and theoretically coherent foundation. The model evaluation exercise not only demonstrates the statistical adequacy of the forecasts generated by the model but also highlights the considerable improvements in forecasts obtained through the imposition of the theory-based long-run restrictions. The predictive distribution functions relating to single events and the various joint event probabilities presented illustrate the flexibility of the functions in conveying forecast uncertainties and, from the observed independence of probability forecasts of events involving inflation and growth, in conveying information on the properties of the model. The model averaging approach also provides a coherent procedure to take account of parameter and model uncertainties as well as the future uncertainty.

12

Global modelling and other applications

The modelling approach described in Chapters 2–7, and adopted in the detailed description of the UK macroeconometric model of Chapters 8–11, is widely applicable and has been recently employed in a variety of studies investigating important macroeconomic issues. We conclude the book with a brief description of a number of these applications. The applications have been chosen to illustrate the flexibility of the modelling approach and the range of topics that can be addressed using these techniques. The *first* group of applications are concerned with the widespread use of the Structural Cointegrating VAR modelling approach, and provides a brief description of a global VAR (GVAR) model, which is aimed at capturing regional interdependencies in the world economy. The GVAR illustrates how the modelling approach advanced in the book can be generalised to build a global model within which the core UK model could, in principle, be subsumed. The *second* area focuses on the increasing use of impulse responses and the ways in which the VAR estimates can be interpreted, commenting on the construction of a high-frequency (monthly) version of the core model which is of particular use in identifying monetary policy shocks. Finally, a *third* area of applications focuses on recent use of probability forecasts, including a description of a measure of 'financial distress' that provides probabilistic statements on events in the UK unsecured credit market, investigated as a 'satellite' of the core UK model.

12.1 Recent applications of the structural cointegrating VAR approach

There has been considerable interest and activity in the application of the Structural Cointegrating VAR approach to macroeconometric modelling within academia, and from central bankers, government and industry in recent years. The flexibility of the modelling techniques is evidenced by the sheer variety of studies employing the techniques in the academic literature. So for example, recent applications have investigated monetary policy transmission mechanisms in Australia and New Zealand (Haug *et al.*, 2005), the link between wage setting, minimum wages and inflation in France (L'horty and Rault, 2004), the determinants of the demand for electricity in Greece (Hondroyianis, 2004), the demand for exports in Hong Kong (Abbott and De Vita, 2002), employment dynamics in India (Roy, 2004), the link between financial variables and import demand in Japan (Tang, 2004), the *PPP* hypothesis and the relationship between macroeconomic stability and growth in Turkey (Yazgan, 2003; Ismihan, Metin-Ozcan and Tansel, 2005), and the demand for calories in Zimbabwe (Tiffin and Dawson, 2003).

The approach to modelling the macroeconomy, as opposed to particular macroeconomic relationships, has also been illustrated in models of the US economy, in Anderson *et al.* (2002), the Canadian economy, in Crowder and Wohar (2004), and for the euro area in Brand and Cassola (2004). In the US model, a six-variable cointegrating VAR is obtained (including the CPI, the GDP deflator, real money balances, the federal funds rate, the yield on long-term bonds, and output), and anchored by four long-run relationships suggested by economic theory: namely, a money demand relationship, the Fisher inflation parity relationship, a term-structure relationship, and a relationship linking the two measures of prices. In the Canadian case, the six variables under consideration include disposable income, consumption, wealth, the interest rate, real money balances and the GDP deflator, while the long-run relationships include consumption–income and consumption-wealth relationships, the money demand relationship and the *FIP* relationship. For the euro area, Brand and Cassola's model describes real money balances, inflation, short-term and long-term interest rates and GDP, taking into account a demand for money relationship, a term-structure relationship and the *FIP*, again motivated with reference to the economic theory of the long run.

In each case, the models perform well by various statistical criteria and against alternative models and uncover important policy-relevant features. Hence, the US study concludes that the model provides forecasts that are very similar to those published by government agencies and so could provide a useful tool on which to base policy recommendations, accommodating the steady-state growth model of the economy implicitly shared by many government agencies and private forecasters. The Canadian and

euro area studies both focus on the impact of monetary policy change: the Bank of Canada's shift to a stable price level target in the early 1980s was associated with a once-and-for-all shift in the long-run relationships, while no major distortions were found with the advent of Stage Three of Economic and Monetary Union in the euro area model. In all cases, there is no doubt that practitioners, who need manageable and interpretable models to answer specific questions, appreciate the transparency and pragmatism of this modelling approach and that these methods are already in increasingly widespread use in the policy-making and decision-making communities.

In the case of the emerging market economies, in an interesting and thorough application of the long-run structural modelling, Akusuwan (2005) develops a small quarterly macroeconometric model for the Thai economy over the period 1980q1–2002q4, and establishes the existence of three long-run relations, namely the Fisher interest parity, the uncovered interest parity, and the long-run money demand. By allowing for a possible break in the domestic variables following the 1997 Asian crisis, she finds that the crisis has significant effects on the short-run structure of the model, but not on its long-run relationships.

The merits of the application of the approach to macroeconometric modelling are investigated recently by Jacobs and Wallis (2005). In their study, the core model of the previous chapters is compared and contrasted with COMPACT, a large-scale simultaneous equation model of the UK of the type described in Chapter 2 and elaborated in Wren-Lewis *et al.* (1996). It is noted that, with approximately ten times more variables and around 20 behavioural relations, the SEM is able to address a broader set of issues than the core model, but requires the use of single-equation and small sub-system estimation techniques. However, focusing on the main macroeconomic variables that are common to both models, Jacobs and Wallis compare the dynamic responses of the two models to a foreign output shock and to an oil price shock. They find that the core model performs well on the former exercise, compared to the unrealistically slow response of COMPACT, but fails to properly take into account the UK's changing response to oil price changes (given that the UK started and ended the period as a net importer of oil, but was a net exporter mid-sample). These findings, of course, reflect the VAR's power in fitting complicated dynamics and also its relatively simple form. Jacob and Wallis also use simulation methods to uncover the long-run relationships implicit in COMPACT and to compare these to the immediately apparent long-run relationships of the core model. This analysis shows a reassuring degree of consensus, with the interest rate parity (*IRP*), output gap (*OG*) and *FIP* relationships all holding in both models, and a further relationship described as a 'small deviation from the *PPP* relationship' also present in COMPACT's long-run properties.[1] The paper concludes that further research is required to investigate the effects of how best to treat the foreign variables (and in particular whether these are best treated as endogenous or exogenous variables), but highlights the strengths of these modelling approaches and illustrates well the emerging consensus between SEMs and our own approach that was anticipated and described in the discussion of Chapter 2.

