An Empirical Analysis of Business Cycle Fluctuations in the Context of a Multisectoral Model - Full Report

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November 1994

Abstract

The project "An Empirical Analysis of Business Cycle Fluctuations in the Context of a Multisectoral Model" was an ESRC-funded project (ref. no. R000233608) carried out at the Department of Applied Economics, University of Cambridge between July 1992-June 1994. The full End-of Award Report follows.

1. Introduction

The research undertaken under this project is concerned with the analysis of output ‡uctuations in the UK and elsewhere, focusing on the di¤erent sources of shocks which generate ‡uctuations in sectoral outputs and on the role of sectoral interactions in the propagation of shocks across sectors and over time. The work takes as its starting point the theoretical models of in cyclical ‡uctuations such as the Real Business Cycle literature, and the empirical work investigating the order of stationarity and cointegrating properties of macroeconomic variables. The objectives of the research, stated brie‡y, are to develop the theoretical framework for consideration of cyclic ‡uctuations in a multisectoral context, to develop the statistical methods with which to analyse the time series properties of sectoral output data, and to apply these to the analysis of data for the UK and elsewhere.

On the theoretical side, the research has (i) considered the scope for developing disaggregated applied general equilibrium models allowing for the intertemporal nature of consumption and investment decisions; developed solution techniques for multivariate Rational Expectations models which allow a standard RBC model to be expressed in terms of a VAR framework; and introduced alternative methods with which to compute the equilibria of linear Rational Expectations models in which economic agents are di¤erentially informed; (ii) considered the econometric techniques suitable for the analysis of disaggregated data sets in which there is data available for a large number of economic units over a relatively long period of time, as are typically available in the study of industrial output data; and developed model selection criteria for use in various contexts, including the discrimination between aggregate and disaggregate models; (iii) developed econometric methods, based on a Vector Autoregressive modelling framework, which quantify the e¤ects of shocks from di¤erent sources on sectoral variables, and which describe the time pro…le of the e¤ects of shocks on the variables in the model. These methods accommodate the possibility of various kinds of interdependency between the sectoral series, allowing for long run equilibrium relationships that may exist between the sectoral variables. Moreover, the methods which have been

developed are of general applicability, in a variety of multivariate contexts, and in our opinion represent an important advance in modelling long run structural relations in a VAR context; and (iv) developed the "Persistence Pro…le" analysis and "Generalised Impulse Response" analysis for use in measuring the e¤ects of shocks in VAR models over time. Unlike the traditional impulse response analysis, the proposed tools are invariant to the ordering of the variables in the VAR, and can be used to analyse the persistent e¤ects of system-wide shocks, or of shocks to speci…c variables, on any or all of the variables in the system. In particular, the speed of convergence of variables to their equilibrium relations following a shock can be considered using these tools.

On the empirical side, the research has (i) investigated the role of sectoral interactions in the explanation of cyclic ‡uctuations in the UK economy; (ii) considered shocks of various types in an investigation of the source of shocks with persistent e¤ects, with particular emphasis on the role played by expectational errors in this process; and examined the e¤ect of shocks to the sectors of the UK economy as they evolve over time through the use of 'persistence pro…les' and 'generalised impulse response analysis'; and (iii) analysed output growth across the G7 economies, considering the sources and persistence of shocks to output growth, and the time pro…le of the persistent e¤ects of shocks, accommodating the interdependencies which exist between output determination across countries.

In what follows, we shall elaborate on each of these areas, summarising the main outcomes of the research and conclusions drawn. The research work is described more fully in the referenced papers.

2. The development of a framework for analysis of a multisectoral model of cyclical fluctuations

2.1. Theoretical framework

Applied General Equilibrium (AGE) models have been developed over the last few years to help inform discussion on policy issues as diverse as the optimal choice of tax system, the gains from international trade, and the e¤ects of policy initiatives on the environment. More recently, the related Real Business Cycle (RBC) models have been introduced into economists' discussion on policy changes, focusing primarily on issues relating to business cycle ‡uctuations. Both types of model attempt to convert the Walrasian general equilibrium framework from an abstract theoretical model of the economy into a form which is amenable to quantitative modelling. Such models are typically not estimated by econometric techniques, but are calibrated, often to one year's data, and more importantly, there is generally little e¤ort taken to test the model speci…cation statistically. Y. Lim and Pesaran (1994) provide a review of the various types of AGE and RBC models which have appeared in the literature, distinguishing between multisectoral and static AGE models, aggregate RBC models which emphasise intertemporal optimisation under uncertainty, and multisectoral AGE models which are dynamic, but assume perfect foresight. They also consider the estimation and calibration approaches to analysing macroeconomic phenomena that have been employed in this area, and describe criteria by which the performance of the di¤erent models, achieved by alternative means, can be evaluated. This work makes clear the considerable achievements made by the AGE and RBC models in recent years, but also highlights the di¢culties involved in the construction of such models in the absence of statistical estimation and testing.

