

The Effect of Skill Shortages on Unemployment and Real Wage Growth: A Simultaneous Equation Approach

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Abstract

This paper attempts to quantify the effect of skill shortages on the UK labour market by developing a simultaneous equation model of unemployment and real wage growth. The model is developed following a structural approach based on *a priori* economic information and is initially estimated using a two-stage least squares procedure. The model is also estimated using Zellner's seemingly unrelated regressions estimation technique, with similar results. It is shown that skill shortages have a positive effect on real wage growth and a negative effect on unemployment, with both these effects economically and statistically significant.

JEL classifications: C32, C51, C52, E24

Keywords: Skill Shortages, Unemployment, Wages, 2SLS

1. Introduction

Academic and vocational qualifications are commonly used as a proxy for skills when assessing the personal and social returns of training and education and the level of skills in a country. The use of qualifications as a proxy for skills is a useful and objective way of measuring an individual's skill base but it does have its limitations when looking at the implications of skill levels on the UK economy. The UK has experienced a major shift in its occupational structure in the past 20 to 30 years, with a corresponding shift in the demand for skills. The demand for generic skills such as communication and problem solving has increased whilst the demand for skills relating to manual occupations has declined. Qualifications, although being a relatively good indicator of the supply of skills, do not provide a measure of the demand for skills. More emphasis needs to be put on identifying the skill needs and shortages that exist in the UK.

The need has been recognised. In 1998 the Secretary of State for Education and Employment established the Skills Task Force (STF), set up to help develop a National Skills Agenda by providing evidence on skill needs and shortages in the UK. A Research Programme was also set up under the direction of Terence Hogarth and Rob Wilson at the Institute for Employment Research (IER), at the University of Warwick, in order to “provide evidence on the nature, extent and pattern of skill needs and shortages and their likely future development”¹. A major part of this research included two Employer Skill Surveys (ESS), carried out in 1999 and 2001, aimed at providing a comprehensive analysis of skill deficiencies in the UK². The research programme also included a review of existing surveys, including those by the Confederation of British Industries (CBI) and the British Chambers of Commerce (BCC).

In a recent *Labour Market Trends* article it was noted, “there has been increasing media reporting of skills shortages and their possible implications within the UK economy”³. The aim of this paper is to quantify the effect of skill shortages on unemployment and real wage growth in the UK by developing a simultaneous equation model. This model will

¹ See foreword of Bosworth *et al* [6].

² These surveys were undertaken by IFF Research and the IER.

³ See [14]. This article also provides a good overview of the current extent of skill shortages in the UK.

include a measure of skill shortages, which will be taken from the CBI's Industrial Trends Survey. The effect of skill shortages on real wage growth and unemployment can then be assessed.

Section 2 provides background information and comparisons of the various measures of skill shortages that are available to the researcher, introducing the CBI and BCC surveys and the Employer Skill Surveys. I will also discuss the reasoning behind choosing the CBI survey for my regression analysis. Section 3 will introduce the model used to quantify the effect of skill shortages on real wage growth and unemployment. I will also discuss the economic rationale behind the model and the structural approach that I have followed.

Section 4 introduces the variables I am using in my model, with some summary statistics and *a priori* observations of the data, and Section 5 discusses my estimation and sample period. Section 6 presents the basic result of the two-stage least squares estimation of my real wage growth and unemployment equations, with model evaluation and diagnostics in section 7. Section 8 builds on sections 6 and 7 by introducing an alternate estimation technique, seemingly unrelated regressions, and comparing the results with the two-stage least squares estimation. The implications of my equations and the link between skill shortages and unemployment are discussed in sections 9 and 10, respectively. Section 11 outlines possible directions of future research and section 12 concludes.

2. Background

2.1. Skill Shortages and Skill Surveys

There are three main skill surveys conducted in the UK that provide information on the level of skill shortages. These are the Employer Skills Survey, the CBI Industrial Trends Survey, and the BCC Quarterly Economic Survey. The problem that arises for a researcher is that these surveys are not based on the same measurement of skill shortages. The DfEE research into existing survey evidence on skill deficiencies noted that, "The interpretation of these surveys is bedevilled by differences in methodology, terminology,

and phraseology”. Caution must therefore be taken when comparing the results of these surveys.

The Department for Education and Skills (DfES, formerly Department for Education and Employment) defines skill shortages vacancies as a “A situation where there is a genuine shortage in the accessible external labour market of the type of skill being sought, and which leads to a difficulty in recruitment”. Skill shortage vacancies are thus vacancies explicitly attributed to a lack of job applicants with the required skills, qualifications or work experience. This is only one possible definition of skill shortages and other sources use different definitions, or measure different things when trying to quantify skill shortages.

The DfES also identifies internal skill gaps, which reflects a situation where employees’ current skills are insufficient to meet the business objectives of the employer. One problem that arises is that some surveys count this type of skill gap and others do not. In the Employer Skill Surveys this measure of skill shortage is separated from other types of skill shortages. In the CBI survey only one measure of skill shortages is recorded and this includes internal skill gaps. The BCC survey measure of skill shortages does not consider internal skill gaps, focusing solely on recruitment difficulties. It is clear then that caution must be taken when comparing the three surveys⁴.

A problem that all three of the surveys suffer from is the idea of latent skill gaps. The DfES identifies two types of latent skill gaps that can occur and hence bias survey data,

Latent skills gaps can take two main forms. First, for a variety of reasons, employers may fail to report some problems. This may be because the respondent is unaware that they exist or they may choose not to report vacancies (for instance, if they feel that there is no hope of filling them). Second, and potentially much more important, respondents may simply not perceive that they have a problem, because they are not fully aware of skills that might be needed to optimise their company’s performance.

⁴ In section 2.4. I will attempt to provide some comparison of the three surveys considering the different measures adopted of measuring skill shortages.

Both types of latent skill gaps identified above will lead to employers understating the level of skill shortages⁵, thus survey results will tend to understate the true level of skill shortages. Bosworth *et al* [7] assess the importance of latent skill gaps using the 1999 Employer Skill Survey. The econometric analysis suggests that establishment's perceptions of their skill needs are linked to their strategies and their success. Their key finding regarding latent skill gaps is that "enterprises that adopted new working practices were, on average, much more likely to report lower levels of proficiency amongst their workforce and that those that had adopted new technologies or new products were likely to be significantly more satisfied with the quality of their employees". They conclude that, "the incidence of both internal skill gaps and external recruitment difficulties would rise significantly for such establishments were they to be transformed by raising their aspirations and improving their performance. The intensity of reported external recruitment problems would increase sharply as well, especially for skill shortage vacancies".⁶

2.2. Employer Skill Surveys

The DfES undertook surveys of the *Skill Needs in Britain* (SNB) on an annual basis between 1990 and 1998 in order to provide a snapshot of skill needs at the time of each survey. Although these surveys proved useful, the two Employer Skill Surveys (ESS) conducted in 1999 and 2001 were of a much larger scale and were undertaken as part of a comprehensive analysis of skill deficiencies. The aim of the surveys was to identify the incident, causes and implications of skill deficiencies reported by employers.

The ESS 1999 surveyed establishments employing five or more employees with a representative sample being drawn from all sectors except agriculture. The survey consisted of 23,070 telephone interviews and 3,882 face-to-face interviews. The ESS 2001 surveyed establishments with one or more employee and included all sectors. The survey

⁵ The first type of skill gap is essentially not a latent skill gap but a consequence of measurement error. The second type is simply not recognised and so is a true latent skill gap.

⁶ See Bosworth *et al* [7] and also 'News and Research – DfES News' in *Labour Market Trends*, Volume 110, January 2002, Pg. 8.

consisted of 27,031 telephone interviews⁷. The scale of the two surveys makes them the most representative and comprehensive surveys of skill shortages in the UK. Care has to be taken however when comparing the results of these two surveys as the shift in the sample had a significant impact on the survey results, this is allowed for in the ESS 2001 statistical report⁸.

