THE DETERMINANTS OF UK BUSINESS CYCLES

*Allison Holland**

and

*Andrew Scott***

*Bank of England, Threadneedle Street, London, EC2R 8AH.

**London Business School, Sussex Place, Regent's Park, London, NW1 and All Soul's College, Oxford OX1 4AL.

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Contents

	Abstract	5
1	Introduction	7
2	UK business cycles and a stochastic growth model	8
3	Measuring productivity and taste shocks	13
4	Granger causality tests	19
5	Implications	27
6	Conclusion	30
	Tables	32
	Figures	43
	Appendix I	45
	Appendix II	46
	References	48

Abstract

This paper considers the causes of post-war UK business cycles. Using an extended stochastic growth model we construct estimates of productivity and preference shocks both of which are highly persistent, volatile and potentially capable of explaining UK business cycles. We find the productivity term is the dominant explanation of UK output fluctuations but our estimated preference shift is crucial in understanding employment movements. We use a variety of Granger causality tests to establish whether these productivity and preference terms are predictable and so can be potentially considered as the cause of UK business cycles or whether they are themselves Granger caused by other variables. We find our estimated productivity term is *not* predicted by any demand-side variable, including various fiscal and monetary policy instruments, but is to a limited extent by oil prices and the share of taxes in GDP. This suggests that our 'productivity' shock may also reflect other supply-side influences. In contrast we find our 'preference' shift is predicted to a substantial extent by real variables, such as the terms of trade and oil prices, and nominal variables, such as the money supply and the price level. The implications of these findings for competing theories of the business cycle and for the monetary transmission mechanism are discussed.

1. Introduction

The aim of business cycle theory is to identify the causes of business cycles and outline the various propagation mechanisms through which these produce cyclical fluctuations. The purpose of this paper is to study the former - using UK data we attempt to outline the main sources of UK post-war business cycles. Our aim in doing so is to discriminate between competing theories of the business cycle as well as to increase our understanding of particular episodes of UK post-war economic history. To achieve this aim we focus on two fundamental sources of business cycle fluctuations: productivity shocks and a preference shift, or more generally a supply and demand shock. We choose these because (i) they can be easily calculated using only published data, avoiding the need for any econometric identification assumptions (ii) they represent the simplest extension to the neoclassical stochastic growth model which can explain observed UK business cycle patterns. They therefore form a natural benchmark with which to assess Prescotts (1986) claim that this model can account for both growth and business cycles. An additional reason for studying these shocks is that productivity disturbances have been the focus of much attention in the recent macroeconomic literature although to our knowledge this study is the first that uses UK data. While our main focus is on these two shocks our methodology is broad enough to allow for a wide range of potential causes of UK business cycles.

In Section 2 of the paper we outline some stylised facts of the UK business cycle and motivate more rigorously our focus on productivity and preference shocks. In Section 3 we provide estimates of these shocks, discuss their univariate properties and examine their correlation with key business cycle variables. We find both shocks to be very volatile and persistent with the productivity variable accounting for a large proportion of output fluctuations and preference shifts more important in explaining employment movements. Simulations show that in combination with a neoclassical growth model these shocks are capable of matching UK business cycles. However, if these shocks are to be considered as the underlying cause of business cycle fluctuations they must be exogenous to other macroeconomic variables. One weak implication of this is that if our neoclassical model is correct in identifying these shocks as the sources of UK business cycles they should not themselves be predicted by any other economic variable. Section 4 examines whether our constructed preference and productivity terms are unpredictable using a variety of specifications, estimators, sample periods and data definitions. We treat our neoclassical model and its orthogonality implications for our measured preference and productivity terms as a null hypothesis. By choosing different sets of regressors, eg money supply, interest rates, inflation, government expenditure, the fiscal deficit, to test the orthogonality properties of the preference and productivity terms we are implicitly selecting different alternative hypothesis against which to test our null. If one set of regressors predicts either of our constructed impulses then our neoclassical model is rejected and attention should be focused on these alternative variables as the source of business cycles.

Our results suggest that the estimated productivity term is not predicted by a wide range of demand-side variables, including fiscal and monetary policy instruments. This finding is robust across a range of data definitions, sample periods and estimators and is in stark contrast to US results where productivity variables are strongly predicted by monetary policy and fiscal variables. However, we find that oil prices and taxes predict a small proportion of productivity fluctuations, suggesting this measure can be interpreted more widely as capturing supply-side influences rather than productivity movements *per se*. By contrast our measured preference shift is predictable and is related to numerous variables, including the money supply. In Section 5 we interpret these results, draw comparisons with previous studies, assess the limitations of our methodology and discuss the implications of our results for Real Business Cycle (RBC) models and the monetary transmission mechanism. We show how our empirical results potentially rule out a number of theoretical explanations of UK business cycles and highlight the areas where our results suggest it is important to focus. A final section concludes.

2. UK business cycles and a stochastic growth model

Table A quotes some ‘stylised facts’ for UK business cycles (see Blackburn and Ravn (1992) for a more extensive analysis). For reasons of comparability we follow the recent literature in quoting these statistics for the cyclical component of each variable, as defined by the Hodrick-Prescott filter. Our aim in this section is to use Table A, in conjunction with the stochastic growth model of Brock and Mirman (1972), to select two particular candidates for the source of UK business cycles. In this section we justify the choice of these particular shocks and in the remainder of the paper we assess their plausibility as the exogenous driving force behind UK economic fluctuations.

Focusing first on relative volatilities, Table A echoes the standard US findings : (i) the most volatile macroeconomic component is investment (although UK investment is much less volatile than in the US) and (ii) the volatility of GDP is matched by volatility in total hours worked. However, there are also some distinctive features of the UK economy: (i) non-durable consumption is as volatile as GDP, in contrast to the United States where consumption is noticeably smoother; (ii) the volatility in total hours worked is spread equally between the intensive (average hours) and extensive (employment) margin rather than purely the extensive margin as in the United States. Turning to the dynamic correlations we see that consumption, employment and investment are all generally procyclical. However, while consumption, investment, total and average hours all peak contemporaneously with GDP, employment tends to lag output. A notable feature of Table A is the fact that the real wage shows no clear cyclical pattern.

At the heart of the stochastic growth model is a consumer who maximises discounted utility

$$\max E_t \sum_{j=0}^{\infty} \beta^{t+j} u(c_{t+j}, l_{t+j}, \varphi_{t+j}) \quad \textbf{(1)}$$

where c denotes consumption, l leisure, β is the discount factor and φ is a parameter vector which is potentially time varying so as to allow for stochastic shifts in the utility function. The consumer maximises utility by choosing the capital stock, which obeys the transition equation

$$k_t = (1-\delta)k_{t-1} + A_t f(k_{t-1}, T - l_t) - c_t \quad \textbf{(2)}$$

where δ is the depreciation rate of capital, $f(.)$ is the production function, T-l is the number of hours worked and A is a potentially stochastic productivity term. The first order conditions for this problem are:

$$u_{ct} = \beta E_t A_{t+1} f_k (k_t, T - l_{t+1}) u_{ct+1} \quad \textbf{(3)}$$

$$u_{ct} A_t f_l (k_{t-1}, T - l_t) = u_{ct} w_t = u_{lt} \quad \textbf{(4)}$$

$$u_{lt} = \beta E_t A_{t+1} f_k (k_t, T - l_{t+1}) u_{lt+1} \frac{w_t}{w_{t+1}} \quad \textbf{(5)}$$

where u_{it} denotes the derivative of the utility function with respect to argument *i* at time t, f_i denotes the derivative of the production function with respect to argument *i* and *w* denotes the real wage.

Equation **(3)** is the Euler equation for consumption and essentially says that absent any interest rate fluctuations agents smooth the marginal utility of consumption. Equation **(4)** determines how consumers trade off consumption and leisure and states that the marginal rate of substitution between them equals the real wage rate. Under standard assumptions on the utility function **(4)** suggests that increases in the real wage should bring forth some combination of higher consumption and hours worked. Equation **(5)** is derived from **(3)** and **(4)** and determines relative labour supply between time periods, forming the basis for the intertemporal substitution of labour supply. Consumers try and smooth their marginal utility of leisure but will be prepared to work harder (less) if wages are temporarily high (low) relative to next periods wages. As we have written the model there are two sources of stochastic variation in the model (i) the productivity term, A_t and (ii) the preference shift, φ_t. In this model these are the ultimate causes of business cycle fluctuations and the propagation of these shocks is through capital accumulation. We shall now consider whether these shocks can potentially explain the stylised facts of Table A.

Using US data Prescott (1986) argues that if $\ln A_t = \rho \ln A_{t-1} + u_t$ where $\rho \approx 1$ (and implicitly $\varphi_t = \varphi, \quad t$) then a modified form of the model can account for a large proportion of business cycle fluctuations. The modification is required because **(5)** cannot explain the observed US fact of strongly procyclical employment and acyclical real wages unless an implausibly large intertemporal elasticity of substitution is assumed. The modification is to adopt the indivisible labour model of Hansen (1985) which has the implication (broadly consistent with US data) that fluctuations in employment occur along the employment margin rather than through average hours worked. Table A reveals the same combination of procyclical employment and acyclical wages in the UK but because UK employment fluctuations are *equally* composed of movements in employment and average hours worked, **(5)** cannot be remedied by using the indivisible labour assumption. Instead we take an alternative route to explaining this fact by allowing for shifts in the utility function, reflected in φ. With a shifting utility function causing movements in the labour supply curve and productivity shocks shifting the labour demand curve the net result is large variation in employment but small variation in real wages. Thus introducing preference shifts has the potential of reconciling **(5)** with Table A without assuming a highly elastic labour supply curve.

Allowing the utility function to be stochastic also has the potential to rectify a further difficulty with the model, stressed by Barro and King (1984). In the absence of any variation in the real wage, **(4)** suggests that any cyclical movement in consumption should be inversely related to variations in total hours because consumption and leisure are complements. In other words, consumption and employment should be negatively correlated over the cycle, whereas Table A shows a clear positive relationship. If the preference shift φ affects the trade-off between consumption and leisure within the period then we can reconcile procyclical consumption and employment in the presence of an acyclical real wage (see Bencivenga (1991)). Finally, if this preference shift alters the trade-off between consumption in different time periods it can also explain the volatility of UK consumption. Using US data, consumption is about 40% as volatile as output which is consistent with the consumption smoothing implications of **(3)** whereas Table A shows that for the UK consumption and output are equally volatile. By allowing for autonomous consumption shifts through φ (see Scott (1995)) we can reconcile the stochastic growth model with Table A. Because of variation in φ smoothing the marginal utility of consumption does not equate with smoothing consumption and so preference shifts generate additional volatility in consumption growth over and above the standard model.