Some of these di¢culties are addressed in Binder and Pesaran (1995), however, who provide a review of the solution and estimation methods for multivariate ra-

tional expectations models. A new method is proposed which provides a complete characterisation of the possible classes of solution to such models, and which allows for many forms of non-stationarity and non-linearity in the models' forcing variables. Moreover, the method is straightforward to apply and ensures that the model can be written in a VAR-framework which is readily estimated using full information methods. The relevance of these solution methods to the analysis of business cycle ‡uctuations is made clear through an application of the method to a Real Business Cycle model analysed by Christiano and Eichenbaum (1992). Through this example, it is demonstrated that the solution methods developed allow one to directly approach the problem of evaluating RBC models without recourse to stochastic simulation.

Finally, Binder and Pesaran (1994) address the problem, fundamental in the analysis of multisectoral models of cyclic ‡uctuations, of attaining a Rational Expectations equilibrium when economic agents are di¤erentially informed. In this, it is noted that situations in which decision makers have private information and/or base their decisions only on a subset of the information which is available (focusing on signals which are most likely to minimise their forecast errors) often lead to the problem of 'in…nite regress' in expectations (in which there is a recursive dependence of expectations formation in each sector on the expectations formed in other sectors). A review is provided of the solution algorithms proposed in the literature for handling this problem (eg. Townsend (1983a,b) and Sargent (1991)), and a method for computing the equilibria of such models is also introduced. The method is based on a 'common knowledge' assumption about mean beliefs and makes use of the solution methods described in Pesaran and Binder (1995). This 'common knowledge' assumption provides an operational framework for the econometric analysis of Rational Expectations models under asymmetric or heterogenous information and, as demonstrated in Binder (1994), di¤erentiated information of this kind is quantitatively important in real business cycle analysis.

2.2. The econometric analysis of disaggregated datasets

A second strand of the research is concerned with the development of appropriate econometric methods for use in the analysis of multisectoral datasets and for evaluating the (statistical) usefulness of the disaggregated sectoral data in comparison with aggregate time series data.

On the …rst of these issues, our recent work suggests that many of the procedures currently adopted in the estimation of long run relationships using dynamic

panels can be misleading. The estimation of long-run relationships has been a continuing concern of econometrics, but the relationships have traditionally been estimated in two distinct ways. One approach uses aggregate time-series (averaged over groups in the population) to estimate either distributed lags (e.g. Jorgenson (1966) and Almon (1965)) or cointegrating relationships among integrated variables. (e.g. Engle and Granger (1991)) The other approach uses cross sections (often averaged over time for each group) in the belief that these provide better estimates of long run e¤ects than time series (see, for example, Baltagi and Gri¢n (1984)). In Pesaran and Ron Smith (1994b), we carry out a comparative analysis of di¤erent methods of estimating long-run relationships in the context of dynamic heterogenous panels, which represent a generalisation of the static Random Coe¢cients Model (RCM). If we limit attention to the static RCM, it is noted that there are four procedures that can be applied to such data sets. They are averaged over groups and aggregate time-series estimated; they are averaged over time and cross sections estimated on group means; they are combined imposing common slopes but allowing for …xed or random intercepts and pooled regressions estimated; or separate regressions are estimated for each group and the coe¢cients averaged over groups. This last procedure is referred to as the mean group estimator. All four procedures give average estimates of the (sector-speci…c) slope coe¢cients. The di¤erence is that in the case of the last estimator the averaging is explicit, while in the other cases it is implicit. In applied work, the time-series and cross-section procedures are most commonly used, the pooled estimators less often, and explicit averaging over estimates for each group is rather rare. In the case where the regressors are all strictly exogenous, and the parameters are assumed to be random and distributed independently of the regressors, then all four procedures give unbiased estimates of the mean of the parameters, albeit with di¤erent variances. Thus applied workers can argue that if they are primarily interested in unbiased estimates of the mean e¤ect, it does not matter which they use. This is essentially the argument of Zellner (1969), who showed that there is no aggregation bias under these conditions.

