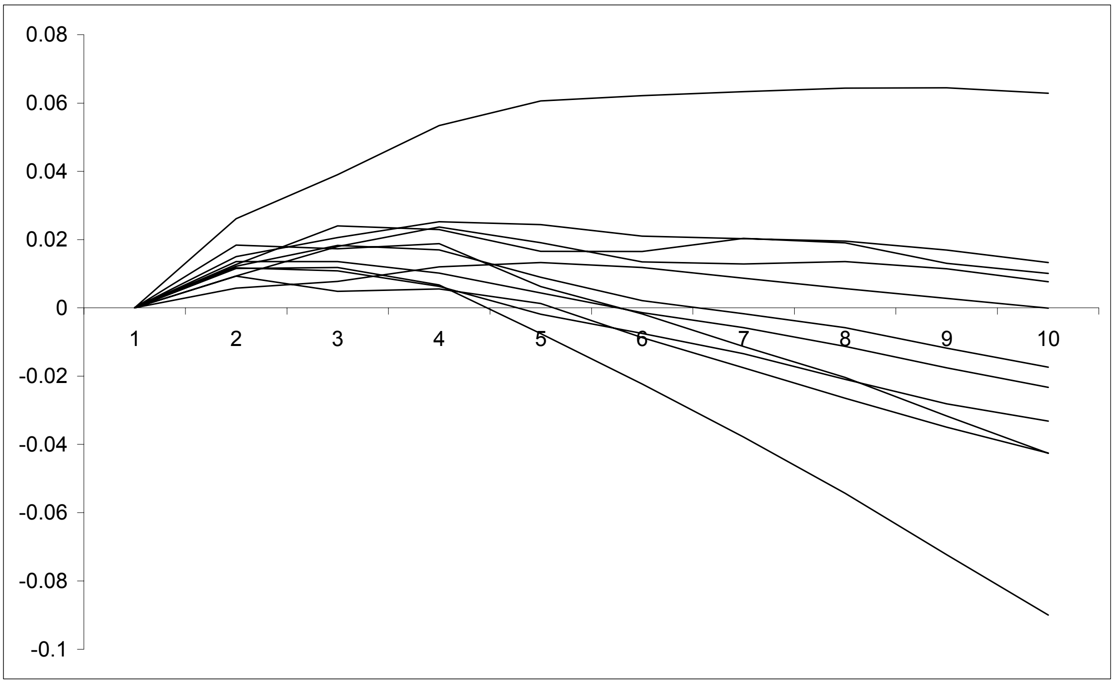
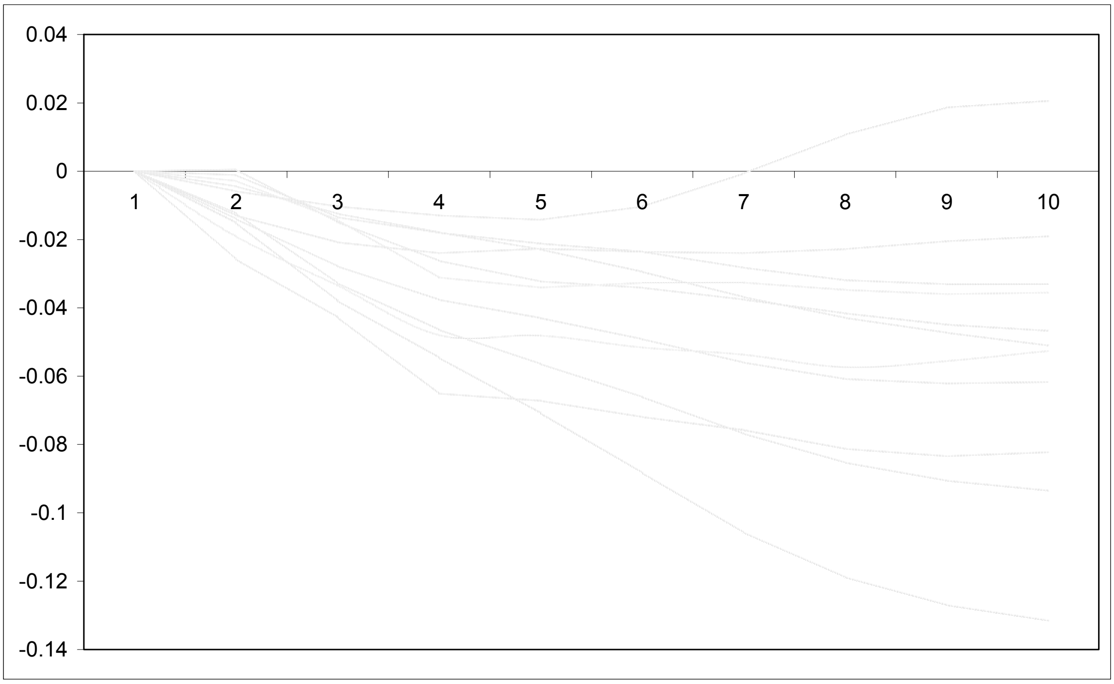


Figure 179: Public Administration



: Transport



Appendix 13: NKPC Estimate Using Output Gap

Table 87: Estimates for UK NKPC using adhoc (HP detrended) output gap

	OG v1	t-stat		OG v2	t-stat	
inf (t+1)	0.481	5.468	***	0.768	9.644	***
se	0.088			0.080		
inf (t-1)	0.520	5.987	***	0.250	4.101	***
se	0.087			0.061		
OG	0.104	1.002		-0.424	-3.636	***
se	0.104			0.117		
R2	0.805			0.788		
DW	2.482			2.568		

