6 Implications of Different Structures

It is important to understand the robustness of the conclusions regarding adjustment mechanisms to different assumptions about predicted economic behaviour, especially with respect to possible asymmetries between the UK and the euro area.

When the interest elasticity of UK demand is assumed to be higher than in the euro area, as suggested by some empirical evidence, the ability of the economy to respond to asymmetric shocks deteriorates since the perverse real interest rate effect is strengthened. For symmetric shocks, the higher interest elasticity implies that the ECB would deliver a more vigorous response than the UK, outside EMU, would have experienced.

If UK prices were assumed to be more flexible than the euro areas, as some evidence suggests, then output volatility would be reduced inside EMU but inflation variation would increase as relative prices take on the primary adjustment role. So, depending on policymakers' preferences, more flexibility in the UK may be preferred to a case where price-setting responses in the UK and euro area are both less flexible. However, the preferred outcome would be characterised by a high degree of flexibility in both the UK and euro area.

6.1 The analysis of Sections 3-5 has deliberately adopted a benchmark version of the 'Three Bears' model where all possible behavioural asymmetries in the structure of the model were assumed to be absent. This approach was motivated by three main considerations, all of which are analysed in more detail in the EMU study *EMU and the monetary transmission mechanism:*

- first, there is a good deal of empirical evidence to suggest that the transmission of monetary policy is actually rather similar across EU countries (see for example Ehrmann, 2000 and Ramaswamy and Sloek, 1998);
- second, to the extent that empirically estimated macromodels do show evidence of variations in behaviour, these differences are often found to result from arbitrary differences in equation specification across countries, or from variations in theoretical specification across models (see BIS, 1995, for a comprehensive comparative study of this issue); and
- third, it has been argued that even if there are differences in the behavioural characteristics of EMU, then the very process of EMU may quickly bring about 'endogenous convergence' of these structural characteristics (see Frankel and Rose, 1998).[1] Perhaps the best example relates to the behaviour of UK consumers who have been found empirically to be more sensitive to variations in short-term interest rates compared to average behaviour in the euro area. This can be attributed to the history of relatively high inflation in the UK that has led to a greater reliance on floating rate mortgage finance.[2]

[1] This is a particular manifestation of the Lucas critique (see Lucas, 1976) that any model estimated under one policy regime, in this case an independent monetary policy, is likely to break down when confronted with an alternative regime, in this case EMU.

[2] For an extended discussion, see the EMU study by HM Treasury *Housing, consumption and EMU*.

But to the extent that this characterisation is true, it can be argued that any differences in the preferred means of housing finance, and hence in the sensitivity of consumers to short-term interest rates, would be less, and in the limit would disappear once UK consumers were subject to the same monetary regime as the rest of the euro area.

6.2 Nevertheless, one of the striking conclusions that has emerged from the analysis so far is that even when behavioural asymmetries are assumed to be absent, interesting and important differences are apparent in the adjustment mechanisms of the economy inside EMU compared to outside.

6.3 But what if there are current and prospective behavioural differences in the structure of the UK economy compared to the euro area? This question has been examined more comprehensively elsewhere (see, for example, BIS, 1995). Here it is useful to focus on some of the more plausible asymmetries to see how understanding of the adjustment processes inside EMU might be extended. Two particularly important potential asymmetries are examined; first relating to the sensitivity of demand to interest rates, and second, to the degree of flexibility of prices.

What if UK demand is more sensitive to interest rates?

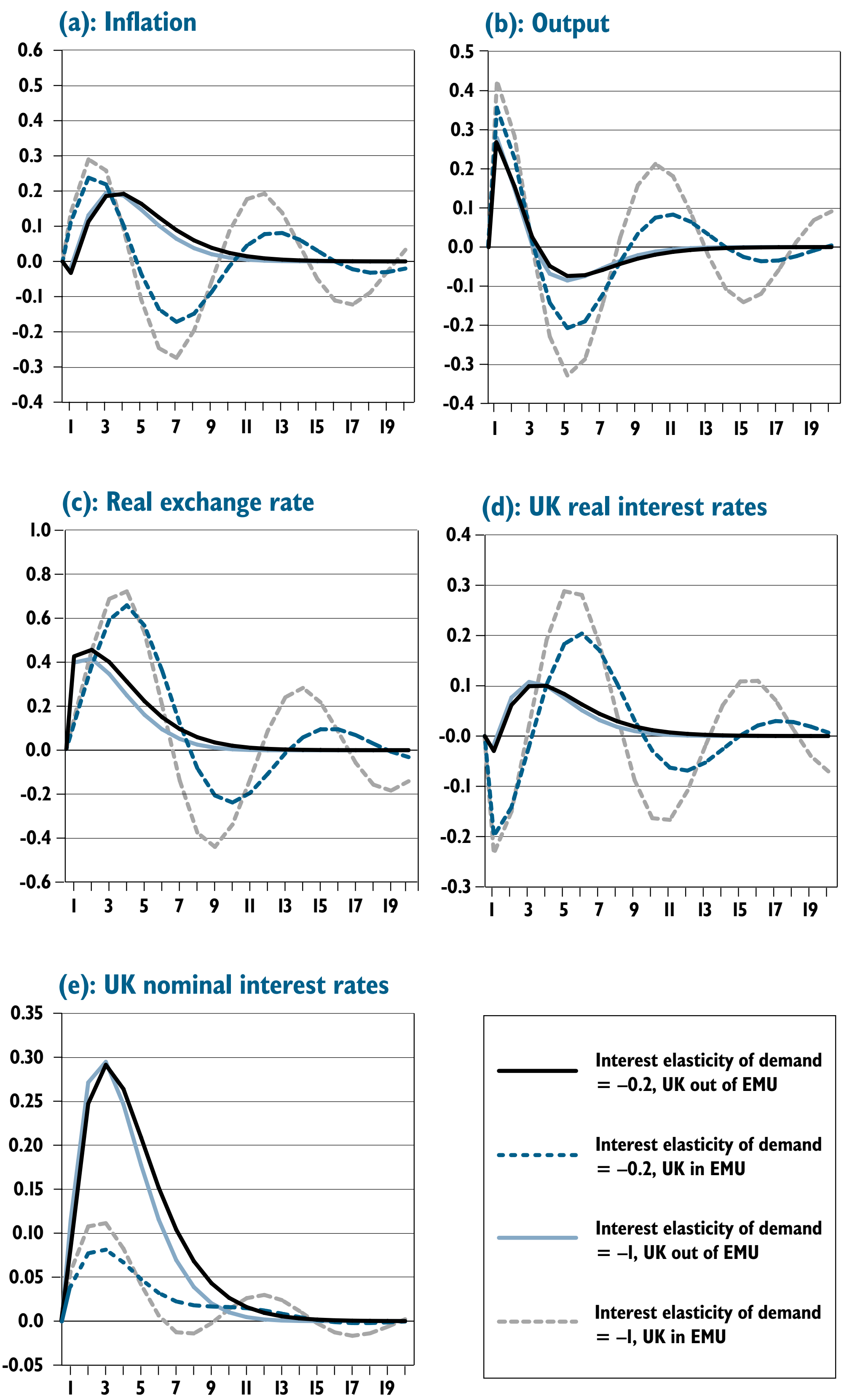
6.4 While it has been argued above that there may be reasons why the sensitivity of UK consumers to short-term interest rates might eventually converge inside EMU, there is nevertheless a range of arguments as to why UK consumers may be more sensitive to interest rates. The EMU study by HM Treasury *Housing, consumption and EMU* examines the important role played by the UK housing market in the transmission mechanism of monetary policy, noting in particular the high relative degree of owner occupation. More recently, UK consumers have increasingly been able to take advantage of their housing equity as a means of consumer credit via mortgage equity withdrawal (for a theoretical justification of this transmission channel, see Aoki *et al.*, 2002). The case for a higher elasticity of UK consumption with respect to short-term interest rates is borne out by empirical estimates of this elasticity (see NIESR, 2003; OEF, 2002; and the contribution by Geoffrey Meen to the EMU study *Submissions on EMU from leading academics*).

6.5 Charts 6.1(a)-(e) and 6.2(a)-(e) below illustrate the simulation responses when:

- the interest rate elasticity in the IS curve is equal to its benchmark value of 0.2 in both the UK and the euro area; and these are compared to
- an alternative where the UK elasticity is assumed for illustrative purposes to be five times higher (i.e. equal to unity).

6.6 Charts 6.1(a)-(e) compare the sets of responses to the asymmetric demand shock to the UK considered in earlier sections.

Chart 6.1: Temporary asymmetric demand shock to UK: illustration of effect of changing interest-rate elasticity in UK's IS curve



More cyclical responses to asymmetric shock when elasticity is higher

6.7 With independent monetary policy, macroeconomic responses are very similar for both versions of the IS curve. This can be explained by the fact that, outside EMU, the increase in real interest rates in response to the shock is rather moderate, only 0.1 percentage points by the end of the first year. More of the burden of adjustment is taken by the nominal exchange rate.

6.8 Inside EMU, the effect of the stronger interest elasticity is more marked. It was noted in Sections 3 and 4 that the real interest rate channel could become potentially destabilising under EMU in the face of asymmetric shocks (due to the Wicksellian effect on real interest rates); Chart 6.1(a) shows how real interest rates fall by 0.2 percentage points. So the effects of this potential instability become more severe the higher is the degree of interest rate sensitivity. Inflation, output, the real exchange rate and real interest rates all display increased cyclicality in their responses in the high-elasticity case. The implications of this in the face of a random sequence of demand shocks (rather than in the face of a single demand shock) are examined empirically in Section 7.

6.9 Charts 6.2(a)-(e) compare the sets of responses to a symmetric positive demand shock, that is a shock not only assumed to hit the UK but also, simultaneously, the euro area.

6.10 As with the responses to the symmetric demand shock[3] described in Section 3, the differences between the results when the UK is assumed to be inside or outside EMU are rather small. But comparing the overall UK responses between the two cases with the different interest rate elasticities, some interesting insights emerge:

- the initial movement in interest rates is largely driven by the effect of the demand shock on output and so is similar across regimes and for different versions of the model. Outside EMU, interest rates are brought back towards base values more quickly in the high-elasticity case since interest rates are more effective in curbing demand. But inside EMU, interest rates are held higher for longer since policy is tailored to the lower responsiveness of the euro area as a whole (see Chart 6.2(e)). So inside EMU, UK output returns to base more quickly – Chart 6.2(b). This in turn impedes the process of bringing inflation back to target levels – Chart 6.2(a);
- the depreciation of the real UK-euro area real exchange rate needs to be larger in the high elasticity case to boost demand by enough to offset the effect of the stronger interest rate response on demand; and
- as with the asymmetric case, the responsiveness of the economy inside EMU is more cyclical in the high elasticity case.

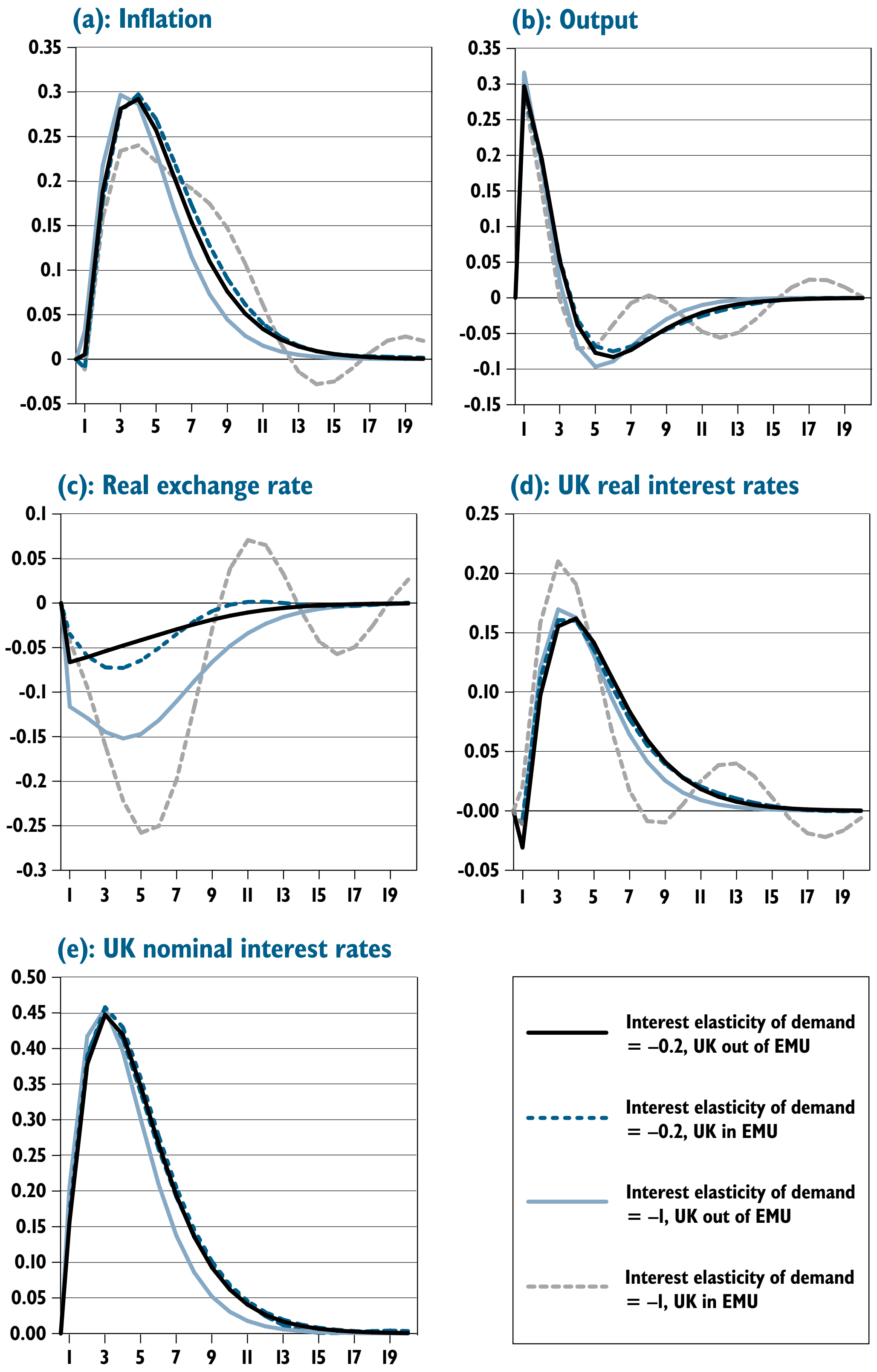
6.11 Consideration of these different types of demand shock under different behavioural assumptions has reinforced arguments developed in Sections 3 and 4:

- the response of output and inflation in the face of a particular shock would not necessarily get more volatile inside EMU compared to outside. Here, in the case of the symmetric shock, interest rates would be moved too strongly for the UK inside EMU when the UK is more interest-sensitive, so the output correction would be more vigorous than would have occurred outside EMU[4]; and

[3] The only difference between that shock and the symmetric demand shock considered here is that the symmetric demand shock is assumed to feed identically into the respective UK and euro area IS curves. The effect of the rest-of-the-world shock depends on the degree of openness and the degree of trade exposure to the rest-of-the-world in the UK and euro area respectively.

[4] This effect would be even greater if the assumed policy rule for the UK outside EMU was tailored to the higher interest rate sensitivity of UK output. This would occur because the UK's independent monetary policy response to the output gap would be smaller than the ECB's response to the euro area output gap because of the greater effect on output of interest rate charges in the UK.

Chart 6.2: Temporary symmetric demand shock to UK and euro area illustration of effect of changing interest-rate elasticity in UK's IS curve



- the earlier finding that monetary policy in the UK would tend to 'under-react' to UK-specific shocks inside EMU, tending to destabilise the response of real interest rates, would be made worse when the UK interest rate elasticity is assumed to be higher.

What if UK prices are more flexible than in euro area?