The Employer Skill Surveys investigate two different kinds of skill deficiencies, these are,

- *external recruitment difficulties, focusing in particular on hard-to-fill vacancies and what are referred to as **skill-shortage vacancies**, (hard-to-fill vacancies explicitly attributed to a lack of job applicants with the required skills, qualifications or work experience)*
- ***internal skill gaps** (defined as occurring where a significant proportion of existing staff in a particular occupation are not fully proficient at their current jobs).*

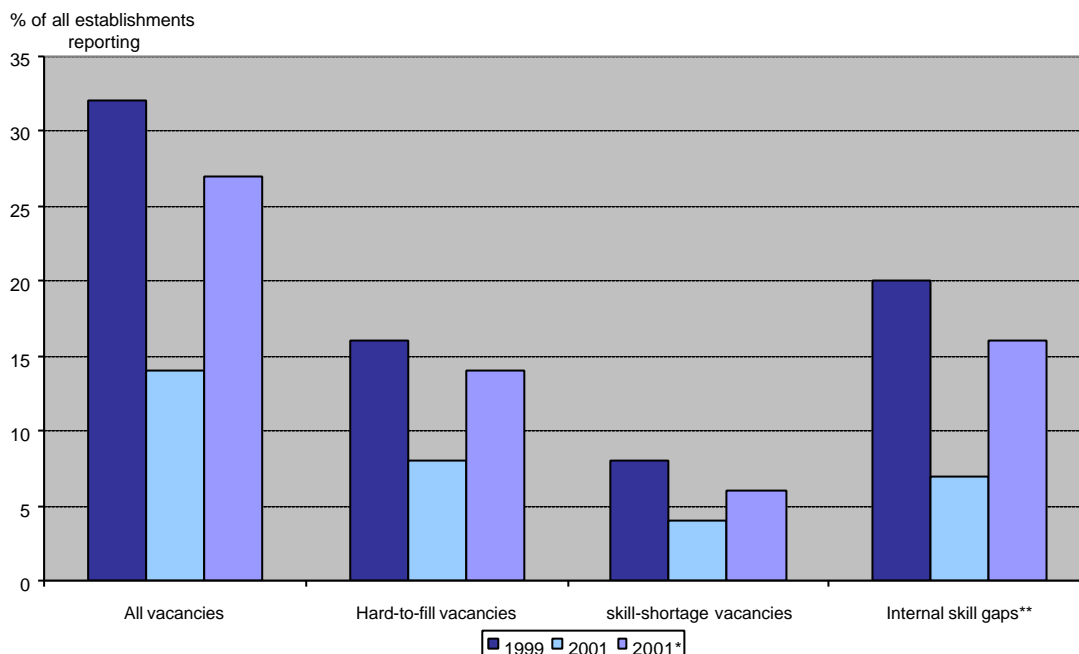
The Employer Skills Survey Statistical Reports, [6] and [21], present the survey results on vacancies, hard-to-fill vacancies, skill-shortage vacancies and internal skill gaps in various breakdowns, including by sector, occupation, region and establishment size. For my purposes the aggregate level of these measures is most important.

Figure 1 below shows the overall percentage of establishments reporting the three measures of vacancies and internal skill gaps in the two surveys and also the results from the reduced 2001 sample, which corresponds to the sample used in the ESS 1999. It can be seen that the all the measures of skill deficiencies have fallen in 2001 compared to 1999, even if the reduced 2001 sample is used. The effect of reducing the sample can be seen to have a large affect on the results.

⁷ In comparison the last Skill Needs in Britain survey consisted of 4,000 telephone interviews. See the technical appendix of Hogarth *et al* [21] for further technical detail on this survey.

⁸ See Hogarth *et al* [21].

Figure 1
Employer Skills Survey; 1999 and 2001; Vacancies, Hard-to-fill vacancies, Skill-Shortage Vacancies and Internal Skill Gaps



Source: ESS 1999 and ESS 2001 (IER/IFF)

* ESS 2001 with Establishments with 5 or more employees only, this corresponds to the sample used in the ESS 1999.

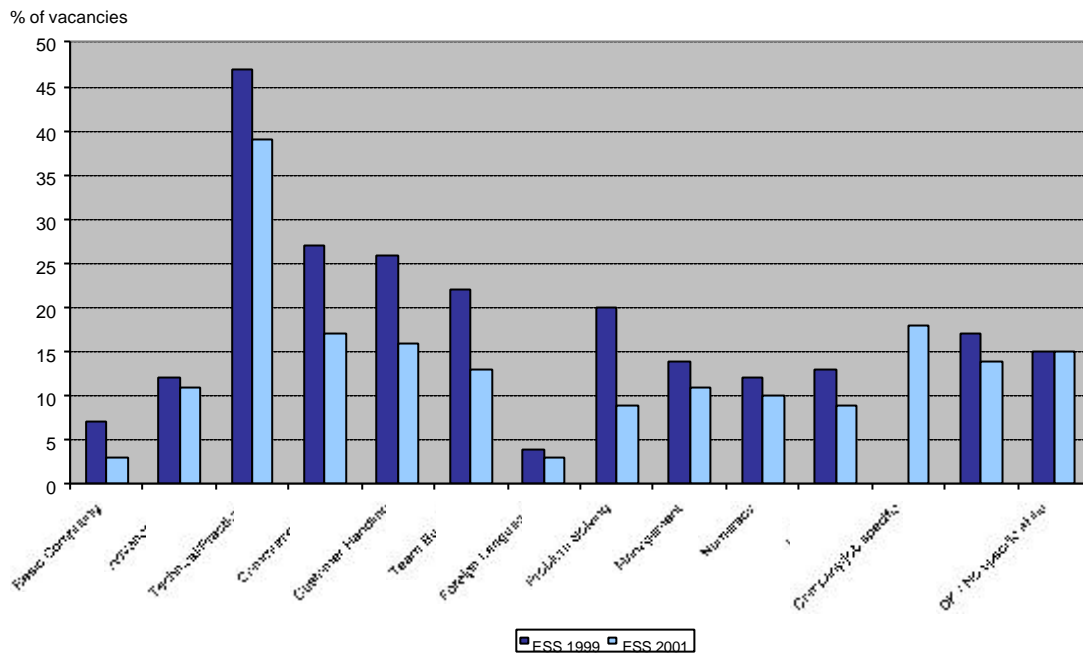
** Narrow measure, which includes only those establishments where a significant proportion of the workforce was reported as lacking proficiency. An employee-based measure is also available.

The measures shown above provide a good snapshot of the incidence of skill deficiencies in 1999 and 2001. The surveys also consider the causes of these skill shortages and their implications for firms. Figure 2 below shows the skills sought in connection with the skill shortage vacancies reported by establishments⁹. The graph gives an idea as to where the lack of skill is occurring and which skills there is demand for.

It can be seen that in both the ESS 1999 and the ESS 2001 the majority of skill shortage vacancies are due to a lack of technical and practical skills. The ESS 2001 also shows the emergence of company/job specific skill as a skill connected with skill shortage vacancies. Communication and team building can also be seen to be important areas where job applicants lack skills. Lack of IT and computing skills are relatively less important in both the ESS 1999 and the ESS 2001.

⁹ Skills sought in connection with hard-to-fill vacancies and internal skill gaps are also reported in the ESS Statistical Reports.