Appendix 14: Fits of Inflation vs Alternative Models, Rest of Regions

Figure 180: Plots of Inflation vs Alternative 'Fitted' Measures EA

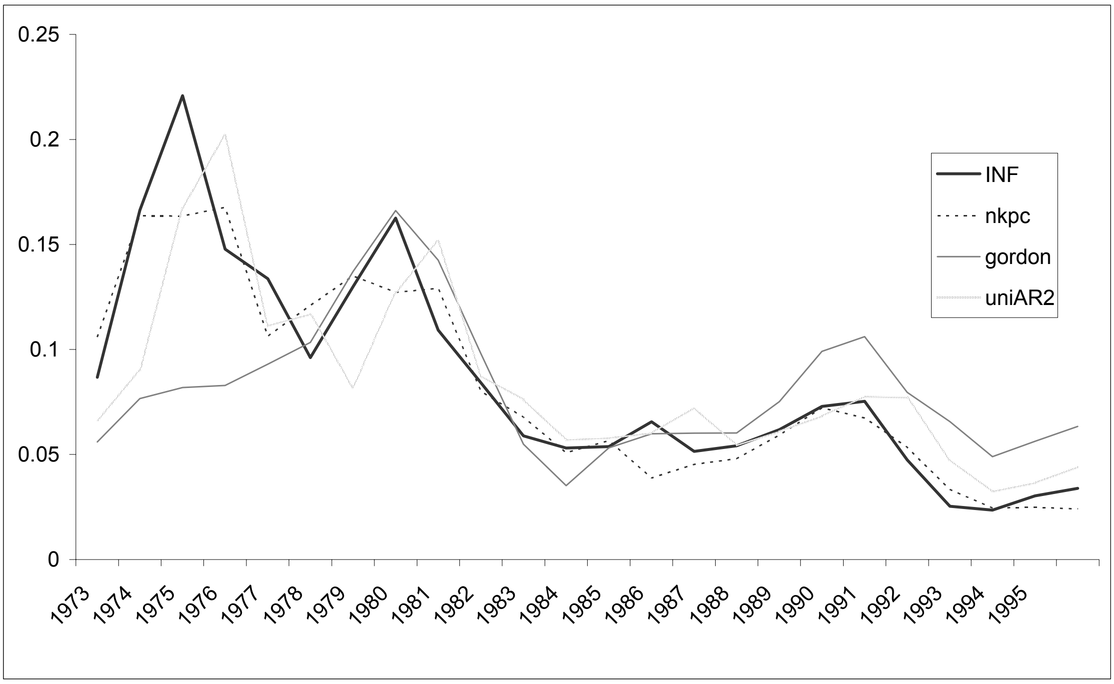


Figure 181: Plots of Inflation vs Alternative 'Fitted' Measures EM

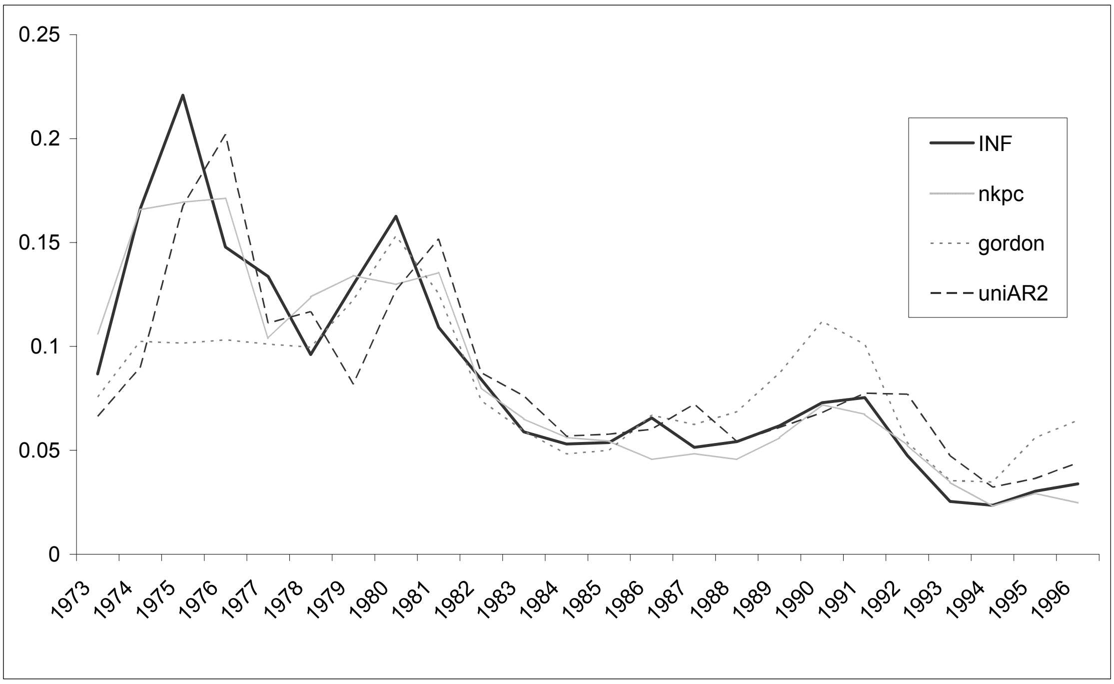


