Modelling monetary policy and financial markets

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Chapter 1

Introduction

Macro economic outcomes have tended to exhibit serious instability from time to time. One policy reaction to this has been to suggest interventionist rules for monetary and regulatory policy. Examples of these have been the idea that the UK should join the euro as a substitute for a domestic monetary policy that has led to macro instability; that monetary policy should stabilise rates of growth of nominal variables rather than their levels as a way of stabilising unemployment; and that financial markets need regulation to avoid inefficiency and 'bubbles'. These three examples are what are addressed in this thesis.

In the first part I look at the proposal to join the euro; plainly such a proposal might look attractive if domestic monetary policy is poorly constructed. However equally plainly it must be possible for a government to decide on good monetary policy. I examine the euro proposal within that context. I use the Liverpool Model of the UK, which is a well-known forecasting model that has been reasonably successful in forecasting the economy in both the 1980s and 1990s. This model has been influential in developing the counter-inflation (demand-side) and anti-unemployment (supply-side) policies of the UK. The model also has had a fairly good forecasting record, successfully predicting several major UK episodes. So the model not only produces reasonably good forecasts, but also gives credible answers to questions about the effects of policy changes. I therefore suggest that the Liverpool Model is a suitable vehicle for evaluating the impact on the economy's behaviour in response to a major policy shift, such as joining EMU.

Using the model I compare the effect of shocks on the economy under the floating case and under EMU. I first identify the typical shocks hitting the economy and estimate their variability. A large number of sets of random drawings from each shock distribution is then generated, which are then applied to the model in sequence, to generate a scenario for the economy over that period. The variances of the variables are then computed from this large sample of observations for the given monetary regime. I can then compare them across regimes. The welfare of the representative agent is also calculated to compare the effects the differences in variability have. A household utility function that fits well with what we know about risk-aversion and inter-temporal substitution is the Constant Relative Risk Aversion function with a unitary elasticity of substitution between consumption and leisure. The value shares of consumption and leisure are set at 0.7 and 0.3 respectively, and the risk-aversion parameter is set to 1.5. The differences in utility are then estimated from the stochastic simulations and then compared under floating and EMU.

I also investigate what the comparison would be if the assumptions about both regimes were wrong due to an 'exogenous' mistake in the parameter values and applicable in both regimes. I examine the effects of i) having greater nominal rigidity in wages (as the Liverpool Model has very little nominal wage rigidity); ii) the UK having lower demand sensitivity to interest rates (as one of the differences between the UK and the continent that exacerbates the asymmetric effect of shocks is the overdraft lending system and the variable rate mortgage); iii) the effect of the UK having greater labour market flexibility (as greater flexibility of real wages in response to shocks would dampen unemployment variability); iv) greater volatility of the pound outside EMU (as it is sometimes asserted that floating exchange rates generate high volatility because of the varying risk-premia attached to the pound); and finally v) raising the fiscal stabiliser (advocates of EMU say that discretional fiscal policy could largely replace monetary policy as a stabiliser).

In the second part I look more narrowly at domestic monetary policy and ask whether one could envisage less emphasis on output stabilisation and move from the existing practice of targeting the growth rates of nominal variables to targeting their levels. This would bring monetary policy closer to the classical norms of the gold standard and avoid the problem of existing practices that the variance of the nominal price level becomes infinite as the time horizon of prediction stretches into the future. The monetary regimes I consider are:

1. various sorts of targets for expected outcomes. Each is implemented via setting the expected money supply for the coming period; the actual money supply is subsequently delivered with an independent stochastic error. The targets considered are for inflation, money supply growth, the price level and the money supply level

2. a rigorous interest-rate-control regime where an interest rate target is chosen for the coming period and then exactly adhered to.

I use two models which can be considered to come from opposite ends of the spectrum. On the one hand, there is a representative agent model, calibrated rather than estimated and essentially theoretical in construction. On the other hand, I use a forecasting model, the Liverpool Model of the UK (described above). The idea of this contrast is to achieve some robustness in the assessment of policy.

The models both assume:

1. competitive markets in labour and output.

2. overlapping wage contracts, with a variable indexation parameter chosen optimally by workers; however a marginal labour supply is always provided to the auction market at an auction supply price.

3. Cobb-Douglas production functions.

4. Monetary policy is implemented via money supply feedback rules.

The key differences are that the representative agent model does not allow consumers to access the credit markets. The Liverpool Model is an open economy model so that it embodies efficient international bond markets. The two models differ in detail and in the extent of theoretical abstraction rather than in basic approach.

Both models are shocked in order to estimate the effects on each of the different monetary regimes. In order to assess the welfare of society from different monetary policy rules the average household has the standard Constant Relative Risk Aversion utility function with Cobb-Douglas preferences across consumption and leisure.

In the third part I consider the need for financial market intervention or regulation, revisiting the question of financial market efficiency to investigate whether a model of complete market efficiency could explain the FTSE. This question is highly complicated by the possibility of multiple regimes for profits and hence productivity growth — which creates a 'peso problem' in evaluating the FTSE's behaviour. To allow for this problem I take the Monte Carlo approach of constructing the working or null hypothesis of efficiency under multiple regimes and asking whether draws from the error distributions of these regimes could account for the joint behaviour of profits (the market 'fundamental') and the FTSE. I ask the question: is there some latent model of a fundamental in an efficient market that can link the data on the fundamental to the data on stock prices, accounting for the behaviour of both simultaneously? If so then one cannot reject the 'null hypothesis' that the market is efficient.

One can think of an economy where the capital stock generates the profits or dividends that are valued as equities. The profits are mainly driven by productivity shocks since variations in labour inputs mainly change wages while changes in the capital stock mainly dilute the equity base. So I assume that the fundamental, profits per share, can be identified with productivity.

I suggest that the recognition of several regimes for productivity growth could be a helpful generalisation of the time-series process governing it. Thus for example one might identify periods of poor productivity growth, for example during war time or times of poorly-adapted institutions (the UK during the 1970s); also periods of rapid productivity associated with surges of innovation (the industrial revolution, the computer revolution etc.); and finally periods of normal growth, when innovation is being digested undisturbed by wars or dysfunctional institutions.

I create a regime switching model with four regimes (where the regimes represent high, normal and low growth, as well as a crash) with the probability of each regime constant over time: this model generates a profits series. The rational expectation of the future profits is used to create the present discounted value which is used as the generated FTSE series. There is a constant probability of each future regime and so the variance around future returns is fixed, as are any risk-premium terms, so I have an efficient market world of rational agents. I then use stochastic simulations to see if the model can statistically match the data.

Chapter 2

Britain and EMU: Assessing the Costs in Macroeconomic Variability

2.1 Literature Review

Robert Mundell (1961) laid the foundations of the theory of optimum currency areas in his classic article 'A Theory of Optimum Currency Areas'. In this paper the author states that for a system of flexible exchange rates to work effectively and efficiently it must be demonstrated that: (1) an international price system is dynamically stable; (2) the exchange rate changes necessary to eliminate normal disturbances to dynamic equilibrium are not so large as to cause violent and reversible shifts between exports and import-competing industries; (3) the risks created by variable exchange rates can be covered at reasonable costs in the forward markets; (4) central banks will refrain from monopolistic competition; (5) monetary discipline will be maintained by the unfavourable political consequences of continuing depreciation; (6) reasonable protection of debtors and creditors can be assured; and (7) wages and profits are not tied to a price index in which import goods are heavily weighted.

He also states that if the world can be divided into regions within each of which there is factor mobility and between which there is factor immobility, then each of these regions should have a separate currency which fluctuates relative to all other currencies. If labour and capital are not mobile within a country then a flexible exchange rate will not be stabilising, and this could lead to varying rates of unemployment or inflation. If these factors are mobile across national boundaries then a flexible exchange system would become unnecessary.

Mundell's ideas were extended by Ronald McKinnon (1963) and Peter Kenen (1969). McKinnon develops Mundell's idea of optimality by discussing the influences of the openness of the economy using the ratio of tradable to non-tradable goods. As well has the factor mobility among regions that Mundell was concerned with McKinnon says that factor mobility among industries is also important. Once the problems of factor immobility among industries is considered, the author concludes that it may not be feasible to consider splitting the world into currency areas along industrial groups rather than geographical groups. Though, an optimal geographical size still exists even when we are only concerned with inter-industry factor mobility.

Kenen's article takes a look at the papers on Mundell and McKinnon, and comes to the conclusion that fixed rates are the most appropriate to well-diversified national economies. He states that countries with fixed rates have to have potent and sophisticated internal policies, as diversified national economies may be particularly vulnerable to monetary shocks. So, they need to maintain rather close control over money-wage rates. Also, because of the imperfect mobility of labour, fixed rate countries must have a wide array of budgetary policies to deal with regional unemployment. In conclusion he states that the principle developed countries should adhere to the Bretton Woods regime, whereas the less developed countries should make frequent exchange rate changes or resort to full flexibility as they are less diversified and less well-equipped with policy instruments.

The empirical literature on optimal currency areas has followed different approaches. One approach was pioneered by Bayoumi and Eichengreen (1993). In this paper they use a structural VAR to identify the supply and demand shocks from the observed data on output and unemployment. The cross country correlations of these shocks are then calculated, so they can group countries according to the cross-country correlations of these shocks. They find a distinction between the supply shocks affecting Germany, France, Belgium, the Netherlands and Denmark and the very different supply shocks affecting the UK, Italy, Spain, Portugal, Ireland and Greece. Supply shocks to the first set of countries were both smaller and more correlated across neighbouring countries. The demand shocks experienced by these countries were also smaller and more inter-correlated, though the difference wasn't as large. They also do a similar comparison for the US, and find that the US regions adjust to both demand and supply shocks more quickly than EC countries. This could reflect the greater factor mobility in the US. The authors conclude that because the supply shocks are larger and less correlated across regions in Europe than in the US the EC may find it more difficult to operate a monetary union that the US. The large idiosyncratic shocks they find strengthen the case for policy autonomy and suggest that significant costs may be associated with its sacrifice.

Another approach has been to measure the degree of flexibility of labour markets in Europe. Decressin and Fatas (1995) investigate regional labour market dynamics in Europe over a 25 year period, and compare the results to those obtained for the US. They examine the extent to which labour market shocks are shared by all regions and how regional employment, unemployment and labour force participation adjust to labour demand shocks which are region-specific. The authors find that in Europe 80% of the dynamics in employment growth are region-specific, this is compared to 40% for the US. In terms of an optimal currency area, they come to the conclusion that the regions in Europe form a less suitable single currency area than the states in the US. Europe shocks are distributed less symmetrically across regions and people migrate less rapidly in response to them.

The empirical analysis of optimum currency areas has also concentrated on the issue of whether the degree of asymmetry of shocks is likely to decline (or to increase) when countries integrate further. The EU Commission report 'One Money, One Market' (1990) stresses the view that trade integration leads to the convergence of economic structures and therefore reduces the scope for asymmetric shocks. This paper comes to the conclusion that the likely impacts of EMU are microeconomic efficiency and macroeconomic stability. The main benefits are: (1) a gain in efficiency and a strengthening of the trend of investment and growth; (2) price stability; and (3) valuable gains for many countries' national budgets. Whilst the main cost is the loss of monetary and exchange rate policy as an instrument of economic adjustment at the national level.

The viewpoint that the degree of asymmetry of shocks is likely to increase when countries integrate is defended by Krugman (1993). Krugman looks at the case of regional crises in the US to illustrate some of the difficulties that EMU will face at a regional level. He points out that during the 1980s and early 1990s several regional economies in the US had been subject to large adverse shocks for which they had no policy recourse because the US has a common currency. The main focus is on the slump in New England, and argues that if New England had been a sovereign country, it might have devalued its currency and/or pursued an expansionary monetary policy. The argument of the paper is that the New England experience is a bleak illustration of some of the difficulties that EMU will face at a regional level. The author concludes that the theory and experience of the US suggests that EC regions will become increasingly specialised, and will thus become more vulnerable to region-specific shocks.

Building on the above theory Bayoumi (1994) set out a formal model of optimum currency areas. His model embodies the criteria for optimum currency areas suggested by the papers by Mundell (1961), McKinnon (1963) and Kenen (1969). Using this model the author calculates the welfare effects of currency unions. He finds that while a currency union can raise welfare of the regions within the union, it unambiguously lowers welfare for regions outside the union. The reason for this is that the gains from the union (the lower costs of transacting business) are limited to the members of the union, while the losses from the union (lower output due to the interaction between the common exchange and the nominal rigidity) affect everybody. An implication of this result is that the incentives for a region to join a currency union are different from the incentives to admit a region into the union. The entrant gains from lower transactions costs with the entire existing union, while the incumbent regions only gain on their trade with the potential entrant. So, a small region will have a greater incentive to join a union than the union will have an incentive to admit the new member.

Many papers have concentrated on the formation of the European Monetary Union, and attempted to evaluate the effects of EMU. Minford, Rastogi and Hughes Hallett (1992) evaluate the alternative policy regimes for EMS and EMU. They use stochastic simulation methods on the Liverpool annual global model to evaluate the variability of inflation and output under the various exchange rate arrangements. They argue that EMS produces instability. They find that the best regime for EC countries would be floating with monetary policies either coordinated worldwide or, if this is impossible, coordinated within an EC-wide coalition in a world of independent Nash behaviour. Otherwise the UK would gain from staying out of EMU, returning to a floating exchange-rate.

This result is in contrast to that of the EC Commission's One Market, One Money paper, which concluded that EMS reduces average inflation variability. Masson and Symansky (1992) provide a comparative assessment of the two studies above, and show that the resulting differences are because of differences in experimental design rather than differences between the models. They compare results from the IMF's MULTIMOD with those of the Liverpool model, and since MULTIMOD was used by the EC Commission study they are able to illustrate the sensitivity of results to certain key assumptions. One of these is the treatment of risk premia and the method by which these are estimated and assumed to change under EMU. The authors show that the EC Commission's method of estimating risk premia produces gains from EMU that are far larger than obtained by other methods, whereas in the Minford, Rastogi and Hughes Hallett paper, the treatment of exchange-rate realignments under EMS is shown to cause most of the instability in their results. The authors conclude that EMS is much less of a potential course of instability than implied by the Minford, Rastogi and Hughes Hallet paper, but they also find no strong evidence to support EMU over the alternative regimes.

Whitley (1992) uses deterministic simulation rather than stochastic simulation to analyse the effects of specific single shock under EMS and EMU using various different multi-country models. He finds that expansionary fiscal policies are observed to be more inflationary under EMU than under independent monetary policy. However, there is little evidence of higher inflation under EMU than EMS. For an oil shock the author finds that the diversity of the output responses across the models make it difficult to draw any general conclusions about the convergence under the different policy regimes, and conclude that there is no tendency for EMU to reduce the recessionary effect of higher oil prices on European output levels or to moderate inflationary pressures.

In a more recent paper Barrell and Drury (2000) analyse two different regimes, one where the UK is inside the monetary union and another where the UK stays outside monetary union. They use a large macro model which includes descriptions of all the European economies and applied stochastic simulation techniques to evaluate the performance of the UK economy under the different regimes. They use data from the period 1991q1 to 1997q4 to draw their shocks. The authors find that the volatility of UK output is larger when inside the monetary union, whereas inflation variability is decreased. They conclude that if the UK faces a turbulent future then the case for membership of EMU is strengthened.

In a review of the five years since the introduction of the Euro Rogoff (2005) says that the euro has had some marked successes, but the pain has probably outweighed the gain as Europe still remains far from an optimal currency area. The author says the one of the successes of the euro has been in maintaining low and stable inflation, but the costs of having a common monetary policy are also apparent, and Germany would have been better off with its own currency. From the authors viewpoint Europe may be an optimal monetary area from a political point of view, but not from an economic one.

2.2 Introduction

The British Chancellor of the Exchequer has proposed 'five (economic) tests' for whether the UK should join the euro (HMTreasury, 2003, reports his largely negative assessment). The central macroeconomic issue is embodied in the first and second of these tests which ask how far the UK will suffer in the form of increased macroeconomic volatility — 'boom and bust' — from losing its power to set its own independent interest rate through having its own currency and exchange rate. This issue (alone) is the focus of this paper; we must emphasise that we do not seek to minimise the importance of other issues bearing on the choice. These are discussed in Minford (2002). This paper is intended to discuss the narrow but important technical question of the effects on macro variability; since macro policy loses freedom of action, an efficient government will necessarily face higher variability, at least in the absence of helpful structural changes induced by giving up that freedom, but the extent of it and the possible effects of such changes is an important element in the decision about joining.

One can use indirect evidence on this from a variety of sources — such as the extent to which the euro-zone and the UK business cycles have been similar and the degree of asymmetry of the two region's shocks. Such evidence has been assembled for a number of countries, including the UK, within the 'optimal currency area' literature; the general verdict of this literature is that a country such as the UK is exposed to substantially 'asymmetrical' shocks and that this is likely to impose a non-trivial cost on it if it gives up monetary autonomy. However this evidence is only indirect in the sense that it does not give us a quantitative estimate of what would happen if we joined EMU as compared with continuing outside. It indicates the likely direction of effect but cannot tell us its likely size and therefore its likely painfulness. The same applies to studies of the experience of US states within the US monetary union, with its unique relationships and history. To find out the consequences for the UK itself with its own particular characteristics we would ideally like to try EMU out. Unfortunately we cannot of course as EMU is effectively irreversible; the nearest thing to a try-out was our experience of the European Exchange Rate Mechanism, which was not entirely encouraging, but it was not EMU, since our exchange rate was fixed but adjustable whereas under EMU it is fixed and never again adjustable. However, there is one course open to us, indeed essentially the only one: we can use a model of the UK economy of the sort used regularly to give answers about the effects of other policies and to make forecasts; and we can simulate its behaviour in response to typical shocks under our present arrangements and then by contrast under EMU. Such stochastic simulation analysis gives us a reading on the difference in the volatility of the UK economy under the two monetary regimes.

This question is not to be confused with the question of the likely short-term outlook for the economy if it joins or stays out. That is of interest too (and would depend on what exchange rate we joined at, whether our interest rates had 'converged' or not, and other elements in the initial situation when we joined); but this is of little importance for a long-lasting, even permanent, decision to join EMU because these short-term differences in the forecast would give way, in the absence of further shocks, to a similar outlook. Our inflation target is basically the same as the ECB's; and our growth rate over the long-term will not be affected by a different monetary regime with a similar inflation target. So the serious issue is how the economy behaves in response to shocks once embedded in a different monetary regime. That behaviour could be very different and the difference long-lasting because the regimes are so different; under one we can react to shocks by changing our interest rates, under the other we cannot.

To examine this issue of relative volatility we use a well-known forecasting model that has been reasonably successful in forecasting the economy in both the 1980s and the 1990s, the Liverpool Model of the UK; it has also been influential in developing the counter-inflation (demand-side) and anti-unemployment (supply-side) policies of the UK. We first say a few words about the model and describe the methods we are using on it, before turning to previous results of such exercises and then the results we get in this one.

2.3 The Liverpool Model of the UK and the Stochastic Simulation Method Used

The model (an account can be found in Minford, 1980) has been used in forecasting continuously since 1979, and is now one of only two in that category. The other is the NIESR model, which however has been frequently changed in that 20-year period: the only changes in the Liverpool Model were the introduction in the early 1980s of supply-side equations (to estimate underlying or equilibrium values of unemployment, output and the exchange rate) and the shift from annual data to a quarterly version in the mid-1980s. In an exhaustive comparative test of forecasting ability over the 1980s, Andrews et al. (1996) showed that out of three models extant in that decade — Liverpool, NIESR, and LBS — the forecasting performance of none of them could dominate that of the others in non-nested tests, suggesting that the Liverpool Model during this period was, though a newcomer, at least no worse than the major models of that time. For 1990s forecasts no formal test is available, but the LBS model stopped forecasting and in annual forecasting post-mortem contests the NIESR came top in two years, Liverpool in three. In terms of major UK episodes, Liverpool model forecasts successfully predicted the sharp drop in inflation and the good growth recovery of the early 1980s. From the mid-1980s they rightly predicted that the underlying rate of unemployment was coming down because of supply-side reforms and that unemployment would in time fall steadily in consequence. Then they identified the weakness of UK membership of the ERM and its likely departure because of the clash between the needs of the UK economy and those of Germany at the time of German Reunification. After leaving the ERM they forecast that inflation would stay low and that unemployment would fall steadily from its ERM-recession peak back into line with the low underlying rate — as indeed was the case. Thus we would suggest that the Liverpool Model forecasting record is reasonable at the very least.

A model should not only be capable of producing good forecasts; it should also give credible answers to questions about the effects of policy changes. In this respect, the Liverpool Model has been extensively used in policy analysis bearing on the 'monetarist' and 'supply-side' reforms of the 1980s and 1990s, now generally considered to have been broadly successful.

We therefore suggest that the Liverpool Model can be regarded as a suitable vehicle for evaluating the impact of a major policy shift — that of joining EMU — on the economy's behaviour in response to shocks. Comparative work on other models would also be of interest, though in the past few years resources devoted to such models has been drastically reduced as a result of the ESRC's cut-off of funds for their support. There is the NIESR model of the UK and also NIGEM the NIESR's linked model of the UK and other major world economies; we discuss below a comparable study to ours using NIGEM carried out by Barrell and Dury (2000). There are also models in the public sector — those of the Treasury and the Bank of England — though their theoretical basis and their forecasting record are both rather unclear, as is their fitness at this stage for stochastic simulation — an exercise which is highly demanding of the model's structure. It is a major undertaking to carry out stochastic simulation on any model. It requires that the model have a reliable economic structure so that its behaviour in response to a wide range of shocks is reasonable, something that comes from regular use in analysis and forecasting over a long period. It also requires a great deal of detailed work on the inputs and a considerable familiarity with the model's workings so that assumptions are made that do not conflict with the model's logic. In practice this can only be done by a team working regularly on the model. For our work on the Liverpool Model we obviously have access to and have used our own forecasting team in Cardiff Business School — but plainly we do not have similar resources for dealing with other models and our understanding is that the same may be true of the teams themselves dealing with these models. Fortunately, as we have seen the Liverpool Model has strong claims to give relatively authoritative assessments.

Lucas (1976) set out a well-known critique of using such models for analysis of such a fundamental regime change as joining EMU; his point was that the parameters of models that were not totally 'structural' (only the parameters of tastes or technology can be considered such) would shift under the new regime because of the resulting changes in incentives. The Liverpool Model could be vulnerable to such effects in principle, but there is no reliable way of measuring their extent or speed. What we have done to assess the possible errors in our estimates is to carry out sensitivity analysis on the key parameters.

The method of stochastic simulations involves

1. Identifying the typical shocks hitting the economy and estimating their variability on relevant data, usually over the past two decades; this variability is assumed to match the chosen sample period.

2. Randomly draw a vector of error terms for period t. These error terms are added to the model, and it is solved for period t.

3. Draw another vector or error terms for period $t + 1$. These errors and the solution values for period t are then used to solve the model for period $t + 1$.

4. Repeat step 2 for periods $t + 2$ to $t + N$. This is then considered one repetition, from which we obtain a prediction of each endogenous variable for periods t through $t + N$.

5. Repeat steps 1 through 3 J times for J repetitions.

We ran a large number of randomly generated sequences of drawings, filtering out those generating extreme instability as unrealistic. We retained 183 sets, that is 183 different scenarios for a given 'monetary regime', either floating as now or EMU. The reason for omitting the replications that generated extreme instability is that if the economy reacted in such a way to the large shocks the government would respond and there would be a policy response to try and curb the instability. Essentially what is happening in these variants is that negative supply-side shocks (mainly from policy itself) are driving up unemployment and lowering Y*; such a series of bad policies and catastrophic effects would seem likely to generate some offsetting response from policy, much as indeed happened in the 1980s. In this sense the model would be subject to the Lucas Critique, in that policy shocks are treated as exogenous random walks and this would be likely to be overridden under these high-variance cases. As an example of the effect of the large shocks Table 2.1 shows the average of the variances of a sample of omitted replications and a sample of included replications. It can be seen that the variances of all variables are larger for the omitted cases, and very much so for output and unemployment. For this reason we decided to exclude these from the analysis.

Table 2.1: Comparison of Variances for Omitted and Included Replications

	Y	RS	INFL	U	Y*	U*
Omitted	32722633.68	0.000640	0.000237	399657.211	12275291.222	191247.248
Included	12949801.03	0.000622	0.000180	24704.466	2199058.531	6645.064
Ratio	2.526883124	1.029394	1.309518	16.177528	5.582067	28.780349

From our 183 scenarios over 66 quarters we obtain 12,078 observations on the state of the economy, i.e. on each of prices, interest rates short and long, on GDP and other variables. We compute their variances from this large sample of observations for the given monetary regime. We can then compare them across regimes.

A great many assumptions go into such an analysis and it is only reasonable to question them in detail. The fact is we are attempting to see how the future might unfold and the future may fail to resemble the past in particular ways. The virtue of the stochastic simulation method is that we can investigate such concerns quantitatively by simply redoing the analysis under interesting differences of assumption. This can generate a range of possible differences in variability between our two regimes. We can look at these sensitivity tests in two ways. First, we can assume that the relevant changes would have occurred anyway under both regimes; second, that they occur purely as a result of joining EMU — this interpretation could be defended for certain parameter changes such as enhanced labour market flexibility. We report both types of analysis below; our approach is not to attempt any evaluation of the likely extent of parameter changes but merely to investigate their effects within a possible range.

2.3.1 A Short Description of the Model

The Liverpool Model of the UK is a quarterly large non-linear RE model and can be regarded as an open economy version of an IS-LM model. The IS curve has as its components the fiscal deficit, real interest rates and the real exchange rate. In addition, there are wealth effects on consumption and investment. The wealth effects in the Liverpool Model are powerful and respond to changes in expectations of real interest rates and inflation. These cause unanticipated changes in nominal interest rates that alter financial asset values.

The demand for money is given by the standard expression except for the presence of real financial assets, included because the holders of money are assumed to be sensitive to the proportion of money in their overall financial assets. The supply of money has the property that monetary growth can be independent of the fiscal deficit in the short run but it must be consistent with it in the long run since, if this were not the case, with wealth effects real interest rates would diverge. The growth rate of money supply is determined by a long run tendency which is related to the underlying state of the budget deficit and by a temporary component generated by open market policy.

The model's Phillips or supply curve is of the New Classical type and assumes overlapping wage contracts. A key element is the price surprise term that represents the errors in inflation expectations formed over past wage contract dates. The labour demand and supply equations are central in determining the supply side response which impacts on the natural rates of output and unemployment. Thus, unemployment depends on output, a productivity trend, real wage costs, and on product taxes. In turn, real wages depend on benefits, union power, unemployment, and the price surprise term. The Phillips curve includes a persistence effect from implied capital formation while deviations of output from its natural rate are driven by the price surprise term.

Financial markets are assumed to be 'efficient' so that the short term rate of interest, the long rate, and the exchange rate are linked together by the UIP condition and the RE theory of the term structure.

Forward rational expectations are on inflation, output, and the real exchange rate. While the expectations of inflation determine interest rates via the Fisher equation, expectations of output determine real expenditure in the private sector. Expectations of the future real exchange rate are used to solve for the real rate of interest in the UIP condition.

When solving, the model assumes that all lagged variables are known with certainty. Thus, expectations are conditional on the information set, which includes all variables in the previous period.

In the fixed exchange rate case the model is changed so that money supply is exogenous and prices are set according to European prices and exchange rate, and the nominal interest rate is set at the European rate. We have not taken into account the more general advantages of EMU. These include transactions costs which should decrease on entering EMU. This could yield gains in efficiency, though this would be less for larger countries, such as the UK, than smaller, less developed countries. Another advantage is that the countries in a union would be working together which could lead to co-operative policies which may lead to a more stable economy.

2.3.2 Results Of Previous Stochastic Simulation Exercises On The UK And EMU

There has been a variety of previous work on the effects of joining EMU, both for European countries generally and for the UK alone. The general conclusion of this work has been that there would be a substantial increase in variability under EMU; the variances of output and inflation are the principal focus of these studies. The earliest independent study was in 1992 by Minford, Rastogi and Hughes Hallett (1993) building on their earlier work in the late 1980s using the Liverpool Multi-country Model and also the UK model; later Masson and Symansky (1992) used the IMF's Multi-Mod, a multi-country model. The range of findings by these authors for European countries generally was quite wide; Masson and Symansky (1992) found rises of inflation variance up to 40% and of output variance up to 30%, Minford et al. found very much larger rises, probably because they permitted monetary policy to be optimised in respect of these variances. The EU Commission (1990, Annex E) also published a study of this type which purported to find that EMU actually reduced macro variability; their methods were strongly criticised by these other authors on the grounds that they had unrealistically over-estimated the variances of the risk-premia on national EU currencies which of course disappear on entry into EMU. Hence their comparison is biased heavily in favour of EMU. We discuss the far more recent study by Barrell and Dury (2000) below.

For the UK the only previous study was by Minford et al., where they found very large rises, of 80% for the output variance and nearly six times for the inflation variance. That study was similar in method to the one here. The main difference in this one is that the data we are using are more recent, for the late 1980s and 1990s instead of for the 1970s and 1980s; we have also taken the opportunity to use the method of bootstrapping the actual data instead of using estimated variances and covariances within a normal distribution. Finally we have carefully overhauled all aspects of the operation and made a number of detailed improvements. Nevertheless it is likely that the main difference is from the newer data.

2.3.3 The Results Of This Exercise

The basic result of our exercise is displayed in Figure 2.1 which shows the variances for four key variables — output around its potential or 'trend', inflation, unemployment and real short-term interest rates. There are two diamond-shaped graphs; one shows on a logarithmic scale the combination of these variances under floating, the other under EMU. For ease of comparison the floating ones are set equal to 0.1 so that the EMU diamond shows the EMU variances as a proportion of the corresponding floating ones. What we see is that all the implied variances are considerably higher under EMU than under floating. The variance is used, as is standard, in our measures of welfare cost. That of output around its trend is nearly a quarter higher; that of unemployment nearly a fifth higher; real interest rates a multiple of over four times; and that of inflation under EMU is approximately twenty times that under floating. The EMU environment is one in which ECB nominal interest rates are moving a fair amount for euro-zone-wide reasons and yet because they are poorly addressed to UK shocks the UK economy experiences considerably worse output, employment and above all inflation swings.

How can such a big difference arise? First, let us be clear about the monetary rule we have used under floating. It is one in which interest rates react in a rather standard way to the deviations of current output, inflation and also M0 from their targets (the change in short-term nominal interest rates reacts to all three, in terms of deviations from their long-run target, with a coefficient of 1.33). This gives a standard deviation of real interest rates of 2.7% (p.a.), of inflation of 1.5% (p.a.), and of output of 2.6% around its trend; these values seem to match reasonably with what we would expect from the current environment under the Monetary Policy Committee — supporting the use of this rule, though different monetary rules could of course be used to change this combination of variabilities.

Comparison of Variances (Basic Case)

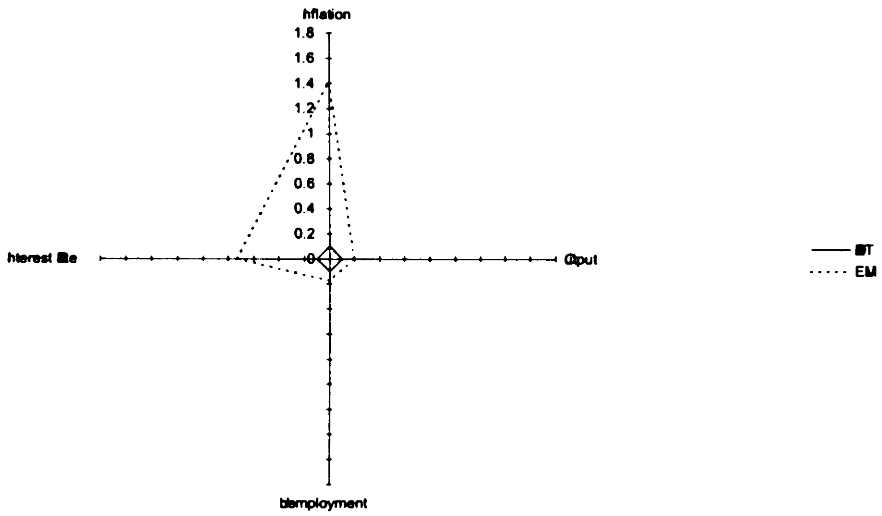

Figure 2.1: Floating and EMU compared (Basic Case)

Second, consider the factors driving inflation under EMU. UK prices of traded goods and services would be set in world markets at euro prices. They would be impacted upon therefore by three forces: the movements in the euro exchange rate (principally against the dollar), competing euro-zone prices and in UK costs. UK non-traded prices would be driven by UK costs and to some degree the pressure from traded prices. This makes up a cocktail of shocks. The euro has been notoriously volatile against the dollar. UK costs have had a roller-coaster ride from the push and pull of Tory and Labour supply-side policies. Finally, euro inflation has had the usual ups and downs.

Meanwhile under EMU euro-interest rates are reacting to their own euro-agenda and not targeted on UK inflation or output except as a small part of an overall euro-average. Hence these interest rates act not as a reactive stabiliser but as an independent source of shocks to the UK economy. We should stress that to the extent there has been any correlation of these interest rates with UK shocks over the past decade and a half it is wholly picked up in our methods described in the Annex. But because this correlation is small, and inflation variance is raised under EMU by the shocks described in the last paragraph, the variance of the real short-run interest rate (the nominal interest rates minus expected future inflation) also rises sharply.

When we consider the nature of the EMU regime in this way, we should not really be too surprised at the greater variability it creates. We can perhaps see an example of this at work in recent EMU experience in two ways. First, there is the extraordinary case of Ireland, where under the impact of the boom induced by reducing interest rates to euro-levels of 3% or so and of the sharp depreciation of the euro, inflation — which in spite of Ireland's rapid growth in the previous decade had been muted — rose to a peak of 7% by November 2000 and was still running at 3.9% in mid-2003. Given some similarities and close trading relations between the UK and Ireland, it is reasonable to expect that had the UK also joined the euro on Jan 1 1999 it too would have experienced these problems to at least some degree. Second, we can inspect the range of inflation currently (July 2003) in the euro-zone: from 0.8% in Germany to 2.9% in Spain and 3.5% in Greece, much like Ireland. The range across countries is 3.1% and has peaked thus far at 6%. By contrast in the past five years UK inflation (RPIX) has stayed well within the range of 1% either side of the Bank of England's 2.5% target.

It is natural to ask what these differences in variability imply for 'welfare' or the degree of painfulness of the EMU option. The usual approach has been to give weights to the different variances .that appear to cause political and popular concern, namely the ones we have just discussed, and add them up with a negative sign into a measure of welfare (or with reversed sign of welfare cost). In line with this, we give the variances of output and unemployment each a weight of 1 and those of inflation and real interest rates each a weight of 0.1 (the precise numbers are arbitrary but it is usual to give such price variables a lower weight in such welfare functions on the grounds that they affect people's living standards more indirectly); plainly then we wind up with a big difference in welfare. EMU welfare on this measure is 45% of that under floating — equivalently the EMU welfare cost is 2.21 times that of floating. We will use this approach in what follows and refer to it as the popular welfare cost of EMU.

This does not measure the average person's welfare, however one plays with the weights, because it is in effect treating political reaction as equivalent to true dissatisfaction. But of course the extent of politically-expressed displeasure exaggerates the true average discomfort, partly because to get results in the cross-currents of debate one's case must be put as strongly as possible but mainly because the costs of volatility fall disproportionately on groups that are different from the average — for example, those who lose their jobs or have their houses repossessed or whose businesses fail. We will argue that we should pay attention to the popular welfare cost because it is the bitterness and displeasure of these groups that gets reflected in the political debate more than the calm of the average person.

