A Nation Divided?

Price and Output Dynamics in English Regions¶

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Abstract

In this paper we estimate a VECM model for inflation and output growth in different English regions, allowing for interactions between variables and between regions. The model permits the estimation not only of the degree of inter-regional correlation of price and output innovations, but also of the degree of heterogeneity in the dynamics of regional responses to these innovations. Although regional shocks are highly correlated, there is much more heterogeneity in regional responses to these shocks.

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1. Introduction

The introduction of the European Single Currency has generated a great deal of interest in the measurement of the costs incurred by regions that share a common currency but experience asymmetric macroeconomic shocks. The logic driving the analysis at the European level (at which "region" stands for a nation-state) has also been applied at the national level, the implicit question being: Have OECD nation-states been optimum currency areas? Examples of the latter are Funke and Hall (1998), Obstfeld and Peri (1998) and Giacometti and Pinelli (1999). The degree of heterogeneity between regions within an individual country has become a politically sensitive one in the UK, with the Bank of England having to defend itself from the charge that its stabilization policy gives more weight to the services-dominated South East than to the manufacturing-dominated North (see for example George, 2000). Our paper forms part of this literature: we will produce measures of the degree of asymmetry in shocks to different English regions. However, our paper differs from previous work in two ways.

The first is that existing papers focus on shocks to regional value added and/or employment and/or producer prices. In contrast, the main variable of interest to UK policymakers – as reflected in the Bank of England Act – is the rate of growth of consumer prices, with short-term output and employment stabilization as secondary concerns. It is therefore likely that knowledge of the degree of regional heterogeneity in shocks to consumer prices, and in the dynamics of the regional response to these shocks, will be more informative to British policymakers than knowledge about regional producer prices. The econometric model in this paper uses regional consumer price data along with regional GDP data.

The second difference concerns the econometric methodology implemented. The analysis is undertaken within a multi-region Vector Error Correction framework (VECM) of regional output and consumer prices. The framework allows for an extremely flexible method for characterising the evolution of each of the variables in each region, whilst accommodating potentially complicated forms of feedback, and interactions between the variables as well as the regions. In particular, it obviates the need to impose controversial theoretical restrictions.

The plan of the paper is as follows. Section 2 reviews the theoretical background that motivates our choice of consumer prices instead of producer or value added prices as the focus of attention. Section 3 describes the econometric methodology that

2

will be used to analyse these regional data series. The results of the analysis are presented in Section 4 and Section 5 summarises and concludes.

2. Why Focus on Consumer Prices?

Existing econometric studies of the macroeconomics of UK regions have typically measured prices using aggregate output price series or value added deflators, both in deflating regional output and in constructing regional inflation series. Recent examples include Funke and Hall (1998) and Barrios et al. (2001). However, the Bank of England Act sets out a target rate of inflation for a retail price index. This policy focus on consumer prices is reflected in the explicit objectives of other central banks (for example, those of Australia, Canada and New Zealand). The use of producer prices in econometric work seems to be based on data availability. But what is the rationale for the use of consumer prices in central bank reaction functions?

Vickers (1999) summarises a UK Monetary Policy Committee perspective on the rationale. He argues that the central bank's objective should be the stability (or at least predictability) of the money price of current consumption. Efficient inter-temporal allocation of consumption – and hence maximisation of the representative consumer's utility – depends on full information about the rate of exchange between money and consumption in every time period. Any unpredictability in the rate of exchange (for example, because of consumer price responses to exogenous shocks) will lead to a lower aggregate utility level.

These arguments are a response to the suggestion that central bank policy should be based on a range of price indices that encompasses more than just consumer prices (Alchian and Klein, 1973). Although the argument for a wider range is currently focussed on asset prices, it also applies to output and labour prices. The reason for excluding all these prices from the central bank's objective function is the same: they do not directly impact on the representative consumer's utility in the way that consumer prices do. Efficient policy-making requires a clear and coherent distinction between those macroeconomic variables that correspond directly to arguments of the utility function (real income/consumption; consumer price variability) and those that provide information about the macroeconomic environment in which the policy-maker is trying to facilitate utility maximisation. For example, in a Taylor Rule framework this is the distinction between the variables appearing in the policy-maker's loss function and those appearing (implicitly or explicitly) in the constraint.

For this reason it is the behaviour of consumer prices that is most directly relevant to an analysis of the size of the costs that arise when several regions share a single currency and monetary authority. The presence of asymmetric regional shocks (or of asymmetric regional responses to shocks) will mean that the extent to which a single monetary authority can stabilise the money price of current consumption across all regions simultaneously is limited, with consequent welfare losses to consumers in each region.[1]

Official regional consumer prices are not published in UK, so there are (to our knowledge) no existing studies of regional shocks that employ consumer prices. Nevertheless, it is possible, using official UK statistics, to construct an index of the major components of the retail price index that are likely to show substantial regional variation. Appendix 1 describes the construction and properties of this regional consumer price index, which will be used in our econometric analysis. The appendix also describes the properties of the officially published regional GDP data.[2,3]

3. The Modelling Framework

3.1 Overview

There are two established approaches to the estimation of regional shocks and their consequences. The first (exemplified by Funke and Hall, 1998) has focussed on the identification of aggregate supply and demand shocks in each region, using long-run restrictions in the style of Blanchard and Quah (1989). Because the interpretation of these structural innovations is the subject of some controversy (Levtchenkova et al., 1998), other authors (for example Giacometti and Pinelli, 1999) have chosen not to impose a particular set of theoretical long-run restrictions on their model. Instead they explore the dynamics of prices and output in each region through impulse response

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[1] Of course, in the absence of monetary policy interventions, asymmetric short-term regional price movements (i.e., variations in regional real exchange rates) can be efficient responses to asymmetric real shocks that bring each region closer to full employment. But they can nevertheless still lead to welfare losses through the uncertainty that they bring, and the resulting inefficiency in the inter-temporal allocation of consumption.

[2] Some private organisations do produce annual regional consumer price indices; but these series are not reported for periods prior to the mid-1970s, and so do not provide a large enough sample for time-series analysis.

[3] For reasons outlined in Appendix 1 it turns out not to be possible to construct the consumer price index for the Celtic Fringe regions, so the analysis will be restricted to England.

analysis. However, the application of impulse response analysis is not theoretically innocuous. The impulses to which the system's response is measured are orthogonalisations of the estimated reduced form innovations. These orthogonalisations (for example, Choleski decomposition) are not invariant to the ordering of the variables in the system. Implicit in the ordering is a theory about how the variables interact: in effect, a set of short-run restrictions.

We wish to avoid such restrictions, since our intention is to provide insights into regional differences and similarities in the evolution of observed variables rather than in the structural model underlying them. Our analysis of the dynamics is conducted by constructing measures of persistence and persistence profiles, as described below.

The overall modelling approach is based on a VAR framework in regional output growth and inflation. This framework provides a flexible method for characterising the evolution over time of regional output growth and inflation, as well as readily accommodating relatively complicated forms of inter-regional interactions and feedback.

Our model will include measures of output growth and inflation for the different regions of England. We begin by considering a general model of output growth (Δy) and inflation (Δp) for $i = 1, 2, \dots, m$ regions:

$$\Delta y_{it} = \mu_i^{y^*} + \sum_{s=1}^{q} b_{yiyis} \Delta y_{i,t-s} + \sum_{s=1}^{q} c_{yis} \Delta \overline{y}_{-i,t-s} + \sum_{s=1}^{q} d_{pis} \Delta \overline{p}_{t-s} + e_{it}^{y} \tag{1}$$

$$\Delta p_{it} = \mu_i^{p^*} + \sum_{s=1}^{q} b_{pipis} \Delta p_{i,t-s} + \sum_{s=1}^{q} c_{pis} \Delta \overline{p}_{-i,t-s} + \sum_{s=1}^{q} d_{yis} \Delta \overline{y}_{t-s} + e_{it}^{p} \tag{2}$$

where e_{it}^{z} represents an innovation in variable x in region i at time t ($z = [y, p]$), and the $\mu_i^{z^*}$ are intercept terms. Equations (1–2) include the terms:

$$\Delta \overline{y}_{-i,t-s} = \frac{1}{m-1} \sum_{h \neq i} \Delta y_{ht} \qquad \text{and} \qquad \Delta \overline{p}_{-i,t-s} = \frac{1}{m-1} \sum_{h \neq i} \Delta p_{ht} \tag{3}$$

which represent aggregate output growth and inflation outside of region i, and also the terms:

$$? \overline{y}_{t-s} = \frac{1}{m} \sum_i \Delta y_{it} \qquad \text{and} \qquad ? \overline{p}_{t-s} = \frac{1}{m} \sum_i \Delta p_{it} \tag{4}$$

which denote aggregate output growth and inflation across all regions. This is effectively a restricted VAR, the restrictions constraining any inter-regional feedbacks to work through an aggregate effect.