Therefore the inclusion in a stochastic growth model of a persistent productivity shock and a preference shift which alters the intertemporal allocation of consumption and the intratemporal trade-off between consumption and leisure can potentially account for the stylised facts shown in Table A. We shall therefore take as our two candidates for the driving forces of UK business cycles a productivity term and a preference shift, or more generally a supply and demand shock respectively.[1] There are many other ways of revising the stochastic growth model to explain Table A, eg introducing additional disturbances, more complex propagation mechanisms. However, we focus on productivity and preference shocks because:

(i) we can construct measures of them using only published data, avoiding the need for any econometric identification assumptions.

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[1] However, as shown in Benhabib, Rogerson and Wright (1991) our stochastic utility function may reflect fluctuations in the productivity of home production and so the term 'demand' shock may be misleading. We use it in the broad sense that there are shifts in the utility function which causes the demand for market produced consumption goods to vary.

(ii)because we have not had to make assumptions regarding how to introduce a monetary sector, a government or missing markets these shocks offer a general and easily interpreted extension to the stochastic growth model with which to test Prescott's (1986) claim that this model can account for business cycles.

However, while our main focus is on these two potential sources of UK business cycles our proposed methodology is such that we allow for a variety of different explanations of business cycles. Under the null of **(3)-(5)** we can construct estimates of a preference and productivity term. If these are genuinely the source of UK business cycles then they must be exogenous with respect to other macroeconomic variables (this implication has been tested and rejected for US data, see Hall (1988) and Evans (1992)). A weak implication of causality is that these preference and productivity variables should not be predicted by any other variable. In particular alternative models to **(3)-(5)** suggest different causes of economic fluctuations, ie traditional Keynesian models suggest an important role for the fiscal deficit, monetarists would stress the importance of the money supply, etc and so we would expect these variables to predict our constructed productivity and preference terms. If our constructed terms are not predictable then the data is consistent with **(3)-(5)** with productivity and preference shocks as the cause of UK business cycles. However, if any variable predicts these 'productivity' or 'reference' terms then the model of **(3)-(5)** is rejected and the variable which has predictive power should instead be investigated as a potential cause of UK business cycles. In this way we can use a variety of variables which are suggested by alternative business cycle models as a misspecification test for model **(3)-(5)** and so examine the causes of UK business cycles.

3. Measuring productivity and taste shocks

In this section we construct estimates of an aggregate productivity measure and a preference shift for the United Kingdom and examine their univariate properties. Our intention here is twofold. Firstly, as stressed by Cogley and Nason (1995) these univariate properties are informative in discriminating between competing theories. For instance, capital accumulation is a sufficiently weak propagation mechanism that to explain the business cycle RBC theorists must rely upon the productivity shock being both volatile and highly persistent. Similarly if our estimated preference shock has only a small standard deviation it is unlikely to reconcile **(3)-(5)** with Table A. Secondly, understanding the stochastic properties of these variables offers some insight into how to interpret them.

(i) *Productivity measure*

We estimate a stochastic aggregate productivity variable by assuming a Cobb-Douglas production function which combines employment (N_t, measured by total hours worked), and capital (K_t) to produce output (Y_t), in other words

$$Y_t = A_t K_{t-1}^{\alpha} N_t^{1-\alpha}$$

or **(6)**

$$y_t = a_t + \alpha k_{t-1} + (1-\alpha) n_t$$

where lower case letters represent natural logarithms and we have assumed constant returns to scale (an issue to which we return in Section 5). A_t is our stochastic productivity measure and represents the part of output fluctuations which *cannot* be attributed to changes in factor inputs, that is employment growth and increases in the capital stock. Under the assumption of perfect competition in factor markets, α is the share of output received by capital. The simplest estimate of α is obtained by constructing a measure of total income (trading profits, rents, non-trading income) earned by the trading sector (corporate and public sector plus the rents, dividends and interest payments received by the personal sector) and then divide by GDP.[2] This produces an estimate of α = 0.32, similar to the US capital share.

[2] Appendix I gives full definitions, including ONS codes, of all variables used. An ASCII data file is available on receipt of a blank disk by Allison Holland at the Bank of England.

However, as pointed out by Cooley and Prescott (1994), this approach is not consistent with the simple stochastic growth model in which y and k are taken to denote whole economy output and capital stock. Measured GDP does not include the services received from the capital stock of the personal sector (mainly consumer durables) or that of the government sector and the capital stock measure excludes the capital stock of the personal and government sector. In Appendix I we show how to construct whole economy measures of output and capital and using these wider measures we arrive at a capital share (α) of 0.44. Throughout this paper we shall quote results using this more extensive measure of the capital share. However, we find our results are not sensitive to the choice of α.[3]

To construct quarterly estimates of the capital stock we used the annual series in the Blue Book, Table 14.8 for the gross capital stock and the quarterly flows of total gross domestic fixed capital formation. This requires applying a depreciation rate for each quarter and this was derived (for each year) using the formula $K_t = (K_{t-1}(1-\delta)^4 + I_1(1-\delta)^3 + I_2(1-\delta)^2 + I_3(1-\delta) + I_4)$ where K_t and K_{t-1} represent annual capital stocks for two adjacent years, I_i denotes the quarterly gross investment flows and $(1-\delta)$ is the implied depreciation rate. We use as our measure of total hours worked the product of total employment (including self-employed) and average hours worked in manufacturing. The resulting estimate of a_t (the logarithm of the productivity shock) is shown as *S1* in Figure 1.1 and in first difference form in Figure 1.2. While by construction it need not be, our estimate of a_t is orthogonal to current period changes in employment and capital stock, suggesting the validity of our Cobb-Douglas assumption.

Examination of Figure 1 suggests our estimated productivity variable can potentially account for a significant amount of UK business cycle fluctuations, declining as it does in the recessions of 1973-74, 1979-81 and 1988-91 and rising sharply in the boom years of 1985-88 and 1991-93. Cogley and Nason (1995) show that the stochastic growth model provides only limited propagation of shocks and so if this productivity variable is to explain UK business cycles it must be both very persistent and volatile. Table B shows the results of unit root tests on *S1*. Neither the ADF or Phillips and Perron tests can reject the null of non-stationarity for the logarithm of the productivity shock but firmly

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[3] If we extend our definition of capital to include human as well as physical capital then α would be significantly higher. However, this broader interpretation of capital is normally assumed to explain certain stylised facts of long-run economic growth rather than business cycles. We therefore follow the rest of the business cycle literature in interpreting K as physical capital only.

rejects the same null for the first difference. Using Stock's (1991) approach we find that the 95% confidence interval for the autoregressive root is a narrow one - between 0.972 and 1.039. In other words, UK 'productivity' shocks are very persistent and so potentially may account for persistent output fluctuations. We also used the AIC and SIC criteria to choose the best ARMA specification for the logarithmic change in productivity and found ARMA(0,0) was the chosen specification so that the change in the productivity term is unpredictable. Examining *S1* we find that it has a mean growth rate of 0.2% per quarter, so that around 0.8% of growth per annum (approximately 45% of GDP growth) is attributable to underlying technology changes, with a standard deviation of 0.93%.

(ii) *Preference shifts*

To construct a measure of a preference shift we specify the utility function[4]

$$U\left(C_t, L_t\right) = \frac{C_t^{1-\tau}}{1-\tau} \frac{L_t^{\theta\varphi_t}}{\theta} \tag{7}$$

where φ_t is a random term which influences the consumer's trade-off between consumption and leisure within period and also the allocation of consumption over time, τ is the coefficient of relative risk aversion and $\theta\varphi_t$ is the elasticity of the marginal value of time. The consumer chooses their labour supply so that the marginal rate of substitution between consumption and leisure (U_l/U_c) equals the real wage rate, which under the assumption of competitive factor markets equals the marginal product of labour. Therefore

$$\frac{\theta}{1-\tau} \frac{C_t}{L_t} \varphi_t = (1-\alpha) A_t \left(\frac{K_{t-1}}{N_t}\right)^{\alpha} \tag{8}$$

As discussed in Section 2, the effect of φ_t is to generate variations in the consumption/leisure ratio even when the real wage is constant. Empirically the role of φ_t is to account for any changes in the relationship of consumption and employment which are not explained by changes in real wages. High values of φ_t require some combination of a fall in consumption and a rise in leisure and so act as a negative 'demand' shock, depressing consumption and leading to a fall in employment. Taking logarithms of **(8)** and rearranging gives

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[4] Hall (1994) performs a similar analysis but assuming a utility function which is logarithmic in both consumption and leisure.

$$\ln\varphi_t = \ln(1-\alpha) + a_t + \alpha(k_{t-1} - n_t) + l_t - c_t - \ln\left(\frac{\theta}{1-\tau}\right) \quad \textbf{(9)}$$

Given assumptions about θ, τ and α we can therefore construct an estimate of preference shifts using data on *c*, *k*, *a* and *n* (given that leisure is equal to *T-n* where *T* is the time endowment). By considering our definition of a_t in (6) we can see that estimates of φ_t are invariant to definitions of the capital stock or which estimate of α we select. For *n* we used the same measure of total hours worked as in constructing our productivity term and we used total non-durable consumption as our measure of *c*. We use the econometric results of Alogoskoufis (1987) to set θ=-4 and the results of Alogoskoufis (1987) and Acemoglu and Scott (1994) to set τ=5.

Figure 2 plots our estimated series for the logarithm of the preference shift (*P*) and its first difference. As we found for productivity, the estimated preference shift is both large and very volatile. Visual inspection shows that *if* this measure is an accurate indicator of stochastic preferences it can potentially explain the big increase in unemployment in the early 1980s and the smaller increase in the early 1990s. These 'preference' shifts also suggest that the strong economic growth of the late 1980s was a result of a shift of preferences away from leisure towards consumption which stimulated both demand and the observed fall in unemployment. Both the ADF and the Phillips-Perron tests (Table C) suggest the productivity shift is I(1), although the 95% confidence intervals are fairly wide at (0.849,1.032) suggesting that the preference shock may just be a very persistent mean reverting process rather than I(1). Both the AIC and SIC criteria suggest that the preferred specification for the change in the preference shift is an ARMA(0,0). Over the full sample the mean of the growth of the preference shift is 0.001 and its standard deviation is 1.6%, considerably larger than the volatility of both the productivity shock and GDP and capable of generating the large consumption fluctuations of Table A.

(iii) Business cycle correlations

Having constructed our business cycle impulses we now briefly examine which impulses are most important in explaining certain business cycle features. We do so to help aid the economic interpretation of the Granger causality tests in the next section. If these constructed productivity and preference shocks affect different variables then they are clearly capturing different business cycle features. If in turn these constructed impulses are found to be Granger caused by different sets of macroeconomic variables then we can be more precise about exactly how our basic model **(3)-(5)** fails.