There also seems to be an implicit assumption that the above argument can be extended to dynamic heterogenous models with lagged endogenous variables, in the sense that all four estimators will be consistent rather than unbiased. However, as Pesaran and Smith (1994b) demonstrate, it is not true that time series, cross-section and pooled estimators will generally give consistent estimates in dynamic random coe¢cient models. In particular aggregating and pooling can produce highly misleading estimates of long run e¤ects in heterogeneous dynamic

panels, while cross-section regressions are only appropriate when they are based on reasonably long time averages. The mean group estimator seems to be the most appropriate of all the four procedures when both time and cross- sectional dimensions are large. These results are of some importance, given the prevalence of aggregation and pooling in applied work, and indicate that the common assumption of homogeneity in dynamic models is far from innocuous. All the four estimation procedures are applied to sectoral employment demand equations in the UK in Pesaran and Smith (1994b), and to the estimation of long run income and price elasticities of energy demand for ten South-East Asian economies (as reported in Pesaran and Smith (1994c)).

Another aspect of the analysis of multisectoral models is the development of appropriate techniques for the comparison of the multisectoral models with their aggregate (macro) counterparts. In particular, investigators often need to (i) establish the usefulness of the macro and micro models in terms of their ability to explain the evolution of the aggregate of interest (the prediction criterion); and (ii) assess the models in terms of their ability to estimate the responsiveness of the aggregate to changes in explanatory variables (aggregation bias). We have pursued both of these issues under this research project. Speci…cally, the concept of a Generalised R2, based on squared prediction errors, is developed in Pesaran and Richard Smith (1994) for use as a model selection criteria. The principle on which this is based is employed both in Pesaran, Pierse and Lee (1994), and in Lee, Pesaran, and van Garderen (1994), to develop model selection criteria for discriminating between aggregate and disaggregate models, where the models are estimated by instrumental variable (IV) methods in the former paper, and where the micro-behavioural relations are represented by a non-linear model in the latter paper. Aggregation bias tests were also described in Pesaran, Pierse and Lee (1994) for use in the context of model comparison when the models are estimated using IV methods, extending earlier work by the authors on aggregation bias testing in the OLS context. As documented below, the econometric methods developed under this aspect of the research provides extremely useful tools with which to judge the usefulness of sectoral data in empirical work (eg. in modelling business cycle ‡uctuations, or in modelling speci…c behavioural relations which may be important in explaining the propagation mechanism by which the e¤ects of shocks are transmitted over time and across sectors).

2.3. Long run structural modelling and the generalised impulse response analysis

A third strand of the research concerning the theoretical and econometric methods for analysis of multisectoral data has focused on long-run structural modelling within a VAR framework and the development of impulse response analyses of the e¤ects of shocks to the model which do not require the orthogonalisation of the shocks (in contrast to the analysis described in the work of Sims). This aspect of the research developed out of earlier work by the authors analysing the persistence of shocks to multisectoral models (and the application of the methods to UK and US industrial data). However, the work has resulted in the development of a general framework for identi…cation, estimation and hypothesis testing in cointegrating systems, subject to general non-homogenous restrictions on long-run relations. This framework is of widespread applicability, in a variety of multivariate contexts and, in our opinion, represents an important advance in modelling long run structural relations in a VAR context. Further, complementing this work, tools have been developed with which the time pro…le of the e¤ects of shocks to multivariate systems can be considered; namely 'Persistence Pro…le' analysis and Generalised Impulse Response (GIR) analysis. This analysis is fundamentally different to, and advocated as a superior alternative to, the orthogonalised Impulse Response analysis frequently used in the analysis and interpretation of estimated VAR models.

One of the main problems in econometric analysis of cointegrating systems is that in general the cointegrating relations are identi…ed only upto a non-singular transformation. There are two main system approaches currently available in the literature for estimating cointegrating relations: Johansen's (1988, 1991) autoregressive vector error correction (AVEC) model, and Phillips' (1991) triangular vector error correction (TVEC) model. Both of these approaches implicitly deal with the identi…cation problem by imposing r2 arbitrary restrictions, where r is the number of identifying restrictions.