The model embodied by equations (1–2) assumes (i) that lagged output growths (inflation) outside the region of interest, have an equal effect on $? y_{it}$ $(? p_{it})$; (ii) lagged values of output growth in all regions have an equal effect on inflation in region i; and (iii) lagged values of inflation in all regions have an equal effect on output growth in region i. Although such a model restricts the possible interactions that exist between different regions, it will be a good approximation of the true DGP as long as there is not a great deal of heterogeneity in inter-regional feedback effects. Note also that there is no restriction on the structure of the correlation of contemporaneous shocks to different regions, so there is still scope for substantial inter-regional heterogeneity within the estimated model.

If important interactions exist between the levels of z_t, the existing modelling framework can be readily adapted to allow for the presence of cointegrating relationships. For example, the expression for output growth can be written as:

$$\begin{aligned} ? y_{it} = \mu_i^{y^*} &+ \sum_{s=1}^{q} b_{yiyis} ? y_{i,t-s} + \sum_{s=1}^{q} c_{yis} ? \overline{y}_{-i,t-s} + \sum_{s=1}^{q} d_{pis} ? \overline{p}_{t-s} \\ &+ l_{yi} (y_{it-1} - \overline{y}_{-i,t-1}) + l_{pi} (p_{it-1} - \overline{p}_{-i,t-1}) + l_i (y_{it-1} - p_{it-1}) + e_{it}^y \end{aligned} \tag{5}$$

and an analogous expression can be written for the inflation. In expression (5), $\overline{y}_{-i,t}$ and $\overline{p}_{-i,t}$ represent (equal-weighted) aggregates of (log) output and (log) prices, respectively, outside the region i of interest. Hence, in its most general form, the model allows for the possibility for the same long-run relationship across all m

regions between output levels, the same long-run relationship amongst price levels across all regions, and for price and output series in region i to be cointegrated.[4]

3.2 Measuring the persistence of shocks

The multi-region, multivariate VECM model presented above provides a flexible framework within which an analysis of output and price determination can be carried out. Of particular interest are the long-run responses of the variables in z_t to shocks, and the dynamics of adjustment to the long run. Pesaran et al. (1993), Lee and Pesaran (1993) and Lee and Shields (1999) provide the means for identifying the effects of specified types of shock, and for distinguishing between the effects of shocks common to all regions and those associated with individual regions. We can investigate the evolution of individual variables in response to shocks, without resorting to a priori restrictions, by using persistence profiles (see Lee, Pesaran and Pierse, 1992, henceforth LPP).[5] We will next provide a brief description of the measurement of the impact of shocks, showing how they may be used to construct measures of interest.

If a series is non-stationary, then the effects of a shock to the series is permanent and the size of the permanent effect of the shock is termed the 'persistence' of the shock. In LPP, a measure of persistence is suggested which can be applied to a multi-region model, and is based on the change in the conditional variance of z_t at the infinite horizon. If z_t is stationary, then eventually the series will return to its mean level with certainty, so the change in the conditional variance of predictions of z_t will tend to zero. Conversely, if z_t is I(1), the conditional variance of predicted future z_t continues to grow as the forecast horizon extends. Hence the extent of the permanent effect of a shock is reflected by the size of the growth in the conditional variance at the infinite horizon.

Specifically, referring to the multivariate, multi-region model described in expressions (1) – (3), if e_r is a (2m x 1) selection vector with unity in its rth element,

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[4] This would be the case, if, for instance, all the series were driven, equiproportionately, by the same (stochastic) trend, such that the series do not diverge in the long run.

[5] "Persistence profiles" are sometimes referred to as "generalised impulse responses".

and zeros elsewhere, then the persistence of a shock to output ($1 \leq r \leq m$) or prices ($m+1 \leq r \leq 2m$) in region i is given by:

$$P_i(x_i) = \left(\frac{e_r{'}A(1)\Omega A(1){'}e_r}{e_r{'}A_0\Omega A_0{'}e_r} \right)^{1/2} \qquad (6)$$

where $A_0 = I_{2m}$ and $x_i = (y_i, p_i)$. $P_i(y_i)$ (or $P_i(p_i)$) is to be interpreted as measuring the long-run response of output (prices) in region i to a shock the whole system that causes a number of changes in regional output and price levels, including an immediate unit change in output (prices) in that region. The persistence measures incorporate all of the interactions between variables in the system, insofar as they affect output (or prices) in region i at the infinite horizon. Just as the asymptotic persistence measure given in equation (6) is of potential importance in understanding the response of the English economy to shocks, so also is the path to the asymptote. This time profile of the response to shocks ("persistence profile") is calculated as in equation (6), but replacing $A(1)$ (which represents the infinite horizon entity) with the corresponding n^{th} horizon matrix, $A(L) = \sum_{k=0}^{n} A_k L^k$.[6] Both the asymptotic measure and persistence profiles will be discussed in the following section.

In a similar vein, we can calculate a measure of the permanent effect on region i's output of a shock to the whole system that causes a number of changes in regional output and price levels, including a immediate unit change in the output of the whole country, by using the selection vector w_y (or w_p). This is a $2m \times 1$ selection vector with ones in the first m ($m+1$ to $2m$) elements, and zeros elsewhere. The persistent effect on region i's output, when a shock causes economy-wide output to rise by one percent is given by:

$$P_i(y) = \left(\frac{e_r{'}A(1)\Omega A(1){'}e_r}{w_y{'}A_0\Omega A_0{'}w_y} \right)^{1/2} \qquad (7)$$

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[6] See Lee and Pesaran (1993), Lee (1998), Lee and Shields (1998) for further details of how persistence profiles can be derived.

where the value of r $(1 \leq r \leq m)$ determines the selection of the output of a particular region. An analogous expression can be given for a shock to the system that includes a unit change in the inflation rate of the whole country $(P_i (p))$ by using w_p in place of w_y in expression (7) with $m+1 \leq r \leq 2m$.

It is possible to construct various decompositions of these persistence measures. Consider first decomposing the vector of shocks to each variable in each region into three orthogonal components: a part due to a nationwide output shock, a part due to a nationwide price shock plus an idiosyncratic component. More formally,

$$\mathbf{e}_t = \overline{e}_t^{\ y} w_y + \overline{e}_t^{\ p} w_p + \mathbf{e}_t^d \qquad (8)$$

where $\overline{e}_t^{\ y}$ and $\overline{e}_t^{\ p}$ represent the nationwide output and price shocks and $\mathbf{e}_t^d$ is the $2m \times 1$ vector of idiosyncratic innovations. Now consider a typical e_t, that is, one causing aggregate output across the country to rise by one percent on impact. For each region i, it is possible to construct a persistence profile for output corresponding to the common-output-shock component of this e_t. This persistence measure will be denoted $P_i (\overline{y}_i)$. $P_i (\overline{y}_i)$ can be thought of as one component of $P_i (y)$, the other main component being the output persistence measure corresponding to the idiosyncratic innovation $\mathbf{e}_t^d$.[7] This measure will be denoted $P_i (\tilde{y}_i)$.

An analogous exercise can be performed with price persistence profiles. Consider a typical e_t causing prices in all regions to rise by one percent on impact. For each region i, it is possible to construct a persistence profile for prices corresponding to the common-price-shock component of this e_t. This persistence measure will be denoted $P_i (\overline{p}_i)$. $P_i (\overline{p}_i)$ can be thought of as one component of $P_i (p)$, the other main component being the price persistence measure corresponding to the idiosyncratic innovation $\mathbf{e}_t^d$. This measure will be denoted $P_i (\tilde{p}_i)$.