Figure 182: Plots of Inflation vs Alternative 'Fitted' Measures NE

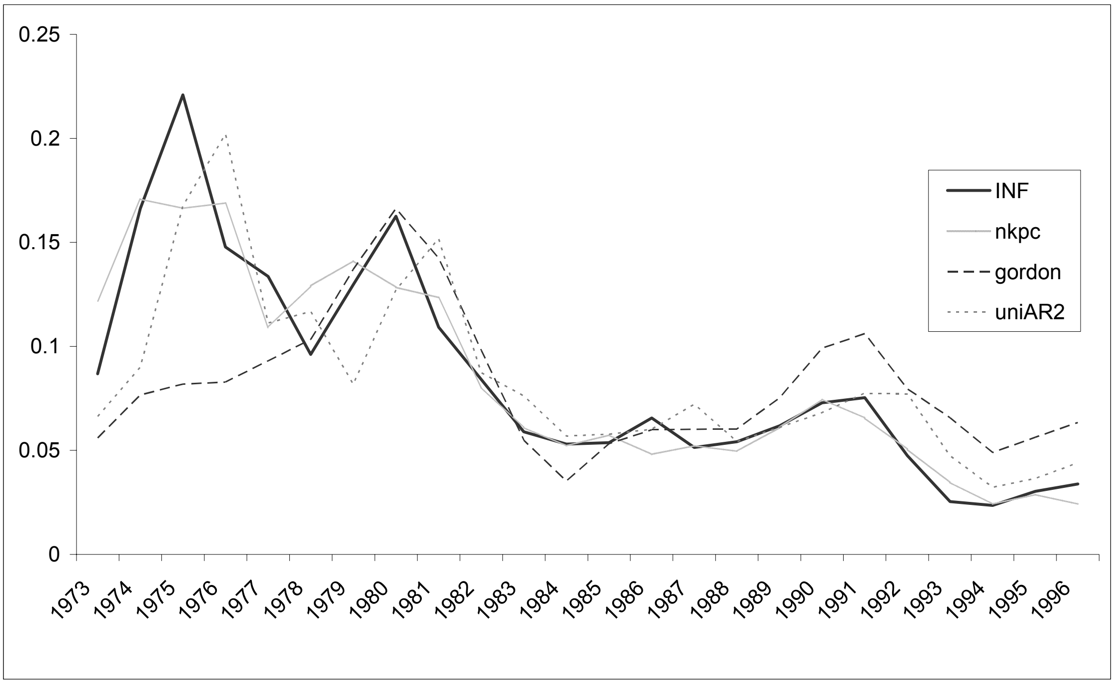


Figure 183: Plots of Inflation vs Alternative 'Fitted' Measures NW

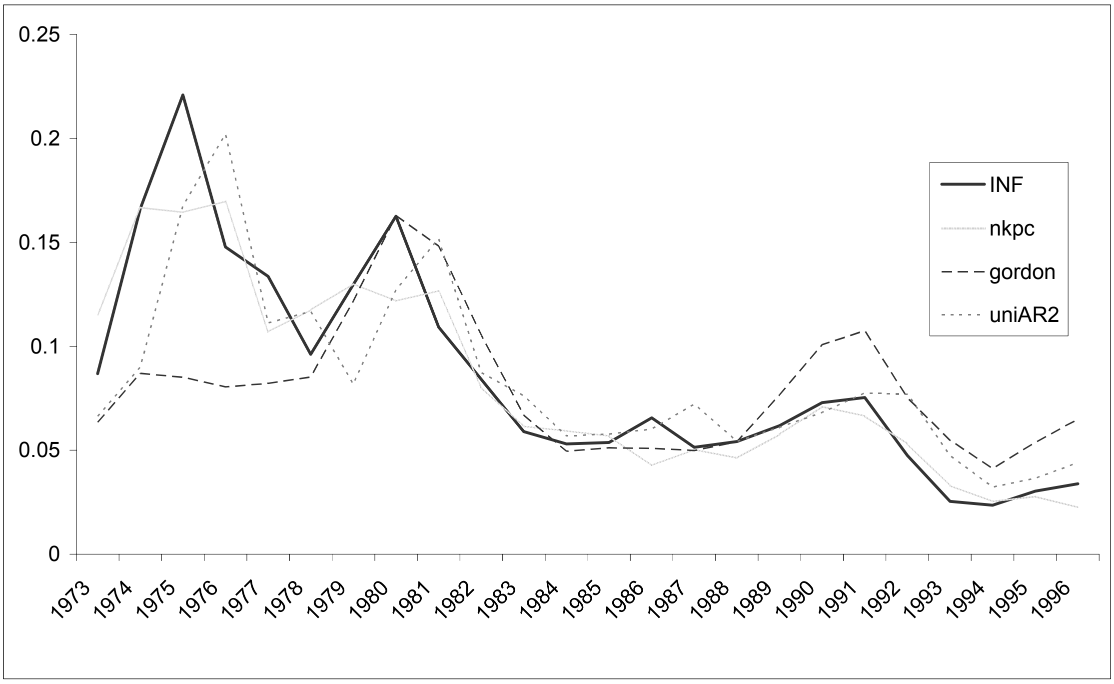


Figure 184: Plots of Inflation vs Alternative 'Fitted' Measures Sco