In Pesaran and Shin (1994b) [PS], a general framework is developed for identi…cation, estimation and hypothesis testing in cointegrating systems subject to general non-homogeneous restrictions on long-run relations, which is more general than Johansen's procedure and explicitly deals with the exactly identifying restrictions making use of a priori information from economic theory. The approach also does not require the a priori decomposition of the system variables as in Phillips procedure. In particular, PS discusses the identi…cation problem

when r or more a priori restrictions on the r cointegrating relations are available. It considers quite a general set of restrictions; allowing for parametric restrictions across the cointegrating relations as well as for homogeneous and non- homogeneous restrictions on individual cointegrating vectors. PS also presents numerical algorithms for the Full Information Maximum Likelihood (FIML) estimation of the cointegrating relations subject to exactly identifying and/or over-identifying restrictions, and develops tests of the over-identifying restrictions on the cointegrating vectors. Following the work of Phillips (1991), Johansen (1991) and Saikkonen (1993), PS shows that the limiting distribution of the restricted estimators of the cointegrating vectors is the Gaussian mixture normal with a singular covariance matrix. Hence, the validity of over-identifying restrictions can be tested using standard Likelihood Ratio test procedures. More details of the econometric model, the estimation and testing procedures can be found in PS. Here, however, it is worth emphasising the general applicability of the methods that have been developed, and in particular, in future work, we hope to apply the methods in the context of macroeconomic modelling of the UK economy. In such an application, the framework provides the means of evaluating economic theories, which suggest long run structural relations between macroeconomic aggregates, within the context of a small but complete macroeconomic system, fully and transparently taking into account the interdependencies that exist between the macroeconomic aggregates in the generation and propagation of cyclic ‡uctuations.

An important tool in the analysis and interpretation of estimated VAR models is the orthogonalised Impulse Response analysis (see, for example, Litterman and Weiss (1985)), which provides an analysis of the time pro…le of the e¤ects of shocks to the variables in the model. The advantages of working with orthogonal shocks is clear in that it allows the e¤ect of variable-speci…c shocks on the dynamic evolution of the system to be analysed. However, as argued in Cooley and LeRoy (1985), orthogonalised shocks are di¢cult to interpret economically, and the orthogonalised Impulse Response analysis crucially depends on the particular ordering chosen for the variables in the VAR model. The limitations of the orthogonalised impulse Response analysis are well discussed in the literature, and recently in Lee and Pesaran (1993a).

In a series of papers emanating from the project (Lee and Pesaran (1993a), Pesaran and Shin (1994a), Pesaran, Potter and Shin (1994), Koop, Pesaran and Potter (1994)), an alternative approach to the analysis of the e¤ects of shocks in VAR models has evolved, resulting in the Generalised Impulse Response analysis. This approach considers the impulse response function as the outcome of a con-

ceptual experiment in which the time pro…le of the e¤ect of a hypothetical shock, hitting the system of equations at time , is compared with a baseline pro…le in which the e¤ect of shocks at time (and in the future) are averaged out. The hypothetical shock can be a system-wide shock, or a shock to speci…c variables within the system, and their e¤ects on any or all of the variables in the system can be analysed. In particular, the analysis can be applied to linear combinations of variables which represent (di¤erent) long-run equilibrium relations, so that the tools can be used to investigate the (di¤erential) speeds of convergence of variables to their equilibrium relations. The approach is general, and can be applied to multivariate linear models as well as to non-linear models. The GI response function explicitly takes into account the patterns of correlations that have been observed historically among the various innovations in the system. This contrasts with the traditional impulse response approach which considers the e¤ects of an (arbitrarily chosen) shock, while attempting to 'turn o¤' other forms of shock, even if they typically occur in conjunction with the 'shock of interest'. Unlike the traditional impulse response analysis, the GI response function is invariant to the ordering of the variables in the VAR, and provides a relatively simple tool for analysing the persistence properties of dynamic systems. As we shall describe below, this tool has been particularly useful in characterising the e¤ects of shocks to output series, and hence the nature of business cycle ‡uctuations, in linear and non-linear models of aggregate and disaggregate output data in the UK and elsewhere.