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[7] The common price shock $\overline{e}_t^{\ p}$ will also lead to changes in output in each region. However, the corresponding persistence measures all turn out to be very small, and are not discussed in the next section.

Formally, if $W^y = E(\overline{e_t^{y^2}})w_y w_y'$, $W^p = E(\overline{e_t^{p^2}})w_p w_p'$ and $W^d = E(e_t^d e_t^{d'})$, the two additional persistence measures are defined as:

$$P_i(\overline{y}_i) = \left(\frac{e_r 'A(1)\Omega^y A(1)'e_r}{w_y 'A_0 \Omega A_0 'w_y}\right)^{1/2} \qquad \text{and} \qquad P_i(\overline{p}_i) = \left(\frac{e_r 'A(1)\Omega^p A(1)'e_r}{w_p 'A_0 \Omega A_0 'w_p}\right)^{1/2} \qquad (9)$$

where $1 \le r \le m$ for $P_i(\overline{y}_i)$ and $m+1 \le r \le 2m$ for $P_i(\overline{p}_i)$. In a similar way, we can construct persistence measures for output and prices corresponding to the idiosyncratic component of e_t, e_t^d.

In summary, we have three types of persistence measure for output growth (and inflation). Estimates of these three measures will be presented in the following section:

1. $P_i(y_i)$ (or $P_i(p_i)$): a measure of how output (or prices) in each region evolves in response to a typical shock to the system causing a unit change in output (or prices) in that region.

2. $P_i(y)$ (or $P_i(p)$): a measure of how output (or prices) in each region evolves in response to a typical shock to the system causing a nationwide unit change in output (or prices).

3. $P_i(\overline{y}_i)$ (or $P_i(\overline{p}_i)$): a measure of how output (or prices) in each region evolves in response to the common-output-shock component (or common-prices-shock component) of a typical shock to the system causing a nationwide unit change in output (or prices). Corresponding to this measure is a measure of persistence in response to the regionally idiosyncratic component: $P_i(\widetilde{y}_i)$ (or $P_i(\widetilde{p}_i)$).

All three measures are of potential importance in understanding how the English economy responds to economic shocks. The first measure provides a basic indication of how similar or dissimilar the dynamics of output and prices are across English regions. If two or more regions exhibit similar persistence profiles, this suggests some inter-regional homogeneity in their dynamic response to macroeconomic shocks. And even if these profiles differ in shape, there might still be some long-run convergence regarding the effects of a shock, indicated by similar values of the asymptotic persistence measures $P_i(y_i)$ and $P_i(p_i)$. However, these measures do not directly

indicate the extent of inter-regional homogeneity with regard to a "nationwide" shock. For this reason the second measure of persistence is also of potential interest.

The second persistence measure is of potential use in evaluating the impact of a shock that is known to have a certain effect on impact on output (or prices) in the aggregate. It is often the case that the effect of a certain policy innovation on the national macro-economy – both the effect of the innovation on impact and the subsequent long-run response – has been estimated with some precision. Empirical studies of the monetary transmission mechanism, for example, are now highly sophisticated (Bank of England, 1999). But little if anything is known about the regional decomposition of such aggregate effects. The aggregate effect of a certain shock might be a result of moderate movements in output (or prices) in all regions, or alternatively a result of large movements in some and no movement in others. Knowledge about which regions bear the brunt – or gain the benefit – of a certain policy innovation ought to be an important part of any evaluation of the welfare effects of the policy.

Construction of the persistence measures P_i (y) and P_i (p) can help to address this issue. They show the asymptotic regional effects of a "typical" aggregate shock to output (or prices). In other words, they show what we can expect the regional decomposition of an aggregate shock and its consequences to look like, on average, and how much heterogeneity there is in the effect of the shock at the regional level. Of course, if output (or prices) turn out to be co-integrated across all regions, then there will be no heterogeneity at the infinite horizon. But even in this case, there might be substantial regional heterogeneity in the path to the asymptote. The larger the magnitude of such heterogeneity, the greater will be the degree of inter-regional "inequality" resulting from the policy shock.[8]

To the extent that there does exist any heterogeneity in P_i (y) or P_i (p) across regions, we will be interested in the reasons for this heterogeneity. Does it arise because an aggregate shock translates into different effects on impact in different regions, or because the dynamic response to the shock varies across regions? For example, inter-regional variation in P_i (p), or in the corresponding persistence profile, might be largely because an unanticipated increase in aggregate prices (after,

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[8] In the figures and tables reported below, the infinite horizon is approximated by a 30-year horizon, so there are some (very small) inter-regional differences in the asymptotic price persistence measures.

say, an increase in the base interest rate) typically involves immediate inflation of differing magnitudes in different regions. Alternatively, the effect of the shock on impact might be homogenous across regions, the inter-regional variation in $P_i(p)$ resulting from different dynamics in different regions. In the latter case, the heterogeneity in $P_i(y)$ or $P_i(p)$, to the extent that there is any, is a consequence of differences in the structures of regional economies that generate differences in the way the economies respond to the same shock.

Evidence on this kind of decomposition is provided by the third measure of persistence. This measure is an indication of the relative importance of the common-output-shock component (or common-price-shock-component) of a "typical" shock to output (or prices) in a particular region (i.e., a shock to the system incorporating a unit change in output or prices in that region). If the persistence measures corresponding to these common-shock components ($P_i(\overline{y}_i)$, $P_i(\overline{p}_i)$) are large relative to the persistence measures corresponding to the idiosyncratic innovations ($P_i(\widetilde{y}_i)$, $P_i(\widetilde{p}_i)$) then any regional heterogeneity in the aggregate shock persistence measures $P_i(y)$ and $P_i(p)$ must be largely due to regional differences in the dynamic response to shocks. If on the other hand $P_i(\widetilde{y}_i)$ and $P_i(\widetilde{p}_i)$ are the major components of $P_i(y)$ and $P_i(p)$, then we cannot ascribe the regional heterogeneity just to heterogeneous dynamics: regional variations in the effects on impact corresponding to an aggregate shock are part of the story.

4. Estimating Regional Measures of Persistence

In this section we present our estimates of the three persistence measures discussed in Section 3, using the regional price and GDP data discussed in Appendix 1. These measures are based on a VECM model of annual consumer price inflation[9] and GDP growth in each English region for the period 1967-1996: the South East (SE), East Anglia (EA), the South West (SW), the East Midlands (EM), the West Midlands (WM), Yorkshire-Humberside (YH), the North West (NW) and the North (NO).

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[9] As discussed in Appendix 1, the inflation measure is limited to those components of the RPI that are likely to exhibit substantial regional variation. Appendix 1 also explains the motivation for the sample period.

4.1 Time-series properties of the data and estimation of the VECM model

The first stage of our empirical analysis is to test for the order of integration of our price and output series, using the standard panel unit root test of Im et al. (1997). We stack the regional output series and the regional price series and perform just two unit root tests, and under the assumption that all the output series and all the price series will be of the same order of integration, the test statistics have a standard normal distribution. The panel unit root test statistics are reported in Table 1. The table indicates the logarithms of both prices and output to be difference stationary, so the modelling framework in difference form outlined in the previous section is appropriate to our data.

We also test for the three types of cointegration implicit in equation (5) above: cointegration between prices and GDP within one region, cointegration between regional and national prices and cointegration between regional and national GDP. Details of the cointegration tests are available on request. Briefly, we find that:

1. For no region is GDP cointegrated with prices.

2. For no region is GDP cointegrated with national average GDP.

3. For all regions prices are cointegrated with national averages prices, with a loading insignificantly different from [1, –1]. In other words, there is inter-regional PPP in levels with a fixed wedge.

So the estimated VECM is a restricted version of equation (5) in which l_{yi} and l_i are set to zero. In fact, the cointegration term l_{pi} is insignificant in all of the GDP regressions. It is significantly negative in all the price regressions, except for the South East where it is insignificantly different from zero. In other words, prices outside the South East adjust to keep in line with (i.e., a constant fraction of) national prices, but South East prices do not adjust in response to those in the rest of the country. In this sense, the South East is the dominant region in England. Cointegration in regional prices is achieved by price adjustment in N–1 regions; the Nth region is the South East.

