Business Cycles and the Labour Market
Can Theory fit the Facts?

Stephen Millard[*]

Andrew Scott[+]

and

Marianne Sensier[#]

* Bank of England.
+ Department of Economics, London Business School; All Souls College, Oxford; and Bank of England.
# Institute of Economics and Statistics, Oxford University.

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Abstract

We examine the ability of six labour market models to account for the business cycle behaviour of UK labour markets when embedded in a stochastic growth model. We assess the models in terms of: (i) their ability to mimic general business cycle correlations and volatility, (ii) their success at explaining the persistence of labour market fluctuations, and (iii) whether the models can explain why the growth and speed of adjustment of labour market variables changes between periods of expansions and contractions.

The main success of the models is the ability to broadly account for business cycle correlations and co-movements, and the changes in employment/unemployment growth rates between expansions and contractions. However, there are three main failures: (i) the models tend to produce insufficiently volatile employment and unemployment fluctuations, (ii) the models tend to produce too strong a correlation between wages and employment, and (iii) most of the models generate only brief temporary deviations in unemployment in response to shocks, rather than the protracted dynamics of the data.

1 Introduction

The Real Business Cycle (RBC) paper of Kydland and Prescott (1982) heralded a new methodology in macroeconomics, whereby numerical simulation of stochastic dynamic general equilibrium models became an established means of evaluating macroeconomic models. By expressing models in terms of the primitives of an economy (technology, preferences and market structure), this approach has delivered the form of macroeconomic modelling advocated in the seminal paper of Lucas (1976). This approach offers both detailed microeconomic foundations of business cycle phenomena and a platform on which to construct optimal economic policy. Since its original emphasis on productivity shocks, the RBC literature has developed in numerous directions, eg incorporating money (eg Cooley and Hansen (1989) and Fuerst (1992)), extending to an open economy (eg Backus, Kehoe and Kydland (1992)), introducing government expenditure and taxation (eg, Braun (1994) and McGratten (1994)) as well as models of sticky wages and prices (eg Cooley and Hansen (1994) and Yun (1996)). While these contributions have met with varied empirical success, there is now a wide range of basic general equilibrium models with which to view macroeconomic phenomena.

One particularly active area of research has focused on labour markets (see, among others, Hansen (1985), Hansen and Sargent (1988), Bencevenga (1991), Benhabib, Rogerson and Wright (1991), Christiano and Eichenbaum (1992), Cho and Cooley (1994), Danthine and Donaldson (1990), Boldrin and Horvath (1995) and Merz (1995)). The reasons for this focus are twofold:

(i) Fluctuations in employment seem fundamentally connected to the business cycle. For both the United States and the United Kingdom, the cyclical volatility of hours worked is of the same magnitude as the volatility in output, suggesting that 'an understanding of aggregate labour market fluctuations is a prerequisite for understanding how business cycles propagate over time' (Kydland (1994)). Further, in terms of the policy debate, the main social cost of business cycles is invariably seen as fluctuations in unemployment.

(ii) At the heart of the basic RBC model (see King, Plosser and Rebelo (1988)) is a neo-classical model of the labour market, which essentially explains employment fluctuations via intertemporal substitution. In other words, employment varies because of changes in relative wages between periods. According to this mechanism, when wages are high, agents are prepared to work harder, whereas when they are low, labour supply declines. The difficulties faced by this model in explaining observed fluctuations have been well documented (eg Barro and King (1984) and Mankiw, Rotemberg and Summers (1985)), but as yet no consensus has emerged regarding an alternative model.

The purpose of this paper is to examine a sample of these alternative aggregate labour market models, and see the extent to which they can satisfactorily account for certain features of UK data. While other studies (eg Hansen and Wright (1992), Burgess (1993) and Fairise and Langot (1994)) have compared alternative labour market models, two features distinguish our approach:

(i) We use UK data to evaluate the competing labour market models. This is important because many of the models we examine have been constructed in order to explain US data but, according to the methodology outlined in Prescott (1986), these models (suitably calibrated) should also account for UK data. Given the extreme behaviour of UK labour markets, this represents a substantial challenge.

(ii) Our analysis differs in the way it assesses the performance of these labour market models. Within the RBC literature, the customary way of evaluating models is to compare standard deviations and cross-correlations constructed from the data with the same measures constructed from simulations of the model. However, there are numerous other important and well documented statistical features of the labour market for which these theoretical models should account. For instance, Blanchard and Summers (1986) show that European unemployment is highly persistent, so that shocks to unemployment have very long-lasting if not indefinite effects. Furthermore, numerous authors (eg Neftci (1984), Stock (1989) and Acemoglu and Scott (1994)) document that the behaviour of the labour market changes over the business cycle. In particular, they find that the growth of labour market variables differs between expansions and contractions, and also that their persistence changes—shocks tend to have longer-lasting impacts in recessions. We therefore examine the ability of our theoretical models to explain both the persistent and asymmetric nature of labour market fluctuations.

The structure of the paper is as follows. Section 2 outlines the key stylised facts about the cyclical behaviour of the UK labour market that we want our theoretical models to replicate. Section 3 then discusses the various alternative models we examine, and Section 4 examines the simulation properties of these models and their ability to mimic the data. A final section summarises our conclusions.

2 UK labour markets and the business cycle

2.1 Cyclical stylised facts

Table A documents some basic stylised business cycle facts about the UK labour market. In doing so, it follows the majority of the RBC literature, and quotes standard deviations and cross-correlations for the cyclical component of UK labour market variables (the data is explained in an Appendix). Our main interest is in the volatility of different macroeconomic variables over the business cycle, and also in whether groups of macroeconomic variables move in tandem. In order to focus on the business cycle component, we first detrend the data using the Hodrick-Prescott (1980) filter. Both the choice of this filter when used to define the business cycle and the relevance of this set of statistics have been the subject of much criticism. (See eg Harvey and Jaeger (1993), King and Rebelo (1993), Cogley and Nason (1995a) and Watson (1993).) However, in order to enable easy comparison with the rest of the literature, we follow standard practice in applying the Hodrick-Prescott filter.

Table A: Business cycle facts for the UK labour market

	Std. dev.	-3	-2	-1	0	1	2	3
Total hours	1.11	0.39	0.54	0.72	0.86	0.74	0.62	0.51
Employment	0.75	0.15	0.35	0.53	0.69	0.77	0.80	0.78
Average hours	0.63	0.46	0.48	0.57	0.62	0.29	0.12	-0.01
Real wages	0.68	-0.25	-0.21	-0.06	0.01	0.08	0.01	0.02
Unemployment	8.43	-0.05	-0.18	-0.41	-0.63	-0.79	-0.83	-0.83
Vacancies	8.64	0.55	0.65	0.75	0.80	0.67	0.48	0.30
		Correlation with employment						
Real wages		-0.28	-0.26	-0.10	0.00	0.07	0.08	0.03
		Correlation with vacancies						
Unemployment		0.27	0.05	-0.24	-0.54	-0.63	-0.66	-0.63

Notes: For data definitions see the Appendix. The first column of statistics shows the standard deviation of the cyclical components of the variable listed in the first column divided by the standard deviation of the cyclical component of output. The remaining columns show the correlation between the cyclical component of output and the cyclical component of the variable listed in the first column. The columns show the correlation of X_{t+j} with output at time t, where j is given by the column heading, eg -3 means how current output is correlated with the variable three periods ago. Therefore, the left-hand side of the table focuses on whether or not the variable leads output over the business cycle.

From Table A, we stress the following business cycle facts concerning the UK labour market:

(i) Whole-economy total hours worked are at least as volatile as output (as measured by GDP).

(ii) Changes in total hours are split approximately equally between average hours worked and employment.

(iii) All the employment measures are strongly procyclical (ie employment increases and decreases at the same time as output).

(iv) Employment tends to lag, and average hours tend to lead, output over the business cycle.

(v) Real wages are barely correlated with employment or output.

(vi) Unemployment and vacancies display the most variability over the business cycle.

(vii) Unemployment is strongly countercyclical and tends to lag output, whereas vacancies are procyclical and tend to lead output.

(viii) There is a strong negative relationship between unemployment and vacancies over the business cycle (the so-called 'Beveridge Curve')

It is these core facts that we shall use to examine the performance of our various candidate theoretical models.

2.2 Persistence in the labour market

While these stylised facts are illuminating, there are many other important features of the labour market that are ignored in Table A. One of these is the belief that labour market fluctuations are extremely *persistent*: that is, shocks to employment or unemployment tend to have long-lasting effects. For instance, Blanchard and Summers (1986) argue that European unemployment is characterised by significant hysteresis. As a consequence, negative shocks to unemployment do not lead to merely temporary changes in the unemployment rate, but tend to produce permanent increases in unemployment.