2.3.4 Measuring The Welfare Of The 'Representative Agent':

We may nevertheless look at a second approach under which one measures the welfare of a representative or average household, bearing in mind that households are the people in our economy who own 'the UK economy' and to whom governments answer. A household utility function that seems to fit rather well with what we know about risk-aversion and inter-temporal substitution is the Constant Relative Risk Aversion (CRRA) function with a unitary elasticity of substitution between consumption and leisure. The value shares of consumption and leisure would be set at 0.7 and 0.3 respectively if one says that leisure time excluding unemployment is roughly equal to working time (sleep hours being ignored) and that through unemployment benefits the leisure choice is subsidised so that its marginal utility is perhaps just under a half of an hour spent working and getting consumption. With the risk-aversion parameter being generally found to be of the order of 1.5, we come up with a function:

$$Utility = \left[\frac{(C^{0.7}(1+U)^{(1-1.5)}}{(1-1.5)} \right]$$

where C is consumption and U is the unemployment rate.

To estimate the difference of utility in our stochastic simulations, we take the model-generated values for consumption and unemployment, compute the resulting average value for utility under floating and compare it with that under EMU. Because it is essentially only the variability of outcomes that differ across the two regimes, the difference of utility will reflect the difference of variances. Households then penalise variance (increased risk) through the law of diminishing marginal utility (since a fair bet offering an equal chance of 150 and 50 will be worth less utility than keeping 100 for sure).

Plainly extra uncertainty (variance in our income) is something that trades off rather weakly against a rise in average living standards (a rise in our mean income). Hence we would not expect these increases in the variances of consumption (which behaves similarly to income in our model) and of unemployment under EMU (respectively 30% and 80%) to generate much of a fall in equivalent living standards, simply because on average people can handle extra variance at moderate cost — for example by insurance or the use of savings. Thus we find that the fall in utility calculated in this way is equivalent to a 0.012% fall in the living standard of the average person. This translates into a current price loss of £0.12 billion per year in 2001 prices; if one assumes a real long-term interest rate of 3% and a growth rate of 2.5%, then the present discounted value of this is £24billion. This is not large relative to the scale of UK wealth; probably about the same small 0.012% as for the fall in living standards. This reflects the ease with which most people can insure themselves against the sort of variability at stake.

2.3.5 Checking The Results For Sensitivity

We begin by investigating what the comparison would be if our assumptions about both regimes were wrong due to an 'exogenous' mistake in the parameter values and applicable to both regimes — in a later section we consider the effects of changes induced, in the manner suggested by Lucas (1976), by the change-over to EMU. The results of this first analysis are brought together in Table 2.2.

Table 2.2: The welfare losses (political cost) produced by EMU compared with floating (floating=1.0)

		Ratio of variances (EMU/floating)$^{+}$ —			
		Output	Unemployment	Interest Rate	Inflation
The Central Case	2.21	1.24	1.18	4.32	20.17
No Indexation	2.74	1.63	1.51	5.56	23.27
Low Interest Rate Sensitivity	2.16	1.03	1.04	5.17	21.62
More Labour Market Flexibility	2.72	1.18	1.08	4.04	33.19
High Unemployment	2.23	1.21	1.21	4.80	20.15
More Exchange Rate Instability	2.04	1.23	1.18	3.27	17.48
Enhanced Fiscal Stabilisers*	2.29	1.20	1.12	5.50	21.64

$^{+}$The weights used in the political cost are (all divided by the weights total of 2.2):
1 for output and unemployment variance; 0.1 for inflation and real interest rate variances.
Monetary policy response to inflation under floating raised by a third (to 1.3), to output lowered by a third (to 0.7), to counteract greater inflation volatility from greater wage volatility.
*assumes no enhanced fiscal activism under floating
**under our Montecarlo sampling procedure with the number of draws at 12,078 the standard error of the floating regime's variance, VARF, is 0.013VARF (Wallis, 1995). Hence a ratio in excess of 1.026 indicates that the EMU regime's variance is higher than that of floating at the 95% confidence level. Thus all the numbers in this table are statistically significant.

Greater nominal rigidity of wages (no indexation)

The Liverpool Model in its current version has very little nominal wage rigidity — a surprise 1% rise in prices only lowers real wages by 0.3% after one quarter and by 0.1% after two quarters, and this dies away altogether in another three quarters. In other words there is a great deal of effective indexation of wages to prices. So we check how much effect on the results would occur if the effect after one quarter was raised to 1% and thereafter dies out linearly in the next four quarters as contracts are renegotiated. Such a rise to maximum nominal rigidity (effectively zero indexation) makes the Model's Aggregate Supply or Phillips Curve flatter — that is a given rise in demand has a lesser effect on wages and prices but a greater effect on output, giving the model a more Keynesian character. This should reduce inflation variance and lower output variance the lower the variation of demand relative to that of supply. In the UK supply shocks are important and under floating demand can be stabilised by the movement of interest rates so output variance should tend to fall under floating. Under EMU the variation of demand becomes much larger in the absence of interest rate stabilisation and this should mean that output variance would rise, perhaps markedly.

This lessening of indexation under floating does indeed reduce inflation variance significantly and also reduces output variance. But under EMU while inflation variance falls markedly, those of output and unemployment rise sharply. The gap between EMU and floating correspondingly widens; the variance of output is now 1.63 times, of unemployment 1.51 times, while that of real interest rates is now 5.56 times and inflation 23.27 times. Our political cost measure of EMU rises to 2.74 times that of floating. We should note that the more Keynesian the model (i.e. the more nominal wage rigidity it has) the worse the effect of joining EMU on output and unemployment variability.

The effect of the UK having lower demand sensitivity to interest rates

One of the differences between the UK and the continent that exacerbates the asymmetric effect of shocks is the overdraft lending system and the variable rate mortgage. These mean that as short-term interest rates rise they have a big impact on small businesses and consumers because they immediately pay more for their existing borrowings, not merely on any new borrowings. It has been argued that this might change now that inflation has been reduced systematically. If so, we would expect it to narrow the differences between floating and EMU since the stabilising variation of interest rates permitted by floating would have less beneficial effect while the destabilising variation of euro-interest rates would have less damaging effects.

So indeed it proves though the effects on the floating case are essentially negligible. We divide the model's interest rate responses by three. There is a substantial fall in output and unemployment variability under EMU as the lower interest rate sensitivity of the economy reduces the effect of euro-zone interest rate movements on the UK; inflation and real interest rate variability is unaffected. The gap in the variances therefore narrows, especially for output (+3%) and unemployment (+4%). The political cost measure falls to 2.16 times. It can be seen that much less interest rate sensitivity is helpful to the EMU case but only modestly and still leaves substantial disruption due to inflation and real interest rate volatility.

The effect of the UK having greater labour market flexibility

Much is made in the debate over the euro of labour market (meaning real wage) flexibility. It is pointed out that if interest rates are unable to stabilise asymmetric shocks then greater flexibility of real wages in response to shocks would dampen unemployment (and so also output) variability in a useful alternative way. Our basic case showed that existing UK flexibility is inadequate to provide much alternative adjustment; possibly it is rising under the influence of labour market reforms over the past two decades. Accordingly we ask what the effect would be of a substantial rise in UK flexibility: we multiplied the response of real wages to unemployment by 1.52 and reran the exercise.

We find that under both regimes unemployment variance drops substantially; and it does so proportionately more under EMU, confirming that enhanced flexibility could be indeed an important help in eradicating the greater imbalances produced by EMU. Output variance drops by less as the change is focused on the labour market; and again output variance drops rather more under EMU. We see that EMU and floating come closer together, with the ratio of the unemployment variance down to 1.08 and that of output down to 1.18; however, still a big gap remains. Interestingly the greater labour market flexibility tends to make inflation more volatile under floating which is a source of general instability; to counteract this monetary policy has to respond more fiercely to inflation and worry less about output variability — we assume that the response to inflation rises by a third while that to output diminishes by a third. As a result inflation variability is cut back sharply under floating, with some small cost in higher output variance (of the order of under 10% judging from other work). So the comparison of inflation variance under EMU is now correspondingly worse; the ratio rises to 33.19. The political cost of EMU under labour market flexibility therefore actually rises to 2.72 times; but within that the cost of output and unemployment variability falls.

What if unemployment is very high?

Our results hitherto have shown the variability of unemployment under EMU relative to the benchmark situation under floating. Since this benchmark has quite a small variability of unemployment (a standard deviation of about 301,000, only 1.1% of the labour force) the difference under EMU, though big proportionally, is small absolutely. However, as the floating benchmark's unemployment rate variability rises, the model exhibits not merely a greater absolute variability differential between floating and EMU but also a larger proportional differential. The reason for this is that at high rates of unemployment the Model's real wage elasticity to employment falls. There is a constant real wage elasticity to unemployment, as widely found empirically — Blanchflower and Oswald (1994); Minford (1983). Theoretically, the rationale is that as unemployment rises more people find themselves on the margins between unemployment benefit and the working wage; so when employment falls, real wages drop less as more people opt for benefits.

We checked this for a rise by 2.15 times the benchmark unemployment rate under floating. While the relative variability of other elements in our political cost measure remains roughly unchanged (and so therefore does the overall political cost measure), relative unemployment variance under EMU rises to 1.21 times that of floating. In plain terms this means that if due to poor supply-side policies the underlying (non-inflationary) unemployment rate were to rise back to the rates of the early 1980s of around three million (which would represent roughly a tripling from the average rate in our floating base line) then the standard deviation of floating unemployment would rise some 2.7 times to around 800 thousand but that of EMU would rise three times to around 900 thousand. Of course with such high baseline unemployment rates that sort of absolute rise in variability, of 100,000, would add materially to the unpopularity of a switch to EMU.

Could greater volatility of the pound outside EMU change the comparison?

It is sometimes asserted (e.g. Britain in Europe, 2000) that floating exchange rates themselves generate high volatility because of the varying risk-premium attached to the pound (in the manner of a 'bubble'): by eliminating this sterling bubble EMU would reduce UK volatility. We already have in our floating model a varying risk-premium for the pound. It is the error in the real interest rate equation (endogenous error 6 in Table A1 in Appendix 1, no. 10 in the model listing) which is governed by Uncovered Interest Parity, in other words the speculative market behaviour that forces sterling real interest rates to compensate for sterling risks. So our basic comparison already allows for the variability present over the past decade. However, we also ask further what would happen to our comparison if we were to have a big increase in this variability in the future. So we tripled the standard deviation of this error and reran the comparison.

As one would expect there is a narrowing of the difference as this raises the variability of both the real exchange rate and the real interest rate. However, the model is rather robust to this effect, since monetary policy is able to offset it rather easily. It is as if there is an extraneous agent varying real interest rates in ways unwished-for by the Bank of England; it reacts by altering the money supply to dampen this effect. This then spreads the total effect of the bubble between interest rates and the exchange rate. Consider the following example: the risk-premium rises, pushing up the interest rate at a given exchange rate. The Bank then increases the money supply to stop interest rates rising so much; this drives down the pound. The fall in the pound stimulates output while the rise in interest rates reduces it; if output rises under the balance of these forces, then the demand for money may rise as much as the supply, leaving prices not much affected. Certainly the rises in variability across the board are rather small. The political cost of EMU falls somewhat to 2.04 times that of floating.

Raising the fiscal stabilisers

Another hope of those who advocate EMU is that discretionary fiscal policy could largely replace monetary policy as a stabiliser. Of course the Stability Pact does in fact limit this possibility and even limits the automatic stabilisers. In our basic EMU case as for floating we permit not only the full operation of the automatic fiscal stabilisers but also a certain degree of discretionary fiscal action — public spending reacts to the output cycle contemporaneously with the small negative (counter-cyclical) elasticity of -0.125. Consider the example where output falls 3% below potential (i.e. actual output fell 0.5%), public spending on goods and services would be raised by 0.375%, i.e. approximately 0.1% of GDP. Hence our comparison already allows for probably the maximum realistic fiscal action envisageable under the Pact, if we remember that the automatic stabilisers worsen the budget sharply; the Model implies that the budget deficit would rise by 1.7% of GDP in this example. In a recession where this occurred two years running the deficit would thus rise by 3.4% of GDP before any discretionary boost; our suggested boost would push the rise to 3.6%. But we did look at what could be achieved fiscally by tripling the discretionary fiscal response under EMU, leaving floating policy unchanged. The results show a slight relative improvement in EMU variability and the cost drops to 2.19 times. But what this shows is that realistic fiscal activism cannot solve the variance problems created by EMU.

2.3.6 Sensitivity — Overall Conclusions

What we see in these sensitivity trials is that some worsen the relative position of EMU while some improve it. But in no case does the relative position of EMU become reversed, nor does it even come close to that. Whatever one does to the structure of the British economy, it remains the case that EMU makes our economy much more unstable. In Appendix 3 we look further at the source of this greater instability by type of shock (on the Basic Case assumptions); what we find is that about one quarter of the increase in instability is due to the inability of interest rates and the exchange rate to adjust to shocks under EMU, the other three quarters is due to the additional shocks (mainly the swings of the euro against the dollar) injected into the UK economy by EMU. Thus EMU creates 'boom and bust' for the UK not merely because there is inadequate flexibility provided by other mechanisms within EMU to substitute for the stabilising powers of independent monetary policy; but also because EMU itself creates important new sources of instability for the UK because the euro-zone behaves quite differently from the rest of the world (i.e. basically the dollar area) with which the UK has trading relations as important as those with the euro-zone.

2.4 Utility Losses of the Representative Agent

As we have seen, the estimates of utility reflect the variances produced. In this section we convert these variances into the equivalent percentage loss of consumption for the representative agent (Appendix 2 gives details.)

Inspection of Table 2.3 reveals startlingly how little value the representative agent attaches to variance, even on a wide range of values for ρ, the coefficient of relative risk aversion. However, one can see that this would be the case by considering the trade-off between mean consumption and its variance for an agent experiencing no unemployment. In this case the Taylor expansion yields:

Table 2.3: The welfare losses produced by EMU compared with floating

	The Popular Cost+ (Weighted variance) (%)	The representative agent equivalent consumption loss (%, converted to £bn p.a.)* $\rho = 1.0$ (logarithmic utility)	$\rho = 9.0$
The Central Case	121(5)	0.23(2)	1.3(2)
No Indexation	174(1)	0.36(1)	2.0(1)
Low Interest Rate Sensitivity	116(6)	0.04(7)	−(7)
More Labour Market Flexibility	172(2)	0.20(6)	1.1(5)
High Unemployment	123(4)	0.22(4)	1.0(6)
More Exchange Rate Flexibility	104(7)	0.22(4)	1.3(2)
Enhanced Fiscal Stabilisers	129(3)	0.23(2)	1.2(4)

*UK GDP is approximately £1,000 billion p.a. hence these numbers can be read as percentages by one point to the left: eg £1.3 billion= 0.13% of GDP.

+Order in brackets

$$\frac{\Delta Ec}{\bar{c}} = 0.5\rho\left(\frac{\Delta var(c)}{\bar{c}^2}\right)$$

In our basic case simulations the rise in consumption variance on joining EMU as a percentage of base line consumption squared is just 0.0002%. Or put another way the rise in the standard deviation of consumption is 0.01% of consumption. (This is non-durable consumption; adding in the whole of private investment, as if this non-durable spending could be included in consumption would double it to 0.02%.) Even with a ρ as high as 9 the implied loss of equivalent consumption only reaches 0.0018%, or £0.018 billion per annum.

Hence, in summary, though the ordering of the losses by expected utility is very largely the same as that by the political cost measure we (and others) have used, the scale of effect in terms of percentage change in welfare is massively smaller. Nevertheless, as noted earlier, political experience suggests that popular opinion as reflected in polls and elections is highly sensitive to macroeconomic volatility; consequently we take it, as do other studies, that the relevant measure is what we have termed the political or popular cost, the weighted variance measure.

2.5 EMU and Induced Parameter Change

We also wish to examine sensitivity to the possibility that joining EMU would itself induce structural changes in parameters. Plainly, because of the political aspects of the EMU relationship, pressures for change will be exerted not merely by the new behavioural incentives within monetary union but also by the accompanying institutional changes that are part of EMU. Minford (2002) notes that the evaluation of the decision must take account of the whole bundle of relationships involved. So it is also with macro variability; its behaviour under EMU will alter with any associated parameter changes.

Of the variations we examined, the more active use of fiscal stabilisers is not a structural change but rather a deliberate act of policy regime adjustment; as such we have in any case already evaluated it above where we compared EMU with this adjustment against floating without it. Whether the UK has more exchange rate bubbles under floating has no connection with EMU and has also already been evaluated.

A higher natural rate of unemployment could be induced by joining EMU through the adoption of general tax and regulative changes; Minford (2002) does point to the possibility that the greater closeness of the EMU relationship (a 'club within a club') could make it more difficult for the UK to resist the higher tax levels and more union-friendly labour laws of the continent. On the other hand it could be argued that EMU would induce greater general labour market deregulation across the EU in the long term because of the need to limit large swings in unemployment.

Labour market flexibility is a similar issue. On the one hand, it could be that the greater fluctuations of unemployment under the common monetary policy of EMU would induce more flexibility of real wages through the incentive to limit unemployment movement. On the other hand if the UK was less able to resist the greater labour market distortions just discussed then flexibility would be reduced.

A reduction in indexation (more nominal wage rigidity) could result from joining EMU, if for example German-style unionisation and associated long-term nominal wage contracts became more widespread in the UK. Again, the pressures under EMU to limit unemployment swings could induce even more indexation.

Lesser consumer sensitivity to interest rates (e.g. through longer-term mortgages) could occur under EMU. The argument would be that the UK housing market would become more like the continental as monetary policy and regulation became shared. However, financial regulation is specifically not likely to change in the UK, given the special position of the City and the UK government's resistance to proposals such as the EU investment income withholding tax on the grounds of damage to the City. Also, the progress of the Single Market could produce greater deregulation of the housing and financial markets, both on the continent and in the UK. The UK model's high interest rate response appears to be a reflection of consumer and investor choice within relatively deregulated markets (for example, the choice of variable-rate mortgages may well reflect the desire of UK investors to avoid the capital-value risk associated with long-term nominal debt). Hence it could become higher still if deregulation spread.

Dealing with these possibilities therefore involves a double-sided approach in that EMU could induce parameter changes that go both ways in these four dimensions. In the interests of avoiding a plethora of further cases, we compare floating and EMU under our existing high and low assumptions, first assuming the combination of high and low that is the more favourable to EMU and then the alternative. These comparisons — Table 2.4 — effectively attribute not merely the monetary regime change to joining but also the change due to the altered parameter assumption.

What we see from Table 2.4 is that if we treat the parameter changes induced by EMU as favourable to stability the comparison becomes most markedly more favourable for quantity variables. The key element is enhanced labour market flexibility (or fairly

Table 2.4: Effects of EMU-induced parameter change — The welfare losses (political cost) produced by EMU compared with floating (floating=1.0) assuming EMU induces parameter changes

	Political WelfareCost* (utility-based)	Ratio of variances (EMU/Floating) — Output	Unemp.	Interest Rate	Inflation
The Central Case	2.21 (0.23)	1.24	1.18	4.32	20.17
Indexation — EMU low, Float high	2.24 (0.32)	1.46	1.44	4.49	15.34
Indexation — EMU high, Float low	2.82 (0.27)	1.38	1.24	5.35	30.56
Interest Rate Sensitivity — EMU low, Float high	2.06 (0.04)	1.00	0.99	5.31	20.21
Interest Rate Sensitivity — EMU high, Float low	2.32 (0.23)	1.28	1.25	4.21	21.50
Labour Market Flexibility — EMU high, Float low	1.72 (0.16)	1.12	0.18	4.38	20.53
Labour Market Flexibility — EMU low, Float high	15.44 (0.27)	1.30	7.01	3.99	32.61
Unemployment Natural Rate — EMU low, Float high	1.71 (0.14)	1.23	0.20	3.79	19.60
Unemployment Natural Rate — EMU high, Float low	5.06 (0.31)	1.22	7.29	5.48	20.72
Highly Favourable Combination for EMU**	1.57 (−0.03)	0.90	0.16	4.17	19.80
Highly Favourable Combination for Float**	5.28 (0.29)	1.45	7.40	4.04	23.20

$^{+}$The table compares welfare under EMU and floating with changed paramters. For each parameter the first row takes the assumption more favourable to EMU, assigning the alternative to floating; the second row shows the reverse, with the more favourable assumption assigned to floating.

*The weights used in the political cost are (all divided by the weights total of 2.2): 1.0 for output and unemployment variances; 0.1 for inflation and real interest rate variances. The utility-based welfare cost in parentheses is the extra cost (in £billion p.a.) of EMU for the representative agent, assuming $\rho = 1$

**The favourable combination involved is low-interest-rate sensitivity, high labour-market flexibility, and enhanced fiscal stabilisers. The alternative is the central case parameters. In turn the favourable combination is applied to the one regime with the alternative applied to the other similarly a reduced natural rate of unemployment) which dramatically reduces unemployment variability. A reduction in interest sensitivity under EMU would also eliminate any rise in output variability, though at a large cost in greater real interest rate variance. If there were to be a reduction in indexation under EMU, this would cut inflation variability compared with floating, but at a cost of roughly 20% more output and unemployment variance. None of these has any helpfully stabilising impact on real interest rates or inflation since they do not impinge on the factors (largely the euro's swings against the dollar) that destabilise them.

Switching the assumptions to favour floating implies that EMU dramatically worsens unemployment variance, and moderately worsens output variance; in the unemployment case real interest rate variance and in the labour flexibility case inflation variance are very seriously worse under EMU.

To construct a generally favourable combination for each, we combine the better assumption on interest rate sensitivity and labour market flexibility (to include the unemployment assumption would effectively duplicate the effect of flexibility, while the effect of indexation is two-edged, not clearly favouring either regime; we also allow the enhanced fiscal stabilisers under EMU and for symmetry we do the same under floating, though it has little importance). Under these combinations the same features stand out: EMU when generally favoured by structural changes reduces the variances of both output and unemployment compared with floating, the latter massively. Vice versa, when floating is generally favoured. EMU increases the variances of both, and again massively for unemployment. Under both sets of assumptions, EMU greatly increases inflation and real interest rate variance, much as in the base comparison.

Hence a constant in these comparisons is that EMU destabilises real interest rates and inflation very substantially. It is this constant that prevents EMU, even under the most favourable assumptions about structural change, generating an overall reduction in macro variability. The political welfare cost index still rises 57% compared with floating in this situation. In the case of the representative agent's welfare cost, in this situation it only just turns marginally in favour of EMU; in all other comparisons it remains stubbornly against, albeit by small amounts absolutely for reasons we discussed above. Of course if EMU were to produce destabilising structural change, then the political cost index would rise by 428% with appalling quantity variation aggravating this constant source of loss.

We conclude that though structural change could much affect the quantity comparison, turning it potentially in EMU's favour, overall macro variability would be worsened by EMU even under the most optimistic assumptions because of the destabilisation of real interest rates and inflation.

2.6 Comparison With Barrel and Dury

An earlier study by Barrell and Dury (2000), using the National Institute's multi-country model, found smaller costs than we have. If we translate their findings into the terms of our boom and bust index, their index of welfare cost would be 42% worse under the euro than under floating. They find that under the euro UK output (and so by implication unemployment) would be 51% more volatile as measured by its variance against our 27%; this greater effect is probably the result of their model structure being more Keynesian (with less price and wage flexibility). However, on inflation they find rather strangely that inflation volatility would actually fall 44% under the euro — our finding was that it would rise by a massive 1,900%, essentially because the euro's volatility against the dollar would move traded goods prices around sharply, rather as has happened recently in Ireland. On inspection we can account for this different finding in terms of three major differences in the methods they use. First, they assume that the risk-premium on sterling is given by the 'forecasting error' between the forward rate and the exchange rate outturn. However, these two things are different; the risk-premium is an element included in the forward rate as the price of risk, whereas the forecast error is an element occurring later after the price has been quoted. Plainly, the price of risk reflects the anticipation of possible future errors on average (typically their variance); it cannot be assumed to be equal to any and every actual future error. To assume it in a stochastic simulation exercise like this one will in practice make the assumed risk-premium excessively volatile by a large margin. A similar assumption was used by the EU Commission, 1990, in its initial stochastic simulation exercise where it dramatically biased the results in favour of EMU; it was strongly criticised by Minford et al. (1993) and also rejected by Masson and Symansky (1992).

Second, Barrell and Dury assume that UK monetary policy is set according to somewhat arbitrary rules — they impose a rigid postulated 'inflation target' operating rule. We assume by contrast that UK interest rates are set according to the rule discussed above under which the Monetary Policy Committee reacts to deviations from its objectives using the freedom given it by floating exchange rates. Given that the MPC has done a rather good job of stabilising both inflation and output in an essentially pragmatic way, and can presumably learn to adjust to changes both in circumstances and the UK's economic behaviour, to assume otherwise as done by Barrell and Dury puts the floating regime under an unfair handicap.

Third, the period from which they draw the shocks with which their model is peppered is 1991–7 during which the crucial euro-dollar exchange rate happens to have been more stable than in the fuller 1986–2000 period we use. One can understand this point more clearly by reference to Figure 2.2; there one can see that from 1986 to 1991 the dollar fell considerably against the euro (Dm before January, 1999); from 1991–97 it moved up and down moderately; before then rising again in the latest period to 2000. Thus by omitting both the earlier and the later period the euro-dollar rate's instability is markedly understated. It is likely that were the Barrell-Dury study to be rerun on this basis they too would find that inflation volatility would increase under the euro quite substantially. If so then their overall boom-and-bust index would be comparable to ours, thus joining a series of studies of models indicating this cost would be substantial.

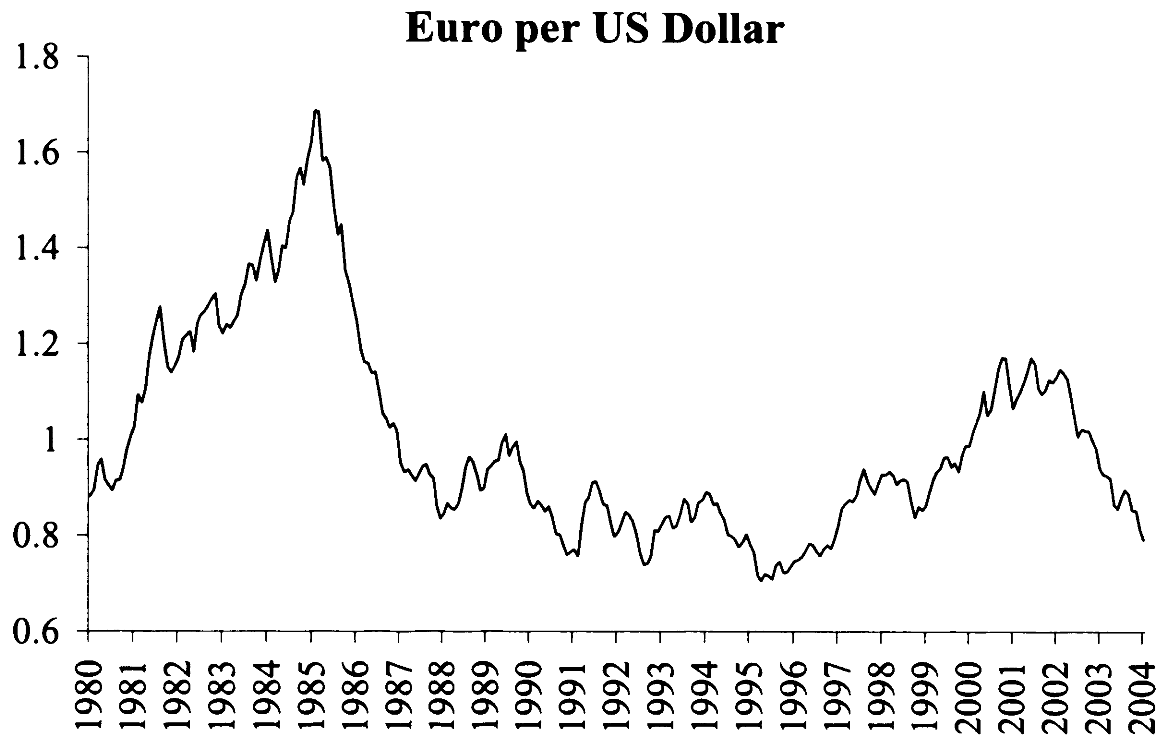

Figure 2.2: Euro per US dollar (Dm before 1 January, 1999)

In a recent article Barrell (2002) has criticised our own study here on a number of grounds. The first is that we drew shocks from the 1980s 'for a currency that nobody then assumed would exist'. However we have to have a sample of shocks for a duration long enough to represent the range of experience the UK might face. 1991–97, chosen by Barrell and Dury, has the problems we saw above; yet even then the euro did not exist. Given the existence of active exchange rate coordination by France (as well as most other countries later forming the euro-zone) with the Dm during the 1980s, it seems reasonable to assume that, had the euro existed, it would have behaved something like the average of the euro currencies. As it happens its behaviour since 1997 has echoed the volatility of the late 1980s as explained already; it would seem safer, given that we must factor in the euro's behaviour, to use a longer period rather than focus on an artificially less volatile, shorter period.

Secondly, Barrell argues that we neglect the reaction of the ECB through its interest-rate setting to the euro's behaviour and in general to UK shocks which are correlated with euro-zone shocks. However, we allowed fully for any correlations between the euro interest rate and both the euro and all UK shocks; the drawings of shocks made for our stochastic simulation are done by the bootstrap method in which the whole set of shocks for a quarter is drawn at once. This means that the correlations between the shocks in the data are fully preserved in the simulations. Barrell asserts that this can be done better by simulating a multi-country model in which an assumption is made about the ECB's reaction function. But this would be to substitute assumptions for actual historical reactions.

On the particular point that UK inflation volatility would be greater inside the euro, Barrell counters that the ECB would react to dampen it down (unlike in the case of Ireland). Would it do so more than by the average of euro-zone behaviour already captured in the historical correlations? One must doubt it given that the UK would be one country of 13, with a GDP weight of about a fifth.

Interestingly, when all is said and done Barrell and Dury find a much greater increase of UK output volatility on going into EMU than we do. It is over inflation that they differ; and there it is hard to resist the conclusion that they have made a variety of special assumptions that have the effect of greatly understating the inflationary problems the UK would experience, along the lines that Ireland has so dramatically found.

2.7 Conclusions

We can summarise our findings as follows. Joining EMU would more than double the variability of the UK economy — the 'boom-and-bust' factor. This is also a widely-used measure of the cost, as experienced by politicians facing popular pressures. One quarter of this extra cost comes from the loss of the stabilising powers of independent UK monetary policy; the other three quarters comes from the instability of the euro-zone's own interest rates and exchange rates (which when the UK is floating are absorbed within the general world instability to which UK monetary policy reacts but which when the pound is fixed to the euro actually become the UK's own interest rate and exchange rate, hence impacting directly on the economy.)

This increased cost is largely insensitive to the sort of ameliorative changes that euro advocates have put forward. Greater UK labour market flexibility helps; so does smaller UK responsiveness to interest rates. But the extent is limited; the big difference remains. Only if the highly optimistic assumption is made that both these parameter changes will come about solely as a result of joining EMU does output variability fall under EMU; even then variability in inflation and real interest rates is undiminished and the overall macro variability compared with floating is only halved. Of course it is at least as likely that these parameters could move adversely as a result of joining EMU, in which case macro volatility would be much worse.

This is the case even though we freely allow fiscal stabilisers full play, not merely the automatic ones but also extra discretionary public spending response to the cycle; tripling that discretionary response helps a little more but the major differential volatility under EMU remains. Were unemployment to reach the double-digit rates we have seen in the early 1980s and early 1990s the difference of variability would be even larger, and it would be more serious too, as the absolute variation in unemployment would rise proportionately more than this higher baseline unemployment. Euro advocates claim that outside EMU the pound would suffer enhanced volatility; our estimates allow for the volatility in the pound's risk-premium experienced in the past decade but we checked what would happen to the comparison if we allowed for a tripling of it. Again, the difference is reduced but not much, basically because the economy's built-in monetary shock absorbers work pretty well.

That then remains the key point; running a modern economy with popular consent requires efficient shock absorbers and joining EMU not merely removes them but provides an additional source of shocks from the euro itself.

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2.A Appendix 1

2.A.1 Methods And Assumptions In The Stochastic Simulations Of Floating And EMU

The method of stochastic simulation involves applying shocks to a model of the economy. The Liverpool Model of the UK has two versions — the currently used one under floating exchange rates with an independent monetary committee and an EMU variant in which interest rates are set by the ECB. A full listing of each model is appended. An exposition of the nature of the modelling differences that have been applied here can be found in chapter 8 of Minford (1992)

It is potentially important to allow for the inter-correlations of the shocks. In order to do this faithfully we use the method of bootstrapping. The shocks used are the sample residuals from the fitted equations over the period 1987(3) to 2000(4), set out in the table below. They have been purged within the equations of any serial correlation so that each shock is independent of past and future shocks. However, contemporaneously one shock can be correlated with another. In bootstrapping one draws all the shock residuals for just one randomly chosen period of the sample; this is then applied to the model; one then replaces it and repeats the process, applying the new shocks to the model; and so on. Hence one obtains a scenario in which all the shocks are repetitions of the actual shocks experienced over 1987–2000; any correlations between the shocks are preserved because all the different shocks are drawn together. It is as if one repeats the experience of all the quarters of actual history but randomly reshuffled.

We filtered out those scenarios that produced very large variability (defined as one with a deviation of output from the base run of more than 10%, under floating with our default monetary rule). This would have created unrealistic overall variances. The source of such extreme drawings are the supply-side shocks in the data; most of these are policy shifts and are found to be 'random walks', because policy changes of these sorts are unpredictable; this means that each random change accumulates permanently in the new 'level' of policy. When a scenario is formed automatically by picking the policy errors in a random order, it is possible that a series of large policy errors could be picked, that would together cumulate to a very large policy shift; however, politically such a large shift would be very likely to generate a backlash, causing the policy to be rescinded because of the large and damaging effect on the economy. One might be tempted to argue that were the cumulation to be good for the economy, it would be permitted (indeed welcomed); however, again it would be likely that any such very large shift in policy would be opposed by vested interests that would lose out, hence delaying or somehow reducing the size of the shift. We decided to filter out all scenarios therefore that produced extreme variability. Out of 400 randomly drawn scenarios that we tried, this left us with the 183 we used.