The cointegration of regional prices means that, by construction, regional persistence measures for nationwide price shocks will converge asymptotically. However, the persistence profiles for regional prices might still exhibit substantial heterogeneity, since the convergence is consistent with regional heterogeneity in short run price dynamics. The absence of cointegration in regional GDP means that heterogeneity in persistence profiles is a possibility in both the short and the long term.

4.2 Estimates of regional persistence in output

Before discussing the persistence measures in detail, it is worth noting that the estimated e_t indicate a reasonably high degree of inter-regional correlation of shocks to both output growth and inflation. The correlation coefficients for the innovations to regional output growth and inflation are listed in Table 2.[10] All correlation coefficients are large and positive. For output growth, all correlations with the South East, the economically dominant region in England, are 70% or greater. For inflation, correlation coefficients are generally slightly lower, but all correlations with the South East are still positive. (The two regions with relatively low correlation coefficients are the North of England and the East Midlands.) The generally high inter-regional correlations are consistent with previously published findings, for example Funke and Hall (1998). If our discussion of regional English economic shocks were limited to observations about the correlation of shocks on impact, then we would conclude, as have previous authors, that there is a large degree of similarity across the country, and not that much heterogeneity.

Locations of the Various Persistence Measures in Figures and Tables

$P_i(y_i)$: Table 3A , Figures 1A–1B $P_i(p_i)$: Table 3A , Figures 3A–3B

$P_i(y)$: Table 3B , Figure 2A–2B $P_i(p)$: Table 3B , Figures 4A–4B

$P_i(\overline{y}_i)$: Table 4A $P_i(\overline{p}_i)$: Table 4A

$P_i(\widetilde{y}_i)$: Table 4B $P_i(\widetilde{p}_i)$: Table 4B

However, when we go on to construct persistence measures for English regions, the picture becomes rather less straightforward. For GDP, the first persistence measure ($P_i(y_i)$, the response in region i to a shock causing a unit change to output in region i on impact) reveals a substantial degree of inter-regional heterogeneity, as indicated by

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[10] The results relate to measures from the 'restricted' version of the VECM model, where zero restrictions have been imposed on coefficients for which the absolute t values are less than unity. Having obtained a more parsimonious representation, F-tests on the joint validity of the restrictions have been carried out in order to ensure that their imposition does not violate the data. Similar conclusions, however, arise from the unrestricted form.

the asymptotic persistence measures in Table 3A and the corresponding persistence profiles in Figures 1A–1B.[11] The asymptotic effect of a 1% shock to GDP in East Anglia is estimated to be 0.49%; at the other extreme the corresponding figure for the West Midlands is 1.31%, and for the South East 1.27%. Two different regions can respond very differently to an initial shock to output in those regions. (Standard errors are small enough for the difference between the two extremes to be significant at the 5% level. Imposing more restrictions on regional dynamics would reduce the size of the standard errors, but we do not pursue this here.)

This heterogeneity in regional dynamics is also apparent when one considers the response of GDP in each region to an aggregate national shock to GDP $(P_i(y))$, recorded in Table 3B and in Figures 2A–2B. Again, the greatest persistence is shown by the West Midlands and the South East, with the other regions showing substantially less, especially East Anglia and the North. If there were a shock to aggregate output, the eventual impact on different parts of England would typically vary substantially. Table 4 suggests that in fact the effects of the common-output-shock component of the aggregate shock dominate the effects of regionally idiosyncratic ones, since the persistence measures corresponding to the common-output-shock component $(P_i(\bar{y}_i))$ are much larger than the persistence measures corresponding to the idiosyncratic component $(P_i(\tilde{y}_i))$ in all regions. Such dominance fits in with the observation that there is a high degree inter-regional correlation in shocks to GDP (Table 2A). This high correlation does not save the different English regions from substantial heterogeneity in the evolution of GDP, because the dynamics of their responses to shocks are so different (Figures 1A–1B). When there is a shock to aggregate output, the impact on each region is typically quite similar, and the response to the idiosyncratic component of the regional impact does not constitute an important part of the regional persistence profile. But the regionally common shock that constitutes the main part of a typical aggregate income shock does not translate into a regionally homogenous response to the shocks: different regions, with different underlying economic structures, respond in different ways.

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[11] The profile for East Anglia (Figure 1B) is shown separately from those for other regions (Figure 1A) because there is some oscillation towards equilibrium in East Anglia that is absent in other regions, and because convergence on the steady state takes somewhat longer.

4.3 Estimates of regional persistence in prices

Since the regional price series are cointegrated with each other, the persistence measures for aggregate price shocks ($P_i(p)$) converge together, as indicated in Table 3B and Figures 4A–4B. Moreover, there is a group of regions ("Group A" in Figures 3A and 4A) which share almost identical price dynamics, as indicated by the persistence measures for responses to region-specific shocks ($P_i(p_i)$) depicted in Figure 3A. Correspondingly, the persistence profiles in Figure 4A (illustrating the responses to an aggregate price shock for this group) are virtually indistinguishable. A 1% shock to prices in any of these regions leads eventually to a 0.6%–0.8% change in the price level, with some overshooting along the way. The group consists of East Anglia, the East Midlands, the North, the South West and Yorkshire-Humberside.

However, there are three regions ("Group B" in Figures 3B and 4B) for which the price dynamics are somewhat different. The differences in the West Midlands and the North West are relatively minor: in the West Midlands the overshoot is larger, and in the North West it persists for longer. But the overall pattern of these regions' transition to the asymptote is similar to that of Group A's. The one outlier is the South East, whose persistence profile exhibits no overshooting, but rather oscillates on its way to the steady state. In the reduced-form framework of the model estimated in this paper, it is not possible to state categorically why the price dynamics of the South East should be atypical, but the oscillating pattern for prices is consistent with a housing market that is particularly prone to booms and busts.

One cautious conclusion to be drawn from these results is that there is less heterogeneity in the dynamics of regional consumer prices than there is in the dynamics of regional output. One stylised scenario that we can reject is that cross-regional price variations absorb the effects of real shocks and mitigate asymmetries in regional output growth and employment. With the (admittedly large) exception of the South East, regional consumer price inflation rates do not exhibit a great deal of heterogeneity.

This leads to a tentative policy conclusion. Even if there is substantial regional variation in output prices, resulting from regional heterogeneity in the structure of production (some regions being more or less intensive in manufactures or services than others), this is not necessarily of great importance to a policy-maker who is concerned only about variations in inflation. Regardless of the regional variations in

producer prices, movements in consumer prices – those prices that are likely to enter directly in the representative consumer's utility function – are quite homogenous across regions. So the costs of regional asymmetries will be large only if income has substantial weight in the policy-maker's loss function. However, a very important caveat to this conclusion is that our estimated persistence profile for the South East is anomalous. Exploring the reasons for and robustness of this anomaly will constitute an important avenue of future research.

5. Summary and Conclusion

Having constructed a model of regional GDP growth and consumer price inflation for the English economy, we find that shocks to different regions are quite highly correlated, and that the typical shock to aggregate prices or output translates into corresponding regional shocks that are reasonably homogenous. This result is similar to those of previous papers on regional UK data, for example Funke and Hall (1998). Moreover, regional prices are cointegrated in levels, so that the ratio of prices in one region to those in another is constant in the long run: over the long run regional inflation rates will not diverge.

However, these results mask a substantial degree of heterogeneity across English regions. The response of inflation to a given shock does vary somewhat from one region to another, with some regions' prices departing from their long-run level by a greater degree, or for a longer time, in the wake of a shock. In these respects the South East, the economically dominant region in the UK (with over 3 times the GDP of the next largest region), is the most atypical, following a path to equilibrium that is very different from that of the rest of the country. With the exception of the South East, the regional variations are relatively minor. A policy-maker whose main goal was price stability should be concerned about likely difference between the impact of a policy innovation on the South East, and its impact on the rest of the country; but other regional asymmetries are quite minor.

However, there is more substantial heterogeneity in the response of regional GDP to shocks. GDP levels are not cointegrated across regions, so a shock common to all regions can have a heterogeneous impact on those regions in the long run. For a given percentage shock to regional GDP, the largest degree of persistence is in the South East, the smallest in the North and East Anglia. (Broadly, "multiplier" effects in the core of the country are larger than in the periphery: a stylised fact that merits further

research.) These variations are large enough to warrant considerable care in interpreting the welfare effects of the estimated aggregate output response to a given innovation. In the long run, the aggregate response masks large differences from one region to another.