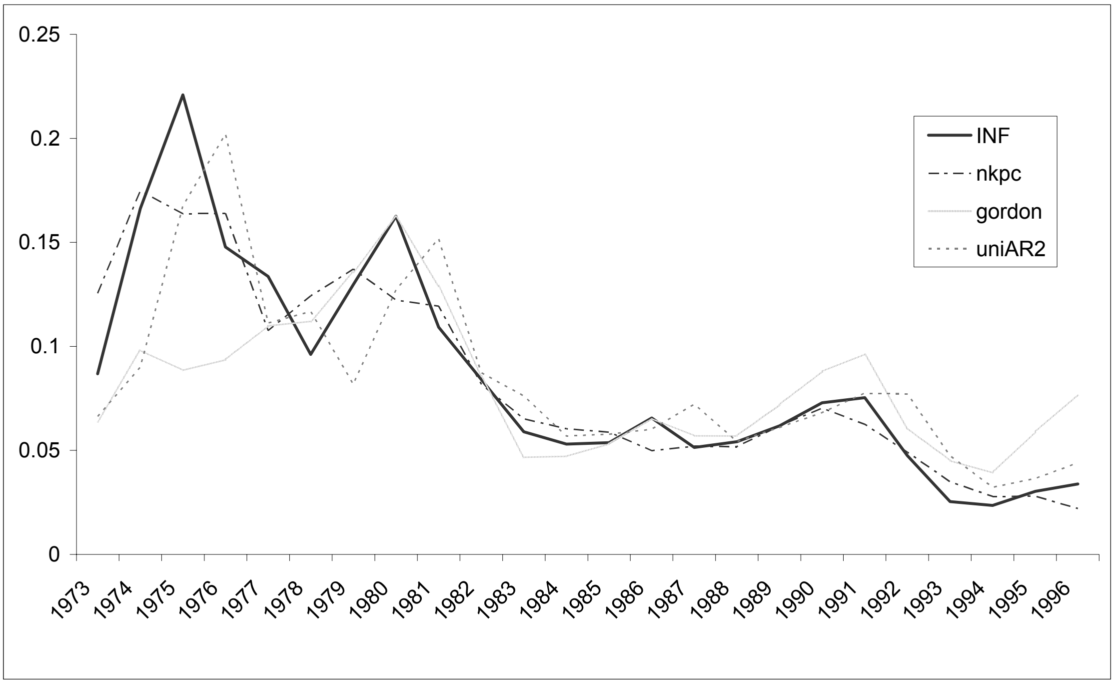


Figure 185: Plots of Inflation vs Alternative 'Fitted' Measures SW

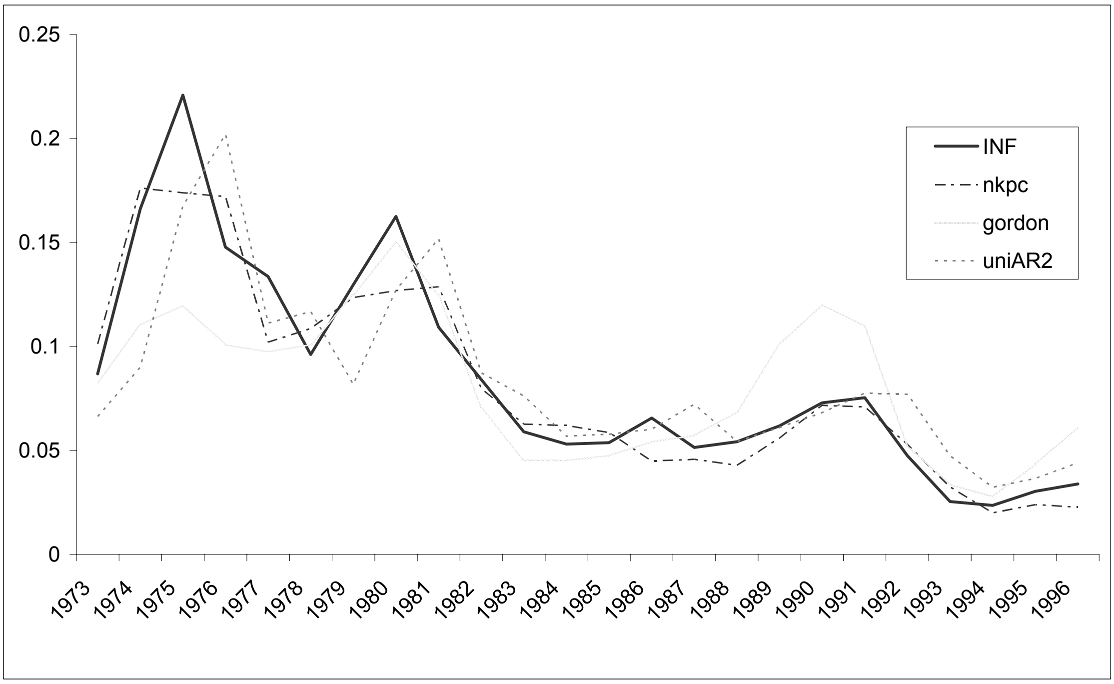


Figure 186: Plots of Inflation vs Alternative 'Fitted' Measures Wal

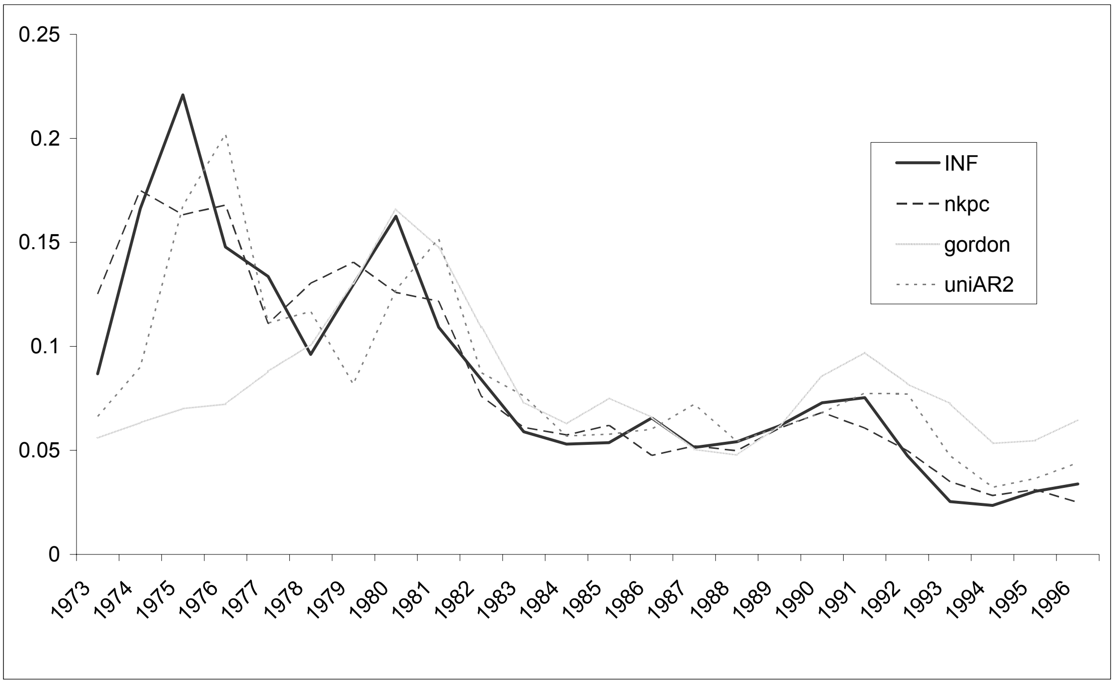
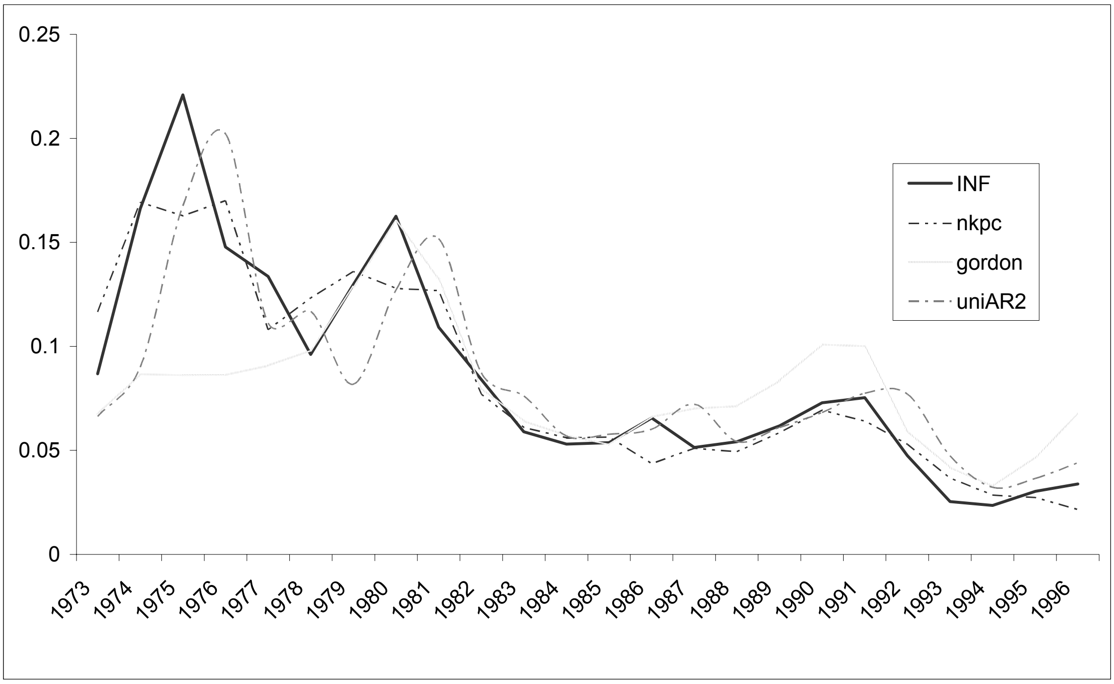