Table 2.A.1: The shocks applied under EMU and floating (Exogenous variables)

Shocks (Exogenous Variables)		Standard Error
World short-term real interest rates, RSUS, (n.a. EMU) fraction p.a.	$RSUS_t = c + 0.899 RSUS_{t-1} + e_t$	0.00396
Euro nominal short-term interest rates, EUNRS (n.a. floating) fraction p.a.	$EUNRS_t = c + 0.977 EUNRS_{t-1} + e_t$	0.00471
World trade, WT	$\Delta \log WT_t = c + e_t$	0.01196
Employers' NI contributions, BO (fraction)	$\Delta BO_t = c + e_t$	0.00216
VAT (fraction)	$\Delta VAT_t = c - 0.286 \Delta VAT_{t-1} + e_t$	0.0273
Unionisation rate, UNR (fraction)	$\Delta UNR_t = c + 0.869 \Delta UNR_{t-1} + e_t$	0.00106
Real Unemployment benefits, UB (fraction of initial average wages)	$\Delta UB_t = c + e_t$	0.00266
Employees' tax and NI contributions, LO (fraction)	$\Delta LO_t = c + e_t$	0.00419
Average rate of tax net of transfers, TAX (fraction)	$\Delta TAX_t = c - 0.365 \Delta TAX_{t-1} + e_t$	0.01191
Euro real exchange rate index, EURXR (n.a. floating)	$\Delta \log EURXR_t = c + 0.235 \Delta \log EURXR_{t-1} + e_t$	0.02743
Euro CPI, EUCPI (n.a. floating)	$\Delta \log EUCPI_t = c + 0.503 \Delta \log EUCPI_{t-1} + e_t$	0.00285

Table 2.A.2: The shocks applied under EMU and floating (Endogenous variables)

Shocks (Endogenous variable errors)		Shock no. in model listing	Standard error
1. Net export volume	$e_t = c + 0.608e_{t-1}$	17	0.02234
2. Current account (£m at constant prices)	$e_t = c + 0.186e_{t-1}$	6	1166.2
3. Real M0 demand, log (n.a. EMU)	$e_t = c + 0.793e_{t-1}$	1	0.01141
4. Nominal M0 supply, log (n.a. EMU)	$e_t = c + 0.658e_{t-1}$	5	0.00863
5. Unemployment (000's) log	$e_t = c + 0.913e_{t-1}$	9	0.01844
6. Uncovered interest parity (n.a. EMU), fraction p.a.	$e_t = c + 0.652e_{t-1}$	10	0.00844
7. Stock of all durable goods, log	$e_t = c - 0.272e_{t-1}$	2	0.00187
8. Non-durable consumption, log	$e_t = c + 0.376e_{t-1}$	3	0.00628
9. Real wages, log	$e_t = c + 0.683e_{t-1}$	8	0.01495
10. Price-cost equation, log	$e_t = c + 0.142e_{t-1}$	7	0.03396

Period of estimation: 1987(2)–2000(4); c is the constant (not used) and e_t is the equation error whose standard deviation is shown in the last column

MODEL LISTING

FLOAT

$$Y_t^{**} = \exp((a_{29}E_t^{**} + a_{27}\log WT_t + a_{47})\,/(-a_{28}))$$

$$E_t^{**} = a_1[\log W_t^{**} + \log(1.0 + BO_t) + (1.0 + a_1)\log(1.0 + VAT_t) + a_{41} + a_2 TREND_t - 0.064UNR_t - 0.0525\left(\tfrac{TREND_t - 108.0}{4.0}\right) D87_t]$$

$$W_t^{**} = \exp a_{43} + a_9 \log U_t^{**} + (0.95)(UNR_t)(-a_{10})(D83_t) +0.04\{(TREND_t - 108.0)/4.0\}(-a_{10})(D87_t) + a_7 UNR_t + a_8(\log UB_t + \log(1.0 + LO_t)/(-a_{10})$$

$$U_t^{**} = \exp[a_{42} + a_3 \log Y_t^{**} + a_4 \log W_t^{**} + \log(1.0 + BO_t) + \log(1.0 + VAT_t) -(0.095)(UNR_t)(D83_t) - 0.04\{(TREND_t - 108.0)/4.0\}D87_t + a_5 TREND_t/(1.0 - a_6)]$$

$$EG_t^{*} = Y_t^{**}TAX_t + (PEQ_t/4.0)Y_t^{**}(FIN_t/Y_t^{**}) - (RDI_{t-4} + RDI_{t-5} + RDI_{t-6} + RDI_{t-7})/4.0$$

$$EG_t = \exp(\log EG_t^{*} + a_{39}\log(Y_t/Y_t^{**}))$$

$$BDEF_t = EG_t - 2.0TAX_tY_t + TAX0(Y0)$$

$$AFC_t = Y_t[0.65883(AFC_{t-1}/Y_{t-1}) + 0.1966416(AFC_{t-3}/Y_{t-3}) + 0.145006(AFC_{t-4}/Y_{t-4})]$$

$$PSBR_t = BDEF_t + RDI_t$$

$$XVOL_t = a_{40}Y_t^{**}(a_{27}\log WT_t + \mathbf{shock}_{17} + a_{28}\log Y_t + a_{47} + a_{29}(E_t^{**} + 0.6(RXR_t - E_t^{**})) + a_{30}(XVOL_{t-1}/a_{40}Y_{t-1}^{**}))$$

$$XVAL_t = XVAL_{t-4} + (XVOL_t - XVOL_{t-4}) + a_{31}\{0.32Y_t^{**}(RXR_t - RXR_{t-4} - E_t^{**} + E_{t-4}^{**})\} + a_{32}error_7 + \mathbf{shock}_6$$

$$error_7 = XVAL_{t-1} - [XVAL_{t-5} + (XVOL_{t-1} - XVOL_{t-5}) +a_{31}\{0.32Y_{t-1}^{**}(RXR_{t-1} - RXR_{t-5} - E_{t-1}^{**} + E_{t-5}^{**})\}]$$

$$RL_t = (RXR_t - EEXL_t/5.0) + RLUS_t$$

$$NRL_t = RL_t + PEXL_t$$

$$M0_t = \exp[a_{44} + a_{13}\log M0_{t-1} + a_{14}(\log Y_t + \log(1.0 + TAX_{t-1})) + a_{15}UB_{t-2} +a_{16}TREND_t + a_{17}NRS_t + a_{18}VAT_t + \mathbf{shock}_1]$$

$MON_t = \exp[\log MON_{t-1} + (1.0 - a_{34})(PEQ_t/4.0) + a_{34}\log(MON_{t-1}/MON_{t-2})$

$+a_{52}(NRS_t - NRS_{t-1}) + a_{55}(\log Y_t - \log Y_t^{**}) + a_{56}(INFL_t - 0.025) + MTEM_t +$ $\mathbf{shock}_5]$

$DMXR_t = [RXR_t - RXR_{t-1} - GERX_t + GERX_{t-1} - \log(P_t/P_{t-1}) + \log(GEP_t/GEP_{t-1}) +$ $1.0DMXR_{t-1}]$

$P_t = \exp(\log P_{t-4} + INFL_t)$

$INFL_t = \log MON_t - \log MON_{t-4} - \log M0_t + \log M0_{t-4}$

$error_{22} = \log U_{t-1} - [a_{42} + a_3\log Y_{t-1} + a_4(\log RW_{t-1} + \log(1.0 + BO_{t-1}) + \log(1.0 + VAT_{t-1})) -$ $0.095UNR_{t-1} - 0.04(TREND_{t-1} - 108.0/4.0)D87_{t-1} + a_5 TREND_{t-1} + a_6\log U_{t-2}]$

$U_t = \exp[a_{42} + a_3\log Y_t + a_4(\log RW_t + \log(1.0 + BO_t) + \log(1.0 + VAT_t)) - 0.095UNR_t -$ $0.04(TREND_{t-1} - 108.0/4.0)D87_t + a_5 TREND_t + a_6\log U_{t-1} + a_{36} error_{22} + \mathbf{shock}_9]$

$RS_t = (RXR_t - EEX_t) + RSUS_t + \mathbf{shock}_{10}$

$NRS_t = PEXP_t + RS_t$

$G_t = \exp[a_{45} + a_{19}RL_t + a_{20}(\log G_{t-1} - \log FIN_{t-1}) + a_{21}(\log G_{t-1} - \log G_{t-2}) + \log G_{t-1} +$ $\mathbf{shock}_2]$

$GINV_t = G_t - G_{t-1} + a_{38}G_{t-1}$

$W_t = FIN_t + G_t$

$C_t = \exp[a_{46} + a_{22}RL_t + a_{23}\log W_t + a_{24}QEXP_t + a_{25}\log C_{t-1} + \mathbf{shock}_3]$

$Y_t = GINV_t + C_t + EG_t + XVOL_t - AFC_t$

$RW_t = \exp[a_{43} + a_7 UNR_t + a_8(\log UB_t + \log(1.0 + LO_t)) + a_9\log U_t + a_{37}\log RW_{t-1}$

$+(0.95)(-a_{10})UNR_t + DELTA + 0.04(TREND_{t-1} - 108.0/4.0)(D87_{t-1})(-a_{10})$

$+a_{10}\log RW_{t-2} + a_{11}ETA_t + a_{12}ETA_{t-1} + \mathbf{shock}_8]$

$error_{14} = RXR_{t-1} - [a_{41} + a_1(\log RW_{t-1} + \log(1.0 + BO_{t-1})) + a_{53}(\log P_{t-1} - \log P_{t-5})$

$+(1.0 + a_1)\log(1.0 + VAT_{t-1}) + a_2 TREND_{t-1} - 0.064UNR_{t-1}$

$-0.0525(TREND_{t-1} - 108.0/4.0)D87_{t-1}]$

$RXR_t = [a_{41} + a_1(\log RW_t + \log(1.0 + BO_t)) + a_{53}(\log P_t - \log P_{t-4})$

$+(1.0 + a_1)\log(1.0 + VAT_t) + a_2 TREND_t - 0.064UNR_t$

$-0.0525(TREND_{t-1} - 108.0/4.0)D87_t + a_{35}error_{14} + \mathbf{shock_7}]$

$FIN_t = EG_t - Y_t(TAX_t) + XVAL_t + a_{54}FIN_{t-1} + (1.0 - a_{54})\,(FIN_{t-1}(P_t/P_{t-1})^{0.66})((1.0-0.155)(NRL_t/NRL_{t-1})) - 1.0 + RDI_t$

$RDI_t = -0.5(NRL_{t-1}/4.0)(FIN_{t-1}(P_t/P_{t-1})^{0.66} - 1.0) + PSBR_t(0.32(NRS_{t-1}/4.0) + 0.5(NRL_{t-1}/4.0))FIN_{t-1} - 0.32(NRL_{t-1}/4.0)FIN_{t-1} + RDI_{t-1}$

$UR_t^* = U_t^{**}/POP_t$

$DY_t = Y_t/Y_{t-4} - 1.0$

$Q_t = \log(Y_t/Y_t^{**})$

$YAFC_t = Y_t + AFC_t$

$RXRN_t = [RXR_t - RXR_{t-1} - \log(P_t/P_{t-1}) + WINF_t/4.0 + 1.0]RXRN_{t-1}$

EMU

$Y_t^{**} = \exp((a_{29}E_t^{**} + a_{27}\log WT_t + a_{47})\,/(-a_{28}))$

$E_t^{**} = a_1[\log W_t^{**} + \log(1.0 + BO_t) + (1.0 + a_1)\log(1.0 + VAT_t) + a_{41}$
$+a_2 TREND_t - 0.064UNR_t - 0.0525\left(\frac{TREND_t - 108.0}{4.0}\right) D87_t]$

$W_t^{**} = \exp a_{43} + a_9 \log U_t^{**} + (0.95)(UNR_t)(-a_{10})(D83_t)$
$+0.04\{(TREND_t - 108.0)/4.0\}(-a_{10})(D87_t) + a_7 UNR_t + a_8(\log UB_t + \log(1.0 + LO_t)/(-a_{10})$

$U_t^{**} = \exp[a_{42} + a_3 \log Y_t^{**} + a_4 \log W_t^{**} + \log(1.0 + BO_t) + \log(1.0 + VAT_t)$
$-(0.095)(UNR_t)(D83_t) - 0.04\{(TREND_t - 108.0)/4.0\}D87_t + a_5 TREND_t/(1.0 - a_6)]$

$EG_t^* = Y_t^{**}TAX_t + (PEQ_t/4.0)Y_t^{**}(FIN_t/Y_t^{**}) - (RDI_{t-4} + RDI_{t-5} + RDI_{t-6} + RDI_{t-7})/4.0$

$EG_t = \exp(\log EG_t^* + a_{39}\log(Y_t/Y_t^{**}))$

$BDEF_t = EG_t - 2.0TAX_tY_t + TAX0(Y0)$

$AFC_t = Y_t[0.65883(AFC_{t-1}/Y_{t-1}) + 0.1966416(AFC_{t-3}/Y_{t-3}) + 0.145006(AFC_{t-4}/Y_{t-4})]$

$PSBR_t = BDEF_t + RDI_t$

$XVOL_t = a_{40}Y_t^{**}(a_{27}\log WT_t + \mathbf{shock}_{17} + a_{28}\log Y_t + a_{47} + a_{29}(E_t^{**} + 0.6(RXR_t - E_t^{**})) + a_{30}(XVOL_{t-1}/a_{40}Y_{t-1}^{**}))$

$XVAL_t = XVAL_{t-4} + (XVOL_t - XVOL_{t-4}) + a_{31}\{0.32Y_t^{**}(RXR_t - RXR_{t-4} - E_t^{**} + E_{t-4}^{**})\} + a_{32}error_7 + \mathbf{shock}_6$

$error_7 = XVAL_{t-1} - [XVAL_{t-5} + (XVOL_{t-1} - XVOL_{t-5})$
$+a_{31}\{0.32Y_{t-1}^{**}(RXR_{t-1} - RXR_{t-5} - E_{t-1}^{**} + E_{t-5}^{**})\}]$

$RL_t = (RXR_t - EEXL_t/5.0) + RLUS_t$

$NRL_t = RL_t + PEXL_t$

$M0_t = \exp[a_{44} + a_{13}\log M0_{t-1} + a_{14}(\log Y_t + \log(1.0 + TAX_{t-1})) + a_{15}UB_{t-2} + a_{16}TREND_t + a_{17}NRS_t + a_{18}VAT_t + \mathbf{shock}_1]$

$P_t = \exp(0.00625 + RXR_t - RXR_{t-1} + DLEUCPI + \log P_{t-1} - DEURXR)$

$INFL_t = \log P_t - \log P_{t-1}$

$MON_t = \exp\left(INFL_t + \log MON_{t-4} + \log M0_t - \log M0_{t-4}\right)$

$error_{22} = \log U_{t-1} - [a_{42} + a_3 \log Y_{t-1} + a_4(\log RW_{t-1} + \log(1.0 + BO_{t-1})$
$+ \log(1.0 + VAT_{t-1})) - 0.095UNR_{t-1} - 0.04(TREND_{t-1} - 108.0/4.0)D87_{t-1} +$
$a_5 TREND_{t-1} + a_6 \log U_{t-2}]$

$U_t = \exp[a_{42} + a_3 \log Y_t + a_4 (\log RW_t + \log(1.0 + BO_t) + \log(1.0 + VAT_t))$
$-0.095UNR_t - 0.04(TREND_{t-1} - 108.0/4.0)D87_t + a_5 TREND_t + a_6 \log U_{t-1} +$
$a_{36} error_{22} + \mathbf{shock}_9]$

$RS_t = NRS_t - PEXP_t$

$NRS_t = EUNRS_t$

$G_t = \exp[a_{45} + a_{19} RL_t + a_{20} (\log G_{t-1} - \log FIN_{t-1}) + a_{21} (\log G_{t-1} - \log G_{t-2}) + \log G_{t-1} +$
$\mathbf{shock}_2]$

$GINV_t = G_t - G_{t-1} + a_{38} G_{t-1}$

$W_t = FIN_t + G_t$

$C_t = \exp\left[a_{46} + a_{22} RL_t + a_{23} \log W_t + a_{24} QEXP_t + a_{25} \log C_{t-1} + \mathbf{shock}_3\right]$

$Y_t = GINV_t + C_t + EG_t + XVOL_t - AFC_t$

$RW_t = \exp[a_{43} + a_7 UNR_t + a_8 (\log UB_t + \log(1.0 + LO_t)) + a_9 \log U_t$
$+a_{37} \log RW_{t-1} + (0.95)(-a_{10}) UNR_t + DELTA$
$+0.04(TREND_{t-1} - 108.0/4.0)(D87_{t-1})(-a_{10}) + a_{10} \log RW_{t-2} + a_{11} ETA_t + a_{12} ETA_{t-1} +$
$\mathbf{shock}_8]$

$error_{14} = RXR_{t-1} - [a_{41} + a_1 (\log RW_{t-1} + \log(1.0 + BO_{t-1})) + a_{53} (\log P_{t-1} - \log P_{t-5})$
$+(1.0 + a_1) \log(1.0 + VAT_{t-1}) + a_2 TREND_{t-1} - 0.064UNR_{t-1}$
$-0.0525(TREND_{t-1} - 108.0/4.0)D87_{t-1}]$

$RXR_t = [a_{41} + a_1 (\log RW_t + \log(1.0 + BO_t)) + a_{53} (\log P_t - \log P_{t-4})$
$+(1.0 + a_1) \log(1.0 + VAT_t) + a_2 TREND_t - 0.064UNR_t$
$-0.0525(TREND_{t-1} - 108.0/4.0)D87_t + a_{35} error_{14} + \mathbf{shock}_7]$

$FIN_t = EG_t - Y_t(TAX_t) + XVAL_t + a_{54} FIN_{t-1}$

$$+ (1.0 - a_{54})\,(FIN_{t-1}(P_t/P_{t-1})^{0.66})((1.0 - 0.155)(NRL_t/NRL_{t-1})) - 1.0 + RDI_t$$

$$RDI_t = -0.5(NRL_{t-1}/4.0)(FIN_{t-1}(P_t/P_{t-1})^{0.66} - 1.0) + PSBR_t(0.32(NRS_{t-1}/4.0)$$

$$+0.5(NRL_{t-1}/4.0))FIN_{t-1} - 0.32(NRL_{t-1}/4.0)FIN_{t-1} + RDI_{t-1}$$

$$UR_t^* = U_t^{**}/POP_t$$

$$DY_t = Y_t/Y_{t-4} - 1.0$$

$$Q_t = \log(Y_t/Y_t^{**})$$

$$YAFC_t = Y_t + AFC_t$$

$$RXRN_t = [RXR_t - RXR_{t-1} - \log(P_t/P_{t-1}) + WINF_t/4.0 + 1.0]RXRN_{t-1}$$

$$LEUCPI_t = 0.502789LEUCPI_{t-1}$$

$$LEURXR_t = 0.23475LEURXR_{t-1}$$

Coefficient values in order A1-56:

1.528	-0.003	-2.150	0.792	0.010	0.804	0.470	0.210	-0.018	-0.224
-0.290	0.189	0.870	0.150	0.000	-0.002	-0.349	0.839	-0.016	-0.004
0.640	-0.215	0.056	0.153	0.870	0.000	0.529	-1.205	-0.388	0.429
0.103	0.193	0.000	0.000	0.931	0.271	1.000	0.012	-0.125	0.320
0.170	25.262	0.102	-0.337	0.013	0.666	11.503	-0.016	-0.011	0.017
0.011	0.750	-0.750	0.300	-1.000	-1.000				

2.A.2 Glossary of model variables:

Endogenous	**Variables**
Y	GDP at factor cost
P	Consumer Price Level
INFL	Percentage growth rate of P (year-on-year)
MON	Nominal Money Stock (M0)
RW	Real wages (Average Earnings/Price)
U	Unemployment
Q	Output deviation from trend (Y/YSTAR)
AFC	Adjustment to factor cost
EG	real government spending on goods and services
BDEF	interest-exclusive budget deficit (deflated by CPI)
PSBR	public sector borrowing requirement (deflated by CPI)
XVAL	real current account of balance of payments
XVOL	net exports of goods and services
RS(RL)	real short term (log term) interest rate
NRS (NRL)	nominal short term (long term) interest rate
M0	real money balances (M0)
G	real private stock of durable goods, including inventories
W	real private stock of wealth
FIN	real private stock of financial assets (net)
C	real private non-durable consumption
RXR	real exchange rate (relative CPI, UK v. ROW)
RDI	real debt interest
GINV	gross private investment in durables plus stock building
DY	percentage growth rate of Y (year-on-year)
RXRN	trade-weighted exchange rate
AE	average earnings
YAFC	GDP at market prices
Y^{**}	equilibrium output
E^{**}	equilibrium real exchange rate
W^{**}	equilibrium real wage
U^{**}	equilibrium unemployment
EG^{*}	equilibrium government expenditure
UR^{*}	equilibrium unemployment rate

Exogenous Variables

MTEM	Temporary growth of money supply
PEQ	Growth of money supply
BO	Employers national insurance contributions
UNR	Trade Unionisation rate
LO	Average amount lost in taxes and national insurance
TREND	Time trend
WT	World Trade
TAX	Overall tax rate
UB	Unemployment benefit rate (in constant pounds)
EUNRS	Euro nominal short-term interest rates
EURXR	Euro real exchange rate index
EUCPI	Euro CPI
RSUS	Foreign real short-term interest rate
RLUS	Foreign real long-term interest rate
POP	Working population
DMXR	German exchange rate

2.A.3 Listing of All Simulation Results

Table 2.A.3: FLOAT Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	0.000119	0.000801	2.2E+10	3711885	1.32E+10	1.94E+09	15161133	22465389
St. Dev	0.010903	0.028303	148194.6	1926.625	115027.7	44084.1	3893.73	4739.767
Average	0.001094	0.003192	-15492.8	-259.554	-10218.4	-5266.72	67.48218	29.72129

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	7043237	9231424	0.000116	0.000737	0.000217	0.011352	9283989	78794638
St. Dev	2653.91	3038.326	0.010756	0.027149	0.014719	0.106548	3046.964	8876.634
Average	-115.571	166.4819	0.000614	0.002044	0.001274	-0.00391	-586.704	935.9343

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.007196	10014349	0.003753	0.005278	41239.3	109285.2	0.000741	525687.3
St. Dev	0.08483	3164.546	0.061265	0.072647	203.0746	330.5831	0.027226	725.0429
Average	-0.00373	313.4304	-0.0055	-0.00271	18.07004	39.33082	0.000235	4.28844

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000681	7987661	603860.5	29863112	65627005	4.92E-05	96.75649	53345089
St. Dev	0.026099	2826.245	777.0846	5464.715	8101.05	0.007017	9.836488	7303.772
Average	-0.002	18.48419	132.8041	34.0699	843.6342	0.000623	-1.22841	-481.596

	mon	p	dmxr	leurxr	leucpi	pop
Variance	13849894	0.010107	0.061549	0.00082	2.79E-05	0
St. Dev	3721.545	0.100534	0.24809	0.028637	0.005278	0
Average	-141.349	0.018659	-0.02706	0.000123	2.62E-05	0

Table 2.A.4: EMU Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.59E-05	0.000313	3.01E+10	3113029	1.67E+10	3.7E+09	15663411	26948245
St. Dev	0.008711	0.017694	173351.3	1764.378	129122.3	60802.83	3957.703	5191.17
Average	8.2E-05	0.000385	-23979.5	-168.966	-17257.1	-6713.64	194.9503	-132.729

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	8456395	9253813	0.000211	0.003186	0.00437	0.012774	12855035	82060947
St. Dev	2907.988	3042.008	0.01452	0.056442	0.066103	0.11302	3585.392	9058.75
Average	96.01488	295.2198	0.000342	0.000937	0.000462	-0.0046	-764.584	1102.209

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.007245	10014418	0.003753	0.005278	41239.63	129069.2	0.000871	631476.2
St. Dev	0.085117	3164.556	0.061265	0.072647	203.0754	359.262	0.029515	794.6548
Average	-0.00498	313.3906	-0.00549	-0.00271	18.07132	55.49672	0.000188	-21.1339

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000844	8496701	571961.8	35828415	68513919	4.92E-05	696.134	65912374
St. Dev	0.029044	2914.91	756.2815	5985.684	8277.314	0.007017	26.38435	8118.644
Average	-0.00315	55.84001	-41.0225	-153.989	985.1326	0.000624	1.669791	-786.538

	mon	p	dmxr	leurxr	leucpi	pop
Variance	69623715	0.26401	0	0.000941	8.38E-06	0
St. Dev	8344.083	0.513819	0	0.030679	0.002894	0
Average	786.6501	0.074803	0	0.000164	2E-05	0

Table 2.A.5: FLOAT (No Indexation Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	0.000108	0.000673	2.16E+10	3529134	1.3E+10	1.82E+09	14882124	21076143
St. Dev	0.010383	0.025937	147011.3	1878.599	114218.6	42704.56	3857.736	4590.876
Average	0.001086	0.0026	-15926.8	-221.922	-10329.4	-5586.35	68.13982	37.97551

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	6713032	9111974	0.000102	0.000596	0.000143	0.011131	8612954	78381230
St. Dev	2590.952	3018.605	0.010102	0.024403	0.01196	0.105503	2934.784	8853.317
Average	-113.981	167.869	0.00049	0.001245	0.001283	-0.00469	-574.408	935.9653

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.007571	10014364	0.003753	0.005278	41239.39	104229.4	0.000691	492721
St. Dev	0.087009	3164.548	0.061265	0.072647	203.0748	322.8458	0.026284	701.9409
Average	-0.00377	313.4258	-0.0055	-0.00271	18.07032	27.92679	0.000139	4.474015

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000611	7276068	495505.9	28014733	65260161	4.92E-05	95.55489	51772503
St. Dev	0.024715	2697.419	703.9218	5292.895	8078.376	0.007017	9.775218	7195.311
Average	-0.00186	27.89942	140.0931	42.30291	844.062	0.000623	-1.22743	-486.773

	mon	p	dmxr	leurxr	leucpi	pop
Variance	13325538	0.009056	0.061097	0.00082	2.79E-05	0
St. Dev	3650.416	0.095166	0.247179	0.028637	0.005278	0
Average	-157.084	0.015332	-0.02855	0.000123	2.62E-05	0

Table 2.A.6: EMU (No Indexation Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.43E-05	0.000313	3.11E+10	3080573	1.71E+10	4.1E+09	16282436	30256578
St. Dev	0.00862	0.017694	176440.2	1755.156	130794.4	64049	4035.15	5500.598
Average	9.89E-05	0.000385	-23166.1	-170.045	-17159.4	-5997.32	191.2512	-113.158

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	8976660	9656258	0.000298	0.003313	0.003329	0.014388	14502424	82038541
St. Dev	2996.107	3107.452	0.017272	0.057559	0.057694	0.119948	3808.205	9057.513
Average	62.08679	293.8766	0.000295	0.000898	0.000437	-0.00477	-737.022	1082.177

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.008679	10014425	0.003753	0.005278	41239.68	157147.9	0.000964	709175.3
St. Dev	0.09316	3164.558	0.061265	0.072647	203.0756	396.4188	0.031043	842.1255
Average	-0.00496	313.3814	-0.00549	-0.00271	18.07168	68.46458	0.000246	-17.1527

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000994	9021913	611078.1	40226927	68561450	4.92E-05	696.1015	68678046
St. Dev	0.031534	3003.65	781.7149	6342.47	8280.184	0.007017	26.38374	8287.222
Average	-0.00312	47.69694	-15.1748	-130.266	967.9593	0.000624	1.671111	-769.323

	mon	p	dmxr	leurxr	leucpi	pop
Variance	65375059	0.243166	0	0.000941	8.38E-06	0
St. Dev	8085.484	0.493119	0	0.030679	0.002894	0
Average	716.4067	0.0692	0	0.000164	2E-05	0

Table 2.A.7: FLOAT (Low Interest Rate Sensitivity Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	0.000128	0.000809	2.21E+10	3722559	1.35E+10	1.8E+09	15065889	21919577
St. Dev	0.01132	0.028449	148697.7	1929.393	116236.9	42397.02	3881.48	4681.835
Average	0.001117	0.003416	-15286.1	-272.913	-10262.8	-5021.52	74.81998	21.22236

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	7029317	9425131	0.000126	0.000757	0.000203	0.011589	9265095	78782254
St. Dev	2651.286	3070.038	0.01122	0.02751	0.014242	0.107651	3043.862	8875.937
Average	-118.323	174.1411	0.000614	0.002203	0.00129	-0.00404	-602.906	932.1926

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.007195	10014368	0.003753	0.005278	41239.37	103652.9	0.000735	512685.5
St. Dev	0.084825	3164.549	0.061265	0.072647	203.0748	321.9518	0.027103	716.0206
Average	-0.00376	313.4268	-0.0055	-0.00271	18.07004	38.7173	0.000248	3.097489

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000658	7832349	557387.4	29135731	65615207	4.92E-05	101.3529	54023283
St. Dev	0.025643	2798.633	746.5838	5397.752	8100.321	0.007017	10.06742	7350.053
Average	-0.00205	22.25022	139.0152	24.40087	840.0265	0.000623	-1.39166	-479.055

	mon	p	dmxr	leurxr	leucpi	pop
Variance	13384160	0.009258	0.064477	0.00082	2.79E-05	0
St. Dev	3658.437	0.096217	0.253924	0.028637	0.005278	0
Average	-152.457	0.018899	-0.03226	0.000123	2.62E-05	0

Table 2.A.8: EMU (Low Interest Sensitivity Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.64E-05	0.000313	2.76E+10	3262479	1.69E+10	2.3E+09	14725280	22820666
St. Dev	0.008743	0.017694	166023.1	1806.233	130179.5	47952.49	3837.353	4777.098
Average	0.000101	0.000385	-28837.8	-197.229	-21653.7	-7175.86	329.2213	-326.474

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	7715249	9078435	0.000401	0.003914	0.004385	0.01292	9106476	81364495
St. Dev	2777.634	3013.044	0.020029	0.062566	0.066219	0.113668	3017.694	9020.227
Average	127.7196	435.9078	0.000303	0.000896	0.000395	-0.00555	-952.599	1090.269

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.007131	10014453	0.003753	0.005278	41239.44	107999.7	0.000768	533869.6
St. Dev	0.084445	3164.562	0.061265	0.072647	203.075	328.633	0.027713	730.6638
Average	-0.00608	313.3502	-0.00549	-0.00271	18.07301	58.07401	9.65E-05	-47.6621

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.00068	7753428	354203.1	30333679	67806514	4.92E-05	695.7647	61836510
St. Dev	0.026076	2784.498	595.1497	5507.602	8234.471	0.007017	26.37735	7863.619
Average	-0.00433	99.23999	-29.1264	-373.834	971.2885	0.000624	1.667883	-947.937

	mon	p	dmxr	leurxr	leucpi	pop
Variance	73835088	0.265371	0	0.000941	8.38E-06	0
St. Dev	8592.735	0.515142	0	0.030679	0.002894	0
Average	749.9794	0.073521	0	0.000164	2E-05	0

Table 2.A.9: FLOAT (More Flexibility Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	0.000101	0.000765	2.2E+10	3783285	1.33E+10	1.91E+09	14774325	20684881
St. Dev	0.010033	0.02766	148420	1945.067	115246.5	43758.27	3843.738	4548.063
Average	0.000876	0.002926	-14295.8	-244.514	-9292.26	-4994.84	21.51018	61.16389

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	7133512	8768359	0.000114	0.000799	0.000134	0.01005	8826429	78083309
St. Dev	2670.863	2961.142	0.010686	0.028258	0.011587	0.100249	2970.931	8836.476
Average	-102.682	113.8582	0.000643	0.002273	0.000807	-0.00266	-557.514	952.4644

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.004052	10014370	0.003753	0.005278	41239.36	18414.23	0.000752	483931.8
St. Dev	0.063659	3164.549	0.061265	0.072647	203.0748	135.6991	0.02742	695.6521
Average	-0.00256	313.4271	-0.0055	-0.00271	18.07022	13.40907	0.000239	10.53728

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000651	8168151	558549.6	27496267	65004832	4.92E-05	76.77895	53273823
St. Dev	0.025517	2857.998	747.3618	5243.688	8062.557	0.007017	8.76236	7298.892
Average	-0.00177	16.94148	118.0449	71.87897	858.8327	0.000624	-1.21698	-437.111

	mon	p	dmxr	leurxr	leucpi	pop
Variance	10615827	0.003531	0.049582	0.00082	2.79E-05	0
St. Dev	3258.194	0.059423	0.222671	0.028637	0.005278	0
Average	-234.495	0.011509	-0.02897	0.000123	2.62E-05	0

Table 2.A.10: EMU (More Flexibility Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.55E-05	0.000313	2.77E+10	3285892	1.63E+10	2.85E+09	15055832	23690510
St. Dev	0.008687	0.017694	166362	1812.703	127553.1	53403.14	3880.185	4867.29
Average	8.41E-05	0.000385	-30118.1	-195.141	-21629	-8481.07	337.5624	-329.833

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	8163214	8830758	0.000186	0.003225	0.004456	0.011482	11447527	81454064
St. Dev	2857.134	2971.659	0.013631	0.056788	0.066753	0.107154	3383.419	9025.191
Average	126.9666	443.3866	6.99E-05	0.001078	0.000368	-0.00585	-919.745	1084.207

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.004051	10014392	0.003753	0.005278	41239.48	19817.78	0.000856	554737.2
St. Dev	0.063646	3164.552	0.061265	0.072647	203.0751	140.7756	0.02925	744.8068
Average	-0.00559	313.4164	-0.00549	-0.00271	18.06982	22.3	8.79E-05	-50.219

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000766	8202092	415374.8	31493786	67890681	4.92E-05	696.1387	62368918
St. Dev	0.027676	2863.929	644.4958	5611.933	8239.58	0.007017	26.38444	7897.399
Average	-0.00434	96.78676	-30.9798	-379.958	964.8155	0.000623	1.669424	-987.924

	mon	p	dmxr	leurxr	leucpi	pop
Variance	72398707	0.258841	0	0.000941	8.38E-06	0
St. Dev	8508.743	0.508764	0	0.030679	0.002894	0
Average	721.6583	0.071596	0	0.000164	2E-05	0

Table 2.A.11: FLOAT (High Natural Rate of Unemployment Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	0.00012	0.000817	2.02E+10	3289274	1.25E+10	1.63E+09	14424169	20664849
St. Dev	0.010943	0.028592	142243.9	1813.636	111896.3	40324.01	3797.916	4545.861
Average	0.001114	0.003237	-13862.1	-244.082	-9623.02	-4244.47	31.1103	56.83806

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	6445440	8453984	0.000125	0.000841	0.000223	0.011392	8955699	71841505
St. Dev	2538.787	2907.574	0.011181	0.029007	0.014936	0.106733	2992.607	8475.937
Average	-83.7987	127.8644	0.000605	0.002263	0.001183	-0.00323	-545.506	923.2775

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.008798	9086758	0.003754	0.006475	252142.3	660670	0.000764	483596.4
St. Dev	0.093799	3014.425	0.061267	0.080466	502.1377	812.8161	0.027637	695.4109
Average	-0.00349	298.5368	-0.0055	-0.00301	44.68703	103.6397	0.000266	10.24626

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000687	7278343	520563.1	27470066	59828483	0.000301	126.6546	49402093
St. Dev	0.026207	2697.84	721.5006	5241.189	7734.887	0.017351	11.25409	7028.662
Average	-0.00184	17.82237	101.2386	67.46296	832.2004	0.001543	-1.63744	-438.575

	mon	p	dmxr	leurxr	leucpi	pop
Variance	11894342	0.010085	0.080829	0.00082	2.79E-05	0
St. Dev	3448.817	0.100422	0.284304	0.028638	0.005278	0
Average	-131.071	0.018004	-0.0385	0.000124	2.64E-05	0

Table 2.A.12: EMU (High Natural Rate of Unemployment Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.74E-05	0.000313	2.66E+10	2775992	1.53E+10	2.95E+09	14816164	24201706
St. Dev	0.0088	0.017694	163161	1666.131	123596.7	54278.52	3849.177	4919.523
Average	4.99E-05	0.000385	-22311.8	-155.681	-16534.9	-5772.85	167.0887	-94.939

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	7578992	8376967	0.000385	0.004038	0.004496	0.012607	11959684	74334609
St. Dev	2752.997	2894.299	0.019616	0.063543	0.067056	0.112282	3458.278	8621.752
Average	92.86697	270.2905	0.00019	0.000334	0.000482	-0.00523	-697.141	1056.682

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.008824	9086044	0.003753	0.006474	252123	796754.2	0.00088	566925.9
St. Dev	0.093936	3014.307	0.061265	0.080463	502.1185	892.6109	0.029658	752.9448
Average	-0.00588	298.4719	-0.00549	-0.00301	44.68753	127.1993	0.000215	-13.0145