In this paper we have avoided making controversial assumptions about the structure of the English macro-economy, and have not imposed theory-based restrictions on our econometric model. However, the results of our study suggest that an effective and equitable macroeconomic policy in the country will require an understanding of the economic structure underlying the regional heterogeneity that we have uncovered. Any accurate structural representation of the economy must allow for a substantial degree of regional variation.

References

Bank of England (1999) Economic Models at the Bank of England, London.

Barrios, S., Brülhart, M., Elliott, R. and Sensier, M. (2001) "A Tale of Two Cycles: Co-fluctuations between UK Regions and the Euro Zone", Centre for Growth and Business Cycle Research Discussion Paper Series #3, University of Manchester

Blanchard, O. and Quah, D. (1989) "Dynamic Effects of Aggregate Demand and Supply Disturbances", American Economic Review, 79, P655-73.

Funke, M. and Hall, S. (1998) "Aggregate Demand and Aggregate Supply in UK Regions", Journal of Economic Studies, 25, 260-76.

George, E. (2000) Speech to the Leeds and Bradford Chartered Institute of Bankers and Bradford Chamber of Commerce, 11 April 2000, http://www.bankofengland.co.uk/speeches/speech81.htm

Giacometti, R. and Pinelli, D. (1999) "Asymmetric Shocks and Long-Run Economic Performances Across Italian Regions", unpublished manuscript, University of Bergamo, Bergamo, Italy.

Im, K., Pesaran, M. and Shin, Y. (1997) "Testing for Unit Roots in Heterogenous Panels", unpublished manuscript, University of Cambridge, Cambridge, England.

Lee, K. and Pesaran, M. (1993) "Persistence Profiles and Business Fluctuations in a Disaggregated Model of UK Output Growths", Richerche Economiche, 47, 293-322.

Lee, K., Pesaran, M. and Pierse, R. (1992) "Persistence of Shocks and their Sources in a Multisectoral Model of UK Output Growth", Economic Journal, 102, 342-56.

Lee, K. and Shields, K. (1999) "Information, Business Survey Forecasts and Measurement of Output Trends in Six European Economies", Centre for European Economic Studies DP no. 99/7, University of Leicester, England.

Levtchenkova, S., Pagan, A. and Robertson, J. (1998) "Shocking Stories", Journal of Economic Surveys, 12, 507-32.

Obstfeld, M. and Peri, G. (1998) "Regional Non-Adjustment and Fiscal Policy", Economic Policy, 207-47.

Pesaran, M., Pierse, R. and Lee, K. (1993) "Persistence, Cointegration and Aggregation: A Disaggregated Analysis of Output Fluctuations in the US Economy", Journal of Econometrics, 56, 57-88.

Vickers, J. (1999) "Monetary Policy and Asset Prices", paper presented to the 31st Annual MMF Conference, Oxford, September 22nd.

Wold, H. (1983) A Study in the Analysis of Stationary Time Series, Uppsala: Almqvist and Wiksells.

Table 1: Panel Unit Root Test Statistics

variable	null I(1)	null I(2)
log(gdp)	0.40	−7.25
log(prices)	6.42	−8.37

Table 2: Conditional Correlation Coefficients for GDP and Inflation

A. Conditional Correlation Coefficients for GDP

	NO	YH	NW	EM	WM	EA	SE	SW
North	1.00	0.74	0.84	0.67	0.70	0.60	0.70	0.79
Yorks-Humberside	0.74	1.00	0.90	0.92	0.86	0.77	0.89	0.84
North West	0.84	0.90	1.00	0.80	0.84	0.70	0.90	0.83
East Midlands	0.67	0.92	0.80	1.00	0.79	0.72	0.75	0.86
West Midlands	0.70	0.86	0.84	0.79	1.00	0.68	0.83	0.78
East Anglia	0.60	0.77	0.70	0.72	0.68	1.00	0.75	0.66
South East	0.70	0.89	0.90	0.75	0.83	0.75	1.00	0.76
South West	0.79	0.84	0.83	0.86	0.78	0.66	0.76	1.00

B. Conditional Correlation Coefficients for Inflation

	NO	YH	NW	EM	WM	EA	SE	SW
North	1.00	0.59	0.79	0.24	0.63	0.44	0.35	0.55
Yorks-Humberside	0.59	1.00	0.75	0.51	0.70	0.63	0.54	0.70
North West	0.79	0.75	1.00	0.34	0.70	0.69	0.64	0.77
East Midlands	0.24	0.51	0.34	1.00	0.57	0.57	0.45	0.59
West Midlands	0.63	0.70	0.70	0.57	1.00	0.63	0.65	0.76
East Anglia	0.44	0.63	0.69	0.57	0.63	1.00	0.58	0.67
South East	0.35	0.54	0.64	0.45	0.65	0.58	1.00	0.66
South West	0.55	0.70	0.77	0.59	0.76	0.67	0.66	1.00

Table 3: Persistence Measures

A. Asymptotic Persistence Measures for Region-Specific Shocks
(With Standard Errors)

region	gdp: $P_i(y_i)$	(s.e.)	prices: $P_i(p_i)$	(s.e.)
North	0.7521	0.1856	0.7452	1.2798
Yorks-Humberside	1.1583	0.3598	0.7643	1.2948
North West	0.9398	0.2482	0.9115	1.1327
East Midlands	1.0827	0.3072	0.7223	1.1630
West Midlands	1.3061	0.3847	0.7780	1.5862
East Anglia	0.4873	0.1443	0.6418	1.1099
South East	1.2748	0.3392	0.6319	1.0456
South West	0.8734	0.2392	0.6040	1.0556

B. Asymptotic Persistence Measures for Nationwide Shocks
(With Standard Errors)

region	gdp: $P_i(y)$	(s.e.)	prices: $P_i(p)$	(s.e.)
North	0.1140	0.0281	0.1108	0.1903
Yorks-Humberside	0.1512	0.0470	0.1107	0.1875
North West	0.1502	0.0397	0.1093	0.1358
East Midlands	0.1498	0.0425	0.1138	0.1833
West Midlands	0.1675	0.0493	0.1112	0.2268
East Anglia	0.0600	0.0178	0.1107	0.1914
South East	0.1715	0.0456	0.1114	0.1842
South West	0.1261	0.0345	0.1104	0.1930

N.b. footnote 8 on page 11 above.

Table 4: Decomposed Persistence Measures

N.b. the sum of the squares of persistence measures A and B in this table is not exactly equal to the square of persistence measure B in Table 2. This table shows the persistence measures corresponding to only two of the three components of a nationwide shock indicated in equation (13). The GDP figures in Table 3A below measure persistence with respect to $\overline{e}_t^y$ only, and the price figures measure persistence with respect to $\overline{e}_t^p$ only. Table 3B below indicates persistence with respect to $\boldsymbol{e}_t^d$.

A. Asymptotic Persistence Measures for Common Component of Nationwide
Shocks (With Standard Errors)

region	gdp: $P_i(\overline{y}_i)$	(s.e.)	prices: $P_i(\overline{p}_i)$	(s.e.)
North	0.0964	0.0224	0.0067	0.0584
Yorks-Humberside	0.1448	0.0450	0.0067	0.0584
North West	0.1175	0.0310	0.0067	0.0584
East Midlands	0.1353	0.0384	0.0067	0.0584
West Midlands	0.1633	0.0481	0.0067	0.0584
East Anglia	0.0634	0.0092	0.0067	0.0584
South East	0.1582	0.0420	0.0067	0.0585
South West	0.1109	0.0294	0.0067	0.0584

B. Asymptotic Persistence Measures for Idiosyncratic Component of
Nationwide Shocks (With Standard Errors)

region	gdp: $P_i(\widetilde{y}_i)$	(s.e.)	prices: $P_i(\widetilde{p}_i)$	(s.e.)
North	0.0566	0.0165	0.1121	0.2891
Yorks-Humberside	0.0419	0.0130	0.1121	0.2891
North West	0.0533	0.0141	0.1121	0.2888
East Midlands	0.0640	0.0182	0.1121	0.2889
West Midlands	0.0743	0.0219	0.1121	0.2892
East Anglia	0.0314	0.0059	0.1121	0.2891
South East	0.0725	0.0196	0.1121	0.2894
South West	0.0494	0.0156	0.1121	0.2891

Appendix 1. Constructing Regional English Consumer Price Indices

Our econometric analysis is designed to explore whether there is any regional heterogeneity in the evolution of consumer price or output growth. Some of the components of the national UK retail price index are, by definition, lacking in any regional variation, since the relevant transactions are not geographically located. Most financial services prices fall into this category. Others (for example, fuel and consumer durables) are traded with very low marginal transportation costs relative to the value of the product, so their price is unlikely to vary much from one region to another. Nevertheless, there remain large components of the RPI that measure prices of commodities for which transportation costs are large (for example, basic foodstuffs) or infinite (for example, housing services). These two commodity groups together make up about 40% of the UK RPI, and there might well be some regional variation in them.