To measure the persistence of UK labour market variables, we utilise the unit root test of Cochrane (1988). The intuition behind this test is relatively simple. If a variable is a random walk (ie the best forecast of the variable next period is equal to its current value, so that any shocks today have a permanent influence on future values) then the further ahead in time one goes, the more uncertainty there is about the level of the variable. In particular, the variance of two-period changes in the variable should be twice the variance of one-period changes; the variance of three-period changes in the variable should be three times the variance of one-period changes; and so on. Cochrane (1988) therefore proposes a test of a unit root, which examines the variance of the *k*-period changes relative to *k* times the variance of one-period changes.[1] If Cochrane's test has a value near to zero, then the variable tends to show only temporary changes in response to a shock or, in other words, permanent shocks are not very important. However, if the test statistic is near to one, then persistence is very important and shocks have a long-lasting effect. If the test statistic goes above one, then there is even more persistence in the variable, and the effect of the shock gets amplified over time. An alternative interpretation of Cochrane's test that we shall sometimes use is that it measures the relative importance of permanent shocks in contributing to the volatility of a

(1) More specifically, the test is $kVar(\Delta x_t)/(\Delta_k x_t)$.

variable: the nearer to zero is the test statistic, the less important are permanent shocks.

Charts 1a and 1b show the results of the Cochrane test for our set of UK labour market variables. The finding of Blanchard and Summers (1986) regarding the persistence of UK unemployment is immediately obvious: shocks to unemployment have a very long-lasting impact, with no evidence that eventually things return to their previous equilibrium. The evidence from vacancies also suggests that these contain important permanent shocks. However, unlike unemployment, the value of the Cochrane test for vacancies does decline after around ten quarters, suggesting that, while shocks to vacancies have a long-lasting effect, they are not as persistent as shocks to unemployment. The same comment holds for the unemployment-vacancy ratio: in other words, over the course of the cycle, the Beveridge Curve changes position and shows no tendency to return. Like unemployment, employment shows strong evidence of permanent shocks affecting the labour market, and this naturally feeds through into the total hours series. Average hours and average earnings show less in the way of persistence, although even after 30 quarters, the test statistic suggests that even these series reflect important close-to-random-walk behaviour. Overall, the picture that emerges is not one of temporary fluctuations in the labour market but, rather, fluctuations that are characterised by highly persistent changes or regime shifts.

Chart 1a: Labour market persistence

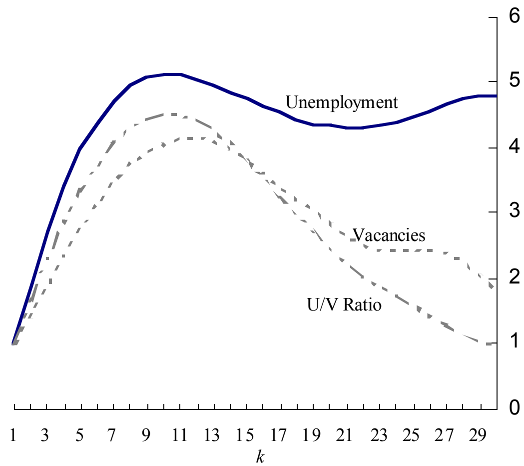
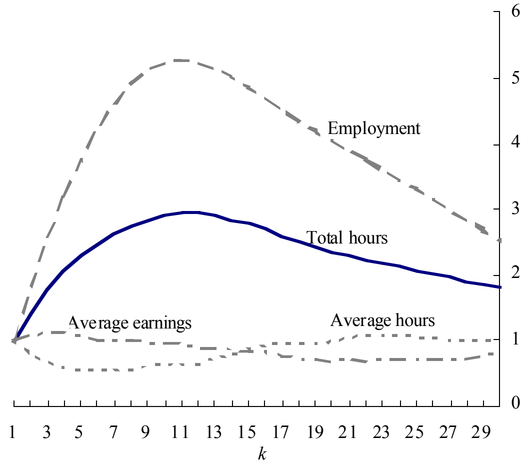


Chart 1b: Labour market persistence



2.3 Asymmetric behaviour in the labour market

Another distinguishing feature of the labour market is its non-linear behaviour over the business cycle. Burgess (1993) stresses that in order to explain cyclical labour market phenomena, it is crucial to understand how hiring costs change over the cycle with the tightness of the labour market. Neftci (1984), Stock (1989) and Acemoglu and Scott (1994) all document evidence that reveals that the stochastic properties of the labour market change over the business cycle. To investigate this issue, we estimate equations of the form:

$$\Delta x_t = \mu_0 + \mu_1 S_t + \rho_0 \Delta x_{t-1} + \rho_1 S_t \Delta x_{t-1} + e_t \quad \textbf{(1)}$$

where S is an indicator variable that takes the value one when the economy is in recession and zero otherwise, and x denotes a particular labour market variable (such as employment, unemployment, average earnings, etc). If the growth of x is lower in recessions than expansions, then we should find μ_1 to be significantly negative. (We shall call this *mean asymmetry*.) If the persistence (or the speed at which the labour market responds to exogenous disturbances) of x also varies, then ρ_1 should also be significantly different from zero. If ρ_1 is negative, then labour market dynamics slow down in recession, whereas if it is positive, the labour market works more quickly. (We shall call evidence that ρ_1 does not equal zero *dynamic asymmetry*.) The economic hypothesis here is whether shocks feed through the labour market quicker in economic downturns than in upturns. This idea captures the fact, for instance, that unemployment tends to rise more quickly in recessions than it declines in expansions.

To detect labour market asymmetries in this way relies upon a particular choice of *S*, or, equivalently, a particular definition of the UK business cycle. Acemoglu and Scott (1994) use a variety of different measures, but in this paper we utilise the Hodrick-Prescott filter to define our cyclical indicator in order to provide consistency with our earlier results. We use the Hodrick-Prescott filter to define a cyclical component of GDP $y_t^c = y_t - y_t^{HP}$ where *y* denotes GDP and y^{HP} is the estimate of the trend from the Hodrick-Prescott filter. We then define $S_t = 1$ if $y_t^c < 0$ and $S_t = 0$ otherwise. Therefore, our recessions are defined as periods when output is below trend, and expansions where output is above trend.

We test for mean asymmetry by examining whether $\mu_1 = 0$ and for dynamic asymmetry by whether $\rho_1 = 0$. (In cases where we use longer lags in the dependant variable, then the test is for all the interactive terms between the recession dummy and lags.) Table B shows the results of testing for labour market asymmetries using equation (**1**) and quotes the *p*-values for the significance of the asymmetries. A '*' denotes that we find evidence in favour of asymmetries at the 5% significance level. We also show the estimated conditional growth rate of the variables in expansions and contractions (μ_E and μ_C respectively) and estimates of the persistence in expansions and contractions (ρ_E and ρ_C respectively).(2)

Table B: Business cycle asymmetries in the UK labour market

Variable	Mean asymmetries	μ_E	μ_R	Dynamic asymmetries	ρ_E	ρ_R
Total hours	0.018*	0.003	-0.004	0.044*	0.016	-0.345
Employment	0.468	0.001	0.000	0.858	0.737	0.734
Average hours	0.008*	0.000	-0.002	0.659	-0.038	-0.558
Average earnings	0.544	0.006	-0.006	0.527	0.846	0.785
Unemployment	0.057	-0.002	0.006	0.527	0.846	0.785
Vacancies	0.009*	0.014	-0.006	0.001*	0.510	0.818
U/V	0.026*	-0.008	0.011	0.001*	0.643	1.021

Notes: The table shows the *p*-value of a restriction test for excluding the recession dummy. Mean asymmetry denotes a test for whether the growth rate differs over the business cycle, and dynamic asymmetry denotes a test for whether dynamics differ over the business cycle. A '*' denotes that the recession dummy is significant and there are business cycle asymmetries. All tests reported are from the optimal lag length AR model where the lag length was chosen using the Schwarz Information Criterion. The columns μ_E and μ_E denote the mean growth rate of the variable in expansion and recession periods respectively, and ρ_E and ρ_E denote the persistence of the variable in expansion and recession periods respectively.

(2) We define persistence here as simply the sum of the coefficients on all the lagged dependent variable terms in equation (**1**).

Although the evidence is not as pervasive as that outlined in Acemoglu and Scott (1994), there is still evidence that the behaviour of the labour market varies over the business cycle.[3] In particular, growth in total hours worked is positive in expansions but negative in recessions, average hours contract in recessions but not in expansions, vacancies rise in expansions and decline in contractions, and the UV curve moves in during an expansion and shifts out in recessions.