3. The empirical analysis of business cycle fluctuations in the UK and elsewhere

3.1. The role of sectoral interactions in business cycle ‡uctuations in the UK economy

While there is some degree of consensus in the theoretical literature on the potential importance of sectoral interactions in the explanation of the dynamic evolution of the macroeconomy, this aspect of the functioning of the economy is one which is often neglected in applied research. For example, it is often noted that output growth in the UK averaged around 2.9% per annum (pa) during the 1980's, compared to 3.1% and 3.2% pa during the 1950's and 1960's, and based on these average …gures, it is sometimes argued that the 1980's was a decade in which long term aggregate output returned to a growth path which is normal by post-war standards, following the anomalous experiences of the 1970's (during which output growth averaged just 2.1% pa). However, this aggregate picture disguises the major changes which have taken place in the industrial structure of the UK economy over the post- war period, and the impact that these changes have for the nature and extent of business cycle ‡uctuations. Hence, while output from the manufacturing and energy sectors fell by some 0.9% pa over the period 1979-84, rose by 3.2% pa over 1984-89, and then fell again by 1.8% pa during 1989- 91, service sector output grew by 1.8% pa and 4.2% pa during 1979-84 and 1984-89, respectively, and remained unchanged over the most recent period.

In Lee (1993), we study the issues raised by the acknowledgment of diversity within the manufacturing and service sectors, and investigate the extent to which detailed industrial data is useful in understanding economic growth in the UK. In the paper, we review some of the statistical techniques described in section II above, and describe how we might use these to judge whether an adequate representation of sectoral output has been achieved for any level of disaggrega-

tion. We then apply the techniques to a quarterly dataset covering UK output in twenty-four industries, including seven manufacturing sector industries and fourteen service sector industries. In order to investigate the importance of using disaggregated data in modelling cyclic ‡uctuations in the UK, analysis of the data is carried out having grouped the data into four alternative classi…cations with progressively increasing degrees of aggregation.

Three alternative ways are used to consider the statistical 'adequacy' of a model of an economy's output growth. The …rst of these assesses the model purely in terms of its ability to 'predict' the aggregate output growth series over the sample period evaluated by means of the 'prediction criteria' described in section II.2 above. The second focuses on the potential for 'aggregation bias' in estimated aggregate relationships, and considers measures of the persistence of an (economy-wide) shock to aggregate output as obtained from an aggregate model and from the (three di¤erent) disaggregated models. And the third approach to comparing aggregate and disaggregate models is based around the possibility of introducing some economic structure to the model(s) through the use of information contained in input-output tables. In this, restrictions can be imposed on coe¢cients of the VAR model of industrial output growths to re‡ect the relative importance of output growth in sector j as it a¤ects sector i as suggested by speci…c kinds of feedback between sectors. Three alternative sets of restrictions of the multisectoral model are considered: the …rst assumes that feedbacks to sector i from all other sectors are equally important; the second re‡ects the importance of feedbacks to sector i from the suppliers to the industry; and the third re‡ects the importance of feedbacks to sector i from its customers. In this …nal approach to considering aggregate and disaggregate models, non-nested testing techniques are used to compare the alternative models in order to investigate the importance of the structural information contained in the input-output coe¢cients.

The results presented in the paper provide compelling arguments for the use of disaggregated data in the analysis of output growth in the UK. Apart from the fact that di¤erent industries have experienced considerably di¤erent growth rates over the period, and that the variability of these growth rates over time also di¤ered signi…cantly between sectors, it was found that valuable structural information is contained in the input-output tables relating an industry's output growth to movements in the output growths of the industries purchasing its output. It is noted that such information cannot be accommodated into an analysis carried out at a high level of aggregation. It is also shown that disaggregated models of sectoral output growth are superior to their aggregate counterparts in terms of

their ability to predict aggregate output growth, and it appeared that the main gains were from the disaggregation of manufacturing sector output rather than service sector output. Finally, tests of aggregation bias carried out on measures of the persistence of shocks to aggregate output indicated that, once more, the most satisfactory analysis of output growth was that which was carried out at the highest level of disaggregation, as the persistence measures obtained from this model were estimated more precisely than in the other models.