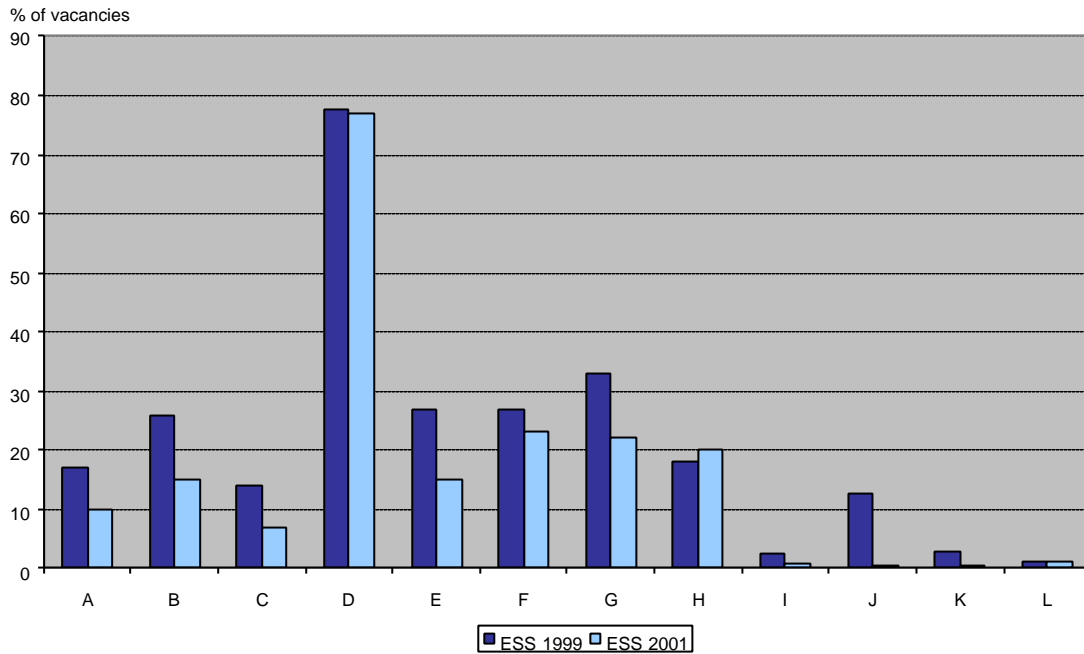
Figure 2
ESS 1999 and 2001; Skills Sought in Connection with Skill-Shortage Vacancies



Base: All Skill shortage vacancies
 Source: ESS 2001 Statistical Report (IER/IFF). ESS 1999 and ESS 2001.

Figure 3 below shows the causes of skill shortage vacancies as identified by employers. A low number of applicants with skills can be seen as the main cause of skill shortage vacancies with figures for both the ESS 1999 and ESS 2001 close to 80%. The second most important cause of skill shortage vacancies is a lack of work experience. Interestingly a lack of qualifications is the causes of only around 20% of vacancies, lack of skills is a much bigger cause of skill shortage vacancies. Factors such as pay and location are not significant causes of skill shortage vacancies.

Figure 3
ESS 1999 and 2001; Causes of Skill-Shortage Vacancies



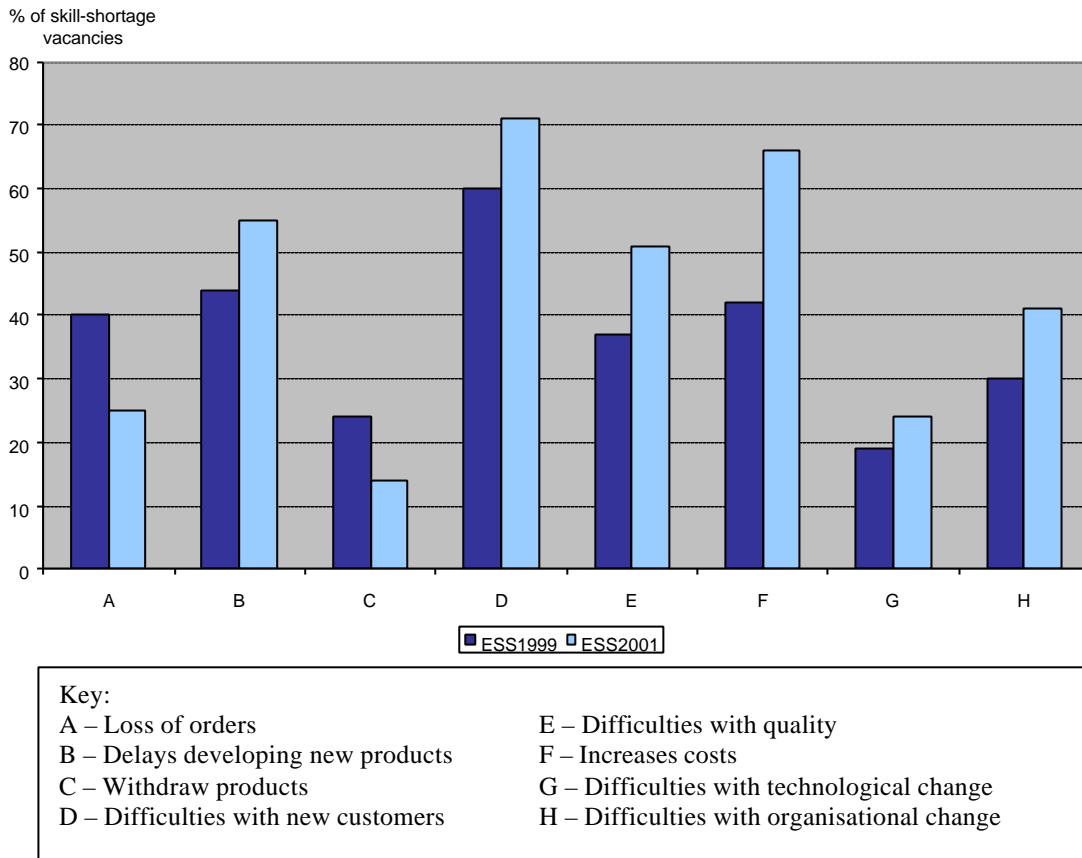
Key:

A – Too much competition	G – Lack of work experience
B – Not enough people interested	H – Lack of qualifications
C – Company does not pay enough	I – Company location
D – Low number of applicants with skills	J – Irregular Hours
E – Low number of applicants with motivation etc.	K – Unattractive conditions of work
F – Low number of applicants generally	L – Other

Base: All Skill shortage vacancies
Source: ESS 2001 Statistical Report (IER/IFF). ESS 1999 and ESS 2001.

The implication of skill shortages will vary from firm to firm and hence part of the ESS focuses on the impact of skill shortage vacancies, as well as the impact of the other measures of skill deficiencies. Figure 4 below shows the impact of skill shortage vacancies on the performance of firms. The most important impact on performance due skill shortage vacancies is on customer service. In 2001 some 71% of skill shortage vacancies meant that firms had difficulties with customer service. Increased costs, delays developing new products and difficulties with quality were also important impacts of skill shortages in 1999 and 2001.

Figure 4
ESS 1999 and 2001; Impact of Skill-Shortage Vacancies on Performance



Base: All Skill shortage vacancies
Source: ESS 2001 Statistical Report (IER/IFF). ESS 1999 and ESS 2001.

The graph also show that skill shortages vacancies are having a greater impact in all areas of performance, except loss of orders and needing to withdraw products, in 2001 than in 1999. Establishments in the survey were also asked what solutions have been adopted to combat skill shortage vacancies and skill gaps. Common solutions to skill shortages included increased salaries and increased training. Some 80% of establishments provided further training as a solution to skill gaps with relocating work within the company an increasingly common response.

The data presented above provides only a small sample of the wide range of data available from the Employer Skill Surveys¹⁰. The surveys also highlight the importance of regional and sectoral differences in the incidence of hard-to-fill vacancies, skill shortage vacancies

¹⁰ The reader is referred the Employer Skill Survey Statistical Reports, [6] and [21], for a full summary and analysis of the Survey results.

and skill gaps. These differences could have implications when estimating aggregate wage and unemployment equations.

Due to their large sample size and representative coverage the Employer Skill Surveys can be regarded as the most comprehensive surveys of skill shortages in the UK. Their only problem lies in the fact that they only represent two points in time and so say little about changes in the level of skill shortages over time. Hence, they cannot be used for time series regression analysis.

2.3. CBI Industrial Trends Survey

The CBI industrial Trends Survey (ITS) was first introduced in 1958, when it was published three times a year, and covers only manufacturing firms in the UK. Since 1972 it has been conducted on a quarterly basis, with the most recent survey being July 2002. The survey results are disaggregated by four employment size groups, three market sectors, twelve broad industrial sectors and 50 individual industries. The total sample (UK) data is weighted according to industrial sector, net output and employment size to give a representative sample of the UK. The most recent sample covers over 1500 UK firms and is currently conducted by post. The sample has been criticised for being more representative of larger employing firms but this is allowed for in weighting the results.