Figure 187: Plots of Inflation vs Alternative 'Fitted' Measures WM

Figure 188: Plots of Inflation vs Alternative 'Fitted' Measures Yks



Appendix 15: Bootstrapping Omega Estimate distributions[31]

1. Take the estimated unrestricted VAR process $Z_t = \hat{W}Z_{t-1} + \hat{y}_t$ as the data generating process (DGP), save the residuals $\{ \hat{y}_1, \hat{y}_2,.. \hat{y}_t\}$, T is sample size, with Z_t comprising the complete variable set, parameters and instruments (inflation, marginal cost, interest rates, output gap, exchange rate).
2. Simulate i = 1, …1,000 artificial samples $\{Z_t^i\}_{t=1}^T$ by taking random draw with replacement from the estimate residual coefficient vector and inserting them into the assumed DGP.
3. Compute the GMM coefficient for each data sample.

The following distributions of omega are produced for the regions. The distributions whilst reasonably normally distributed around the median estimates also exhibit a small frequency increase at higher levels of the parameter. This is down to the non-linear estimation, there being a second solution to the estimation. This is a result of the quality of the dataset and given we are bootstrapping with the methodology outlined above (ie a new variable set of two parameters and four instruments with an annual dataset this slight flaw is not unexpected.

[31] As outlined by Sondergarrd (2003).