3.2. Sources of shocks to the UK economy and the time pro…les of their e¤ects

The econometric techniques developed to investigate the persistence of shocks to industrial output can be used to consider the sources of shocks which have a persistent e¤ect on output, and to this end, measures of the persistence of shocks can be decomposed to quantify the importance of particular types of shock. In Lee, Pesaran and Pierse (1992) [LPP], we considered explicitly the role of shocks to oil prices, to the stock market, to the money supply and to foreign exchange markets as possible sources of cyclic ‡uctuations in the UK economy through their inclusion in a multisectoral model of UK output growth. More recently, C.H. Lim (1993a) has employed the same modelling framework to investigate the in‡uence of housing market shocks in the explanation of sectoral output growth in the UK, and work is currently underway investigating the persistent e¤ects of productivity shocks to UK industry, measured by unexpected changes in the number of patents awarded (see Fabiani (1994)). This work has found that shocks to some of the speci…ed variables have statistically signi…cant e¤ects, although in all cases, the contribution of the persistence of these 'macro' shocks to total persistence of shocks are small, re‡ecting the fact that these shocks are small (in size) relative to the other (unidenti…ed) shocks. Nevertheless, it is interesting to note that, among the four types of shock considered in LPP, exchange rate shocks were found to display the largest persistent e¤ect, primarily exerted through their in‡uence on the Durable and Non-Durable Manufacturing sectors of the economy. Oil price shocks and Stock Market shocks were also shown to be in‡uential, although smaller numerically, while money supply shocks were the least important.

In Lee and Pesaran (1993a), the work of LPP is extended through the use of 'persistence pro…les' to examine the whole time pro…le of the e¤ects of the different types of shock. Here, it is shown that the 'in…nite horizon' measures of the persistent e¤ect of shocks presented in LPP are in fact achieved within eight

quarters in most sectors. Pro…les of shocks to 'Agriculture' and Service' sector output growths take rather longer to achieve their ultimate e¤ect (although even in these sectors, the majority of the persistent e¤ects have occurred within four years). These …ndings put into perspective the 'long run' nature of the persistent e¤ects of shocks, and illustrate the extent and duration of the structural dislocation that occurs during the transition of the economy to its long run equilibrium in the response to shocks. Moreover, examination of the persistence pro…le of the e¤ect of shocks show that, while the contribution of macro shocks to total persistence remains less than the contribution of other, unidenti…ed shocks in all sectors, this contribution grows over time in the Construction, Durable Manufacturing, and Non-Durable Manufacturing industries), while it declines in the other sectors of the economy. Taken in combination with the 'in…nite horizon' results, this breakdown emphasises the importance of the role played by the production sectors in propagating and sustaining the e¤ects of macroeconomic shocks to the economic system as a whole.

The 'persistence pro…le' and the Generalised Impulse Response analyses can also be applied to capture the speed of convergence of the dynamic systems to their long-run equilibrium position, assuming, of course, that such a long run equilibrium exists. In Pesaran and Shin (1994a), attention focuses on the persistence pro…le of the e¤ects of a (system-wide) shock on the cointegrating relations between variables and hence, on the speed with which the system converges to its long run, equilibrium position following the shock. The tools are illustrated in the context of a …ve-variable system containing domestic (UK) and foreign prices, the exchange rate, and domestic and foreign interest rates as originally investigated in Johansen and Juselius (1992). Here the two equilibrium concepts that are considered are the long run relation between the …rst three of these variables suggested by Purchasing Power Parity, and the Uncovered Interest Parity condition between domestic and foreign interest rates. Persistence pro…les for these two relations are estimated and plotted, along with their 95% con…dence intervals, to demonstrate that while the UIP condition is reestablished relatively quickly following a shock (i.e in the region of 3 years), the PPP condition is reestablished only after a prolonged period of disequilibrium (in excess of twelve years). These ideas are further explored in Lee, Pesaran and Shin (1994), where the model is supplemented with data on domestic and foreign output levels and with a further long run equilibrium relation, based on 'convergence' between these two output measures. The Generalised Impulse Response analysis is employed in the paper to investigate the dynamic response of particular variables (as well as the equilibrium relations) to

particular, variable-speci…c shocks as well as to system-wide shocks. This analysis shows the vulnerability of the analysis of the original Johansen and Juselius (1992) to extensions of the sample period and in the data set, but illustrates again the sluggishness of the adjustment of domestic prices, relative to exchange rates an interest rates, to disequilibria in the current and capital accounts. In this way, the analysis focuses attention on the dynamic adjustment of the macroeconomy in response to shocks, noting the di¤erential speeds of adjustment towards di¤erent equilibrium positions, and highlighting the signi…cance of these issues for the understanding of the nature of cyclic ‡uctuations in the macroeconomy.