The Ministry of Agriculture, Food and Fisheries publication *The National Food Survey* includes quantum and value series for regional consumption of foodstuffs, from which can be constructed an aggregate food prices series for each region of England. The series can be constructed annually for the period 1967–96, giving 30 observations, for the pre-1996 standard regions of England: the South East (SE), East Anglia (EA), the South West (SW), the East Midlands (EM), the West Midlands (WM), Yorkshire-Humberside (YH), the North West (NW) and the North (NO). Comparable post-1996 data are unavailable (regional borders having been redrawn), as are Northern Irish data. Scottish and Welsh data are published, but contain several anomalies; inclusion of the Scottish and Welsh data in the estimated model resulted in incredibly large parameter values. Hence our analysis is restricted to the regions of England.

Similarly, the *Family Expenditure Survey* includes regional data on household expenditure on housing services. Assuming that each household owns or rents only one house (which is true of over 99% of households), the expenditure series is equivalent to a housing services price series. The regional food and housing services price series can then be used to construct an aggregate regional price index (using expenditure values as weights). Although this series excludes some components of the RPI that are likely to vary from one region to another (for example, some local services), the weights in the national RPI suggest that the two components of regional

prices that we have identified constitute over 90% of those RPI components with prices that are likely to exhibit some regional variation.

Appendix Table 1 below provides basic descriptive statistics for the regional consumer prices index we have constructed. The table also includes descriptive statistics for the output series used in our econometric analysis: (deflated) regional GDP as published in Regional Trends. There does not seem to be substantial regional variation in the sample mean and variation of consumer price inflation. As noted in Section 3, the price series are cointegrated, so over the long-run growth rates are very similar. The heterogeneity in price behaviour is restricted to the short run. There is rather more heterogeneity in the sample statistics for the (non-cointegrated) GDP series, with mean annual growth rates varying from 4.9% (East Anglia) to 7.2% (the South East). Appendix Table 2 shows that the long run variations in regional GDP growth correspond to variations in the structure of GDP, the fastest growing region having a substantially larger services sector than the rest of the country, and the slowest having a substantially larger agricultural sector. Regions with a relatively large contribution from manufacturing lie in between the extremes for the annual growth rate.

Appendix Tables

Table 1: Descriptive Statistics (% per annum)

	NO	YH	NW	EM	WM	EA	SE	SW
GDP growth								
mean	5.2839	5.7627	6.0489	5.5670	5.8407	4.8865	7.2487	5.6784
s.d.	0.1106	0.1383	0.1042	0.1873	0.1351	0.2361	0.1719	0.2114
inflation								
mean	4.2405	4.2268	4.2285	4.3057	4.2564	4.1806	4.2500	4.2451
s.d.	0.9353	0.9496	0.9471	0.9385	0.9181	0.9638	0.9237	0.9368

Table 2: Components of Regional GDP, 1996

	NO	YH	NW	EM	WM	EA	SE	SW
GDP (£bn)	28.9	48.3	61.6	41.8	53.2	22.9	229.1	49.1
AGR&MIN	3.2%	1.1%	3.2%	3.5%	2.4%	5.6%	1.0%	5.1%
MAN	30.0%	26.5%	25.7%	29.4%	30.1%	21.9%	15.1%	19.3%
CON	5.9%	5.1%	6.1%	5.6%	5.2%	5.8%	4.9%	5.5%
SRV	60.9%	67.3%	65.0%	61.5%	62.3%	66.7%	79.0%	70.1%

AGR&MIN: proportion of value added from agriculture and mining

MAN: proportion of value added from manufacturing

CON: proportion of value added from construction

SRV: proportion of value added from services
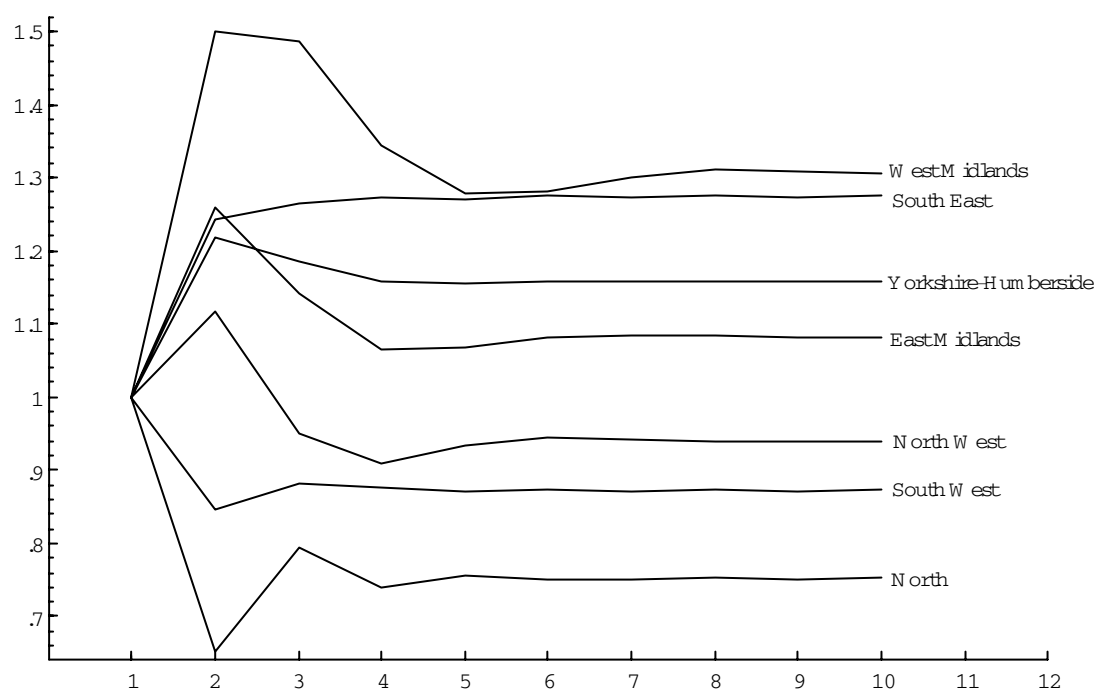
Source: Regional Trends

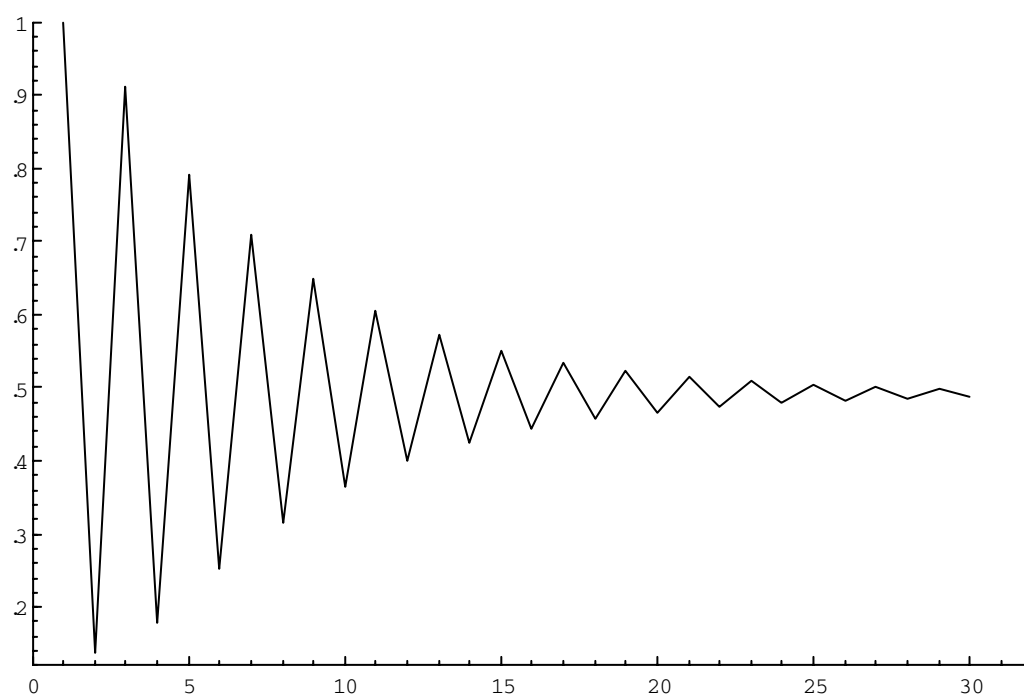Figure 1A : G D P Persistence Profiles for Region-Specific Shocks ($P_i\,(y_i)$) : 7 Regions[12]