We follow the rest of the literature in using the Hodrick-Prescott filter to identify cyclical components and then examine the cross-correlations between our estimated disturbances and various macro variables. Table D shows the correlation of the cyclical part of the productivity and preference terms with GDP. The largest correlation is between GDP and productivity although there is evidence of a large negative contemporaneous correlation between the preference shift and GDP, presumably a high preference shock increases leisure and decreases labour supply and output. However, it is the productivity term which dominates the short run explanation of GDP fluctuations. Regressing GDP growth on lags 1 to 4 of the productivity shock gives an R^2 of 0.66 while the same regression but on employment growth (reflecting potential preference shifts) gives an R^2 of 0.28. Further, the volatility of the productivity term is 93% of the volatility of GDP. As the productivity term represents the part of output fluctuations which is uncorrelated with employment or capital stock changes these findings suggest that by far the most substantial part of output fluctuations is not connected with variation in measured factor inputs.

Tables E-G suggest that consumption is driven most strongly by the preference term; that neither preferences nor productivity exert a strong influence on investment and that preference shifts are crucial for explaining cyclical employment movements (Regressing employment growth on lags 1 to 4 of the preference shock gives an R^2 of 0.69). Because our preference term accounts for all movements in consumption-employment which are not caused by real wage movements these results suggest that most employment fluctuations are not driven by wage movements. Finally Table H shows that neither taste or productivity have a very strong correlation with real wages. It is interesting to note that productivity and taste shocks tend to have opposite signed correlations with real wages - as we remarked earlier this potentially can explain why real wages change very little over the business cycle due to offsetting fluctuations in both labour supply and labour demand.

These results therefore suggest that both the productivity and preference terms are required to explain UK business cycles; that shifting preferences are crucial for understanding employment fluctuations whereas productivity fluctuations not associated with movements in either capital or labour seem most important for GDP fluctuations and neither impulse explains much of investment or real wage variability.

(iv) Simulations

In the next section we examine whether or not our constructed preference and productivity shocks are predictable by a standard set of macroeconomic variables or whether they can be considered as possible exogenous influences on the UK business cycle. However in this sub-section we consider whether a calibrated growth model subject to the shocks outlined above can mimic the stylised facts of Table A. If such a calibrated model can replicate UK business cycles then testing the exogeneity of preference and productivity shocks becomes a substantive issue. If these shocks are unpredictable *and* simulations confirm the models relevance then our modified RBC model is completely consistent with the aggregate data.

To perform simulations it is necessary to solve **(3)-(5)** for the various parameter values outlined above. To solve the model we used the Parameterised Expectations Algorithm of den Haan and Marcet (1990) which involves substituting the conditional expectation in **(3)** with a polynomial in the state variables and solving a fixed-point problem.[5] One advantage of the Parameterised Expectations approach is that it does not involve any linearisation but instead solves the non-linear equations **(3)-(5)**. Given the relatively high level of risk aversion in our model this is an important feature. Table I shows the results from simulating 500 times a 150 period version of **(3)-(5)** subject only to productivity shocks while Table J shows results when the model is extended to include preference shocks as well. Focusing first on the model with productivity shocks only we see that the model does a reasonable job in accounting for the relative volatility of variables, although compared to the US results the model is more successful at explaining consumption volatility and less so for investment. However, the most striking failure is in explaining the volatility of total hours. Because of the low intertemporal elasticity of substitution with which we calibrated the model and because productivity shocks are all permanent we see hardly any movement in hours worked in our simulations. Turning to the cyclical correlations the productivity shock only model fares reasonably well at generating a standard cyclical pattern and co-movement amongst the variables. However, the reliance upon only one shock means that there is too much co-movement

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[5] We specify our polynomial as $\{1, \ln k_t, \ln k_t^2\ \ln k_t^3, \ln k_t \ln A_t, \ln k_t \ln \varphi_t, \ln A_t, \ln A_t^2\ \ln \varphi_t, \ln \varphi_t^2\}$ and use the accuracy test of den Haan and Marcet (1994) to assess the reliability of our solution. For the model with just productivity shocks and for 1000 simulations of a 1000-period model and using 5% significance levels we found 4.3% of simulations were in the lower tail and 6.1% in the upper tail. For the model with productivity and preference shocks the numbers were 4.1% and 5.3% respectively suggesting we have reasonably accurate solutions for both models.

between variables in comparison to Table A. Further, Table I shows that reliance on productivity shocks alone makes real wages far too procyclical.

Table J shows that the addition of preference shocks substantially improves the performance of the model. It makes the volatility of consumption and output closer to their empirical counterparts in Table A and makes employment volatility substantially closer to its value in the data. While consumption and investment still display a close correlation with output, the correlation of employment with output declines substantially and the presence of shifts in the labour supply curve solves the problem of the procyclical wage. While such stylised facts from simulations offer only a weak test of the underlying model they do confirm our earlier analysis: a stochastic growth model augmented to include productivity and preference shocks can potentially account for a large proportion of stylised facts regarding the UK business cycle.

4. Granger causality tests

The previous section suggests that our measured productivity and preference terms could account for a substantial proportion of UK business cycles, both empirically and via simulations. However, as pointed out by Hall (1988), if these variables are the cause of business cycles then they should be exogenous and unpredictable by other macroeconomic variables. For US data this implication has been tested and rejected (for productivity shocks) by Hall (1988) and Evans (1992). It is to this issue we now turn. As commented earlier, the motivation for this section is to consider a wide range of alternative theories of the business cycle which are *not* consistent with our model of Section 2. For this purpose we examine whether our estimated shocks are predictable by fiscal, monetary and nominal variables plus several measures of world trade and international prices. In essence this section is performing a specification test on **(3)-(5)** where we are testing the implication of our model that our productivity and preference shocks are unpredictable by any other variable. The variables we choose to test this implication are all motivated by rival theories of business cycle fluctuations. If we find our constructed impulses to be predictable we can reject the model **(3)-(5)** and we can pursue two alternative routes. We can either extend the neoclassical structure of **(3)-(5)** to include a more involved description of the economy (ie a monetary sector, a government, etc) or we can reject the neoclassical structure and move towards alternative models (ie Keynesian, New Keynesian, etc). We discuss in a following section our own interpretation of the results.

In what follows we shall focus on a weak implication of exogeneity. We shall see if our constructed preference and productivity terms are predicted (Granger caused) by any other variable. We shall also leave unexamined the contemporaneous correlation between our constructed shocks and different business cycle variables. A natural way to examine the contemporaneous correlations would be to use a structural VAR analysis, use identification assumptions to estimate a preference and productivity shock, estimate impulse response functions and perform variance decompositions at different forecast horizons. However, the emphasis in such an approach is to examine the propagation mechanism of shocks and how important different shocks are for different variables at different time horizons. These issues can only be analysed once it has been decided how many impulses to focus on, which impulses to model and how to identify them. Instead the emphasis in our paper is not on how shocks are propagated over time but which impulses are most important for UK business cycles. It is for this reason that we focus on the predictability of our constructed preference and productivity term. If either term is significantly predicted by another variable then it should not be considered as an impulse for business cycles. In other words we consider our analysis to be logically prior to a VAR analysis of the data. Once we have detected which impulses are likely to be most important for business cycle fluctuations we can then use structural VAR analysis to examine how these shocks are propagated over time and we can also use simulations to examine whether theoretical models can account sufficiently for these propagation mechanisms. However, both the structural VAR analysis and the simulations approach rely upon the appropriate selection of economic impulses. It is precisely this issue which our paper focuses on.

To investigate the exogeneity of our estimated shocks we use Granger (1969) causality tests in the context of bivariate and multivariate error correction models. The need to allow for cointegration arises because of the non-stationarity of our measured productivity and preference terms. For each of these (denoted *u*) and an *n* x 1 vector of explanatory variables **X** we estimate :

$$\begin{bmatrix} \Delta u_t \\ \Delta \mathbf{X}_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \begin{bmatrix} A_{11}(L) & \boldsymbol{A_{12}(L)} \\ A_{21}(L) & \boldsymbol{A_{22}(L)} \end{bmatrix} \begin{bmatrix} \Delta u_{t-1} \\ \Delta \mathbf{X}_{t-1} \end{bmatrix} + \begin{bmatrix} \gamma_1(u_{t-1} - \beta_1 \mathbf{X}_{t-1}) \\ \gamma_2(u_{t-1} - \beta_2 \mathbf{X}_{t-1}) \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \qquad \textbf{(10)}$$

Our focus is on whether our estimated impulses,[6] Δu, truly are unpredictable so we are interested in the significance of the coefficients $A_{12}(L)$ (a lag polynomial of order p) and γ_1. If A_{12}(L) is significantly different from zero then we say X cyclically Granger causes *u*, while if γ_1 is significant we say X error correction (EC) Granger causes *u*. The variables that form X are chosen with specific alternative macroeconomic models to **(3)-(5)** in mind. We examine this issue using two different approaches. Firstly, in Tables K-L and N-O we examine a variety of bivariate models (eg *n*=2) where we see whether each measured impulse is in turn predictable by only one other variable. We examine this issue using a variety of different sample periods so as to check for robustness and also for a variety of different values of *p*. Cyclical Granger causality is examined by considering an F test for the exclusion of the A_{12}(L) terms. The *p*-value of this restriction is reported in Tables K and N, values below 0.05 suggest the exclusion restriction can be rejected at the 5% level so that *X* does cyclically Granger cause *u*. Tables L and O quote p-values for the exclusion of the error correction term, once more low values suggest EC Granger causality from *X* to *u*. More reliable inference regarding EC causality[7] is shown in Tables M and P. Here *X* is a vector of monetary and demand variables and equation **(10)** is estimated by means of Johansen's (1988) Maximum Likelihood technique where Johansen's trace statistic is used to determine the number of cointegrating vectors.[8] This approach enables a more robust analysis of exogeneity by considering higher dimensional models as well as allowing a more sophisticated treatment of cointegration.

We present results for both forms of causality but we argue that it is 'cyclical' causality that is most important for attempting to understand the sources of business cycle fluctuations. Firstly, the significance of the error correction term relates most strongly to the zero frequency behaviour of our variables. Given our interest is in the business cycle it seems we should place more focus on short-run dynamics rather than adjustment to the long run. For similar reasons we do not attempt to investigate here the various cointegration restrictions that **(3)-(5)** places on the data. Secondly, the error correction term is likely to capture

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6 We shall refer to *u* as an impulse because both our preference and productivity term were found to be ARIMA(0,1,0) processes, implying that their first difference (*u*) will reflect the innovation in each term.