6.12 There is considerable anecdotal and empirical evidence that UK product and labour markets are more flexible than those in the euro area (see, for example, Barrell and Dury, 2003). The EMU study *EMU and labour market flexibility* provides corroborative quantitative and qualitative evidence to the argument that UK labour markets are more flexible.[5] But as already noted, it is important to distinguish clearly between those types of flexibility which improve the level of potential (e.g. by causing the NAIRU to fall) and those which make the economy more flexible in response to shocks around that level of potential.[6]

6.13 Here, as in the previous section, the implications of greater price flexibility will be examined in a simple way. This is done by analysing the response of the economy if prices were to be perfectly flexible.[7] Two variants are examined. First, the UK alone is assumed to have more flexible prices while prices in the euro area are assumed to remain sticky. This allows an examination of the limiting case where the UK is more flexible than the euro area. Second, euro area prices are also assumed to be perfectly flexible (as was previously assumed for the responses shown in Section 5, Charts 5.3(a)-(d)). This is interesting because, by comparing this outcome with the first variant where euro area prices are sticky, it casts light on whether it is better to be more flexible or more symmetric.

6.14 Charts 6.3(a)-(d) illustrate the first variant, again for a temporary UK-specific shock to demand, where UK prices alone are assumed to be fully flexible. The results echo the conclusions arrived at in the previous section where the same shock was examined but the euro area as well as the UK was assumed to be perfectly flexible. Outside EMU, perfectly flexible prices allow the UK to achieve its inflation target perfectly with no variability in the output gap. Any required equilibrating movements in the exchange rate are taken up by shifts in the nominal exchange rate. But once EMU is entered, the situation changes. Output gap variability can still be eliminated, but now relative inflation movements are required to take the burden of greater adjustment. So as Chart 6.3(a) shows, in the face of asymmetric shocks, inflation volatility is actually higher, not only than in the non-EMU case, but also higher than in the sticky price EMU situation.[8]

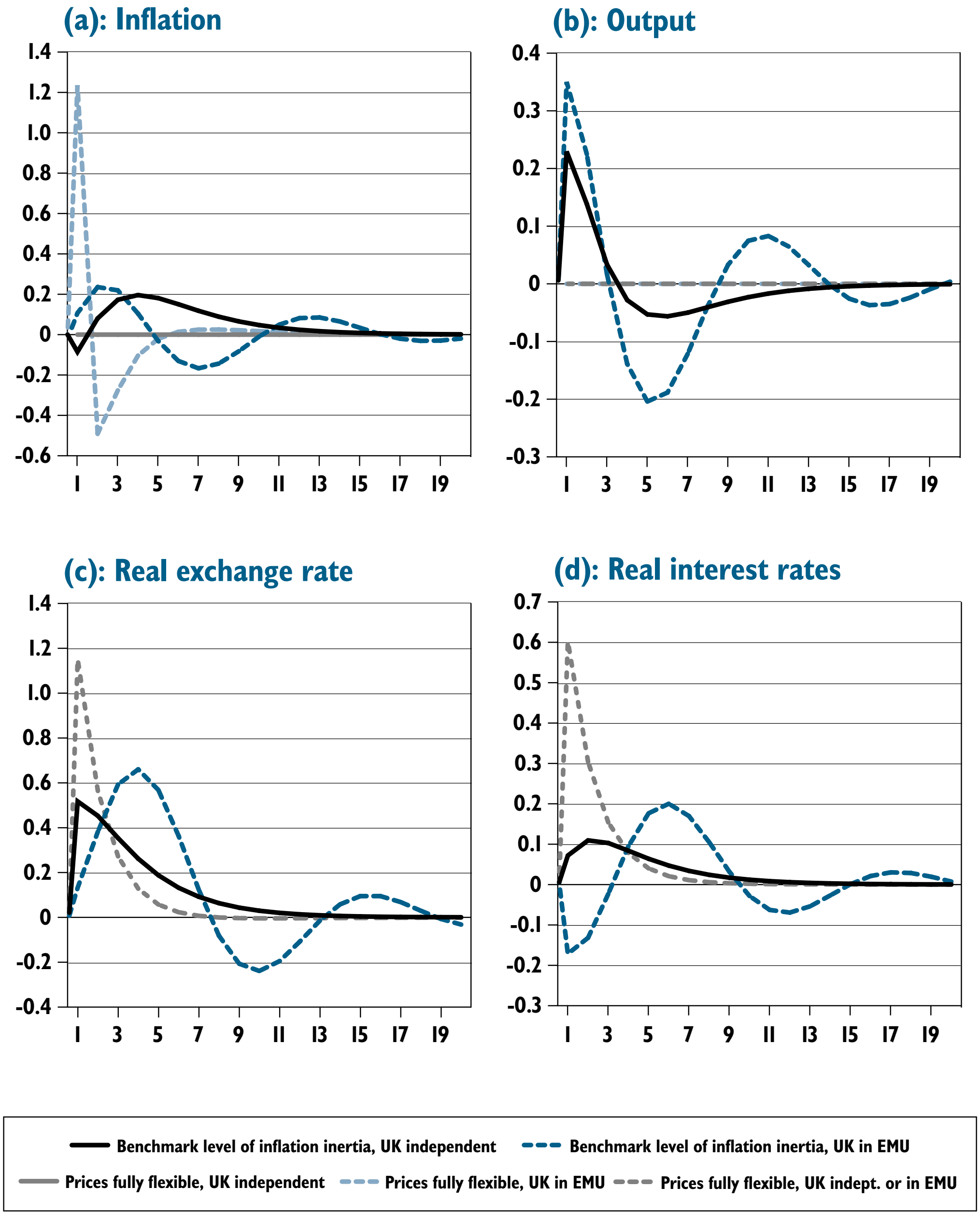
[5] Higher flexibility of 'out' countries raises questions of the incentives for those countries to join a less flexible monetary union, and for the member countries to accept new members (see Hughes Hallett and Hougaard Jensen, 2002, for example). These political economy issues are not addressed here.

[6] Nevertheless, in practice the contribution of 'real inertia' which causes the NAIRU to increase may interact with the dynamics caused by price stickiness (nominal inertia) to make the adjustment to shocks more protracted (see Layard *et al.*, 1991).

[7] This approach is also adopted in the EMU study *Modelling the transition to EMU* in the context of explaining movements in the short-term equilibrium exchange rate.

[8] Note also that Chart 6.3(d) shows that the perverse Wicksellian effect on real interest rates disappears inside EMU when prices are sufficiently flexible because UK inflation does not increase.

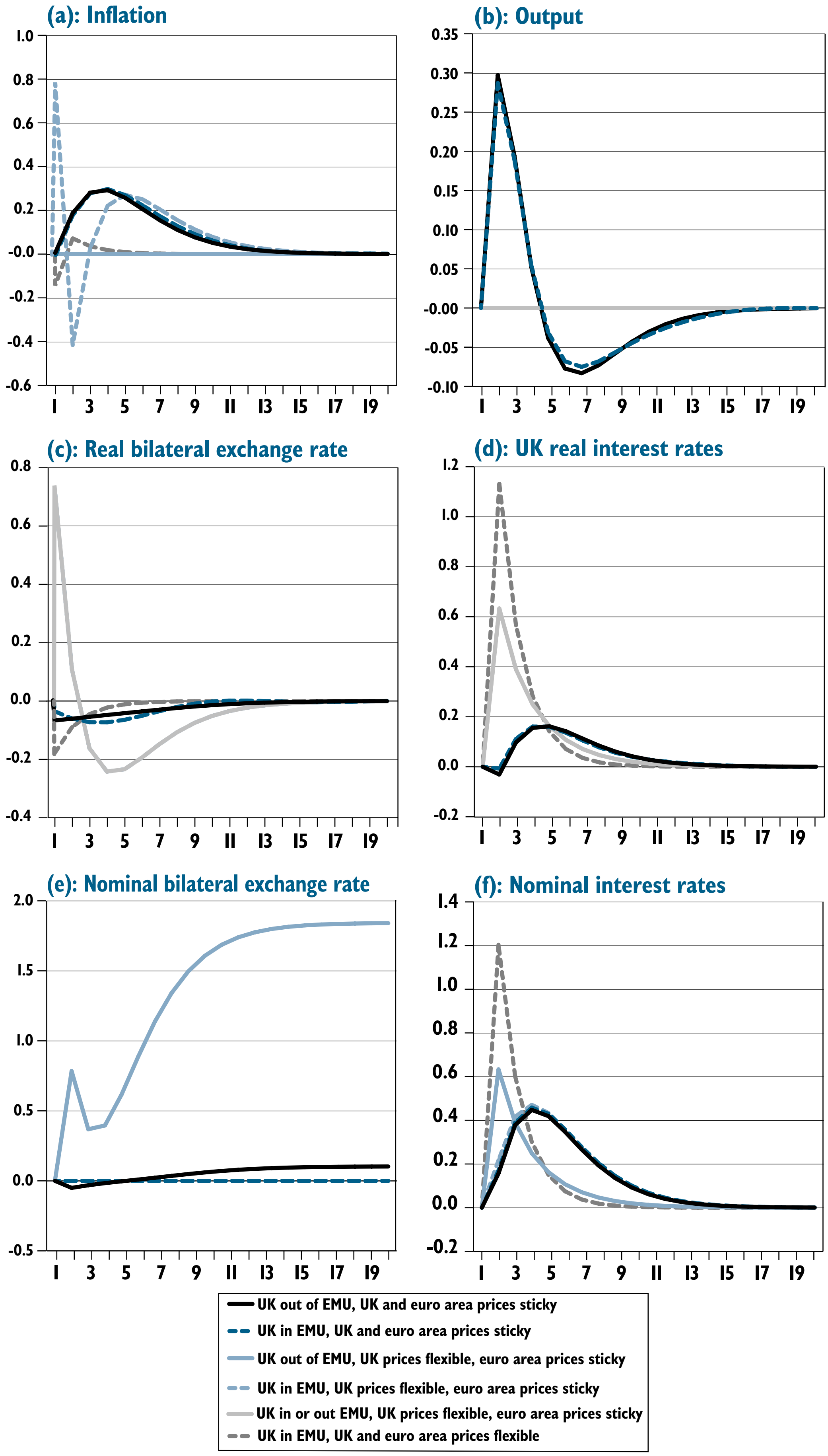
Chart 6.3: Responses to asymmetric demand shock when UK prices are perfectly flexible



6.15 Comparing the responses in Chart 6.3(a) with those shown in the previous section in Charts 5.3(a), it can be seen that the required inflation adjustment is slightly larger in the case when euro area prices are sticky (i.e. in chart 6.3(a)). This would seem to suggest that the relative degree of price flexibility between the UK and the euro area is relatively unimportant.

6.16 But this would be a misleading conclusion because a large relative price adjustment is needed in this case whether euro area prices are sticky or flexible. A more important influence of euro area flexibility on UK responses can be seen, however, when considering the response to a symmetric shock. When the degree of price flexibility is the same in the UK and the euro area, the required relative price adjustment is small because the shock is symmetric. But if price flexibility is high in the UK while prices are sticky in the euro area, the response is more complicated.

Chart 6.4: Temporary symmetric demand shock to UK and euro area: illustration of effect of changing price flexibility in UK and euro area



6.17 Charts 6.4 (a)-(d) illustrate the responses for the same temporary demand shock as before but now assumed to impinge simultaneously on the UK and the euro area.

6.18 Outcomes are presented for the cases when inside and outside EMU the UK and the euro area are assumed to have sticky prices, when the UK is assumed to have flexible prices but the euro area prices remain sticky, and when both the UK and euro area have flexible prices. The following features of the comparison are noteworthy:

- when both the UK and euro area are assumed to have sticky prices, the inflation and output responses are very similar whether the UK is inside or outside EMU, as would be expected given the symmetric 'behavioural' structures of the 'Three Bears' model;
- if the UK is assumed to have fully flexible prices, then outside EMU, despite the asymmetry in price setting behaviour, inflation can be controlled perfectly at target with no output costs. With euro area prices still assumed to be sticky, the asymmetry gives rise to a required appreciation in the real exchange rate relative to the euro area (see grey solid line in Chart 6.4(c)). But this is brought about via the nominal exchange rate (with a contribution from changes in euro area prices);
- but inside EMU, fully flexible prices imply that the burden of the same required real exchange rate adjustment must fall on relative prices. And since UK prices respond more readily, UK inflation rises by almost one percentage point in the first year; and
- if euro area prices are assumed to be flexible too, the required movement in the real exchange rate is again small since the shock and the structures of the UK and euro area economies are broadly symmetric. As a consequence, the effect of the shock on UK inflation is minimal.[9]

General lessons from study of asymmetric structures

6.19 There is a tendency in the optimal currency area literature, and indeed in discussion about EMU, to discuss asymmetries in 'symmetric' terms. In other words, it is implied that an asymmetry in one direction is just as bad for the appropriateness of EMU membership as an asymmetry in another. But the two examples given in this section show that this is not necessarily the case and suggest that the nature of the asymmetry is relevant to assessing its implication.

6.20 With interest rate sensitivity, it was shown that higher elasticities for the UK could have important implications for macroeconomic prospects inside EMU:

- either because the ECB might react too vigorously to symmetric shocks if the UK were inside EMU; or
- because of the potentially destabilising role that real interest rates can play inside a monetary union in the face of asymmetric shocks. So the lower the interest rate sensitivity of the economy is, or the more forward-looking private sector agents might be, the less harmful this effect might be inside EMU.

[9] It is not zero because a small fall in UK inflation offsets a slightly larger increase in euro area inflation to leave the ECB's inflation rate exactly at target.

6.21 The price flexibility example brought to light a more nuanced message. Again, in considering entry to EMU, it illustrated that policymakers would not be indifferent between situations where prices were more flexible than euro area averages, and one where they were less flexible. If UK prices were more flexible than in the euro area, EMU membership would be likely to imply that the effects of symmetric and asymmetric shocks would show up in inflation volatility. But if prices were less flexible, greater output volatility would be expected because markets are less able to cope with the implications of an inappropriate interest rate. But of the various outcomes, the preferred situation is likely to be one in which both the UK and the euro area are highly flexible. In that case, the UK economy would suffer less output volatility in the face of all shocks, and little inflation volatility in the face of of symmetric shocks; but for asymmetric shocks, inflation differentials would still need to bear the burden of adjustment inside EMU, even in the flexible case.

6.22 Having touched on this issue already, this brings to prominence the importance of the relationship between policymakers' output-inflation preferences and the likely degree of convergence of the economy entering monetary union. The next section tackles this issue directly.

7 Modelling the Net Macroeconomic Costs of EMU Membership

Net macroeconomic costs of a policy regime can be evaluated by weighting together expected inflation and output gap volatilities, though more sophisticated criteria might be preferable in theory.

On *a priori* grounds, it is not possible to conclude whether net macroeconomic costs will be higher or lower inside EMU.

Stochastic simulation analysis represents a method for estimating such costs conditional on particular models and assumptions about the shocks expected to hit the economy.

Previous model-based stochastic simulation studies examining whether the UK should join EMU give conflicting messages regarding the predicted effects on output and inflation volatility.

Several factors explain why results differ across models. The treatment of exchange rate shocks and how they might change if the UK were to enter EMU is especially important. The scale of estimated exchange rate shocks applied in the stochastic analysis depends on how 'fundamental' shocks and 'extraneous' shocks to the exchange rate are disentangled in estimation. And the estimates may be importantly affected by the time period chosen to sample the shocks.

7.1 This study has examined a number of empirical measures designed to shed light on differences in the business cycle behaviour of the UK and euro area economies. And the previous sections have analysed a stylised model of the interaction between the UK and euro area economies in an attempt to disentangle the different influences that may be relevant in evaluating the net costs of EMU membership for the UK. But no attempt has yet been made to evaluate whether, on the basis of the modelling exercise, there would be net macroeconomic costs arising from the single monetary policy if the UK were to join EMU.

7.2 It is worth re-emphasising that these monetary policy consequences are not the only ones to be considered in modelling an overall cost-benefit analysis of the UK's decision to join EMU. This study has deliberately not considered, for example, the possible welfare gains to be had from a reduction in transaction costs and possible increases in market integration occurring as a consequence. Nor has it considered possible supply-side improvements that may result from EMU. But in economic terms, the ramifications of the single monetary policy for the costs of adjustment to shocks are likely to constitute the most significant potential ongoing costs. So if, for example, these ongoing costs were estimated to be small, this would represent an important argument in favour of EMU membership for the UK. Or if they were large, it would be necessary to consider even more carefully the possible benefits from EMU arising from other channels.