Figure 1B : G D P Persistence Profile for Region-Specific Shocks ($P_i\,(y_i)$) : East Anglia

[12] In all figures, the vertical axis measures percentage changes in output (or prices) and the horizontal axis measures years elapsed from the shock. See also footnote 11 on page 15.
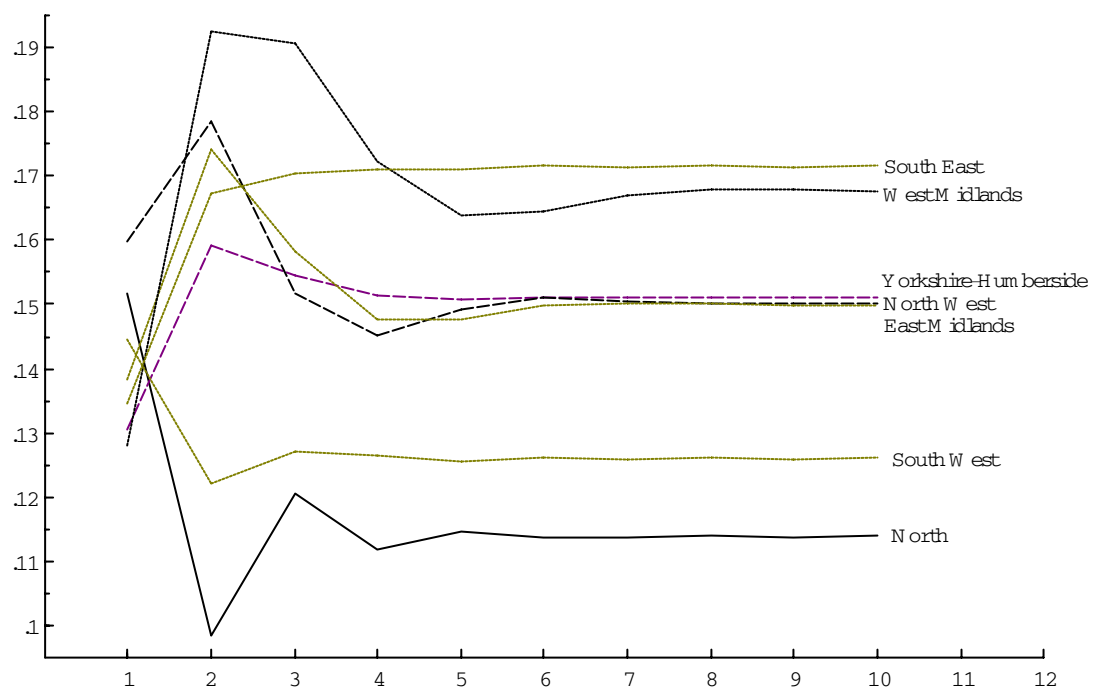
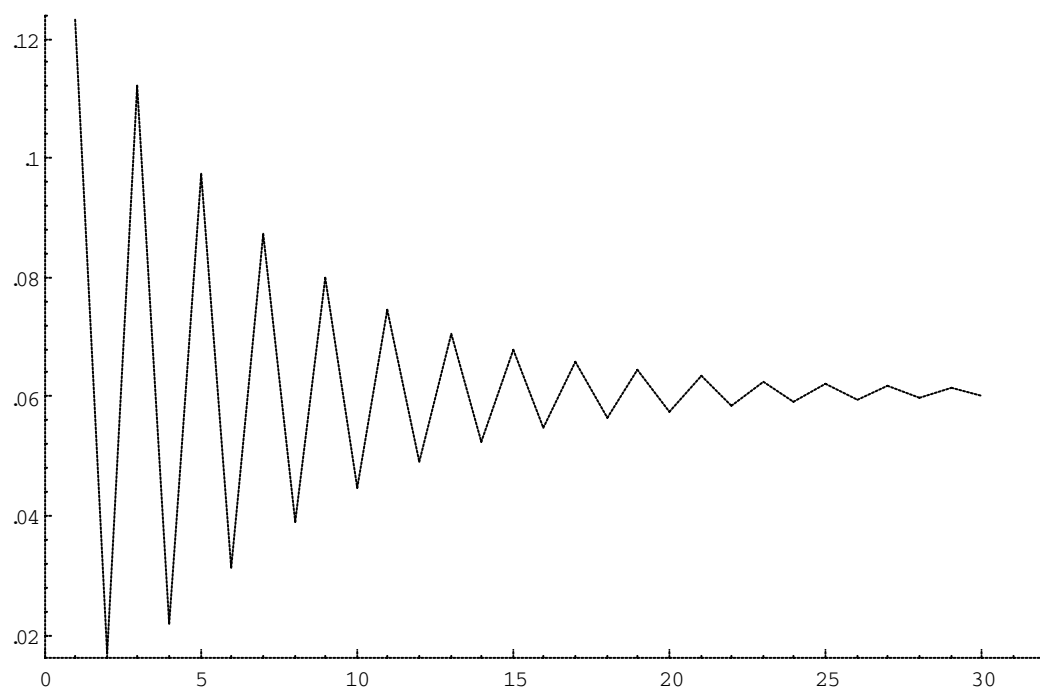Figure 2A : GDP Persistence Profiles for Aggregate Shocks $(P_i(y))$: 7 Regions