7 The evidence regarding EC causality is more reliable in Tables L and O because we test for the existence of cointegrating vectors, whereas we do not in Tables L and O. The results of Sims, Stock and Watson (1990) show that if X and u are not cointegrated then the p-values of Tables L and O are invalid (although our inference regarding cyclical causality is unaffected).

8 Following Reimers (1992) we use a small sample adjustment on this test statistic.

complex features about the propagation of shocks rather than their origins. For instance, consider the monetary real business cycle model of King and Plosser (1984) in which money responds endogenously to higher output caused by productivity shocks. In this model, a productivity shock can cause an increase in money/credit which is required to service higher expected output growth. In other words, a productivity shock now leads to higher money supply which can also forecast future productivity growth. However, there is no 'real' causality in this model from money to output. Money is endogenously determined and rises in anticipation of higher future money demand. This complex pattern of causality can be expected to complicate tests for both forms of Granger causality but we argue that it makes EC Granger causality tests particularly hard to interpret as it is the error correction term which encapsulates all dynamic adjustment to the long run.

(a) Productivity

Table K shows the results of cyclical Granger causality tests for our productivity variable. No one variable has predictive power across all sub-periods, although the Retail Prices Index comes closest. Interestingly, there is no evidence that the GDP deflator predicts the productivity term suggesting it is the difference between the GDP deflator and the Retail Prices Index that accounts for this predictability. The main difference between the two series is the higher weight the RPI places on prices of imported goods as well as the effect of indirect taxes. Both these features are consistent with Table K where the nominal price of oil is found to Granger cause the productivity shock as are the two tax variables (reflecting total taxation and share of taxation in GDP). Both oil prices and taxes can be interpreted as supply side influences (and have been in the literature, see Kim and Lougini (1992), Braun (1994), McGrattan (1994)) and so what is most striking about Table K is the lack of causality from standard demand-side variables such as money and government expenditure. If the productivity shock is crucial for accounting for UK output fluctuations, Table K suggests a limited role for demand variables[9] in driving business cycle fluctuations. The regressors chosen in Table K were all selected with particular alternative macroeconomic models in mind but for a more general test of the predictability of the productivity variable we regressed it on lags of itself and also GDP and, in a separate regression, the part of GDP

[9] If demand variables predict the preference term then as this effects employment it is possible for demand variables to influence output. However, the results of Section 4 suggest that the majority of output fluctuations are unrelated to changes in factor inputs thereby limiting the importance for output of demand-side variables.

due to changes in employment and capital. For no sample period or any lag structure did we find any causality from GDP to our productivity term. Table L shows some sign of EC Granger causality over the shorter sample periods, but not for the whole sample. For the post-1980 data set there is evidence of EC causality from trade, M4 and interest rates. However, because M4 and the productivity term do not cointegrate the *p*-values in Table L are incorrectly sized and so are not necessarily revealing of EC causality. The EC causality from interest rates could reflect a demand-side influence but as our earlier comments suggest it is difficult to interpret EC causality as ruling out productivity shocks as being exogenous. The model of **(3)-(5)** will, through the first order condition for capital, generate a strong correlation between the interest rate and the productivity shock so that in the long run the interest rate might predict the productivity term.

Tables K and L relate to bivariate models and so may give misleading results due to omitted variable problems. Further, Tables K and L have not established the existence of any cointegrating vectors and so Table L could be potentially misleading if there is no cointegration between *X* and *u*. Table M overcomes this problem by using Johansen's approach for various different systems of variables. The only case in which there is a cointegrating vector is when interest rates are included in the system. There is only one case now where there is any evidence of cyclical Granger causality, and that is from the tax variable. Even if we assume that both interest rates and the money supply jointly represent the impact of monetary policy we can find no evidence that money affects the productivity shock (the *p*-values for the exclusion of both money and interest rates for the VAR with the optimal lag length varied between 0.28 and 0.41). In other words, Tables K-M suggest strongly that the productivity term is largely exogenous and the extent to which it is predictable simply reflects the influence of other supply side variables such as taxes and oil prices. Therefore, we can think of our constructed productivity term as representing more generally supply side disturbances. Moreover, examining the predictive ability of these other supply side influences we find them to be small. For instance, regressing the change in the productivity shock on its lagged values plus lags of the tax variable leads to an adjusted R^2 of 0.11, using lags of the oil price instead gives 0.07 and using both variables only leads to an R^2 of 0.13. The fact oil price movements only account for a small amount of output fluctuations is consistent with the real business cycle analysis of Kim and Lougini (1992) who find that introducing oil price shocks only modestly reduces the importance of productivity shocks. In other words, a large proportion of fluctuations in this supply term are exogenous to other demand and supply shocks and could reflect stochastic variations in aggregate productivity.

(b) Preference shock

In contrast to the productivity term, Table N suggests numerous variables cyclically Granger cause our constructed preference shock. The variables with predictive ability fall into two categories: nominal variables, such as M4 and the price level (both PGDP and RPI), and world trade variables, such as the oil price, terms of trade and the volume of world trade. The predictive ability of these variables holds across sub-periods. Table O shows less evidence of EC Granger causality but there are still significant effects from interest rates, the oil price and the price level. Table P suggests the only cointegrating vector that exists is between prices, money and the interest rate but nearly every specification shows substantial evidence of cyclical Granger causality. Once again it is the price level, oil prices and money which exert the most significant effect. Further, the predictive ability of these variables is substantial - a regression of the change in the preference shock on lagged values of itself, money, the price level, the oil price and the terms of trade gives an adjusted R^2 of 0.39 and reduces the standard error of the 'pure preference' shock to 1.3%. In other words, there is strong evidence that our estimated preference shock is not exogenous and that therefore labour market fluctuations are intimately connected with money, prices and international trade.[10] However, while these variables have a significant role to play in accounting for our constructed preference shock and so in explaining non-wage related employment moves they still leave unexplained a large amount of the preference shock. For instance, at a one-year horizon 13% of forecast uncertainty connected to changes in the preference shock is accounted for by M4, around 10% by prices, oil prices account for 7% and world trade around 5% and nearly 65% of forecast uncertainty in the preference shock is unrelated to any of these variables. At a three-year forecast horizon these proportions are respectively 13.5%, 12.5%, 10%, 4% and 60%.

Robustness

The previous sub-section tested for Granger causality over various sample periods, lag structures and variable specifications in an effort to establish robust results. However, equally important is the robustness of our results to the methods we use to construct our estimates of the

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[10] We also examined whether our productivity and preference shocks were predictable by one another. Once we made allowance for the disruptive effects of the 1974 three-day week via a dummy there was no evidence that the preference shock Granger caused the productivity term. However, at very strong significance levels we found the productivity variable predicting the 'preference' term.

productivity and preference shock terms. It is this issue we now focus on.

We have already remarked on the robustness of our results to different measures of α, the share of value added accounted for by capital income. Another feature of our results is that our Granger causality findings for the preference term are robust to very different assumptions regarding θ and τ. As can be seen from **(9)** the choice of θ and τ only influence the level of ln φ_t and not its stochastic features. In other words, the variability and predictability of our constructed preference shock is independent of the parameters in the utility function (although obviously our simulation results will vary with these parameters).

Another potential source of non-robustness is the criticism that our measure of the productivity shock assumes that data on the capital stock or total hours are an accurate measure of capital or labour utilised in production, or in other words that there is no factor hoarding (see Burnside and Eichenbaum (1994)). To partially overcome this problem for capital we use the Quarterly CBI Industrial Trends Survey to construct an alternative measure of capital. We use the approach of Minford, Wall and Wren-Lewis (1988) to convert the proportion of ‘yes’ responses to the question ‘are you currently working below capacity’ into a measure of capacity utilisation. Making an assumption about how firms are distributed around the industry average level of capacity and what level of capacity firms consider to be full capacity Minford *et al* (1988) show how to use an unobserved components model to derive a capacity series. Using this alternative measure of capital services we construct another measure of the productivity term, shown as *S2* in Figure 1. While there are big discrepancies in the various capital stock measures, Figure 1.2 suggests this makes little difference to productivity growth (the differences in *S1* and *S2* have a correlation coefficient of 0.84). Performing the same causality tests as outlined above we found no material difference for results using *S1* or *S2*. Therefore in the case of the capital stock it would appear that our Granger causality tests are robust to measurement error. This confirms Prescott’s (1986) claim that the properties of the productivity shock are not very sensitive to variations in capital utilisation.

Measurement error is undoubtedly a problem for our labour input series as well. Aside from issues such as factor hoarding there are also issues concerning efficiency hours (see Hansen (1993)). All of these issues make it difficult to interpret our constructed $\{a_t\}$ as consisting entirely of stochastic variations in productivity, it must also contain a significant measurement error component. However, our results do have one very strong implication for these alternative non-productivity related interpretations of our ‘productivity’ shock - our results suggest that a large component of GDP fluctuations are unpredictable by demand side variables. In other words, regardless of whether a_t reflects productivity impulses or labour hoarding it is not predictable by monetary or fiscal policy variables. Given how estimated productivity shocks account for a large proportion of GDP this in turn has the implication that a large part of output fluctuations are unpredictable. Therefore in terms of the origins of business cycle fluctuations even if $\{a_t\}$ is contaminated by measurement error our finding that the various candidate $\boldsymbol{X}$ variables we examined in Tables K to P do not Granger cause UK business cycles holds. This contrasts with US evidence where the predictability of $\{a_t\}$ by demand side variables is often interpreted as due to labour hoarding and justifying an important role for fiscal and monetary policy and a direct rejection of productivity based explanations of business cycles. However, while our findings regarding the non-causal role of demand side variables are robust to measurement error, any conclusions about the validity of the RBC model will critically depend on accurately measuring $\{a_t\}$. To the extent our productivity shock reflects measurement error we are overstating the importance of productivity shocks in contributing to business cycle fluctuations. However, given the results of Tables I and J and the predictability of the preference shock we have already concluded that a simple productivity driven RBC model is unable to account on its own for UK business cycles. Allowing for measurement error would only serve to strengthen this conclusion by lowering the volatility of estimated productivity shocks and worsening still further any similarities between Tables A and I.