Finally, in an exercise related to our analysis conducted in Chapter 11, Strachan and van Dijk (2004) use the UK model as one of three examples to investigate the uncertainty associated with structural features. Using a Bayesian approach they consider cointegration, exogeneity, deterministic processes and over-identification. Posterior probabilities of these features are then used in a model averaging approach to forecasting and impulse response analysis.

12.2 Regional interdependencies and credit risk modelling

The Jacobs and Wallis (2005) paper also raises the important issue of how national macroeconomic models, obtained using the Structural Cointegrating VAR modelling approach, relate to outside factors. This issue is explored in detail in the global vector error correction model of regional interdependencies advanced in Pesaran, Schuermann and Weiner (2004, PSW). The GVAR is used to examine a variety of problems including the effects of foreign shocks on the euro area in Dees, di Mauro, Pesaran and Smith (2005, DdPS), the modelling of credit risk in Pesaran, Schuermann, Treutler and Weiner (2005), and the counter-factual problem of a quantitative analysis of the possible effects of UK or Sweden joining the euro area in Pesaran, Smith and Smith (2005).

Global modelling is subject to a number of important constraints, including the quantity and quality of data available, the curse of dimensionality that arises out of the many between- and within-country channels of interactions and transmissions, our knowledge of economic theory and institutions and the availability of human and computing resources.

[1] Since money is not included as a variable in COMPACT, the fifth long-run relationship in our core model could not be considered in that model. This is likely to limit the use of COMPACT in analysis of liquidity effects and the possible disquilibrium effects of money markets on output and inflation.

The Global VAR approach developed and applied in the above papers and outlined in Section 3.4 provides a coherent solution by treating the foreign variables as weakly exogenous. This assumption is plausible for small open economies and can be tested empirically for medium size economies such as Japan and the euro area. A different modelling set-up would be needed for the US. In PSW the US economy is modelled as a closed economy except for the effective exchange rate which is treated as weakly exogenous. In extending and updating the GVAR, DdPS also experiment with a US model that includes foreign inflation and output variables as weakly exogenous and find that this is not rejected by the data.

Under the weak exogeneity of the foreign variables, country- (or region-) specific vector error correcting models (VECMs) can be estimated consistently, thus obviating the need for estimating the global model as a whole, which would not be feasible in any case. Despite this the variables in each economy are potentially related to all the variables in other economies. This is accomplished by relating the domestic variables of each economy to corresponding foreign variables constructed to match the international trade pattern of the country under consideration. The trade weights can be either fixed or time varying. The key assumption is that they are predetermined. In principle, different types of weights can also be used in constructing different types of foreign variables. But the limited experiments carried out in DdPS suggest that the GVAR results are likely to be reasonably robust to the choice of the weights. Once the estimates of the individual country models are obtained, they are combined in a consistent and cohesive manner to generate forecasts or impulse response functions for *all* the variables in the world economy simultaneously. See also Section 3.4.

Specifically, PSW consider country/region-specific quarterly models estimated over the period 1979q1–1999q1 for seven countries (namely USA, Germany, France, Italy, UK, Japan, China) along with four broader regions (namely, Western Europe, South East Asia, Middle East, and Latin America).[2] For these eleven regions, domestic variables of interest include real output for area i (y_{it}), the rate of price inflation (Δp_{it}), a real equity price index (q_{it}), the real exchange rate ($e_{it} - p_{it}$), where e_{it} is the log of nominal exchange rate in terms of a reference currency (US dollar), an interest rate (r_{it}), and real money balances (m_{it}), with $i = 0$ (US), $1, \ldots, 10$. So, in terms of the domestic variables, we have the vector $\mathbf{y}_{it}$ defined in

[2] The data for the four regions was itself constructed from data for 18 countries. The output of the 25 countries incorporated in the model covers more than 80% of total world output.

(3.21) set as $\mathbf{y}_{it} = (y_{it}, \Delta p_{it}, q_{it}, e_{it} - p_{it}, r_{it}, m_{it})'$, with $k_i = 6$.[3] The vector of foreign variables (indices), denoted by $\mathbf{y}^*_{it}$, is a $k^*_i \times 1$ vector are constructed as weighted averages, with region-specific weights:

$$\left.\begin{aligned} \mathbf{y}^*_{it} &= (y^*_{it}, \Delta p^*_{it}, q^*_{it}, e^*_{it}, r^*_{it}, m^*_{it})', \\ y^*_{it} &= \textstyle\sum_{j=0}^{10} w_{ij} y_{jt}, \quad p^*_{it} = \sum_{j=0}^{10} w_{ij} p_{jt}, \\ q^*_{it} &= \textstyle\sum_{j=0}^{10} w_{ij} q_{jt}, \quad e^*_{it} = \sum_{j=1}^{10} w_{ij} e_{jt}, \\ r^*_{it} &= \textstyle\sum_{j=0}^{10} w_{ij} r_{jt}, \quad m^*_{it} = \sum_{j=0}^{10} w_{ij} m_{jt}, \end{aligned}\right\} \tag{12.1}$$

where the weights w_{ij}, for $i, j = 0, 1, \ldots, 10$, are based on trade shares (namely the share of region j in the total trade of region i measured in US dollars). Note that $w_{ii} = 0$, for all i.

Region-specific cointegrating VAR models are estimated treating the relevant foreign variables, along with the price of oil, as exogenous in each case. As noted earlier the only foreign variable included by PSW in the US model was e^*_{it}. A VAR of order 1 is assumed across the regions given the small amount of data available, and careful analysis of the cointegrating properties of the data is employed to choose the cointegrating rank of each regional model. The underlying exogeneity assumptions are confirmed to be acceptable and the adequacy of the dynamic properties of the regional models is established, both taking the regions one at a time and when taken together. In the latter case, the regional models are brought together to form a global model following the steps outlined in expressions (3.23)–(3.27) in Section 3.4. To be more specific, each of the individual region-specific cointegrating VAR models is written in terms of the variables from all other regions, using the definitions in (12.1), and these are then stacked in a large global system accommodating all the contemporaneous and lagged interactions across the 60 plus variables of the system. The corresponding reduced form representation provides the vehicle for forecasting and impulse response analysis.