3 Some labour market models

In this section, we describe the basic structure and intuition of six alternative models of the labour market, which we then embed in a stochastic dynamic general equilibrium model. The choice of these particular six models is inevitably arbitrary and suffers from sins of omission. However, we choose these models in the belief that they reflect a broad spectrum of views regarding the operation of the labour market, eg Walrasian and non-Walrasian models, models of instantaneous market adjustment and more sluggish adjustment, models with fully competitive markets, and markets with imperfect competition. We are also aware that we have chosen relatively simple models, each of which deviates in a limited number of ways from the textbook neo-classical paradigm. Because a successful labour market model is likely to contain several such deviations, the models here are inevitably going to have the appearance of being ‘straw men’. However, our hope is that even if none of the models can successfully match the various features of the labour market noted above, we can arrive at some suggestions regarding the most promising direction for future research.

3.1 The basic neo-classical labour market

We take as our basic neo-classical model that of King, Plosser and Rebelo (1988). At the heart of this model is a representative agent, who each period decides how many goods and services to consume and how much in the way of labour services to provide. The agent makes these choices by trying to maximise the present discounted value of current and future utility streams. Normalising the time endowment to unity enables us to write his problem as:

$$\text{Max. } E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, 1-n_t\right) \qquad \textbf{(2)}$$

where c denotes consumption, n denotes hours worked (so $1-n$ is leisure) and β is the discount factor.

(3) We attribute this to the fact that our use of the HP filter does not produce as reliable a measure of the UK business cycle as those used by Acemoglu and Scott (1994).

These consumption and leisure choices are made subject to an economy-wide feasibility constraint:

$$c_t + k_t - (1-\delta)k_{t-1} = y_t = \theta_t k_{t-1}^{\alpha} n_t^{1-\alpha} \qquad \textbf{(3)}$$

where k denotes the end-of-period capital stock, δ denotes the rate of depreciation of the capital stock and y denotes output. The second equality defines our production function, where we assume that output is produced by a constant returns to scale Cobb-Douglas function, subject to a random technology term, θ, as in Kydland and Prescott (1982). This problem yields the well known first-order conditions:

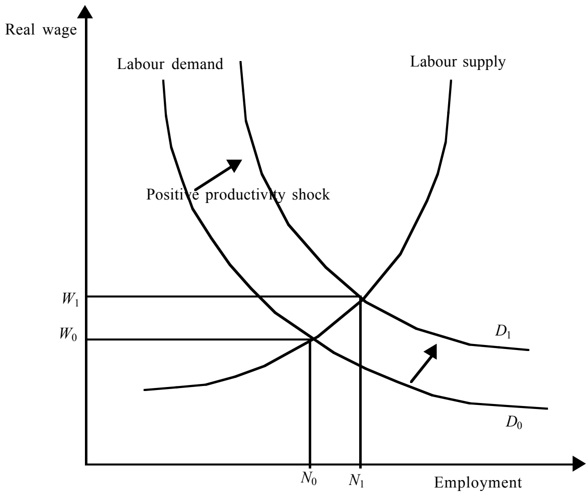
$$\begin{aligned} U_{n,t} &= U_{c,t} MPL_t \\ U_{c,t} &= \beta E_t \left(1 + MPK_{t+1} - \delta\right) U_{c,t+1} \end{aligned} \qquad \textbf{(4)}$$

where U_j denotes the derivative of the utility function with respect to j (ie the marginal utility of leisure or consumption) and *MPK* and *MPL* refer to the marginal products of capital and labour, respectively.

The first equation says that the consumer sets their marginal rate of substitution between leisure and consumption equal to the real wage rate. Therefore, if the real wage rate increases, then because of the convexity of the utility function, this must be met by some combination of increased consumption and lower leisure. The second equation is an intertemporal equation, which relates consumption growth to the net return on capital.

In this simple model, the source of economic fluctuations is variations in the technology term, θ, which causes fluctuations in employment by affecting the *MPL,* or labour demand, as shown in Chart 2. A positive (negative) productivity shock causes an increase (decrease) in labour demand and, assuming a constant labour supply curve, brings about some combination of increased (decreased) wages and employment. The extent to which wages and/or employment benefit from this increased labour demand depends on the slope of the labour supply curve and, as stressed by Lucas and Rapping (1969), this depends on the intertemporal substitution of labour supply. If there are large temporary changes in real wages, and agents are prepared to willingly substitute labour supply between time periods, then the labour supply curve will be flat (ie very elastic), and productivity shocks will bring about large changes in employment but relatively modest increases in wages. By contrast, if agents are unwilling to rearrange their work effort intertemporally, then the labour supply curve will be near-vertical, and wages rather than employment will increase in response to higher labour demand.

Chart 2. Intertemporal substitution model



In summary, this model is based solely on productivity shocks leading to significant shifts in labour demand, which are translated into employment movements according to the willingness of agents to reallocate their work effort between time periods.

3.2 The indivisible labour model

A common criticism of the basic model outlined above is that to generate the observed combination of large cyclical movements in employment and acyclical wages (as seen in Table A), it is necessary to assume a large intertemporal elasticity of substitution. However, a wide body of empirical evidence (see the survey by Pencavel (1986)) based on both microeconomic and aggregate data suggests that male labour supply is fairly inelastic: in other words, agents do not alter their labour supply much when wages change. According to this evidence, the above model is unlikely to account successfully for observed UK business cycle employment fluctuations, as the labour supply curve should be nearly vertical.

This observation motivates the model of Hansen (1985) and Rogerson (1988), which can generate a highly elastic aggregate labour supply curve *irrespective of the labour supply elasticity of individual agents*. The means of achieving this is to assume that all employment fluctuations occur at the *extensive* as opposed to the *intensive* margin. All employment fluctuations occur as a result of changes in the number of people employed, as opposed to variations in the average number of hours worked per person employed. While Table A shows this not to be a good approximation for the United Kingdom, it is a more reasonable assumption for the United States.

The Hansen-Rogerson model assumes that all employed individuals work a fixed shift-length h_0, but that only a proportion φ of individuals work in any time period, so that aggregate hours worked in the economy is $n_t = h_0 \varphi_t$. All those agents who are not employed (1-φ of them) consume their time endowment totally as leisure. To justify this result that agents work either zero or h_0 hours, Hansen assumes that working involves some fixed costs (such as commuting time), which means that agents prefer either to work a fixed shift or not at all. In other words, it is not optimal for each agent to work $\varphi\, h_0$ hours.

To determine who is employed in any one period, Hansen and Rogerson assume the (stylised) existence of a lottery, in which every individual has a probability φ of obtaining work. The effect of the lottery is to convexify individuals' preferences, so that the utility of the representative agent is linear in employment, ie the marginal utility of leisure is the same irrespective of how many hours the representative agent works. As a result, the labour supply curve of the representative agent is highly elastic, as large employment fluctuations bring about no changes in the marginal utility of leisure. Therefore, by assuming that labour is indivisible, the Hansen model can generate a flat labour supply curve, and potentially explain the observed combination of large fluctuations in employment and the absence of cyclical variation in wages.

3.3 Labour hoarding

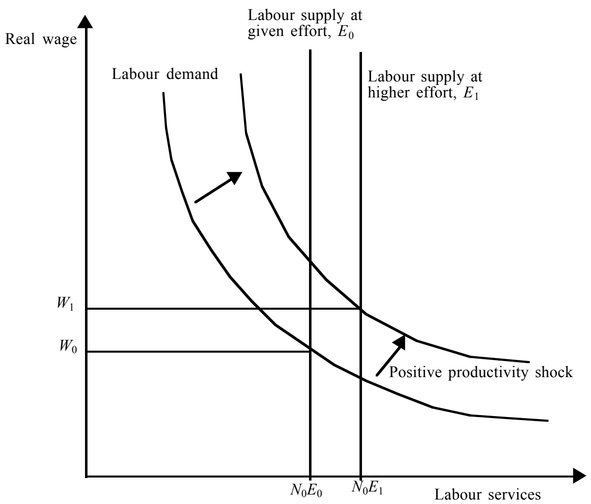
The Hansen-Rogerson model assumes that firms can only increase total hours worked by increasing employment; it rules out any adjustment along the intensive margin. In contrast, Burnside, Eichenbaum and Rebelo (1993) place the main focus of their model on the intensive margin, ie average hours. As in the indivisible labour model, they assume that individuals work a fixed shift-length h_0. However, what is important for the production function is not the length of the shift that individuals work, but how much effort they contribute during their shift. In other words, actual labour services supplied by individuals are given by eh_0, where e denotes effort and which we normalise to be unity in steady state. If individuals work at their normal (steady state) level of effort, then $e = 1$, while if they put in no effort, $e = 0$. Burnside *et al* motivate this effort variable in terms of labour hoarding or, in other words, labour utilisation. As e tends to zero, labour hoarding rises. Letting n be the number of individuals employed, the production function is now:

$$y_t = \theta_t k_{t-1}^{\alpha} \left(e_t h_0 n_t \right)^{1-\alpha} \qquad \textbf{(5)}$$

From the consumer's perspective, leisure is given by $1-\chi-eh_0$, where χ is a fixed cost to working (eg commuting time), and the final term shows that the disutility from working depends on how much effort people contribute during their shift.