5. Implications

The Granger causality results of the previous section can be used to discriminate between competing business cycle theories. Hall (1988) argues that increasing returns and imperfect competition should lead our estimated productivity term to be predictable so our finding that it is largely exogenous suggests that neither of these features are important for UK business cycles. To check the validity of constant returns to scale we also performed instrumental variables estimation, regressing the change in output on the change in the capital stock and total hours worked. The results are shown in Table Q where we also quote the results of various coefficient restrictions. Reassuringly, the coefficient estimates are consistent at high *p*-values with both our estimates of the capital income share (with our estimate of 0.4436 receiving most support) and the evidence is strongly consistent with constant returns to scale.[11] Although our confidence intervals cannot reject the hypothesis of modest increasing returns to scale, the point estimates offer little support for this hypothesis. There is certainly no evidence of short run increasing returns to labour. This has the implication that 'sunspots' are an unlikely cause of UK business cycle fluctuations. Farmer and Guo (1994) show that in a model of increasing returns 'sunspots' can exist whereby exogenous shifts in consumer's beliefs can drive cyclical fluctuations and account for a variety of stylised facts of the US business cycle. By finding evidence in favour of constant returns to scale we rule out a crucial component of this model.

The fact our estimated productivity shock is unpredictable by demand-side variables also clearly questions the importance of traditional Keynesian/fiscal policy arguments. The evidence suggests that the majority of output fluctuations (as measured by our productivity term) are unrelated to changes in factor inputs and that this component of output is unrelated to demand side variables. The fact that these non-factor related movements in output were partly predictably by taxes and oil prices suggests that instead supply side variables may be more important, partly confirming the emphasis in the RBC literature.

However, it should be made clear that our empirical work clearly rejects the RBC claim that a suitably modified stochastic growth model can explain UK business cycle fluctuations. While we found the productivity term to be mainly unpredictable we found the opposite for the preference shock. As shown in Tables I-J the model with only

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11 The relatively low explanatory power in Table Q once more confirms the fact that the majority of output fluctuations are unrelated to changes in factor inputs.

productivity shocks is incapable of explaining UK business cycles and so we cannot consider **(3)-(5)** an adequate explanation of the data. The most general reading of our results is simply that a significant amount of GDP movements are unpredictable and that this is consistent with a pure RBC model (this result is in contrast to the US facts in Rotemberg and Woodford (1996)). However, our results also clearly show that there are significant movements in employment which are uncorrelated with wages and which are predictable by various variables including money. It is this latter fact which leads to us reject the RBC model.

Any interpretation of a_t as reflecting purely variations in productivity is also challenged by examination of Figure 1.2 where it is noticeable that some of the spikes in the series coincide with known events which are widely believed to have fostered economic growth ie the 1967 devaluation, the Barber boom, exit from the ERM. Because we examine the sequence of GDP growth since 1950 it is difficult to draw too many conclusions about particular historical periods. The spirit of our time-series analysis is to look at repeated periods of UK economic fluctuations and try to find whether there is any systematic link between particular variables. As a result we cannot rule out particular episodes being driven by particular shocks. What we can however conclude is that there is no systematic evidence that monetary policy or fiscal policy has any predictive ability for the large amount of output fluctuations that are unrelated to movements in factor inputs. This suggests it is important to try and identify more precisely the mechanism whereby, for instance, the 1967 devaluation exerted an influence on output growth.

The predictability of our preference shift term is not as controversial as the findings for the ‘productivity’ term as it is more consistent with previous findings. This preference shift captures movements in employment which are not accounted for by movements in the real wage. Given Section 3 showed this preference term to be highly important in explaining employment fluctuations it suggests that while **(3)-(5)** might be able to explain output fluctuations it will perform badly in predicting the labour market. The substantial lack of Granger causality of this preference term not only questions the importance of preference shifts as a cause of business cycles but also household production theories (see footnote 2). The importance our Granger causality tests place on the terms of trade and oil prices resonates with the real rigidity results of Layard, Nickell and Jackman (1991) Chapter 9 who find both variables to have an important effect on UK unemployment due to their differential impact on consumer and producer wages. The fact the ‘preference’ term is predicted by a broad money measure, M4, is a similar result to that found for US data by

Hall (1980). Exactly why a nominal variable such as money (or the GDP or Retail price deflator) should influence a real variable such as employment is naturally a problem for the neoclassical model of Section 2. One way of extending the model to account for these findings is to allow money to enter into the utility function or to enforce a cash in advance constraint. Both formulations would potentially account for the predictive content of money for our preference shock. However, the fact that the ‘preference’ term is so crucial in explaining employment suggests that focusing explicitly on the labour market might be a more appropriate strategy. Lucas (1972) argues in favour of nominal price misperceptions which could explain the Granger causality results of Tables K-M. However, the fact that it is anticipated money which predicts the ‘preference’ shift suggests that multi-period contracts, as in Fisher (1977) and Taylor (1979), or more general nominal rigidities (also emphasised by Layard, Nickell and Jackman (1991)) could have an important role to play. Therefore in contrast to our ‘productivity’ findings these suggest that a substantial move away from the neoclassical model is required if we are to understand the business cycle behaviour of the labour market.

Our results clearly have implications for the monetary transmission mechanism. The fact our preference shift is predictable by broad money but the productivity variable is not and that the preference term is crucial in explaining employment fluctuations suggests the monetary transmission mechanism works through the labour market. Changes in nominal variables, such as money, lead to changes in employment which then affect output. However, because the majority of UK output fluctuations are not brought about by changes in employment this implies a limited role for money in instigating UK business cycles. Obviously this is not the same as saying that monetary policy cannot cause business cycle fluctuations, our observation is merely that according to our analysis policy has not Granger caused UK business cycles. It should also be stressed that our focus on causality means that we cannot comment on the issue of whether monetary policy has amplified or served to lengthen UK business cycles. Our conclusion can only weakly be stated that money does not appeared to have caused post-war UK business cycles.[12]

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[12] Our focus on Granger causality means that we cannot rule out instantaneous effects from broad money (or interest rates) on either our preference or productivity term. However, the limited evidence we find for monetary causality suggests that if money does affect output with ‘long and variable lags’ it does so through its effect on employment and is not the major source of output fluctuations. Further, our evidence only relates to linear causality.

Finally, while a significant proportion of our measured ‘preference’ shock is predictable a sizeable component remains exogenous. Given the volatility of consumption in Table A and the results of Scott (1995) it is likely that there are some significant autonomous shifts in consumption over the business cycle. While these are not a major contributor to output fluctuations they do exert a significant impact on consumption suggesting they are worthy of study as a business cycle impulse.

6. Conclusion

We have used an extended neoclassical stochastic growth model as a way of interpreting UK business cycles. Using this model we constructed measures of two sources of business cycle fluctuations, a ‘productivity’ variable and a ‘preference’ shift. Both of these are very volatile and highly persistent and visual inspection reveals they are good candidates for the causes of UK business cycles. We found the productivity term was crucial in understanding output movements but the preference shift was required to explain employment fluctuations. However, only the productivity term proved to be substantially unpredictable with only a small amount of predictability coming from oil prices and a tax variable which could both be accounted for as supply-side influences. By contrast the preference term was predictable by oil prices, the terms of trade, money and prices. Therefore using a different methodology we arrived at similar conclusions as to many other studies regarding the key dynamic determinants of employment fluctuations and the importance of real and nominal wage rigidity. Our results also serve to reject the RBC claim that a stochastic growth model subject to only taste and technology shocks can account for UK business cycles.

Our results can usefully be used to orientate future research on UK business cycles. Our finding that productivity shocks are exogenous and that constant returns to scale cannot be rejected suggests that work focusing on increasing returns, imperfect competition, and sunspots may be unfruitful using UK data. Further, our results suggest focusing on the various supply side based disturbances which have triggered post-war output fluctuations as well as more accurate measures of factor inputs actually used in the production process (as in Burnside, Eichenbaum and Rebelo (1995)). By contrast, the results relating to our measured preference shift suggest that both supply and demand shocks have had an important role to play in driving employment and output. Supply shocks such as terms of trade shifts have affected employment, presumably through some form of real wage rigidity, while demand variables such as M4 also seem to have had an effect suggesting some form of nominal wage rigidity at work. These findings suggest that monetary non-neutralities arise from the labour market but that while they are important they do not account for the most substantial part of GDP fluctuations. In addition, we are also left with some evidence of autonomous shifts in consumption and labour supply as a source of business cycle fluctuations.

Overall our results are striking in offering a clear picture of the causes of output fluctuations. We find that fluctuations in productivity, unrelated to movements in capital or labour input, explain most of GDP variability and that movements in this variable are unrelated to any obvious demand-side variables. Our analysis does not enable us to rule out all non-productivity based explanations for these output fluctuations but at the very least our results suggest that a large component of GDP fluctuations are unpredictable and not Granger caused by a standard list of macroeconomic variables. Our results also suggest that nominal variables, and particularly the money supply and prices, do influence output but not to a large extent and only indirectly through employment. However, the effect of nominal and real rigidities on employment are substantial and suggest that a more complex set of facts and theories that that offered by the stochastic growth model is required to explain UK employment fluctuations.

Table A : Business cycle facts

	Std Dev (%)	*t*-4	*t*-3	*t*-2	*t*-1	*t*	*t*+1	*t*+2	*t*+3	*t*+4
GDP	1.63	0.278	0.459	0.635	0.810	1.000	0.810	0.635	0.459	0.278
Consumption (*C*)	1.56	0.211	0.368	0.527	0.647	0.753	0.682	0.622	0.541	0.419
Investment (*I*)	3.91	0.237	0.390	0.490	0.588	0.690	0.647	0.553	0.443	0.318
Total Hours(*THRS*)	1.63	-0.013	0.196	0.366	0.584	0.768	0.745	0.657	0.556	0.408
Average Hours	1.10	0.107	0.262	0.343	0.483	0.589	0.429	0.236	0.074	-0.120
Employment(*EMP*)	1.14	-0.172	-0.017	0.163	0.358	0.540	0.672	0.742	0.760	0.736
Real Wage(*RW*)	1.19	-0.226	-0.245	-0.185	-0.075	0.104	0.087	0.088	0.039	0.064

The first column reports the standard deviation of the variable listed in the first column. The remaining columns show the correlation of the variable listed in the first column with GDP at lags 4 and 1 (*t*-4, *t*-1) and leads 1 and 4 (*t*+1, *t*+4). All data are detrended using the Hodrick-Prescott filter. Sample period: 63q2-94q4.

Table B : Unit root tests for productivity variable

	ADF test-statistic[1]	Phillips-Perron z_α test	Phillips-Perron z_t test
S1	-1.093 (4.05)	-2.009 (-13.692)	-1.430 (-2.915)
DS1	-4.528 (4.05)	-151.229 (-13.692)	-13.949 (-2.915)

95% critical values in parantheses. *DS1* denotes the first difference of *S1*. The ADF test was calculated including a constant and a time trend and with lags 1 and 4 of the left hand side variable included to whiten the equation residuals. The Phillips-Perron test (1988) was calculated using the Tukey-Hanning kernel with automatic window selection using the approach of Andrews (1991) and uses a time trend. Sample period: 63q2-94q4.