DdPS, building on the work of PSW, develop a global model covering 33 countries grouped into 25 countries and a single euro area economy comprising eight of the 11 countries that joined the euro in 1999. To deal with the modelling issues that arise from the creation of the euro area (a single exchange rate and a single short-term interest rate post 1999), the GVAR model is estimated with the euro area being treated as a single economy. This turns out to be econometrically justified and allows DdPS to

[3] Asset prices were excluded from the models for China and the Middle East on the grounds that the capital markets are less well-developed.

consider the impact of external shocks on the euro area as a whole without the danger of being subject to possible inconsistencies that could arise if the different economies in the euro area were modelled separately. The effects of external shocks on the euro area are examined based on different simulations using generalised as well as structural impulse response functions. Compared to the previous version of the GVAR developed by PSW, this Mark II version, in addition to increasing the geographical coverage, also extends the estimation period, and includes long-term as well as short-term interest rates, thus allowing more fully for the possible effects of bond markets on output, inflation and equity prices.[4]

DYNAMIC PROPERTIES OF THE GLOBAL MODEL

The GVAR provides a general, yet practical, global modelling framework for a quantitative analysis of the relative importance of different shocks and channels of transmission mechanisms for the analysis of the co-movements of output, inflation, interest rates, exchange rates and equity prices. Using generalised impulse response functions, it is possible to estimate the effects of shocks to one variable in one country on the other variables in the same country and/or in the rest of the world. PSW illustrate the power of the analysis by focusing on the effects of a one standard error (unit) negative shock to US equity prices, oil prices and interest rates. DdPS provide further experiments in relation to the euro area.

As an example in Figure 12.1 we reproduce (from PSW) the time profiles of the effects of shocks to US equity market on equity prices worldwide. On impact, a fall in the US equity prices causes prices in all equity markets to fall as well but by smaller amounts: 3.5% in the UK, 4.5% in Germany, 2.4% in Japan, 2.6% in South East Asia, and 4.8% in Latin America, as compared to a fall of 6.4% in the US. However, the falls in equity prices across the regions generally start to catch up with the US over time, and even get amplified in the case of Italy and Latin America. While the precise values of the responses need to be treated with caution, the relative position and pattern of the impulse response functions confirm the pivotal role played by the US stock market in the global economy, for example, and suggest that in the longer run scope for geographic diversifications across equity market might be somewhat limited.

[4] DdPS also provide a theoretical framework where the GVAR is derived as an approximation to a global unobserved common factor model. Also using average pairwise cross-section error correlations, the GVAR approach is shown to be quite effective in dealing with the common factor interdependencies and international co-movements of business cycles.

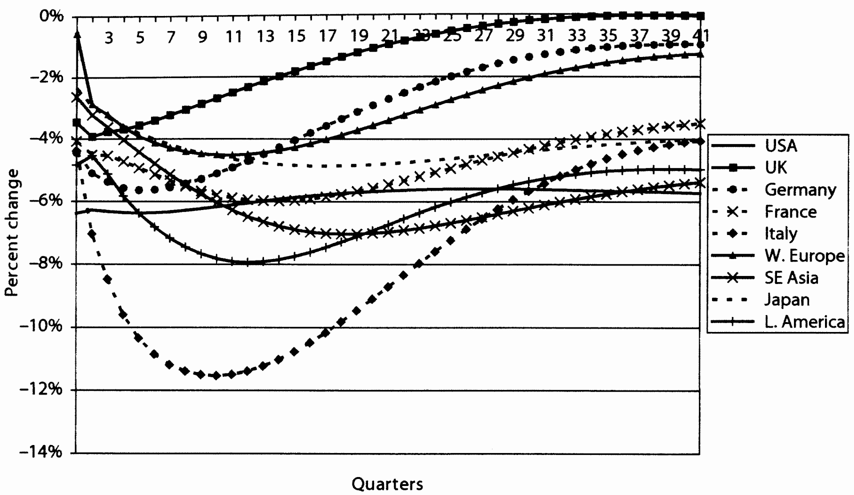


Figure 12.1 Impulse response of a negative one standard error shock to US real equity prices on real equity prices across regions.

The time profiles of the effects of the shock to the US equity market on real output across the different regions are shown in Figure 12.2.

The impact effects of the fall in the US equity market on real output are negative for most regions, but rather small in magnitude. After one year, real output shows falls of around 0.31% in the US, 0.25% in Germany, 0.29% in the UK, 0.26% in Latin America, and 0.12% in South East Asia, respectively. Japanese output only begins to be negatively affected by the adverse US stock market shock much later. The two regions without capital markets are either not affected by the shock (Middle East) or even show a rise in output (in the case of China). Once again, while these point estimates should be treated with caution, they provide a very useful indication of the likely dynamic effects of changes in the US equity market. Further exercises are provided in PSW to show the effects of a shock to the equity markets of South East Asia (providing useful insights with which to judge the experiences of the events surrounding the 1997 South East Asian crisis), and to derive a credit portfolio model based on forecasted default probabilities and loss distributions.

In PSW and elsewhere, the GVAR model has also been used as a global macroeconomic engine driving credit risk models. This is particularly relevant for policy analysis, where one would like to be able to examine how shocking a given macroeconomic variable in a given region could

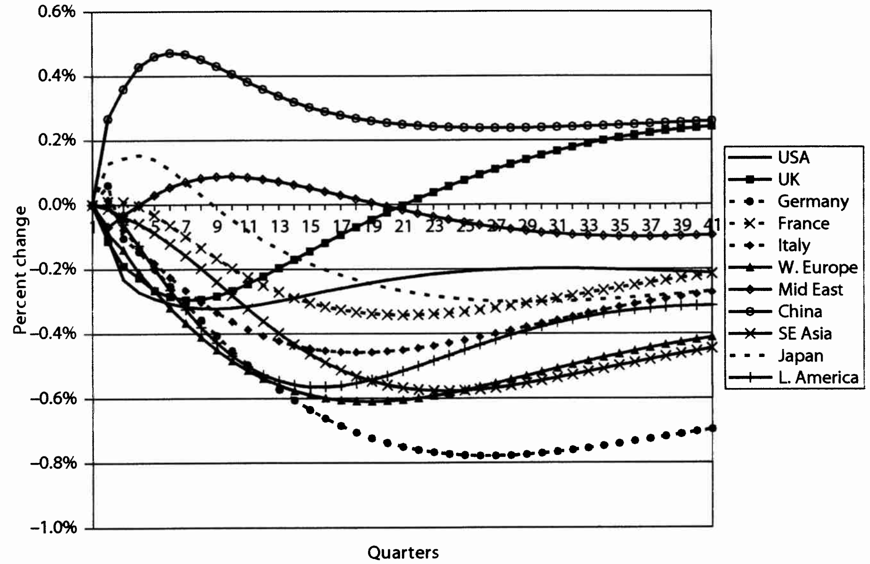


Figure 12.2 Impulse response of a negative one standard error shock to US real equity prices on real output across regions.

affect risk of a globally diversified credit portfolio. For example, it might be of interest to determine the effects of a contemporaneous 10% drop in the Japanese equity prices on other macroeconomic variables, and the effects that these have on the credit risk. As before, generalised impulse response functions can be used to carry out this type of analysis. For further details see Pesaran, Schuermann, Treutler and Weiner (2005) and Pesaran, Schuermann and Treutler (2005).