7.3 This section deals with two hitherto unanswered questions:

- How should the expected degree of macroeconomic volatility in the face of a range of plausible shocks under the two different regimes be estimated?
- For a given set of predictions regarding the degree of UK macroeconomic volatility inside EMU compared to outside, how should these adjustment costs be compared?

How should the costs of adjustment to shocks be compared?

7.4 So far in this study, the question of how to evaluate and compare the amount of macroeconomic volatility under different policy regimes has been treated in a rather *ad hoc* manner. In describing the simulation responses of the stylised model in earlier sections, for example, the results were largely described in qualitative terms. This was appropriate and informative when attempting to gain insight into the key adjustment mechanisms of the economy for particular shocks. But in evaluating the macroeconomic implications of a whole range of possible shocks, a more systematic quantitative approach needs to be adopted. Obviously, if all macroeconomic series became more volatile in moving between policy regimes, then it would be straightforward to conclude that the initial regime was more stable. But in practice, as will be seen, there may be more complicated trade-offs to consider with some variables becoming more volatile and others less volatile.

7.5 Conventionally, macroeconomic performance is often evaluated in terms of a simple quadratic cost function of the form

$$C_T = \sum_{t=0}^{T} \partial^i \{a(dp_{t+i} - dp^{targ}_{t+i})^2 + b(y_{t+i} - ys_{t+i})^2\} \qquad [1]$$

i.e. a time-discounted, weighted combination of the squared deviations of inflation (dp) from target (dp^{targ}) and output (y) from potential (*ys*) are summed over some finite time horizon T.[1] This approach is widely adopted and is consistent with the argument, discussed earlier, that macroeconomic volatility has costs that may have implications for the level of real activity.[2] In this study too, the focus of attention will primarily be on inflation and output variability. And in the results that are reported in this and the following section, the implications of EMU membership for the UK will be drawn out in terms of the effects on both inflation and output variability. But no attempt is made here to specify a preferred relative weighting between inflation and output volatility. This is beyond the scope of this study.

[1] In empirical evaluations, a finite time horizon, T, is necessarily adopted though theoretically, the appropriate time horizon would usually be infinite with a suitable discount factor. In practice, T is typically chosen to be large enough such that the expected volatility in macroeconomic variables has reached its long-run or asymptotic variance. Alternatively, the asymptotic variance itself can be used as the objective function; this measure will be close in value to the original objective function if T is large and the discount function is not too different from unity.

[2] No attempt is made to model the effects of volatility on productive potential in this study.

7.6 But before describing this, it is important to emphasise some of the key features of this specification and to point out some alternative approaches:

- the conventional specification embodies the assumption that the aim of policymakers, in the context of responding to shocks, is to stabilise output around its natural rate rather than attempt to achieve a higher level. If instead, policymakers are assumed to try to achieve an infeasibly high level of output, or to drive unemployment below its natural rate, then an 'inflationary bias' will result.[3] Here, the analysis follows Blinder (1998) in assuming that policymakers do not adopt this strategy;

- it is possible to add in to the cost function other macroeconomic variables which may affect economic welfare, for example deviations in unemployment from its natural rate, exchange rate volatility, or interest rate volatility, either in nominal or real terms (see for example Minford, 2001) and sectoral or distributional considerations.[4] The simple two-variable objective function is usually justified on the grounds that the main costs associated with volatility in these additional macroeconomic variables will be reflected in output and inflation volatility; and

- problems arise when examining the costs associated with moving between regimes with different explicit or implicit inflation targets (as may happen in moving from the UK's inflation targeting regime to EMU, for example). For the purposes of simplicity, this complication is ignored here.

7.7 In fact, most of these complications can be avoided if a more explicit welfare-maximising approach to the policy optimisation problem is taken. This is done in the recently developed dynamic stochastic general equilibrium (DSGE) modelling approach as introduced briefly in Section 2.[5] These models are designed to have rigorous micro-foundations in the sense that all behaviour is derived from utility maximising behaviour subject to budget constraints and technological constraints. Accordingly, the objective function for policymakers is naturally defined in terms of the welfare of the representative consumer who maximises utility defined in terms of consumption but where labour effort has disutility.[6]

7.8 Some authors have attempted to show that the 'first generation' *ad hoc* objective functions described above provide a good approximation to the more rigorous definition of utility. The intuition here is that a policy that minimises inflation and output uncertainty will look very similar (see Woodford, 1999, for the closed economy case and Clarida *et al.*, 2001, for the open economy extension).

7.9 These arguments are relied on here to underpin the focus on inflation and output variability in this study rather than one based on a more rigorous utility-based approach.

[3] This type of objective function which leads to an 'inflationary bias' has been extensively studied in a literature initiated by Barro and Gordon (1983); and Kydland and Prescott (1977).

[4] For example, the objective function might be defined to include variability in regional or sectoral performance, for example between the traded and non-traded sectors.

[5] See, for example, the seminal textbook, Obstfeld and Rogoff (1996).

[6] Some models in this category also include an effect from money holdings on individuals' utility.

7.10 As an aside, it is worth noting that there is one important set of circumstances where the more *ad hoc* approach may yield misleading conclusions. This occurs when considering the implications of asymmetric (i.e. country-specific) shocks in a world where consumers are able to diversify their wealth holdings, thus lowering their exposure to shocks occurring in their own countries. In the extreme case where consumers are able to take advantage of fully integrated financial markets and where consumers express no bias towards domestically produced goods, consumers will hold claims (in the form of shares) on the output of all countries. Thus consumers in different countries are able to 'share the risks' associated with country-specific shocks and so maintain smooth consumption paths in the face of these shocks. This has important implications in the context of the OCA criteria since it implies that asymmetric shocks should not be seen as an obstacle to EMU. In practice, the real world economy is some distance away from this picture of 'complete markets' described in theory. This is confirmed by empirical work carried out in a growing risk-sharing literature; see for example Sørensen and Yosha (1998). For this reason, the analysis here does not consider this issue further.[7]

The role of stochastic simulations in evaluating volatility

7.11 Some of the empirical tools described in this study have given a broad indication of what the expected net macroeconomic costs associated with the adjustment to shocks inside EMU compared to outside might be. For example, measures of *ex ante* business cycle convergence give some indication of how well aligned the UK and euro area economies might be in the future. And macroeconomic models, both econometric and calibrated, have illustrated how the UK economy might respond to *particular* shocks either in or out of EMU. Such exercises are sometimes known as 'deterministic simulations' since they involve the simulated response to a shock that is assumed to be known.

7.12 But none of these exercises reveal how the UK might perform in the face of the full range of possible shocks that might hit it. This involves consideration of the stochastic environment; that is where the probability distribution of the possible shocks might be known, but the precise shocks likely to occur at any particular time are not. Fortunately, using the modelling tools that have been described in this study, an attempt can be made to answer this question. Inevitably, these estimates are only as precise as the models and assumptions used to generate them. Nevertheless, by making these assumptions explicit, it provides a powerful tool for exploring the likely scale of these net costs and the possible sensitivities according to different assumptions.

7.13 This technique, whereby macroeconometric models can be used to explore the likely outcomes arising from different policy scenarios, is known as stochastic simulation analysis. The approach is intuitively straightforward and involves two key ingredients:

- first, a model of the behaviour of the economies in question needs to be adopted (eg NiGEM, IMF Multimod, etc.); and

[7] The EMU study *The United States as a monetary union* reviews this literature for the US. Other implications of risk-sharing are considered in the EMU studies by HM Treasury *EMU and business sectors* and *EMU and the cost of capital*.

- second, a statistical distribution of all relevant shocks expected to hit those economies needs to be postulated. For empirically estimated macroeconometric models, these shocks can be obtained from the residuals of the estimated equations. Ideally, if the estimated equations are well-specified, the residuals will be white noise (i.e. mean zero with no serial correlation).[8,9]

7.14 Obviously, it is important to evaluate the macroeconomic implications of a particular policy regime associated with the full range of possible shocks. For example, simulation response analysis may have revealed that the UK economy can cope relatively easily inside EMU in response to symmetric shocks (vis-à-vis the euro area) but may fare less well in the face of asymmetric shocks. So to understand the full picture, it is necessary to calculate how these different types of shocks interact and how prevalent each type of shock is.

7.15 Stochastic simulations are able to do this, as follows:

- by choosing a random combination of shocks from the estimated or assumed distribution;
- by subjecting the model to these shocks, one period at a time over the period of interest.[10] This will give one possible outcome (or one 'realisation' as it is technically known);[11]
- by taking repeated drawings from the shock distribution so as to simulate alternative 'realisations'; and
- by generating a large number of drawings, so allowing the calculation of the average or expected amount of volatility in any macroeconomic variable such as inflation or output.[12]

Previous empirically – based stochastic simulation exercises

7.16 Considering the importance of the question and the relevance of the technique, there have been relatively few attempts to conduct stochastic simulation exercises quantifying the net costs of joining EMU, either in the specific UK case or for European countries more generally. Those studies that examined the problem before EMU was set up tended to predict that there would be an increase in macroeconomic volatility. Examples include the work on the Liverpool models (both the UK and multi-country versions) described in Minford *et al.* (1993) and an application to the IMF's Multimod model (another multicountry model) by Masson and Symansky (1993). But an influential study by the European Commission (1990) arrived at the opposite conclusion, suggesting that EMU would lead to more stability.

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[8] In practice, unless the whole model has been estimated as a simultaneous system, these shocks do not have a ready economic interpretation as demand or supply shocks. As such, they may have a tendency to be correlated with each other. In practice, too, adjustments often need to be made to estimated residuals to adjust the mean to zero and to remove the autocorrelation.

[9] Cross equation correlations are often captured by the use of 'bootstrapping' techniques where, period-by-period, randomly chosen time-slices of residuals are applied to the model. The motivation for this approach is that the set of residuals which actually occurred should accurately reflect the appropriate degree of cross-correlation.

[10] In models where agents are assumed to be forward-looking, it is necessary to shock the model one-period-at-a-time so as to build in the assumption that the shocks in each period are unanticipated. For more details of the need for this stacked-solution technique, see Ireland and Westaway (1990).

[11] The 'deterministic' simulations described earlier in the study e.g. the response to an asymmetric demand shock, can be thought of as particular realisations of the shock process.

[12] Note that the expected level of any macroeconomic variable will be the same as that on the forecast base since the shocks are assumed to be normally distributed with mean zero.

7.17 More recent studies have been carried out specifically to evaluate the macroeconomic costs or benefits of UK membership. Table 7.1 summarises the main results from these studies.[13]

Table 7.1: Recent stochastic simulation results addressing the UK decision to join the EMU

	UK in / UK out (ratio of variability)[1]	
	Output	**Inflation**
Barrell and Dury (2000)		
UK inflation targeting out, ECB combined rule (shocks drawn from 1991-97)	1.23	0.75
UK inflation targeting out, ECB combined rule (shocks drawn from 1993-97)	1.61	0.78
UK combined rule out, ECB combined rule (shocks drawn from 1993-97)	1.73	0.78
Minford (2001)		
UK out: interest rates respond to inflation, output and M0, UK in: interest rates hit by shocks to ECB rate (shocks drawn from 1986-2000)		
Basic case	1.12	3.12
More exchange rate instability out	1.10	2.92
Enhanced fiscal stabilisers	1.09	3.12

[1] Note, estimated volatility in macroeconomic variables can be reported in different ways. In this section, volatility will usually be defined in terms of standard deviations and all ratios analysing the costs of EMU membership compared with staying out are presented on that basis. In fact, the NIESR results here are defined in terms of root mean squared deviations. Some studies, as in Minford (2001) for example, present volatility in terms of expected variance.

7.18 These findings have turned out to be just as ambiguous as the earlier results:

- Barrell and Dury (2000), apply the technique to NiGEM, the global multi-country macroeconometric model utilised in Section 2. They adopt a range of assumptions on UK monetary policy outside EMU[14] and on the period from which the stochastic shocks are estimated. They find that inflation variability is predicted to be lower by some 22-25 per cent inside EMU[15] while output volatility is estimated to be between 23 and 73 per cent higher;[16] and

- by contrast, the most recent application of this technique by Minford on the Liverpool model (see Minford, 2001) predicts that both inflation variability and output volatility will increase inside EMU under a range of modelling assumptions. In the main case, inflation is expected to be as much as three times more volatile in EMU while output volatility also rises by around 10 per cent.

[13] This is not intended to be exhaustive. Other studies have also examined this issue. For example, using the National Institute's model of the UK economy (NiDEM), Blake and Young (1998) predict that EMU membership would imply, with an unchanged fiscal policy regime, a doubling of inflation volatility and a ten per cent increase in the volatility of output growth.

[14] In all variants, the ECB are assumed to adopt a 'combined rule' whereby nominal interest rates respond to a weighted average of inflation and money GDP relative to some target levels. Outside EMU, the UK are assumed to adopt either 'inflation targeting' (i.e. a feedback rule which responds to inflation only) or a 'combined rule'.

[15] The authors also report falls in price-level volatility within EMU which they argue have important beneficial implications for the supply-side of the UK economy.

[16] This study has recently been updated in Barrell *et al.* (2003). These preliminary results suggest that, while the predicted changes in volatility caused by EMU entry are more moderate, the conclusions are broadly similar.

7.19 More detailed descriptions are contained in the original studies and are drawn on in the contributions by Barrell and Minford to the EMU study *Submissions on EMU from leading academics*.

7.20 Although there are many differences between these studies, two particularly striking results seem apparent:

- first, under all assumptions adopted, Barrell and Dury (2000) predict lower inflation volatility in EMU, with higher output variability; and
- second, for all assumptions adopted, Minford finds higher inflation and output variability inside EMU, considerably more in the case of inflation.

7.21 To try to understand the differences between these empirically-based results, it is helpful to return to the simple set of inferences described in the introduction of this study. This explained how, without getting into the specific details of any particular model-related exercise, the following simple principles should guide thinking about the macroeconomic costs of entering EMU:

i for any country entering a monetary union, the loss of the domestic interest rate as an instrument of monetary policy and the loss of the nominal exchange rate as a 'shock absorber' would compromise the ability of the economy to respond to shocks;

ii but other adjustment mechanisms may compensate for the absence of an independent monetary policy;

iii and the nature of the transmission mechanism for the country entering monetary union might alter so as to lessen this problem; or

iv some of the shocks impinging on the economy might change their nature, offering a further potential mechanism acting to lessen or even outweigh the costs of inefficient adjustment to other shocks.

7.22 A focus on these simple principles allows some insights to be gained into the model-based results. Three differences between the studies seem most significant:

- the treatment of monetary policy regimes in and out (relating to (ii) above[17]);
- the properties of the macroeconometric models on which the stochastic simulation are run (relating to (i) above); and
- the techniques used to calculate the shocks, in particular regarding the exchange rate shocks (this relates to (iv) above[18]).

Characterisation of monetary policy regimes in versus out

7.23 In evaluating the effects of EMU membership, the comparison is more straightforward if the policy reaction of the UK outside EMU, and of the ECB in EMU is assumed to take the same form (e.g. a Taylor rule).

[17] Minford (2001) and Blake and Young (1998) also conduct sensitivity analysis on the implications of assuming a more activist fiscal policy regime in EMU. This does not alter the main thrust of Minford's conclusions. Blake and Young, however, predict that output growth volatility would be lower than in the *ex ante* case outside EMU (without an active fiscal policy regime).

[18] Note that because neither set of studies assume that there are any 'endogenous convergence' effects upon entering EMU, at least in the main results presented here, (iii) is not considered in attempting to understand the results.

7.24 In fact, for both studies considered here, the evaluation of the effects of EMU membership is complicated by the assumptions adopted.