Figure 2B GDP Persistence Profiles for Aggregate Shocks $(P_i(y))$: East Anglia

27
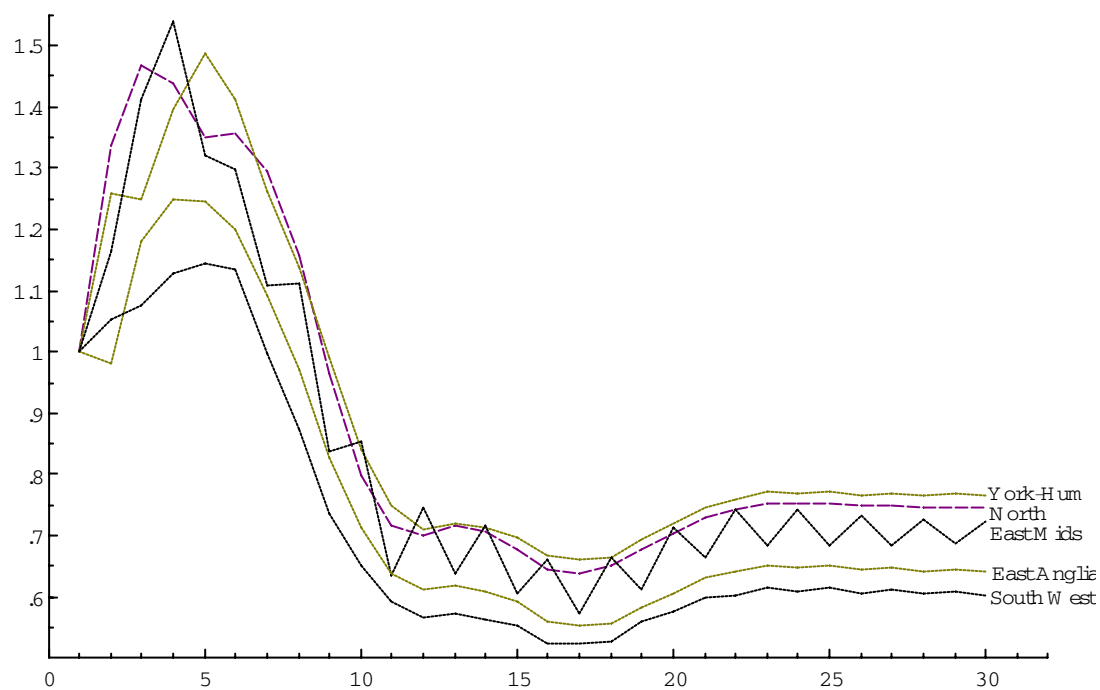
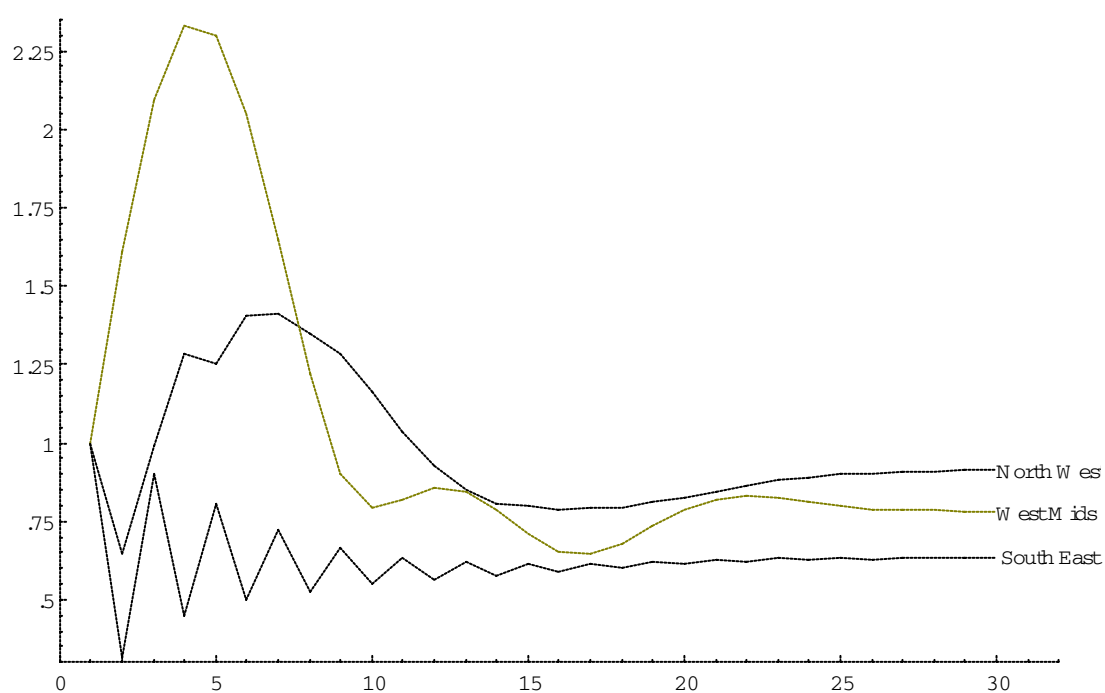Figure 3A : Price Persistence Profiles for Region-Specific Shocks $(P_i(p_i))$: Group A

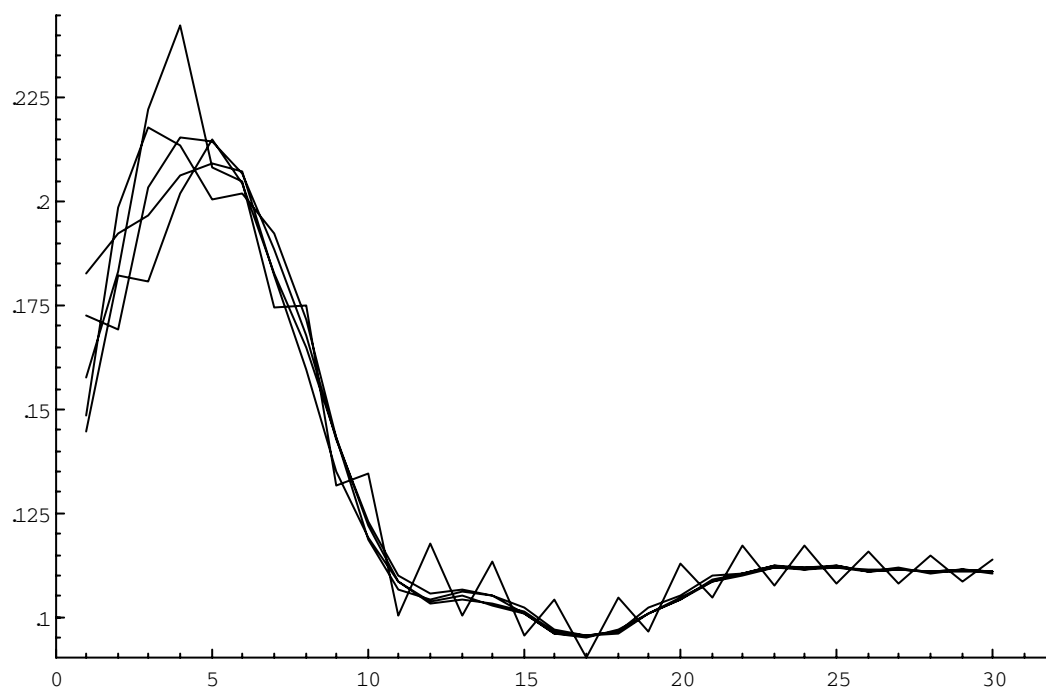Figure 3B : Price Persistence Profiles for Region-Specific Shocks $(P_i(p_i))$: Group B

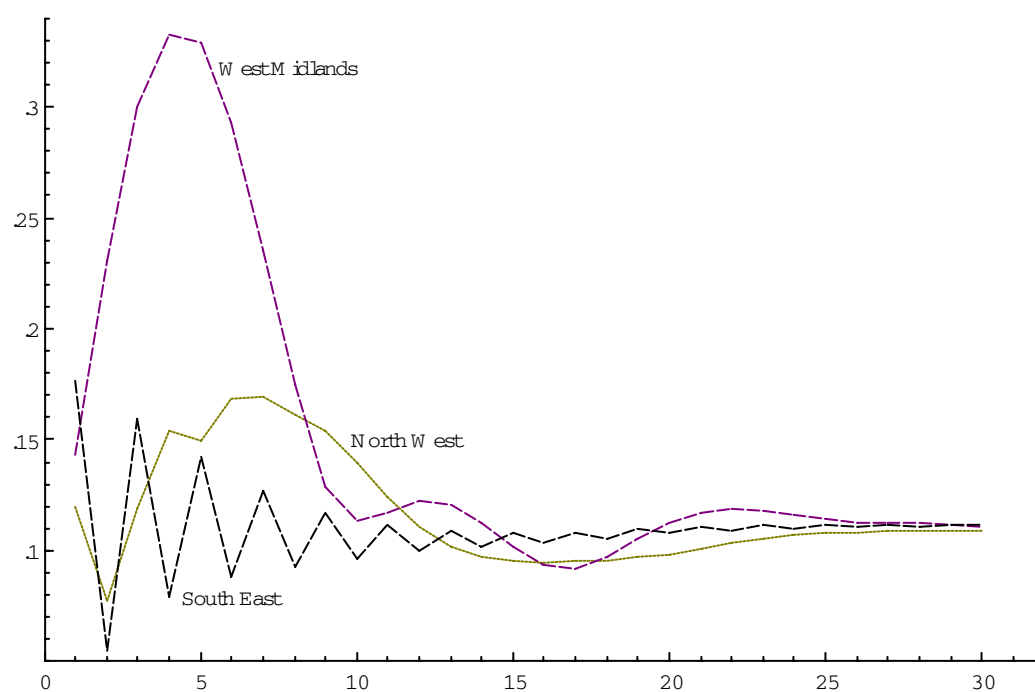Figure 4A : Price Persistence Profiles for Aggregate Shocks (P_i (p)):Group A

Figure 4B : Price Persistence Profiles for Aggregate Shocks (P_i (p)):Group B