12.3 A monthly version of the core model

The interest in investigating structural cointegrating VAR models of the macroeconomy has been mirrored by a surge of interest in the use of impulse response analysis, work on the identification of trends and shocks and attempts to decompose the effects of these shocks. The analysis of the macroeconomic models of Canada, the US and the euro area described in the previous section, and the GVAR model, were all accompanied by impulse response analyses to interpret the implicit model properties. In a similar vein, there has been increased interest in obtaining economically meaningful shocks through the imposition of theory-based restrictions and the decomposition of trends. Hence, for example, Crowder *et al.* (1999) provide a decomposition of the effects of shocks to their four-variable cointegrating VAR model of the US to illustrate the historical importance of demand and supply shocks; Wickens and Motto (2001) illustrate the effects of money supply shocks in another four-variable model of the US through imposition of economically motivated restrictions on the cointegrating VAR; Mitchell (1999) examines the effects of monetary policy shocks in the G7 economies using models of a similar form to that of our core model; Ribba (2003) provides a permanent–transitory decomposition of measures of core inflation based for the US; Schumacher (2002) uses a permanent–transitory decomposition to investigate trend output in the euro zone which is, in turn, used to obtain measures of the output gap; and so on.

As the discussion of the earlier chapters made clear, the identification schemes of the short run used to identify economically meaningful shocks are frequently based on the timing of decisions and/or release of news. These identification schemes are often most easily motivated with reference to high frequency data, where temporal aggregation issues are less common. In this section, we briefly describe an application of the modelling techniques developed in the earlier chapters which constructs a monthly version of the core model of the UK, as discussed in Garratt, Lee and Pesaran (2005a). Such a model is particularly relevant for the conduct and the analysis of monetary policy, which is typically updated at a monthly frequency. It is particularly interesting to consider the impulse responses of a model, based on monthly observations that match more closely the decision-making frequency, and to contrast these with those obtained previously on quarterly data to gauge the robustness of the findings of the earlier modelling exercise.

THE STRUCTURE OF THE MONTHLY MODEL

The illustration below uses monthly data for the UK over the period 1965m1–2002m9 (453 observations). We undertake a modelling exercise of precisely the same form as in Chapter 9 and conduct an impulse response exercise, using the exact short-run identification scheme described in Chapter 10 to compute monetary policy and oil price shocks. Where possible, we collected the exact or near exact monthly equivalents of the quarterly measures used in the earlier chapters; see Garratt, Lee and Pesaran (2005a) for details. The variables available at the monthly

frequency are p_t, $\tilde{p}_t$, p_t^o, r_t, r_t^* and m_t. The remaining three variables, y_t, y_t^* and nominal domestic GDP are not directly observable on a monthly basis. We therefore use a linear exponential monthly interpolation method described in Dees, di Mauro, Pesaran and Smith (2004, appendix) for these variables.

The long-run structure we consider in the monthly model is identical to that described and estimated in Chapter 9, the lag length is six months (matching two quarters previously used). In this model, the long-run estimates obtained from the monthly model are given by:

$$(p_t - p_t^*) - e_t = \widehat{\xi}_{1,t+1}, \tag{12.2}$$

$$r_t - r_t^* = \widehat{\xi}_{2,t+1}, \tag{12.3}$$

$$y_t - y_t^* = \widehat{\xi}_{3,t+1}, \tag{12.4}$$

$$h_t - y_t = -\underset{(33.44)}{134.72}\, r_t - \underset{(0.00028)}{0.0021}\, t + \widehat{\xi}_{4,t+1}, \tag{12.5}$$

$$r_t - \Delta\tilde{p}_t = \widehat{\xi}_{5,t+1}. \tag{12.6}$$

It is worth recalling that the estimates of the coefficients in the money demand equation based on the quarterly model were 56.10 and 0.0073, as compared to the above estimates of 134.72 and 0.0021, respectively. To ensure that the two estimates of the interest rate effects are comparable the one based on the monthly model should be divided by 3, which yields the estimate of 33.7 which is only somewhat lower than the estimate of 56.10 obtained from the quarterly model.[5] The estimate of the trend coefficient is also lower using the monthly model, partly reflecting the more recent sample that underlies the monthly model. As noted before it is unlikely that the downward trend in real money balances observed pre-1999 should continue into the future. The log-likelihood ratio statistic for testing the 23 over-identifying restrictions is 71.73, which is again in line with the results obtained for the quarterly model.

Table 12.1 reports the estimates of the loading matrix $\boldsymbol{\alpha}$ for the cointegrating terms in the error correction specification, along with various diagnostic test statistics.

The estimates of the loading coefficients show that the long-run relations make an important contribution in most equations and that the error correction terms provide for a complex and statistically significant set of interactions and feedbacks across commodity, money and foreign

[5] Note r_t is measured on a per annum basis and hence an approximate comparison with the quarterly coefficient would be the number is $134.72/4 = 33.7$.

Table 12.1 Reduced form error correction equations of the monthly model.