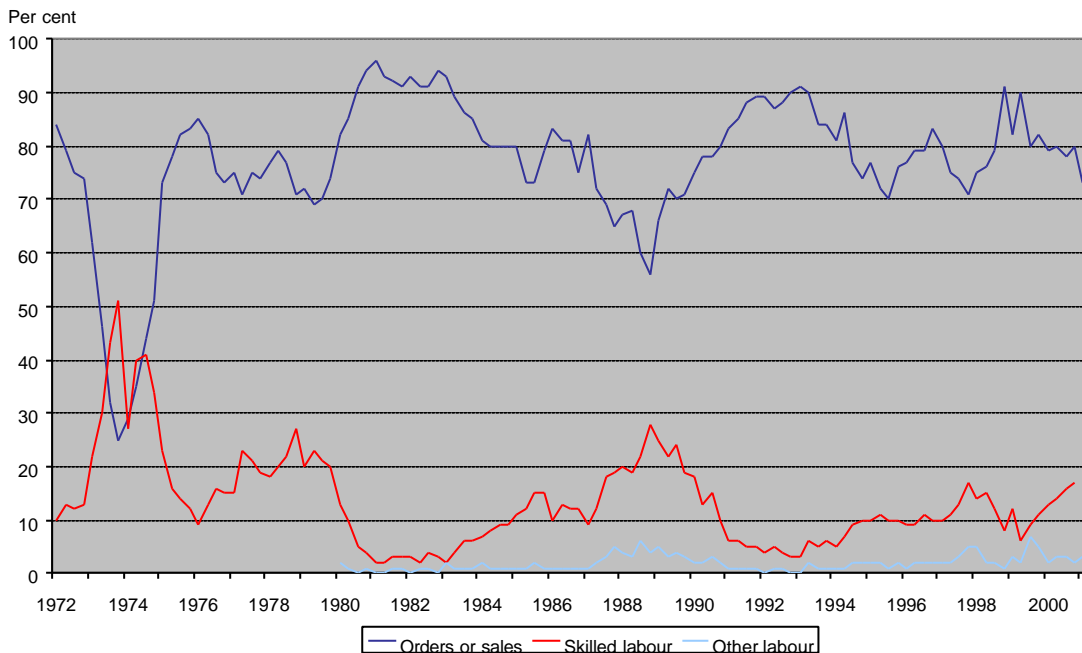
The survey asks firms a range of questions but the one that is directly relevant to skill shortages is question 14 of the survey, which is:

What factors are likely to limit your output over the next four months? Please tick the most important factor or factors. If you tick more than one factor it would be helpful if you could rank them in order of importance.

- a) Orders or Sales*
- b) Skilled Labour*
- c) Other Labour*
- d) Plant Capacity*
- e) Credit or Finance*
- f) Materials or Components*
- g) Other*

The proportion of respondents identifying skilled labour as a factor limiting output can then be used as a measure of skill shortages. Figure 5 below shows the CBI survey data for the period 1972 to 2001. The graph shows the proportion of respondents identifying, orders or sales, skilled labour, and other labour as factors limiting output. It is clear that the majority of firms in the survey identified orders or sales as the main factor limiting output, except for a period in 1973-74 when skilled labour became a more important factor.

Figure 5
CBI ITS: Proportion of Respondents Identifying each Factor as Main Factor Limiting Output; UK; 1972 to 2001, not seasonally adjusted



Source: CBI Quarterly Industrial Trends Survey

The skilled labour time series above can be used as a measure of skill shortages and provides a good length time series for regression analysis. The data from the survey is also generally regarded as representative; see Hart [17], Rosewell [30], or Blake *et al* [5].¹¹

¹¹ Haskel and Martin [18] use the CBI skill shortages data to test the effect of skill shortages on Productivity.

2.4. BCC Quarterly Economic Survey

The BCC Quarterly Economic Survey covers both manufacturing and service sector firms and has been running since 1985. The 2001 Q4 survey covered 7182 companies employing 900,000 people, 2556 manufacturing firms responded employing 297,779 people and 4626 service sector firms employing 618,224 people. Since 1989 total responses have been weighted according to the actual distribution of companies by size within the UK to try to ensure representative results, before this results were neither representative of all UK regions nor weighted. Due to the size of the survey it is considered the most representative of its kind in the UK¹².

The survey questions most relevant to skill shortages are the following,

BCC7a. Have you attempted to recruit staff over the past 3 months?

Yes/No

BCC7c. Did you experience any recruitment difficulties finding suitable staff?

Yes/No

BCC7d. If yes, for which of the Following categories?

a) Skilled manual and technical

b) Professional and managerial

c) Clerical

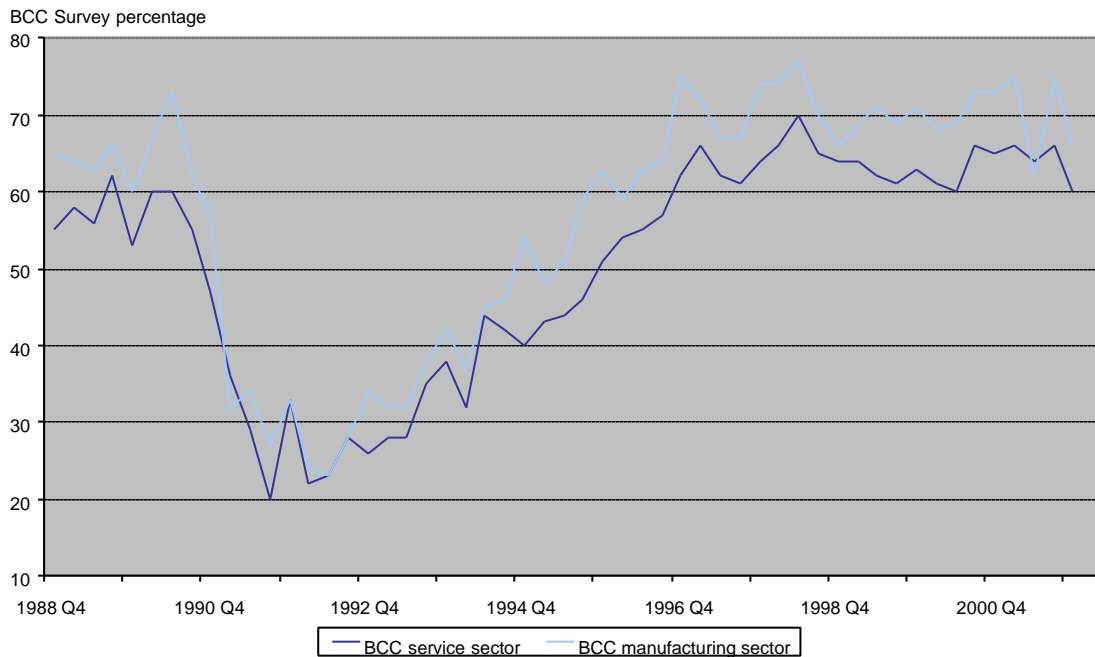
d) Unskilled and semi-skilled labour

Question *BCC7c.* is the main skill shortages measure, with question *BCC7d.* giving information as to the type of skills that are required for the recruitment difficulties reported. The proportion of respondents identifying recruitment difficulties can be used as a measure of skill shortages and the resultant time series can be used to look at the path of skill shortages over time. Figure 6 below shows the BCC survey data for the period 1988

¹² The DfES warns that the survey has increased significantly over time. See Blake *et al* [5].

Q4 to 2001 Q4 for question *BCC7c*, showing the proportion of respondents identifying recruitment difficulties in both the manufacturing and service sectors.

Figure 6
BCC Quarterly Economic Survey; Proportion of Firms Identifying Recruitment Difficulties; UK; 1988 Q4 to 2001 Q4, not seasonally adjusted (NSA)



Source: BCC Quarterly Economic Survey

Using the BCC series as a measure of skill shortages it can be seen that over the period 1988 to 1991 there was a sharp decline in the level of skill shortages. Since then there has been a steady upward trend in skill shortages until around 1997, with skill shortages remaining at about the same level since then. This is the same for both the manufacturing and service sector, with the two series moving together for the whole period, but with manufacturing skill shortages generally slightly higher.