Figure 189: Omega Bootstrap Distribution, Wal

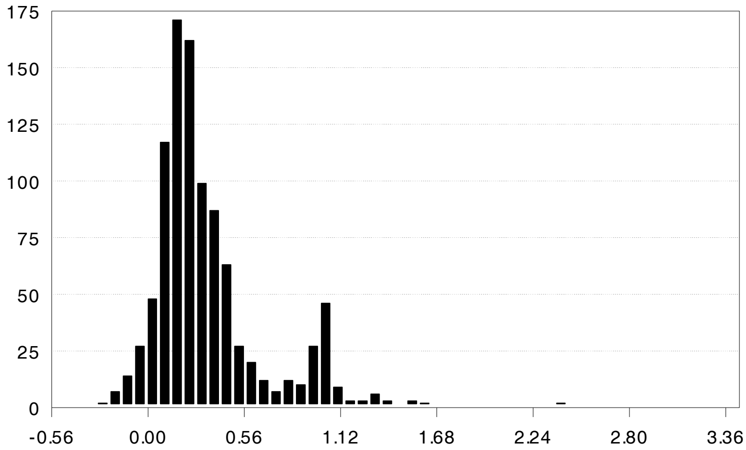


Figure 190: Omega Bootstrap Distribution, Sco

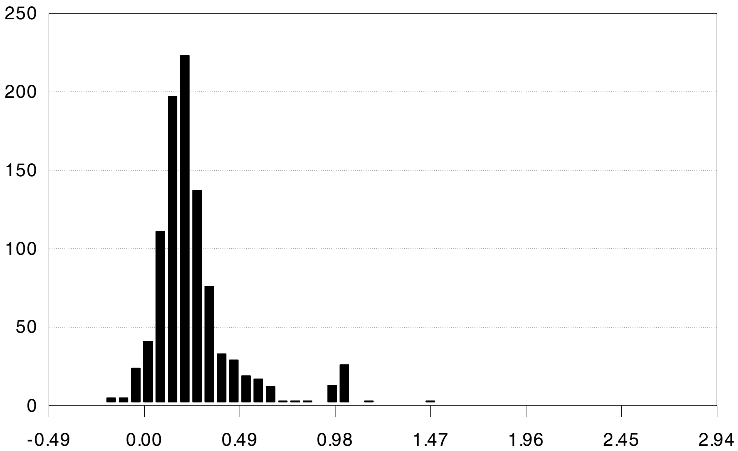


Figure 191: Omega Bootstrap Distribution, NW

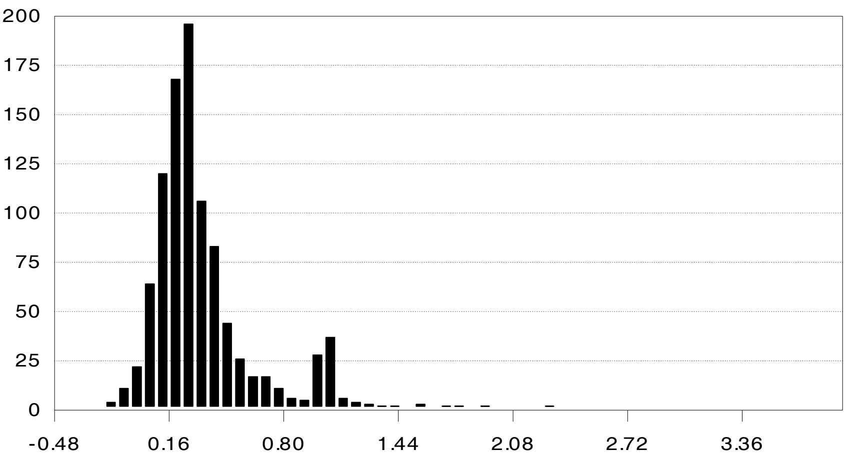


Figure 192: Omega Bootstrap Distribution, WM

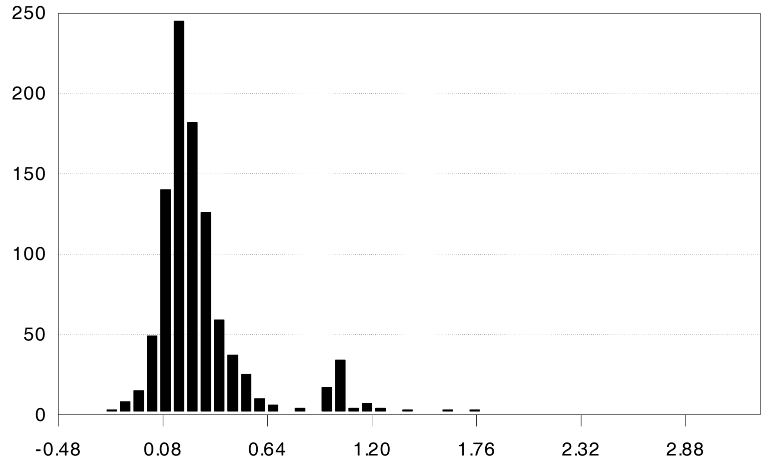


Figure 193: Omega Bootstrap Distribution, SW

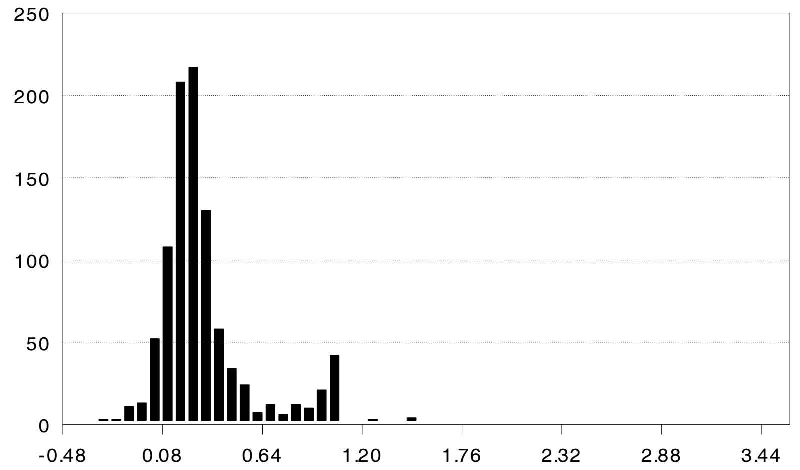


Figure 194: Omega Bootstrap Distribution, SE