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000832	7637029	445791.6	32175449	62011229	0.000301	695.8867	59263199
St. Dev	0.028853	2763.518	667.6762	5672.341	7874.721	0.01735	26.37966	7698.26
Average	-0.00293	50.87913	-42.4649	-107.819	945.2377	0.001543	1.672693	-737.874

	mon	p	dmxr	leurxr	leucpi	pop
Variance	84191197	0.358106	0	0.000941	8.38E-06	0
St. Dev	9175.576	0.59842	0	0.030679	0.002894	0
Average	862.4056	0.086437	0	0.000164	2E-05	0

Table 2.A.13: FLOAT (Bubble Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	0.00012	0.000991	2.18E+10	3769653	1.32E+10	1.93E+09	15218153	22480513
St. Dev	0.010973	0.031484	147724.1	1941.559	114755.9	43949.16	3901.045	4741.362
Average	0.001087	0.003288	-17246.3	-269.433	-11430.2	-5808.25	109.4965	-21.9859
	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	7080474	9300847	0.000117	0.000973	0.00025	0.011404	9219571	78810677
St. Dev	2660.916	3049.729	0.010795	0.031201	0.01581	0.106788	3036.375	8877.538
Average	-104.362	210.5855	0.000553	0.002038	0.001422	-0.00436	-630.173	935.3464
	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.007208	10014350	0.003753	0.005278	41239.32	109795.2	0.000758	526095.2
St. Dev	0.084902	3164.546	0.061265	0.072647	203.0747	331.3536	0.027526	725.3242
Average	-0.00408	313.4291	-0.0055	-0.00271	18.07009	41.2462	0.000224	-3.66595
	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000687	7927149	689637.3	29884452	65656569	4.92E-05	97.11308	53206726
St. Dev	0.026214	2815.519	830.4441	5466.667	8102.874	0.007017	9.854597	7294.294
Average	-0.00233	26.38922	129.4102	-25.5935	841.6953	0.000623	-1.56715	-541.309
	mon	p	dmxr	leurxr	leucpi	pop		
Variance	14035632	0.010274	0.061761	0.00082	2.79E-05	0		
St. Dev	3746.416	0.101359	0.248518	0.028637	0.005278	0		
Average	-125.588	0.020673	-0.03569	0.000123	2.62E-05	0		

Table 2.A.14: EMU (Bubble Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.59E-05	0.000313	3.01E+10	3113029	1.67E+10	3.7E+09	15663411	26948245
St. Dev	0.008711	0.017694	173351.3	1764.378	129122.3	60802.83	3957.703	5191.17
Average	8.2E-05	0.000385	-23979.5	-168.966	-17257.1	-6713.64	194.9503	-132.729

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	8456395	9253813	0.000211	0.003186	0.00437	0.012774	12855035	82060947
St. Dev	2907.988	3042.008	0.01452	0.056442	0.066103	0.11302	3585.392	9058.75
Average	96.01488	295.2198	0.000342	0.000937	0.000462	-0.0046	-764.584	1102.209

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.007245	10014418	0.003753	0.005278	41239.63	129069.2	0.000871	631476.2
St. Dev	0.085117	3164.556	0.061265	0.072647	203.0754	359.262	0.029515	794.6548
Average	-0.00498	313.3906	-0.00549	-0.00271	18.07132	55.49672	0.000188	-21.1339

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000844	8496701	571961.8	35828415	68513919	4.92E-05	696.134	65912374
St. Dev	0.029044	2914.91	756.2815	5985.684	8277.314	0.007017	26.38435	8118.644
Average	-0.00315	55.84001	-41.0225	-153.989	985.1326	0.000624	1.669791	-786.538

	mon	p	dmxr	leurxr	leucpi	pop
Variance	69623715	0.26401	0	0.000941	8.38E-06	0
St. Dev	8344.083	0.513819	0	0.030679	0.002894	0
Average	786.6501	0.074803	0	0.000164	2E-05	0

Table 2.A.15: FLOAT (Enhanced Fiscal Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	0.000116	0.000782	2.23E+10	3700787	1.34E+10	2E+09	14818082	21480892
St. Dev	0.01079	0.027967	149341.4	1923.743	115753.4	44687.53	3849.426	4634.748
Average	0.001087	0.003184	-15458.2	-259.934	-10266.8	-5187.36	62.60193	31.57903

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	7547732	8692059	0.000116	0.000731	0.000207	0.011303	9103156	77643513
St. Dev	2747.314	2948.23	0.010773	0.027031	0.014389	0.106313	3017.144	8811.556
Average	-109.187	161.6981	0.000603	0.002046	0.001255	-0.00386	-582.058	939.1866

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.007141	10014344	0.003753	0.005278	41239.28	106216.5	0.000692	502489.4
St. Dev	0.084505	3164.545	0.061264	0.072647	203.0746	325.9088	0.026309	708.8649
Average	-0.00371	313.448	-0.0055	-0.00271	18.06946	38.54779	0.000217	4.586779

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000631	8577043	620443.1	28552874	65789196	4.92E-05	94.32542	53914930
St. Dev	0.025124	2928.659	787.6821	5343.489	8111.054	0.007017	9.712128	7342.679
Average	-0.00197	21.57854	129.4694	36.26904	847.8806	0.000623	-1.23827	-482.547

	mon	p	dmxr	leurxr	leucpi	pop
Variance	13358059	0.009104	0.060066	0.00082	2.79E-05	0
St. Dev	3654.868	0.095416	0.245084	0.028637	0.005278	0
Average	-145.777	0.018173	-0.02724	0.000123	2.62E-05	0

Table 2.A.16: EMU (Enhanced Fiscal Case) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.69E-05	0.000313	2.88E+10	3291492	1.68E+10	3.12E+09	15048583	24927897
St. Dev	0.008769	0.017694	169673.1	1814.247	129597.4	55834.03	3879.25	4992.784
Average	9.73E-05	0.000385	-30152.9	-197.115	-22220.8	-7922.82	340.7361	-335.67

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	8946990	8505949	0.000385	0.004017	0.00448	0.012587	12404528	80486586
St. Dev	2991.152	2916.496	0.019628	0.063379	0.066931	0.112191	3522.006	8971.432
Average	151.854	447.7225	0.000282	0.000923	0.000383	-0.00564	-942.124	1105.934

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.007159	10014420	0.003753	0.005278	41239.53	119382.5	0.000796	584197.6
St. Dev	0.084613	3164.557	0.061265	0.072647	203.0752	345.5177	0.028218	764.3282
Average	-0.00617	313.3707	-0.00549	-0.00271	18.07219	61.81407	8.07E-05	-49.642

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000755	9016597	440830.5	33142983	68071421	4.92E-05	695.7989	64571082
St. Dev	0.027482	3002.765	663.9507	5756.994	8250.541	0.007017	26.378	8035.613
Average	-0.00442	127.7888	-24.8119	-385.139	963.5026	0.000624	1.666171	-996.903

	mon	p	dmxr	leurxr	leucpi	pop
Variance	73824731	0.265087	0	0.000941	8.38E-06	0
St. Dev	8592.132	0.514866	0	0.030679	0.002894	0
Average	748.2067	0.073445	0	0.000164	2E-05	0

Table 2.A.17: FLOAT (Highly Favourable Combination) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	0.000118	0.000813	2.19E+10	3748608	1.34E+10	1.75E+09	14549397	19166221
St. Dev	0.010857	0.028516	147839.6	1936.132	115618	41875.45	3814.367	4377.924
Average	0.001084	0.003426	-14890.3	-269.653	-9908.76	-4980.35	49.14953	31.91144
	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	7498625	8802909	0.000122	0.000787	0.000188	0.010337	8458082	77468979
St. Dev	2738.362	2966.97	0.01104	0.028056	0.013715	0.101669	2908.278	8801.646
Average	-110.898	143.8706	0.000595	0.002336	0.001224	-0.00331	-580.497	937.1269
	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.004009	10014363	0.003753	0.005278	41239.32	17322.89	0.000681	447949.9
St. Dev	0.063317	3164.548	0.061265	0.072647	203.0747	131.6164	0.026095	669.2906
Average	-0.00281	313.4202	-0.0055	-0.00271	18.0705	12.72227	0.000229	7.528129
	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000583	8425515	565594.4	25473109	65587852	4.92E-05	91.18965	53464708
St. Dev	0.02414	2902.674	752.0601	5047.089	8098.633	0.007017	9.549327	7311.957
Average	-0.00192	25.63089	135.0704	39.79293	845.5359	0.000623	-1.41126	-461.27
	mon	p	dmxr	leurxr	leucpi	pop		
Variance	12900087	0.007964	0.058042	0.00082	2.79E-05	0		
St. Dev	3591.669	0.089239	0.24092	0.028637	0.005278	0		
Average	-165.664	0.01734	-0.03413	0.000123	2.62E-05	0		

Table 2.A.18: EMU (Highly Favourable Combination) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.48E-05	0.000313	2.86E+10	3121666	1.72E+10	2.5E+09	14368210	20354974
St. Dev	0.008646	0.017694	169037.5	1766.824	131327.3	50003.73	3790.542	4511.649
Average	8.46E-05	0.000385	-23374.6	-166.399	-17300.6	-6064	161.3881	-116.956

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	8392247	8737852	0.000209	0.003075	0.004301	0.011852	8562396	81181843
St. Dev	2896.937	2955.986	0.014444	0.05545	0.065581	0.108868	2926.157	9010.097
Average	106.5758	260.3643	0.000246	0.00094	0.000541	-0.00421	-744.411	1113.837

	rw	y*	e*	w*	U	u	dy	afc
Variance	0.003907	10014405	0.003753	0.005278	41239.35	17351.79	0.000721	476057.1
St. Dev	0.062503	3164.554	0.061265	0.072647	203.0747	131.7262	0.026842	689.9689
Average	-0.00405	313.351	-0.00549	-0.00271	18.07262	16.96652	0.000173	-14.6157

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000614	8505281	466270.6	27054674	68675077	4.92E-05	696.1543	63218694
St. Dev	0.024778	2916.381	682.8401	5201.411	8287.043	0.007017	26.38474	7951.018
Average	-0.00293	67.32179	-39.9156	-131.197	988.3913	0.000624	1.669978	-761.673

	mon	p	dmxr	leurxr	leucpi	pop
Variance	68865574	0.259593	0	0.000941	8.38E-06	0
St. Dev	8298.528	0.509503	0	0.030679	0.002894	0
Average	786.0265	0.074195	0	0.000164	2E-05	0

2.B Appendix 2

2.B.1 Taylor Series Expansion of Expected Utility

It might seem that we can take the percentage change in utility between EMU and floating as the percentage changes in UK welfare. However, the utility unit is not invariable to units. For example take logarithmic utility: $U = \alpha \ln c + (1-\alpha)\ln(1+u)$. If we double the unit of consumption we add $\alpha \ln(2)$ to U; thus cutting the percentage differences produced by the changes.

What we would like to know is the equivalent percentage change in expected consumption ('living standard') of our changes in expected utility. To discover this we take a second-order Taylor-series expansion of expected utility around its value at some fixed point (given by $\bar{c}$ and $\bar{u}$, for example) and set the total differential to zero.

$$\begin{aligned} 0 &= \frac{\Delta EU}{N} = \frac{\delta U}{\delta c}\frac{\Delta(Ec-\bar{c})}{N} + \frac{\delta U}{du}\frac{\Delta(Eu-\bar{u})}{N} \\ &+\Delta 0.5\frac{\left[\left(\frac{\delta^2 U}{\delta c^2}\right) var(c) + \left(\frac{\delta^2 U}{\delta c^2}\right) var(u) + \left(\frac{2\delta U}{\delta c}\frac{\delta U}{\delta u}\right) cov(c,u)\right]}{N} \end{aligned}$$

where N is the number of observations we have (in this case all our 12, 078 stochastic periods). It follows that in order to hold expected utility constant,

$$\frac{-\delta U}{\delta c}\frac{\Delta(Ec-\bar{c})}{N} + \frac{\Delta U}{\delta u}\Delta(Eu-\bar{u}) = \Delta 0.5\frac{\left[\left(\frac{\delta^2 U}{\delta c^2}\right) var(c) + \left(\frac{\delta^2 U}{\delta c^2}\right) var(u) + \left(\frac{2\delta U}{\delta c}\frac{\delta U}{\delta u}\right) cov(c,u)\right]}{N}$$

Since the move to the euro involves no change in mean, it follows that the term on the right-hand side of the equation due to changing variances is the effect we are picking up in our simulations and there is no change in $E(c)$ or $E(u)$; hence the left-hand side of the equation is zero. If we want to know what percentage consumption change would be equivalent (i.e. would just offset the simulated change in variances), we solve this equation for:

$$\frac{\Delta \frac{Ec-\bar{c}}{\bar{c}}}{N} = \frac{1}{\bar{c}\frac{\delta U}{\delta c}} \left\{ \Delta 0.5 \frac{\left[\left(\frac{\delta^2 U}{\delta c^2}\right) var(c) + \left(\frac{\delta^2 U}{\delta c^2}\right) var(u) + \left(\frac{2\delta U}{\delta c}\frac{\delta U}{\delta u}\right) cov(c,u)\right]}{N} \right\}$$

This is what we report in the text: the expected percentage consumption fall that is the equivalent of the losses created by the higher variances and covariances.

2.C Appendix 3

2.C.1 Decomposing the Results by Types of Shock:

In the work reported above we lump all shocks together. This makes sense because shocks are correlated with one another; to run one and then another separately when the two are connected, distorts the effect of each. Nevertheless it can shed some light on the main sources of our results to run groups of shocks separately, provided one bears this in mind.

We first separated out the demand shocks: Tables 2.C.1–2.C.2. The ratios of variances (EMU/floating) are 1.21 for output, 1.28 for unemployment, 8.33 for real interest rates, and 19.56 for inflation. The political cost would be 2.40. Supply shocks alone would therefore produce about a quarter of the total political cost (three quarters of the output variance).

Tables 2.C.3–2.C.4 show the supply shocks on their own. It can readily be seen that floating and EMU are rather similar in dealing with these, with the ratios of inflation, unemployment and the real interest rates falling.

In Tables 2.C.5–2.C.6 we examine the external shocks on their own. It can be seen that under EMU the effect of external shocks is many multiples of their effect under floating, reflecting two things; that floating insulates the economy from external shocks whereas EMU does not, and secondly that EMU introduces new external, EMU-specific, shocks. One can see that external shocks are thus by far the most important source of the gap between floating and EMU variability.

It is more informative to break the external shocks from EMU down further. In Tables 2.C.7–2.C.9 we include all the external shocks present in both EMU and floating — world real interest rates and world trade — but only enter in turn and alone the three external shocks from EMU: those from the euro real exchange rate, from euro prices, and from euro interest rates. We can see that the last is the least important in destabilising the UK under EMU. However the other two each on their own heavily destabilise the UK under

EMU; clearly they must be negatively correlated since the two together have less effect than separately.

The matter in which we are most interested is how far the problem created by EMU stems from the fact that interest rates and the exchange rate cannot react to shocks, how much from the fact that the movement in euro interest rates, prices and the euro real exchange rate injects additional shocks into the UK economy. Table 2.C.10 shows what happens under EMU if all shocks enter it except these last three sets of euro shocks — this is 'EMU Passive case'.

It can be seen that the ratio of EMU (Passive) to floating variances are: 1.10 for output, 1.07 for unemployment; 0.89 for real interest rates; 5.66 for inflation. The political cost would be 1.29 times. As we can see above, these figures are not too dissimilar to the effect of the supply shocks on their own; so we could say that supply shocks provoke a helpful response from domestic monetary policy that is of course absent under EMU because it is a passive monetary system from the UK's viewpoint. Compare these with the ratios to floating for the total EMU case (1.24, 1.18, 4.32 and 20.17) and one can by subtraction see that how important is also the active part of EMU, the additional shocks. Specifically they contribute the following percentages of the extra EMU variances: output 52%, unemployment 61%, real interest rates 103%, and inflation 76%, with an additional political cost of 0.92. We can summarise this as saying that EMU, in so far as it does not permit interest rates and exchange rates to react to UK shocks, would increase political costs by about 33%; in so far as it injects additional shocks into the UK, it raises costs by a further 60%.

In sum, about a quarter of the political cost of EMU is due to its passive inability to stabilise the economy in the face of shocks, mainly supply shocks; about three quarters is due to its active injection into the UK economy of EMU-specific shocks.

Table 2.C.1: FLOAT (Demand Shocks) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	5.01E-05	0.000238	2.02E+10	2837077	1.09E+10	1.95E+09	13264378	17514303
St. Dev	0.007079	0.015423	142019.6	1684.362	104430.5	44197.3	3642.029	4185.009
Average	0.000454	0.00087	-19128.5	-191.353	-14998.8	-4124.94	8.569552	-24.8891

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	6563946	7141045	2.28E-05	0.00018	0.000127	0.0055	5428423	79340865
St. Dev	2562.02	2672.273	0.004771	0.013433	0.011251	0.074165	2329.898	8907.349
Average	-73.2003	121.467	0.000118	0.000296	0.000715	-0.00306	-366.063	1003.871

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.006606	10536737	0.003893	0.005431	44492.55	97633.73	0.000249	410792.1
St. Dev	0.081278	3246.034	0.06239	0.073695	210.9326	312.464	0.015784	640.9307
Average	0.000854	121.3708	-0.00183	0.001596	29.29421	40.83319	-3.3E-05	-3.13038

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000484	7218099	280024.6	23287255	66182490	5.29E-05	89.17622	30678197
St. Dev	0.021999	2686.652	529.1735	4825.687	8135.262	0.00727	9.443316	5538.79
Average	-0.00101	-55.9123	16.54879	-27.7736	913.0939	0.001008	-0.18441	-787.323

	mon	p	dmxr	leurxr	leucpi	pop
Variance	13531975	0.012073	0.054325	0	0	0
St. Dev	3678.583	0.109878	0.233078	0	0	0
Average	-108.805	0.011946	-0.00058	0	0	0

Table 2.C.2: EMU (Demand Shocks) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	2.8E-05	0	2.52E+10	2635790	1.35E+10	2.86E+09	13346263	20613728
St. Dev	0.005289	0	158732.6	1623.512	116396.2	53500.4	3653.254	4540.234
Average	-1.6E-05	0	-25283.2	-171.468	-20221.7	-5053.48	122.6759	-146.01

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	7307967	6640926	9.51E-05	0.001504	0.002476	0.006339	7715131	80077733
St. Dev	2703.325	2576.999	0.009754	0.03878	0.04976	0.079621	2777.612	8948.616
Average	26.26927	242.3235	-0.00039	-0.00098	0.000461	-0.005	-468.32	1062.939

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.006634	10536757	0.003893	0.005431	44492.56	125242	0.000349	483465.9
St. Dev	0.081448	3246.037	0.062391	0.073694	210.9326	353.8954	0.018676	695.3171
Average	-0.00073	121.4127	-0.00183	0.001597	29.29226	47.77753	-5.9E-05	-20.5315

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	0.000587	7549230	133868.9	27399922	66707474	5.29E-05	424.3341	39079308
St. Dev	0.024229	2747.586	365.8809	5234.493	8167.464	0.00727	20.59937	6251.344
Average	-0.00184	-16.0416	-43.1953	-166.194	960.5971	0.001008	0.585625	-1003.72

	mon	p	dmxr	leurxr	leucpi	pop
Variance	51538193	0.175081	0	0.00082	0	0
St. Dev	7179.011	0.418427	0	0.028637	0	0
Average	437.7312	0.049922	0	0.000123	0	0

Table 2.C.3: FLOAT (Supply Shocks) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	1.42E-05	0.000155	2.77E+09	1570912	1.53E+09	3.21E+08	641274.8	9377968
St. Dev	0.00377	0.012469	52646.94	1253.36	39110.99	17920.33	800.7964	3062.347
Average	-6.9E-05	1.72E-05	3879.979	-11.7318	2239.953	1655.507	49.52094	248.0063

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	86925.23	707054.3	1.59E-05	0.000143	3.47E-05	0.00436	1097995	758661.9
St. Dev	294.8309	840.8652	0.003985	0.011968	0.005887	0.066034	1047.853	871.012
Average	11.50661	53.17621	8.64E-06	1.47E-05	0.00025	-0.006	18.42378	72.78777

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.005667	10016344	0.003753	0.005276	41249.99	78819.6	2.83E-05	221703.6
St. Dev	0.075279	3164.861	0.061263	0.072636	203.1009	280.7483	0.005315	470.8541
Average	-0.00312	313.2092	-0.00549	-0.00271	18.0806	20.34024	0.000166	37.44382

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	5.01E-05	248168.3	88305.42	12483098	616760.5	4.92E-05	38.47177	4652439
St. Dev	0.007078	498.1649	297.1623	3533.143	785.341	0.007018	6.202562	2156.951
Average	-0.00042	35.67462	23.34106	285.3374	64.24479	0.000624	-0.32224	141.2993

	mon	p	dmxr	leurxr	leucpi	pop
Variance	3471708	0.000825	0.024103	0	0	0
St. Dev	1863.252	0.028729	0.15525	0	0	0
Average	32.65722	0.004205	-0.00359	0	0	0

Table 2.C.4: EMU (Supply Shocks) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	3.72E-08	0	3.75E+09	1465602	2.09E+09	4.9E+08	589653.7	10777795
St. Dev	0.000193	0	61219.98	1210.62	45766.82	22126.72	767.8891	3282.955
Average	2.14E-06	0	5290.637	-10.0467	2952.549	2336.073	7.359717	296.1657

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	135699.7	549896.1	3.15E-05	0.000205	0.000263	0.003616	1793551	721783.6
St. Dev	368.3745	741.5498	0.005612	0.014334	0.016208	0.060133	1339.235	849.5785
Average	9.573781	7.134156	-7.7E-06	0.000235	-0.0005	-0.00529	63.35065	83.43586

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.005591	10015433	0.003753	0.005276	41250.54	79836.35	3.26E-05	256090.4
St. Dev	0.074775	3164.717	0.061263	0.072638	203.1023	282.5533	0.005706	506.0538
Average	-0.00275	312.9922	-0.00549	-0.00271	18.0812	22.79485	0.00021	47.59241

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	7.49E-05	160542.8	15367.43	14353848	580733.6	4.93E-05	5.36E-06	6452755
St. Dev	0.008654	400.6779	123.9654	3788.647	762.0588	0.007018	0.002315	2540.227
Average	-0.00016	24.67583	14.5679	344.1407	74.75653	0.000623	-0.00052	189.4806

	mon	p	dmxr	leurxr	leucpi	pop
Variance	6957779	0.009936	0	0	0	0
St. Dev	2637.76	0.099679	0	0	0	0
Average	-122.022	-0.00574	0	0	0	0

Table 2.C.5: FLOAT (External Shocks) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	4.46E-08	1.02E-06	140687.6	310.7505	93227.37	50690.92	111.1419	1302.926
St. Dev	0.000211	0.001008	375.0835	17.62812	305.3316	225.1464	10.54239	36.09607
Average	2.54E-05	-0.00022	276.5811	11.2383	262.9516	16.60434	4.106694	-4.15069

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	394.5767	146.6754	6.44E-08	1.53E-06	2.52E-07	1.96E-06	338.4212	257.546
St. Dev	19.86396	12.11096	0.000254	0.001237	0.000502	0.001401	18.39623	16.04824
Average	-4.32776	5.520371	-2.2E-05	-0.00047	1.01E-05	-0.00014	-13.2445	-5.91947

	rw	y*	e*	w*	u*	u	dy	afc
Variance	2.07E-06	414.9802	1.77E-08	2.18E-08	0.266149	36.21963	7.51E-08	32.28405
St. Dev	0.001439	20.37106	0.000133	0.000148	0.515896	6.018274	0.000274	5.681906
Average	1.23E-05	0.111623	-2.1E-07	2.57E-07	-0.00382	-1.22991	-1.4E-05	-2.34875

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	5.39E-08	1082.877	360.4444	1708.381	213.9023	9.04E-11	0.017839	678.4217
St. Dev	0.000232	32.9071	18.98537	41.33257	14.6254	9.51E-06	0.133563	26.04653
Average	-2.6E-05	4.422435	7.511033	-6.86594	-5.47615	8.45E-07	0.085666	7.514958

	mon	p	dmxr	leurxr	leucpi	pop
Variance	430.7441	1.01E-06	2.49E-05	0.00082	2.78E-05	0
St. Dev	20.75438	0.001003	0.004993	0.028631	0.005273	0
Average	11.65511	0.000188	0.004477	0.000123	2.59E-05	0

Table 2.C.6: EMU (External Shocks) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.33E-05	0.000313	1.57E+09	537346.2	8.55E+08	4.1E+08	711007.4	1977007
St. Dev	0.008564	0.017694	39684.67	733.039	29244.47	20244.7	843.2125	1406.061
Average	8.05E-05	0.000385	-17397.7	-65.3963	-12899.8	-4493.55	430.4356	-557.058

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	525649.1	872148	8.5E-05	0.002467	0.003514	0.002598	1346723	265624.6
St. Dev	725.0166	933.8886	0.009218	0.049668	0.059276	0.050968	1160.484	515.3879
Average	113.9311	448.258	-0.00041	7.79E-05	0.000493	-0.00364	-480.151	-21.8347

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.000203	415.1834	1.77E-08	2.18E-08	0.266401	4673.95	5.77E-05	46159.31
St. Dev	0.014247	20.37605	0.000133	0.000148	0.516141	68.3663	0.007598	214.8472
Average	-0.00349	0.103513	6.71E-07	9.19E-07	-0.00385	25.5051	-0.00028	-84.1285

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	7.96E-05	309810	282427.7	2628084	211670.1	8.87E-11	696.1801	2888415
St. Dev	0.008921	556.6058	531.4392	1621.137	460.0762	9.42E-06	26.38523	1699.534
Average	-0.00359	121.3529	6.806195	-640.798	-34.1807	8.28E-07	1.670289	-587.756

	mon	p	dmxr	leurxr	leucpi	pop
Variance	82070214	0.26535	0	0.000941	8.37E-06	0
St. Dev	9059.261	0.515122	0	0.030679	0.002894	0
Average	1200.45	0.075903	0	0.000164	2.02E-05	0

Table 2.C.7: EMU (EUCPI Shock only) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.01E-05	0	1.58E+09	14266.4	8.55E+08	4.07E+08	688698	1914463
St. Dev	0.008374	0	39806.41	119.4421	29236.99	20166.43	829.8783	1383.641
Average	8.7E-05	0	-16692.3	-60.864	-12414.3	-4270.69	404.0875	-521.26

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	335759.7	844617.6	8.23E-05	0.00219	0.00341	0.002519	1312970	51057.35
St. Dev	579.4477	919.0308	0.009074	0.046793	0.058397	0.050188	1145.849	225.9587
Average	121.7545	420.9525	-0.0004	-0.00035	0.000529	-0.00348	-454.579	-5.07392

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.000196	415.1823	1.77E-08	2.18E-08	0.266399	4515.465	5.56E-05	44720.13
St. Dev	0.014001	20.37602	0.000133	0.000148	0.516138	67.19721	0.007455	211.4714
Average	-0.00329	0.10416	6.38E-07	9.36E-07	-0.00388	23.99538	-0.00025	-78.8438

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	7.7E-05	265448.2	59422.79	2545162	32725.33	8.87E-11	680.837	2862710
St. Dev	0.008776	515.2167	243.7679	1595.356	180.9014	9.42E-06	26.09285	1691.954
Average	-0.00337	111.3816	-10.9792	-599.753	-18.1431	8.28E-07	1.589686	-561.664

	mon	p	dmxr	leurxr	leucpi	pop
Variance	80283689	0.257735	0	0.000941	0	0
St. Dev	8960.117	0.507676	0	0.030679	0	0
Average	1235.448	0.075337	0	0.000164	0	0

Table 2.C.8: EMU (Eurxr Shock only) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	7.33E-05	0	1.63E+09	14719.96	8.79E+08	4.16E+08	706685.7	1971459
St. Dev	0.008561	0	40326.19	121.3258	29648.67	20384.13	840.646	1404.087
Average	8.19E-05	0	-17656.9	-64.5858	-13091.8	-4558.31	428.9591	-554.891

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	344432.2	867184.6	8.5E-05	0.002266	0.003514	0.002597	1355005	52003.45
St. Dev	586.8834	931.2275	0.009217	0.047603	0.059275	0.050959	1164.047	228.0427
Average	128.0611	446.6804	-0.00041	-0.00031	0.000496	-0.00363	-482.004	-7.17046

	rw	y*	e*	w*	u*	u	dy	afc
Variance	0.000203	415.1857	1.77E-08	2.18E-08	0.266404	4663.273	5.74E-05	46046.71
St. Dev	0.014245	20.37611	0.000133	0.000148	0.516144	68.28816	0.007578	214.585
Average	-0.00348	0.103564	6.71E-07	9.36E-07	-0.00386	25.4233	-0.00028	-83.9062

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	7.93E-05	273698.9	60572.79	2620878	33330.47	8.87E-11	696.1832	2927557
St. Dev	0.008906	523.1624	246.1154	1618.913	182.5663	9.42E-06	26.38528	1711.011
Average	-0.00358	118.8219	-9.8538	-638.429	-20.9075	8.28E-07	1.670444	-596.58

	mon	p	dmxr	leurxr	leucpi	pop
Variance	82582682	0.265365	0	0.000941	8.37E-06	0
St. Dev	9087.501	0.515136	0	0.030679	0.002894	0
Average	1238.541	0.075919	0	0.000164	2.02E-05	0

Table 2.C.9: EMU (EUNRS Shock Only) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	4.81E-07	0.000313	83977322	512644.2	46510558	10228635	5301.52	15476.71
St. Dev	0.000694	0.017694	9163.914	715.9917	6819.865	3198.224	72.81153	124.4054
Average	2.91E-06	0.000385	229.7489	-1.66185	166.1807	62.96409	3.636187	-6.44124

	bdef	xvol	rl	rs	infl	rxr	c	eg
Variance	224242.3	6146.294	5.64E-07	0.000331	1.9E-05	1.54E-05	20221.16	227493.5
St. Dev	473.5422	78.39831	0.000751	0.018195	0.004362	0.003918	142.2011	476.9628
Average	-12.4496	3.401766	1.12E-05	0.000442	-3.5E-05	5.35E-05	-0.74573	-14.3342

	rw	y*	e*	w*	u*	u	dy	afc
Variance	4.91E-06	415.0326	1.77E-08	2.18E-08	0.266184	46.21423	6.02E-07	363.8425
St. Dev	0.002217	20.37235	0.000133	0.000148	0.51593	6.798105	0.000776	19.07466
Average	-1.8E-05	0.117063	3.06E-07	8.45E-07	-0.00404	1.063876	-1.7E-05	-1.5871

	q	psbr	rdi	yafc	eg*	ur*	rxrn	ginv
Variance	6.35E-07	49327.97	249514.6	20563.86	187287.4	8.96E-11	3.143414	128400.8
St. Dev	0.000797	222.099	499.5143	143.4011	432.7671	9.46E-06	1.772968	358.3305
Average	-4.4E-05	4.602288	16.40307	-8.12419	-13.1227	8.36E-07	0.058557	3.704819

	mon	p	dmxr	leurxr	leucpi	pop
Variance	1637379	0.001049	0	0	8.36E-06	0
St. Dev	1279.601	0.032387	0	0	0.002891	0
Average	-12.8585	-0.00048	0	0	2.07E-05	0

Table 2.C.10: EMU (Passive Case - All Shocks Except EUNRS, EUCPI and EURXR) Simulation Results

	nrl	nrs	w	m0	g	fin	xval	y
Variance	1.04E-07	0	2.6E+10	2747912	1.47E+10	2.81E+09	15318834	25085820
St. Dev	0.000322	0	161093.9	1657.683	121338.8	53038.57	3913.928	5008.575
Average	2.65E-05	0	-10997.1	-120.718	-7110.29	-3887.6	-114.794	259.4484
	bdef	**xvol**	**rl**	**rs**	**infl**	**rxr**	**c**	**eg**
Variance	7654582	8335883	0.000106	0.000657	0.001229	0.00898	11253067	79912608
St. Dev	2766.691	2887.193	0.010303	0.02564	0.035061	0.094762	3354.559	8939.385
Average	-3.52837	-28.397	0.000704	0.000898	-0.00014	-0.00179	-434.69	1098.707
	rw	**y***	**e***	**w***	**u***	**u**	**dy**	**afc**
Variance	0.007223	10014380	0.003753	0.005278	41239.2	117071.2	0.000794	587976
St. Dev	0.084988	3164.551	0.061265	0.072647	203.0744	342.1567	0.028183	766.7959
Average	-0.00248	313.3714	-0.0055	-0.00271	18.07201	35.63409	0.000351	36.69232
	q	**psbr**	**rdi**	**yafc**	**eg***	**ur***	**rxrn**	**ginv**
Variance	0.000749	7918037	134378.4	33350585	66534643	4.92E-05	1.96E-06	60233900
St. Dev	0.027363	2813.901	366.5766	5774.997	8156.877	0.007017	0.0014	7761.05
Average	-0.0006	-34.0762	-31.5361	295.7191	995.1724	0.000624	0.000261	-339.095
	mon	**p**	**dmxr**	**leurxr**	**leucpi**	**pop**		
Variance	11229038	0.023659	0	0	0	0		
St. Dev	3350.976	0.153815	0	0	0	0		
Average	-188.68	0.004118	0	0	0	0		

Chapter 3

Heterogeneity and Monetary Regimes

3.1 Literature Review

Analytical investigation of the effects and importance of the stochastic nature of large non-linear econometric models is impossible. Using stochastic simulation bypasses this problem by performing a large number of replication of the model simulation. The method of stochastic simulation involves adding shocks to the equations, parameters, or the exogenous variables and simulating the model. After a number of replications the simulations are collated so that it is possible to calculate a range of statistics from the simulated data. Using a large number of replications ensures that the estimates provide a good guide to the performance of the model.

The method of stochastic simulation has a long history in macroeconomics. One of the earliest studies is the study of cyclical behaviour by Fisher (1952). Using a simple three-equation macroeconomic model of the Samuelson type, the paper shows the possibility of generating cycles in income by subjecting the two behavioural equations to exogenous random shocks.

The method has also been applied to large macroeconomic models. The seminal paper in this area is Adelman and Adelman (1959), which introduced the idea of drawing errors to analyse the properties of econometric models. The authors use the annual forecasting model of Klein and Goldberger (1955) and then added shocks the equations to see if the model could reproduce the cyclical behaviour of the US economy. They find that the shocked model produces oscillatory movements with periods of 3 to 4 years with similar magnitude to those experienced by the US economy after World War II. The paper concludes by saying that the model cannot explain the cyclical process in the absence of shocks. When the random shocks are added to the model the cyclical fluctuations that result are similar to those described by the NBER as characterising the US economy.

In the Adelman and Adelman (1959) paper they run just one stochastic simulation. Nagar (1969) uses a condensed version of the Brooking econometric model with 112 behavioural equations and runs 20 stochastic simulations. The author finds that the model reflects cyclical behaviour extremely well early on in the simulation period and less well as the prediction period is lengthened.

In the Adelman and Adelman (1959) paper it was assumed that the disturbances in individual equations were independent across equations and over time. Papers by Green, Liebenberg and Hirsch (1972), Evans, Klein and Saito (1972) and Fromm, Klein and Schink (1972) use a more realistic method which involves allowing for intercorrelation of the errors in different equations and, in some applications, for serial correlation in the errors of individual equations. These simulation experiments are much more ambitious and underline the practical significance of stochastic simulation, especially in longer term simulations.

Green, Liebenberg and Hirsch (1972) apply stochastic simulations to the Office of Business Economics (OBE) Model. This is a quarterly model of the US economy with 56 stochastic equations and the authors ran fifty simulations with stochastic shocks applied to the endogenous behavioural variables. Twenty five of the simulations used serially correlated random shocks, while the other twenty five used non-serially correlated shocks. They find that both sets of shocks reveal cyclical movements, though the serially correlated shocks produce series with less ragged time paths than the non-serially correlated shocks, which is more typical of real-world data. They also find that GNP series from the simulations with random shocks applied to endogenous behavioural equations rarely show downturns, though when measured as deviation from the control solution values, real GNP shows definite cycles.