The BCC data gives some indication of the changes in skill shortages over time. The series is however only representative since 1989 and so provides only a limited period of time series data compared to the CBI data. The use of recruitment difficulties as a measure for skill shortages is also questionable, the ESS discussed above makes a distinction between recruitment difficulties (hard-to-fill vacancies) and skill-shortage vacancies, and the surveys show that recruitment difficulties are generally much higher than skill-shortage vacancies. Hence not all recruitment difficulties are due to skill

shortages and so the BCC data used as a measure of skill shortages is overestimating the level of skill shortages¹³.

2.5. Comparisons and Regression Analysis

A comparison of the three surveys above can be somewhat misleading and care has to be taken in doing so. Different methodologies and phraseologies mean that results cannot be compared directly. Table 1 below shows a comparison of the three surveys and includes an appropriate definition of the skill shortage measure being used in each survey.

*Table 1
Comparison of CBI Industrial Trends Survey, BCC Quarterly Economic Survey and the Employer Skill Surveys; 1999 and 2001.*

Survey	Definition of skill shortage measure	1999	2001	2001*
ESS	<i>All vacancies</i>	32	14	27
ESS	<i>Hard-to-fill vacancies</i>	16	8	14
ESS	<i>skill-shortage vacancies</i>	8	4	6
ESS	<i>Internal skill gaps**</i>	20	7	16
CBI	<i>Shortage of skilled labour limiting output</i>	9.5	15.75	-
BCC Services	<i>Recruitment Difficulties</i>	62.5	64	-
BCC Manufacturing	<i>Recruitment Difficulties</i>	70	69.5	-

Source: ESS 1999 and ESS 2001 (IER/IFF); CBI Industrial Trends Survey; BCC Quarterly Economic Survey

Notes: CBI and BCC figures are taken from quarterly data and are averages for the year.

* ESS 2001 with Establishments with 5 or more employees only, this corresponds to the sample used in the ESS 1999.

** Narrow measure, which includes only those establishments where a significant proportion of the workforce was reported as lacking proficiency.

The CBI data is a measure of total skill shortages, whilst the ESS data has two measures of skill shortages, skill-shortage vacancies and internal skill gaps. Comparing the CBI data to the sum of the two ESS measures gives different pictures of skill shortages. Using either of the two 2001 samples for the ESS, skill shortages in 2001 fell compared to 1999, whilst the CBI data indicates an increase in skill shortages. The BCC data can only really be compared to the ESS data for hard-to-fill vacancies in terms of absolute values¹⁴. These two measures of recruitment difficulties also show different pictures, with the ESS

¹³ The BCC data may still provide a good measure of the time path of skill shortages.

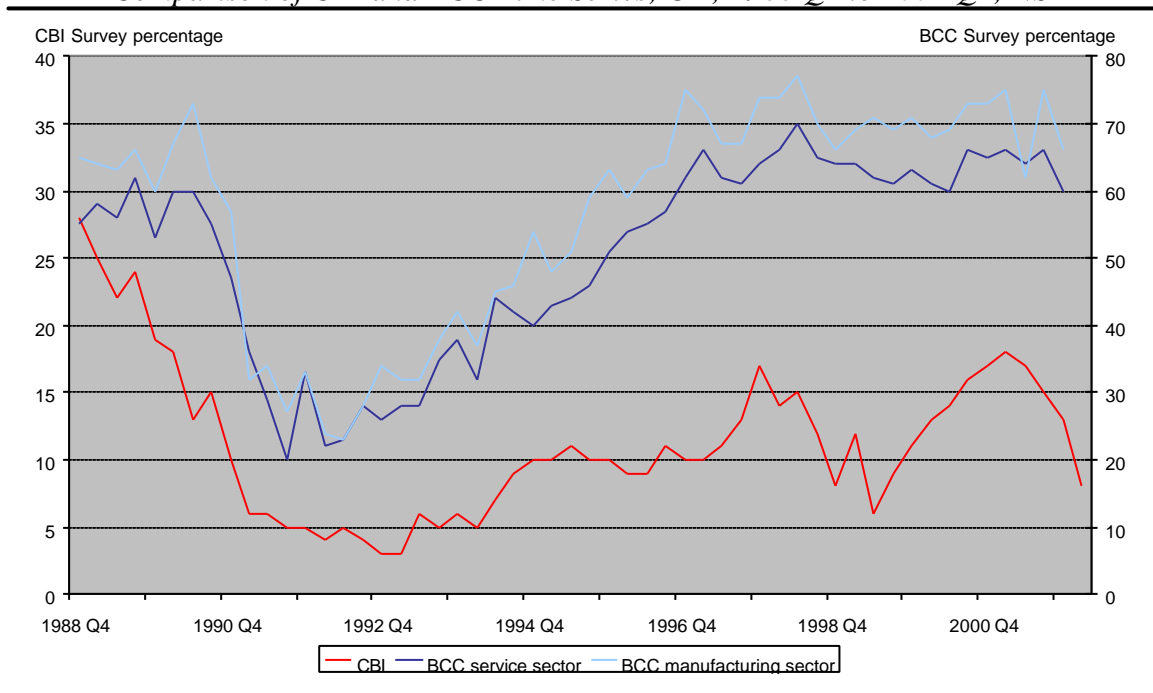
¹⁴ I will compare the trend of the BCC data with that of the CBI data later.

indicating reduced recruitment problems and the BCC indicating increased recruitment problems in the service sector and slightly reduced recruitment problems in the manufacturing sector.

One other problem in comparing the surveys is the nature of the questions. The ESS ask about establishment current situation, the CBI question asks about the next 4 months, so is essentially an estimate of future skill shortages, and the BCC survey asks about the previous 3 months. The ESS data is also a snapshot of a specific point in time, whereas the CBI and BCC are time series data. This leads to difficulties as to which CBI and BCC measures to compare with the ESS data. Using the yearly average of the quarterly data as I have done above may not be appropriate given the nature of the ESS data and the variations in skill shortages that occur over the period of a year. These differences lead to difficulties when comparing the results.

For my purposes I need a time series for skill shortages and so only the CBI or BCC survey data are available. Before deciding on the best series to use it is useful to compare the two time series to compare how they behave against each other. Figure 7 below show the CBI and BCC time series for the period 1988 Q4 to 2002 Q1.

Figure 7
Comparison of CBI and BCC Time Series; UK; 1988 Q4 to 2002 Q1; NSA



Source: CBI Industrial Trends Survey; BCC Quarterly Economic Survey

Figure 7 above shows that the CBI and BCC series exhibit similar behaviour over the period even though their absolute level differ quite dramatically. The difference in absolute level is due to the BCC data having a much wider definition of skill shortages than the CBI. Both series show a decline between 1984 and 1992, followed by an increase until about 1997. Since then the BCC data has been relatively stable with the CBI data less stable, but still fluctuating around its 1997 value. The main difference in the series is that the BCC data indicates that skill shortages in 2001 Q4 are above their 1988 level, whilst the CBI data indicates that skill shortages are below their 1988 level.

For my time series analysis I will be using the CBI time series as opposed to the BCC time series for a number of reasons. Firstly the CBI time series is a much longer series than the BCC series. The BCC series is only representative of the UK since 1989; this would limit my sample significantly. Given the finite sample properties of two-stage least squares a larger sample is preferable.

The CBI series is also closer to the definition of skill shortages used by the DfES and in the Employer Skill Surveys. The CBI series has tended to be consistent with the *Skill Needs in Britain* surveys¹⁵ and is generally regarded as representative of the UK. Although the CBI survey data does not appear consistent with the ESS data (see table 1 above) the difficulties in making comparison should be considered. The CBI skill shortage measure is of the same magnitude as the ESS data, unlike the BCC data, and so although showing a slightly different picture between 1999 and 2001 is much more consistent with the ESS.