- In Minford (2001), no explicit policy rule is assumed for the ECB because the exercise is conducted on a single country model of the UK, with ECB policy responses proxied by shocks to the otherwise exogenous ECB interest rate. This may therefore underestimate the extent to which the ECB's monetary policy response might be able to respond to shocks inside EMU. So the increase in inflation and output volatility predicted in EMU by Minford (2001) may be overestimated.[19]

- Barrell and Dury (2000), on the other hand, do assume an explicit policy rule for the ECB, but this takes the form of a monetary policy rule which includes some element of price-level targeting[20] whereas the UK outside EMU is assumed to target inflation. One consequence is that, for this reason alone, price-level stability may be predicted to be more stable inside EMU[21] compared to a regime where the ECB also targets inflation.[22] In fact, row 3 of Table 7.1 suggests that this is unlikely to explain much of the fall in inflation variability inside EMU because there is a similarly large fall when the UK is assumed to adopt the same 'quasi-price-level targeting' rule outside EMU.[23]

Differences in model properties

7.25 Another difference between the NIESR and Liverpool studies is the macroeconometric model on which the stochastic simulations were conducted:

- the NiGEM model adopted in Barrell and Dury (2000) is a large multi-country model where the linkages between countries are contained within the model, and the effect of shocks to different countries can be treated explicitly (for more details, see NIESR, 2003). In terms of theoretical structure, the individual countries are not vastly different from that of the UK in the Liverpool model, each country being based on New Keynesian principles, with nominal inertia in wage and price setting causing slow adjustment back to a well-defined neoclassical long run; and

- the Liverpool model used in Minford (2001) is a single country model of the UK economy where the rest of the world (including the euro area) is treated exogenously, though subject to stochastic shocks. The model has strong neoclassical underpinnings.[24] As such, while the model embodies nominal inertia as in NIGEM, it tends to have quicker inflation dynamics than competing empirical models of the UK economy (see Wallis *et al.*, 1987).

[19] This potential shortcoming is shared by Blake and Young (1998) which similarly uses a single country model of the UK economy to evaluate the costs of EMU membership.

[20] The ECB is assumed to adopt a 'combined rule' which responds to a mixed target of inflation targeting and money GDP targeting. It is the latter element that embodies an element of price-level targeting. Barrell and Dury justify this approach by arguing that the remit of ECB monetary policy is better characterised by a rule with an element of price-level targeting. Accordingly, they do not examine the policy scenario with the ECB adopting an inflation-targeting rule, which would allow the contribution of this assumption on the results to be disentangled.

[21] Price level targeting is also likely to imply higher output volatility than under inflation targeting, as in the NiGEM case, though in theory, Svensson (1999) has shown that output volatility can be lower if price flexibility is sufficiently high.

[22] Whether this will necessarily imply that inflation is more stable too will depend on the degree of forward-looking pricing behaviour in the model (see Svensson, 1999).

[23] The preliminary results reported in Barrell *et al.* (2003), however, find a larger influence on the results from the specificaton of the UK's policy rule outside EMU.

[24] The Liverpool model was the first empirical UK model to incorporate forward-looking rational expectations in response to the influential Lucas critique.

7.26 It is possible that the greater degree of price flexibility in the Liverpool model may be accounting for the greater degree of inflation volatility inside EMU in that study. The discussion in Sections 5 and 6 has already noted how, in the face of asymmetric shocks in an economy with full price flexibility, the mechanism by which the real exchange rate necessarily adjusts is transferred from the nominal exchange rate outside EMU to the relative inflation rate inside EMU. So since prices are more flexible in the Liverpool model, it seems possible that there will be increase in price and inflation volatility in moving to monetary union (see also the discussion in Minford and Peel, 2002).

7.27 But even if this explains why inflation volatility in EMU may be greater according to the Liverpool model, this does not explain why the overall level of inflation volatility actually falls inside EMU in many of the scenarios examined in the NIESR studies.

7.28 One alternative explanation is suggested by the conclusions of the earlier deterministic simulation results on the stylised model. There it was shown how, for some shocks, usually those with symmetric or near-symmetric effects on the UK and euro area economies, it was possible that either inflation volatility or output volatility could on average be lower in EMU compared to outside.[25] In fact, experimentation with a range of deterministic shocks on NiGEM itself suggests that this outcome is relatively uncommon, the more typical outcome being that both inflation and output responses would tend to be larger. So this explanation is unlikely to be the whole story.[26]

Differences in shocks applied to the model

7.29 To get a handle on this key difference, it is necessary to consider additionally the characterisation of the shocks hitting the UK economy in and out of EMU and how they might alter in moving between the two regimes.

7.30 In fact, the answer is quite straightforward and intuitively obvious. If it is assumed that the transmission mechanism of the UK economy does not alter upon entering EMU, then the only way that the environment can become less volatile is if the shocks hitting the UK economy become more benign. This may not necessarily be sufficient to overcome the less efficient outcome implied by the single monetary policy in response to those shocks that remain the same, but it should certainly make the EMU outcome less volatile than it otherwise would be.

7.31 There are two broad reasons why the shocks hitting the economy are likely to differ inside EMU compared to out:

- first, shocks to UK interest rates will no longer be present. In this specific context, shocks should be interpreted as meaning unexpected deviations of interest rates from their policy rule. Or, to use the terminology of structural VARs described in Section 2, shocks refer to the 'unsystematic' component of policy. As such, they may impart unnecessary volatility to the economy[27,28]. Of course, once inside EMU, the UK economy will instead be directly influenced by 'shocks' to the ECB interest rate that may be more or less detrimental to

[25] This result may be partly dependent on the maintained assumption that a simple Taylor rule is specified for UK monetary policy outside EMU, and for the ECB inside EMU. The results of the volatility comparison may be different if monetary policy were to be set 'optimally' in some sense.

[26] To resolve this question systematically, it would be necessary to subject NiGEM successively to different subsets of the stochastic shocks to determine whether particular shocks were causing inflation volatility to fall inside EMU. This would be a resource-intensive exercise.

[27] See Artis (2000) and Kontolemis and Samiei (2000) who argue that 'bad' monetary policy was partly responsible for macroeconomic volatility in the UK over the 1970s and 1980s.

[28] In practice, empirically estimated measures of this unsystematic component may additionally capture more beneficial aspects of interest rate movements that are not adequately captured by simply specified policy rules.

stability. So it is not possible to draw any *a priori* conclusions about the implications of EMU entry; and

- second, inside EMU, shocks to the bilateral sterling-euro rate will be absent, by definition. So this source of macroeconomic volatility will be removed. But the volatility of the shocks to the UK's bilateral nominal exchange rate with all other currencies (e.g. sterling-US dollar) will in EMU take on the volatility characteristics of the shocks to the euro's bilateral exchange rate with that currency (i.e. euro-US dollar).[29] This may be either greater or smaller within EMU. So the overall effect on the volatility of shocks to the exchange rate in effective terms could be positive or negative.[30] And the key point remains that the question of whether EMU can result in higher macroeconomic volatility will hinge importantly on the magnitude and influence of exchange rate shocks. This issue is examined in more detail in the EMU study by HM Treasury *The exchange rate and macroeconomic adjustment*.

7.32 Does consideration of these two classes of shock help to interpret the differing results of the various empirical studies?

- As far as interest rate shocks are concerned, neither set of authors place any emphasis on this feature, so this will not be considered further here.
- Importantly, however, the authors of both sets of studies acknowledge that there is an important role for exchange rate shocks in influencing their respective results.[31]

The role of exchange rate shocks

Estimating exchange rate shocks

7.33 To understand how different assumptions regarding exchange rate shocks may be important, it is necessary to examine how empirical measures of exchange rate shocks might be derived. Box 7.1 considers this technical issue in more detail.

[29] Or, as will be assumed later in this section, it may take on an appropriately weighted average of sterling's previous bilateral volatility with these currencies and that of the euro, where obviously the weight of sterling is now smaller, here assumed to be 0.2. This is discussed in more detail in Taylor (2002) and in the EMU study *The exchange rate and macroeconomic adjustment*.

[30] Of course, any such calculations also require an assumption to be made on whether EMU will additionally change the nature of these underlying shocks if the UK were to join.

[31] The stochastic simulation exercise carried out by the European Commission in the One Market, One Money study (see European Commission, 1990) also includes an extensive discussion of alternative treatments of exchange rate shocks.

Box 7.1: Estimating shocks to the exchange rate

Consider the models of the exchange rate adopted in both the Liverpool and NIESR models. These are based on the UIP (uncovered interest parity) condition, as used in the 'Three Bears' model already studied:

$$\text{i.e. } e_t = e^e_{t+1} + rdif_t - sig_t + u^e_t$$

where e_t is the exchange rate for some bilateral pair of currencies at time t, e^e_{t+1} the one-period ahead expectation of the exchange rate at time t+1, $rdif_t$ the differential between interest rates in the pair of countries and sig_t the risk premium which captures constant or slow moving elements of the bilateral risk between two countries (so when country-specific risk is high, interest rates in that country need to be higher). u^e_t represents the 'shock' to the exchange rate, which can be thought of as a time-varying element of the risk premium that captures 'fad'-based movements in the exchange rate, or changing perceptions about the risk characteristics of different currencies.

To complete the model of the exchange rate, it is necessary to specify how exchange rate expectations are formed. In the stochastic simulation exercises, it is assumed that economic agents are able, at the beginning of period t, to predict correctly the value of the exchange rate next period on the basis of information available to them at that time. So if there were no shocks to any part of the economy during period t, then they would predict the next period's exchange rate perfectly. But in fact, period by period, they will make errors due to unexpected shocks which cause the exchange rate to move.

$$\text{i.e. } e^e_{t+1} = e_{t+1} + u_t$$
$$= e_{t+1} + u^e_t + u^y_t$$

where u_t represents a combination of forecast errors due to the presence of the exchange rate noise, u^e_t, as well as forecast errors due to unexpected shocks to any other part of the economy, u^y_t, which will have caused an endogenous response from the exchange rate.

When conducting stochastic simulations on a macroeconometric model, this distinction between the two types of shocks impinging on exchange rate movements becomes crucial:

- **the response of the exchange rate to 'fundamental shocks', i.e. u^y_t, will be predicted by the model itself. So no explicit assumption needs to be made by the modeller; but**
- **the time series properties of the exchange rate shocks, u^e_t, need to be assumed explicitly, ideally on the basis of their historical behaviour. This is a tricky task empirically. Not only is it necessary to measure *ex ante* exchange rate expectations but also to estimate how much the *ex post* forecast error is caused by the exchange rate shock itself (which is the object of interest) and how much is caused by other shocks.[a]**

[a] Different approaches to this problem were discussed in Annex E of the European Commission study (European Commission, 1990).

7.34 The key point from Box 7.1 is that observed volatility in the exchange rate can be attributed to two sources. Conceptually, these are clearly distinct, but empirically, the two are very difficult to disentangle, comprising:

- 'fundamental' volatility caused by the endogenous response of the exchange rate to real shocks (such as demand and supply); and
- 'financial market' volatility that can not be justified by observed economic fundamentals.

7.35 In the context of model-based stochastic simulations, the distinction is crucial. An explicit assumption about the stochastic properties of the 'financial market' shocks needs to be made by the modeller. But the endogenous response of the exchange rate to 'fundamental' shocks should be automatically generated by the model.[32]

7.36 The NIESR and Liverpool studies approach the estimation of these exchange rate shocks in different ways:

- the NIESR study circumvents this problem by effectively assuming that all the *ex post* failure of the UIP condition is caused by exchange rate noise (i.e. by u_t^e as defined in Box 7.1);
- Minford (2001), on the other hand, assumes that the distribution of exchange rate shocks is based on the stochastic distribution of the exchange rate itself.[33]

7.37 Perhaps as important as the method used to estimate the shocks is the historical time period from which the shocks are estimated:

- Minford argues that on average, over the last 20 years, sterling-US dollar shocks have been negatively correlated with sterling-euro shocks, so tending to offset each other in their effect on the sterling effective exchange rate. At the same time, Minford estimates that euro-dollar shocks have been more volatile still. So once in EMU, when sterling would take on the historical volatility of the euro vis à vis the dollar, this would imply an overall increase in the volatility of shocks to sterling in effective terms;
- the NIESR study estimates the shocks over a more recent time period, the early to late 1990s only,[34] when shocks to sterling in general may have tended to be more volatile than those affecting other bilaterals such as euro-dollar. If these assumptions are assumed to condition the behaviour of future exchange rate shocks if the UK were to join EMU, then the UK effective exchange rate would benefit from much more benign shocks than when it had been outside.

7.38 Both these sets of judgements on estimation method and sample period are likely to be important in affecting the conclusions:

- if the estimated exchange rate residuals have not satisfactorily disentangled the noise component (which is required) from the fundamentals component (which is not) then the resulting stochastic simulation results will wrongly impart volatility directly to the exchange rate, when in fact, the relevant fundamental shocks are already being taken into account in the exercise. So the effects will be double-counted; and
- even if it is possible to estimate the shocks appropriately over the past, heroic assumptions are required on the likely stochastic behaviour of these risk premium effects if the UK were to join EMU.

[32] In general, too, the definition of what constitutes a 'fundamental' shock will likely differ across models.

[33] As European Commission (1990) discuss, the change in the exchange rate will only approximate the shocks when expectations are based on a random walk model.

[34] Using a sample period based on the 1990s, Table 7.1 shows that the NIESR results are affected by starting the sample in 1991 or 1993, presumably reflecting the importance of including or excluding the episode of sterling's exit from the ERM in 1992.

SVAR-based approach to estimating exchange rate shocks

7.39 Other approaches are available to distinguish between the different influences on exchange rate movements. One potentially powerful approach is provided by structural VAR techniques (already described briefly in Section 2). Inevitably, these methods too rely on a host of underlying assumptions but they at least attempt to account systematically for the different types of shocks to which exchange rates might respond. This approach is discussed briefly in Box 7.2 but is examined more thoroughly in the EMU study *The exchange rate and macroeconomic adjustment*. There it is suggested that, although the empirical evidence is not overwhelming, the balance of evidence tends to suggest that a non-negligible proportion (and in some studies, the majority) of exchange rate volatility has been caused by 'fundamental' shocks rather than by 'extraneous' noise.

Box 7.2: The role of SVARs in identifying the shocks which cause exchange rate movements

In an influential study, Clarida and Gali (1994) used an SVAR-based approach to suggest that movements in the dollar were largely driven by shocks to real demand (e.g. to fiscal policy, foreign trade or consumer preferences). Astley and Garrett (1998) subsequently replicated these findings in the case of sterling. The implicit conclusion was that exchange rates tended to be moving in response to shocks[a] rather than as an exogenous source of noise.

Confusingly, however, an alternative strand of research findings using very similar techniques has tended to arrive at the opposite conclusion. Research by Artis and Ehrmann (2000) takes the contrary view (see also Canzoneri *et al.*, 1996, Funke, 2000, and Thomas, 1997 for similar approaches). They argue that most exchange rate fluctuations can be explained by nominal shocks associated with exchange rate risk premia that ought to disappear inside EMU[b] strengthening the case, other things equal, for EMU.

In an attempt to resolve this puzzle, Labhard and Westaway (2002) apply the techniques of Clarida-Gali and Artis-Ehrmann to a common dataset and over a common sample period. Importantly, they find that the conflicting message remains, implying that the different conclusions obtained depend on the technique adopted, not on differences in the dataset adopted.[c]

To investigate which technique is more reliable, Labhard and Westaway (2002) adopt a stylised model similar to that adopted in this paper. For a given calibration of the model, and for given assumptions about the properties of the shocks, a stochastic simulation is performed in order to generate a quasi-history of data. The advantage of these data series compared to the real data is that the true contribution of exchange rate shocks to the movements in macroeconomic variables is exactly known. They then apply the techniques of Clarida-Gali and Artis-Ehrmann to uncover which approach most accurately reproduces the true model. Interestingly, they find that Artis-Ehrmann has a tendency to overexaggerate the contribution of exchange rate shocks, while Clarida-Gali has a tendency to be inaccurate when the countries under consideration are highly asymmetric.

On balance, the SVAR-based evidence tends to support that there is a significant shock-absorbing role for the exchange rate. So any empirical approach which implicitly assumes that exchange rate volatility is largely caused by 'extraneous shocks' may over-exaggerate the degree of volatility arising directly from speculation in financial markets.

[a] Primarily to real demand shocks.

[b] In practice, 'nominal shocks' comprise a mixture of exchange rate risk-premium shocks and unsystematic interest rate shocks. Artis and Ehrmann (2000) use a technique devised by Smets (1997) to disentangle the two based on an assumed contemporaneous response of the monetary authorities to exchange rate changes.

[c] The EMU study *The exchange rate and macroeconomic adjustment* replicates this result.

8 Stochastic Simulations on the 'Three Bears' Model

Stochastic simulations on the 'Three Bears' model suggest that asymmetric shocks will cause inflation and output volatility to increase, while symmetric shocks are predicted to have more modest effects.