Evans, Klein and Saito (1972) apply similar techniques to the Wharton Model, which contains 47 stochastic equations and again ran 100 replications. These authors also find that the stochastic solution with serially correlated shocks present results in outcomes that are much smoother than those with serially uncorrelated errors, and as a result their cyclical patterns are more distinct. The serially correlated shock results are also more consistent with the historical facts on business cycles.

Fromm, Klein and Schink (1972) perform 50 replications on the Brookings Model which is a quarterly model and has 230 equations of which 118 are stochastic. They find that while some of the stochastic simulations drift, the majority fluctuated about the control path.

Stochastic simulations have also been applied to models for other countries. Sowey (1973) applies 20 replications to a quarterly nonlinear model for Australia with 55 simultaneous equations, which includes 24 behavioural equations. The paper aims to assess the model's goodness of fit, the differential behaviour under dynamic and one-step simulations, and to compare the mean stochastic simulation path with the deterministic simulation path. The paper concludes that deterministic simulation is much cheaper in terms of computer time, but the use of stochastic simulation can yield results which are not only more detailed but are also fully assessable in terms of statistic reliability.

In another early application of stochastic simulation Cooper and Fischer (1972) use stochastic simulation to study the effects of different monetary rules on the rates of inflation and unemployment. They compare two models, the Federal Reserve Board-MIT-Pennsylvania (FMP) Model which is Keynesian in nature, and the St. Louis (SL) Model which represents a strict monetarist view. The FMP Model is larger having 66 stochastic equations compared to the five stochastic equations of the SL Model. The authors find that simple feedback control rules reduce the variability of the target variables (inflation and unemployment) relative to the rule in which the money supply is increased at a constant r

3.2 Introduction

In this paper we ask whether heterogeneous labour market experience matters for the choice of monetary regimes. The usual procedure in choosing between regimes is to evaluate the welfare function of a representative agent. Implicitly this procedure assumes that shocks affect all agents in a similar way, in other words it assumes away heterogeneity. To build up the fiction of this representative agent, it is usually assumed that there is perfect pooling across agents of all shock effects (Lewis, 2003a,b). In particular, 'unemployment' is achieved by a lottery, so that some people are allocated leisure but perfect compensation across agents ensures that they are no better or worse off than the others who work. Yet this contradicts the basic facts of the labour market and the impact of business cycles on households.

We would argue that the key heterogeneity perhaps of a macro economy is the one between the unemployed and the employed. In a highly flexible labour market, unemployment will purely consist of people spending short amounts of search time between jobs; in such a case it seems reasonable to assume that those unemployed are essentially no different from the employed — unemployment is an occasional state all, or most, experience. Here the pooling assumption is quite appropriate.

However most, maybe all, economies have not so flexible a labour market: various forms of social intervention ensure that a significant number of unemployed remain so for a long period because the jobs they can find are less rewarding than their unemployment package. Such unemployed will be on the margin of unemployment benefits and employment and hence will tend to be relatively unskilled (in benefit systems, the majority, where benefit/earnings replacement ratios rise markedly as one moves down the wage distribution). It is natural in such economies therefore to group the adult working population into those relatively unskilled for whom the risk of long-term unemployment is substantial and the rest. The labour economics literature has adopted the terms 'outsider' and 'insider' respectively for these two groups: we will generally use 'unskilled' and 'skilled' instead, indicating the overlap with income distribution differences.

It follows that unemployment variation will impact most heavily on the former groups, whereas consumption variation will impact most heavily on the latter. Thus the typical representative agent welfare function will tend to undersetimate the costs of the business cycle to the former group. We treat the welfare of the second group as dependent only on consumption, that of the first only on unemployment. (We will also show averages of the two groups' welfare; but these have no status as welfare measures unless we are willing to give the two groups weights based on some political or other ranking). In terms of modelling behaviour both of our models are aggregative and thus implicitly assume, as is usual with macro models, that any effects of heterogeneity are picked up by the model's coefficients; a full treatment of heterogeneity would involve separating households into two diverse sets of agents with different constraints and behaviour but such a treatment lies beyond the scope of this paper (for examples of models where heterogeneity is embedded in the structure, see Storesletten et al, 2004 and Heathcote, 2005) and we conjecture that our results would not be sensitive to the disaggregation of behaviour as opposed to welfare. That conjecture would be interesting to test in later work. Thus we stay within the usual aggregative macroeconomic framework used for monetary policy evaluation; we extend it only by considering the implications for the welfare of two separate groups of agents.

We will be evaluating monetary regimes on the assumption that they produce the same mean behaviour in response to shocks; hence differences between them purely concern higher moments, of which we only examine the variance (using 2nd order Taylor series expansions). Our method will be to compare welfare rankings of monetary regimes for the unskilled and the skilled. If rankings are different, we will conclude that heterogeneity matters and attempt some assessment of how much.

Much analysis of monetary policy assumes either a lack of indexation altogether or a fixed indexation scheme such as lagged indexing. Yet Minford et al (2003) showed that the reaction of indexation to monetary policy is important in determining what type is optimal. In particular it argued that monetary policy targeting nominal *levels* of variables (such as prices or money) could be superior to those targeting rates of change of those variables (inflation or money supply growth). For analysing this issue they developed a model in which indexation was endogenous, chosen to optimise their welfare by skilled agents who were assumed to be continuously employed. This model is well suited to considering the issue here; in that paper the welfare measure used was a weighted average of the two groups' welfare — here we use the heterogeneous measures.

That model can be considered as a calibrated macro model with a moderate degree of nominal rigidity (from overlapping contracts) related to the extent of indexation. The resulting model is close to the 'New Classical' end of the modelling spectrum. However, to test the robustness of this stylisation, we also look at an estimated forecasting model of the same general type, the Liverpool Model of the UK (Minford, 1980). It would be interesting to know how far the results we obtain would generalise to other models with nominal rigidity and endogenous indexation; but we (and as far as we know others) have been unanble so far to do this work and so it must await future research.

The monetary regimes we consider are:

1. various sorts of (exact) targets for expected (one-period-ahead) outcomes. Each

is implemented via setting the expected money supply for the coming period; the actual money supply is subsequently delivered with an independent stochastic error (a 'trembling hand' which can be interpreted in various ways — e.g. a banking system supply error or an error in current-period setting of a supply instrument such as bank reserves). The targets we consider are for: inflation, money supply growth, the price level and the money supply level. A burgeoning literature has grown up (a partial list is: Bank of Canada, 1994; Berg and Jonung, 1999; Casares, 2002; Duguay, 1994; Fischer, 1994; Hall, 1984; Kiley, 1998; Nessen and Vestin, 2000; Smets, 2000; Svensson, 1999a and b; Vestin, 2000; and Williams, 1999) around the issue of whether prices or inflation (money or its growth rate) should be targeted; under level targeting the level is stationary, under rate of change targeting the level is non-stationary.

2. alternative ways of organising current-period responses to shocks. Specifically, we consider a rigorous interest-rate-control regime where an interest rate target is chosen for the coming period and then exactly adhered to; against a money-supply-control regime as above where the money error is random. This is often referred to as the issue of 'operating procedure'; in a quarterly model this is not quite exact but it is helpful. The issue was first addressed by Poole; and since then there have been a large number of papers assuming that it is interest rates that are controlled by central banks, for example in the manner of the Henderson-McKibbin-Taylor rules (Henderson and McKibbin, 1993; Taylor, 1993). Our reason for reopening this old issue is simply that it acquires a new dimension when indexation is endogenous and also when there are two sets of agents.

3.3 The Models Used

Our two models both assume:

1. competitive markets in labour and output.
2. overlapping wage contracts, with a variable indexation parameter chosen optimally by workers; however, marginal labour supply is always provided to the auction market at an auction supply price.
3. Cobb-Douglas production functions.
4. Monetary policy is implemented via money supply feedback rules (i.e. with the expected money supply being set for the next period in response to current information; actual money supply is then determined by the impact of shocks under the assumed operating procedure, initially taken to be that of money-supply-control). However this assumption is a convenience only; the same rules could be expressed as a feedback from current information to expected future interest rates, with actual interest rates being determined by shocks, again under the assumed operating procedure.

Therefore both models share the familiar labour supply curve (based on a combination of contracted and free labour) and labour demand curve (based on marginal labour productivity); and the aggregate supply curve (from production function and employment) interacts with an aggregate demand curve (from the interplay of money markets, LM curve, and an IS curve).

Two key differences should be mentioned. The calibrated model (henceforth CM) does not allow consumers to access the credit markets; the reason is to create a strong incentive to smooth consumption via the wage contract. The Liverpool Model (henceforth LPM) is an open economy model — here using floating exchange rates — so that, in addition to the relationships already mentioned, it embodies efficient international bond markets (which imply the Uncovered Interest Parity condition, forcing the real interest rate differential into equality with expected real exchange rate change — a constant can also be added for the risk-premium arising from model covariances but this does not affect simulation properties) and a current account equation related to home and world output and the real exchange rate. LPM also assumes that inflows of foreign capital occur flexibly in response to investment needs so that the production function treats the capital stock as endogenous. Hence it can be seen that the two models differ in detail and in the extent of theoretical abstraction rather than in basic approach.

LPM is in essence a less restricted, open economy, version of CM. It is a rational expectations IS-LM model, such as can be derived from a micro-founded model by suitable approximations (McCallum and Nelson, 1999) — thus for example in LPM the IS curve has the expectation of future output in it, the hallmark of this approximation. The model's Phillips or Supply curve assumes overlapping wage contracts as in CM. The labour market underpinning it is explicit and the model solves for equilibrium or natural rates of output, unemployment and relative prices. Thus from a theoretical viewpoint the model could be considered reasonably protected against Lucas' (1976) critique. From the empirical viewpoint, we have found the model's parameters to be rather stable. In recent work a new FIML algorithm developed in Cardiff University (Minford and Webb, 2005) has been used to re-estimate the model parameters: it turns out that the new estimates are little different from the model's original ones, based partly on single-equation estimates, partly on calibration from simulation properties. In terms of forecasting tests, as we discuss next, the model has performed fairly well across a variety of regime changes, not merely on the monetary but also on the supply side of the economy.

LPM has been used in forecasting continuously since 1979, and is now one of only two in that category. The other is the NIESR model, which however has been frequently changed in that 20-year period: the only changes in LPM were the introduction of the explicit natural rate supply-side equations in the early 1980s and the shift from annual data to a quarterly version in the mid-1980s. In an exhaustive comparative test of forecasting ability over the 1980s, Andrews et al (1996) showed that out of three models extant in that decade — LPM, NIESR, and LBS — the forecasting performance of none of them could 'reject' that of the others in non-nested tests, suggesting that LPM during this period was, though a newcomer, at least no worse than the major models of that time. For 1990s forecasts no formal test is available, but forecasting with the LBS model stopped and in annual forecasting post-mortem contests the NIESR came top in two years, LPM in three. Thus we would suggest that LPM has a respectable forecasting record, at least on a par with the only other model available of the general type we seek — viz. micro-founded and suitably estimated. Comparative work on the NIESR model would also be of interest; so far it has not been possible. There are also models in the public sector — those of the Treasury and the Bank of England — but they are not easily accessible as yet with the required back-up of micro-foundations and forecasting record.

Lastly, in respect of simulation properties and use of these for policy analysis, we note that LPM has been extensively used in policy analysis in support of the 'monetarist' and 'supply-side' reforms of the 1980s and 1990s, which are generally considered to have been broadly successful. We therefore suggest that the LPM could be regarded as a suitable vehicle for checking the 'realism' of the policy conclusions we will initially derive from CM.

In order to clarify the two models' structures we list each of them below opposite the categories already used:

Table 3.1: Structures of Both Models

Equation category	RAM equation nos[1]	LPM equation nos[2]
Labour supply/wage contract	A1, A4, A5	B8
Labour demand	A7	B5
Production function, cost equations	A3	B9
IS curve	A6	B14
Investment	A2	B22, B6
Consumption	(=M_{t-1}/p_t via no-credit constraint)	B7
Other	none	B1, B19
Money Demand and supply	A10, A9, A8	B4, exog money supply eq, B11, B12, B13
Open economy:	n.a.	
Capital Account (UIP)		B10
Current account		B2, B3

[1]Full listing in 3.A

[2]Full listing in 3.B

3.4 Targeting Within a Calibrated Model (CM):

The CM model can be organised most simply in terms of aggregate supply (shifted by the productivity shock, ϕ) and aggregate demand (shifted by the money supply shock, m). Monetary targeting then moves planned next period's m so as to produce the target price or money in that period; however the actual m is then delivered with a random error. To do this one solves out for the money supply (equation A10) needed next period to hit the target in the absence of a shock and fixes it to that level. Then a shock is added to the resulting money supply and the model is solved with that shock and the shock from productivity. For the interest-rate-control regime the money supply shock is implicitly forced to be whatever reaction of money would keep interest rates at their planned setting. The planned setting is worked out in a similar way as with the targeting regimes, so the interest rate is solved to give the target value next period. The model's behaviour in response to the two shocks is standard. The key innovation in the model is the finding that from society's viewpoint reducing indexation improves the economy's stability in the face of supply shocks because it both flattens the AS (Phillips Curve) and steepens the AD curve, as illustrated in Figure 3.1 below. The indexation response depends in turn on the *persistence* of the two shocks(Minford et al, 2003): this is in contrast to the usual Fischer-Gray result which depends on the *size* of the shock variances. The reason persistence matters is that indexation is spent with a delay (from the cash-in-advance lag); hence in the presence of temporary shocks to prices it does not pay to index wages because the shock effect on consumption only lasts one period and indexation will produce extra consumption in the following period, which *adds* to the overall variance of consumption. On the other hand if shocks persist, the indexation payment will offset the effects on consumption that persist beyond the first period; hence indexation becomes desirable. Rising indexation steepens the Phillips Curve in a well-known way, in that price surprises now clearly will induce (after period 1) less of an effect on real wages and hence on employment and output. It also flattens the Aggregate Demand curve because the greater responsiveness of wages to prices implies that, given the fixed available money supply (which is required by employers and the government to pay the bill for wages and unemployment benefits), rising prices induces a greater reduction in employment.

The resulting intersections for a supply shock as shown at A (high indexation) and B (low indexation). Thus the drop in indexation is stabilising to both employment and prices in the face of a supply shock. Of course for a money (demand) shock the result is greater employment instability, though probably less price instability; however money is a policy-controlled variable and if the policy error in setting it can be kept within limits then supply shocks will matter most.

Though the focus in this paper is on the separate welfares of our two groups, it is useful in the discussion to refer also to aggregate measures; for example when both groups gain it is helpful to measure by how much on average — arbitrary as that average of course must be, it is like an index. For this purpose we use two measures. The first, Welfare #1, is the standard measure used in representative agent models, the Constant Relative Risk

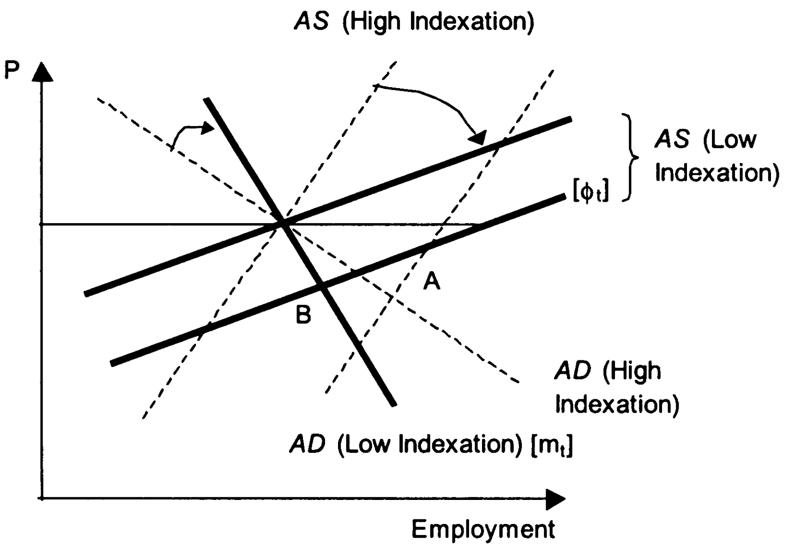

Figure 3.1: The effect of reduced indexation on slopes of AS and AD curves [ϕ_t = productivity shock; m_t = monetary shock]

Aversion utility function with Cobb-Douglas preferences across consumption and leisure:

$$U_t = \sum_{\tau=t}^{\infty} \delta^{\tau-t} \left\{ \frac{(c_\tau^{\nu}[\lambda + a_\tau]^{1-\nu})^{1-\rho} - 1}{1-\rho} \right\}$$

where

$$c_t = \frac{\overline{W}_{t-1}}{p_t}(1 - a_{t-1}); \lambda = 1$$

implying that leisure time is equal to working time when unemployment a_t is zero. We set $v = 0.7$, based on the marginal valuation of leisure at wages net of unemployment benefit. Because households get unemployment benefit on their spells of eligible unemployment, a_t, this implies that their choice is distorted; they choose leisure (l, which we in practice set at unity, is the ineligible part of leisure) in response to the differential between wages and benefits. But then of course they must pay for the benefit burden via taxes; the present discounted value of this tax burden is the same as this benefit bill and so we deduct this from their consumption to obtain total private utility.

The second measure, Welfare #2, is simply the inverse of a weighted average of the two variances, of consumption and unemployment, with similar weights, 0.7 for consumption and 0.3 for unemployment.

We examine the relative merits of various forms of monetary targeting. The main current targeting choice of central banks is inflation targeting; we therefore make this the benchmark regime against which to measure alternatives. The first with which we compare it is price-level targeting. A target rule chooses a money supply for next period that forces the expected inflation, or price-level respectively, to be on target in this next period; this money supply plan is however executed with an error, the model's 'monetary shock' (which can in practice be interpreted as a shock on either the supply or demand side of the money market; it is the model's demand shock). There is thus no current response of money supply to shocks; nor any implied interest rate smoothing in the current period — we defer such issues to the next section.

Our results can be summarised simply. Inflation-targeting generates a high degree of indexation. When price-level targeting is undertaken but indexation is assumed constant, welfare falls, because the variability of unemployment rises sharply. But when indexation is allowed to change endogenously, it drops to nil and the result is a rise in welfare, with the variance of consumption down markedly and that of unemployment down substantially.

What we notice in Table 3.2 comparing inflation and price-level targeting is that both variances fall as we move to price-level targeting, once allowance is made for the endogenous response of indexation. This response eliminates indexation which means that the Phillips Curve flattens causing unemployment to respond little to the current productivity shock.

However, it is worth noticing that if indexation for some reason does not respond, then there is a marked difference in the two variances: unemployment variance shoots up while consumption variance falls on the move to price targeting (naturally as real wages are smoother with the price level being held to its expected trajectory). Hence what we see from Table 3.2 that CM's properties are very much in line with the usual views

Table 3.2: Price-level and inflation targeting in CM

standard error in parenthesis+					
Inflation-target = 100	Indexation (%)	Welfare #1	#2	Var (cons.)	Var (unemp.)
Inflation-targeting	71	100	100 (3)	100 (3)	100 (3)
Price-level targeting (holding indexation fixed)	71	98	96	99	119**
Price-level targeting (indexation endogenous)	0	102	125	96	69**

+standard error of Montecarlo sample variance = est. variance $\times\sqrt{\left(\frac{2}{n}\right)}$ where n is the number of replications (here 2000) — source Wallis, 1995

Definition: #1 is the standard CRRA formula in the text; #2 is the weighted average (weight on consumption, of employed $= 0.7$, on unemployment $= 1.0$;the latter weight includes . the effect of unemployment on consumption) of the two (inverted) variances

* significant at 10% level;** significant at 1% level

of macroeconomists under the usual assumption that indexation is constant: viz. that targeting the price level would destabilise employment and output, even if the stability of prices would indeed yield benefits to those with long term, nominal, or partly nominal, contracts, as here exemplified by workers with wage contracts that are not fully indexed. (The details of how CM generates this result are unravelled to a reasonable extent in 3.C, using a simplified linear version of CM).

Of course the endogenous response of indexation should occur; but it could take some time to occur (especially if the shift of regime is not at all clearly communicated). What we are seeing here therefore is a potential conflict of interest between the skilled and unskilled groups. The skilled welcome price targeting because it smooths consumption; the unskilled do not because it worsens employment variability.

Money targeting is not helpful to real wage smoothing; the reason is that unlike price level targeting it does not remove the persistent effect on prices (and so on real wages) of the productivity shock (in fact when indexation remains fixed it slightly increases the effect of productivity persistence on the real wage). But it does reduce the variance of unemployment even when there is no response of indexation, as can be see in Table 3.3.

Table 3.3: Money-level and Money-growth targeting in CM

standard error in parenthesis+					
Inflation-target = 100	Indexation (%)	Welfare #1	#2	Var (cons.)	Var (unemp.)
Money-growth-targeting (=inflation targeting in this model)	71	100	100 (3)	100 (3)	100 (3)
Money-level targeting (holding indexation fixed)	71	100.6	102.8	102	94**
Money-level targeting (indexation endogenous)	37	104	135**	100	56**

+standard error of Montecarlo sample variance = est. variance $\times\sqrt{\left(\frac{2}{n}\right)}$ where n is the number of replications (here 2000) — source Wallis, 1995

Definition: #1 is the standard CRRA formula in the text; #2 is the weighted average (weight on consumption, of employed = 0.7, on unemployment = 1.0;the latter weight includes . the effect of unemployment on consumption) of the two (inverted) variances

* significant at 5% level;** significant at 1% level

The reason is that the persistence in the money supply shock is eliminated and hence the aggregate demand curve is less variable. As indexation falls and the Phillips Curve flattens this effect becomes more important. Also the effect of productivity shocks is dampened on both employment and prices. Hence the additional move to lower indexation makes the money-level rule more stabilising, just as it did with the price-level rule.

If we look at the two policies from the viewpoint of average welfare, then we find that money targeting is superior before indexation has adjusted — confirming the majority macroeconomist viewpoint that price targeting is too rigid in driving prices back to their target track. Money targeting however is flexible enough to deliver some benefit overall compared with inflation targeting; it slightly destabilises consumption but markedly stabilises employment. After indexation has adjusted, it turns out that the two policies deliver rather similar improvements in general welfare.

But we also need to compare money with price level targeting from the viewpoint of different agents. First, we see that under conditions where indexation has not yet changed, money targeting is preferred by unskilled workers, whereas price targeting is preferred by skilled workers. Second, even once indexation has changed, money targeting is still preferred by the unskilled, while price targeting is still preferred by the skilled. The fact that money targeting is better liked by those most vulnerable to the economic cycle underlines its 'compromise status' between pure price stabilisation and pure employment stabilisation; in line with this it induces the elimination of only half the indexation we start off with under inflation targeting.

3.5 Targeting Within the Liverpool Forecasting Model of the UK (LPM)

As part of our robustness check, we now turn to LPM. Our method is as with CM to run our monetary rules in LPM under stochastic simulation. We shock the full range of endogenous and exogenous errors, exactly as in the model specification. We adopt the same expressions to evaluate welfare, the only difference being that in LPM we use non-durable consumption in place of total consumption, since LPM has no measure of the latter (in it durable consumption is included with other investment). The model's wage equation is written in terms of the real wage reacting to the real benefit rate and to unemployment, which are the auction wage components (implicitly the auction wage element has a weight of 0.2), and negatively to the difference of the price level from the average forecast of it at the times of wage contracting, then positively to this difference lagged.

For our purposes here we adapt it as follows:

$$\overline{W_t} = vP_t + wE_{t-j}P_t + \alpha(P_t) + w^* \ldots = (\alpha + v)(P_t - E_{t-j}P_t) + E_{t-j}P_t + w^* \ldots$$

Now we lag the auction and indexed elements two periods because of a delay due to the firm's internal checking procedures in adjusting pay to the unexpected change in the price level and obtain the real wage as:

$$\overline{W_t} - P_t = -(P_t - E_{t-j}P_t) + (\alpha + v)(P_{t-2} - E_{t-j-2}P_{t-2}) + w^* \ldots$$

Hence the two-period-lagged term carries the extent of real wage protection. It is this part that is adjusted endogenously by the employed to minimise the variance of their real wage.

The results within LPM are about as favourable to price-level targeting as in the calibrated model. Again, they show that under inflation-targeting there is a high degree of indexation and that this would drop to nil under price-level targeting. Similarly, too, they show that if indexation is assumed endogenous, welfare will rise significantly if price-level targeting is introduced; in LPM the variance of consumption falls more and that of unemployment falls less than in the calibrated model but both fall significantly.

However there is a crucial difference: when indexation is held fixed, the variances behave very much the same in LPM as when indexation is endogenous. There is still a substantial gain over inflation targeting, revealing that the mechanisms at work cannot be the ones in CM, whereby the Aggregate Demand and Supply curves' slopes are changed by indexation.

The first reason appears to be that the great improvement in stability both for consumption and unemployment between rows 1 and 2 comes about because price-level targeting greatly reduces the variability of private *wealth* (it reduces the variance of wealth by 8%, regardless of the degree of indexation): price-level targeting makes the real price of bonds more stable because it makes the variability of the price level so much smaller (thus future bond prices are set in nominal terms by the nominal rate of interest which in turn depends on the real rate plus the expected rate of inflation; but future *real* bond prices are additionally dependent on the future price level). In LPM private wealth has strong demand effects on private consumption and investment; thus dampening its variability

Table 3.4: Inflation and price-level targeting in LPM

standard error in parenthesis+ Inflation-target = 100	Indexation (%)	Welfare #1	#2	Var (cons.)	Var (unemp.)
Inflation-targeting	80	100	100 (1.3)	100 (1.3)	100 (1.3)
Price-level targeting (holding indexation fixed)	80	102.3	119**	81**	90**
Price-level targeting (indexation endogenous)	0	102.4	120**	81**	89**

+standard error of Montecarlo sample variance = est. variance $\times\sqrt{\left(\frac{2}{n}\right)}$ where n is the number of replications (here 183) — source Wallis, 1995

Definition: #1 is the standard CRRA formula in the text; #2 is the weighted average (weight on consumption, incl. unemployed's = 0.7, on unemployment = 0.3) of the two (inverted) variances.

* significant at 5% level

** significant at 1% level

dampens an important demand shock. We can demonstrate this by redoing the stochastic simulations without wealth effects; we find that under price level targeting with the same 80% indexation as inflation targeting the variance of consumption is 10.2% higher than under inflation targeting and the variance of unemployment 6.2% higher, very much in line with the familiar macroeconomists' intuition that having to reverse inflation shocks subsequently to hit a price level target is destabilising to the economy. In LPM this intuition is overridden by the destabilising wealth effects of prices, which price level targeting reduces.

Second, the indexation mechanism in LPM does indeed work (a little) to dampen the effects of supply shocks which are the main source of shocks in LPM; thus if we simulate the price-level target regime with 80% indexation and then again with zero indexation for supply shocks only, we find that the zero indexation reduces the variance of consumption by 2% and that of unemployment by 1%. But this plainly is not a powerful effect. (For demand shocks too the move to indexation is slightly favourable — comparing zero with 80% indexation there is no difference for consumption variance and a 2.5% reduction in unemployment variance. But within LPM, demand shocks also have a 'supply' element because via the exchange rate effect they enter the Phillips Curve so the sharp distinction of CM is not present). Thus in effect indexation as such (the difference between rows 2 and 3 for Table 3.4) has very little effect within LPM — confirming that LPM is a model very much at the 'New Classical' end of the spectrum, that is with little effect of nominal rigidity. It does however have powerful wealth effects (notably of government bonds), thus it is highly 'non-Ricardian', that is it does not exhibit Ricardian equivalence under which a bond-financed tax cut would raise savings by the tax cut, leaving consumption unchanged.

In sum what the Liverpool Model shows pre-eminently is the importance of wealth shocks to demand and the way in which price-level targeting helps to make the economy more stable by dampening these.

When we turn to a comparison of money targeting with price targeting, we find that money targeting relatively stabilises nominal and real interest rates, real investment and total wealth, but it relatively destabilises prices and inflation and hence the real value of financial wealth (nominal bonds). From Table 3.5 we see that the variance of unemployment and output rise as we switch from price- to money-targeting while that of consumption falls. The key to these differences lies in the behaviour of the expected future price level which in an IS/LM framework enters the IS curve in terms of its percentage difference from the current price level. Under price-level targeting expected future prices do not move whereas under money-level targeting they are positively correlated with current prices because any permanent supply shock will continue to affect prices in the same direction in the next period. Hence under money-targeting expected inflation varies less which disturbs the IS curve less. This reduced IS variability under money-targeting implies less interest rate variability, real and nominal too; and also less variability in the real capital stock. However, this also leads to a reduction in real exchange rate variability via uncovered interest parity; this means less dampening of net trade volume variability (consider a rise in world trade, the main such source of variance; under money-level targeting, it shifts IS less rightwards, generating less of a rise in real interest rates and so in the real exchange rate which would counteract the rise in net trade). Thus of the three exogenous sources of output demand variability, consumption's and investment's fall because of reduced interest rate and wealth volatility but net trade's goes up by more, as does thus also output and employment volatility rise.

Aggregate welfare under price- and money-targeting are roughly the same. However when we turn to the welfare of the two groups, we find that under LPM the preference ordering of both between price and money level targeting is reversed compared with CM: now the employed/skilled prefer money targeting while the unemployed/unskilled prefer price targeting.

Table 3.5: Inflation-, price- and money-targeting in LPM

standard error in parenthesis+ Inflation-target = 100	Indexation (%)	Welfare #1	Welfare #2	Var (cons.)	Var (unemp.)
Price-level-targeting (indexation endogenous)	0	102.4	120**	81**	89**
Money-level-targeting (indexation endogenous)	40	102.7	122**	68**	97*

+standard error of Montecarlo sample variance = est. variance $\times\sqrt{\left(\frac{2}{n}\right)}$ where n is the number of replications (here 183) — source Wallis, 1995

Definition: #1 is the standard CRRA formula in the text; #2 is the weighted average (weight on consumption, incl. unemployed's = 0.7, on unemployment = 0.3) of the two (inverted) variances.

* significant at 5% level ** significant at 1% level

Contrasting LPM with CM, we find that the major role of wealth effects in LPM, entirely absent in CM, gives a rather different perspective on monetary rules. In LPM the endogeneity of wage contracting is of little importance; even if it does change one transmission mechanism, it is minor in its overall impact on variances. Instead we find that the key source of macro variability is the variability in nominal variables, themselves primarily controlled by monetary policy; when monetary policy increases the stability of these nominal variables, the macro economy too is less variable.

3.6 Should Interest Rates or the Money Supply be Controlled as the Operating Instrument?

We come last to a well-worn issue of monetary policy — whether monetary policy should control (i.e. keep fixed) interest rates in the very short run, operating, period (of say a month ahead) or should control the money supply. The seminal work of Poole (1970) noted that the answer depended, within the IS/LM model, on the relative variances of the IS and LM shock. The issue is how stable the Aggregate Demand curve can be kept in response to the 'nuisance' shocks in the IS and LM curves. Instability in the AD curve will spill over into prices and output and so into the welfare function used here.

We can analyse both CM and LPM in these terms. Notice that because the IS curve responds to $(E_t p_{t+1} - p_t)$ it potentially matters which *targeting* regime is being followed: thus under inflation targeting $(E_t p_{t+1} - p_t)$ will not move whereas under price-level targeting $E_t p_{t+1}$ will not move so that $(E_t p_{t+1} - p_t)$ moves by the full amount of $-p_t$. Under money-level targeting $(E_t p_{t+1} - p_t)$ moves by less than this amount because $E_t p_{t+1}$ will vary directly with but less than p_t. So each targeting regime must be considered separately.

3.6.1 Interest-Rate-Control Within CM

Within CM, an important feature is a very flat IS curve. This can be seen from the large size of the parameter on the real interest rate in equation A2 (for the capital stock). In linearised form this equation (see 3.C) is:

$$K_t = 1.11 \left\{ \frac{k(1-\mu)(1-T_o)}{r_0} \right\} \left\{ (d_t - \left[\frac{r_t}{r_o} \right] \right\} \qquad \text{(A2)}$$

The relevant parameter is therefore $-1.11 \left\{ \frac{k(1-\mu)(1-T_o)}{r_0} \right\} \left\{ \left[\frac{1}{r_o} \right] \right\}$Notice the denominator is $(\frac{1}{r_0})^2$ which is a very large number owing to the small size of r, the real interest rate, whose units are fractions per period. Now note that $r_t = R_t - (E_t p_{t+1} - p_t)$.

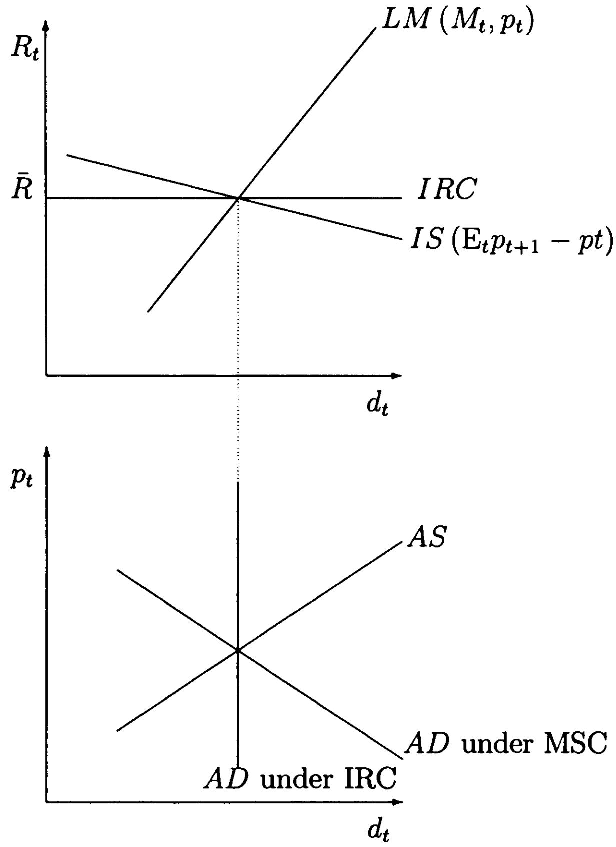

Figure 3.2: The Poole set-up illustrated for CM under inflation-targeting; MSC= money supply control, IRC= interest rate control.

Under the inflation targeting regime, which we consider first, $(E_t p_{t+1} - p_t)$ is kept at the target level by the monetary rule. This implies that fixing nominal interest rates, R_t, will also fix real interest rates, r_t. Also movements in the price level will not shift the IS curve. Thus the Aggregate Demand Curve will slope vertically under inflation targeting and interest-rate control (IRC). Figure 3.2 illustrates CM under inflation targeting. However under money supply control (MSC) the AD curve will slope normally because the LM curve will react to prices. Finally we note that the IS curve is shifted in CM by productivity shocks in a real business cycle manner, since investment reacts sharply to productivity prospects.

IRC implies that IS curve shocks are unaffected by movements in prices because these are offset by equal movements in future prices; nevertheless the IS curve is so flat that only a very small interest rate change is produced and thus effectively the IS barely shifts at given interest rates; thus shifts in the AD curve are very small. By contrast with MSC the LM curve shifts with random movements in money supply which introduces larger shocks to the economy. In Poolean terms, here shocks to the money supply dominate IS shocks in their impact on the economy. Table 3.6 below shows IRC or MSC under CM with inflation targeting.