3. The Model

3.1. The structural model

The model used to estimate the effect of skill shortages on unemployment and real wage growth is based on the structural approach used by Manning (1993), Layard and Nickel (1985) and discussed by Bean (1994). The model uses *a priori* economic information

¹⁵ See [12].

and is most closely based on a Phillips curve type relationship. The model specification does however differ from the conventional approach in order to avoid the wage equation being unidentified. In the conventional approach no variable is excluded from the wage equation and so it is unidentified¹⁶. The model is estimated of the form:

$$\Delta(W - P)_t = \mathbf{a}_0 + \mathbf{a}_1 UN_t + \mathbf{a}_2 X_{1t} + u_{1t}$$

$$UN_t = \mathbf{b}_0 + \mathbf{b}_1 \Delta(W - P)_t + \mathbf{b}_2 X_{2t} + u_{2t}$$

Where, $\Delta(W - P)$ is the rate of change of real wages, UN is the unemployment rate, X_1 is a vector containing factors that affect real wage growth, X_2 is a vector containing factors that affect unemployment and u are stochastic disturbances.

The first equation is generally interpreted as a wage setting equation and the second equation a labour demand curve or pricing equation. The conventional wage setting equation includes variables such as union power and the replacement ratio. I did not want to use data such as this due to limited availability and concentrated more on key indicators of the macro economy.

One thing to notice about the equations above is that they do not contain a productivity variable. In the theoretical foundations of the Phillips curve productivity does not play an important role in structural wage equations, although it is important for the long run growth of wages. As Manning notes, “this does not mean that productivity growth does not cause the growth in real wages over time. But, suppose that the labour market was competitive and that labour supply was totally inelastic. Then productivity growth leads to real wage growth, but it would be strange to argue from this that one should include productivity directly in the estimate of the structural labour supply curve”. Here we are interested in the variability of real wage growth not the long-run growth.

¹⁶ The Issue of identification has become central to the wage determination literature. See Manning (1993) and Bean (1994).

3.2. Final Specification

The final specification of the model was determined after testing various alternate specifications and by removal of superfluous arguments in a stepwise fashion. The alternate specifications that were tried did not perform as well and produced less robust results. The final specification is as follows:

$$WGrowth_t = \mathbf{a}_0 + \mathbf{a}_1 UN_t + \mathbf{a}_2 WGrowth_{t-1} + \mathbf{a}_3 WGrowth_{t-4} + \mathbf{a}_4 SkillShortage_t + \mathbf{a}_5 SkillShortage_{t-1} + \mathbf{a}_6 Stock / GDP_t + \mathbf{a}_7 GDPGrowth_t + \mathbf{a}_8 GDPGrowth_{t-1} + \mathbf{a}_9 GFCF_{t-1} + u_{1t}$$

$$UN_t = \mathbf{b}_0 + \mathbf{b}_1 WGrowth_t + \mathbf{b}_2 UN_{t-1} + \mathbf{b}_3 UN_{t-4} + \mathbf{b}_4 GDPGrowth_t + \mathbf{b}_5 r_{t-4} + u_{2t}$$

Where *WGrowth* is real wage growth, *UN* is the unemployment rate, *SkillShortage* is the CBI's measure of skill shortages, *Stock/GDP* is the stock (inventories) to Gross Domestic Product ratio, *GDPGrowth* is the quarter on quarter yearly growth rate, *GFCF* is gross fixed capital formation (millions), and *r* is the short-term interest rate. u_{1t} and u_{2t} are stochastic disturbance terms.

3.3. Economic Rationale for Variables

The *GDPGrowth* variable is included to capture the general state of the economy and is expected to have a positive effect on real wage growth and a negative effect on unemployment. The *GFCF* and *Stock/GDP* variables are included to pick up the importance of labour (and therefore influence wages) in firms output decisions. Prior beliefs on the direction of these variables are less certain. An increased stock to GDP ratio could give firms more wage bargaining power and so reduce wage growth but could also result in increased wage growth due to the labour requirements of increasing inventories.

The appearance of the interest rate in the unemployment equation has no theoretical foundation but has been found by many authors, including Manning [27], to be an important determinant of unemployment in empirical studies. The interest rate variable is expected to have a positive effect on unemployment.

The skill shortages variable is included for obvious reasons, as it is the effect of which we are ultimately trying to measure. We would expect the variable to have a positive effect on real wage growth, with increased skill shortages implying scarcer labour and hence pushing up the price of that labour. We would also expect an increase in skill shortages to be associated with reduced unemployment.

Variables such as average hours and union density, which are commonly found in the wage setting equation, are not included in the final specification due to limited data availability. Such variables have commonly been found to be important determinants of real wage growth but inclusion would have limited my estimation sample.

Lags of variables are generally based on testing alternative specifications, except for lags of the endogenous variables, the aim of which is to pick up the cyclical and the random walk features of both real wage growth and unemployment.

4. Variables

4.1. Data Sources

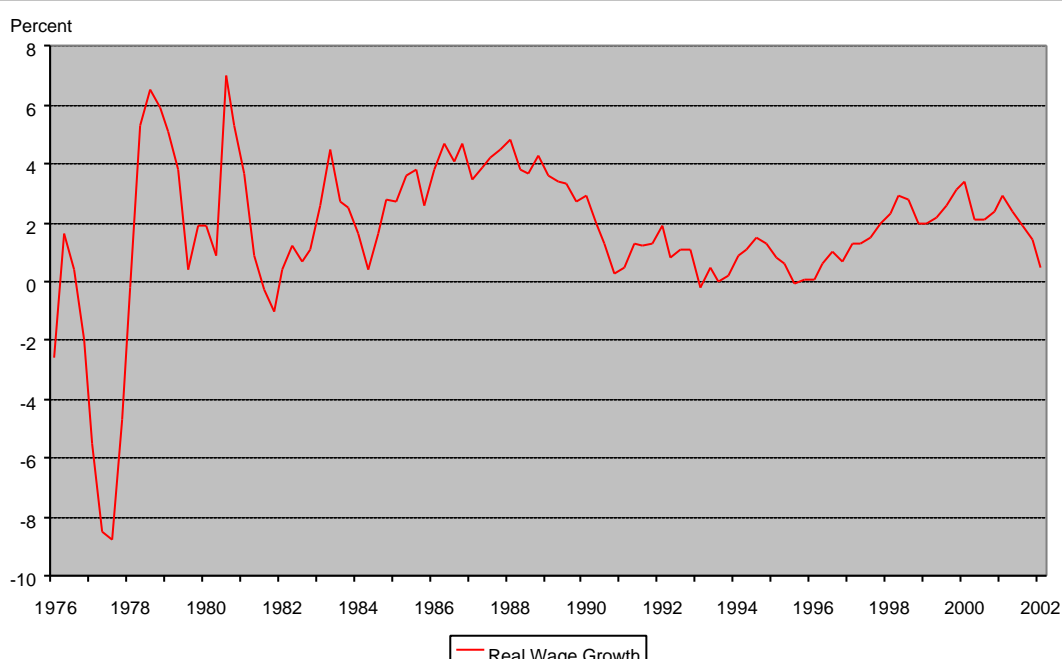
All of the variables, except for the CBI skill shortages variable described above, were collected from StatBase on the Office for National Statistic (ONS) Website. Quarterly data from 1976 Q1 to 2002 Q1 was collected giving a total sample of 105 observations for each variable¹⁷ with the exception of the *Stock/GDP* variable for which only data back to 1976 Q1 was available. Other variables not included in the equation above were also collected, including average hours, the amount of Government Supported Training programmes and union density, but these series were only available from 1992 Q2 in quarterly format and so are too short for a reasonable regression analysis. The CBI skill shortage variable was made available by the CBI to the ONS and was obtained via WinCSDB.

¹⁷ Detailed descriptions of the variables as they appear in StatBase are available from the author upon request. The CBI and the unemployment series were collected back until 1971 for comparison, this was not possible with other variables.

4.2. The Data

A brief description of the variables used is useful before proceeding to my results. Figure 8 below shows real wage growth for the period 1976 to 2002. The most notable feature is the greater quarter-to-quarter variation in yearly growth rates prior to the mid 1980's. Since 1986 real wage growth has remained within a 5-percentage point band, where previously it fluctuated by as much as 16-percentage points.