Table C : Unit root tests for preference shift

	ADF test-statistic	Phillips-Perron z_α test	Phillips-Perron z_t test
P	-2.463 (4.05)	-6.846 (-13.692)	-2.198 (-2.915)
DP	-4.772 (4.05)	-136.741 (-13.692)	-12.328 (-2.915)

DP is the first difference of *P*, the preference shock. 95% confidence intervals in parantheses. See Table B for discussion of tests.

Table D : Correlation with Output (*GDP*)

	t-4	*t*-3	*t*-2	*t*-1	*t*	*t*+1	*t*+2	*t*+3	*t*+4
Productivity	0.440	0.530	0.642	0.718	0.846	0.584	0.394	0.211	0.059
Preference Shift	0.071	-0.130	-0.294	-0.479	-0.606	-0.671	-0.667	-0.636	-0.527

Table E : Correlation with Consumption (*C*)

	t-4	*t*-3	*t*-2	*t*-1	*t*	*t*+1	*t*+2	*t*+3	*t*+4
Productivity	0.501	0.597	0.616	0.610	0.642	0.477	0.343	0.158	0.000
Preference Shift	-0.157	-0.265	-0.436	-0.584	-0.731	-0.704	-0.648	-0.587	-0.500

Table F : Correlation with Investment (*I*)

	t-4	*t*-3	*t*-2	*t*-1	*t*	*t*+1	*t*+2	*t*+3	*t*+4
Productivity	0.466	0.491	0.493	0.504	0.509	0.348	0.220	0.129	-0.000
Preference Shift	0.039	-0.155	-0.337	-0.487	-0.558	-0.607	-0.619	-0.552	-0.496

Table G : Correlation with total hours (*THRS*)

	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4
Productivity	0.466	0.517	0.485	0.467	0.316	0.233	0.053	-0.028	-0.179
Preference Shift	-0.120	-0.285	-0.481	-0.643	-0.869	-0.698	-0.601	-0.423	-0.311

Table H : Correlation with real wages (*RW*)

	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4
Productivity	0.064	0.024	0.094	0.100	0.112	-0.081	-0.125	-0.173	-0.140
Preference Shift	0.064	-0.158	-0.162	-0.111	-0.127	-0.064	0.116	0.174	0.240

All correlations constructed using Hodrick-Prescott filtered data with λ=1600. Sample period: 63q2-94q4

Table I : Simulation results for model with productivity shocks only

	Std.Dev (%)	*t*-4	*t*-3	*t*-2	*t*-1	*t*	*t*+1	*t*+2	*t*+3	*t*+4
Consumption	1.153	0.082	0.253	0.459	0.704	1.000	0.707	0.463	0.258	0.088
Investment	1.541	0.091	0.261	0.465	0.708	0.999	0.702	0.456	0.249	0.078
Total Hours	0.030	0.144	0.307	0.500	0.726	0.994	0.670	0.406	0.190	0.075
Wages	1.193	0.084	0.255	0.461	0.709	1.000	0.706	0.461	0.256	0.086

Standard Deviation of GDP was 1.205.

Table J : Simulation results for model with productivity and preference shocks

	Std.Dev (%)	*t*-4	*t*-3	*t*-2	*t*-1	*t*	*t*+1	*t*+2	*t*+3	*t*+4
Consumption	1.287	0.102	0.245	0.453	0.701	1.000	0.702	0.456	0.248	0.129
Investment	1.942	0.099	0.249	0.456	0.701	0.998	0.698	0.451	0.242	0.104
Total Hours	1.138	0.047	0.132	0.231	0.345	0.487	0.344	0.221	0.112	0.062
Wages	1.270	0.075	0.145	0.278	0.434	0.622	0.433	0.289	0.165	0.091

Standard Deviation of GDP was 1.336.

The first column reports the standard deviation of the variable listed in the first column. The remaining columns show the correlation of the variable listed in the first column with output at lags 4 through 1 (*t*-4,*t*-1) and leads 1 through 4 (*t*+1,*t*+4). All data are detrended using the Hodrick-Prescott filter. The results reported are an average over 500 simulations of a 150-period model.

Table K : Cyclical exogeneity of productivity variable

	1965:1-1994:4			1972:1-1994:4			1980:1-1994:4		
X-vector	*L*=5	*L*=4	*L*=1	*L*=5	*L*=4	*L*=1	*L*=5	*L*=4	*L*=1
M4	0.9109	0.8225	0.7142*^	0.7950	0.7806	0.6484*^	0.2508	0.1552	0.4031*^
M0				0.2390	0.4143	0.9166*^	0.7858	0.7108	0.5724*^
LRS				0.5402	0.4576	0.6950*^	0.8682	0.8016	0.8186*^
PGDP	0.1634	0.2366	0.1769*^	0.1761	0.2259	0.1817*^	0.7887	0.5976	0.5493*^
RPIsa	0.3996	0.2785	0.0612***^**	0.1602	0.1572	**0.0245*^**	0.7013	0.2570	**0.0204*^**
POIL	**0.0434**	0.0684	**0.0400*^**	0.0607	0.0905	**0.0319*^**	0.6535	0.5105	0.0993*^
ROIL	0.0672	0.1196	0.0713*^	0.1011	0.1543	0.0583*^	0.9608	0.9271	0.2559*^
TOT	0.4502	0.3418	0.3210*^	0.4529	0.3089	0.2695*^	0.7521	0.5447	0.9746*^
M6T				0.6541	0.5496	0.2349*^	0.1101*	0.2099	0.1610^
IMFT	0.1011	0.0628*	0.7913^	0.2405	0.1561	0.8641*^	0.2617*	0.2502	0.3877^
GE	0.5651	0.4495	0.8249*^	0.5485	0.4115	0.5588*^	0.8618	0.8995	0.9224*^
GC	0.2741	0.1896	0.3247*^	0.3244	0.2082	0.5606*^	0.4663	0.6535	0.7051*^
TAX	**0.0011**	**0.0005***	**0.0155^**	**0.0061**	**0.0035***	0.0947^	0.7539	0.7334	0.6615*^
TAW	**0.0008**	**0.0003***	**0.0245**^	**0.0040**	**0.0019***	0.0757^	0.5337	0.5623	0.4998*^

Sample period shown in column headings. First column lists variables in bivariate Granger Causality test with impulse (see Appendix I for explanation of variable names). *L* in the column headings denotes the order of the lag polynomials in each variable. A * denotes preferred specification according to the AIC and ^ denotes preferred specification according to SIC. Number reported is *p*-value for the test of whether the productivity shock is exogenous with respect to the variable named in first column. A low value indicates productivity term is not exogenous. Empty cells represent missing data.

Table L : EC Exogeneity of productivity variable

	1965:1-1994:4			1972:1-1994:4			1980:1-1994:4		
X-vector	*L*=5	*L*=4	*L*=1	*L*=5	*L*=4	*L*=1	*L*=5	*L*=4	*L*=1
M4	0.0625	0.0674	0.1210*^	0.0689	0.0762	0.1225*^	**0.0354**	0.0502	0.0969*^
M0				0.7044	0.5106	0.4352*^	0.4017	0.5525	0.4051*^
LRS				0.0578	**0.0324**	**0.0087*^**	0.1113	0.0521	**0.0162***^
PGDP	0.3939	0.2865	0.3728*^	0.6479	0.5391	0.4492*^	0.1476	0.4192	0.1902*^
RPIsa	0.3244	0.3339	0.4067*^	0.6925	0.6444	0.5973*^	0.8650	0.8690	0.7869
POIL	0.8615	0.9621	0.8321*^	0.8310	0.8952	0.8870***^**	0.4740	0.4680	0.7857*^
ROIL	0.8103	0.6424	0.3775*^	0.5258	0.4966	0.3672*^	0.2882	0.4377	0.3575*^
TOT	0.1570	0.1157	0.0516***^**	0.1272	0.1128	0.0645*^	0.2018	0.3268	0.5881*^
M6T				0.0541	0.0502	0.1429*^	**0.0390***	0.1957	0.5017^
IMFT	0.3459	0.3571*	0.4546^	0.4227	0.3939	0.3597*^	**0.0132***	**0.0302**	0.0838^
GE	0.2402	0.2976	0.6085*^	0.3212	0.3074	0.6445*^	0.1209	0.2880	0.5402*^
GC	0.2468	0.3004	0.4743*^	0.4240	0.4363	0.3680*^	0.1116	0.2462	0.3713*^
TAX	0.4939	0.3900*	0.3552^	0.7277	0.5506*	0.4031^	0.3313	0.6475	0.0996*^
TAW	0.3679	0.3969*	0.6339^	0.1870	0.2065*	0.5456^	0.7734	0.8514	0.5592*^

See Table K for interpretation of results.

Table M : Multivariate causality tests for productivity variable

Variables in VAR (as well as *S1*)	Lag length	No. of Cointegrating Vectors	Cyclical Granger causality of Variable 1	Cyclical Granger causality of Variable 2	Cyclical Granger causality of Variable 3	Cyclical Granger causality of Variables 1-3
RPIsa, RS & M4	2	1	0.8562	0.3640	0.2859	0.3251
PGDP, RS, & M4	3	1	0.3255	0.4496	0.4382	0.3061
PGDP, M4 & TAW	5	0	0.2512	0.8940	**0.0139**	**0.0437**
TOT, POIL & M6T	4	0	0.3565	0.1513	0.4452	0.2486
TOT & POIL	3	0	0.4066	0.0893	-	0.0819
POIL & M6T	5	0	0.0914	0.5522	-	0.2226

There is one cointegrating vector present in the VARs of *S1*, *RPIsa*, *RS* & *M4* and *S1*, *PGDP*, *RS* & *M4*; the *p*-value of these vectors are 0.0106 and 0.0404 respectively. We also tested the joint significance of *M4* and *RS* in the two systems in which they were included, the *p*-values of their joint significance were 0.2780 and 0.4121 respectively. Sample period: 71q1-94q4.