Results from a calibrated version of the model suggest that, overall, inflation and output volatility would increase inside EMU compared to outside.

But this deterioration might be mitigated by more active use of discretionary fiscal policy.

And the result might be reversed, so macroeconomic volatility might be lower inside EMU, if the contribution of exchange rate 'noise' to macroeconomic volatility outside EMU is estimated to have been sufficiently great.

8.1 The analysis of the previous section goes some way to reconciling the apparently conflicting conclusions to be drawn from stochastic simulations carried out on empirically estimated macroeconometric models.

8.2 But as an additional aid to understanding the problem, it is also useful to examine the predictions of stochastic simulation exercises carried out on the stylised 'Three Bears' model developed and analysed in Sections 3-6. There, the stylised responses to particular shocks gave some generic insights into the adjustment mechanisms inside and outside EMU. Here too, this approach can be used to disentangle the effects of different modelling assumptions on the overall conclusions of the stochastic simulations.

8.3 There are a number of advantages to using the stylised model:

- the shocks to the stylised model have well-defined economic interpretations in terms of demand shocks, supply shocks, monetary policy shocks and exchange rate shocks; and
- it is straightforward to implement the assumption that particular shocks are symmetric or asymmetric. By contrast, estimated equation residuals in empirical macroeconometric models may be difficult to interpret.

8.4 Of course, the major disadvantage with using a calibrated stylised model is that the stochastic properties of the different shocks are not readily available. In the illustrations that follow, this problem is confronted in two stages:

- first, the contribution of each type of shock to inflation and output volatility is presented for a unit variance shock. Even without empirical estimates of their relative size and frequency, this can provide relevant information on the potential impact of different types of symmetric and asymmetric shocks and on how their relative contribution varies according to the calibration of the model; and
- second, the building blocks developed in the first stage will be weighted together according to a range of empirical estimates of the actual shocks estimated according to structural VAR analysis. With this additional information, broad conclusions will be drawn on the likely net macroeconomic costs of entering EMU not only for our benchmark calibration but also for plausible alternative scenarios.

8.5 It should be emphasised that the objective of this approach is not to derive a superior set of stochastic simulations to those from the studies discussed in Section 7. Rather it is intended as an aid to the interpretation of the results from this type of exercise. Nevertheless, this approach does allow tentative conclusions to be drawn from the 'Three Bears' model as to how macroeconomic volatility is likely to be affected if the UK were to enter EMU. But these conclusions will be conditional on particular assumptions about the properties of the stylised model and conditional on the particular pattern of shocks assumed to be impinging on the model. Since the underlying model and shock processes are only relatively crudely calibrated, it is therefore important to examine the effects of varying key assumptions, either about the model or the shocks. This will help to illustrate the robustness of the conclusions to different features of the exercise.

Results for the benchmark calibration on a shock-by-shock basis

8.6 Table 8.1 below provides estimates of the predicted degree of volatility in inflation and output first outside EMU, then inside, in the face of unit variance shocks to each of the four different kinds of disturbance allowed for in the 'Three Bears' model:[1]

- demand shocks (comprising shocks specific to the UK, the euro area and the rest of the world, as well as a shock symmetric to the UK and the euro area);
- supply shocks (comprising shocks which are UK-specific, euro area-specific and symmetric to both);
- exchange rate shocks (outside EMU comprising shocks to the risk-premium associated with sterling, the euro and the rest-of-the-world (ROW) currency respectively, the latter being symmetric shocks to sterling and the euro); and inside EMU comprising shocks to the euro-ROW bilateral exchange rate, where the euro-specific shocks are a weighted average of the previous sterling and euro area shocks); and
- monetary policy shocks (comprising shocks specific to the UK policy rule, shocks specific to the ECB policy rule and shocks symmetric to both when the UK is outside EMU, and shocks to the ECB rule only when inside EMU).

8.7 At this stage, these results are derived using the benchmark version of the model where the only asymmetries in the structure between the UK and euro area arise because of differences in trade patterns and the degree of openness.

[1] The results are generated for each shock by calculating the estimated long-run, or asymptotic, standard deviations derived from running 100 antithetic simulations, i.e. 200 in total, where for each stochastic simulation, the opposite (i.e. negative) shocks are applied in a second run. The shocks are assumed to be unexpected each quarter, so the stochastic simulation must be solved using a stacked solution technique (see for example, Ireland and Westaway, 1990). Each simulation was run for 80 quarters, with the shocks applied for the first 60. The long-run standard deviation was calculated by averaging the estimated standard deviation at all time periods to which shocks were applied, excluding the first 20 periods when the model responses had not reached their steady state. Larger numbers of replications were found to give minimal improvements in the estimates of the asymptotic standard deviation.

Table 8.1: Long-run volatility comparison of EMU versus non-EMU regimes for UK: 'Three Bears' model
- all identified shocks
- symmetric version of 'Three Bears' model

		UK outside EMU		UK in EMU		Ratio in/out	
		Inflation	Output gap	Inflation	Output gap	Inflation	Output gap
Demand shocks	Symmetric	0.38	0.38	0.38	0.37	1.01	0.98
	RoW shock	0.06	0.06	0.05	0.06	0.94	1.03
	UK shock	0.23	0.32	0.30	0.44	1.30	1.38
	Euro area shock	0.13	0.05	0.40	0.17	3.12	3.60
Supply shocks	Symmetric	0.58	0.87	0.59	0.86	1.02	0.98
	UK shock	0.43	0.86	0.53	1.03	1.23	1.20
	Euro area shock	0.16	0.05	0.63	0.31	3.92	6.37
Exchange rate shocks	£	0.26	0.13	0.03	0.02	0.13	0.14
	€	0.10	0.04	0.14	0.07	1.41	1.61
	$	0.17	0.09	0.17	0.09	0.98	1.04
Policy shocks	UK	0.28	0.19	0.00	0.00	0.00	0.00
	Euro area	0.08	0.04	0.22	0.16	2.58	4.22
	Symmetric	0.22	0.16	0.22	0.16	0.99	1.03

8.8 How should these results be interpreted? Of course, without having information on the relative frequency of different types of shocks, it is not possible with this information to come up with a firm model-based estimate of the overall costs associated with shocks inside and outside EMU with this structure of the model. Even so, the results are very informative, building on the insights already gained from the deterministic simulations.

8.9 The following points seem particularly important:

- for all asymmetric shocks, with the obvious exception of those which will actually disappear inside EMU, the long-run level of output and inflation variability always increases inside EMU. This is particularly marked in the case of shocks specific to the euro area which, outside EMU, would be predicted to have rather small effects on the UK, but inside EMU would induce interest rate charges unnecessary from the UK perspective. These results are entirely consistent with the results of the deterministic simulations which similarly showed a deterioration in performance in the face of asymmetric shocks;

- in particular, it was noted with the deterministic simulations of UK-specific shocks that price level stability and potentially inflation stability could be enhanced for UK-specific shocks inside EMU. This result emerged because of the quasi-price-level targeting properties under EMU; that is, for shocks where the long-run real exchange rate is unchanged, the UK price level needs to be brought back to euro area levels, whereas with independent monetary policy, the price level could 'slip' due to the nominal exchange rate shock absorber role. But in the stochastic simulations, the potentially beneficial impact on inflation is overwhelmed by the deterioration in the ability of ECB interest rates to control UK inflation;

- in the case of symmetric shocks, the results are somewhat more nuanced, usually implying a small change in the trade-off between output and inflation variability, rather than an outright deterioration, in EMU. Again, these results are consistent with those shown in the earlier deterministic simulations (see for example Charts 3.2(a)-(d)); and

- as expected, shocks to the sterling-euro risk premium and to the UK interest rate policy rule both incur costs for the UK economy in the regime where interest rates are set autonomously, but are much smaller in EMU (disappearing completely in the case of policy shocks and having a much smaller contribution to exchange rate volatility in the case of the sterling shocks).[2]

Sensitivity analysis of the stylised stochastic simulation results

8.10 To stress test these results, is useful to compare them with a number of alternative calibrations of the model, along the lines of the earlier robustness checks in Sections 5 and 6, to highlight the potentially important role of different structural assumptions and different asymmetries which may be more relevant for the UK-euro area comparison than has been assumed so far. Here the sensitivity analysis will be carried out on the following aspects:

- the role of trade-related asymmetries (Table 8.2);
- the role of the interest-sensitivity of demand (Table 8.3);
- the role of price flexibility (Table 8.4);
- the possibility of an enhanced role for fiscal policy as an additional adjustment mechanism inside EMU (Table 8.5); and
- the sensitivity of results to different assumptions about exchange rate shocks (Table 8.6).

The role of openness and trade asymmetries

8.11 First consider the role of those structural asymmetries that remain in the benchmark version of the 'Three Bears' model used so far. These are related to differences in the degree of openness between the UK and the euro area, and to differences in their respective trade patterns with each other and the rest of the world. As the results in Table 8.1 have already shown, the influence of these asymmetries is rather minor since the inflation and output consequences of symmetric shocks are rather similar whether the UK is assumed to be in or out of EMU. This is confirmed by Table 8.2 below which shows the consequences of removing the trade-related asymmetries altogether:[3]

- as expected, the predicted macroeconomic costs would be identical in and out of EMU in the face of symmetric demand shocks; and
- for asymmetric demand shocks, the relative increase in inflation volatility improves slightly in EMU (the ratio is 0.97). The increase in output volatility is now less severe inside EMU but still increases by 28 per cent in EMU despite the symmetry of the structures of the model.

[2] The effects of the sterling risk premium do not disappear altogether in EMU because of the maintained assumption that once the UK joins EMU, shocks to the euro are a weighted average of those to the old euro currency and the previously improving on sterling where sterling has a weight of 20 per cent.

[3] This is done by making the degree of UK and euro area openness equal at 0.25 (the average of their respective values in the benchmark), the relative trade intensities equal at 0.5, and the share of import prices in the domestic consumer price equation to be equal at 0.85. So the comparison with the asymmetric case is affected both by the removal of the asymmetries and the change in the degree of openness in the UK.

Table 8.2: Long-run volatility comparison of EMU versus non-EMU for UK: 'Three Bears' model
- Demand shocks
- Symmetric versus benchmark version of 'Three Bears' model

		UK outside EMU		UK in EMU		Ratio in/out	
Model version	**Shock type**	**Inflation**	**Output gap**	**Inflation**	**Output gap**	**Inflation**	**Output gap**
Symmetric	Symmetric	0.42	0.38	0.42	0.38	1.00	1.00
Benchmark	Symmetric	0.38	0.38	0.38	0.37	1.01	0.98
Symmetric	UK shock	0.30	0.33	0.29	0.42	0.97	1.28
Benchmark	UK shock	0.23	0.32	0.30	0.44	1.30	1.38

The role of interest-rate sensitivity

8.12 In fact, the benchmark calibration of the stylised model was partly chosen to highlight the richness of the contrast in dynamic responses inside EMU compared to out, even without large behavioural asymmetries. But, as in Section 6, it is interesting to examine how additional asymmetries, possibly reflecting more plausible assumptions than embodied in the benchmark case, might affect the stylised results. Table 8.3, for example, illustrates the implications of modifying the benchmark calibration by assuming that the interest-rate elasticity of demand in the UK is twice as high as in the euro area.

Table 8.3: Long-run volatility comparison of EMU versus non-EMU for UK: 'Three Bears' model
- Demand shocks
- Variations in degree of interest-rate sensitivity of IS curve

		UK outside EMU		UK in EMU		Ratio in/out	
Model version	**Shock type**	**Inflation**	**Output gap**	**Inflation**	**Output gap**	**Inflation**	**Output gap**
Interest elasticity doubled in UK IS curve	Symmetric	0.35	0.36	0.35	0.34	1.00	0.96
Benchmark	Symmetric	0.38	0.38	0.38	0.37	1.01	0.98
Interest elasticity doubled in UK IS curve	UK shock	0.23	0.32	0.32	0.46	1.38	1.45
Benchmark	UK shock	0.23	0.32	0.30	0.44	1.30	1.38

8.13 The stochastic results are consistent with the simulation responses in the face of symmetric and UK-specific demand shocks described in Section 6:

- for symmetric shocks, the implication of a higher interest-rate elasticity in the UK is that, if the UK were in EMU, the ECB would over-compensate for symmetric shocks from the UK's perspective. So inflation and output volatility would improve slightly inside EMU; but
- for UK-specific asymmetric shocks, the UK's higher interest rate sensitivity worsens the 'Wicksellian' instability described in Section 4, so inflation and output volatility deteriorate inside EMU.

The role of price flexibility

8.14 Earlier sections have already highlighted the crucial role that price flexibility plays in determining the potential costs of EMU. Broadly, it has been shown that the more flexible are prices, then the less volatile will output become relative to potential. Outside EMU, increased price flexibility allows the monetary authorities to target inflation more accurately, but inside EMU, inflation deviations will tend to increase as relative prices are forced to take the short-term burden of relative price adjustments.

8.15 Table 8.4 below compares the predictions for inflation and output variance results on the benchmark model with results for two alternative versions of the model, first when the UK is assumed to be more flexible than the euro area by having a greater degree of forward-lookingness in price-setting, then in a more extreme case where UK prices are assumed to be fully flexible.

Table 8.4: Long-run volatility comparison of EMU versus non-EMU for UK: 'Three Bears' model
• Demand shocks
• Variations in degree of price flexibility

		UK outside EMU		UK in EMU		Ratio in/out	
Model version	**Shock type**	**Inflation**	**Output gap**	**Inflation**	**Output gap**	**Inflation**	**Output gap**
UK fully flexible	Symmetric	0.00	0.00	1.17	0.00	–	–
UK and euro area fully flexible	Symmetric	0.00	0.00	0.15	0.00	–	–
UK Phillips curve more forward-looking	Symmetric	0.26	0.31	0.31	0.31	1.20	0.98
Benchmark	Symmetric	0.38	0.38	0.38	0.37	1.01	0.98
UK fully flexible	UK shock	0.00	0.00	1.29	0.00	–	–
UK and euro area fully flexible	UK shock	0.00	0.00	1.09	0.00	–	–
UK Phillips curve more forward-looking	UK shock	0.19	0.28	0.20	0.33	1.05	1.18
Benchmark	UK shock	0.23	0.32	0.30	0.44	1.30	1.38

8.16 In both cases, the results are consistent with the principles described in earlier sections:

- if price-setting in the UK is more flexible (here captured by a greater weight on forward-looking expectations in the Phillips curve, i.e. 0.75 compared to 0.25 in the benchmark case and in the euro area), then the less volatile is inflation and output, in or out of EMU. This is an important result in the context of the flexibility test, the second of the Government's five economic tests, because it implies that more flexibility may be preferred even if it implies greater structural asymmetry with the euro area; but
- the greater degree of price flexibility does imply that inflation volatility in the face of symmetric shocks would increase by more upon UK entry to EMU compared to the benchmark case (though the increase in inflation volatility would be smaller for asymmetric shocks);
- in the limiting case where price flexibility in the UK is complete, EMU membership would imply a huge increase in inflation volatility since inflation differentials would take on all of the burden of relative price adjustment; but
- this increase would be greatly reduced if it were additionally assumed that prices in the euro area were also fully flexible. Under that assumption, the increase in inflation variability is much less than when the UK alone was flexible.

The benefits of discretionary fiscal policy inside EMU

8.17 One important issue discussed in Section 5 is the extent to which UK fiscal policy action might be enhanced inside EMU to compensate for the loss of an independent monetary policy. Table 8.5 compares the benchmark results with a case where a stylised discretionary fiscal policy is adopted, i.e. where the automatic stabilisers are augmented by a response to inflation and output deviations. Three clear messages emerge, again consistent with the conclusions drawn from the deterministic simulations in Section 5:

- inflation and output volatility could be lowered, inside or outside EMU, by the more active use of discretionary fiscal policy action[4] (where, as in the earlier section, it is important to emphasise the caveat that the discretionary fiscal rule and its effectiveness is characterised in a stylised way[5]);
- on assuming that fiscal policy would be available inside EMU as well as out, inflation and output volatility would increase upon EMU entry (by 5 and 18 per cent respectively) but this would be less than the predicted deterioration (of 30 and 38 per cent respectively) when no compensating fiscal policy action was assumed; and
- since fiscal policy in the UK's is not currently characterised by an active role for discretionary fiscal policy, it may be more relevant to compare the results outside EMU without fiscal policy with the performance inside EMU with discretionary fiscal policy. On this basis, inflation and output volatility would be very similar inside and outside EMU. So, under these stylised assumptions at least, fiscal policy inside EMU can effectively mimic the effects of monetary policy outside EMU.