Eq	$\Delta(p_t - p_t^*)$	Δe_t	Δr_t	Δr_t^*	Δy_t	Δy_t^*	$\Delta(h_t - y_t)$	$\Delta(\Delta\tilde{p}_t)$
$\widehat{\xi}_{1,t}$	−0.009*	0.0263*	0.0002	−0.0002	0.007*	0.0109*	−0.0093	−0.0055
	(0.0027)	(0.011)	(0.0002)	(−0.0002)	(0.003)	(0.0019)	(0.0056)	(0.003)
$\widehat{\xi}_{2,t}$	−0.878*	1.433	0.007	0.0493*	1.187*	1.101*	−1.045	−1.237*
	(0.296)	(1.229)	(0.03)	(0.0171)	(0.341)	(0.210)	(0.622)	(0.342)
$\widehat{\xi}_{3,t}$	0.0157	−0.0623	−0.0015*	−0.00065	−0.0473*	−0.0108	0.0491*	0.0177
	(0.0085)	(0.035)	(0.0009)	(0.0101)	(0.009)	(0.006)	(0.0178)	(0.0098)
$\widehat{\xi}_{4,t}$	0.009*	−0.0152	−0.00024	−0.00002	−0.0097*	−0.0071*	−0.0020	0.0056
	(0.002)	(0.0084)	(0.0002)	(0.0001)	(0.0023)	(0.001)	(0.0043)	(0.0023)
$\widehat{\xi}_{5,t}$	0.052	−0.185	−0.0235*	−0.0152	−0.1984*	−0.1659*	0.5063*	0.700*
	(0.085)	(0.352)	(0.0086)	(0.0049)	(0.0976)	(0.0602)	(0.178)	(0.0981)
$\bar{R}^2$	0.2210	0.0697	0.0811	0.2689	0.2606	0.2401	0.2736	0.4682
$\hat{\sigma}$	0.0043	0.0179	0.00044	0.0003	0.0049	0.00308	0.0091	0.005
$\chi^2_{SC}[12]$	15.998	10.39	17.51	28.68	36.73	38.15	34.48	116.57
$\chi^2_{A}[12]$	22.008	3.31	62.63	1.511	116.14	24.91	23.30	9.17
$\chi^2_{N}[2]$	329.31	1804.3	295.2	522.7	262.16	117.23	231.99	305.74
$\chi^2_{H}[1]$	34.33	17.12	68.17	58.48	7.19	40.56	1.56	39.22

Note: To save space only the error correction coefficients are reported, with their standard errors given in parentheses.

exchange markets. The results in Table 12.1 also show that the core model fits the data well and the diagnostic statistics of the equations are generally satisfactory as far as the tests of the residual serial correlation, functional form and heteroscedasticity are concerned.[6]

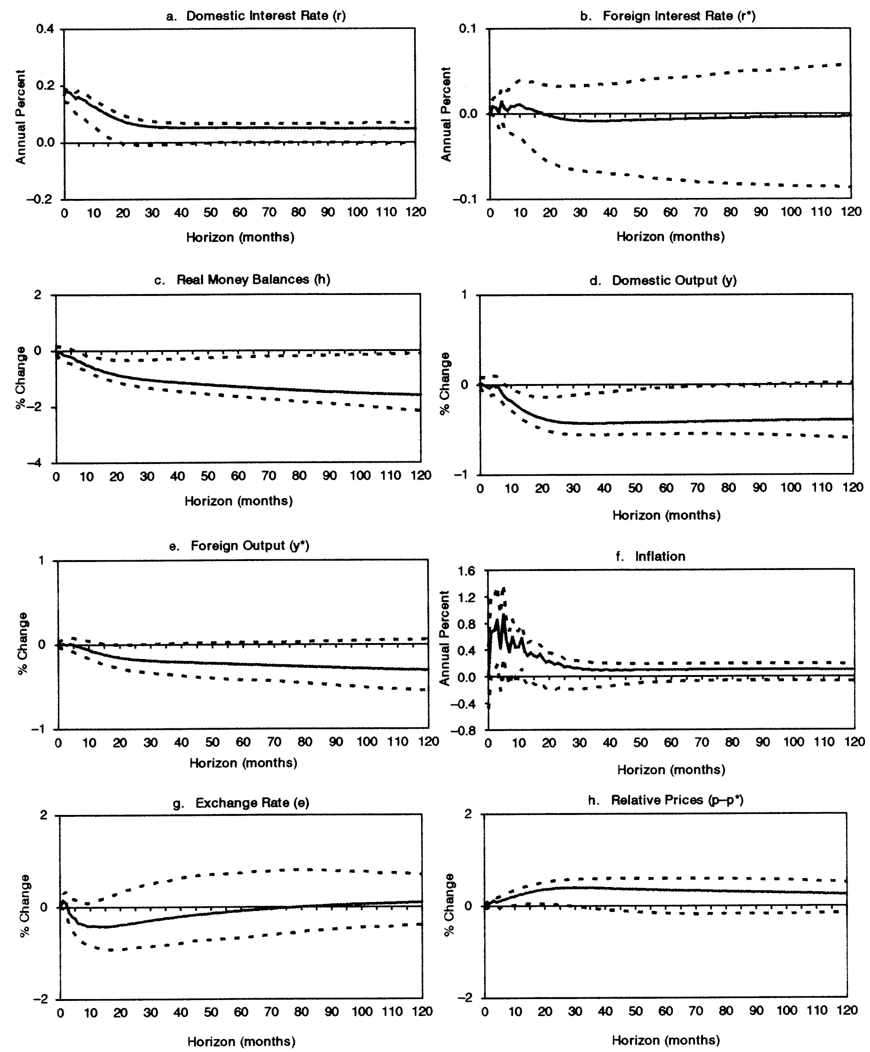
IMPULSE RESPONSE ANALYSIS FOR THE MONTHLY MODEL

Figures 12.3 and 12.4 plot the monthly impulse responses of the variables to a monetary policy and oil price shock corresponding to the impulse responses described for the quarterly model in Section 10.2.

The shape and timing of the monthly and quarterly impulses are very similar. Focusing on the monetary policy shock, for example, the sign of the impact effects is the same in the quarterly and monthly models across all of the endogenous variables, and the shapes of the impulse responses are the same in monthly and quarterly versions for all the series too.[7] Moreover, the timing of the responses is very similar: domestic interest rates settle to their long-run levels after around 30 months in the monthly plots compared to around 12 quarters in the quarterly plot of Figure 10.4;

[6] The normality of the errors is rejected in all of the error correction regressions, and is almost certainly due to the three major oil price hikes experienced during the estimation period.