Table 3.6: IRC or MSC under CMwith inflation targeting

standard error in parenthesis^{+} Index: Money = 100	Indxtn	Welfare #1	#2	Var (cons.)	Var (unemp.)
Money Supply Control, MSC	71	100	100 (3)	100 (3)	100 (3)
Interest Rate Control, IRC	71	101.5	107.4*	96	91

$^{+}$standard error of Montecarlo sample variance = est. variance $\times\sqrt{\left(\frac{2}{n}\right)}$ where n is the number of replications (here 2000) — source Wallis, 1995

Definition: #1 is the standard CRRA formula in the text; #2 is the weighted average (weight on consumption, of employed = 0.7, on unemployment = 1.0;the latter weight includes . the effect of unemployment on consumption) of the two (inverted) variances

* significant at 5% level;** significant at 1% level

When the monetary rule is a price-level one, $E_t p_{t+1}$ is now fixed; thus any movement in p_t represents an equal movement in the real interest rate with a very large effect shifting the IS curve. Thus the AD curve here is very flat mirroring this effect of prices on the IS curve. Now IS curve shocks, combined with a flat AS curve because of zero indexation, will produce large swings in output but prices will be heavily stabilised (as they must be to keep the real, and so the nominal, interest rate constant). Hence IS shocks dominate in the Poole sense. Table 3.7 below reveals that the variance of unemployment rises markedly while price variability falls, stabilising the real wage and so consumption. Overall welfare is reduced, as is that of the unskilled while that of the skilled rises.

Table 3.7: IRC or MSC under CMwith price-level targeting

standard error in parenthesis+					
Index: Money = 100	Indxtn	Welfare		Var	Var
		#1	#2	(cons.)	(unemp.)
Money Supply Control, MSC	92	100	100	100	100
			(3)	(3)	(3)
Interest Rate Control, IRC	92	100.1	97	98	107**

* significant at 5% level;** significant at 1% level

Essentially the same occurs under money-level targeting — Table 3.8. The main difference from price-level targeting is that now expected future prices only change with productivity shocks; under IRC money shocks have no effect and so only productivity shocks matter. These, being entirely permanent, induce far greater persistence in prices and so far greater indexation, which in turn sharply increases the effect of productivity shocks on output and employment.

Table 3.8: IRC or MSC under CMwith money-level targeting

standard error in parenthesis+					
Index: Money = 100	Indxtn	Welfare		Var	Var
		#1	#2	(cons.)	(unemp.)
Money Supply Control, MSC	37	100	100	100	100
			(3)	(3)	(3)
Interest Rate Control, IRC	78	99.3	68**	95	182**

+standard error of Montecarlo sample variance = est. variance $\times\sqrt{\left(\frac{2}{n}\right)}$ where n is the number of replications (here 2000) — source Wallis, 1995

Definition: #1 is the standard CRRA formula in the text; #2 is the weighted average (weight on consumption, of employed = 0.7, on unemployment = 1.0;the latter weight includes . the effect of unemployment on consumption) of the two (inverted) variances

* significant at 5% level;** significant at 1% level

Summarising, we could say that interest rate control also controls prices more. This is good for the skilled, smoothing their real wages. But it destabilises employment and output, which is bad for the unskilled on the margins of the labour market.

3.6.2 Interest-Rate-Control in LPM

The interpretation of LPM results in Poolean terms is similar, except that it has a more standard IS curve with a much more modest interest-rate elasticity, simply because it does not have the fierce real business cycle reaction of CM but rather a looser stock-adjustment reaction of the investment to demand and monetary conditions. Hence LPM is less sensitive to whether the monetary rule is for inflation or price-level targeting. Within LPM IS shocks have a higher variance than LM shocks (remembering the model uses the monetary base rather than any wider definition of money, because of the concern with financial deregulation). It follows in the standard manner of Poole that there will be greater AD instability which will also show up in greater instability of output and prices (and so of both real wages and financial wealth). However the model tends to stabilise consumption since price and output rises are positively correlated; thus a rise in output lowers financial wealth, with the effects of the latter on consumption more than offsetting those of output. This is the pattern that shows up in the simulations of Interest Rate Control below; unemployment, output and price variability all rise but consumption variability falls.

Table 3.9: IRC or MSC under LPM with inflation targeting

standard error in parenthesis^{+} Index: MSSetting = 100	Index	Welfare #1	#2	Var (cons.)	Var (unemp.)
Money Supply Setting	80	100	100 (1.3)	100 (1.3)	100 (1.3)
Interest Rate setting	80	100.8	100.3	97*	106**

$^{+}$standard error of Montecarlo sample variance = est. variance $\times\sqrt{\left(\frac{2}{n}\right)}$ where n is the number of replications (here 164; note lesser number because some runs would not solve under both MSC and IRC) — source Wallis, 1995 Definition: #1 is the standard CRRA formula in the text; #2 is the weighted average(weight on consumption, incl. unemployed's = 0.7, on unemployment = 0.3) of the two (inverted) variances.
* significant at 5% level** significant at 1% level

The one exception to this is the case of money-supply-targeting, where LM shocks

Table 3.10: IRC or MSC under LPM with price-level targeting

standard error in parenthesis+					
Index: MSSetting = 100	Index	Welfare #1	#2	Var (cons.)	Var (unemp.)
Money Supply Setting	0	100	100 (1.3)	100 (1.3)	100 (1.3)
Interest Rate setting	0	99.8	98.8	100	104**

+standard error of Montecarlo sample variance = est. variance $\times\sqrt{\left(\frac{2}{n}\right)}$ where n is the number of replications (here 164; note lesser number because some runs would not solve under both MSC and IRC) — source Wallis, 1995 Definition: #1 is the standard CRRA formula in the text; #2 is the weighted average(weight on consumption, incl. unemployed's = 0.7, on unemployment = 0.3) of the two (inverted) variances.
* significant at 5% level** significant at 1% level

have a higher variance than IS shocks. In this case when the money supply is 'controlled' any independent growth rate of the money supply above its target rate is immediately followed by a growth rate below the target by an equal amount; this variability appears to dominate that from the IS shocks. Hence here output and unemployment are more variable under Money Supply Control, while consumption is less variable because of the same mechanism as above.

Table 3.11: IRC or MSC under LPM with money-level targeting

standard error in parenthesis+					
Index: MSSetting = 100	Index	Welfare #1	#2	Var (cons.)	Var (unemp.)
Money Supply Setting	40	100	100 (1.3)	100 (1.3)	100 (1.3)
Interest Rate setting	40	95.4**	93.0**	112**	97*

+standard error of Montecarlo sample variance = est. variance $\times\sqrt{\left(\frac{2}{n}\right)}$ where n is the number of sample observations (here 10824; note lesser number because some runs would not solve under both MSC and IRC) — source Wallis, 1995 Definition: #1 is the standard CRRA formula in the text; #2 is the weighted average(weight on consumption, incl. unemployed's = 0.7, on unemployment = 0.3) of the two (inverted) variances.
* significant at 5% level** significant at 1% level

When we review the effects on different groups we find that the effect on each group depends on whether the target regime is price/inflation or money-level. The employed prefer IRC under the first but MSC under the second, and vice versa for the unemployed. This leads finally into a discussion of how we might use these results to guide the choice of regime.

3.6.3 Regime Choices Under Robustness Criteria:

In robustness studies it is often suggested that one should avoid policies that produce extreme bad results in any model (Kilponen and Salmon, 2004). The principle — a descendant of Roy's 'safety first principle' — is a way of knocking out a 'potentially dangerous' policy. In this context we are concerned about heterogeneity both of models and of social groups. One can think of this in political terms, from the viewpoint of a policy-maker: the two groups represent the two main sets of voters on whom the macro economy has effects; while the two models represent the possible spectrum of model uncertainties. One can also think of it in welfare terms as a way of seeking to satisfy a practical version of the Pareto principle — that there should be no (serious) losers. This indicates we should look for regimes that badly affect either group under either model, using the existing regime (inflation-targeting under interest-rate-control) as the benchmark. Table 3.12 shows all regime/model combinations relative to this benchmark.

It is clear that if we take the safety principle literally, we must rule out all changes of regime except one. The price-level regime would raise the variance of unemployment sharply under CM if indexation did not adjust or did so very slowly. Similarly money-targeting would raise it sharply under CM under interest rate control. Inflation targeting if it shifted to money supply control would do the same under CM. This only leaves money-targeting under money supply control.

If one is willing to assume that indexation will adjust in the manner predicted by the models then one reaches a similar result but by a different argument. Price-level targeting would then be disaster-free under both MSC and IRC, while money targeting would be disaster-free under MSC. Deciding between these two turns out to depend on which

Table 3.12: Comparing welfare and variances for various combinations (figures taken from sample of 2000 for CMand 10824 for LPM)

Inflation-targeting under interest-rate-control=100								
	RAM(se=3)					LPM(se=1.3)		
	Inflation	P-level optim. indxn	fix indexn	M-level optim. indxn	fix indexn.	Inflation	P-level	M-level
Total welfare:								
MSC	93	117	83	125	96	100	110	124
IRC	**100**	114	83	93	93	**100**	106	115
Var Unemp								
MSC	110^+	75	131^+	62	103	94	84	90
IRC	**100**	81	137^+	113^+	113^+	**100**	87	88
Var Cons:								
MSC	105	100	104	105	107	103	94	77
IRC	**100**	98	96	99	99	**100**	97	86

$^+$ denotes extreme bad variance, interpreted as 10% or more over the benchmark.

model one uses: under CM the employed prefer price-targeting with IRC the unemployed money-targeting (with MSC) but under LPM the unemployed prefer price-level targeting with MSC, the employed money-targeting (with MSC). Hence neither group has a clear preference for either regime. One might in these circumstances take the disaster-free regime which produces the best average welfare across both models: this (again) is money-targeting with MSC.

This regime represents in this context a compromise between price-level targeting and inflation targeting, in that price targeting produces too stark a contrast with the existing benchmark. It also represents a shift away from interest-rate control to money supply control; this occurs because of the switch in targeting regime, in the sense that MSC is dangerous under inflation targeting whereas IRC is dangerous under money-targeting for reasons discussed earlier to do with the different ways expected inflation is formed. Thus we find a 'back to the future' result here: monetary policy should revert to money supply control under a regime of targeting the path of the money supply.

3.7 Conclusions

We looked at the operation of monetary rules both within a calibrated model and within a 'live' forecasting model of the UK, and in both models we distinguished between two groups of agents, the (usually) employed and the (often) unemployed, whom we identified respectively with skilled and unskilled workers. Our aim was to see how allowing for such heterogeneity both in models and in groups could matter for the choice of monetary regime. We found that heterogeneity did matter, in the sense that certain model-policy combinations could cause harm particularly to the unskilled group and therefore would prudently be avoided either from a welfare or a political viewpoint. We concluded that targeting the level of the money supply within an operating system of money-supply-control is the dominant monetary regime. It is both the only regime that strictly avoids a disaster to any group and it is also the one that delivers the highest average welfare across both models and groups.

One possible limitation of our results is that we have tackled the modelling issue by retaining aggregate functions in the models while identifying group welfare recursively — thus the groups may be differently affected, but aggregate behaviour is unaffected by this difference.

There are of course other limitations: we have not investigated possible variations in policy (for example our targeting has all been assumed to be strict, that is no temporary deviations are allowed for in future plans) or in modelling issues (for example money velocity is stable, apart from the current random error) or in models (many other models can be considered). Thus our results should be considered as preliminary in content and methodologically illustrative.

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3.A The Calibrated Model (CM)

The model has two exogenous shocks driving it, a monetary (demand) shock, m_t, to the money supply presumed to originate from monetary policy, and a supply (productivity) shock, ϕ_t. The productivity shock is (rather naturally) modelled as a random walk throughout. Of course whether the money supply shock is transitory or permanent depends on the monetary rule; if it targets for example the level of money it will be transitory, if it targets the money supply growth rate, it will be turned into a random walk. The authors then asked whether the monetary regime should target the growth rate or the level of the money supply; or of prices? They suggested that these choices appear in an unfamiliar light when indexation is endogenous. When the monetary regime moves to a price level rule with exogenous stationary money supply shocks, the aggregate supply curve flattens (as we have seen already above in our Phillips Curve set-up) and the aggregate demand curve steepens, generating a high degree of macro stability (i.e. in the face of supply shocks) provided that money supply shocks themselves are low-variance and stationary.

The representative household is assumed to be entirely liquidity-constrained; this assumption emphasises the importance of the contract choice, since a choice that minimises the variance of the spendable real wage is therefore identical with one minimising the variance of the employed agent's consumption. In a more realistic model with consumption smoothing this motive would have been implemented by including some transactions cost on smoothing, thus providing a motive for smoothing the real wage itself; however, this involves greater complexity than the stark assumption made that the transactions costs are in effect insuperable.

The household is embedded in an environment of profit-maximizing competitive firms which on a large proportion of their capital stock face a long lag before installation (a simple time-to-build set-up) and a government that levies taxes and pays unemployment benefits (which distort households' leisure decisions and introduce a 'social welfare' element into monetary policy). Firms and governments use the financial markets costlessly and settle mutual cash demands through index-linked loans; since there is no binding cash constraint on these agents, these loans are assumed to be unaffected by the imperfections of the price index which are short term in nature. This model is too simplified in many ways to match the data of a modern economy whether in trend or dynamics; however its focus is purely on the wage contract decision and its simplicity is justified in terms of its ability to match the OECD facts about wage contracts.

In calibrating the model the authors chose parameters perceived as plausible for modern OECD economies. The contract length is set at 4 quarters; the elasticity of leisure supply (σ) at 3; the share of stocks and other 'short-term' capital (k) at 0.3; the average life of other capital at 20 quarters; the share of labour income in value-added (μ) at 0.7 (the production function is Cobb-Douglas); the elasticity of the official price index to unanticipated inflation (c) at 0.2 (implying that a 1% unexpected rise in inflation would result in a 0.2% temporary overstatement of the price level faced by the representative consumer). The initial values assume 10% unemployment; a capital-output ratio of 6; an average (=marginal) tax rate of 0.10; a real interest rate of 5%.

The government is assumed to smooth both the tax rate and the growth rate of the money supply by borrowing (from firms). Nevertheless it cannot avoid noise in its money supply setting — the source of this could be its inability to monitor the money supply quickly or even at all (for example in the USA the use of dollars by foreigners around the world makes it impossible to know what the domestic issue of dollars is).

Money supply raises prices in the long run, and in the short run also raises output, with persistence extending up to 15 quarters but with most effect over after 10. In the high-indexed case there is less real effect and less persistence than in the high-nominal case.

These fairly standard properties stem from the model's deliberate drawing on elements that have been shown by past work to be useful in explaining the business cycle and also natural rates as discussed for example by Parkin (1998), though he notes we are still some way from building dynamic stochastic general equilibrium models that can fully explain the business cycle. The elements here include: time-to-build investment, cash-in-advance, nominal contracting (as noted above), household liquidity constraints, and (on the natural rate side) the influence of unemployment benefits on labour supply. With suitable country-by-country calibration one would expect to be able to model OECD countries' business cycle and natural rate experience with at least some modest success.

Minford et al (2003) found that in the face of stationary productivity and money supply shocks indexation would be minimal with only a slight tendency to rise as the variance of money shocks rose dramatically. However when shocks to either became highly persistent indexation to prices or to their close competitor, auction wages, (which together we term 'real wage protection') become large, becoming largest when both shocks are persistent. The reason was that productivity shocks would disturb prices and so the real worth of nominal wage contracts; indexation was of little use in remedying this disturbance if it was temporary because by the time the indexation element had been spent the shock would have disappeared, but with a permanent disturbance indexation can help offset it with a lag. If into this already-indexed world of persistent productivity shocks, monetary persistence is also injected, indexation rises further, to help alleviate the increased disturbance to real wages. This higher indexation also helps to alleviate the instability in unemployment which accompanies the greater shock persistence of money — the point being that this persistence induces persistence in the economy's departure from its baseline and so disturbs unemployment too for longer.

The authors looked at experience in the OECD in the 1970s where it is well-known that real wage protection was substantial; their calibrated model, when estimated variances and persistence of money and productivity shocks were fed into it, predicted high protection in all countries they could cover, apparently in line with the facts. They also found, contrary to much casual comment, that there was little evidence of any diminution of real wage protection in the 1990s; the model also predicted as much, for even though the variance of money supply shocks fell by then, their persistence remained essentially unchanged.

A1 Supply of work

$$a_t = a_c \cdot \left(W_t / \left(b_t \cdot P_{t-4}\right)\right)^{-\sigma} \cdot \varepsilon_t$$

A2 Demand for capital goods

$$K_t = (1-k) \cdot (1-\mu) \cdot E_{t-20}\left[d_t \cdot (1/R_t) \cdot (1-T_t)\right] + k \cdot (1-\mu) \cdot d_t \cdot (1-T_t) \cdot (1/r_t)$$

A3 Output function

$$d_t = \phi_t \cdot K_t^{(1-\mu)} \cdot \{(1-a_t) \cdot N\}^{\mu}$$

A4 Wage rate, solved for W_t

$$\overline{W_t} = (1-v-w) \cdot W_t + v \cdot E_{t-4}\left[W_t/P_t\right] \cdot P_t + w \cdot E_{t-4}\left[W_t\right]$$

A5 Official price index

$$\ln(P_t) = ln\,(p_t) + c \cdot \left(\ln(p_t) - \ln\left(E_{t-1}\left[p_t\right]\right)\right)$$

A6 Goods market clearing, solved for r_t after substituting for K_t from Eqn.2

$$d_t = M_{t-1}/p_t + K_t - K_{t-1}$$

A7 Labour market clearing, solved for p_t

$$N \cdot (1-a_t) = \left(\mu \cdot d_t \cdot (1-T_t) \cdot p_t\right) / \overline{W_t}$$

A8 Money market clearing, solved for $\overline{W_t}$

$$M_t = N\{\overline{W_t} \cdot (1-a_t) + b_t \cdot P_{t-4} \cdot a_t\}$$

A9 Efficiency

$$R_t = E_t\left[f(r)\right]^{1/20} - 1 \; ; \; f(r) = \Pi_{i=1}^{20}\left(1 + \tfrac{r_{t+i}}{4}\right)$$

A10 Money supply

$$M_t = \overline{M_t} + m_t$$

A11 Government budget constraint

$$b_t^g = \left(M_{t-1} - M_t + N \cdot B_t \cdot P_{t-4} \cdot a_t - d_t \cdot p_t \cdot T_t\right)/p_t + \left(1 + \tfrac{r_{t-1}}{4}\right) \cdot b_{t-1}^g$$

A12 Firm's budget constraint

$$d_t \cdot (1-T_t) = K_t - K_{t-1} + \left(\overline{W_t} \cdot (1-a_t) \cdot N\right)/p_t + b_{t-1}^p \cdot \left(1 + \tfrac{r_{t-1}}{4}\right) - b_t^p$$

Notes: 1. By Walras's Law the bond market clearing equation, $b_t^p + b_t^g = 0$, is redundant.

2. To normalise the variables d_t, K_t, r_t, p_t and $\overline{W_t}$ to their base run values constant factors were applied to the right-hand sides of the following equations in their solved form: A2 1.11 (multiplicative); A3 0.629 (multiplicative); A6 +0.0135 (additive); A7 0.7 (multiplicative); A8 0.9574 (multiplicative).

3.A.1 Variables and Coefficients for CM

Endogenous Variables : Base Run Values

a_t	Supply of work	0.10
K_t	Demand for capital goods	6.00
d_t	Output function	1.00
W_t	Wage rate	1.00
P_t	Official price index	1.00
r_t	Real interest rate (fraction per annum)	0.05
p_t	Price level	1.00
$\overline{W_t}$	Average wage	1.00
R_t	Long term real interest rate (fraction per annum)	0.05
M_t	Money supply	1.00
b_t^g	Government bonds outstanding	0.00
b_t^p	Firms' bonds outstanding	0.00

Exogenous Variables : Base Run Values

B_t	Benefits	0.60
ε_t	$N(1.0, 0.01)$	1.00
ϕ_t	$N(1.0, 0.1)$	1.00
$\overline{M_t}$	Money supply target	1.00
m_t	Money shock	0.00
T_t	Tax rate	0.10

Coefficients

$$
\begin{aligned}
a_c &= 0.46 \\
\sigma &= 3.00 \\
k &= 0.30 \\
\mu &= 0.70 \\
N &= 1.00 \\
c &= 0.20
\end{aligned}
$$

3.B The Liverpool Model – Listing of Equations

3.B.1 Behavioural Equations

$$\log(EG_t) = \log(EGSTAR_t) + A39\log(Y_t/YSTAR_t) \tag{B1}$$

$$\begin{aligned} XVOL_t = {} & A40YSTAR_t\{A27\log(WT_t) + A28\log(Y_t) + A47 + \\ & A29\{ESTAR_t + 0.6\{RXR_t - ESTAR_t\}\} + \\ & A30\{XVOL_t - 1/\{A40YSTAR_t - 1\}\}\} \end{aligned} \tag{B2}$$

$$\begin{aligned} XVAL_t = {} & XVAL_{t-4} + \{XVOL_t - XVOL_{t-4}\} + A31 \\ & \{0.32YSTAR_t\{RXR_t - RXR_{t-4} - ESTAR_t + ESTAR_{t-4}\}\} + \\ & A32XVALres_{t-1} \end{aligned} \tag{B3}$$

$$\begin{aligned} \log(M0_t) = {} & A44 + A13\log(M0_{t-1}) + A14\{\log(Y_t) + \\ & \log(1 - TAX_{t-1})\} + A16TREND_t + A17NRS_t + A18VAT_t \end{aligned} \tag{B4}$$

$$\begin{aligned} \log(U_t) = {} & A42 + A3\log(Y_t) + A4\{\log(RW_t) + \log(1.0 + BO_t) + \\ & \log(1.0 + VAT_t)\} + A5TREND_t + A6\log(U_{t-1}) + A36Ures_{t-1} \end{aligned} \tag{B5}$$

$$\begin{aligned} \log(G_t) = {} & A45 + A19RL_t + A20\{\log(G_{t-1}) - \log(FIN_{t-1})\} + \\ & A21\{\log(G_{t-1}) - \log(Gt - 2)\} + \log(G_{t-1}) \end{aligned} \tag{B6}$$

$$\begin{aligned} \log(CON_t) = {} & A46 + A22RL_t + A23\log(W_t) + A24QEXP_t + \\ & A25\log(CON_{t-1}) \end{aligned} \tag{B7}$$

$$\begin{aligned} \log(RW_t) = {} & A43 + A7UNR_t + A8\{\log(UB_t) + \log(1.0 + LO_t)\} + \\ & A9\log(U_t) + A37\log(RW_{t-1}) + \{.095\}UNR_t\{-A10\} + \\ & A10\log(RW_{t-2}) + A11ETA_t + A12ETA_{t-1} \end{aligned} \tag{B8}$$

$$\begin{aligned} RXR_t = {} & A41 + 0.000 + A1\{\log(RW_t) + \log(1.0 + BO_t)\} + \\ & A53\{\log(P_t) - \log(P_{t-4})\} + \{1. + A1\}\log(1. + VAT_t) + \\ & A2TREND_t + A35RXRres_{t-1} \end{aligned} \tag{B9}$$

3.B.2 Identities and Calibrated Relationships

$$RS_t = \{RXR_t - E_t RXR_{t+1}\} + RSUS_t \tag{B10}$$

$$NRS_t = E_t INFL_{t+1} + RS_t \tag{B11}$$

$$RL_t = \{RXR_t - E_t RXR_{t+20}\}/5.0 + RLUS_t) \tag{B12}$$

$$NRL_t = RL_t + E_t \left(\sum_{i=1}^{5} INFL_{t+i}/5 \right) \tag{B13}$$

$$Y_t = GINV_t + CON_t + EG_t + XVOL_t - AFC_t \tag{B14}$$

$$\begin{aligned} INFL_t = {} & \log(MON_t) - \log(MON_{t-4}) - \log(M0_t) \\ & + \log(M0_{t-4}) \end{aligned} \tag{B15}$$

$$\log(P_t) = \log(P_{t-4}) + INFL_t \tag{B16}$$

$$W_t = FIN_t + G_t \tag{B17}$$

$$BDEF_t = EG_t - 2.0 \times TAX_t \times Y_t + TAX_0 \times Y_0 \tag{B18}$$

$$\begin{aligned} AFC_t = {} & Y_t\{0.6588318\{AFC_{t-1}/Y_{t-1}\} + 0.1966416\{AFC_{t-3}/Y_{t-3}\}+ \\ & 0.1454006\{AFC_{t-4}/Y_{t-4}\}+\} \end{aligned} \tag{B19}$$

$$PSBR_t = BDEF_t + RDI_t \tag{B20}$$

$$\begin{aligned} RDI_t = {} & -.5\{NRL_{t-1}/4.0\}FIN_{t-1}\{\{\{Pt/P_{t-1}\}^{0.66}\} - 1.0\}+ \\ & PSBR_t\{.32\{NRS_t/4.0\} + .5\{NRL_t/4.0\}\}+ \\ & 0.32\{NRS_t/4.\}FIN_{t-1} - .32\{NRS_{t-1}/4.\}FIN_{t-1} + RDI_{t-1} \end{aligned} \tag{B21}$$

$$GINV_t = G_t - G_{t-1} + A38G_{t-1} \tag{B22}$$

$$\begin{aligned} FIN_t = {} & EG_t - Y_t * \{TAX_t\} + XVAL_t + A54 * FIN_{t-1}+ \\ & \{1. - A54\} * \{FIN_{t-1} * \{\{P_{t-1}/P_t\}^{0.66}\}\} \\ & \{1.0 - 0.155 * \{\{NRL_t/NRL_{t-1}\} - 1.0\}\} + res\_FIN_t + RDI_t \end{aligned} \tag{B23}$$

3.B.3 Equilibrium Variables (-star):

The -star variables YSTAR, USTAR, ESTAR and WSTAR are the equilibrium values of Y, U, RXR and RW respectively, found by solving equations 2,5,8 and 9 under the conditions that XVOL=0 and exogenous variables maintain their current values; EGSTAR is the value of EG that would produce a constant debt/GDP ratio with Y=YSTAR.

3.B.4 Coefficient Values in Order A1–56:

```
1.528 -0.003 -2.150 0.792 0.010 0.804 0.470 0.210 -0.018 -0.224
-0.290 0.189 0.870 0.150 0.000 -0.002 -0.349 0.839 -0.016 -0.004
0.640 -0.215 0.056 0.153 0.870 0.000 0.529 -1.205 -0.388 0.429
0.103 0.193 0.000 0.000 0.931 0.271 1.000 0.012 -0.125 0.320
0.170 25.262 0.102 -0.337 0.013 0.666 11.503 -0.016 -0.011 0.017
0.011 0.750 -0.750 0.300 -1.000 -1.000
```

(Exogenous variables — e = error term)

$RSUS_t = c + 0.899 RSUS_{t-1} + e_t$

$EUNRS_t = c + 0.977 EUNRS_{t-1} + e_t$

$\Delta \log WT_t = c + e_t$

$\Delta BO_t = c + e_t$

$\Delta VAT_t = c - 0.286 \Delta VAT_{t-1} + e_t$

$\Delta UNR_t = c + 0.869 \Delta UNR_{t-1} + e_t$

$\Delta UB_t = c + e_t$

$\Delta LO_t = c + e_t$

$\Delta TAX_t = c - 0.365 \Delta TAX_{t-1} + e_t$

$\Delta \log EURXR_t = c + 0.235 \Delta \log EURXR_{t-1} + e_t$

$\Delta \log EUCPI_t = c + 0.503 \Delta \log EUCPI_{t-1} + e_t$

$$\Delta \log MON_t = PEQ_t + MTEM_t + e_t$$

3.B.5 Model Notation:

Endogenous Variables	
Y	GDP at factor cost
P	Consumer Price Level
INFL	Percentage growth rate of P (year-on-year)
MON	Nominal Money Stock (M0)
RW	Real wages (Average Earnings/Price)
U	Unemployment
Q	Output deviation from trend (Y/YSTAR)
AFC	Adjustment to factor cost
EG	real government spending on goods and services
BDEF	interest-exclusive budget deficit (deflated by CPI)
PSBR	public sector borrowing requirement (deflated by CPI)
XVAL	real current account of balance of payments
XVOL	same, at constant terms of trade
RS(RL)	real short term (log term) interest rate
NRS (NRL)	nominal short term (long term) interest rate
M0	real money balances (M0)
G	real private stock of durable goods, including inventories
W	real private stock of wealth
FIN	real private stock of financial assets (net)
CON	real private non-durable consumption
RXR	real exchange rate (relative CPI, UK v. ROW)
RDI	real debt interest
GINV	gross private investment in durables plus stock building
Exogenous Variables	
MTEM	Temporary growth of money supply
PEQ	Growth of money supply
BO	Employers national insurance contributions
UNR	Trade Unionisation rate
LO	Average amount lost in taxes and national insurance
TREND	Time trend
WT	World Trade
TAX	Overall tax rate
UB	Unemployment benefit rate (in constant pounds)
EUNRS	Euro nominal short-term interest rates
EURXR	Euro real exchange rate index
EUCPI	Euro CPI
RSUS	US real short-term interest rate

3.C Targeting Rules and Their Effects Within CM

To examine how targeting works within the CM which though small is nevertheless non-linear and not analysable therefore in its original form (hence our use of stochastic simulations to discover its properties), it is necessary to linearise the model and simplify it into a form where we can derive its key analytical properties. The following lists the linearised equations (the numbering corresponds to that of the full model of 3.A). The numbers shown are the effect of the normalising constants referred to in 3.A. In order the equations are: (1) marginal labour supply which reacts to the auction wage; (2) the demand for capital; (3) the production function; (4) the actual nominal wage, a weighted average of auction (weight of α), indexed (weight of v), and nominal.; (5) the over-reaction of the official price index to the true price index; (6) goods market-clearing; (7) labour market-clearing; (8) money market-clearing.; and (9) the real spendable wage (wages are paid with a 1-period lag so the real spendable wage is the lagged one, deflated by the current price level).

$$a_t = -a_0 \sigma W_t \tag{3.C.1}$$

$$K_t = 1.11 \left\{ \frac{k(1-\mu)(1-T_o)}{r_0} \right\} \left\{ (d_t - [\frac{r_t}{r_o}] \right\} \tag{3.C.2}$$

$$d_t = \frac{(1-\mu)}{K_0} K_t + \phi_t - \frac{\mu}{(1-a_0)} a_t \tag{3.C.3}$$

$$\overline{W}_t = \alpha W_t + v P_t \tag{3.C.4}$$

$$P_t = (1+c) p_t \tag{3.C.5}$$

$$d_t = m_{t-1} - p_t + K_t - K_{t-1} \tag{3.C.6}$$

$$a_t = \frac{-[\mu(1-T_o)]}{0.7} (d_t + p_t - \overline{W}_t) \tag{3.C.7}$$

$$m_t = \frac{(1-a_o)}{0.96} \overline{W}_t - \left(\frac{\overline{W}_o}{0.96} - B_o \right) a_t \tag{3.C.8}$$

$$\overline{W}_{t-1} - p_t = \alpha W_{t-1} + v(1+c) p_{t-1} - p_t \tag{3.C.9}$$

where $\alpha = (1 - v - w)$; equation numbers correspond to 3.A.

For simplicity we have omitted all price and wage expectations from the wage-setting equation, (5); these are all dated at t-4. Similarly from the labour supply equation, (1), we omit the 4-quarter lagged price level which indexes unemployment benefits. Hence in effect the model solves in terms of the news occurring between t-4 and t, and in the case of (9), the real wage available for spending, because wages are paid with a 1-period lag, news between t-5 and t. The very long lag (20 quarters) terms determining the demand for capital are similarly omitted. We now explain the model's structure in terms of supply and demand.

Equation (3.C.9) is the implied behaviour of the employed consumer's living standard, whose uncertainty is being minimised by the contract structure. We can progressively reduce the simultaneous block of equations (3.C.1)–(3.C.8) to three as follows. We can use equation (3.C.3), the production function, and (3.C.6), the supply of savings from goods market clearing, while also using (3.C.1) to eliminate a_t, to obtain:

$$\Delta d_t = Z(d_t - m_{t-1} + p_t) + \Delta\phi_t + \frac{a_o \mu \sigma}{(1 - a_o)} \Delta W_t \tag{3.C.10}$$

where $Z = \frac{1-\mu}{K_o}$

This is the output supply made available by savings (and so capital) and by labour supply; the first terms in Z emerge from equation (3.C.6) as the amount of savings (i.e. the output not devoted to consumption which is $m_t - p_t$). Note in passing that we can solve equation (3.C.2) for r_t conditional on d_t, m_{t-1}, and p_t: since the latter determine available savings, the interest rate has to force the demand for capital to equal this availability. Hence equation (3.C.2) and the interest rate are in a second, recursive block, and can therefore be ignored.

Equations (3.C.1) and (3.C.7), labour supply and demand, yield with (3.C.4) and

(3.C.5), defining wages and the price index,

$$W_t = \frac{\mu(1 - To)/0.7}{[\alpha\mu(1 - T_o)/0.7] + a_o\sigma}\,[d_t + (1 - v')p_t] \qquad (3.C.11)$$

(3.C.11) therefore specifies the free wages that would clear the labour market, given output and the price level. (3.C.10) and (3.C.11) between them constitute the supply-side of the model, augmented to include the market for savings (which depend on last period's money supply).

Finally, using the money market equation (3.C.8) together with labour supply (3.C.1) (which defines the split between benefits and wage payments) we obtain:

$$W_t = Q[m_t - (v'(1 - a_o)/0.96)p_t] \qquad (3.C.12)$$

where

$$Q = \frac{1}{\alpha(1 - a_o)/0.96 + (\overline{W}_o/0.96 - B_o)a_o\sigma}$$

(3.C.12) is reminiscent of Robertson's 'wages fund'; there is a certain stock of money available to pay wages and benefits and given the structure of contracts, it determines free (auction) wages.

The full solution is complex. However, we can represent the model's main workings by reducing equations (3.C.10) and (3.C.11) to a 'supply curve' between free wages and the price level; and juxtapose it with the 'demand curve' given by (3.C.12), the wages fund equation. We neglect terms in Z as of small magnitude, which conveniently allows us to rewrite (3.C.10) in levels form as

$$d_t = \phi_t + \frac{a_o\mu\sigma}{(1 - a_o)}W_t + c_0$$

where c_0 is a constant, ignored in what follows, reflecting the initial values of d_t, ϕ_t and

W_t. In this case the supply curve from (3.C.10) and (3.C.11) becomes:

$$W_t = V[\phi_t + (1 - v')p_t] \text{ where } V = \frac{1}{\alpha + \frac{0.7a_o\sigma}{\mu(1-T_o)} - \frac{a_o\mu\sigma}{1-a_o}} \tag{3.C.13}$$

It follows that:

$$p_t = \pi(Qm_t - V\phi_t) \text{ where } \pi = \frac{1}{[Qv'(1-a_0)/0.96] + V'(1-v')} \tag{3.C.14}$$

and

$$W_t = lV\phi_t + (1-l)Qm_t \text{ where } l = \frac{[Qv'(1-a_0)/0.96]}{[Qv'(1-a_0)/0.96] + V'(1-v')} \tag{3.C.15}$$

and the spendable real wage is

$$\overline{W}_{t-1} - p_t = \alpha W_{t-1} + v'p_{t-1} - p_t \text{ where } \alpha = 1 - v - w \tag{3.C.16}$$

For $0 < v' < 1$ the resulting demand and supply picture is familiar. Figure 3.2 shows the model in p_t, W_t space; since labour supply $(1 - a_t)$ varies directly with the auction wage, this is also price level, employment space (output depends also on the capital stock, but is closely related to employment, and so this is also effectively familiar price, output space.) As v' tends to 0, DD (eq. 3.C.12) steepens and the SS (eq. 3.C.13) flattens.