In Koop, Pesaran and Potter (1993), and Pesaran, Potter and Shin (1994) the widespread applicability of the Generalised Impulse Response analysis is elaborated. In particular, in these papers, the GIR analysis is described in its most general form, demonstrating that it is applicable in the context of non-linear, as well as linear multivariate, systems. In the case of non-linear dynamic models, the e¤ects of a shock to the system depend not only on the size and type of shock impacting on the system, but they also depend on the state of the system when the shock occurs. This enables one to investigate not only the persistent e¤ects of shocks, but also the asymmetries that might exist in the response of shocks to di¤erent types of shocks in di¤erent circumstances. Moreover, empirical work described in Pesaran and Potter (1993b) has investigated the importance of non-linearities in the analysis of business cycle ‡uctuations in the US, and found that negative shocks are less persistent than positive shocks. Moreover, the e¤ects of shocks to output growth rates in the US, at least for aggregate data, are history dependent, in the sense that and that ‘‡oor’, ‘corridor’ and ‘ceiling’ regimes exist in which the same shock can have very di¤erent e¤ects. Alternative forms of non- linearity are also considered in the context of an analysis of US GNP in Koop, Pesaran and Potter (1993), and once more the GIR analysis is employed to demonstrate the complexities of the response of output to shocks depending on the position of the system (i.e whether the economy is in a period of boom or slump) when the shock occurs.

A …nal area of empirical analysis focusing on the source and time pro…le of the e¤ects of shocks is described in Lee (1994a), in which attention is directed explicitly to the role of expectations formation in business cycle ‡uctuations in the UK. In this paper, we consider expectations formation, and its contribution to cyclic ‡uctuations, in the context of a multisectoral Vector Autoregressive (VAR) model of industrial output growths in the UK economy, making use of direct measures of expectations on output growth. These direct measures are available quarterly for

eight industries within the UK manufacturing sector over the period 1975-1993, and are obtained from the Confederation of British Industry (CBI)'s Survey of Industrial Trends. The availability of direct observations on expected industrial outputs provides an invaluable means of investigating empirically the role played by the process of expectations formation in generating cyclic ‡uctuations and its part in the dynamic evolution of industrial output levels since it enables a direct analysis of the process by which expectations are formed to be undertaken, and allows the modelling of actual and expected sectoral output data to take place without the use of an underlying structural model of output determination.

In the paper, we provide: (i) a discussion of a VAR model of the actual and derived expected output series, where actual output is assumed to be I(1) and expectational errors are I(0); (ii) a brief summary of the methods developed in LPP for use in the analysis of multisectoral data and a discussion of their use in the analysis of the dynamic e¤ects of shocks to actual and expected industrial output data; and (iii) a discussion of the methodology by which qualitative survey responses can be converted to quantitative expectations data and of a test that can be applied to investigate the rationality of expectation formation. We then provide an overview of the actual and the derived expected output data and present the results of the tests of the rationality of the expectation formation process. The analysis of actual and expected output across the eight industries is then presented, describing measures of persistence of shocks to actual and expected output, and presenting 'persistence pro…les' with which to examine the evolution of the e¤ects of shocks over time.

The paper shows that an analysis of survey data requires an appropriate treatment of measurement error introduced in the conversion of qualitative survey data to quantitative series, but that, under particular (relatively uncontroversial) assumptions on the nature of the conversion error, the rationality of output expectations formation cannot be rejected. Moreover, the modelling exercise described in the paper shows that actual and expected output levels are jointly determined, and that a time series analysis of the actual output series data considered independently of the expectations data may be misleading. Expected levels of industrial output are considerably less responsive to shocks than are actual output levels, and this serves to mitigate the e¤ects of shocks on actual output levels at short time horizons (i.e. one or two quarters). However, interactions between industries are most important in understanding the dynamic response of output levels to shocks at longer time horizons. In particular, it is found that there are strong interdependencies between expected output growth across sectors. The interac-

tion of expected output growths across industries, and the subsequent in‡uence these expectational e¤ects have on actual outputs, result in relatively high persistence measures in manufacturing industries at longer time horizons. The indirect nature of the mechanism by which the e¤ects of shocks are propagated across industries is re‡ected by a period of adjustment to shocks which is prolonged (four to …ve years) in almost all industries when compared to results obtained without taking into account the expectational data.