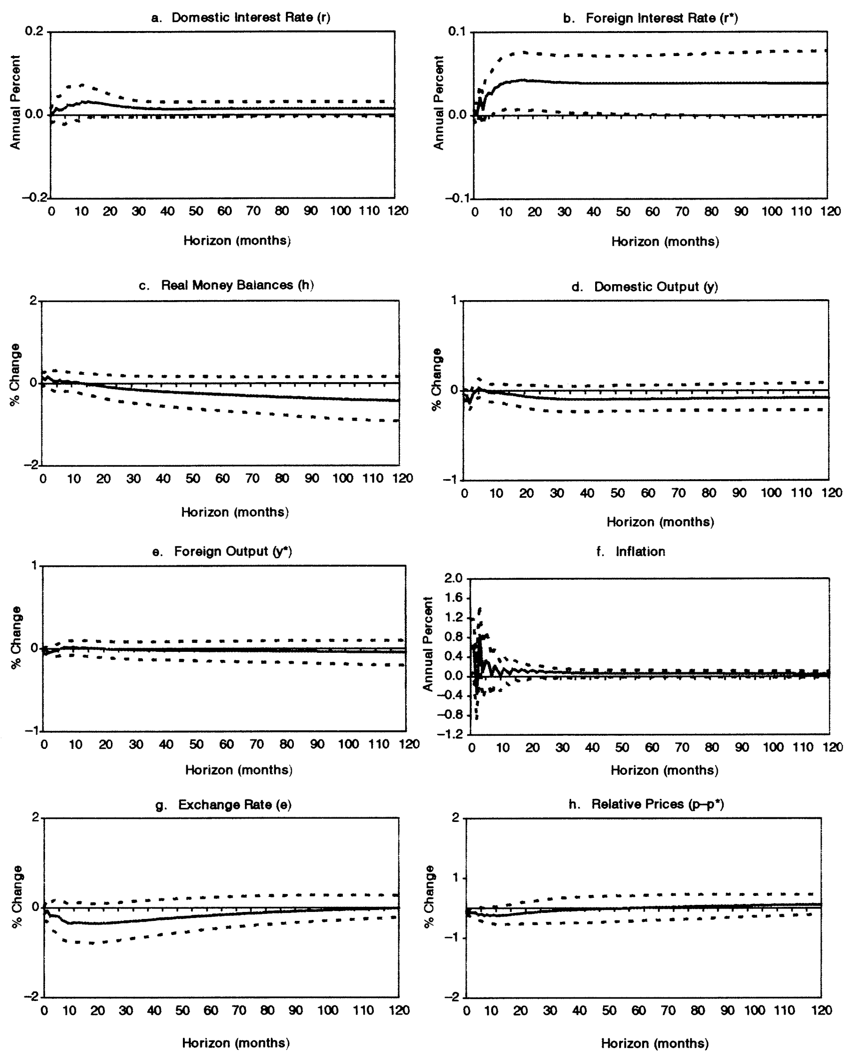
[7] There is, however, a minor exception in the core of the impulse responses for the effects of the monetary policy shock on the exchange rate. Unlike the quarterly model the monetary policy shock shows a brief (two month) period of depreciation in the monthly model.



Note: The solid and dashed lines plot the point estimates and 95% confidence intervals of the impulse responses, which are generated from the bootstrap procedure using 2000 replications.

Figure 12.3 Monthly generalised impulse responses to a positive unit shock to monetary policy.

the initial upward impact on domestic output is reversed after six months in the monthly plot compared to two quarters in the quarterly plots; the puzzling rise in inflation in response to the contractionary shock shows in the monthly model as in the quarterly model, but the effects are relatively



Note: The solid and dashed lines plot the point estimates and 95% confidence intervals of the impulse responses, which are generated from the bootstrap procedure using 2000 replications.

Figure 12.4 Monthly generalised impulse responses to a positive unit shock to the oil price.

short-lived and effectively disappear after 12 months (*cf.* four quarters in Figure 10.4). Similar comments apply to the impulse responses arising from the oil price shock. Again the responses from the monthly model are very similar to those obtained in the quarterly model, shown in Figure 10.6,

both in terms of the sign of the impact effects and the shape and timing of the subsequent responses. (Perhaps the only notable feature that is distinctive is the higher volatility of the inflation response in the monthly plots compared to those in the quarterly plots.)

12.4 Probability forecasting and measuring financial distress in the UK

The material of Chapter 11 showed that probability forecasting is an extremely useful means of providing information on the properties of a model and conveying the uncertainty that surrounds the predictor of future events of particular interest. This type of analysis is also becoming increasingly popular, particularly as investigators recognise the ease with which the probability forecasts can be produced with the small and flexible models of the type we have promoted in our work. This is especially true for analyses of inflation forecasts and monetary policy formulation; see, for example, Diebold *et al.* (1999), Ehrmann and Smets (2003), and Hall and Mitchell (2005). In the illustration below, we consider the recent work of Lee and Mizen (2005) who focus on the use of the probabilistic statement as a macroeconomic indicator. The illustration is also of interest because it provides an example of the use of a satellite model, supplementing the core, as described in Section 3.3.2.

12.4.1 *A satellite model of the UK financial sector*

The extension of the model considered here concerns the measurement of 'financial distress' at the macroeconomic level. Financial distress relates to the vulnerability of individuals in their financial decision-making and is reflected in periods of high levels of defaults on loan repayments and bankruptcies. This has become a topic of some interest in recent years as the levels of credit card debt, in the UK, the US and elsewhere, have risen to unprecedented levels. There is widespread anxiety that this could generate financial instability if there were to be an adverse macroeconomic shock in the form of higher interest rates or low growth. Indeed, current levels of the 'debt burden' (showing debt interest payments on repayments based on unsecured debt relative to income) are, in 2005, at their highest ever level in the UK and have recently exceeded those observed in the early 1990s when many households experienced considerable financial hardship, personal bankruptcies were widespread and loan repayment defaults were extremely high.

Lee and Mizen (2005) consider this problem using the long-run structural modelling approach developed in the earlier chapters applied to the core macroeconomic model and to a satellite model of UK households' portfolio and expenditure decisions. Economic theory is used to motivate the long-run relations that are likely to hold between household consumption expenditure (c_t), money deposits (m_t) and borrowing (l_t) where a household can consume more than current income and money balances by borrowing at a 'credit card' interest rate r_t^l. The long-run relationships of the satellite model suggested by the theory relating to household portfolio and expenditure decisions can be written as

$$c_t = b_{10} + b_{11}t + \widetilde{y}_t + b_{12}r_t + \xi_{c,t+1}, \quad (12.7)$$

$$m_t = b_{20} + b_{21}t + \widetilde{y}_t + b_{22}r_t + \xi_{m,t+1}, \quad (12.8)$$

$$l_t = b_{30} + b_{31}t + \widetilde{y}_t + b_{32}r_t^l + \xi_{l,t+1}, \quad (12.9)$$

$$r_t^l = b_{40} + b_{41}t + r_t + \xi_{r,t+1}, \quad (12.10)$$

where $\widetilde{y}_t$ refers to real net labour income. This can be written more compactly as

$$\xi_{bt} = \beta_b'(\mathbf{w}_{t-1}, r_{t-1}) - \mathbf{b}_0 - \mathbf{b}_1(t-1),$$

where

$$\mathbf{w}_t = \left(c_t - \widetilde{y}_t, m_t - \widetilde{y}_t, l_t - \widetilde{y}_t, r_t^l\right)'.$$

$$\mathbf{b}_0 = (b_{10}, b_{20}, b_{30}, b_{40})', \ \mathbf{b}_1 = (b_{11}, b_{21}, b_{31}, b_{41})',$$

$$\xi_{bt} = (\xi_{ct}, \xi_{mt}, \xi_{lt}, \xi_{rt})',$$

and

$$\beta_b' = \begin{pmatrix} 1 & 0 & 0 & 0 & -b_{12} \\ 0 & 1 & 0 & 0 & -b_{22} \\ 0 & 0 & 1 & -b_{32} & 0 \\ 0 & 0 & 0 & 1 & -1 \end{pmatrix}. \quad (12.11)$$