With the exception of the introduction of an effort variable, this model is the same as for our previous models. However, they make one additional assumption. They assume that firms have to choose employment, *n*, before they are aware of the value of θ and once they are aware of the productivity shocks, they then have to choose *e*. In other words, firms make their decision about hiring or firing workers based on their experience of what the productivity shock will be. Once they discover the true value of the productivity shock, they cannot immediately adjust their workforce: hiring and firing have to be done next period. However, while they cannot adjust labour at the extensive margin in response to productivity shocks, they can alter it at the intensive margin by persuading workers to contribute more effort. Thus, they adjust their input of labour services by varying *e* or, in other words, by varying labour hoarding, as shown in Chart 3. For instance, if there is a bad productivity shock firms would want to reduce employment but cannot do so this period, and so instead they lower *e*. However, at the end of the period, they can adjust the level of employment so that, in essence, the Burnside *et al* model is one where the firm faces an infinite adjustment cost to changing employment within the current period, but no adjustment cost at the end of the period.

Chart 3: Labour hoarding



3.4 Search

The above variants of the neo-classical model are Walrasian in that they try to explain labour market fluctuations by the intersection of time-varying labour supply and labour demand curves. A popular model of the labour market that dispenses with this Walrasian perspective is the search model. (For a textbook treatment, see Pissarides (1990), and for an application to the RBC literature, see Merz (1995).) The basic insight of search models is that increases in employment cannot be instantaneously achieved, but instead it takes time to match up unemployed workers with firms who are advertising vacancies, and therefore employment increases only slowly. Furthermore, the speed at which the unemployed find jobs depends on how many people are competing for the same vacancy, so that the speed at which the labour market adjusts will vary over the cycle.

The key analytical concept in search models is the matching function, which determines how individuals seeking work (the unemployed) combine with firms offering vacancies to produce new hires. Following the UK evidence of Jackman, Layard and Pissarides (1989), we write this matching function as

$$m_t = A v_t^{\eta} u_t^{1-\eta} \qquad \textbf{(6)}$$

where m denotes new hires, v denotes the number of vacancies available, u denotes the number of individuals unemployed, and A is a parameter that reflects the efficiency of the matching process. The matching function is analogous to a production function, but in this case the inputs are individuals looking for work and firms looking for workers and the output is the number of new hires, ie the number of vacancies filled during the period. While equation (**6**) explains inflows into employment, we also need to explain outflows into unemployment. Mortensen and Pissarides (1994) offer a model of endogenous job destruction but, for ease of analysis, we follow Merz (1995) and assume that every period a proportion, δ, of the workforce enter into unemployment. The maximisation problem of the representative consumer is as outlined in equation (**1**), except that employment now evolves subject to the law of motion

$$n_{t+1} = (1-\delta)n_t + A v_t^{\eta} \left(1 - n_t\right)^{1-\eta} \qquad \textbf{(7)}$$

where the consumer takes the level of vacancies as given.

In order to determine employment and output, we need to know the level of vacancies. We assume that posting a vacancy involves a per-period cost (per vacancy) of a, and that firms choose their employment sequence to maximise the present discounted utility value of current and future profits (to reflect that consumers are the ultimate owners of firms). Current-period profits are given by $\theta_t k_{t-1}^{\alpha} n_t^{1-\alpha} - w_t n_t - r_t k_{t-1} - av_t$, where *w* and *r* denote the real wage and rental price of capital respectively. In choosing their optimal level of employment for current and future periods, firms have to balance the fact that hiring may take several periods (so that it may run the risk of having insufficient employment during a high productivity period) against the fact that unfilled vacancies incur a cost per period.

A major difference in the search model compared with our previous labour market models is the determination of wages. In the previous models, factor markets are competitive and so labour is paid its marginal product. However, in the case of search this is no longer the case. Because both the firm and the worker cannot guarantee to find a new employee/job immediately, each side can try to extract rents from the match (the rents being the difference between what the matched job and worker produce and what they would earn elsewhere, *allowing* for the facts that for some time the firm will have an unfilled vacancy and the worker will be unemployed). The distribution of these rents will depend on the monopoly power of the firm and worker in the bargain. However, assuming some monopoly power on the part of labour, the consequence is that wages reflect both the marginal product of labour and also the surplus that is created by the worker and the firm.

The introduction of search into the RBC framework has three main implications:

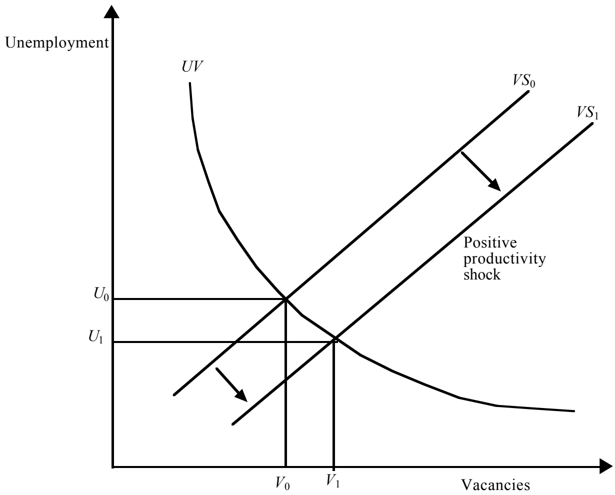
(i) Because it takes time for a firm to fill a vacancy or a worker to find a new job, the search-based model alters the cyclical dynamics of employment. In response to a shock, it now takes employment several periods to respond, so that employment dynamics are more spread out over the cycle, rather than responding rapidly to productivity shocks.

(ii) Wages no longer reflect only the marginal product of labour, and so they will no longer reflect changes in productivity so directly.

(iii) The previous models we have outlined have offered a model of employment, but not explicitly modelled unemployment. Instead, unemployment is simply the opposite of employment. By contrast, the search model contains a detailed structure that explains how vacancies and unemployment vary period to period.

Chart 4 shows how search models explain unemployment and vacancies. The UV (or Beveridge) curve shows how the matching function relates unemployment to vacancies. The higher the level of unemployment, the lower the number of unfilled vacancies on the market: if many people are competing for any jobs that are available, then a large number of vacancies will be filled. By contrast, the VS curve describes how the number of vacancies supplied by firms depends on the level of unemployment. If unemployment is very high, then a firm knows that it will fill its vacancy quickly, and so the expected cost of posting a vacancy is low. As a consequence, firms open up a larger number of vacancies, and so the VS curve is upward-sloping. Labour market equilibrium is where the UV and VS curves intersect to determine equilibrium unemployment and vacancies. As outlined in Pissarides (1990), the VS curve shifts in response to aggregate shocks and so traces out the UV curve, so that unemployment and vacancies are negatively correlated over the business cycle.

Chart 4: The search model



3.5 Gali's imperfect competition model

Gali (1995) also allows for non-competitive factor markets, but in addition he introduces monopoly power on the part of firms in the product market. He then uses this market power to introduce a concept of 'involuntary unemployment', in an attempt to make RBC models make contact with more Keynesian notions of unemployment. In what follows, we give a brief overview of Gali's model.

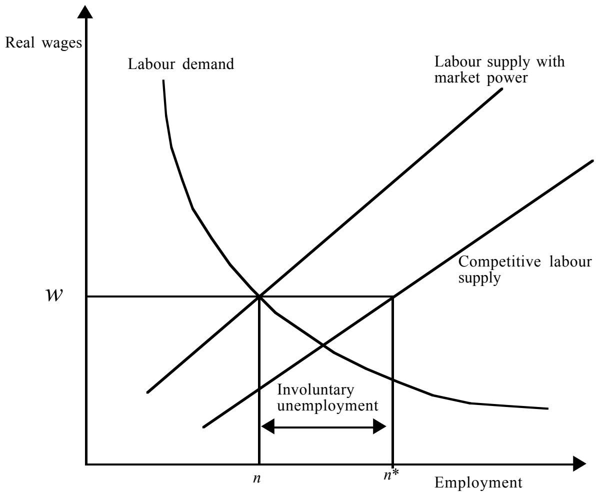
The production side of the economy consists of *intermediate industries*, who provide inputs that are used by the *final-goods-producing firms*. Each intermediate industry has some market power, as different intermediate goods are not perfect substitutes in production of the final goods, and as a result they price their products above marginal costs.