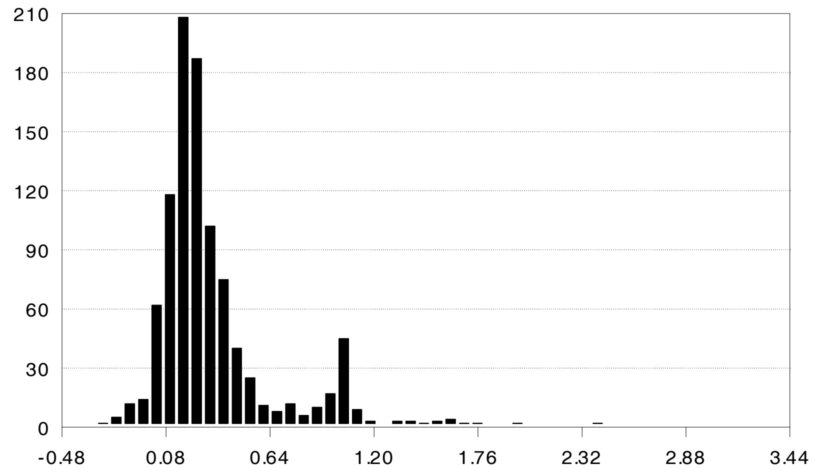


Figure 195: Omega Bootstrap Distribution, Ldn

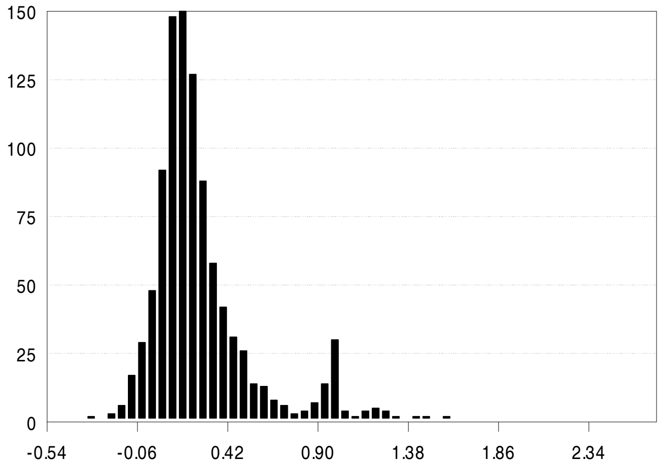


Figure 196: Omega Bootstrap Distribution, EA

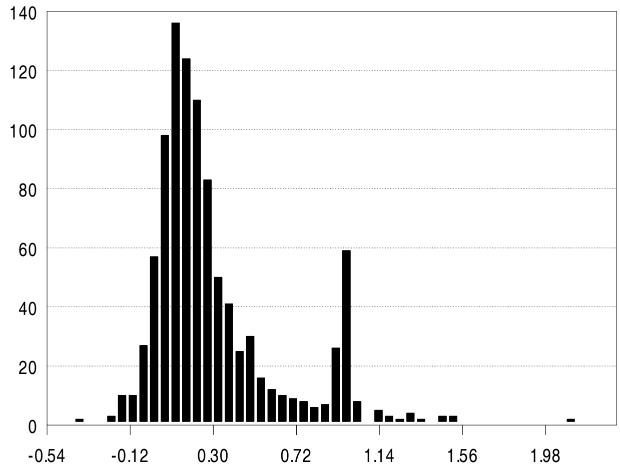


Figure 197: Omega Bootstrap Distribution, NE

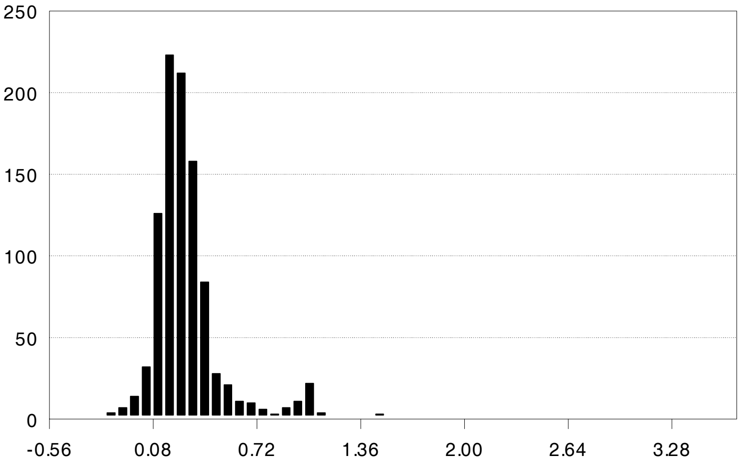


Figure 198: Omega Bootstrap Distribution, EM

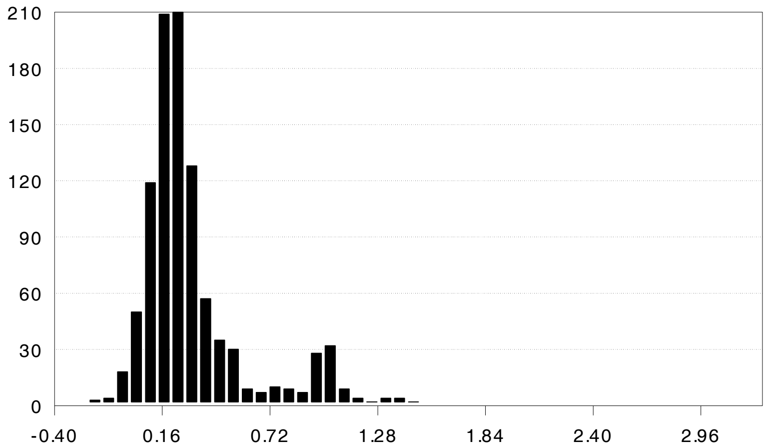


Figure 199: Omega Bootstrap Distribution, Yks

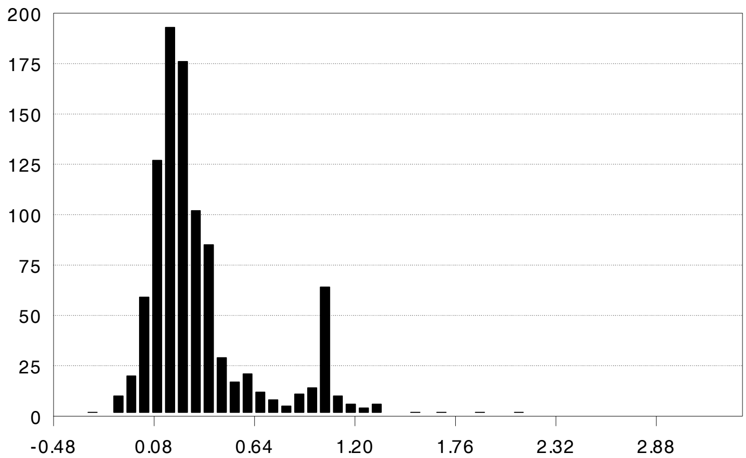
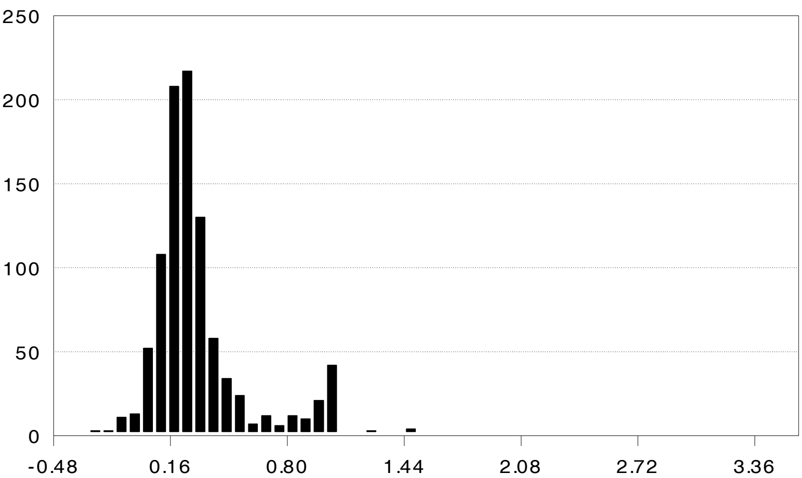