A simplifying assumption is that the household portfolio and expenditure decisions are made taking into account the macroeconomic context, but that these household allocation decisions do not impact on the evolution of the national macroeconomic aggregates. In this case, the set of sectoral variables in $\mathbf{w}_t$ are influenced by the core macroeconomic variables of our core model (including the interest rate r_t) but not *vice versa*, and the modelling framework between a core and a satellite model described in Section 3.3.2 is appropriate. In particular, in these circumstances, the estimation of the core model can be conducted without reference to the satellite model (so that the model of Chapter 9 remains relevant), while the model of the household expenditure and portfolio decisions can be estimated taking the macroeconomic interest rate r_t as an exogenous $I(1)$ variable.

12.4.2 *UK financial distress in the early 1990s and early 2000s*

The estimation of the above model is discussed in Lee and Mizen (2005). The model provided an extremely useful vehicle with which to forecast future events relating to the macroeconomy and/or household portfolio and expenditure decisions. It is argued in Lee and Mizen (2005) that financial distress is associated with particular conjunctions of events involving the disequilibria in the credit market as reflected in the estimated values of ξ_{lt} in (12.9) and the economy's growth prospects. In this case, forecasts of the probability of the occurrence of these events provide useful indicators of financial distress at the macroeconomic level. With this in mind, Lee and Mizen calculate forecasts of various probabilities involving excess credit holdings (*i.e.* $\xi_{lt} > c_1$ for various threshold values, c_1) and recession or slow growth (defined where a four-quarter moving average falls below zero or 1% respectively; *i.e.* $\Delta\widehat{y_t^{MA}} < c_2$, for $c_2 = 0$ or 0.01). The exercise is conducted using the core and satellite models estimated over the period 1965q1–2001q1 and then again, using exactly the same methods, on the data ending in 1990q1 (just prior to the previous period of financial distress). Representative results are provided in Table 12.2.

These show that the estimated probability of excess credit holdings or slow growth occurring were very high in the early 1990s, so that the high levels of financial distress that were experienced would have been reflected in these forecast figures. In contrast, the corresponding probabilities observed for 2001–2002 were very much lower.[8] Despite the very high debt burden levels observed at this time, the point forecasts of excess credit

[8] The fact that the successive columns of the table relating to 2001q1–2003q1 are the same reflects the fact that the joint probability relates exclusively to the probability of slow growth; the probability of excess credit holdings was found to be zero for $c_1 = 0.2$, 0.3 and 0.4.

Table 12.2 Probability forecasts involving credit–income disequilibria and low growth 1990q2–1992q1 and 2001q2–2003q1

Forecast Horizon	$\Pr(A \cup B)$ $c_1 = 0.20$ $c_2 = 0.01$	$\Pr(A \cup B)$ $c_1 = 0.30$ $c_2 = 0.01$	$\Pr(A \cup B)$ $c_1 = 0.40$ $c_2 = 0.01$
1990q2	1.00	0.97	0.49
1990q3	1.00	0.92	0.45
1990q4	1.00	0.66	0.40
1991q1	1.00	0.74	0.46
1991q2	1.00	0.82	0.46
1991q3	1.00	0.84	0.44
1991q4	1.00	0.80	0.42
1992q1	1.00	0.83	0.40
Forecast Horizon	$\Pr(A \cup B)$ $c_1 = 0.20$ $c_2 = 0.01$	$\Pr(A \cup B)$ $c_1 = 0.30$ $c_2 = 0.01$	$\Pr(A \cup B)$ $c_1 = 0.40$ $c_2 = 0.01$
2001q2	0.21	0.21	0.21
2001q3	0.33	0.33	0.33
2001q4	0.38	0.38	0.38
2002q1	0.43	0.43	0.43
2002q2	0.36	0.36	0.36
2002q3	0.32	0.32	0.32
2002q4	0.30	0.30	0.30
2003q1	0.29	0.29	0.29

Note: The probability estimates relate to the quarter-on-quarter forecasts of the credit–income disequilibria and the four-quarter moving average of output growth (denoted Δy_t^{MA}). Slow growth is defined to occur when the latter falls below 1%. Event $A = \{\widehat{\xi}_{lt} > c_1\}$ and $B = \{\Delta y_t^{MA} < c_2\}$. $A \cup B$ means 'disequilibrium exceeds a critical value or slow growth occurs'.

holdings were low (and well below the threshold values for c_1 that were considered to relate to financial distress). Financial distress would be driven by the probability of recession or poor growth in these circumstances, but this seemed relatively unlikely in 2001–2003 also. Hence, the probability forecasts provided in Table 12.2 indicate low levels of financial distress and, as it turned out, this was not a period in which either high levels of loan default or bankruptcy actually occurred.

12.5 Directions for future research

This chapter provides an overview of the various applications and extensions of the long-run structural modelling strategy advanced in this

volume, namely the rigorous use of long-run economic theory in the context of an econometrically coherent time series framework. We are confident that many of the areas that we have highlighted will be adapted or extended to initiate new research avenues in due course. In particular, we believe there to be considerable scope for the further development and use of the techniques in the sphere of global macroeconometric modelling. This chapter briefly discusses the evidence obtained so far in the literature on global VAR modelling. Here, the individual national economy models are combined in a feasible and consistent manner into a global macroeconometric model for use in policy analysis and risk management, very much reminiscent of the pioneering work of the Project Link under the leadership of Lawrence Klein. The GVAR models developed so far impose cointegrating rank restrictions on the individual economy models. The next stage would be to consider the imposition of over-identifying long-run theory restrictions on the cointegrating relations of the individual economies, very much along the lines implemented in this volume for the UK economy, before combining them into a global model. Preliminary analysis suggests that this could indeed be a promising line for future research.

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Concluding remarks

In this book, our aim has been to provide a reasonably comprehensive account of the cointegrating VAR analysis of national and global macroeconomic modelling with a solid underlying long-run economic theory. We have compared our approach to other alternatives, particularly where either little economic theory is used in the modelling process or, where the economic theory is allowed to dominate the empirical evidence. We view both of these strands as valuable from a pedagogical viewpoint. For the modelling exercise to be useful and relevant to a better understanding of the macroeconomic processes and public debates about macroeconomic policy, a middle ground is needed. This book presents such an approach where implications of the long-run economic theory are combined with short-run dynamics within a cointegrating VAR framework. Contemporaneous restrictions from economic theory are imposed subsequently as a means of identification of the monetary policy shock and its impulse responses.