3.3. Economic ‡uctuations in the G7 economies

Complementing the empirical work carried out on industrial data within a single economy, the methods developed in the project have also been applied to multi-country output data to investigate cyclic ‡uctuations at the international level. More speci…cally, in Lee (1994b), we employ the methods to investigate the time series properties of output growth across the G7 economies over the period 1960-1991. Clearly, these methods are able to accommodate the interdependencies that exist between growth in the di¤erent economies, enable an analysis of the sources of shocks to output growth to be carried out, and provide the means of examining the time pro…les of the e¤ects of shocks. The use of international output data provides the potential for obtaining further stylised facts with which to characterise the functioning of the macroeconomy, and one which may provide less circumstantial evidence with which to confront macroeconomic theories. For example, given that technological innovations are likely to cross national boundaries, at least with a lag, one would expect the persistence of output shocks measured in di¤erent economies to be of comparable order of magnitude if technological shocks are the primary source of permanent innovations. Further, while disparities in output levels across economies may be given historically, the transferability of technological innovations across borders would ensure that national output series will grow 'together' (i.e be cointegrated) if these were the only I(1) shock to the system. Some empirical work, reviewed in the paper, has been carried out to obtain evidence on the time series properties of output growth across various industrialised economies, and it has been generally demonstrated that substantial di¤erences exist between the persistence of shocks across di¤erent economies, and that output in the various economies under consideration do not grow together. This work therefore provides some evidence against the view that technology shocks constitute the primary source of persistent shocks.

In Lee (1994b), a preliminary analysis of the data on output of the G7 coun-

tries over the period 1960-91 suggests that both the feedback e¤ects (of output growth in one country on output growth elsewhere) and the in‡uence of explicitly identi…ed global shocks (including oil price shocks, world trade shocks, commodity price shocks and world money supply shocks) are important in understanding the time series properties of the countries' output growth series. In particular, it is shown that the inclusion of the feedback e¤ects and the incorporation of explicitly-identi…ed shocks to the model allows the results to be interpreted with a closer correspondence to economic theory than is generally true with 'black box' time series modelling, and eliminates the need for an ad hoc treatment of an hypothesised structural break in the early 1970's, following the …rst oil price rise.

Further, the estimated persistence pro…le measures obtained through the application of the LPP framework provide some interesting stylised facts which can be used to inform the macroeconomic debate. First, although there are important interdependencies between output growth across countries which exert signi…cant equilibrating pressures on the output growth in the G7 economies, it is clear that the G7 nations are subject to a number of independent shocks. Moreover, the statistical evidence is that the persistence of shocks, while being signi…cantly greater than zero in all countries, di¤ers considerably across countries. The second insight relates to the identi…ed global shocks, and the …nding that these global shocks have signi…cant persistent e¤ects, of a comparable order of magnitude to those of the unidenti…ed shocks. Moreover, the persistent e¤ects are the result of the oil price shocks and the world trade shocks, since commodity price shocks and world money supply shocks were observed not to make a signi…cant contribution. And …nally, the analysis provides insights into the dynamic processes involved in the persistence of shocks to output: the persistence pro…les show that all the e¤ects of shocks which persist are observed to occur within approximately seven years of the impact of the shock, that this persistent e¤ect typically accumulates gradually over time, and that feedback e¤ects and di¤erential speeds of adjustment in the face of di¤erent shocks play an important role in this process.

4. Continuity

A two year ESRC project on "Econometric Models of Non-Linear Dynamic Models with Applications in International Macroeconomics" has been awarded to the principal investigators, M.H. Pesaran and K.C. Lee to investigate the properties of a class of non-linear dynamic models in univariate and multivariate systems. This work follows directly from the work on non-linear modelling initiated under this research project, and it is intended that the analysis of output fluctuations in industrialised economies will provide one of the main arenas in which the non-linear modelling techniques can be applied.

A research proposal has also been submitted by a team from Cambridge which includes M.H. Pesaran and K.C. Lee to the ESRC, under its Macroeconomic Modelling Initiative, to construct a small quarterly, and corresponding monthly, model of the UK economy. It is proposed that the model is constructed on the basis of a VAR, but testing and incorporating theoretical restrictions on the long run relations between variables, employing the framework described in section II.3 above.

5. Concluding Comments

Important advances have been achieved in recent years in the theoretical and empirical analysis of cyclic ‡uctuations in output, and many of the previously held views on the nature and causes of surges and contractions in activity have been reexamined in the light of these advances. The incorporation of sectoral interdependencies in the theoretical literature on business cycles, and the use of disaggregated data in the empirical study of output ‡uctuations appears to be an essential element of achieving a satisfactory understanding of these important macroeconomic issues. The techniques of analysis developed in this project provide the means of investigating models with these sophistications, and the empirical work that has been carried out should encourage further work in this direction.

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