The consumption side of the economy is as before, but with one substantial exception. In previous models, consumers chose their labour supply taking the wage rate as given. In contrast, Gali assumes that labour supply decisions are undertaken by trade unions who set wages, and that firms then choose their employment at these wages. At the beginning of each period, the trade unions negotiate a new wage and firms choose new employment levels. When the trade unions negotiate, they take account of how setting a higher wage will lead to lower labour demand so that the first-order condition for labour supply becomes

$$w_t = \frac{\eta_t \quad U_{n,t}}{\eta_t - 1 \, U_{c,t}} \qquad \textbf{(8)}$$

where η denotes the wage elasticity of labour demand with respect to wages at time *t*. Combining the first-order conditions of firms and consumers gives an equilibrium sequence for employment and wages, which we denote by $\{n_t\}$ and $\{w_t\}$ respectively. This equilibrium wage sequence reflects the fact that the trade union knowingly accepts lower employment as a necessary cost of achieving a higher wage. However, in the absence of trade union power, consumers would want to provide a higher level of employment at this equilibrium wage. Gali uses this insight to define a concept of involuntary unemployment. He computes the employment sequence $\{n^*_t\}$ that consumers would provide given a wage sequence $\{w_t\}$ and in the absence of trade unions, and then defines involuntary unemployment as n^*-n, as we show in Chart 5. Gali terms this a 'Keynesian' model, in the sense that its concept relies on imperfect competition and the notion that under monopoly power, prices will always be too high and output too low relative to the social optimum.

Chart 5: Involuntary unemployment



3.6 Distortionary taxes

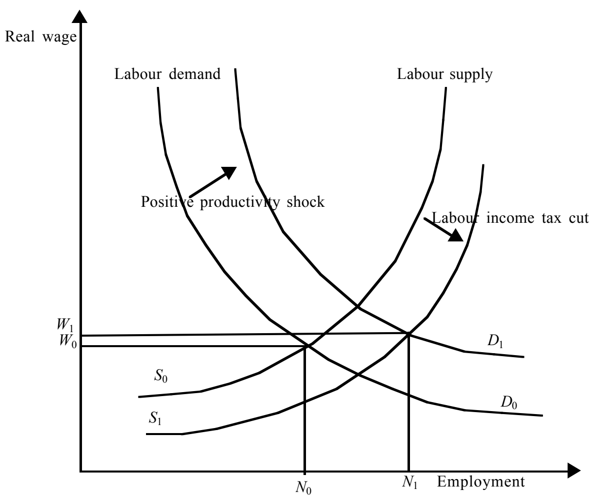
All of the above models have relied upon one shock (random variations in productivity) to produce employment fluctuations. The first-round effects of these productivity shocks is to shift the labour demand curve rather than the labour supply curve. Increasingly, a number of models have developed that rely upon other shocks as well as productivity to explain business cycles (eg monetary policy shocks, as in Cooley and Hansen (1989) and Benhabib and Farmer (1994)). Another important additional source of labour market fluctuations is variation in labour and capital taxes, which affects the real wage and the real interest rate received by individuals, and so influences the equilibrium sequence of output and employment. Using models calibrated to US data, Braun (1994) and McGratten (1994) show how allowing for variations in labour and capital tax rates can improve the performance of the basic RBC model.

In the model we use (that of Braun (1994)), government expenditure enters the utility function, as some fraction of government expenditure is deemed to raise private sector utility, as if it were private consumption. The introduction of distortionary taxes alters the relative prices consumers face, so that the first-order conditions become:

$$U_{n,t} = U_{c,t} MPL_t \left(1 - \tau_{n,t}\right)$$
$$U_{c,t} = \beta E_t U_{c,t+1} \left(1 + \left(MPK_{t+1} - \delta\right)\left(1 - \tau_{k,t}\right)\right) \quad \textbf{(9)}$$

In other words, what matters for labour supply and consumption is the after-tax wage and the net real interest rate. Equation (**9**) makes clear that variations in tax rates will, for a given gross wage, lead to shifts in the labour supply curve. That is, for a given gross wage, an increase in labour taxes reduces the net wage received by the consumer, and so reduces the amount of hours they are prepared to work. Therefore in this model, business cycle fluctuations are caused by productivity shocks shifting the labour demand curve, and changes in taxes shifting the labour supply curve. The advantage of this is that assuming that both labour demand and labour supply curves move together over the business cycle (as shown in Chart 6) will generate large changes in employment but very little fluctuation in real wages, exactly what we observe in the UK data.

Chart 6: Distortionary taxation model



4 Model properties

A key component of the methodological innovations made in Kydland and Prescott (1982) is the use of model calibration and simulation to assess theoretical models. This process involves first choosing values for key model parameters, such as the degree of risk aversion, the persistence of the productivity shocks etc, and then using numerical techniques to solve the model economies.(4) If the simulations are to have any relevance to understanding UK business cycles, the calibration process is critical. It is obviously important to choose the model parameters so that they accord with estimates using UK data. Our use of six models means that we have a large number of parameters to calibrate, and space constraints prevent us from detailing all these calibration decisions.(5) However, common to all of our simulations are the utility and production functions, and so it is important to detail our calibrations of these key features. We assume that the utility function is given by the constant relative risk-aversion form

$$U(c_t, n_t) = \frac{\left(c_t^{\phi}(1-n_t)^{1-\phi}\right)^{1-\tau} - 1}{1-\tau} \qquad \textbf{(10)}$$

where we use the panel data estimates of Attanasio and Weber (1993) to set τ equal to unity (so that utility is logarithmic). We use the results of Alogoskoufis (1981) to set ${}^{1-\phi}\!/\!_{\phi}$ equal to 2. For the production function, we use the results of Holland and Scott (1996) who, using the UK National Accounts, calculate the share of output going to capital, α, to be 0.4436 and specify the random technology shock to follow the process

$$\ln\theta_t = \ln\theta_{t-1} + \mu + \varepsilon_t \qquad \textbf{(11)}$$

where μ is set at 0.207% per quarter and the standard deviation of ε is set at 1%. In other words, the technology process follows a random walk, and technology shocks are both highly persistent and highly volatile. These values were used for all models with the exception of the model with stochastic taxes. As explained in the Appendix, the only data available on tax rates is annual, and so we converted all of these quarterly calibrations into their annual equivalents.

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(4) The details of these numerical techniques are inevitably complex and beyond the scope of this paper. For reference, we use the PEA approach of den Haan and Marcet (1990) to solve all our models except for the search model, which we solved by log-linearly approximating the first-order conditions around the non-stochastic steady state. To assess the accuracy of our solutions, we used the test of den Haan and Marcet (1994). A full collection of GAUSS codes is available on written request.

(5) All of our parameter choices are taken from UK employment studies and, where possible, we choose consensus estimates. A detailed list of choices and sources is given in the Technical Appendix.

4.1 Stylised facts

Tables C and D show the results relating to labour market volatility from simulating each model 1,000 times (each simulation being 150 periods long) and then averaging across all simulations. Our focus is on the labour market variables, so we shall not comment on the mixed performance of the models in explaining consumption and investment volatility. Concentrating on real wages, we can see that the models do fairly well (and the tax model extremely well) in accounting for wage variability. However, with the exception of the tax model, the performance regarding employment and unemployment volatility is far more disappointing. While there are significant differences between the performance of the various models, what is most noticeable is that these differences are insignificant compared with the differences between the data and the model simulations. Employment and unemployment are an order of magnitude more volatile in the data than any of the model can explain. The one exception to this is the performance of the tax model (calibrated on annual data and shown in Table D), which manages to match the volatility of employment in the data almost exactly. The tax model is also the best at explaining unemployment volatility, but even then it can only account for around 6% of the observed volatility in unemployment.

Table C: Business cycle facts and simulations

	Consumption	Investment	Employment	Wages	Unemployment
Data	0.97	2.47	1.11	0.68	8.43
Basic RBC model	0.38	1.42	0.22	0.51	0.12
Indivisible labour	0.83	3.05	0.36	0.31	0.20
Labour hoarding	0.32	1.61	0.42	0.49	0.25
Search	0.87	1.48	0.22	0.89	0.13
Gali	0.32	1.42	0.25	0.48	0.31

Note: Table shows standard deviation of detrended variable listed in column heading divided by standard deviations of detrended output, either in the data (first row) or from the simulations (the remaining rows).

Not surprisingly, the basic RBC model performs worst of all in generating employment and unemployment volatility. This is because of two factors: (i) our calibration of the utility function implies only a modest willingness to substitute employment intertemporally, and (ii) our calibration of the productivity shock implies that shocks are permanent and not temporary, so there is little variation in relative wages between time periods. As a consequence, not only are agents not willing to substitute labour intertemporally, there is also little incentive to do so. The volatility of employment and unemployment improves substantially under both the indivisible labour and labour hoarding assumptions, although by nowhere near enough to account for the data. The Gali (1995) model produces little employment volatility but, with its definition of involuntary unemployment, does best of all the quarterly models at explaining unemployment. Most surprising of all is the poor performance of the search model in accounting for employment volatility. Given our parameterisation of the model, most of the volatility in the search model feeds through into wages rather than employment.