Figure 200: Omega Bootstrap Distribution, SW



Appendix 16: RATS Algorithm Covers Decomposition

```
calendar1976
allocate 1996:1
open data "c:\research\data\p2 y1 hetero deflated.xls"
data(format=xls,org=col) / gdpea gdpem gdpnth gdpnw gdpse gdpsw gdpwm gdpyks
gdpsc gdpwal infea infem infnth infnw infse infsw infwm infyks infsc infuk


system(model=BQ)
var gdpyks infyks
*therefore gdp is(1), inf(2)

lags 1 to 2
det constant
end(system)
estimate(noprint, resids=residuals, outsigma=v)


declare series eyt; set eyt 3 21 = 0
declare series ept; set ept 3 21 = 0
declare series stsup; set stsup 3 21 = 0
declare series stdem; set stdem 3 21 = 0
declare series covstsup; set covstsup 3 21 = 0
declare series covstdem; set covstdem 3 21 = 0

do i=3, 21
com eyt(i)=residuals(1)(i)
com ept(i)=residuals(2)(i)
end do i

com c = %varlagsums
com s1 = %mqform(%sigma,tr(inv(c)))
com s2 = %decomp(s1)
declare rectangular[series]BQstd(2,2)
com g = c*s2
*this gets it to percent normalisation
com g1=
||g(1,1)/%sigma(1,1)**.5,g(1,2)/%sigma(1,1)**.5|g(2,1)/%sigma(2,2)**.5,g(2,2)/%sigma(2
,2)**.5||

declare real alpha
com d = %varlagsums
com alpha = d(1,2)/d(2,2)
com g2 = ||1/(1+alpha),alpha/(1+alpha)|-1/(1+alpha),1/(1+alpha)||


*variance covariance of shock for ASAD then 4 NKPC
*sigma=inverse b times sigma e times inverse b transpose
 com CV2 = (inv(g2)*v*inv(tr(g2)))
```

```
*ASAD causality from supply to demand rho1 demand to supply rho2
com rho1 = cv2(1,2)/cv2(1,1)
com rho2 = cv2(1,2)/cv2(2,2)
com siginddemand = cv2(2,2)-(rho1^2*cv2(1,1))
com sigindsupply = cv2(1,1)-(rho2^2*cv2(2,2))


com sqsup = sqrt(cv2(1,1))
com sqdem = sqrt(cv2(2,2))
com sqidem = sqrt(siginddemand)
com sqisup = sqrt(sigindsupply)
com g2s= ||(sqsup*((alpha*rho1)+1))/(1+alpha),(sqidem*alpha)/(1+alpha)|-((1-
rho1)*sqsup)/(1+alpha),sqidem/(1+alpha)||
com g2d=||(sqisup/(1+alpha)), (rho2+alpha)*sqdem/(1+alpha)|-sqisup/(1+alpha), ((1-
rho2)*sqdem)/(1+alpha)||

*normalise
com g2snorm=
||g2s(1,1)/CV2(1,1)**.5,g2s(1,2)/CV2(1,1)**.5|g2s(2,1)/CV2(2,2)**.5,g2s(2,2)/CV2(2,2)**.
5||
com g2dnorm=
||g2d(1,1)/CV2(1,1)**.5,g2d(1,2)/CV2(1,1)**.5|g2d(2,1)/CV2(2,2)**.5,g2d(2,2)/CV2(2,2)**.
5||
com nkg2snorm=
||nkg2s(1,1)/CV2(1,1)**.5,nkg2s(1,2)/CV2(1,1)**.5|nkg2s(2,1)/CV2(2,2)**.5,nkg2s(2,2)/C
V2(2,2)**.5||
com nkg2dnorm=
||nkg2d(1,1)/CV2(1,1)**.5,nkg2d(1,2)/CV2(1,1)**.5|nkg2d(2,1)/CV2(2,2)**.5,nkg2d(2,2)/C
V2(2,2)**.5||


impulses(decomp=g1,model=bq,results=bqstd,noprint) * 12 *
impulses(decomp=g2,model=bq,results=lucas,noprint) * 12 *
impulses(decomp=g2snorm,model=bq,results=sup2dem,noprint) * 12 *
impulses(decomp=g2dnorm,model=bq,results=dem2sup,noprint) * 12 *
impulses(decomp=nkg2snorm,model=bq,results=nksup2dem,noprint) * 12 *
impulses(decomp=nkg2dnorm,model=bq,results=nkdem2sup,noprint) * 12 *


*recover time series of structural shocks

com denom = (g1(1,2)*g1(2,1))-(g1(1,1)*g1(2,2))
com denom2 = (g2dnorm(1,2)*g2dnorm(2,1))-(g2dnorm(1,1)*g2dnorm(2,2))
do i = 3, 21
com stsup(i)=((g1(2,1)*eyt(i))-(g1(1,1)*ept(i)))/denom
com stdem(i)=((g1(1,2)*ept(i))-(g1(2,2)*eyt(i)))/denom
com covstsup(i)=((g2dnorm(2,1)*eyt(i))-(g2dnorm(1,1)*ept(i)))/denom2
com covstdem(i)=((g2dnorm(1,2)*ept(i))-(g2dnorm(2,2)*eyt(i)))/denom2
end do i
```

```
com label=||'supply shocks','demand shocks','cov supply shocks','cov demand shocks'||
graph(header='times series of structural shocks',nodates,key=below,klabel=label) 4
#stsup; #stdem; #covstsup; #covstdem
com label=||'supply shocks','demand shocks'||
graph(header='times series of structural shocks',nodates,key=below,klabel=label) 2
#stsup; #stdem
com label=||'cov supply shocks','cov demand shocks'||
graph(header='times series of structural shocks',nodates,key=below,klabel=label) 2
#covstsup; #covstdem


com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='BQ',nodates,key=below,klabel=label) 4
#BQstd(1,1); #BQstd(1,2); #BQstd(2,1); #BQstd(2,2)


com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='lucas',nodates,key=below,klabel=label) 4
#lucas(1,1); #lucas(1,2); #lucas(2,1); #lucas(2,2)

com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='lucas sup2dem',nodates,key=below,klabel=label) 4
#sup2dem(1,1); #sup2dem(1,2); #sup2dem(2,1); #sup2dem(2,2)


com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='Cover Causality Dem2Sup',nodates,key=below,klabel=label) 4
#dem2sup(1,1); #dem2sup(1,2); #dem2sup(2,1); #dem2sup(2,2)


com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='nksup2dem',nodates,key=below,klabel=label) 4
#nksup2dem(1,1); #nksup2dem(1,2); #nksup2dem(2,1); #nksup2dem(2,2)

com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='nkdem2sup',nodates,key=below,klabel=label) 4
#nkdem2sup(1,1); #nkdem2sup(1,2); #nkdem2sup(2,1); #nkdem2sup(2,2)


*cum responses
dec rect[series]bqaccum(2,2)
do i= 1, 2
 do j=1, 2
 accumulate bqstd(i,j) 1 12 bqaccum(i,j)
 end do i
end do j

dec rect[series]lucasaccum(2,2)
do i= 1, 2
 do j=1, 2
```

```
 accumulate lucas(i,j) 1 12 lucasaccum(i,j)
 end do i
end do j

dec rect[series]s2daccum(2,2)
do i= 1, 2
 do j=1, 2
 accumulate sup2dem(i,j) 1 12 s2daccum(i,j)
 end do i
end do j

dec rect[series]d2saccum(2,2)
do i= 1, 2
 do j=1, 2
 accumulate dem2sup(i,j) 1 12 d2saccum(i,j)
 end do i
end do j

com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='BQ',nodates,key=below,klabel=label) 4
#BQaccum(1,1); #BQaccum(1,2); #BQaccum(2,1); #BQaccum(2,2)

com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='lucas',nodates,key=below,klabel=label) 4
#lucasaccum(1,1); #lucasaccum(1,2); #lucasaccum(2,1); #lucasaccum(2,2)

com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='s2d',nodates,key=below,klabel=label) 4
#s2daccum(1,1); #s2daccum(1,2); #s2daccum(2,1); #s2daccum(2,2)

com label=||'y,supply','y,demand','i,supply','i,demand'||
graph(header='COVER CAUSALITY Dem2Sup',nodates,key=below,klabel=label) 4
#d2saccum(1,1); #d2saccum(1,2); #d2saccum(2,1); #d2saccum(2,2)


*error decomp
errors(noprint, model=BQ, decomp=g1, results=vdcbq) * 24 *; errors(noprint, model=BQ,
decomp=g2dnorm, results=vcdcover) * 24 *

*relevant matrixes
dis 'alpha'; dis alpha; dis 'var/covar'; dis v; dis 'bq decomp'; dis g1; dis 'Lucas decomp';
dis g2; dis 'Lucas var/covar'; dis cv2; dis 'rho'; dis rho1; dis 'var inddemand'; dis
siginddemand; dis 'gamma'; dis rho2; dis 'var indsupply'; dis sigindsupply


alpha
     0.41928
var/covar
     8.46265
    -3.06725      7.05642
```

bq decomp

0.95649	0.29178
-0.64746	0.76210

Lucas decomp

0.70458	0.29542
-0.70458	0.70458

Lucas var/covar

12.27522	3.72281
3.72281	9.38456

rho
0.30328
var inddemand
8.25551
gamma
0.39670
var indsupply
10.79840