Table 8.5: Long-run volatility comparison of EMU versus non-EMU for UK: 'Three Bears' model
• UK-specific demand shocks
• Variations in degree of assumed fiscal stabilisation

		UK outside EMU		UK in EMU		Ratio in/out	
Model version	**Shock type**	**Inflation**	**Output gap**	**Inflation**	**Output gap**	**Inflation**	**Output gap**
Augmented fiscal policy for UK	UK shock	0.19	0.28	0.20	0.33	1.05	1.18
Benchmark	UK shock	0.23	0.32	0.30	0.44	1.30	1.38

Alternative assumptions regarding exchange rate shocks

8.18 Given the importance attributed to the role of exchange rate shocks in the discussion of the previous stochastic simulation studies discussed in Section 7, it important to examine the implications of making different assumptions regarding exchange rate shocks when running stochastic simulations in the 'Three Bears' model.

8.19 The results for exchange rate shocks shown in Table 8.1 were conditioned by the simplifying assumption that three independent shocks could impinge directly on exchange rates when the UK was assumed to be outside EMU. These shocks were assumed to be associated with UK-specific risk, euro area-specific risk and rest-of-the-world-specific risk respectively.[6] And once the UK was assumed to be inside EMU, shocks to the augmented euro area (i.e. the previous euro area plus the UK) were assumed to comprise a weighted average of the previous UK and euro area shocks (where the UK was assumed to have a weight of 0.2).

8.20 But even given the constraints imposed by the 'Three Bears' model of a world of three country blocks, this may be a serious over-simplification. One possibility, already discussed in the context of describing the results of Minford (2001), is that exchange rate shocks rather than being independent may be positively or negatively correlated. For example, it has been

[4] As noted earlier, this finding was also reported in Blake and Young (1998).

[5] See the EMU study *Fiscal stabilisation and EMU* for a fuller discussion of this issue.

[6] Of course, because the three exchange rates must respect the 'triangulation' identity, an increase in risk to one country will necessarily imply a fall in relative risk for the other two.

observed that over certain periods, movements in the sterling-euro and the sterling-dollar exchange rate have tended to be negatively correlated, so offsetting each other in their effect on sterling's effective exchange rate.[7] Table 8.6 compares the implications for inflation and output volatility of making this alternative set of assumptions.[8] Since these results are closely related to the discussion on exchange rate volatility in the EMU study *The exchange rate and macroeconomic adjustment*, supplementary information on the variation in the real sterling-euro and sterling effective exchange rate is included in columns of Table 8.6.

8.21 The contrast with the previous results in the benchmark case is striking:

- with the previous results where shocks to sterling were assumed to be UK-specific, outside EMU these caused volatility in UK inflation and output. But these were predicted to be greatly reduced inside EMU, by over 80 per cent.[9] And their contribution to real exchange movements was also predicted to be largely eliminated (with movements in the nominal sterling-euro exchange rate, of course, completely eliminated); and

- but when sterling-euro and sterling-US dollar shocks are assumed to be negatively correlated, the picture is reversed. Outside EMU, the shocks to sterling would tend to offset each other in their effects on the sterling effective exchange rate, so inflation and output volatility would be more than halved compared to the benchmark case. But once the UK enters EMU, sterling would 'inherit' the previous greater euro-US dollar volatility.[10] The result is that inflation and output volatility would now double inside EMU and the real effective exchange rate would increase in volatility despite the elimination of nominal sterling-euro fluctuations.

Table 8.6: Long-run volatility comparison of EMU versus non-EMU for UK: 'Three Bears' model
• Variations in correlation of exchange rate shocks

		UK outside EMU				UK in EMU				Ratio in/out	
Model version	Shock type	Inflation	Output Gap	Real £-€	Real £ eff.	Inflation	Output gap	Real £-€	Real £ eff.	Inflation	Output gap
Benchmark	£-€ and £-$ negatively correlated	0.10	0.04	0.59	0.82	0.24	0.13	0.06	0.98	2.48	2.91
Benchmark	£ shocks independent	0.26	0.13	0.51	0.52	0.03	0.02	0.01	0.07	0.13	0.14

[7] It is worth repeating the point from the earlier discussion that the observed stochastic behaviour of a particular exchange rate will be generated by both fundamental shocks and by direct shocks to the exchange rate (See Box 7.1). It is only the effect of the latter that is captured by the 'exchange rate shocks' row in Table 8.1 and Table 8.6.

[8] These two sets of assumptions are also intended to characterise, albeit rather crudely, the respective assumptions regarding exchange rate shocks made in the two emperically-based stochastic simulation exercises examined in Section 7.

[9] It is not eliminated completely because the original sterling shocks are still assumed to impinge on the euro, but with a lower weight of 20 per cent.

[10] If the variance of shocks to £-€ and £-$ are both unity, and if they have a covariance of -1, then in a three-country world, the variance of €-$ will be double that of either of the sterling bilaterals.

An attempted calibration for all shocks

8.22 The preceding discussion of the stylised stochastic simulation results has so far deliberately stopped short of attempting to 'add together' the results for the effects of different shocks.[11] Ultimately, however, policy conclusions can only be drawn on the basis of considering the likely response of the UK economy in the face of all the shocks that are likely to hit, in or out of EMU. So in the final part of this section, an attempt is made to estimate how important different types of shocks might be, in aggregate, for the UK economy, as depicted in the stylised 'Three Bears' model.

8.23 This calibration of the shocks is based on an empirical calibration of the shocks derived from the SVAR analysis already described in Section 2. Box 8.1 describes in detail how this is done. The two key stages to the calibration are:

- estimation of the respective contributions of demand, supply and nominal (policy and exchange rate) shocks to the average of output and inflation volatility in the UK. The analysis suggests that the average split is roughly 50 per cent from demand shocks, 40 per cent from supply shocks and 10 per cent from nominal shocks; and

Box 8.1: Empirical calibration of shocks in the 'Three Bears' model

Since the 'Three Bears' model adopted in this study is calibrated rather than empirically estimated, estimation residuals are not available as they would be with the econometrically estimated models employed in the empirical stochastic simulation exercises described in Section 7.

Instead, an SVAR model of the UK economy based on Gerlach and Smets (1995), as described in Section 2, is estimated. This is used to calculate the relative contribution that different structural shocks have made over the past to UK inflation and output volatility. Two stages are required:

(i) Compute the historical variance decomposition (see Enders, 1995) to derive the relative contribution of real demand shocks, supply shocks and nominal shocks. The results suggest that the split is roughly 50-40-10 for average inflation and output volatility in the UK.

The SVAR analysis considered here does not allow an explicit decomposition of the shocks into symmetric and asymmetric components, or for any shocks implying more complicated covariance with the euro area shocks. Indeed, one shortcoming of the SVAR analysis is that it is designed to reveal the 'average' response to a generic-demand or supply shock and does not usually allow the different types of symmetric and asymmetric shocks to be distinguished. Nevertheless:

(ii) The problem is addressed in the second stage of the calibration by assuming that the average correlation coefficient of the estimated UK and euro area shocks (as shown earlier in Chart 2.5) gives a rough proxy for the degree of symmetry of the shocks. This is estimated to be roughly a half.

It should be emphasised that this is a highly crude measure, since the revealed correlation coefficient for all types of shocks has varied greatly over the most recent 20 years, having had periods when the correlation was higher, but a period during the 1990s (arguably in the wake of German reunification) when the correlation was negative.

For this reason, an alternative assumption where the proportion of symmetric shocks is much higher, at 0.8, is also assumed in the stochastic simulation exercise.

[11] Since the model is linear and since the shocks have been assumed to be independent so far, then it is possible to infer the total variance in macroeconomic outcomes by adding the variances associated with individual shocks, weighted by their relative size and frequency.

- estimation of the contribution to average output and inflation volatility in the UK from symmetric and asymmetric shocks respectively. The analysis suggests that roughly 50 per cent of average output and inflation volatility can be attributed to symmetric shocks, and 50 per cent to asymmetric shocks, though this estimate is especially uncertain, so alternative assumptions are analysed too.

8.24 Table 8.7 gives estimates of total predicted inflation and output volatility comparing outcomes under the assumptions that the UK either stays outside or joins EMU. The following cases are presented:

	Model version adopted	Shock distribution assumed
Case 1	Benchmark assumptions	Benchmark assumptions
Case 2	Benchmark assumptions	Benchmark + symmetric shocks contribute 80 per cent
Case 3	Benchmark assumptions	Benchmark + nominal shocks contribute 75 per cent (of which exchange rate shocks comprise 90 per cent).
Case 4	Benchmark assumptions	Benchmark + negatively correlated shocks to £-€ and £-$
Case 5	Benchmark assumptions + UK IS curve twice as interest-sensitive + UK Phillips curve twice as forward- looking	Benchmark assumptions
Case 6	Benchmark assumptions + active fiscal policy inside EMU	Benchmark assumptions

Table 8.7: Long-run volatility comparison of EMU versus non-EMU for UK: 'Three Bears' model
• Calibrated distribution of all shocks
• Variations around benchmark model

	Model version:	Shocks assumed:	UK outside EMU		UK in EMU		Ratio in/out	
			Inflation	Output gap	Inflation	Output gap	Inflation	Output gap
Case 1	Benchmark	Benchmark	0.64	0.76	0.87	0.92	1.36	1.20
Case 2	Benchmark	Benchmark + shocks 80 per cent symmetric	0.66	0.74	0.70	0.76	1.05	1.02
Case 3	Benchmark	Benchmark + shocks 75 per cent nominal (of which 90 per cent exchange rate)	0.83	0.57	0.70	0.56	0.84	0.99
Case 4	Benchmark	Benchmark + £-€ and £-$ negatively correlated	0.64	1.01	0.76	0.96	1.59	1.27
Case 5	Benchmark+modified UK IS curve and Phillips curve	Benchmark	0.59	0.70	0.78	0.80	1.32	1.15
Case 6	Benchmark + augmented fiscal policy for UK (in EMU only)	Benchmark	0.64	0.76	0.71	0.70	1.11	0.92

8.25 The conclusions to be derived from these results when the model is subjected to the full range of shocks follow naturally from the earlier analysis and from the assumptions made regarding the relative importance of particular types of shocks. Again, it needs to be emphasised that this exercise is based on the predicted response of a stylised model of the UK economy to an assumed set of shocks which are intended to be comparable to those shocks which have hit the economic environment in the past. But these calibrated shocks are necessarily stylised too. Nevertheless, the main points to emerge from this exercise are as follows:

- in the benchmark case, Case 1, both inflation and output volatility are predicted to rise inside EMU, by 36 and 20 per cent respectively;
- but the scale of this increase in volatility could be modified or even reversed under alternative assumptions. In Case 2, when asymmetric shocks are assumed to be much less important in generating macroeconomic volatility, the implications of EMU entry for UK and output inflation volatility are more balanced, showing only a small deterioration in macroeconomic volatility inside EMU;
- alternatively, if nominal shocks are assumed to make a much greater contribution to macroeconomic volatility, and within that, if exchange rate shocks are assumed to be the predominant influence[12] (here 90 per cent) then Case 3 shows it is possible for both output and inflation volatility to fall once the UK enters EMU (by 16 and 1 per cent respectively). These results are consistent with a scenario where outside EMU, the exchange rate has been acting more as a source of shocks than a shock absorber;
- but as discussed earlier, a different assumption regarding exchange rate shocks can worsen the predicted effects for the UK inside EMU. Case 4 shows the effects of assuming instead that sterling-euro and sterling-US dollar shocks are negatively correlated outside EMU, so joining EMU would impart more not less stability from exchange rate shocks, with inflation and output volatility rising by 59 and 27 per cent respectively more than in the benchmark case;
- Case 5 examines the case, previously analysed in Section 6 and earlier in this section, where the UK is assumed to have more behavioural asymmetries than assumed in the benchmark case, first through having a more interest-sensitive demand, and second through having more flexibility in price-setting. If both these asymmetries are assumed to hold together (where here the relevant parameters are both assumed to be doubled), EMU membership still implies a deterioration in output and inflation volatility, though by slightly less than in the benchmark case. This finding is consistent with the earlier deterministic simulations where increased price flexibility was found to improve macroeconomic outcomes;

[12] These assumptions are more in line with the SVAR results of Artis and Ehrmann (2000), rather than the approach to SVAR analysis used in this study which is based on the approach of Gerlach and Smets (1995).

- finally, Case 6 examines the performance under the benchmark assumptions of Case 1, but where, upon entering EMU, UK fiscal policy is assumed to be used more actively as a discretionary instrument of demand management. As would be expected, this has a beneficial stabilising influence compared to Case 1. Now inside EMU, inflation variability is only 11 per cent higher rather than 36 per cent higher when only the automatic stabilisers were operating. And output variability now falls by 8 per cent inside EMU rather than increasing by 20 per cent. This suggests that if fiscal policy were used inside EMU in a discretionary manner, and if it were assumed to operate as effectively as is assumed here, it may be possible for the UK to join EMU without suffering too great an increase in inflation volatility, at the same time achieving slightly more stable output.

9 Conclusions

Key points

9.1 The convergence and flexibility tests are ultimately concerned with a comparison of how well the UK economy would be able to adjust to shocks inside EMU compared to a regime where UK interest rates are set independently and the sterling-euro exchange rate is free to move.

9.2 Many of the standard tools devised to judge the fitness of the UK economy to join EMU (e.g. historical correlations and VAR-based estimates of comparative responses) are highly informative but ultimately, can only be indicative.

9.3 Structural macroeconomic models, though inevitably an approximation and subject to their own flaws, represent a potentially more powerful tool for analysing how the economy might respond to different shocks under the two alternative regimes.

9.4 But most macroeconometric models are difficult to understand. Instead, there is a case for adopting simpler, stylised models that capture the essential features of the transmission mechanism of monetary policy. Such a model is employed in this study to unravel and provide a diagnostic analysis of the key characteristics of the adjustment mechanisms inside EMU. This analysis is new both in terms of the model adopted and in the scope of the questions addressed. But it is conducted in the spirit of earlier work by, for example, the European Commission (1990) in their original 'One Market, One Money' study and is related to more recent work that examine the workings of the adjustment mechanisms inside EMU since 1999 (see for example Blanchard, 2001).

Key features of adjustment

9.5 Outside EMU, under inflation targeting, an independent monetary policy works through two main channels:

- by affecting demand via counter-cyclical movements in real interest rates, where real interest rates impinge directly on domestic demand and indirectly on net trade via the effect on the real exchange rate; and
- by facilitating required relative price changes via movements in the nominal exchange rate which plays a 'shock absorbing' role. In the face of inflationary shocks specific to the UK economy, for example, the UK price level is allowed to 'slip', and the nominal exchange rate will eventually move to accommodate this slippage and help to facilitate re-adjustment of the real exchange rate.

9.6 Inside EMU, the adjustment mechanism would work in much the same way if a symmetric shock prompted a response from the ECB similar to that which would have occurred to the UK outside EMU. But for an asymmetric shock which is specific to the UK, the adjustment mechanism would work rather differently:

- the primary burden would be placed on the bilateral real exchange rate between the UK and the euro area and this would necessarily take place via relative price adjustment;
- for asymmetric shocks, the euro area price level effectively acts as a nominal anchor for the UK price level; and
- real interest rates no longer play the primary adjustment role. Indeed, since the ECB would respond weakly to inflationary shocks that were specific to the UK, real interest rates might actually fall, tending to destabilise the adjustment mechanism.

9.7 Other mechanisms are available inside EMU to facilitate adjustment. Fiscal policy mechanisms can be augmented, but there may be practical problems in doing so. Ultimately wage-price flexibility offers the most effective means of avoiding output costs inside EMU. Greater flexibility among all euro area members would be the first best outcome in terms of minimising UK volatility in EMU. If the UK is relatively more flexible than the euro area, then UK inflation variability may be higher as a result.