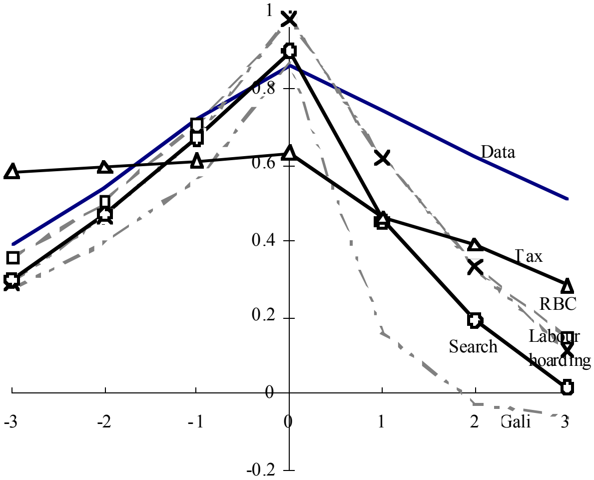
Table D: Annual business cycle facts and simulations for the model with distortionary taxation

	Std dev	-3	-2	-1	0	1	2	3
Consumption	1.35	-005	0.08	0.25	0.53	0.61	0.65	0.61
	(1.13)	(-0.06)	(0.26)	(0.62)	(0.88)	(0.75)	(0.39)	(-0.05)
Investment	2.58	0.49	0.58	0.63	0.61	0.32	0.09	-0.08
	(4.63)	(0.02)	(0.37)	(0.74)	(0.93)	(0.72)	(0.29)	(-0.14)
Employment	1.07	0.41	0.50	0.58	0.63	0.28	0.03	-0.14
	(1.19)	(-0.57)	(-0.28)	(0.23)	(0.74)	(0.94)	(0.73)	(0.30)
Wages	0.95	-0.10	-0.02	0.07	0.26	0.44	0.56	0.59
	(0.91)	(0.22)	(0.24)	(0.31)	(0.45)	(0.53)	(0.41)	(0.15)
		Correlation with employment						
Wages		-0.36	-0.43	-0.50	-0.58	-0.19	0.06	0.23
		(0.23)	(0.21)	(0.29)	(0.34)	(0.28)	(0.07)	(-0.17)

Notes: The first column of statistics shows the standard deviation of the cyclical component of the variable listed in the first column divided by the standard deviation of the cyclical component output. The remaining columns show the correlation between the cyclical component of output and the cyclical component of the variable listed in the first column. The columns show the correlation of X_{t+j} with output at time t, where j is given by the column heading, eg -3 means how current output is correlated with the variable three years ago. Therefore, the left-hand side of the table focuses on whether or not the variable leads output over the business cycle. In each data cell, the figure in brackets gives the value of the relevant statistic in the UK data.

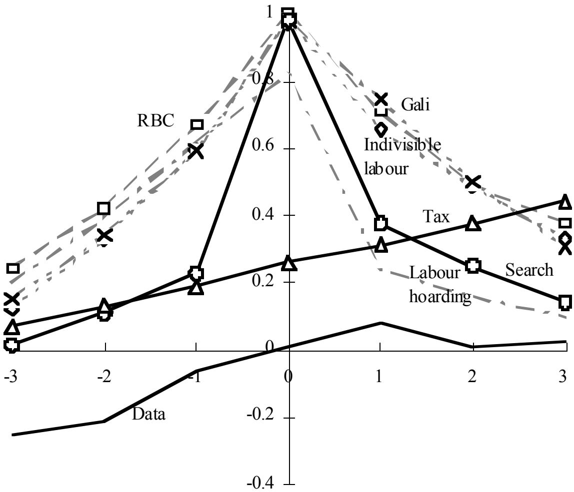
Charts 7a-c show how the correlations between wages, employment and output produced with our simulated models compare with those from the data. Focusing on the employment-output correlations, we see that all of the models perform reasonably well in producing procyclical employment movements closely correlated with output. In particular, the models do extremely well in explaining the correlation of output with lagged employment, although they do less well in explaining the high correlation of employment with lagged output. However, Chart 7b reveals the crucial failing in all of these models: in the data, wages show little correlation with employment, whereas in all of the simulations (with the exception of the tax model) wages are strongly procyclical. This result is due to the fact that underlying all of these models is a single source of business cycle fluctuations: random technology shocks. Positive technology shocks increase labour productivity, boost the demand for labour, and so lead to higher employment but also higher wages. As a consequence, wages are strongly procyclical, in clear contradiction to the data. This result holds for all models with just the single source of uncertainty, regardless of whether the labour market is perfectly competitive or not. The only model that does not display a strong correlation between wages and output is the tax model, in which both the labour supply and demand curves shift in response to tax and productivity shocks. However, even in this case, the model still predicts a small but significant positive relationship between wages and output.

Chart 7a: Employment-output correlations



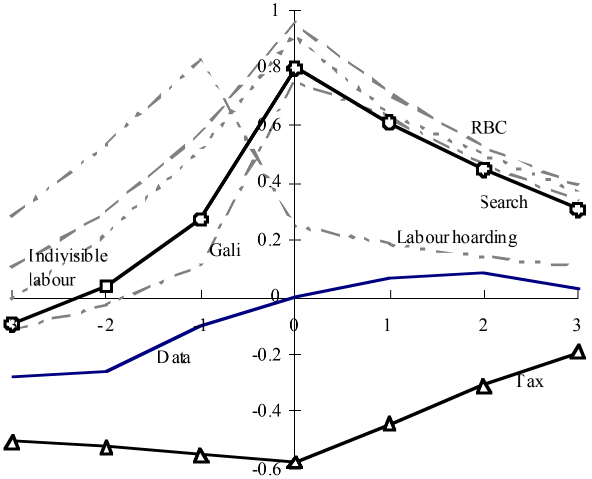
Note: Results for the indivisible labour model are basically identical to those for the labour hoarding model.

Chart 7b: Wage-output correlations



Also revealing is Chart 7c, which shows the correlation between wages and employment. As for the wage-output correlation, most of the models suggest a strong positive correlation, rather than the zero correlation observed in the data. However, while the tax model performs well in explaining the volatility of employment and the correlation of wages with output, Chart 7c shows that this comes at a cost. The movements in the labour supply curve required to generate this employment volatility are so large in our simulations that there is a strong negative correlation between wages and employment, which is as much a contradiction with the data as the positive correlation generated by the other models.

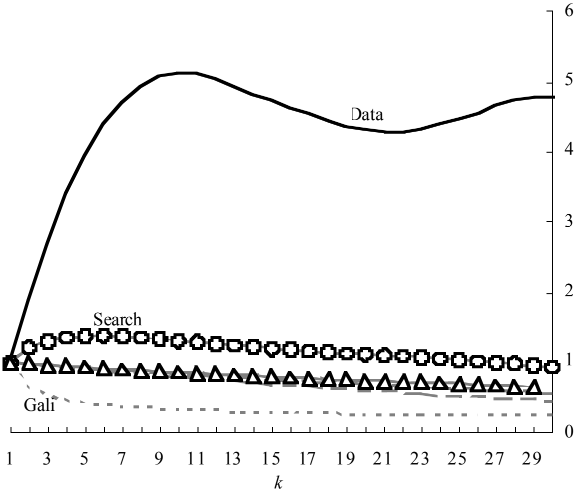
Chart 7c: Wage-employment correlations



4.2 Persistence

Charts 8a-c show our measure of persistence for unemployment, real wages and employment for both the data and our simulated models. The variable whose persistence the models most successfully explain is real wages, although even in this case, no single model clearly outperforms the others. The search and Gali (1995) models perform best in explaining persistence over the first four quarters, and the tax model comes closest to matching the long-run persistence in real wages. In general, most of the models rely on permanent productivity shocks, and Chart 8b suggests that as a result the models tend to generate too much persistence in real wages.

Chart 8a: Persistence measures for unemployment



Note: Results for basic RBC model, indivisible labour model, labour hoarding model and tax model are basically identical. That is why they are not labelled individually in the chart.