Figure 8
Real Wage Growth; 1976 to 2002

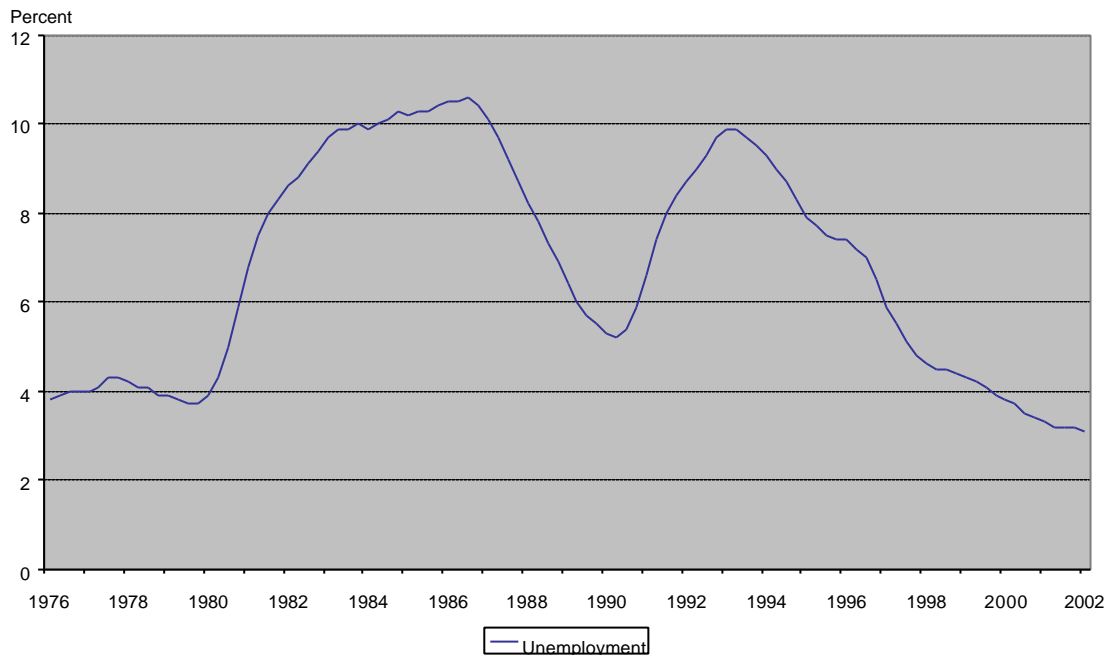


Source: ONS StatBase

Figure 9 below shows unemployment for the period 1976 to 2002¹⁸. This is a familiar graph and needs no discussion but is included as it is an endogenous variable in the model described above. The model will attempt to explain the movements in unemployment that can be seen below.

¹⁸ Claimant Count data is used instead of ILO unemployment because ILO unemployment data is not available on a quarterly basis before 1992.

Figure 9
Unemployment; UK; 1976 to 2002



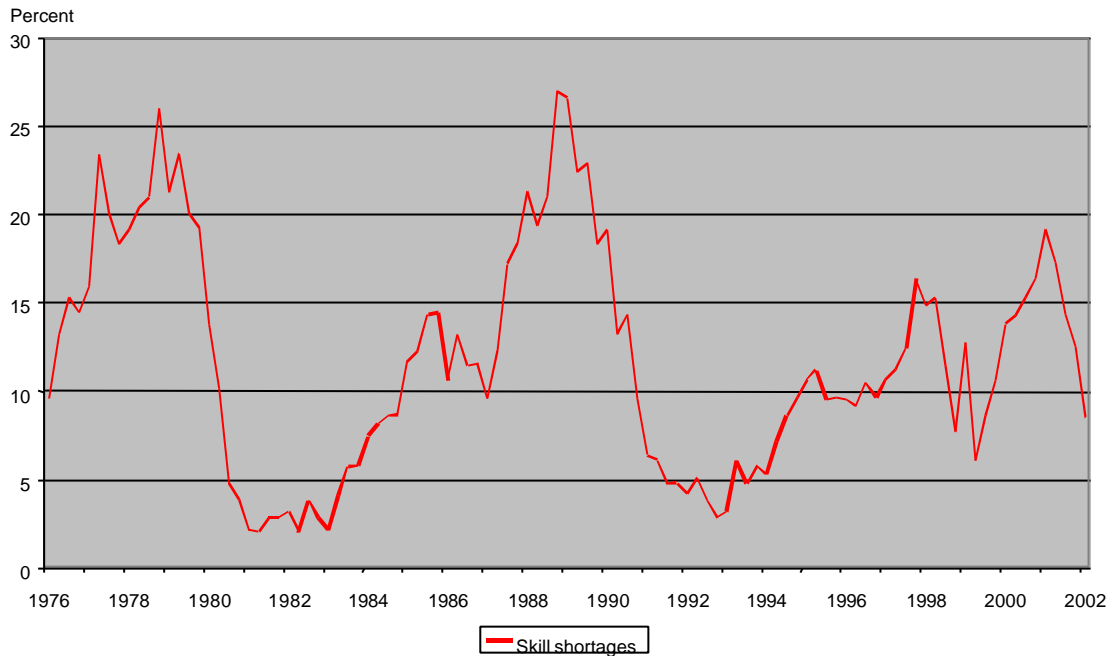
Source: ONS StatBase

Figure 10 below shows the CBI skill shortages series over the period 1976 to 2002. This series is the same as that shown above in Figure 5 but without the other factors that limit output and is also seasonally adjusted¹⁹. The graph shows that over the period the level of skill shortages has fluctuated a lot, with a range of 25-percentage points²⁰. There are also two obvious peaks in the skill shortages series around 1979 and 1990 (and perhaps one in 2001) and the series shows some cyclical tendencies. The DfES argue that the cyclical nature of skill deficiencies is not simply a consequence of the business cycle but also influence it. Blake *et al* [5] conclude that, “Skill shortages do not simply reflect recruitment difficulties associated with the stage of the cycle” and so, the variations in skill shortages could have important implications for real wage growth and unemployment and are not simply a cyclical phenomenon. The focus of this paper therefore, is to assess what affect movements in the level of skill shortages have on unemployment and real wage growth.

¹⁹ The CBI data was seasonally adjusted to correspond with all the other series to be used in my regression analysis, all the other series are seasonally adjusted.

²⁰ See tables 2 and 3 for descriptive statistics.

Figure 10
CBI Skill Shortages; 1976 to 2002, seasonally adjusted



Source: CBI Industrial Trends Survey

Descriptive statistics for all of the variables over the sample period 1976 Q1 to 2002 Q1 are shown in table 2 below²¹. The table is split into endogenous and exogenous variables to aid interpretation. From the table it can be seen that over the sample period there is much more variation in real wage growth than in unemployment, with ranges of 15.8 and 7.5 respectively. The standard deviations are however, both around 2.5. Given that I have estimated my model over a smaller period than my sample, I have also reported descriptive statistics for the reduced sample of 1986 Q1 to 2002 Q1, these are shown in table 3 below.

²¹ Graphs of all the variables are not included due to limited space. Plots of all the variables were however produced and raised issues such as nonstationarity and cointegration, which will be discussed later.