The book also addresses one of the important limitations of VAR for the analysis of relatively large system of equations that arise particularly in the case of global modelling. This is done by means of VARX or VARX* specifications where the familiar VAR model is augmented with $I(1)$ weakly exogenous (or long-run forcing) variables so that the 'core' variables are distinguished from the variables in the satellite sub-models. In the case of national macroeconometric modelling, core variables would typically include real output, inflation, interest rates and exchange rates, whilst the variables in satellite models could be consumption, investment, employment, real wages, imports or exports. At the national level, the core variables would be long-run forcing for the satellite variables, whilst within a global context the foreign variables, denoted as * variables, will be long-run forcing for the core national variables. The resultant modular structure is eminently suitable for a cointegrating analysis of large (log) linear systems.

In combining the long-run theory with empirically based short-run dynamics, particular attention is also paid to a simultaneous treatment of trends and cycles. This contrasts with much of the empirical implementation of the DSGE modelling where individual series are de-trended first, often with the help of Hodrick–Prescott filter, before modelling the relationships that might exist amongst the de-trended series. By building on long-run economic relations that are widely held as providing a solid economic foundation, and by allowing for unit roots and deterministic trends simultaneously, we believe that our modelling framework would be a suitable starting point for the analysis of short-run economic restrictions such as those implied by intertemporal optimisation, learning and expectations formation.

The long-run structural approach is illustrated with an application to the UK macroeconomy. Careful attention is paid to the different stages of the modelling exercise and, in the interest of ready replications of our results by other researchers, data and programs used are supplied with detailed accounts of their implementation. Further applications are considered and recent extensions of the modelling strategy to a global context (namely the GVAR modelling) are also discussed.

To summarise in more detail the book serves to

- explain and promote the long-run structural modelling approach as a way of undertaking macroeconometric research;
- provide a comprehensive illustration of the approach through a description of each stage of the development of the core model of the UK economy; and
- demonstrate how a model obtained following this approach can be used in real-world decision-making.

On the issue of promoting the long-run structural modelling approach, our aim throughout has been to present a fully transparent approach to macroeconomic modelling in which there is a clear statement of the economic theory and the associated econometric methodology. Our explicit description of a macroeconomic theory of the long run aims to highlight the level of abstraction at which an analyst might work in building a model that can be confronted with the data. Similarly, our description of the theory of the short run also exposes the extent to which economic theory might realistically inform our attempts to

interpret macroeconomic dynamics. And our comprehensive description of the econometric methods underlying the long-run structural modelling approach showed how the insights obtained from an explicit statement on the long-run theory (and, if available, on the short-run theory) can be embedded, and tested, within a statistical model that can both possess economically reasonable properties and reflect the characteristics of the data. In brief, the intention is that the economic theory and the econometric methods complement and enhance each other.

We have been keen to compare and contrast our approach to modelling with other popular approaches not just to highlight its transparency and ease of implementation, but also to draw out those areas on which there is consensus in macroeconomics and those areas that are subject to controversy. Our approach emphasises the use of long-run theory on the grounds that this is the area in which there is most agreement. But we acknowledge that some questions require more detailed short-run analysis and so we explain how such an analysis can be undertaken and the assumptions that are required. Our discussion of these issues emphasises the difficulties in identifying economically meaningful shocks on the basis of the identification schemes currently employed in the literature, casting doubt on the ability of the current generation of theories of macroeconomic dynamics to deliver an all-encompassing description of the short run or one that is consistent with the data. However, even if we doubt the validity of some of the currently employed identification schemes, we hope that our work will contribute to what is an ongoing debate and, through our discussion of models employing higher frequency data, hope to focus modellers' attention on more reasonable identification schemes that can be defended with reference to information flows and the precise timing of decisions.

The second aim of the book is to provide an illustration of the entire process of building a model, from the description of the underlying economic theory and its empirical counterpart, through the collection of data and its initial characterisation, through the estimation and testing of the model, to its final use in interpreting the macroeconomy and its use in decision-making. Of course, we hope that the core model of the UK economy that we have obtained is useful in its own right, and we have provided full details of the data and the model estimation in Appendix C for this reason. But the primary purpose of this description is to illustrate the steps and decisions that have to be taken in building a macroeconomic model. The construction and maintenance of a model typically requires a sustained research effort. Our hope is that the description of our modelling activities for the UK economy can provide a blueprint for model construction in a variety of different (global and/or national) contexts so that the first stages of the modelling activity are more easily addressed, and we have provided details of our programs so that these can be readily adapted for the use of others.

The third objective of the book is that the work will be useful to practitioners. As can be seen from the discussion of the previous chapters, many of the methods that we have described are already being applied both inside and outside academia. Practitioners, who need manageable and interpretable models to answer specific questions, appreciate the transparency and pragmatism of the modelling approach so that the methods are already in increasingly widespread use in the policy-making and decision-making communities. Of course, it is true that our core model could not be used to answer questions on the impact of particular tax changes or other very detailed policy effects, which would require a large-scale macroeconomic model. But financial institutions and decision-makers in industry need to answer a large variety of questions and make use of a range of macroeconomic models to address these questions. Some of these models will be more complex than ours and some of them will be less complex. But in any event, the ease of construction of a model following our approach means that such models can be obtained easily either to stand in their own right or as a complementary view to other models. Moreover, as we have noted, a model obtained following our approach can be readily extended either by its inclusion within a broader framework (as in the GVAR model, for example), or by linking it to a more detailed 'satellite' model of the market of interest. In all cases, the relative simplicity and flexibility of the models that are obtained means that they are well-suited for use in simulation and other counter-factual exercises so that we believe they provide an extremely valuable tool for decision-making.

The research reported in this volume also points to a number of important extensions, and suggests a number of new applications that might be pursued. For example, alternative sets of short-run restrictions, motivated by macroeconomic theory, can be imposed and tested using the core long-run structural model; satellite models of labour market and foreign trade can be developed and tested; the global modelling framework can be utilised for identification of long-run theory relations in the world economy; and it can be used to investigate the extent to which

business cycles are synchronised across different economies using the permanent/transitory decomposition of the variables in the cointegrating country-specific models; and so on. In each case, we believe the methods described in the book will contribute to a theoretically informed and evidence-based analysis of important macroeconomic phenomena.