Chart 8b: Persistence measures for real wages

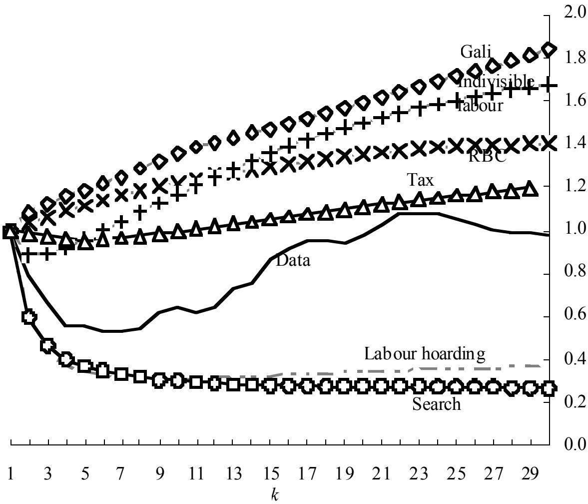
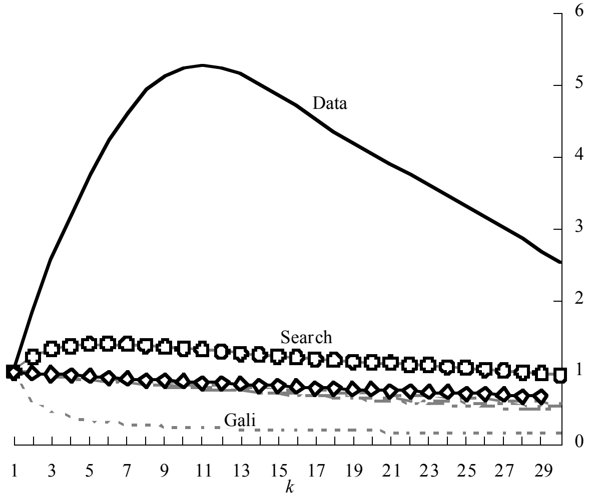


Chart 8c: Persistence measures for employment



Note: Results for basic RBC model, indivisible labour model, labour hoarding model and tax model are basically identical. That is why they are not labelled individually in the chart.

As was the case for the volatility of employment and unemployment, although there are important differences between the various simulated models, Charts 8a and 8c show that the most marked differences are between the data and all the various models. None of the models generates the extreme persistence in unemployment that characterises the UK labour market. As documented by Cogley and Nason (1995b), the RBC models' combination of persistent productivity shocks and capital accumulation provides very little persistence to output and employment fluctuations over and above that inherited from the productivity shock. Where fluctuations in UK unemployment display no evidence of mean reversion, the picture that emerges from most of our simulated models is of small and temporary deviations of unemployment away from its average value.

However, while no one model comes close to matching the data, the search model clearly outperforms all the various other models. The search model is the only one that generates a value greater than unity for the Cochrane test at any horizon. Whereas the Cochrane statistic declines continuously for all the other models, for the search model the test statistic actually increases for the first eight quarters, proving that search does provide a substantial increase in persistence.[6]

(6) The search model also matches the volatility of vacancies extremely well, as well as replicating the Beveridge curve.

4.3 Cyclical asymmetries

Our final criterion for assessing our six models is their ability to explain the fact that the growth and persistence of employment and unemployment varies over the cycle. Tables E and F show the results from our simulations. They show the average *p*-value of testing for the insignificance of dummies that allow the mean and persistence of each variable to alter in recessions compared with expansions. A *p*-value of less than 0.05 suggests that the stochastic properties of the variable do change between stages of the business cycle.

Table E: Mean asymmetries in data and simulations

	Employment	Unemployment	Real wages
Data	0.018*	0.057	0.544
Basic RBC model	0.042*	0.081	0.077
Indivisible labour	0.083	0.076	0.052
Labour hoarding	0.072	0.063	0.102
Search	0.062	0.038*	0.110
Gali	0.039*	0.030*	0.041*
Distortionary taxes	0.748	0.370	0.328

Notes: Table shows *p*-value for test of mean asymmetries in data and average *p*-value from 1,000 simulations. A'*'denotes that cyclical asymmetries are present at the 5% significance level.

Table F: Dynamic asymmetries in data and simulations

	Employment	Unemployment	Real wages
Data	0.044*	0.527	0.572
Basic RBC model	0.225	0.048*	0.041*
Indivisible labour	0.280	0.305	0.076
Labour hoarding	0.238	0.061	0.060
Search	0.621	0.102	0.042*
Gali	0.170	0.060	0.071
Distortionary taxes	0.882	0.058	0.062

Notes: Table shows *p*-value for test of dynamic asymmetries in data and average *p*-value from 1,000 simulations. A '*' denotes that cyclical asymmetries are present at the 5% significance level.

Table E shows that, with one exception, the models do extremely well in capturing shifts in the growth of employment and unemployment over the business cycle. However, Table F shows that while the models have some successes, they are generally less successful in generating changes in the persistence of employment and unemployment over the cycle. As we found in the previous section, the models tend not to be able to adequately capture the dynamics of the labour market: either the overall persistence of the market, or the way in which persistence varies between expansions and contractions.

5 Conclusions

Our examination of six different labour market models has revealed some successes and some failures. Overall, the models tend to produce fluctuations that are characterised by relatively small unemployment fluctuations, which consist of limited and temporary movements of unemployment away from an average rate. On the success side, we have the ability of the models to replicate fairly well the cross-correlations of employment and output over the business cycle, and the ability to mimic the way in which the growth of labour market variables changes over the cycle. However, there were three distinct failures:

(i) The models tend not to generate sufficient volatility in either employment or unemployment.

(ii) The models predict too strong a correlation between wages and employment.

(iii) The models cannot explain the observed persistence of UK unemployment and employment, or the extent to which this persistence varies over the cycle.

The extent of the model failures along these three dimensions were sufficiently large to suggest that none of the basic labour market models that we have outlined can be thought of as adequate to capture UK labour market dynamics. This has wider ramifications, in that it suggests that using any of these labour market models to examine the welfare implications of alternative monetary and fiscal policy rules could be misleading.

Given the simple nature of these models, the finding of these inadequacies is hardly surprising, although the extent to which the differences between the data and the model simulations swamp the differences between the wide variety of models we examine is. However, the main aim of the paper was not to expose limitations, but to investigate potential areas for future development. We believe that our results are informative in this direction. Examining the three main failures of the various models, we find two particular specifications that fared relatively well: the tax model, in explaining employment volatility and in producing a nonpositive correlation between employment and wages, and the search model, in generating additional persistence in employment and unemployment.

All of our models contain a volatile and highly persistent stochastic productivity term. Our simulations suggest that while this alone is capable of generating appropriate amounts of output volatility, it is not sufficient to generate the observed volatility in employment. Only when we supplement the productivity shock with an additional disturbance can we produce enough employment variability. Given the variety of different labour market models we examined, this seems to suggest strongly that in order to account for UK labour market behaviour, we have to introduce an additional source of disturbance into the stochastic growth model. Furthermore, our simulations suggest that, while allowing for varying tax rates offers some scope for improvement, salvation probably involves another source of uncertainty.

Our tax simulations also reveal that the strong positive correlation between wages and employment can be rectified relatively easily, by introducing an additional source of fluctuation that shifts the labour supply curve. In our simulations, introducing stochastic taxes actually took the adjustment too far in the opposite direction and produced a negative correlation, but the general point is clear: adding additional disturbances can help to make employment/unemployment more volatile and lead to a zero correlation between wages and employment. What these simulations do not tell us is which additional shock to include, and there is a wide choice: anything from incorporating preference shifts to sticky prices and monetary shocks would help to improve the performance of the models.

Perhaps the most striking failure of all was the inability of the models to generate enough persistence in employment/unemployment. The only model that helped to extend the time it took unemployment to adjust to a productivity shock was the search-based model, but even this improvement left the models well short of the data.

One way to generate additional persistence would be simply to add costs of adjustment for the firm in changing employment. In particular, the labour hoarding model could be extended to have hiring and firing costs so that, instead of having an infinite current-period adjustment cost but a zero cost at the end of the period, firms always faced some positive finite adjustment cost. However, the relative success of the search model suggests that it may be profitable to investigate additional sources of propagation within this framework. One obvious way would be to allow for the job destruction rate (the inflow into unemployment) to vary endogenously, as in Mortensen and Pissarides (1994). However, we feel that a more likely means of matching the persistence in the search model with that in the data is to move away from the representative agent model. In our simulations, an unemployed individual swiftly moves back into the workforce after a few periods, even allowing for the additional persistence provided by the search mechanism. However, most empirical analysis of the labour market stresses the importance of heterogeneities such as skill, education, age, sex, race and region. Incorporating these heterogeneities into the model would significantly decrease the flexibility of the labour market and the search process, and make unemployment and employment fluctuations much more persistent. Adding additional features such as skill diminution as unemployment continues would improve the model performance yet further.

To summarise, we have found that the basic RBC models we have examined fail in three important ways to mimic the behaviour of the UK labour market over the business cycle. Furthermore, we found that these deficiencies were shared across a wide range of different labour market models, and not only a few categories. This suggests that to explain the UK business cycle an increase in model complexity is required, rather than simply an alternative approach. In particular, we identify adding non productivity based sources of uncertainty and moving away from the representative agent paradigm as potentially the most rewarding ways of proceeding.