We begin by considering within this model the nature of various basic monetary rules to which our discussion of optimality will be related; we then show a monetary rule may be optimised within that model; this discussion is conducted entirely in terms of the simplified linear model. We then consider the performance of various forms of targeting rules within the model in terms of the same model. Finally we use stochastic simulations of the full non-linear model to derive the accurately-calibrated optimality results. We conclude with some policy implications.

3.D Targeting inflation and the level of money or prices — some mechanics of Monetary rules

If we take the linearised version of our model, we find the following solutions in general:

$$p_t = \pi(Qm_t - V\phi_t) \tag{3.D.17}$$

where

$$\pi = \frac{1}{Qv'(1-a_0) + V(1-v')}$$

and

$$W_t = lV\phi_t + (1-l)Qm_t \tag{3.D.18}$$

where

$$l = \frac{Qv'(1-a_0)}{Qv'(1-a_0) + V'(1-v')}$$

Both V and Q vary inversely with the share of auction contracts,α:

$$\begin{aligned} Q &= \frac{1}{\alpha(1-a_o)/0.96 + (\overline{W}_o/0.96 - B_o)a_o\sigma} \\ V &= \frac{1}{\alpha + \frac{0.7a_o\sigma}{\mu(1-T_o)} - \frac{a_0\mu\sigma}{1-a_o}} \end{aligned}$$

Recall that W_t (the auction wage, and the shadow price of labour supply) also directly determines employment through the labour supply function. Thus we can take it and employment as the same subject to some linear transformation.

Real (consumed) wages are:

$$\overline{W}_{t-1} - p_t = \alpha W_{t-1} + v'p_{t-1} - p_t \tag{3.D.19}$$

Suppose that

$$\phi_t = \phi_{t-1} + \eta_t \tag{3.D.20}$$

that is productivity follows a random walk. As we have seen, households raise their real wage protection (of their real consumed wage), the more persistent are price level shocks. Thus if there was zero protection ($\alpha = v' = 0$) they would be wide open to the variability of p_t. The more persistent the price shocks, the higher that variability, because the shocks would cumulate.

If we now compare a money supply rule that eliminates money shock persistence with one that eliminates price shock persistence, the first plainly eliminates one independent source of persistence in price shocks. Thus we would expect to find, and do, that protection falls. The second takes the process one stage further, eliminating all price shock persistence. Thus we should find that protection falls further still. (In the full non-linear model there are other sources of persistence, and these keep some incentive to protection alive; hence it does not disappear altogether). An inflation targeting rule by contrast with both the money and price level targeting rules ensures that prices are expected to be a random walk, entirely persistent; and therefore in this regime indexation is high.

A price level rule is one that sets

$$0 = E_t p_{t+1} = \pi(QE_t m_{t+1} - VE_t \phi_{t+1}) \tag{3.D.21}$$

and hence

$$E_t m_{t+1} = \frac{V}{Q} E_t \phi_{t+1} = \frac{V}{Q} \phi_t \tag{3.D.22}$$

whence the 'price level rule' is

$$m_t = \frac{V}{Q} \phi_{t-1} + \epsilon_t \tag{3.D.23}$$

whereas the ('pure money') rule that eliminates money shock persistence is simply

$$m_t = \epsilon_t \tag{3.D.24}$$

Notice that under the price level rule money supply accommodates known past productivity shifts; this removes persistence from price shocks, though at the cost of persistence in money shocks.

An inflation-targeting rule sets

$$E_{t}p_{t+1} = \pi(QE_t m_{t+1} - VE_t\phi_{t+1}) = p_t = \pi(Qm_t - V\phi_t)$$

and hence (remembering that $E_t\phi_{t+1} = \phi_t$): $E_t m_{t+1} = m_t$ so that the behaviour of the money supply becomes:

$$m_t = m_{t-1} + \epsilon_t$$

When these are substituted into (3.D.18) we obtain

$$\begin{aligned}
\text{(price level rule) } W_t &= (1-l)Q\epsilon_t + V(l\phi_t + [1-l]\phi_{t-1}) && (3.D.25)\\
\text{(pure money rule) } W_t &= (1-l)Q\epsilon_t + V(l\phi_t) && (3.D.26)\\
\text{(inflation rule) } W_t &= (1-l)Q[\epsilon_t + m_{t-1}] + V(l\phi_t) && (3.D.27)
\end{aligned}$$

and when into (3.D.19) we obtain:

$$\begin{aligned}
\text{(price level rule) } \overline{W}_{t-1} - p_t = \pi V[\eta_t - v'\eta_{t-1}] - \pi Q[\epsilon_t - v'\epsilon_{t-1}]&\\
+ \alpha V[l\eta_{t-1} + \phi_{t-2}] + \alpha Q(1-l)\epsilon_{t-1}& \quad (3.D.28)
\end{aligned}$$

and

$$(\text{money level rule})\ \overline{W}_{t-1} - p_t = \pi V[\phi_t - v'\phi_{t-1}] - \pi Q[\epsilon_t - v'\epsilon_{t-1}] + \alpha V[l\phi_{t-1}] + \alpha Q(1-l)\epsilon_{t-1}$$

$$(\text{inflation rule})\qquad \overline{W}_{t-1} - p_t = \pi V[\phi_t - v'\phi_{t-1}] - \pi Q[m_t - v'm_{t-1}] + \alpha V[l\phi_{t-1}] + \alpha Q(1-l)[\epsilon_{t-1} + m_{t-2}] \quad (3.D.29)$$

For the nominal wage, W_t, which is directly related to employment (supply) and hence to output, the stability ranking is, with indexation at a high level as optimal under inflation-targeting, (from the most stable down), money rule>inflation rule>price-level rule; with indexation endogenous, money>price>inflation. For the spendable real wage (consumption), the stability ranking is, with indexation high as for inflation targeting, price>inflation>money; and for endogenous indexation, price>inflation=money. But in fact for spendable real wages all regimes deliver very similar stability; only for price-level targeting with endogenous indexation is the stability gain statistically significant.

Using the relevant equations above, and assuming that the wage contract length is 4 periods, then under the price rule we have:

$$\text{Var}W_t = \left(\frac{V}{Q}\right)^2 [3 + l^2]\sigma_\eta^2 + [(1-l)]^2\sigma_\epsilon^2 \quad (3.D.30)$$

and

$$\text{Var}(\overline{W}_{t-1} - p_t) = \left[\frac{V}{Q}\right]^2 [\pi^2 + (\pi v' - \alpha l)^2 + 2\alpha^2]\sigma_\eta^2 + \{[\alpha(1-l) + \pi v']^2 + \pi^2\}\sigma_\epsilon^2 \quad (3.D.31)$$

whereas under the money rule, $m_t = \epsilon_t$, we have the following variances (all divided for presentational convenience by Q^2):

$$\text{Var}W_t = 4\left(l\frac{V}{Q}\right)^2 \sigma_\eta^2 + [(1-l)]^2\sigma_\epsilon^2 \quad (3.D.32)$$

and

$$\mathrm{Var}(\overline{W}_{t-1} - p_t) = \left\{ \pi^2 + [\pi v' + \alpha(1-l)]^2 \}\sigma_\epsilon^2 + \left(\frac{V}{Q}\right)^2 \{\pi^2 + 3[\pi v' - \alpha l]^2\}\sigma_\eta^2 \right\} \quad (3.D.33)$$

and under the inflation rule we have:

$$\mathrm{Var}W_t = 4\left(l\frac{V}{Q}\right)^2 \sigma_\eta^2 + 4[(1-l)]^2\sigma_\epsilon^2 \quad (3.D.34)$$

and

$$\begin{aligned}\mathrm{Var}(\overline{W}_{t-1} - p_t) &= \left(\frac{V}{Q}\right)^2 \{(\pi)^2 + 3[\pi(1-v') - \alpha l]^2\}\sigma_\eta^2 + \\ &\quad \{(\pi)^2 + [\pi(1-v') - \alpha(1-l)]^2 + 2[\pi v' - \alpha(1-l)]^2\}\sigma_\epsilon^2\end{aligned} \quad (3.D.35)$$

Table 3.D.1: Variances with CMas calibrated in this linearised and simplified version*:

	Indexation as for inflation target	Indexation endogenous
$\mathrm{Var}W_t$	(Indexation parameters: $v' = 0.5; l = 0.7$)	
Inflation rule	100	100 ($v' = 0.5; l = 0.7$)
Money rule	93	35 ($v' = 0..26; l = 0.36$)
Price rule	163	165 ($v' = l = 0$)
$\mathrm{Var}(\overline{W}_{t-1} - p_t)$	(Indexation parameters: $v' = 0.5; l = 0.7$)	
Inflation rule	100	100 ($v' = 0.5; l = 0.7$)
Money rule	102	96 ($v' = 0..26; l = 0.36$)
Price rule	126	82 ($v' = l = 0$)

*calibration: $\pi = 0.2$ (for $v' = 0.5$);$= 0.15$(for $v' = 0$) and $= 0.175$ (for $v' = 0.26$); $\alpha = 0.1$; $\frac{V}{Q} = 1.3$; $\sigma_\eta^2 = \sigma_\epsilon^2 = 0.0001$

While these calculations show that the simplified linear model in our calibrations is somewhat adrift of the full model (especially with respect to the price-level rule for employment), they do show that if indexation is fixed at high inflation-targeting levels the money rule is good for employment stability, while the price rule is bad for it; and that with endogenous indexation the money rule is good for employment stability while the price rule is good for consumption stability.

Chapter 4

Testing Whether the FTSE is Produced by an Efficient Market

4.1 Literature Review

4.1.1 Market Efficiency

The origins of the Efficient Market Hypothesis can be traced back as far as the pioneering theoretical contributions of Bachelier (1900) and the empirical research of Cowles (1933). The work by Bachelier (1900) was the first effort ever to employ theory, including mathematical techniques, to explain why the stock market behaves as it does. Cowles (1933) examined the records of selected financial services and professional investors. He failed to find any evidence of performance superior to that which could be achieved by investing in the market as a whole. Kendall (1953) calculated the first 29 lagged serial correlations of the first differences of 22 time series representing speculative prices. He found that, with two or three exceptions, that knowledge of past prices changes yields substantially no information about future price changes. Also, that essentially, the estimate of the next period's price change could have been drawn at random from a specified distribution with results as satisfactory as the best formula that could be fitted to past data.

The modern literature in economics begins with Samuelson (1965). He proved that if the flow of information is unimpeded and if there are no transactions costs, then tomorrow's price change in speculative markets will reflect only tomorrow's 'news' and will be independent of the price change today. Since 'news' is unpredictable the resulting price changes must also be unpredictable and random.

In an informationally efficient market prices fully incorporate the expectations and information of all market participants; this implies that current price changes should be independent of past known data. Fama (1970) summarised this idea in his classic survey by writing: "A market in which prices 'fully reflect' available information is called 'efficient'." Fama goes on to discuss tests of efficiency. Dividing the work into three categories depending on the nature of the information subset. The information sets due to Roberts (1967) are used:

- Weak-Form Efficiency: The information set includes only the history of prices.
- Semistrong-Form Efficiency: The information set includes publicly available information.
- Strong-Form Efficiency: The information set includes all information known to any market participation (private information).

Fama concludes that the results are strongly in support of the weak form tests, and semi-strong form tests also support the efficient market hypothesis. For the strong from tests he says that one would not expect such an extreme model to be an exact description of the world, and it should be viewed as a benchmark.

More recently the dominance of the efficient market hypothesis has become far less universal. Many financial economists have begun to believe that stock prices are at least partially predictable. They emphasize psychological and behavioural elements of stock-price determination, and believe that future stock prices are to some extent predictable on the basis of past stock price patterns as well as certain fundamental valuation metrics.

Lo and MacKinlay (1988) use weekly US data for the 1962–1985 period and use a variance ratio test to test for serial correlation. They find that short-run serial correlations between successive stock price changes are not zero, and that the existence of too many successive moves in the same direction enable them to reject the hypothesis that stock prices behave as true random walks at all the usual significance levels. They also find that using a base interval of four weeks results in not rejecting the random walk model. The results for weekly returns are also independent of the size effect. Evidence against the random walk hypothesis is strong for small firms, and the test statistic becomes smaller as the size of the firm increases, but even for large-firms portfolios the evidence against the null hypothesis is strong. The portfolio for the smallest quintile has a 42% weekly autocorrelation, whereas the serial correlation for the portfolio returns of the largest quintile is much smaller at 15%, though it is still statistically significant. They conclude by saying that they have rejected the random walk hypothesis for weekly stock market returns, though the rejection of the random walk model does not necessarily imply the inefficiency of the stock-price formation.

Many studies have shown evidence of negative serial correlation over longer holding periods. So over longer periods there is return reversal. Fama and French (1988) regress the return on a stock market index over some period of length T, on returns over the prior period of equal length, and found that for the 1926–1985 period between 25–40% of the variation in long holding period returns can be predicted in terms of the negative correlation with past returns. The slopes of the regressions are generally negative for horizons from 18 months to 5 years, and both the R^2 and the slope increase with the length of the horizon up to 5 years, and then decrease. They report that returns are more predictable for portfolios of small firms (40% predictability) compared with portfolios of large firms (25% predictability). Poterba and Summers (1988) used the same data and also found substantial mean reversion in stock market returns at longer horizons, using a variance ratio test. They also investigate whether mean reversion can be found on the stock exchanges of other countries. Using data for Britain since 1939, and Canada since 1919 they find mean reversion at long horizons similar to the US data. Also, for fifteen other countries for shorter postwar periods twelve display mean reversion. From the international evidence Poterba and Summers conclude that mean reversion is more pronounced in less broad-based and less sophisticated (foreign) equity markets.

There is also evidence of seasonal and day-of-the-week patterns. Rozeff and Kinney (1976) found seasonal patterns in US data for the 1907–1974 period. They found that the average monthly returns in January were about 3.5%, while other months averaged about 0.5%. This was found using data on New York Stock Exchange prices with an equal-weighting. As well as the January effect there also appears to be a number of day-of-the-week effects. French (1980) examines two alternative models of the process generating stock returns: the calendar time hypothesis and the trading time hypothesis. Under the calendar time hypothesis the expected return for Monday is three times that of the other days of the week, whereas under the trading time hypothesis the expected return is the same for each day of the week. French uses daily returns to the Standard and Poor's composite portfolio for the 1953–1977 period. He finds that the results are inconsistent with both models and documents significantly negative returns on Mondays. French also tests whether the systematically negative returns occur only on Monday or after any day that the market is closed. The results indicate that the persistently negative returns for Monday are caused by some weekend effect, rather than by a general closed-market effect.

Lakonishok and Smidt (1988) test for the existence of persistent seasonal patterns in the rates of return using 90 years of daily data on the Dow Jones Industrial Average from 1897–1986. They find that high returns in January are not observed, and that none of the months have returns different from the average. Because this index is composed of only large firms, and an equal weighted index gives small firms greater weight than their share of market value, this suggests that the January effect may be a small firm phenomenon. Lakonishok and Smidt also study the weekend effect, holiday returns, end-of-December returns as well as turn-of-the-month returns. For the weekend effect their results are consistent with French (1980) as they reject the null hypothesis that all days of the week have the same rate of return, and that there are negative returns on Monday. They also find that there are larger positive rates of return on the last trading day of the week. The results for holiday returns shows that the average pre-holiday rate of return is 0.22%, which is 23 times larger than the regular daily rate of return (0.0094%), and that holidays account for about 50% of the price increase in the DJIA. This rate of return is 2–5 times larger than pre-weekend rates of return. The rate of return after holidays is found to be negative, but not significantly different from zero. For the end-of-December returns they find that the price increase from the last trading day before Christmas to the end of the year is over 1.5%. Analysing turn-of-the-month returns the authors find that there is a strong turn-of-the-month effect. The cumulative rate of increase over the four days around the turn of the month is 0.473% compared to 0.0612% for an average four day period. This price increase is shown to be greater than the average monthly price increase, which is 0.349%.

Seasonal patterns have also been studied for other countries. Gultekin and Gultekin (1983) used data from sixteen major industrialised countries to try and find seasonal patterns. They used data from 1959–1979 (except for Singapore where they used data from 1970–1979). Their test shows that seasonality exists in most of the markets, as they reject the null hypothesis that stock returns are time invariant for 12 countries. They also test whether the seasonality is attributed to tax-loss selling which predicts that returns will be higher in the first month of the tax year. They find that for all countries with a January-December tax year, mean January returns were exceptionally large. The UK and Australia do not have January-December tax years, and they find that for the UK mean April returns are larger than all other months except for January, but for Australia they would expect returns in July to be larger than other months, but find that this is not the case. The authors conclude that they find evidence of a seasonal pattern in stock returns for most of the major industrial countries, and find that for most countries large returns occur in January.

Research has also been carried out on the predictability of future stock returns. It is claimed that the dividend yield or the price-earning ratio of the stock market as a whole have considerable predictive power. Campbell and Shiller (1988) use annual Standard and Poor Composite Stock Price Index data from 1871–1986. They regress stock returns on some explanatory variables that are known in advance. They find that the dividend-price ratio has a striking ability to predict returns for various horizons. For one-period returns they find that 3.9% of the variance of returns is explained by the dividend-price ratio. Though this is a small percentage, it is still statistically significant. As the horizon increases they find that the fraction of variance explained also increases, and find that at the 10-year horizon the dividend-price ratio can predict 26.6% of the variance of future returns for the stock market.

Other financial statistics have been found to have some amount of predictive power for stock returns. For example, Fama and Schwert (1977) found that in postwar US data there is a reliable negative relationship between the level of expected returns on common stocks and the level of the treasury bill, and that the risk premium on stocks is inversely related to the interest rate. Campbell (1987) found that using monthly US data for 1959–1979 and 1979–1983 the term structure of interest rates spreads contained useful information for forecasting stock returns, saying that the evidence for predictability of stock returns is very strong.

4.1.2 Peso Problems

The peso problem is a situation where the potential for discrete shifts in the distribution of future shocks to the economy effects the rational expectations held by market participants. One common feature of asset pricing models is that current asset prices incorporate market participants' expectations of future economic variables. A peso problem arises when there is a small positive probability of an important event, and investors take this probability into account when calculating their expectations.

Although the precise origins of the term peso problem are unknown, a number of economists attribute its first use to Milton Friedman in the examinations of the Mexican peso market during the early 1970s. The peso problem hypothesis has often been advocated in the financial literature to explain the historically puzzlingly high premium of stock returns.

A number of papers have argued that the high risk premium of stock returns may be due to a peso problem situation. Rietz (1988) specifies the Mehra and Prescott model to include a low-probability, depression like, third state, where output falls by 50 (or 25) percent of its value with a probability of 0.4% (or 1.4%). He says that this can explain both high equity risk premia and low risk-free returns. Reitz says that the motivation for the third state is that risk-averse equity owners demand a high return to compensate for the extreme losses they may incur during an unlikely, but severe, market crash. Equity owners have been compensated for the crashes that have not occurred, leading to high equity returns. Rietz goes on to say that incorporating the third state in Mehra and Prescott's model not only captures the effects of these crashes, it also solves their puzzle, as he generates ex ante equity premiums consistent with those observed in the US and risk aversion of five (or ten).

In a paper related to Rietz (1988), Danthine and Donaldson (1999) study how the small probability of a depression state modifies the macrodynamic and financial characteristics of a standard equilibrium business cycle model. They find that the effects are most dramatic when the feared 'disaster state' isn't actually present.

A similar idea to the peso problem is that of survival. Brown, Goetzmann and Ross (1995) investigate the ex-post statistical behaviour of the time series of returns that have "survived" for a sample period. Where a market is said to "survive" if the price does not hit an absorbing lower bound. Under these assumptions they show that if the price series did not hit the lower bound, the implied time series of returns should display many features actually observed in US data series, including puzzling risk premia and mean reversion.

Goetzmann and Jorion (1999) show that markets tend to emerge, submerge, and re-emerge through time, and argue that many of today's emerging markets are actually re-emerging markets. Various political, economic and institutional reasons cause investors to lose interest in some markets, which then submerge, only to re-emerge recently. They conclude by saying that market contractions, banking failures, and expropriation have occurred in the past, and are likely to occur in the future.

Jorion and Goetzmann (1999) say that unusual events with a low probability of occurrence but severe effects on prices, such as wars and nationalisations, are not likely to be well represented in samples and may be totally omitted from survived series. They find that from 24 markets for which they have data in 1931, seven experienced no interruption, seven experienced temporary suspension of trading, and ten suffered long-term closure. This indicates that market failures are not a remote possibility. They say that under the assumption that market risks are priced individually, rather than under the assumption of integration, the frequency of failure would provide clear justification for a peso problem explanation. They conclude that major disruptions have afflicted nearly all the markets in their sample, with the exception of a few, including the US, and say that the fact that the US market survived explains their finding that the real capital appreciation return on US stocks is a lot higher than other markets. With real capital appreciation return on US stocks being 4.3% compared with a median return of only 0.8% for the other markets.

One approach economists have used to model peso problems is to suppose that the economy goes through changes in regime. Where the regimes may represent periods of high or low inflation, rising or falling exchange rates or economic recessions and expansions. In one regime the disturbances to the economy are different from another regime, which has different affects on economic variables. So the behaviour of variables such as inflation, interest rates or real output growth could be different in the different regimes. One popular parameterisation is the Markov switching model of Hamilton (1989).

4.1.3 Markov Switching

Markov switching models have become increasingly popular in economic studies of stock prices. Markov switching models are often adopted by researchers wishing to account for specific features of economics time series such as the fat tails, volatility clustering and mean reversion of stock prices. These models are able to generate a wide range of coefficients for skewness, kurtosis and serial correlation even when based on a very small number of underlying states. There is a large body of empirical evidence suggesting that returns on stocks and other financial assets can be captured by this class of models because of their ability to capture outliers, fat tails and skew.

Turner, Startz and Nelson (1989) use a Markov switching model to model the variance of excess returns. They estimate two models one in which the state is known to the economic agent, and one in which agents are uncertain of the state. In both models the market is assumed to switch between two states. Using monthly data from Standard and Poor's composite index for the 1946–1987 period they find that the variance for the high-variance state is more than four times that of the low-variance state. Using a likelihood ratio test they reject the hypothesis that the variances are equal. They also find that the low-variance state will dominate, with the unconditional probabilities being 0.929 and 0.071 for the low- and high-variance states respectively. The median duration of the low-variance state is approximately 43 months, compared to 3 months for the high-variance state, showing that the low-variance state is more persistent. Comparing the two models they find that the model where agents know the state does not support an increasing risk premium, whereas when agents are uncertain of the state the model provides support for a risk premium rising as the anticipated level of risk rises. Also, when the stock market unexpectedly moves into a high-variance state the market will fall (though this fall is generally recovered in the next period), but when it is expected to be in a high-variance state it does not fall. The authors conclude by saying that they have shown that an adequate model of the excess return from the stock market may be constructed with a mixture of normal densities with different means and variances.

The Markov switching model was shown by Rydén, Teräsvirta, and Åsbrink (1998) to be well suited to explaining the temporal and distributional properties of stock returns. Using daily S&P 500 US stock price series from 1928–1991, they split the series into ten subsets of equal length, and then find the best fitting Markov switching model and test whether it is capable of characterising the stylized facts. They compare the mean/standard deviation ratio, skewness and kurtosis of the models with that of the original data. They find that the mean/standard deviation ratio is reproduced rather well, and for the skewness and kurtosis a clear tendency emerges. If the values are relatively small in the data, the models also yield small estimates, and are when the values are relatively large in the data, the models values are also large.

Cecchetti, Lam and Mark (1990) combine an economic model of asset prices with a Markov switching model for the exogenous forcing process driving the economic fundamentals using annual data from the Standard and Poor's index from 1871–1985 to account for the mean reversion in asset prices. The Markov switching model is used because it allows them to model both the negative skewness and excess kurtosis that is present in the raw data. They test for mean reversion by using both the variance ratio statistics used by Poterba and Summers (1988) as well as the long-horizon regression coefficients used by Fama and French (1988). They also report the distributional characteristics for the Markov switching process, and find that the population values of the mean, standard deviation, skewness, kurtosis and first-order autocorrelation and find that the values lie within two standard deviations of the sample values. So they conclude that the Markov switching model can produce both the degree of negative skewness and the amount of kurtosis that are found in the data.

A Markov switching model is used to capture the nonlinear dynamics in the stock market and business cycle by Hamilton and Lin (1996). They use monthly US data from 1965–1993 and investigate the joint time series behaviour of monthly stock returns and growth in industrial production, where the state variable determines both the mean of industrial production growth and the scale of stock volatility. They find that a model that provides a reasonable description of the co-movement of stock returns and economic activity is one in which the shift in regime affects stock returns one month before it affects industrial production. They find that using this model, industrial production falls by 0.75% per month when the economy is in regime 1, and that the unforecastable component of stock returns has a variance that is over ten times as large in regime 1 as it is in regime 2. Regime 1 tends to last on average for 9 months, whereas regime 2 is more persistent and typically lasts for 4 years. This model suggests that economic recessions are a very important cause of stock volatility, and that the index of industrial production should be quite useful in forecasting stock volatility. They also say that this model offers substantially better forecasts of stock volatility than that of the univariate ARCH-type models they considered. The authors also find that this model implies that stock volatility may be useful for forecasting the direction of aggregate economic activity, since they find that stocks are a leading indicator of the state of the business cycle. They conclude by saying that economic recessions are the single largest factor in explaining why stock markets are more volatile at some times that others, and economic recessions account for over 60% of the variance of stock returns, and that their model is useful for both forecasting stock volatility and for identifying and forecasting economic turning points.

The differences in stock returns for small and large firms is considered by Perez-Quiros and Timmermann (2000). They use a flexible econometric framework that allows the conditional distribution of stock returns to vary with the state of the economy, and document the systematic differences in variations over the economic cycle in small and large firms' stock returns. They use monthly excess returns on size-sorted decile portfolios for the 1954–1997 and a Markov switching model that allows for two possible states which are determined by the data. Their results suggest that the two regimes relate to recession and expansion states, and that stock return volatility is highest during economic recessions. Theory suggests that small firms will be adversely affected by lower liquidity and higher short-term interest rates, and the authors find that, consistent with the theory, small firms display the highest degree of asymmetry in their conditional return distribution across recession and expansion states. They find that there is a close relationship between firm size and return volatility, with small firms being most strongly affected by a recession.

A different approach is applied by Whitelaw (2001) who uses a model where the fundamental economic process (consumption) is modelled in a regime-shift framework and asset returns are derived using rational expectations. This model also provides evidence of persistent regimes in stock market returns. Using monthly data for 1959–1996 the author uses a two-regime model that is capable of identifying the expansionary and contractionary phases of the business cycle. This relatively simple model is also capable of generating results that are broadly consistent with the empirical evidence. He finds that the mean consumption growth for the regimes are 0.323% and 0.146% for the expansionary and contractionary regimes with regime half-lives of 92 months and 36 months, respectively. The model also generates a negative unconditional relationship between expected returns and volatility. The author concludes that the model demonstrates not only that a negative and time-varying relation between expected returns and volatility is consistent with rational expectations, but also that such a relation is consistent with aggregate consumption data in a representative agent framework.

Ang and Bekaert (2002), estimate regime switching models on US, UK and German equity and find evidence of a high-volatility, high-correlation regimes, and lower conditional mean which tends to coincide with a bear market, and a normal regime with low correlations and low volatility. Though the evidence on higher volatility is much stronger than the evidence on higher correlation and lower means.

Guidolin and Timmermann (2005) study strategic asset allocation and consumption choice in the presence of regime switching in asset returns and find evidence that four separate regimes are required to capture the joint distribution of stock and bond returns. The regimes are characterised as crash, slow growth, bull and recovery states. The crash state has low persistence and large negative mean excess returns and high volatility. The low growth regime is far more persistent and has low volatility and small positive mean excess returns, while the bull state is the most persistent and is characterised by rapid growth of stock prices. The recovery state is again not very persistent, and has strong market rallies and high volatility for small stocks and bonds. The authors conclude that their model not only captures predictability in the conditional mean of returns, but also in the full (joint) return distribution, including the volatility, skew and kurtosis. Also, because there were two transitory states and two persistent states, the model captures both the short-term and long-term variations in investment opportunites.

4.2 Introduction

The authors above have in various ways found that they can mimic the movements of stock markets using Markov switching models (as in the peso problem) of some driving process. This is an idea we have also adopted here in order to carry out a test of efficiency. For a stock market to be efficient it must reflect the behaviour of the 'fundamental' efficiently. This fundamental must come from the actual data on profits or dividends which are being valued by the market. In other words the 'driving process' used in the models must be consistent with the actual processes at work in the data for efficiency to be established. It is not sufficient for there to be 'some process' if its implied behaviour is at variance with that of the data — if the implied moments of the process were different, then there would be inefficiency in the sense of Campbell and Shiller, with 'excess' or 'inadequate' variation compared with the fundamental.

The test we propose here takes these ideas forward by searching for a regime switching process in a fundamental whose behaviour matches the data for that fundamental and for which the stock market it implies also mimics the data on stock prices. We ask the question here: is there some latent model of a fundamental in an efficient market that can link the data on the fundamental to the data on stock prices, accounting for the behaviour of both simultaneously? If so then one cannot reject the 'null hypothesis' that the market is efficient.

Tests of efficiency based on various forms of regression are beset with problems of interpretation — Minford and Peel (2002, ch. 14) — including the possibility of variable risk-premia, peso problems and rational bubbles. Tests based on whether a rule could be found that would 'beat the market' also have problems of statistical assessment raised by Timmermann and others: how often, particularly with the aid of data-mining, might one not be able to find such a rule in any given set of data and even in a hold-out sample, especially again if the latter is subject, even subconsciously, to data-snooping.

In this paper we follow a procedure inspired partly by the RBC literature. We ask whether a world governed entirely by efficiency could generate a series like the FTSE. Any given sample is a drawing from some true model; therefore if the true model were one of efficiency then a period of history for the FTSE could not be statistically distinguished from other sample drawings from that model. We can classify the properties of the distributions from our model world and compare them with the sample properties of the FTSE; we can then test whether at say the 95% level of confidence we can reject the proposition that the FTSE sample has the same properties. The advantage of this approach is that we can, for the specified null hypothesis, generate exactly the implied statistical distributions, and so test the null with complete rigour.

We create a regime switching model with four regimes (where the regimes represent high, normal and low growth, as well as a crash) with the probability of each regime constant over time, which generates a profits series. The rational expectation of the future profits is used to create the present discounted value which we use as our FTSE series. Because there is a constant probability of each future regime the variance around future returns is fixed, as are any risk-premium terms, so we have an efficient market world of rational agents. As our profits regime is a latent process it cannot be bootstrapped as the true errors are not observed. We use stochastic simulations to see if the model can statistically match the data. In the model with a crash we couldn't match the profits series exactly. This is to be expected because in the sample we used there wasn't a crash. As we cannot match profits exactly we are trying to match two series, one input (profits) and one output (FTSE).

4.3 The Working Hypothesis

There has been a certain amount of work in this line before. What it has shown is that straightforwardly interpretable error processes for news cannot generate the properties of the FTSE, with its booms, crashes and apparent 'bubbles' — or described more technically in terms of its univariate time-series properties, its tendencies to display ARCH, unit roots, and fat tails. However a promising framework has appeared to be one suggested by the 'Peso problem': where the fundamental switches in a Markov process between several regimes.

We can think of an economy (the UK in this case) where the capital stock generates the profits or dividends that are valued as equities (the FTSE). The profits are mainly driven by productivity shocks since variations in labour inputs mainly change wages while changes in the capital stock mainly dilute the equity base. So we shall assume that the fundamental, profits per share, can be identified with productivity (a more elaborate specification would involve a complete RBC model; but to minimise complexity we use this approximative assumption.)

RBC models take the behaviour of productivity as exogenous, usually modelling it via some sort of univariate time-series. The empirical success of these models in matching the macroeconomic facts has been limited however. Their strength has been in supplying an explanation for certain salient macroeconomic correlations and cross-correlations; however most macroeconomic modellers today rely instead on some source of substantial nominal rigidity to generate persistence in inflation and output.

Here we suggest that the recognition of several regimes for productivity growth could be a helpful generalisation of the time-series process governing it. Thus for example one might identify periods of poor productivity growth — during wartime or poorly-adapted institutions (union power in the UK during the 1970s); also periods of rapid productivity associated with surges of innovation (the industrial revolution, the computer revolution etc); and finally periods of normal growth, when innovation is being digested undisturbed by wars or dysfunctional institutions.

Each of these productivity regimes we represent by an ARIMA (1,1, 0) process with drift. The unit root represents the idea that productivity changes are in principle irreversible; the serial correlation the idea that once a change occurs it will be followed by further similar changes. The drift represents the mean growth of the regime. Each period the economy chooses one of the regimes with fixed probabilities — but the lagged effects of the previous regimes still are present. Thus if a war occurs, even when it is over its effects persist until they gradually disappear from the economy; meanwhile other shocks overlay them.

Plainly we have no good theory of productivity growth and hence even RBC models for which it is central treat it as exogenous. However, the discussion above seems a plausible improvement on the bald univariate processes generally assumed in RBC models. One gap in our study to this point is that we do not look at actual UK productivity growth in choosing this regime switching model — ideally we would wish the output from our regime switching process to match the facts of productivity (or strictly of dividends) but at this stage we have not investigated this matching. This gap is in the same spirit as the fact that we have not checked the implicit RBC model for its fit to the other facts of the economy — but this particular check is closer to the specific issue of explaining the FTSE.

However, we identify profits with productivity and treat profits as the fundamental underlying valuation of the FTSE. We test our hypothesis about the regime-switching profits regime not merely against the FTSE but also against the profits fundamental. Thus our profits regimes must generate profits samples from which our actual profits sample cannot be distinguished statistically just as it must also generate FTSE samples under efficiency from which the actual FTSE sample cannot be distinguished statistically. Since the regime-switching profits regime is a latent process its true errors cannot be observed and so it cannot be bootstrapped; however the parameters of the latent process cannot be arbitrarily chosen to generate the FTSE's behaviour; they must also 'match' (in the statistical sense we have described) the observed profits process.

4.4 Our Procedure

Initially we take the three regimes (low, normal and high growth) and assign the same iid normal-error to each. Each period the rational expectation of the future profits level is calculated and used to create the present discounted value (with a constant discount factor) which is the assumed FTSE. Notice that the conditional variance of profits around the future expectation is constant at all times since there is a constant probability of each future regime and hence of all future possible innovations; hence the variance surrounding future returns is equally fixed and with it any risk-premium terms attaching to FTSE valuation. Thus our set-up embodies all the standard assumptions of an efficient market world of rational agents.

At the next stage we search to find the best calibration of this model to the profits and FTSE data. Using the powerful method of grid search we choose the combination of parameters for the 3 ARIMA processes that minimises the distance between a linear combination of the moments of the simulated FTSE and the actual FTSE and those of the simulated profits process from those of the actual process.[1]

Using the best set of parameters the composite process is then simulated stochastically in 10000 runs of 150 periods. With these stochastic simulations we then carry out the tests described at the start of this paper. We wish to know whether the FTSE data can be regarded as a sample drawing from this model. We look first at the FTSE sample moments; do they lie outside the 95% confidence limits of the null hypothesis distributions (found from the 10000 generated samples)? Secondly, we look at the FTSE ARCH process describing the FTSE's dynamics; do its parameters lie outside the 95% confidence limits for the ARCH processes of the 10000 generated samples?

4.5 Methodology

The three regimes each have their own mean (c_1, c_2, c_3) and equal standard deviation (σ_η). The low growth and high growth regimes have probability of occuring π_1, π_3 and therefore $\pi_2 = 1 - \pi_1 - \pi_3$. For each period we choose the regime at random and the corresponding growth (c_i), and then choose a random number $\eta \sim N(0, \sigma_\eta)$. These are then used to calculate our generated FTSE as follows.