Table N : Cyclical exogeneity of preference shift

	1965:1-1994:4			1972:1-1994:4			1980:1-1994:4		
X-vector	*L*=5	*L*=4	*L*=1	*L*=5	*L*=4	*L*=1	*L*=5	*L*=4	*L*=1
M4	0.2002	0.1654	**0.0181*^**	0.3328	0.2421	**0.0308*^**	0.0542*	0.0811	**0.0025^**
M0				0.6911	0.6536	0.1480*^	0.6024	0.4147*	**0.0497^**
LRS				0.4892	0.5272	0.3691*^	0.1571	0.1110*	0.2065^
PGDP	**0.0115**	**0.0078***	**0.0050^**	**0.0010***	**0.0008**	**0.0001^**	0.1561	0.0883*	**0.0133^**
RPIsa	**0.0279***	0.0754	**0.0277^**	**0.0159***	**0.0239**	**0.0067^**	**0.0233**	**0.0265*^**	0.2271
POIL	**0.0105**	**0.0042**	**0.0002*^**	**0.0228**	**0.0134**	**0.0008*^**	0.2423	0.1806*	**0.0391^**
ROIL	**0.0011**	**0.0003***	**0.0000^**	**0.0019**	**0.0005***	**0.0000^**	0.2127	0.1536*	**0.0381^**
TOT	0.1536	0.2291	**0.0267*^**	0.1950	0.2069	**0.0164*^**	0.1926*	0.4765	0.2707^
M6T				0.0730	**0.0457**	**0.0055*^**	**0.0173**	**0.0106***	**0.0001^**
IMFT	0.4468*	0.5984	0.4629^	0.4881	0.6521	0.5148*^	0.8600	0.7821*	0.1055^
GE	0.4218*	0.4469	0.6851^	0.4059	0.4209*	0.6458^	0.8837	0.8217*	0.6028^
GC	0.5107	0.4976	0.4918*^	0.3809	0.3278*	0.3323^	0.5553	0.4348*	0.1157^
TAX	0.1179*	0.1160	0.8394^	0.1685	0.1400*	0.6938^	0.3004	0.3449*	0.2591^
TAW	0.8775	0.7728	0.7011*^	0.8172	0.7418	0.6665*^	0.4757	0.4477*	0.0789^

See Table K for how to interpret these numbers.

Table O : EC Exogeneity of preference shift

	1965:1-1994:4			1972:1-1994:4			1980:1-1994:4		
X-vector	*L*=5	*L*=4	*L*=1	*L*=5	*L*=4	*L*=1	*L*=5	*L*=4	*L*=1
M4	0.9189	0.7751	0.4901*^	0.5790	0.4352	0.2803*^	**0.0025***	**0.0025**	**0.0022^**
M0				0.7704	0.9792	0.5417*^	0.0853	**0.0353***	0.1197^
LRS				**0.0053**	**0.0092**	**0.0068*^**	0.1140	0.1369*	**0.0324^**
PGDP	0.4027	0.5276*	0.7530^	**0.0155***	**0.0331**	**0.0091^**	0.2809	0.1894*	0.2881^
RPIsa	0.3604*	0.5811	0.8014^	**0.0258***	**0.0444**	0.0730^	**0.0250**	0.0617*^	0.7434
POIL	0.3281	0.4087	0.5732*^	0.3820	0.4686	0.3881*^	0.1097	**0.0464***	0.0950^
ROIL	**0.0225**	**0.0269***	0.0817^	**0.0174**	**0.0157***	**0.0439^**	**0.0461**	**0.0253***	0.1085^
TOT	0.5932	0.9194	0.9505*^	0.8654	0.9050	0.9191*^	0.5866*	0.4828	0.1030^
M6T				0.9330	0.9307	0.9995*^	0.3459	0.4870*	0.9929^
IMFT	0.5367*	0.7745	0.8793^	0.7325	0.8931	0.8590*^	0.0842	0.0990*	0.1851^
GE	0.6919*	0.8361	0.9541^	0.9711	0.9049*	0.6177^	0.2388	0.2838*	0.5794^
GC	0.5641	0.7564	0.9692*^	0.4932	0.6336*	0.4547^	0.1163	0.1500*	0.4545^
TAX	0.2630*	0.4614	0.9061^	0.2178	0.3008*	0.7522^	0.0915	0.1116*	0.3072^
TAW	0.5345	0.5455	0.6152*^	0.8692	0.7713	0.6718*^	0.9787	0.9603*	0.6531^

See Table K for how to interpret these statistics.

Table P : Multivariate causality tests for preference shift

Variables in VAR (as well as *P*)	Lag length	No. of Cointegrating Vectors	Cyclical Granger causality of Variable 1	Cyclical Granger causality of Variable 2	Cyclical Granger causality of Variable 3	Cyclical Granger causality of Variables 1-3
RPIsa, RS & M4	4	1	0.4397	0.3952	**0.0113**	0.7578
PGDP, RS, & M4	4	1	**0.0207**	0.4371	**0.0090**	**0.0066**
PGDP, M4 & TAW	4	0	**0.0003**	**0.0166**	0.9942	**0.0132**
TOT, POIL & M6T	4	0	0.6507	0.1203	0.2121	**0.0375**
TOT & POIL	3	0	0.4411	**0.0176**	-	**0.0135**
POIL & M6T	2	0	**0.0137**	**0.0178**	-	**0.0009**

There is one cointegrating vector present in the VARs of *P*, *RPIsa*, *RS* & *M4* and *P*, *PGDP*, *RS* & *M4*; the *p*-value of these vectors are 0.0542 and 0.0598 respectively. We also tested the joint significance of *M4* and *RS* in the two systems in which they were included, the *p*-values of their joint significance were 0.0485 and 0.0475 respectively. Sample period: 71q1-94q4.

Table Q : Estimates of returns to scale

	Coefficient	T-Statistic
Change in Log of Capital Stock (α)	0.402	1.259
Change in Log of Total Hours (β)	0.370	3.267
Adjusted R^2 = 0.26	Standard error = 0.94%	
H_0: α=0.4436 *P*-value = 0.898	H_0: β=0.5564 *P*-value = 0.1022	H_0: $\alpha+\beta$=1 *P*-value = 0.508
H_0: α=0.32 *P*-value = 0.797	H_0: β=0.68 *P*-value = 0.007	

Dependent Variable: Change in logarithm of *GDP*. Instruments: Lags 1 to 4 of change in logarithm of *GDP*, capital stock, total hours, price of oil and *M4*. Sample period: 65q2-94q4.