Data Appendix

The labour market data that we use to present the stylised facts in this paper come from two main sources: *Labour Market Trends* and *The Labour Force Survey*, both published by the Office for National Statistics. All data is for the United Kingdom (unless otherwise stated), and is seasonally adjusted. With the exception of the tax data, all data is quarterly and covers the period 1976 Q2-1996 Q2, apart from the vacancy data which is only available from 1980 Q1. The tax data is annual, and covers the period 1949-96.

Employment is defined as 'employees in employment' (ONS code: BCAJ), and *Total Hours* is 'total actual weekly hours (Great Britain)', taken from the *Labour Force Survey*. This series is only available quarterly since 1992 Q1, and is available annually from 1984. This annual number represents the results of a first-quarter survey, and to arrive at a quarterly series for this period, we interpolated. To arrive at a longer run of data, we then regressed the ratio of average hours worked in non-manufacturing to average manufacturing hours on a constant, the growth of GDP, the share of manufacturing in employment, the share of part-time workers in employment and a time trend for the period for which we have data, and then backcast. We also calculated stylised facts and persistence using other measures of total hours (eg manufacturing), and found our main results to be robust. *Unemployment* is 'claimant unemployment' (ONS code: BCJD), *Vacancies* are 'vacancies at job centres' (ONS code: DPCB) while *Real Wages* are 'index of whole-economy average earnings (1990=100, Great Britain)' (ONS code: DNHS) deflated by the 'Retail Prices Index excluding mortgage interest payments' (ONS code: CHMK). *Output* is measured by 'gross domestic product excluding oil and gas extraction'.

Additionally, the following data were used to calibrate the tax and government spending shock processes in the model of Braun (1994). *Government Spending* is measured as 'general government final consumption' (ONS code: DIAT); *Taxes on Labour Income* is the marginal tax rate faced by a worker on average earnings (which equals the basic rate of income tax plus the marginal national insurance contribution faced by such a worker, divided by one plus the marginal national insurance contribution faced by their employer); *Taxes on Capital Income* is the marginal tax rate faced by a basic rate taxpayer who buys equity at the beginning of the year and sells it at the end of the year having made a return on his holding. (For details, see King and Fullerton (1997).) We are extremely grateful to Mark Robson at the Bank of England for providing us with this data.

Technical Appendix on Calibration

The basic RBC model that we used is that of King, Plosser and Rebelo (1988). In this model, the representative agent's problem is:

$$\text{Max. } E_0 \sum_{t=0}^{\infty} \beta^t \left(\phi \ln(c_t) + (1-\phi)\ln(1-n_t)\right)$$

$$\text{Subject to } c_t + k_t - \mu k_{t-1} = \theta_t k_{t-1}^{\alpha} n_t^{1-\alpha} \qquad \textbf{(A1)}$$

$$\ln(\theta_t) = \ln(\theta_{t-1}) + g + \varepsilon_t$$

where c represents consumption, n represents 'total hours worked', k is the end of period capital stock and ε is a mean zero productivity shock. As explained in the main text, we used the results of Alogoskoufis (1981) to set ϕ to 1/3, and the results of Holland and Scott (1996) to set α to 0.4436, g to 0.21% and the standard deviation of ε to 1%. We assumed a quarterly rate of depreciation of the capital stock of 2.5%.

The indivisible labour model that we used is that of Hansen (1985). In this model, agents now have a choice of working h_0 hours or none at all. However, only a proportion of individuals, φ, are employed. Thus total hours, n, will be given by the product of these, and the utility function becomes:

$$U(c_t, h_t) = \phi \ln(c_t) + (1-\phi)\frac{n_t}{h_0}\ln(1-h_0) \qquad \textbf{(A2)}$$

where we have assumed log-utility. Here we set h_0 such that, in steady state, φ is equal to the average employment rate in UK data for the period 1976 Q2-1996 Q2, 92.1%. In all other respects, this model is the same as the King, Plosser and Rebelo model.

The labour hoarding model is that of Burnside, Eichenbaum and Rebelo (1993). In the model, workers are again assumed to work a fixed shift-length. However, firms are able to vary the intensity with which they work these workers. If we let work intensity be e, the fixed shift-length be h_0, and χ be a fixed employment cost, we can write the representative agent's utility function as:

$$U(c_t, h_t, e_t) = \phi \ln(c_t) + (1-\phi)\frac{n_t}{h_0}\ln(1-\chi-e_t h_0) \qquad \textbf{(A3)}$$

The new parameters in the model are h_0 and χ. We set these parameters such that steady-state effort is equal to unity and, conditional on ϕ which is still fixed at

1/3, steady-state total hours are equal to their value in the King, Plosser and Rebelo model, that is, 0.293.

The search model we use is that of Merz (1995), which combined the 'search theoretic' approach to the labour market with the equilibrium business cycle approach of the previous models. In this model, the representative agent maximises the utility function given in equation (**A1**), but takes employment as given at the beginning of the period. He can choose how much effort to expend on recruiting (through the posting of vacancies, v). Thus we need to consider these in the aggregate resource constraint, which becomes:

$$c_t + k_t - \mu k_{t-1} + \theta_\tau^{\frac{1}{1-\alpha}} a v_t = \theta_t k_{t-1}^{\alpha} h_t^{1-\alpha} \tag{A4}$$

Here, a is the cost of posting a vacancy. Again it is set such that, conditional on ϕ which is still fixed at 1/3, steady-state total hours are equal to their value in the King, Plosser and Rebelo model. In addition, we suppose that employment follows the following process:

$$n_{t+1} = (1-\delta) n_t + A v_t^{\eta} u_t^{1-\eta} \tag{A5}$$

where δ is the exogenous unemployment inflow rate, set at 4.82% to match UK data for the period 1979 Q1-1996 Q2. Following Merz, we set the elasticity of matching with respect to vacancies, η, to 0.4 and, in addition, we normalise A to be unity.

The model of Gali (1995) deals with the problem that none of these models can explain unemployment: hitherto, 'not-working' has corresponded to 'enjoying leisure'. The Gali model explains the presence of involuntary unemployment by having monopolistically competitive firms and worker/firm bargaining. This means that the wage will not be equal to the marginal product of labour and, hence, that there will be involuntarily unemployed workers in equilibrium. Although the model adds significant complications to the standard models and cannot be formulated as a representative agent problem, there are very few additional parameters to calibrate. In particular, consumers maximise the same utility function given in equation (**A1**).

On the production side, perfectly competitive firms produce the final good using inputs of intermediate goods. These are in turn produced by firms in many industries, each of which exhibits Cournot competition. The firm producing intermediate good j has the following production function:

$$y_{jt} = \theta_t \left(k_{jt} - v\theta_{t-1}^{\frac{1}{1-\alpha}} \right)^{\alpha} n_{jt}^{1-\alpha} \tag{A6}$$

where v is a fixed cost that is set so that the steady-state unemployment rate generated by the model matches its average rate in UK data for the period 1976 Q2-1996 Q2. If we let *X(j)* be the output of industry *j*, and *p(j)* be its price, then the final-goods-producing firms' problem is:

$$\text{Max} \left[\int_0^1 X(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 p(j)X(j)dj \qquad \textbf{(A7)}$$

Here, ε is the elasticity of substitution between intermediate goods. We set this to 2, reflecting the average mark-up of prices over marginal costs seen in UK data.

The model of Braun (1994) includes government expenditure in the utility function, as well as the aggregate resource constraint. In addition, the government raises revenue through distortionary taxes on labour and capital income. This model allows government spending to be productive (in the sense of raising utility), and also adds distortionary capital and labour income taxes.
Thus, the consumers' problem is:

$$\text{Max } E_0 \sum_{t=0}^{\infty} \beta^t \left(\phi \ln(c_t + \gamma g_t) + (1-\phi)\ln(1-n_t)\right) \qquad \textbf{(A8)}$$

$$\text{Subject to } c_t + k_t = k_{t-1} + (1-\tau_t^l)w_t n_t + (1-\tau_t^k)(r_t - \delta)k_{t-1} + tr_t$$

where g is government spending, τ^l is the rate of tax on labour income, τ^k is the rate of tax on capital income, $\delta, = (1-\mu)$, is the rate of depreciation of capital, and tr represent transfers from the government to the private sector. The firms' problem is standard, and the government does nothing more than balance its budget given shocks to government spending and the two tax rates. All of these shocks are assumed to follow AR(1) processes. The exact specification of these processes was obtained by estimating AR(1) processes on annual UK data for the period 1949-96 for the tax rates and Hodrick-Prescott filtered government spending. We followed Braun in setting the weight on government spending in the utility function, γ, to 0.4. We also ensured that the steady-state share of government spending in GDP in the model matched its average in UK data for the period 1949-96.

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