9.8 The ease with which the UK economy might be able to respond to different shocks inside EMU is importantly affected by the degree of behavioural asymmetry between the UK and the euro area, for example in the degree of price flexibility and in the degree of sensitivity to interest rates. The conventional view arising from optimal currency area (OCA) theory is that the more diverse are the values of these parameters between the UK and euro area, the more costly EMU becomes in macroeconomic terms. But the analysis here has shown that the implication will differ according to both the source and direction of the asymmetry. So, for example, higher price flexibility in the UK would show up in higher inflation volatility, while lower price flexibility would result in greater output volatility.

9.9 Stochastic simulation methods have been used by empirical modellers in an attempt to measure the net macroeconomic costs of EMU. Overall, the conclusions to be drawn from these studies vary. While a range of technical aspects underlying these conclusions are important, the treatment of shocks to the exchange rate (and the associated question of whether the exchange rate is deemed to be a source of noise or a shock absorber) turns out to be critical. An extensive investigation of the stochastic properties of the 'Three Bears' model, culminating in a series of simulation exercises, tends to predict that EMU is likely to lead to more macroeconomic volatility. But it is shown how reasonable assumptions regarding the assumed specification of the model, or the shocks assumed to impinge, can either magnify or shrink this predicted increase. And under particular assumptions about the nature of the exchange rate shocks assumed outside EMU, it is possible that macroeconomic volatility could fall inside EMU.

9.10 Overall the analysis confirms the prediction that, on *a priori* grounds, it is not possible to say whether macroeconomic volatility in the UK will increase or decrease inside EMU compared to outside. But the analysis has provided a conceptual framework which helps to explain how different assumptions about the workings of the macroeconomic environment can lead to different conclusions regarding the degree of macroeconomic volatility inside EMU compared to outside.

9.11 In concluding, it is important to emphasise that, in making the assessment of the economic case for UK entry to EMU, these costs need to be compared against the potential benefits which EMU entry offers.

9.12 This study informs the assessment of the convergence test, the first of the Government's five economic tests for EMU entry; the flexibility test, the second test; and the growth, stability and jobs test, the fifth test.

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A

Annex A: A Detailed Description of the 'Three Bears' Model

Relationship of 'Three Bears' model to previous work

A1 This annex describes in more detail the 'Three Bears' model. The model adopted has very conventional properties in the spirit of recent simple models adopted for use in the analysis of the design of monetary policy in a single-country context (see Clarida *et al*., 1999, for a survey of this approach). But it is specifically tailored to reveal the key aspects of the interaction between the UK and euro area economies.

A2 There are three country blocks in the model representing the UK, the euro area and the rest of the world (and since these three country blocks in the model can broadly be characterised as small, medium-sized and large, this gives the model its name). In its full form, the model can be run with all three countries endogenous, but here, since the focus of interest is on the interaction between the UK and euro area, the rest of the world is held constant for simplicity.

A3 The behavioural core of each country block in the model is based on what has become known as the 'workhorse' model of monetary policy analysis. Early examples of this type of model were specified in a simple backward-looking form (see for example Rudebusch and Svensson, 1999). But in later versions, as here, forward-looking behaviour has been incorporated consistent with optimising behaviour on the part of firms and consumers (see for example McCallum and Nelson, 1999; and Clarida *et al*. 1999). And open-economy considerations have been taken into account (see for example Blake and Westaway, 1996; Batini and Haldane, 1999; and Ball, 1999).

A4 The 'Three Bears' model represents an innovation relative to most other studies of this type in its explicit modelling of the interaction between the UK, the euro area and the rest of the world. In previous open-economy studies, the second-round effects of one country on another have usually been ignored, but in the context of understanding the implications of EMU membership for the adjustment mechanism in the UK, this additional degree of complexity is vital.

Model overview

A5 The key equations for each country block in the model are as follows:

- a fixed level of potential output;
- an IS curve where aggregate demand depends negatively on the real interest rate; negatively on the respective bilateral real exchange rates and positively with respect to foreign demand pressures;
- a Phillips curve where changes in inflation are driven by the output gap (i.e. the gap between aggregate demand and supply) with important additional dynamics from the real exchange rate;
- bilateral exchange rates between pairs of countries driven by the relevant UIP condition, itself driven by the relevant interest rate differential; and
- a policy rule for nominal interest rates of the 'Taylor' form, specifying a positive response to deviations in inflation from target and to the output gap.

Equation listing

A6 A detailed listing of the model equations for the UK and the euro area now follows:

- equations are numbered where version (a) refers to the UK version and (b) to that for the euro area;

- in most cases, except where specified, the accompanying description of the model equations will refer to those for the UK but the description will in all cases apply to the euro area too (with a suitable change of subscripts and superscripts in the model description);
- all model variables are defined in natural logarithms, except for the real and nominal interest rate variables which are linear; and
- the description will explain how the 'reduced form' coefficients in the equations of the model can be broken down into influences from structural and behavioural parameters.

Output potential (supply):

$$ys_t^{UK} = ysshock_t^{UK} + ysshock_t^{SYMM} \quad [1a]$$

$$ys_t^{EA} = ysshock_t^{EA} + ysshock_t^{SYMM} \quad [1b]$$

A7 Output potential in the UK (ys_t^{UK}) :

- is assumed to be exogenous to the model; and
- is affected by two types of shock, those specific to the UK ($ysshock_t^{UK}$) and shocks which symmetrically hit the euro area too ($ysshock_t^{SYMM}$).

Output determination (IS curve):

$$y_t^{UK} = cy_{lead}^{uk} \cdot y_{t+1,e}^{UK} + cy_{lag}^{uk} \cdot y_{t-1}^{UK} + (1 - cy_{lead}^{uk} - cy_{lag}^{uk}).$$
$$[cy_1^{uk}.r_t^{UK} + cy_2^{uk}.er_t^{UKv.EA} + cy_3^{uk}.er_t^{UKv.ROW} \quad [2a]$$
$$+cy_4^{uk} y_t^{EA} + cy_5^{uk}.y_t^{ROW} + fisc_t^{UK} + ydshock_t^{UK} + ydshock_t^{SYMM}]$$

$$y_t^{EA} = cy_{lead}^{ea} \cdot y_{t+1,e}^{EA} + cy_{lag}^{ea} . y_{t-1}^{EA} + (1 - cy_{lead}^{ea} - cy_{lag}^{ea}).$$
$$[cy_1^{ea}.r_t^{EA} + cy_2^{ea}.er_t^{EAv.UK} + cy_3^{ea}.er_t^{EAv.ROW} \quad [2b]$$
$$+cy_4^{ea} y_t^{UK} + cy_5^{ea}.y_t^{ROW} + fisc_t^{EA} + ydshock_t^{EA} + ydshock_t^{SYMM}]$$

A8 UK output (y_t^{UK}) is determined by an IS curve with the following properties:

- in its general form, it is assumed to include backward and forward-looking elements (with a lag and lead of cy_{lag}^{uk} and cy_{lead}^{uk} respectively) where $y_{t+1,e}^{UK}$ refers to the expectation of UK output in period *t+1* formed at period *t*. This is consistent with optimising models augmented to include elements of inertia, caused for example by habit persistence (see for example McCallum and Nelson, 1999, and Fuhrer, 2000). Since the theory of the optimising IS curve is less well-founded in the open economy case, the constraint that the 'structural' coefficients on the leads and lags of output should add to unity is not imposed in the 'Three Bears' implementation of the model;
- real interest rates impinge negatively on demand with a coefficient cy_1^{uk}, which is a behavioural parameter;
- each bilateral real exchange rate (i.e. between the UK and the euro area and rest of the world, respectively) impinges negatively on UK demand, where the reduced form coefficients (cy_2^{uk} and cy_3^{uk}) appropriately reflect the openness of the UK economy ($open^{uk}$), the share of euro area and rest-of-the-world trade in total UK trade ($t^{uk.ea}$ and $t^{uk.row} = 1 - t^{uk.ea}$), the sensitivity of UK trade to real

exchange rate movements (γ^{uk}) and the degree of pricing-to-market in UK trade prices (ptm^{uk}),

i.e. $cy_2^{uk} = 2.open^{uk}t^{uk.ea}\gamma^{uk}ptm^{uk}$ and $cy_3^{uk} = 2.open^{uk}t^{uk.row}\gamma^{uk}ptm^{uk}$;

- openness and trade shares can be viewed as 'structural' parameters in the sense that they can be easily measured and are unlikely to evolve rapidly, while exchange rate sensitivity and the degree of pricing to market are considered 'behavioural', since they must be estimated;
- foreign demand impinges positively on demand implicitly via the demand for exports, where the reduced form coefficients on euro area and rest-of-the-world demand (i.e. c_4^{uk} and c_5^{uk}) are scaled by openness and trade shares,

  i.e. $cy_4^{uk} = open^{uk}t^{uk.ea}$ and $cy_5^{uk} = open^{uk}t^{uk.row}$; and
- demand in the UK is assumed to be directly affected by two types of shock, those specific to the UK ($ydshock_t^{UK}$) and shocks that symmetrically hit the euro area too ($ydshock_t^{SYMM}$).

Fiscal policy:

$$fisc_t^{UK} = cf_{AS}^{uk}y_t^{UK} + cf_1^{UK}.dp_t^{UK} = cf_2^{UK}.(y_t^{UK} - ys_t^{UK}) \quad [3a]$$

$$fisc_t^{EA} = cf_{AS}^{ea}y_t^{EA} + cf_1^{ea}.dp_t^{EA} = cf_2^{ea}.(y_t^{EA} - ys_t^{EA}) \quad [3b]$$

A9 Fiscal policy ($fisc_t^{UK}$) is assumed to impinge directly on demand:

- in the benchmark case, fiscal policy is assumed to respond only to the automatic stabilisers (with a sensitivity to output fluctuations of cf_{AS}^{uk}); but
- inside EMU, additional discretionary fiscal stabilisation is assumed to operate (as described in Section 5), responding to inflation deviations from target and the output gap (with coefficients cf_1^{uk} and cf_2^{uk} respectively).

Inflation determination (Phillips curve):

$$\begin{aligned} dp_t^{UK} = {} & cp_1^{uk}.dp_{t+1,e}^{UK} + (1 - cp_1^{uk}).dp_{t-1}^{UK} \\ & + cp_2^{uk}.(er_{t+1,e}^{UKv.EA} - er_t^{UKv.EA}) + cp_3^{uk}.(er_t^{UKv.EA} - er_{t-1}^{UKv.EA}) \\ & + cp_4^{uk}.(er_{t+1,e}^{UKv.ROW} - er_t^{UKvROW}) + cp_5^{uk}.(er_t^{UKv.ROW} - er_{t-1}^{UKv.ROW}) \\ & + cp_6^{uk}.(y_t^{UK} + y_{t-1}^{UK} - ys_t^{UK} - ys_{t-1}^{UK}) \end{aligned} \quad [4a]$$

$$\begin{aligned} dp_t^{EA} = {} & cp_1^{ea}.dp_{t+1,e}^{EA} + (1 - cp_1^{ea}).dp_{t-1}^{EA} \\ & + cp_2^{ea}.(er_{t+1,e}^{UKv.EA} - er_t^{UKv.EA}) + cp_3^{ea}.(er_t^{UKv.EA} - er_{t-1}^{UKv.EA}) \\ & + cp_4^{ea}.(er_{t+1,e}^{UKv.ROW} - er_t^{UKvROW}) + cp_5^{ea}.(er_t^{UKv.ROW} - er_{t-1}^{UKv.ROW}) \\ & + cp_6^{ea}.(y_t^{EA} + y_{t-1}^{EA} - ys_t^{EA} - ys_{t-1}^{EA}) \end{aligned} \quad [4b]$$

A10 Inflation in the UK (dp_t^{UK}) is determined by a dynamic open-economy Phillips curve. Box A1 provides a more detailed justification of the specification:

- inflation dynamics are based on the Fuhrer and Moore (1995) overlapping contracts model where inflation is determined as an equally weighted sum of lagged and future inflation (where $dp_{t+1,e}^{UK}$ is the expectation of UK inflation in period $t+1$ formed at period t) This imparts inertia into the inflation process. Following Blake and Westaway (1996), the implementation of this approach here is generalised to allow the weight on backward-looking inflation to be higher to capture additional nominal inertia though the weights are constrained to add to unity to ensure dynamic homogeneity;

- the output gap appears in the Phillips curve via a two-period moving average effect, consistent with the dynamic contracting model;
- the price level (p_t^{uk}) is defined as the cumulated inflation rate;
- the price modelled is a consumer price index[1] defined as an appropriately weighted sum of domestic prices and import prices (where μ^{UK} is the weight of UK-produced goods in the domestic CPI) captured by a weighted average of competitors' prices deflated by the relevant bilateral exchange rates. Pricing to market effects modify the pass-through of exchange rates into import prices;
- the dynamics of the real exchange rate terms are also determined by the dynamic contract model, involving a change term in each of the expected and current bilateral real exchange rates, with respective coefficients of cp_2^{uk} and cp_3^{uk} for the UK-euro area real exchange rate, and cp_4^{uk} and cp_5^{uk} for the UK-rest-of-the-world real exchange rate. The related coefficients depend on the degree of inflation inertia (cp_1^{uk}) , the share of domestic goods in the consumer price basket (μ^{uk}) and the degree of pricing to market (ptm^{uk}),

  i.e. $cp_2^{uk} = cp_1^{uk}.\phi^{uk}t^{uk.ea}$, $cp_3^{uk} = -(1 - cp_1^{uk}).\phi^{uk}t^{uk.ea}$

  and $cp_4^{uk} = cp_1^{uk}.\phi^{uk}t^{uk.row}$, $cp_5^{uk} = -(1 - cp_1^{uk}).\phi^{uk}t^{uk.row}$

  where $\phi^{uk} = 2.(1 - \mu ptm^{uk})/\mu ptm^{uk}$

  and where $\mu ptm^{uk} = \mu^{uk} / (1 - (1 - \mu^{uk}).ptm^{uk})$; and
- supply shocks to the UK ($ysshock_t^{uk}$ and $ysshock_t^{SYMM}$) impinge on the model via their effect on supply potential (ys_t^{UK}) which enters via the output gap terms in the Phillips curve.[2]

Real exchange rate determination:

When the UK sets monetary policy independently:

$$er_t^{UKv.EA} = er_{t+1,e}^{UKv.EA} + r_t^{UK} - r_t^{EA} - sig_t^{UKv.EA} \qquad [5a]$$

When UK in EMU:

$$er_t^{UKv.EA} = p_t^{UK} - p_t^{EA} \qquad [5a']$$

When the UK is outside or inside EMU:

$$er_t^{UKv.ROW} = er_{t+1,e}^{UKv.ROW} + r_t^{UK} - r_t^{ROW} - sig_t^{UKv.ROW} \qquad [5b]$$

AII The equations for the bilateral real exchange rate will depend on the UK's monetary regime:

- outside EMU, real bilateral exchange rates of the UK against the euro area ($er_t^{UKv.EA}$) and the rest-of-the-world ($er_t^{UKv.EA}$) are determined by the uncovered interest parity condition containing the relevant expected exchange rate terms ($er_{t+1,e}^{UKv.EA}$ and $er_{t+1,e}^{UKv.ROW}$, where for example $er_{t+1,e}^{UKv.EA}$ is the expected bilateral UK v euro area real exchange rate in period $t+1$ formed in period t) and the relevant real interest rate differentials (i.e. r_t^{UK} relative to r_t^{EA} and r_t^{ROW} respectively) plus a risk premium ($sig_t^{UKv.EA}$ and $sig_t^{UKv.ROW}$);

[1] To simplify the model, the real exchange rate is defined using consumer prices rather than trade prices which a richer model would additionally incorporate.

[2] In principle, an alternative type of supply shock which does not directly impinge on productive potential could additionally impinge on inflation, for example due to an effect from unwarranted wage pressures. For simplicity, this type of effect is not separately modelled here.

Box A1: Derivation of the augmented Fuhrer-Moore model of inflation dynamics

The characterisation of inflation dynamics employed in the 'Three Bears' model is based on the model of inflation inertia originally developed in Fuhrer and Moore (1995).