Starting with intial values of $w_1 = w_2 = 1$ we generate a 152×150 matrix in which each column will contain the values that we discount to generate our series.

[1]The method we use here is similar to Simulated Method of Moments, though we do not vary the weights on the moments in the critical value.

$$A = \begin{bmatrix} 1 & 1 & w_3 & \cdots & w_{150} \\ 1 & w_3 & w_4 & \cdots & w_{151} \\ w_3 & w_4 & w_5 & \cdots & w_{152} \\ \beta E_3 w_4 & \beta E_4 w_5 & \beta E_5 w_6 & \cdots & \beta E_{152} w_{153} \\ \beta^2 E_3 w_5 & \beta^2 E_4 w_6 & \beta^2 E_5 w_7 & \cdots & \beta^2 E_{152} w_{154} \\ \vdots & \vdots & \vdots & & \vdots \\ \beta^{150} E_3 w_{153} & \beta^{150} E_4 w_{154} & \beta^{150} E_5 w_{155} & \cdots & \beta^{150} E_{152} w_{302} \end{bmatrix}$$

where

$$\begin{aligned} w_t &= w_{t-1} + \rho \Delta w_{t-1} + \eta_t + c_i \\ E_t w_{t+1} &= w_t + \rho \Delta w_t + \pi_1 c_1 + \pi_2 c_2 + \pi_3 c_3 \\ E_t w_{t+2} &= E_t w_{t+1} + \rho(E_t w_{t+1} - w_t) + \pi_1 c_1 + \pi_2 c_2 + \pi_3 c_3 \\ E_t w_{t+3} &= E_t w_{t+2} + \rho(E_t w_{t+2} - E_t w_{t+1}) + \pi_1 c_1 + \pi_2 c_2 + \pi_3 c_3 \\ &\vdots \end{aligned}$$

Here η_t is a random number, c_i is the growth, and π_i is the probability of the regime, where $i = 1, 2$ or 3 depending on which regime is chosen. Each period of our series is then given by

$$A_t = \exp(w_t - 1) + \beta \exp(E_t w_{t+1} - 1) + \beta^2 \exp(E_t w_{t+2} - 1) + \ldots \qquad \text{for } t = 3, 152 \tag{4.1}$$

Where $\beta = 0.99$. We then take the difference in logs of this series and calculate the moments of our simulated FTSE (GFT):

$$GFT = \Delta \log(A_t) \tag{4.2}$$

We want to find which combination of parameters gives a GFT that is the best match of the the actual FTSE. To do this we use a grid search. For the grid search procedure we first ran the following regression on profits:

$$\Delta \log(PROF_t) = \beta_1 + \beta_2 \Delta \log(PROF_{t-1}) + \varepsilon_t \tag{4.3}$$

from this regression we get $\beta_1 = 0.006414$, $\beta_2 = -0.111544$. We use β_1 as the normal growth rate and β_2 as our serial correlation, so we set $c_2 = 0.006414$ and $\rho = -0.111544$.

The next step is to solve the following equations:

$$\overline{E\omega}^2 = \pi_1(c_1 - c_2)^2 + \pi_3(c_3 - c_2)^2 + \sigma_\eta^2 \tag{4.4}$$

$$\overline{E\omega}^3 = \frac{\pi_1(c_1 - c_2)^3 + \pi_3(c_3 - c_2)^3}{\sigma_\eta^3} \tag{4.5}$$

$$\overline{E\omega}^4 = \frac{\pi_1(c_1 - c_2)^4 + \pi_3(c_3 - c_2)^4}{\sigma_\eta^4} + 3\sigma_\eta^4 \tag{4.6}$$

where $\overline{E\omega}^2 = 0.002982$, $\overline{E\omega}^3 = -0.02807$ and $\overline{E\omega}^4 = 1.3246$ are the variance, skewness and kurtosis of $\Delta \log(PROF)$. So we have 3 equations but 5 unknowns $(\pi_1, \pi_3, c_1, c_3, \sigma_\eta)$ as c_2 is known. To solve this problem we do a grid search over $\pi_1 \in [0.01, 0.10]$and $\pi_3 \in [0.01, 0.10]$ (using a step size of 0.01) and solve for c_1, c_3, σ_η. These parameters are then used to generate our simulated FTSE using the method described above and see which set mimizes the following critical value

$$
\begin{aligned}
crit &= ((MOM1_{FTSE} - MOM1_{GFT})/MOM1_{GFT})^2 \\
&\quad +((MOM2_{FTSE} - MOM2_{GFT})/MOM2_{GFT})^2 \\
&\quad +((MOM3_{FTSE} - MOM3_{GFT})/MOM3_{GFT})^2 \\
&\quad +((MOM4_{FTSE} - MOM4_{GFT})/MOM4_{GFT})^2 \qquad (4.7)
\end{aligned}
$$

where $MOM1$, $MOM2$, $MOM3$, $MOM4$ are the moments.

Using the set of parameters that minimised the critical value we then run 10000 simulations, and calculate the moments of our generated series for each run, and also run the regression $GFT = \beta_1$ with a ARCH(1) representation on the residuals of this regression and draw histograms to compare the coefficients of our series with the actual FTSE and see if the actual FTSE lies between the 2.5% tails. We initially estimated $\Delta \log(FTSE) = \beta_1 + \beta_2 \Delta \log(FTSE_{-1})$ with a GARCH(1,1) representation but found that the β_2 and GARCH parameter weren't statistically significant.

4.6 Results

As a base case we wanted to see if we could match the properties of the FTSE using a simple model without the regime switching. To do this we generated 10000 bootstraps using our original model but with $\pi_1 = \pi_3 = 0$ using the errors from the regression of $\Delta \log(PROF)$ instead of a normal distribution. We then compared the 10000 bootstraps with the actual FTSE. The results of the base case can be seen in Table 4.1. The table reports the values for the 2.5% tails and the values from the $\Delta \log(FTSE)$ series.

From Table 4.1 you can see that this model does not match the variance, kurtosis, the ARCH constant or the ARCH parameter. Since this model does not match all the properties of the FTSE we now go on to use our model with regime switching.

Table 4.1: Results for the base model

	Lower 2.5% Limit	Upper 2.5% Limit	Actual
Mean	−0.005021	0.016074	0.004356
Variance	0.001417	0.003413	0.007137
Skewness	−0.994640	0.395325	−0.579837
Kurtosis	2.522443	5.500468	5.715775
β_1	−0.005055	0.016241	0.008181
ARCH Constant	0.001335	0.003081	0.003327
ARCH	0.000000	0.230410	0.455670

The results of the grid search resulted in the combination of $\pi_1 = 0.08$ and $\pi_3 = 0.01$ minimising the critical value. Solving equations (4.4), (4.5) and (4.6) for these values of $\pi_1$and π_3 yields the following parameters:

$$\rho = -0.111544$$
$$c_1 = -0.068896251$$
$$c_2 = 0.006414$$
$$c_3 = 0.152291442$$
$$\pi_1 = 0.08$$
$$\pi_3 = 0.01$$
$$\sigma_\eta = 0.002315467$$

The model using these parameters is unable to match the ARCH process, so to try and match the ARCH process we changed the model so that each regime has a different ρ. The values of the ρ's are calculated so that the average ρ is still equal to the estimated value. We chose to use $\rho_1 = -0.2$, and $\rho_3 = 0.3$ which results in $\rho_2 = -0.1062292$. The results from this model are in Table 4.2.

Again, this model did not generate a FTSE that matched up with the actual FTSE, not matching the variance or the skewness. Though this model did do better than the base case as it matches the ARCH parameters. To see if we could match the properties of the FTSE we adjusted the parameters to see if we could improve on them. The parameters we used were

Table 4.2: Results for the markov switching model

	Lower 2.5% Limit	Upper 2.5% Limit	Actual
Mean	−0.008786	0.011325	0.004356
Variance	0.001727	0.004771	0.007137
Skewness	−0.565648	2.090995	−0.579837
Kurtosis	2.518592	17.563532	5.715775
β_1	−0.009128	0.011935	0.008181
ARCH Constant	0.001552	0.004086	0.003327
ARCH	0.000000	0.600408	0.455670

$$\rho_1 = -0.2$$

$$\rho_2 = 0.2$$

$$\rho_3 = 0.3$$

$$c_1 = -0.2$$

$$c_2 = 0.006414$$

$$c_3 = 0.2$$

$$\pi_1 = 0.08$$

$$\pi_3 = 0.02$$

$$\sigma_\eta = 0.0007$$

Substituting these values in to equations (4), (5) and (6) gives:

$$\begin{aligned}
\overline{E\omega}^2 &= 0.004858 \\
\overline{E\omega}^3 &= -30.154837 \\
\overline{E\omega}^4 &= 353.704206
\end{aligned}$$

These values are not consistent with the facts for this period, which are 0.00298, −0.0281, and 1.325.

For the tests of the moments we find that the FTSE moments lie comfortably inside these 95% limits, and for the second test of the ARCH parameters we find that all the parameter also lies inside the 95% limits. Table 4.3 below shows the results.

Table 4.3: Results for the tweaked markov switching model

	Lower 2.5% Limit	Upper 2.5% Limit	Actual
Mean	−0.021701	0.006399	0.004356
Variance	0.003196	0.007325	0.007137
Skewness	−1.787721	0.528254	−0.579837
Kurtosis	5.042048	10.550043	5.715775
β_1	−0.021652	0.016983	0.008181
ARCH Constant	0.001336	0.007136	0.003327
ARCH	0.000000	0.999998	0.45567

Using the model above with 3 regimes we can either match the properties of the profits series, which results in not matching the FTSE, or match the properties of the FTSE, which results in not matching the profits series. To try and improve on this model we introduce the idea of a 'Peso problem'. This involves including a fourth regime which can be interpreted as a crash, with a low probability of occuring. To calculate the probability of a crash occuring we used share price index data for 38 countries and calculated how many times the indices showed a quarterly growth rate of less than −0.6. Out of 4367 observations this occured once, giving a probability of a crash equal to 0.023%. We think this is a small enough probability of a crash to be reasonable. After introducing this fourth regime equations (4.4), (4.5) and (4.6) now become:

$$\overline{E\omega}^2 = \pi_1(c_1 - c_2)^2 + \pi_3(c_3 - c_2)^2 + \pi_4(c_4 - c_2)^2 + \sigma_\eta^2 \tag{4.4'}$$

$$\overline{E\omega}^3 = \frac{\pi_1(c_1 - c_2)^3 + \pi_3(c_3 - c_2)^3 + \pi_4(c_4 - c_2)^2}{\sigma_\eta^3} \tag{4.5'}$$

$$\overline{E\omega}^4 = \frac{\pi_1(c_1 - c_2)^4 + \pi_3(c_3 - c_2)^4 + \pi_4(c_4 - c_2)^2}{\sigma_\eta^4} + 3\sigma_\eta^4 \tag{4.6'}$$

Where π_4 is the probability of a crash, and c_4 is the growth rate when there is a crash. With $\pi_4 = 0.00023$ and $-1.0 < c_4 < -0.3$ there isn't a solution to equations (4.4'), (4.5') and (4.6') so we can't use the methodology used for the 3 regime model. To overcome this problem we run the model through a search algorithm to see which combination of parameters $(\pi_1, \pi_3, \pi_4, c_1, c_3, c_4, \sigma_\eta)$ minimise the critical value. The search algorithm takes some initial values for the parameters, and in the first iteration increases and decreases one parameter at a time by a set step size, then calculates the critical value. The combination of parameters that minimises the critical value are then used as the starting values for the next iteration. When the algorithm fails to improve on the starting values it then decreases the step size and searches again until it minimises the critical value again. This process is repeated until the step size is sufficiently small.

We impose the following restrictions when implimenting the search algorithm

$$
\begin{aligned}
c_1 &< 0.006414 \\
0.01 &\leq c_3 \leq 0.1 \\
c_4 &\leq -0.3 \\
\pi_1 &\geq 0.01 \\
\pi_3 &\geq 0.01 \\
\pi_4 &= 0.0002
\end{aligned}
$$

With $\pi_4 = 0.0002$ we increased the number of simulations to 50000 to ensure that a crash will happen a sufficient amount of times.

As we cannot strictly match equations (4.4'), (4.5') and (4.6') we cannot use the exact profits moments to fix the model. As a result of this we are now trying to match two series which involves a search over the match between both profits and FTSE. So, as well as seeing if our generated FTSE can match the moments of the actual FTSE, we also want to see if our generated profits series (GPROF) can match the properties of the actual profits series. To see if we can match the properties of the profits series we run the regression $\Delta \log(GPROF) = \beta_1 + \beta_2 \Delta \log(GPROF_{-1})$ and compare coefficients of the regression and the moments of the residuals of this regression. As we are trying to match both the FTSE and profits, the critical value becomes:

$$
\begin{aligned}
crit &= ((MOM1_{FTSE} - MOM1_{GFT})/MOM1_{GFT})^2 \\
&\quad +((MOM2_{FTSE} - MOM2_{GFT})/MOM2_{GFT})^2 \\
&\quad +((MOM3_{FTSE} - MOM3_{GFT})/MOM3_{GFT})^2 \\
&\quad +((MOM4_{FTSE} - MOM4_{GFT})/MOM4_{GFT})^2 \\
&\quad +((MOM2_{PROF} - MOM2_{GPROF})/MOM2_{GROF})^2 \\
&\quad +((MOM3_{PROF} - MOM3_{GPROF})/MOM3_{GROF})^2 \\
&\quad +((MOM4_{PROF} - MOM4_{GPROF})/MOM4_{GROF})^2 \qquad (3.7')
\end{aligned}
$$

The combination of parameters from the search algorithm that minimised the critical value were

$$
\begin{aligned}
c_1 &= -0.063978 \\
c_2 &= 0.006414 \\
c_3 &= 0.1 \\
c_4 &= -0.3 \\
\pi_1 &= 0.07828 \\
\pi_2 &= 0.91172 \\
\pi_3 &= 0.01 \\
\pi_4 &= 0.0002 \\
\sigma_\eta &= 0.003267
\end{aligned}
$$

Using asymmetric ρ parameters for the different regimes with $\rho_1 = -0.2$, $\rho_2 = -0.1086834$, $\rho_3 = 0.3$, $\rho_{crash} = 0.9$ which gives an average $\rho = -0.111544$ which is equal to the ρ estimated earlier. Raising the ρ parameter for a crash increases the importance of the FTSE in our model.

The results for this model are in Table 4.4.

Table 4.4: Results for the markov switching model with a crash

	Lower 2.5% Limit	Upper 2.5% Limit	Actual
FTSE			
Mean	−0.009916	0.013217	0.004356
Variance	0.002323	0.012068	0.007137
Skewness	−1.278085	1.356789	−0.579837
Kurtosis	2.503174	41.085846	5.715775
FTSE Regression			
β_1	−0.011192	0.014199	0.008181
ARCH constant	0.002103	0.005427	0.003327
ARCH	0.000000	0.456564	0.455670
$\Delta\log$(**Profits**) **Regression**			
β_1	−0.011207	0.014974	0.006414
β_2	−0.272949	0.046430	−0.111544
$\Delta\log$(**Profits**) **Regression Residuals**			
Mean	$-4.09e^{-18}$	$4.08e^{-18}$	$-4.08e^{-19}$
Variance	0.002679	0.004964	0.002714
Skewness	−0.650569	0.477425	−0.390942
Kurtosis	2.309765	4.920717	3.991456

As you can see from Table 4.4, the model with regime switching including a crash matches all the properties of both the FTSE and the profits series. Figure 4.1 shows the histograms of the GFT parameters and Figure 4.2 shows the histograms of the GPROF parameters from the 50000 simulations. The black lines show the 2.5% limits and the red line is the actual value. Figure 3 shows the actual FTSE series along with a random selection of our generated FTSE series. Figure 4.3 shows that this model produces series that have the peaks and troughs associated with the actual FTSE series.

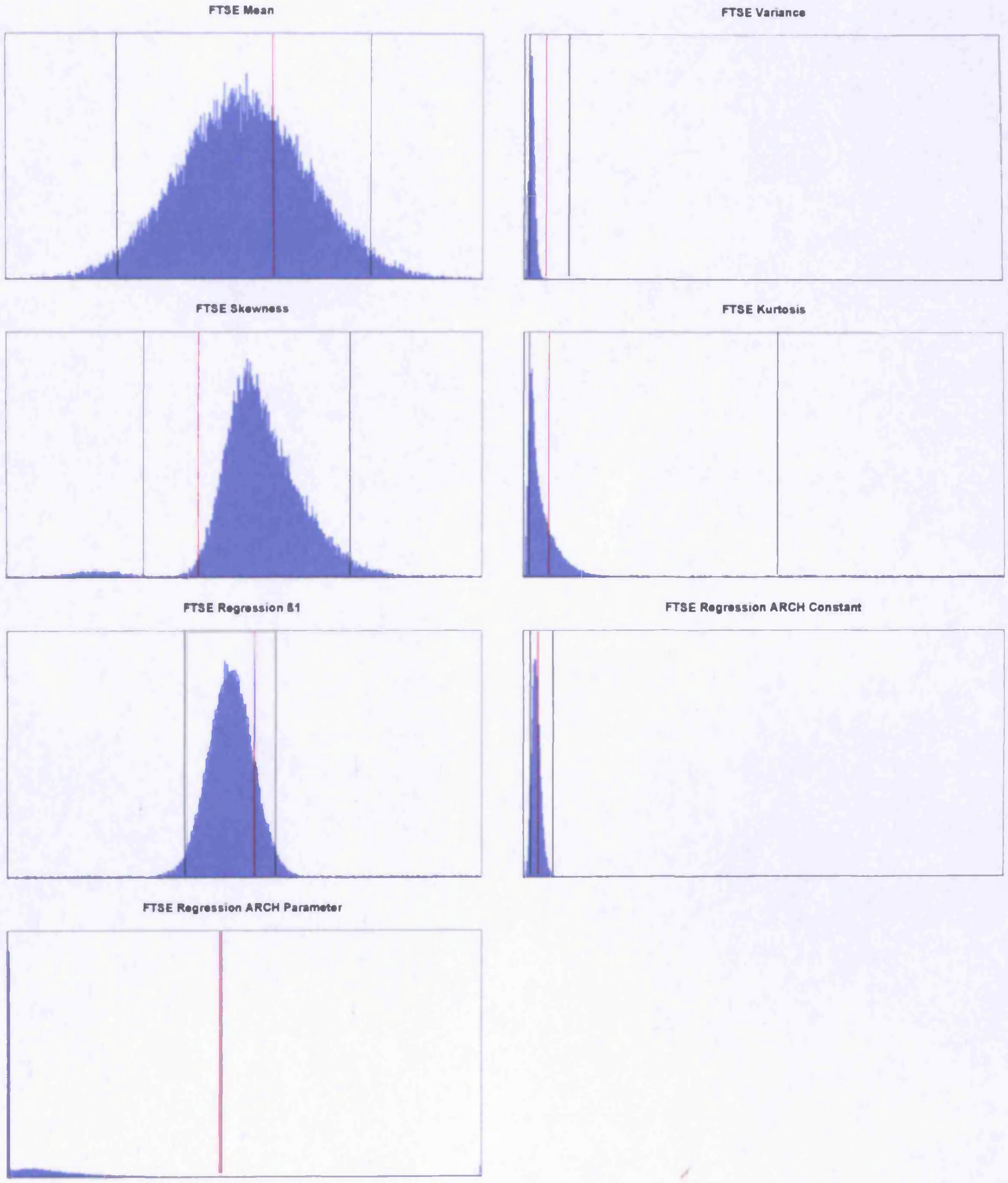

Figure 4.1: Histograms of Generated FT Parameters

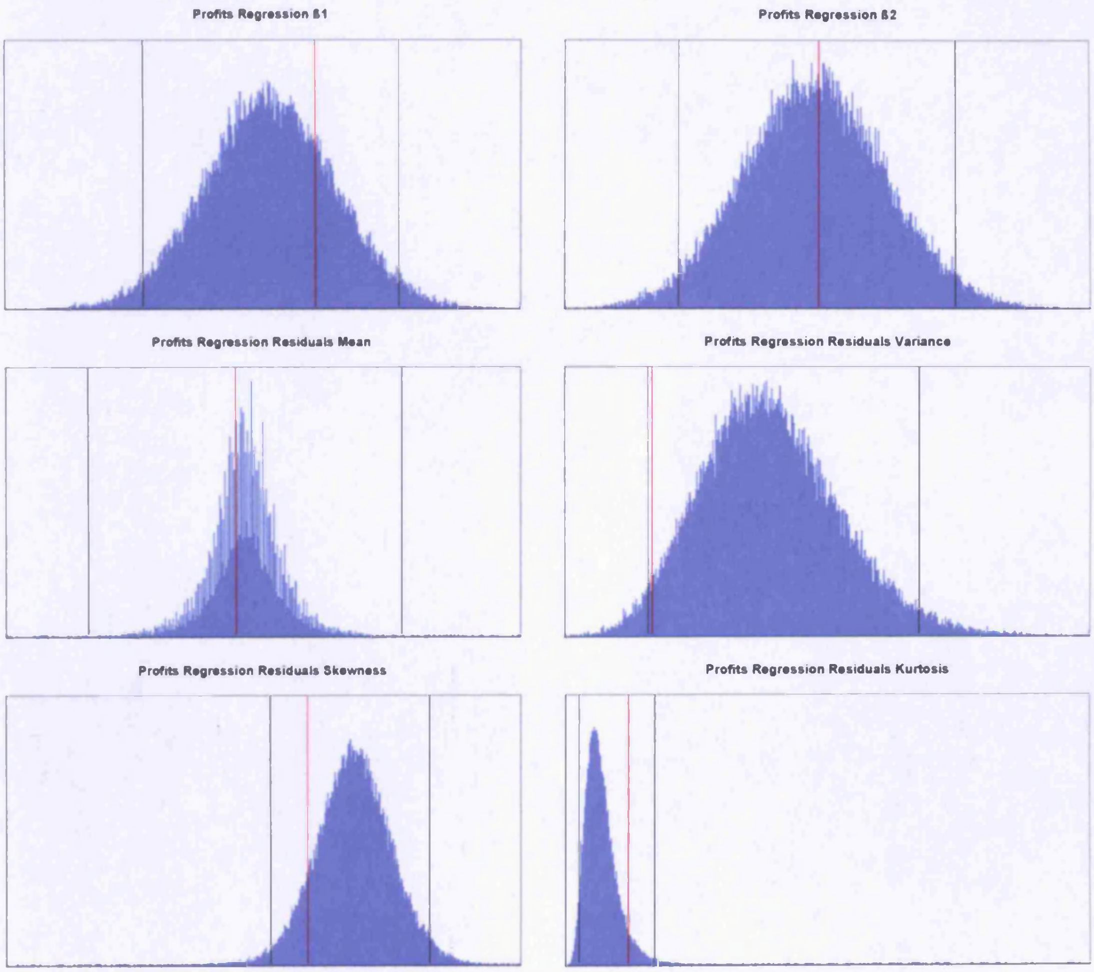

Figure 4.2: Histograms of Generated Profits Parameters

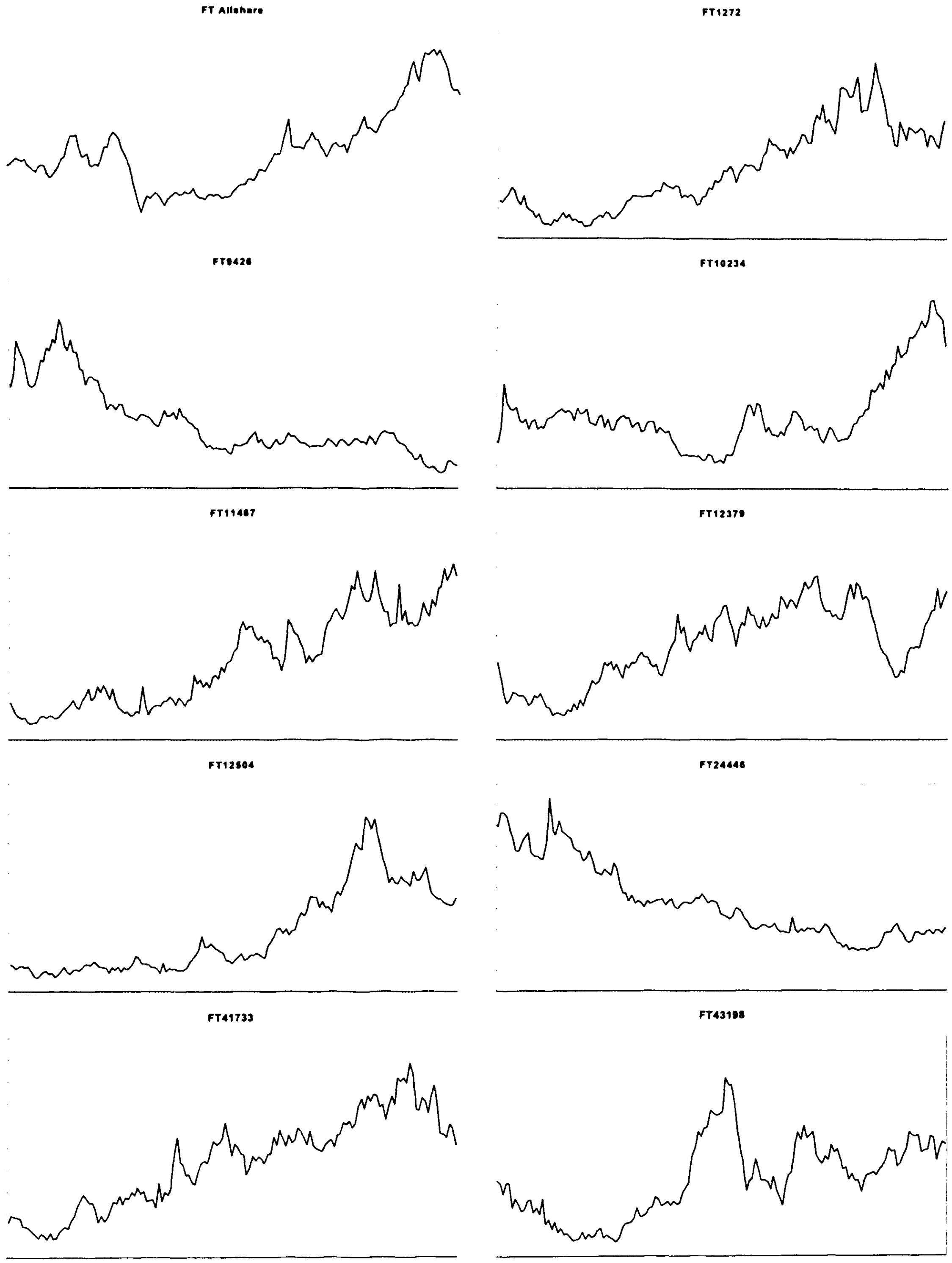

Figure 4.3: Actual FTSE and a Random Selection of Generated FTSE

4.7 Conclusions

In this paper we asked whether a world governed entirely by efficiency could generate a series like the FTSE. Using profits as the fundamental underlying valuation of the FTSE we tested whether, at the 95% confidence level, we can reject the proposition that both the profits and the FTSE samples have the same properties as the series generated from our model. As a base case we tried to match the properties of the FTSE using a model without regime switching; here we took the actual profits series' errors and bootstrapped them, so exactly matching the profits series. We found that this model was unable to generate a series that matched the properties of the FTSE; this result is in line with numerous previous studies. Building on the base case we created a regime switching model with 3 regimes (high, normal and low growth). This model was an improvement, getting closer to matching the properties of the FTSE than the base case, but we found that it could not simultaneoulsy match the properties of both series. Next we added a fourth (crash) regime, with a very small probability of occurrence derived from experience over a large sample of countries. With this four-regime model we find that we are able to match the properties of both profits and the FTSE, in the sense that we cannot reject at the 95% level of confidence the proposition that both the profits and the FTSE samples were generated by our model.

Finally we should recall the widely-held view, notably by proponents of 'behavioural finance', that it is impossible to account for the facts of financial market in terms of efficient-market models.. We have shown here that this is not the case — that indeed the hypothesis of efficiency, if constructed to incorporate the possibility of extreme events, can explain the facts of financial markets. It is of course possible that alternative hypotheses can also explain these facts; but that issue and whether such explanations can be considered better ones, is an issue that must be deferred to further research.

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Chapter 5

Overall Conclusions

Macro economic outcomes have tended to exhibit serious instability from time to time. One policy reaction to this has been to suggest interventionist rules for monetary and regulatory policy. Examples of these have been the idea that the UK should join the euro as a substitute for a domestic monetary policy that has led to macro instability; that monetary policy should stabilise rates of growth of nominal variables rather than their levels as a way of stabilising unemployment; and that financial markets need regulation to avoid inefficiency and 'bubbles'. These three examples are what are addressed in this thesis.

In the first part I looked at the proposal to join the euro; plainly such a proposal might look attractive if domestic monetary policy is poorly constructed. However equally plainly it must be possible for a government to decide on good monetary policy. I examined the euro proposal within that context. Using the Liverpool model with both a floating exchange rate and a fixed exchange rate (EMU) I find that the variances of four key variables — output around its trend, inflation, unemployment and real short-term interest rates — are considerably higher under EMU than under floating. The variance of output around its trend is nearly a quarter higher; that of unemployment nearly a fifth higher; real interest rates a multiple of over four times; and that of inflation under

EMU is approximately twenty times that under floating. The EMU environment is one in which ECB nominal interest rates are moving a fair amount for euro-zone-wide reasons and yet because they are poorly addressed to UK shocks the UK economy experiences considerably worse output, employment and above all inflation swings. When assessing the welfare under both cases I find that welfare under EMU is 45% of that under floating — equivalently the EMU welfare cost is 2.21 times that of floating.

I also checked the results for sensitivity by examining the differences between floating and EMU if our assumptions about both regimes were wrong due to an 'exogenous' mistake in the parameter values. Whilst some of the changes decreased the gap between floating and EMU, some of them worsened the relative position of EMU. But in no case does the relative position of EMU become reversed, nor does it even come close to that. Whatever one does to the structure of the British economy, it remains the case the EMU makes it much more unstable.

Overall I find that joining EMU would more than double the variability of the UK economy. One quarter of this extra cost comes from the loss of stabilising powers of independent UK monetary policy; the other three quarters comes from the instability of the euro-zone's own interest rates and exchange rates. This increased cost is largely insensitive to the sort of changes that euro advocates have put forward. Greater UK labour market flexibility helps; so does smaller UK responsiveness to interest rates. But the extent is limited; the big differences remain. Only if the highly optimistic assumption is made that both these parameter changes will come about solely as a result of joining EMU does output variability fall under EMU; even then variability in inflation and real interest rates is undiminished and the overall macro variability compared with floating is only halved.

In the second part I looked more narrowly at domestic monetary policy and asked whether one could envisage less emphasis on output stabilisation and move from the existing practice of targeting the growth rates of nominal variables to targeting their levels. This would bring monetary policy closer to the classical norms of the gold standard and avoid the problem of existing practices that the variance of the nominal price level becomes infinite as the time horizon of prediction stretches into the future. I looked at the operation of monetary rules both within a calibrated model and within a forecasting model of the UK (the Liverpool model). The main current targeting choice of central banks is inflation targeting; I therefore make this the benchmark regime against which to measure alternatives.

I find that when comparing inflation and price-level targeting using the calibrated model the variances of both consumption and unemployment fall as we move to price-level targeting, once allowance is made for the endogenous response of indexation. If indexation does not respond then unemployment variance actually increases while consumption variance falls on the move to price targeting. This result is very much in line with the usual views of macroeconomists under the usual assumption that indexation is constant: that targeting the price level would destabilise employment and output, even if the stability of prices would indeed yield benefits to those with long term, nominal, or partly nominal, contracts, as here exemplified by workers with wage contracts that are not fully indexed. When comparing inflation and money targeting I find that money targeting is not helpful to real wage smoothing, but it does reduce the variance of unemployment even when there is no response of indexation.

Looking at the price and money targeting from the viewpoint of average welfare, I find that money targeting is superior before indexation has adjusted — confirming the majority macroeconomist viewpoint that price targeting is too rigid in driving prices back to their target track. Money targeting is however flexible enough to deliver some benefit overall compared with inflation targeting; it slightly destabilises consumption but markedly stabilises employment. After indexation has adjusted, it turns out that the two policies deliver rather similar improvements in general welfare.

The results with the Liverpool model are about as favourable to price-level targeting as in the calibrated model. Again, they show that under inflation-targeting there is a high degree of indexation and this would drop to nil under price-level targeting. Similarly, too, they show that if indexation is assumed endogenous, welfare will rise significantly if price-level targeting is introduced. In the Liverpool model the variance of consumption falls more and that of unemployment falls less than in the representative-agent model but both fall significantly. Turning to a comparison of money targeting and price targeting, I find that money targeting relatively stabilises nominal and real interest rates, real investment and total wealth, but it relatively destabilises prices and inflation and hence the real value of financial wealth. The variance of unemployment and output rise as we switch from price- to money-targeting while that of consumption falls. Aggregate welfare under price- and money-targeting are roughly the same.

I also distinguish between two groups of agents, the employed and the unemployed. The aim was to see how for allowing for such heterogeneity both in models and in groups could matter for the choice of monetary regime. I found that heterogeneity did matter, in the sense that certain model-policy combinations could cause harm particularly to the unskilled group and therefore would prudently be avoided either from a welfare or political viewpoint. I concluded that targeting the level of the money supply within an operating system of money-supply-control is the dominant monetary regime. It is both the only regime that strictly avoids a disaster to any group and it is also the one that delivers the highest average welfare across both models and groups.

In the third part I considered the need for financial market intervention or regulation, revisiting the question of financial market efficiency to investigate whether a model of complete market efficiency could explain the FTSE. Using profits as the fundamental underlying valuation of the FTSE I tested whether, at the 95% confidence level, one can reject the proposition that the FTSE sample has the same properties as the series generated from the model. Initially I used a model without regime switching to try to match the properties of the FTSE, but found that this model was unable to generate a series that matched the properties of the FTSE. Building on this model I created a regime switching model with three regimes. This model was an improvement, but still did not match the properties of the FTSE to a sufficient level. Next, I included a fourth regime which represents a crash, with a very small probability of occurrence. Using this model I am able to match the properties of both profits and the FTSE to an acceptable level, matching all of the properties I tested. The model was able to generate the booms and crashes associated with the FTSE as well as the tendency to display ARCH and fat tails. I find that one cannot reject the proposition that the FTSE has the same properties as the series generated from our model.

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MODELLING MONETARY POLICY AND FINANCIAL MARKETS

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Summary

Macro economic outcomes have tended to exhibit serious instability from time to time. One policy reaction to this has been to suggest interventionist rules for monetary and regulatory policy. Examples of these have been the idea that the UK should join the euro as a substitute for a domestic monetary policy that has led to macro instability; that monetary policy should stabilise rates of growth of nominal variables rather than their levels as a way of stabilising unemployment; and that financial markets need regulation to avoid inefficiency and 'bubbles'. These three examples are what are addressed in this thesis.

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In the third part I consider the need for financial market intervention or regulation, revisiting the question of financial market efficiency to investigate whether a model of complete market efficiency could explain the FTSE. This question is highly complicated by the possibility of multiple regimes for profit and hence productivity growth — which creates a 'peso problem' in evaluating the FTSE's behaviour. To allow for this problem I take the Montecarlo approach of constructing the working or null hypothesis of efficiency under multiple regimes and asking whether draws from the error distributions of these regimes could account for the joint behaviour of profits (the market 'fundamental') and the FTSE.