Figure 1.1

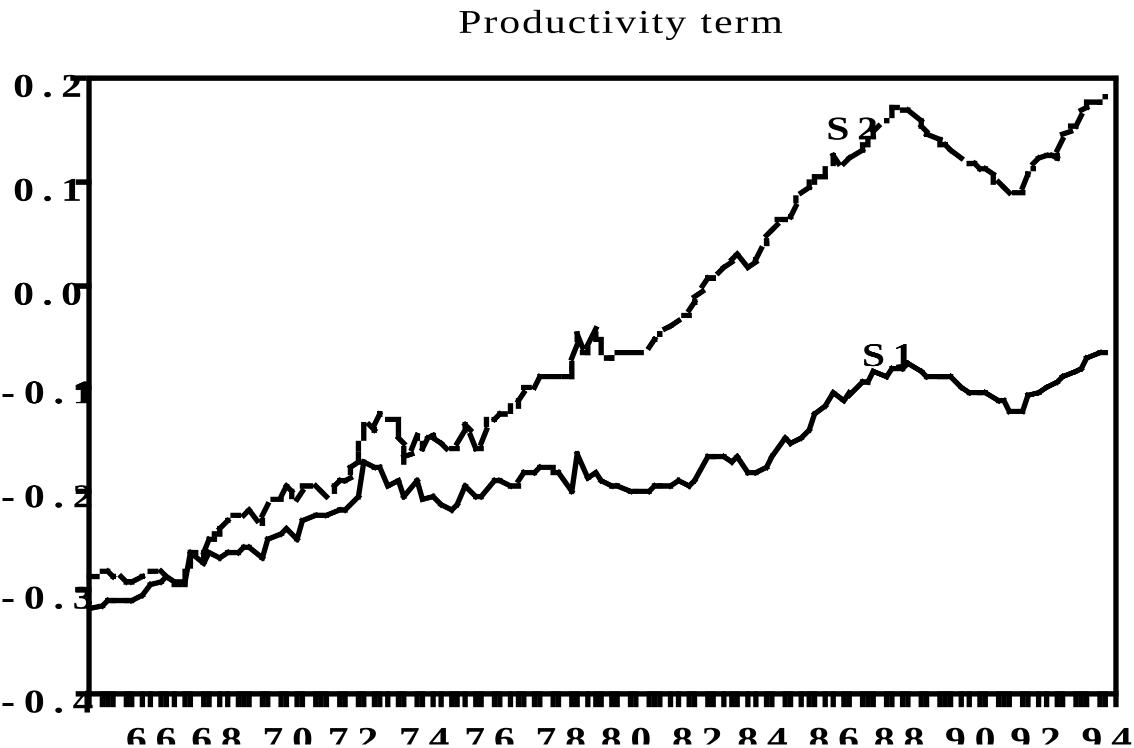


Figure 1.2

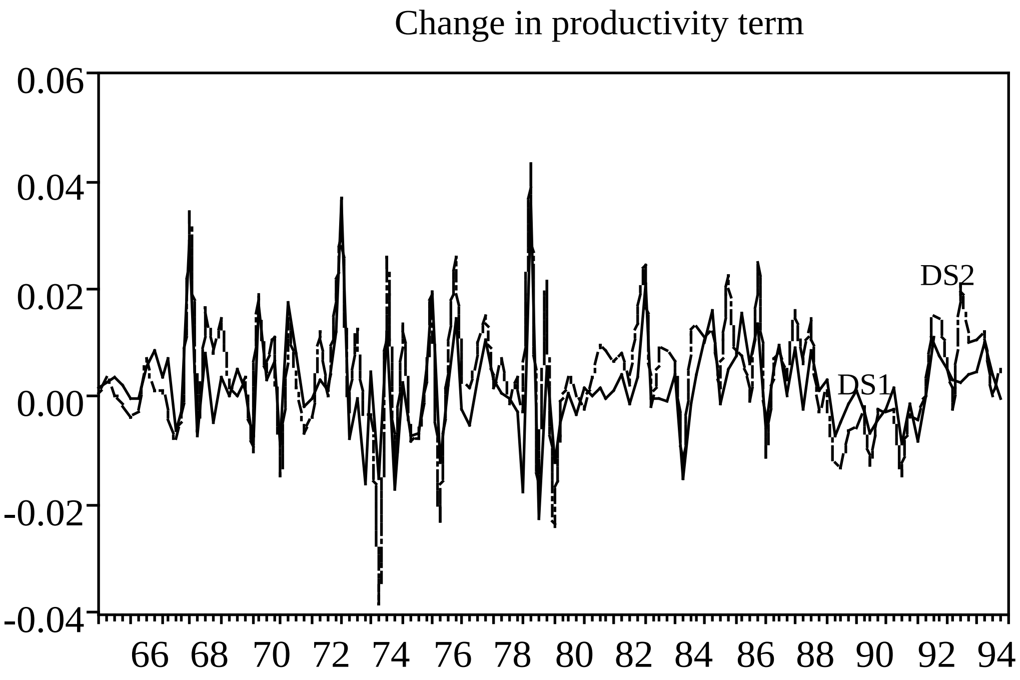


Figure 2.1

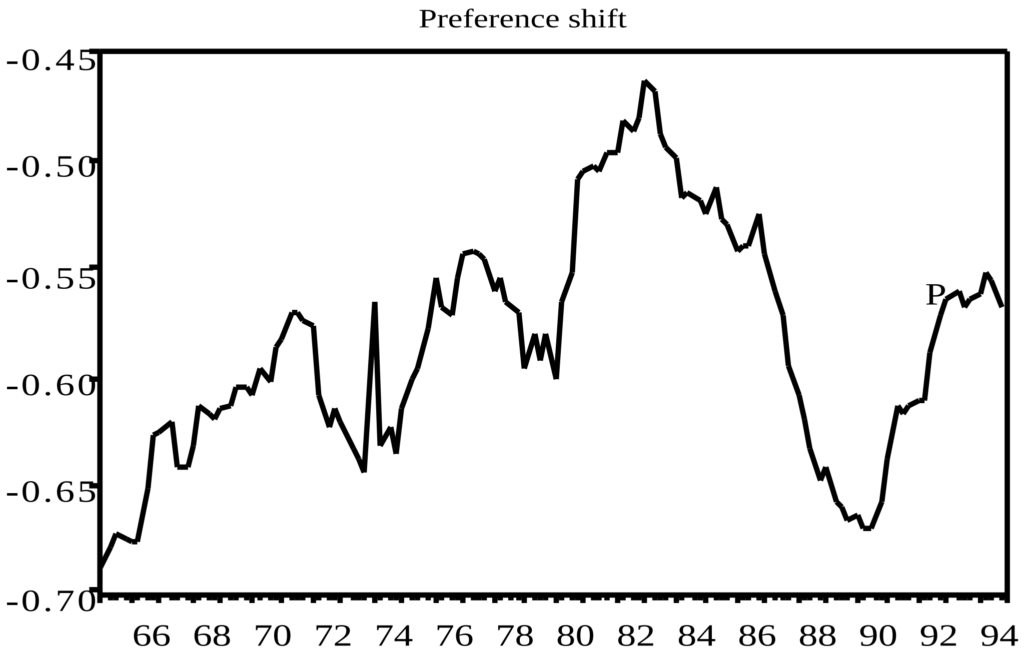
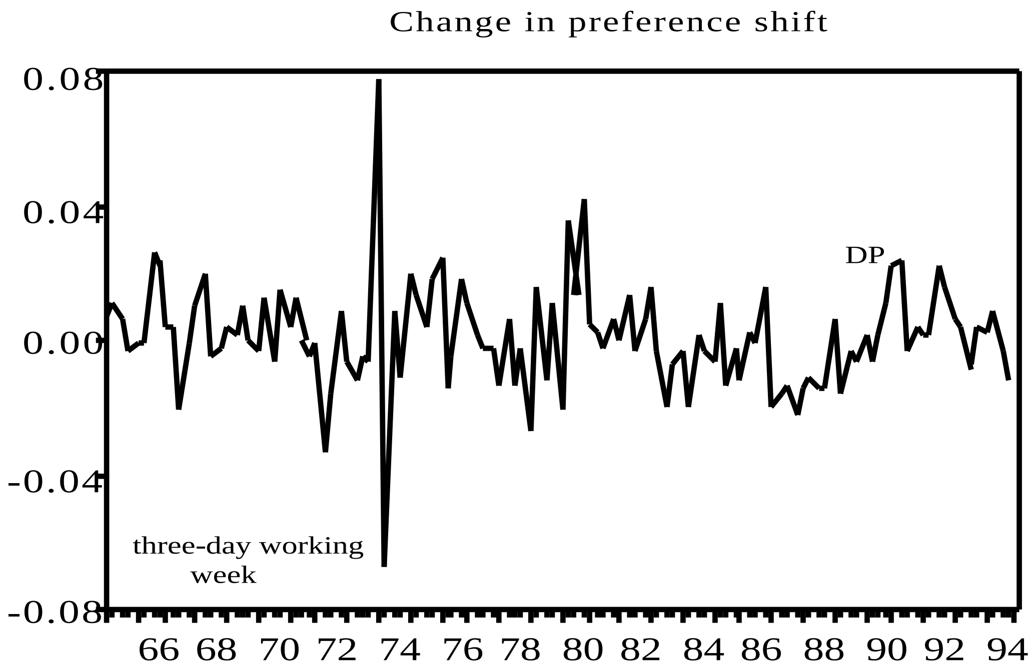


Figure 2.2



Appendix I *Data sources*

Variable Name	ONS MNEMONIC	Description
GDP	CAOP	Gross domestic product at factor cost at 1990 prices, UK Economic Accounts Table A1
EMP	BCAJ, BCAG & BCAH	Employees in employment plus, the self employed and those employed in HM Forces Labour Market Statistics Table 6
THRS		EMP times index of average weekly hours worked in manufacturing, Labour Market Statistics Table
K	EXEP	Gross capital stock at 1990 replacement cost, Blue Book Table 14.8
C	CAAB-CCBW	Total consumers' expenditure (1990 prices) less expenditure on durables, UK Economic Accounts Table A5
I	DECU	Gross domestic fixed capital formation (1990 prices), UK Economic Accounts Table A2
RW	DNAB/DJCM	Average earnings (whole economy) deflated by the GDP deflator
M4	AUYN	Stock of Broad Money, Financial Statistics Table 3.1D
M0	AVAE	Stock of Narrow Money, Financial Statistics Table 3.1C
RS	AMIH	London's Clearing Banks base rate, Financial Statistics Table 7.10
PGDP	DJCM	Implied GDP deflator at factor cost, UK Economic Accounts Table A1
RPI	CHAW	Retail Prices Index (all items), Monthly Digest of Statistics Table 18.1
RPIsa		RPI as above seasonally adjusted using STAMP 5.0: Structural Time Series Analyser, Modeller and Predictor
POIL		Spot price of oil ($) expressed in sterling
ROIL		Sterling price of oil deflated by the GDP deflator
TOT	(DJAZ/DJDG)/ (DJBC/DJDJ)	Terms of trade, UK Economic Accounts Table A2
M6T		Volume of imports with G7 excluding UK (Source IFS)
IMFT		Volume of imports with world excluding UK (Source IFS)
GE	DIAT+DFED	General government expenditure, UK Economic Accounts Tables A2 & A6
GC	DIAT	General government final consumption, UK Economic Accounts Table A2
TAX	ACGN, AAXP, AIIV & ADBH	Total government tax receipts (current prices), Financial Statistics Table 10.1D
TAW	(ACGN+AAXP +AIIV+ADBH) /CAOM	Total tax receipts as a proportion of GDP at factor cost at current prices, Financial Statistics Table 10.1D & UK Economic Accounts Table A1

Appendix II *Calculation of Income Shares*

Our first measure of the share of capital income in domestic output is α_p defined:

$$\alpha_p = \frac{\text{Rental Income} + \text{Corporate Profits} + \text{Net Interest} + \text{DEP}}{\text{GDP} + \text{DEP} - \text{Ambiguous Capital Income}}$$

where the numerator is the sum of (i) rental income of all companies (*CAQH*, Blue Book (BB) Table 5.1) (ii) gross trading profits (including stock appreciation) of all companies (*CIAC*, BB Table 5.1) (iii) total UK non-trading income of all companies (*CIHM*, BB Table 5.1) (iv) other receipts of rent, dividends and net interest of the personal sector (*CFBJ*, BB Table 4.1) (v) total gross trading surplus (including stock appreciation) of public corporations (*ADRD*, BB Table 6.2) (vi) rent and non-trading income of public corporations (*ADRF*=*GISI*+*GISJ*, BB Table 6.2) and (vii) where DEP is the sum of (a) capital consumption of "other fixed assets"; ie excluding residential buildings, by the personal sector (*EXFD*, BB Table 14.3) (b) capital consumption of all fixed assets by all companies (*EXAB* and *EXAA*, BB Table 14.3) (c) capital consumption of all fixed assets by public corporations (*EXFK*, BB Table 14.3).

'Ambiguous Capital Income' (see Cooley and Prescott (1994)) is composed of (i) the difference between the income and average measure of GDP (*GIXQ*, BB Table 1.4) (ii) total income from self-employment in the personal sector (*CFAN*, BB Table 3.1). GDP is gross domestic product at market prices in current prices (*CAOB*, BB Table 1.1). Using these definitions we derive a measure of α_p of 0.32, close to the US value.

However, as mentioned in the text this calculation excludes consumer durables and government capital and so the more approrpiate measure of the capital share can be calculated as

$$\alpha = \frac{Y_{kp} + Y_d + Y_g}{GDP + Y_g + Y_d}$$

where

$$i = (Y_{kp} - DEP) / K_p$$

where K_p is defined as the sum of (i) total tangible assets of industrial and commercial companies (*ALME*, BB Table 12.3) (ii) total tangible assets of financial institutions (*CXBE*, BB Table 12.4) (iii) total tangible assets of public corporations (*ALNF*, BB Table 12.9) (iv)total tangible assets of the personal sector (*ALLU*, BB Table 12.2) (v) less residential buildings of the personal sector (*ALLN*, BB Table 12.2). This gives an average return on capital of 12.55%.

We construct our stock of consumer durables using annual Blue Book data on the stock of consumer durables (*AKTF*, FS Table S2), which is available from 1975 to 1989, along with annual flows on consumption of consumer durables (*AIIL*, BB Table 4.5, which is available from 1968 to 1994. We then use the stock and flow data to calculate an average rate of depreciation over the period 1975 to 1989. This depreciation rate is then used to extrapolate the flow data back to 1967 and forward to 1994. The flow of services to the personal sectors capital stock is then

$$Y_d = (i + \delta_d) K_d$$

where i is the return on capital, δ_d is the depreciation rate calculated above and K_d is the stock of consumer durables from above.

The flow of services to the government capital stock is calclated similarly; with K_g equal to the sum of total tangible assets of central government (*ALNO*, BB Table 12.10) and total tangible assets of local authorities (*ALNX*, BB Table 12.11), and δ_g is derived from the capital stock and expenditure on gross domestic fixed capital formation by central government and local authorities (*AAAC*, BB Table 7.1 and *AAAG*, BB Table 8.1 respectively).

Our final estimate of then comes from

$$\alpha = \frac{Ykp + Yd + Yg}{GDP + Yg + Yd}$$

which gives us a value of 0.44 for capital's share in output. Cooley and Prescott (1994) find that the equivalent measure for the United States is 0.40.

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