Its key characteristic is a model of overlapping wage contracts (w_t) specified in terms of real relativities[a]. This assumes that real wages contracts negotiated in the current period are a weighted average of real wages struck in the previous and following contract period (with weights of α and 1-α respectively, summing to unity to ensure dynamic homogeneity). The original specification of Fuhrer and Moore assumed that the backward and forward-looking weights should be equal with a value of a half, but Blake and Westaway (1996) generalised this scheme to encompass differing degrees of backward-looking behaviour. The value of the wage contract is modified by an effect from the output gap, wage contracts being higher when the economy is operating above potential, i.e.

$$w_t - p_t = \alpha(w_{t-1} - p_{t-1}) + (1-\alpha)(w^e_{t+1} - p^e_{t+1}) + \upsilon y_t \qquad \text{(A1)}$$

where w^e_{t+1} and p^e_{t+1} represent the expected value of wages and consumer prices at the time the contract is struck at time *t*.

In the simplest form of the model where wage contracts last for two periods, with half of all wages being struck each period, then the domestic price is simply a weighted average of domestic costs, i.e.

$$pd_t = 0.5(w_t + w_{t-1}) \qquad \text{(A2)}$$

The consumer price is then defined as a weighted average of domestically produced and imported goods, where domestic goods have a weight of β in the consumer price index, i.e.

$$p_t = \beta 0.5(w_t + w_{t-1}) + (1-\beta)\, pm_t \qquad \text{(A3)}$$

Importing firms are assumed to price to market such that the consumer price of goods in the domestic market have a weight of λ in import prices (pm_t), but no lags are assumed in the adjustment of import prices to changes in prices in domestic markets, or in overseas prices (p^*_t) or to the nominal exchange rate (e_t), i.e.

$$pm_t = \lambda p_t + (1-\lambda)(p^*_t - e_t) \qquad \text{(A4)}$$

The real exchange rate is defined as

$$er_t = e_t + p_t - p^*_t \qquad \text{(A5)}$$

By manipulation of these equations[b], it is possible to derive a Phillips curve relationship for the determination of inflation ($\pi_t = p_t - p_{t-1}$) given by

$$\pi_t = (1-\alpha)\pi^e_{t+1} + \alpha\pi_{t-1} + 2\left(\frac{1-\beta'}{\beta'}\right)((1-\alpha)\Delta er^e_{t+1} - \alpha\Delta er_t) + \upsilon(y_t + y_{t-1}) \qquad \text{(A6)}$$

where $\beta' = \beta/(1-(1-\beta)\lambda)$.

Unlike the earlier model of Taylor (1980) specified in terms of nominal wage relativities, equation (A6) for inflation dynamics contains inflation inertia (i.e. inflation depends on its own lagged values). This is an important property which, compared to a model where inflation is purely forward-looking, is more consistent with the empirical evidence for the dynamic behaviour of inflation in developed economies.

[a] An earlier version of a similar wage-contracting model was also derived in Buiter and Jewitt (1981).

[b] Specifically, it is necessary to add equation (A1) to a lagged version of (A1), then to take a first difference of equation (A3) and a lag of that, then to combine these expressions to eliminate the terms in wages. Then the import price terms should be substituted out using equations (A4) and (A5) to leave only terms in dynamics of inflation, the real exchange rate and output. Equation (A6) follows. This derivation abstracts from the effect of expectational errors in the face of shocks by assuming that $\pi^e_{t,t-1} = \pi_t$ and $er^e_{t,t-1} = er_t$ for all periods including the first.

- inside EMU, when the nominal exchange rate between the UK and the euro area is irerevocable fixed (here at unity for presentational simplicity), the real exchange rate becomes equivalent to the relative price between the UK (p_t^{UK}) and euro area (p_t^{EA}); and
- shocks to the real exchange rate occur via the risk premium terms (see below).

Exchange rate risk premium:

$sig_t^{UKvEA} = risk_t^{UK} - risk_t^{EA}$ [6a]

When UK is outside EMU:

$sig_t^{UKvROW} = risk_t^{UK} - risk_t^{ROW}$ [6b]

When UK in EMU:

$sig_t^{UKvROW} = w.risk_t^{UK} + (1 - w)risk_t^{EA} - risk_t^{ROW}$ [6b']

where w is the share of UK GDP in euro area GDP post UK-entry.

A12 Exchange rate risk premia can be defined in a variety of ways:

- in the simplest case where independent risks can be associated with particular countries, the risk premium on a particular bilateral is defined as the difference between the risks associated with the respective countries. Inside EMU, it is assumed that the risk associated with an extended euro area including the UK is a weighted sum of the previous risks in the UK and euro area; and
- in more complicated cases, as considered for example in the stochastic simulations in Section 8, risk premia may be cross correlated and the simple expression above is implicitly augmented by more terms.

Nominal exchange rate:

$e_t^{UKvEA} = er_t^{UKvEA} + p_t^{EA} - p_t^{UK}$

$e_t^{UKvROW} = er_t^{UKvROW} + p_t^{ROW} - p_t^{UK}$

The bilateral nominal exchange rates (e_t^{UKvEA} and e_t^{UKvROW}) are defined by identity:

- in the case when the UK is inside EMU, the nominal exchange rate is held constant at unity (zero in logarithms).

Real interest rates:

$r_t^{UK} = i_t^{UK} - dp_{t+1,e}^{UK}$ [7a]

$r_t^{EA} = i_t^{EA} - dp_{t+1,e}^{EA}$ [7b]

A13 Real interest rates (r_t^{UK}) are defined in forward-looking terms, i.e. as the difference between the nominal interest rate (i_t^{UK}) and a forward-looking measure of expected inflation ($dp_{t+1,e}^{UK}$).

Nominal interest rate reaction functions:

When the UK sets monetary policy independently:

$i_t^{UK} = dp_{t+1,e}^{UK} + cr_1^{uk}.(dp_t^{UK} - dp_{\text{targ}}^{UK}) + cr_2^{uk}(y_t^{UK} - ys_t^{UK}) + ishock_t^{UK} + ishock_t^{SYMM}$ [8a]

$i_t^{EA} = dp_{t+1,e}^{EA} + cr_1^{ea}.(dp_t^{EA} - dp_{\text{targ}}^{EA}) + cr_2^{ea}(y_t^{EA} - ys_t^{EA}) + ishock_t^{EA} + ishock_t^{SYMM}$ [8b]

When the UK is in EMU:

$$i_t^{UK} = i_t^{EA} \qquad [8a']$$

$$i_t^{EA} = w.dp_{t+1,e}^{UK} + (1-w).dp_{t+1,e}^{EA} + w.[cr_1^{ea}(dp_t^{UK} - dp_{targ}^{EA}) + cr_2^{ea}.(y_t^{UK} - ys_t^{UK})] + (1-w).[cr_1^{ea}(dp_t^{EA} - dp_{targ}^{EA}) + cr_2^{ea}(y_t^{EA} - ys_t^{EA})] \qquad [8b']$$

where w is the share of UK GDP in euro area GDP *post* entry.

AI4 The policy rule for nominal interest rates will depend on whether the UK is in EMU or not:

- outside EMU, nominal interest rates (i_t^{UK}) are set according to a Taylor-type rule responding to deviations in UK inflation from target and in the UK output gap (with coefficients cr_1^{uk} and cr_2^{uk} respectively); and
- inside EMU, UK nominal interest rates are set equal to interest rates in the euro area, which are now assumed to be set by the ECB in response to an appropriately weighted average of inflation deviations and output gaps in the euro area including the UK (and where the Taylor rule parameters and inflation target for the euro area are assumed to be unaffected by UK entry to EMU).

Model solution

AI5 The model is programmed up in the Winsolve modelling package (see Pierse, 2000). It is solved using a Gauss-Newton solution method. All forward-looking expectations in the model are solved using a stacked Newton method under the assumption of model consistent expectations with conventional terminal conditions.

Calibration of the model

AI6 The model is calibrated in order to reproduce in a realistic but inevitably rather stylised manner, the dynamic properties of the UK and euro area economies and their interaction with the rest of the world. As such, parameter values have largely been chosen to provide response patterns that are consistent with SVAR responses and with those observed in larger empirically based macromodels.

AI7 In describing the calibration of the model for the UK and euro area equations, it is useful to separate the model's parameters into three categories, 'long-run structural', behavioural and policy-related.

AI8 Long-run structural parameters relate to features of the economy that tend to be measured, here based on national accounts statistics for GDP and expenditure shares, rather than estimated. As such, they are unlikely to be altered in the short-to-medium term by the monetary regime in place. These are detailed in the table below:

Structural parameters	UK	Euro area
Openness defined as average of import and export to GDP ratio	$open^{uk} = 0.33$	$open^{ea} = 0.165$
Trade shares	$t^{uk.ea} = 0.5$	$t^{ea.uk} = 0.18$
($t^{a.b}$ = share of A in B's trade)	$t^{uk.row} = 1-0.5=0.5$	$t^{ea.row} = 1-0.18=0.82$
Domestic content of CPI	$\mu^{uk} = 0.8$	$\mu^{ea} = 0.9$
Share of GDP in world output	$w^{uk} = 0.04$	$w^{ea} = 0.16$
Share of GDP in output of euro area plus UK	$w = w^{uk} / (w^{uk} + w^{ea})$ = 0.2	1-w = 0.8

A19 Behavioural parameters relate to features of the economy that tend to be estimated or calibrated. These parameters may be more likely to alter endogenously once monetary union begins. Details are given in the table below:

Behavioural parameters	UK	Euro area
Sensitivity of trade to real exchange rate	$\gamma^{uk} = -1.5$	$\gamma^{ea} = -1.5$
Degree of pricing to market	$ptm^{uk} = 0.25$	$ptm^{ea} = 0.25$
Degree of inertia in output	$cy^{uk}_{lag} = 0.5$, $cy^{uk}_{lead} = 0$	$cy^{ea}_{lag} = 0.5$, $cy^{ea}_{lead} = 0$
Interest sensitivity of output	$cy^{uk}_1 = -0.2$	$cy^{ea}_1 = -0.2$
Degree of forward-lookingness in price setting	$cp^{uk}_1 = 0.25$	$cp^{ea}_1 = 0.25$
Output sensitivity of price setting	$cp^{uk}_6 = 0.25$	$cp^{ea}_6 = 0.25$

A20 As in previous studies that have adopted small stylised models to conduct policy analysis (e.g. Blake and Westaway, 1996, and Batini and Haldane, 1999), these behavioural parameters are calibrated partly on the basis of single equation estimates, partly by attempting to match the simulation responses of existing empirically based models (for example, those of NiGEM, IMF Multimod or the Bank of England's medium term macroeconomic model; see NIESR, 2003; Laxton et al., 1998; and Bank of England, 1999). The following assumptions are worthy of note:

- the sensitivity of trade to the real exchange rate (γ^{uk} and γ^{ea}) is calibrated so that the aggregate reduced form elasticity of UK demand to the real exchange rate (i.e. $cy^{uk}_2 + cy^{uk}_3 = -0.7425$) is comparable to that adopted in Batini and Haldane (1999) where the long run elasticity is –1 (though the short-run elasticity adopted there is lower at –0.2 compared to –0.37 in the 'Three Bears' model);
- the degree of pricing to market (ptm^{uk} and ptm^{ea}) is broadly consistent with empirical estimates contained in macroeconomic models. The estimate of 0.25 adopted here is slightly lower than that in the HM Treasury public model but higher than the assumption of zero long-run pricing to market in the Bank of England's medium-term macroeconomic model (see Bank Of England, 1999);
- the backward-looking inertia (cy^{uk}_{lag} and cy^{ea}_6) is slightly less that assumed in Batini and Haldane (1999) and Blake and Westaway (1996) although sensitivity analysis of this assumption is carried out in Section 4;
- the sensitivity of demand to the real interest rate (cy^{uk}_1 and cy^{ea}_1) is comparable to previous studies in terms of its impact elasticity (–0.1 here compared to –0.2 in Blake and Westaway, 1996, and Batini and Haldane, 1999) but lower in terms of its long run impact (–0.2 compared to –1, for example in Batini and Haldane, 1999). This assumption, which is varied in the sensitivity analysis of Section 6, is adopted in order to preserve the stability properties of the model inside EMU. A higher assumed value for this parameter, in conjunction with the assumption that demand responds to short-term interest rates, gives rise to implausibly oscillatory dynamics for the UK inside EMU;
- the degree of forward-lookingness in price-setting (cp^{uk}_1 and cp^{ea}_1) is the same as that previously assumed in Blake and Westaway (1996) and is broadly consistent with estimates for the US in Fuhrer (1997); and

- the responsiveness of real wages to output (cp_6^{uk} and cp_{lag}^{ea}), here assumed equal to 0.25, is comparable to that adopted in previous studies (for example 0.2 adopted in Batini and Haldane, 1999) but somewhat larger that empirical estimates for the US and the euro area reported in Fuhrer (1997) and Coenen and Wieland (2000) respectively.

A21 Policy-related parameters relate

- to the feedback responses of monetary policy in the 'Taylor' specification; and
- to the responsiveness of fiscal policy comprising two components; first, the automatic stabiliser component involving a response coefficient of 0.5 to output changes (see Van den Noord, 2000); and second, an additional discretionary feedback element to inflation deviations and the output gap. This may be required inside EMU to compensate for the loss of independent monetary policy as an adjustment mechanism.

A22 No attempt is made in the paper to choose policy-response coefficients that are 'optimal' in any sense.

Policy rules	UK	Euro area
Monetary policy	$cr_1^{uk} = 0.5$	$cr_1^{ea} = 0.5$
	$cr_2^{uk} = 0.5$	$cr_2^{ea} = 0.5$
Fiscal policy	$cf_{AS}^{uk} = -0.5$	$cf_{AS}^{ea} = -0.5$
	$cf_1^{uk} = cf_2^{uk} = 0.0$	$cf_1^{ea} = cf_2^{ea} = 0.0$

A23 These 13 sets of parameters (five structural, six behavioural and two policy-related) completely define the coefficients of the model. All that remains is to express the reduced-form coefficients in the output and inflation equations in terms of these parameters. Details are given below:

Output determination (IS curve)	UK	Euro area
Degree of inertia	$cy_{lag}^{uk} = 0.5$, $cy_{lead}^{uk} = 0$	$cy_{lag}^{ea} = 0.5$, $cy_{lead}^{ea} = 0$
Interest sensitivity	$cy_1^{uk} = -0.2$	$cy_1^{ea} = -0.2$
Coefficients on real exchange rate terms	$cy_2^{uk} = -0.37125$	$cy_2^{ea} = -0.06683$
(derivation given in 2)	$cy_3^{uk} = -0.37125$	$cy_3^{ea} = -0.30443$
Foreign demand elasticity	$cy_4^{uk} = 0.165$	$cy_4^{ea} = 0.0297$
(derivation given in 2)	$cy_5^{uk} = 0.165$	$cy_5^{ea} = 0.1353$

Inflation determination (Phillips curve)	UK	Euro area
Degree of forward-lookingness	$cp_1^{uk} = 0.25$	$cp_1^{ea} = 0.25$
Coefficients on real exchange rate terms	$cp_2^{uk} = 0.0469$	$cp_2^{ea} = 0.0075$
(derivation given below equation 3)	$cp_3^{uk} = -0.141$	$cp_3^{ea} = -0.0225$
	$cp_4^{uk} = 0.0469$	$cp_4^{ea} = 0.0342$
	$cp_5^{uk} = -0.141$	$cp_5^{ea} = -0.1025$
Output sensitivity	$cp_6^{uk} = 0.25$	$cp_6^{ea} = 0.25$

A24 Arguably, the distinction between structural and behavioural parameters adopted here is slightly arbitrary. In particular, the parameters designated as 'behavioural' here would, in a model more rigorously based on optimising principles, be themselves determined by underlying structural characteristics such as the preferences of economic agents and the technological constraints that they face. But for the purposes of this study, these definitions are used to set up the benchmark calibration of the model where, for simplicity, all 'behavioural' parameters are assumed to be identical between the UK and euro area. This facilitates understanding of the simulation responses of the benchmark version of the model where the only asymmetries between the model structures are in terms of policy setting and long run structural differences reflecting country size and trade patterns. Having understood this benchmark version, the implications of variations in the specification of the model, the assumed policy setting and the shocks assumed to hit the model can easily be introduced.