Table 2
Descriptive Statistics; 1976 Q1 to 2002 Q1

	Variables	Obs	Mean	Median	Std. Dev.	Max	Min	Range
<i>Endogenous</i>	<i>Wgrowth</i>	105	1.76	1.90	2.46	7.00	-8.80	15.80
	<i>UN</i>	105	6.78	6.90	2.49	10.60	3.10	7.50
<i>Exogenous</i>	<i>SkillShortage</i>	105	11.79	11.22	6.36	27.04	2.04	25.00
	<i>GDPGrowth</i>	105	0.58	0.60	0.83	4.20	-2.40	6.60
	<i>StockGDP</i>	65	105.17	102.00	5.25	117.00	100.00	17.00
	<i>GFCF</i>	105	26.82	27.12	6.66	40.79	17.63	23.16
	<i>R</i>	105	9.34	9.38	3.46	16.97	3.87	13.10

Source: CBI Industrial Trends Survey; ONS StatBase

Table 3
Descriptive Statistics; 1986 Q1 to 2002 Q1

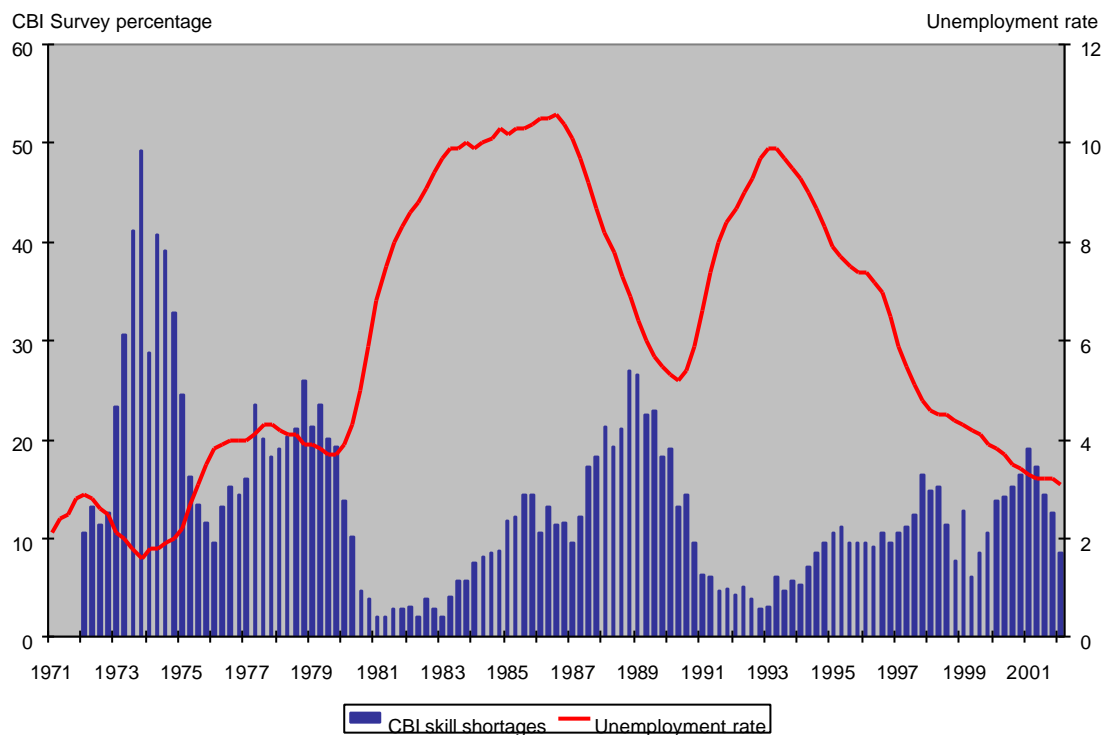
	Variables	Obs	Mean	Median	Std. Dev.	Max	Min	Range
<i>Endogenous</i>	<i>Wgrowth</i>	65	2.04	2.00	1.39	4.80	-0.20	5.00
	<i>UN</i>	65	6.79	7.00	2.33	10.60	3.10	7.50
<i>Exogenous</i>	<i>SkillShortage</i>	65	11.98	11.22	5.69	27.04	2.90	24.14
	<i>GDPGrowth</i>	65	0.64	0.60	0.55	2.10	-1.20	3.30
	<i>StockGDP</i>	65	105.17	102.00	5.25	117.00	100.00	17.00
	<i>GFCF</i>	65	30.99	29.57	4.97	40.79	21.96	18.83
	<i>R</i>	65	8.11	6.73	3.21	15.14	3.87	11.27

Source: CBI Industrial Trends Survey; ONS StatBase

In this reduced sample the range of the unemployment series is greater than that of the real wage growth series, 7.5 and 5 respectively, and the standard deviation of unemployment is larger at 2.33 compared to 1.39. These differences between the two samples are due to the excess volatility of the real wage growth series prior to 1986, with the estimation sample (1986 Q1 to 2002 Q1) excluding this period.

Direct comparison of the real wage growth series and the unemployment series with the skill shortage series give some initial idea as to the likely effect of skill shortages on real wage growth and unemployment. Figure 11 below shows the UK unemployment rate against the CBI skill shortages series for the period 1971 to 2002.

Figure 11
CBI Skill Shortages and Unemployment; 1971 to 2002, seasonally adjusted



Source: CBI Industrial Trends Survey; ONS StatBase

The graph above shows that there is a strong inverse relationship between skill shortages and the unemployment rate, especially after 1980. This relationship is disrupted slightly around 1998 when skill shortages decreased and so did unemployment. The DfES argue that “skills deficiencies are simply not a cyclical phenomenon”²² but actually influence the business cycle. The graph above suggests that we would expect skill shortages to have a negative effect on unemployment.

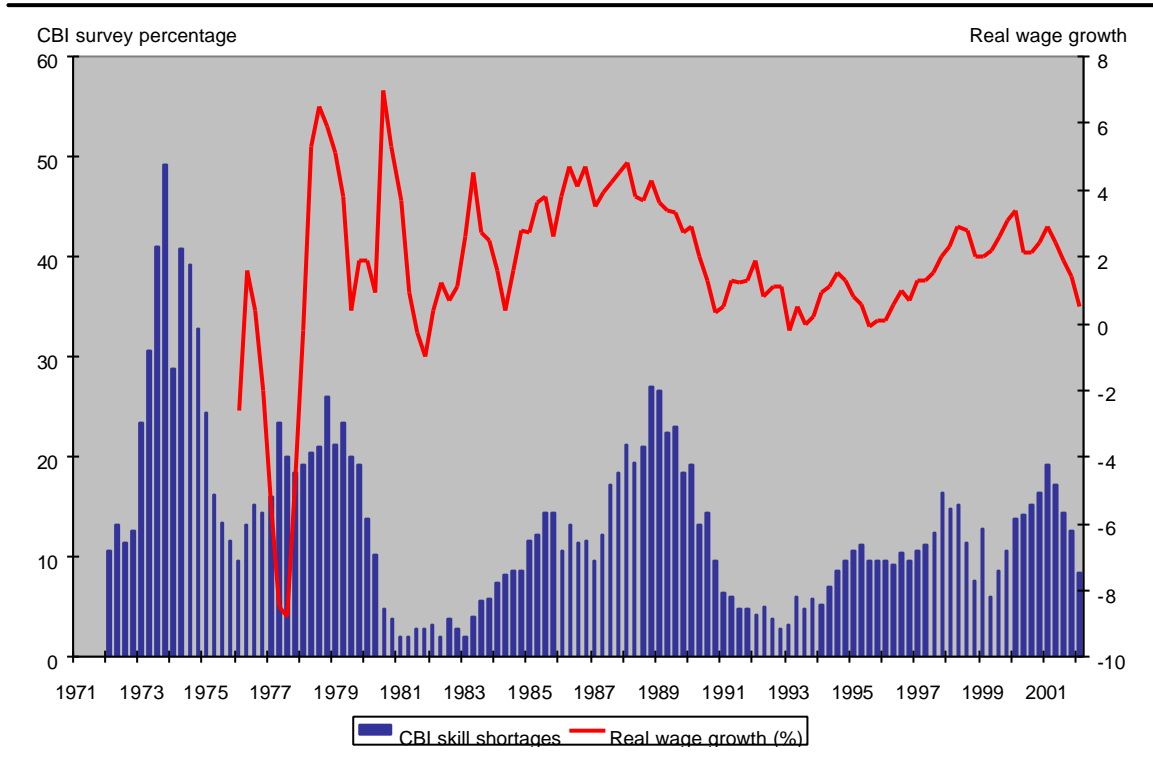
A large proportion of firms in the Employer Skill Surveys highlighted increased salaries as a solution to skill shortages²³. This indicates that a possible response to skill shortages and/or recruitment difficulties could be increased salaries and hence increased real wage growth. We might therefore expect real wage growth to increase during periods of

²² See Bosworth *et al* [7].

²³ Increase salaries was the most common solution to skill shortages adopted with about 50% of respondents, in both the ESS 1999 and ESS 2001, adopting increased salaries as a solution to skill shortages.

increased skill shortages. Figure 12 below shows real wage growth plotted against skill shortages.

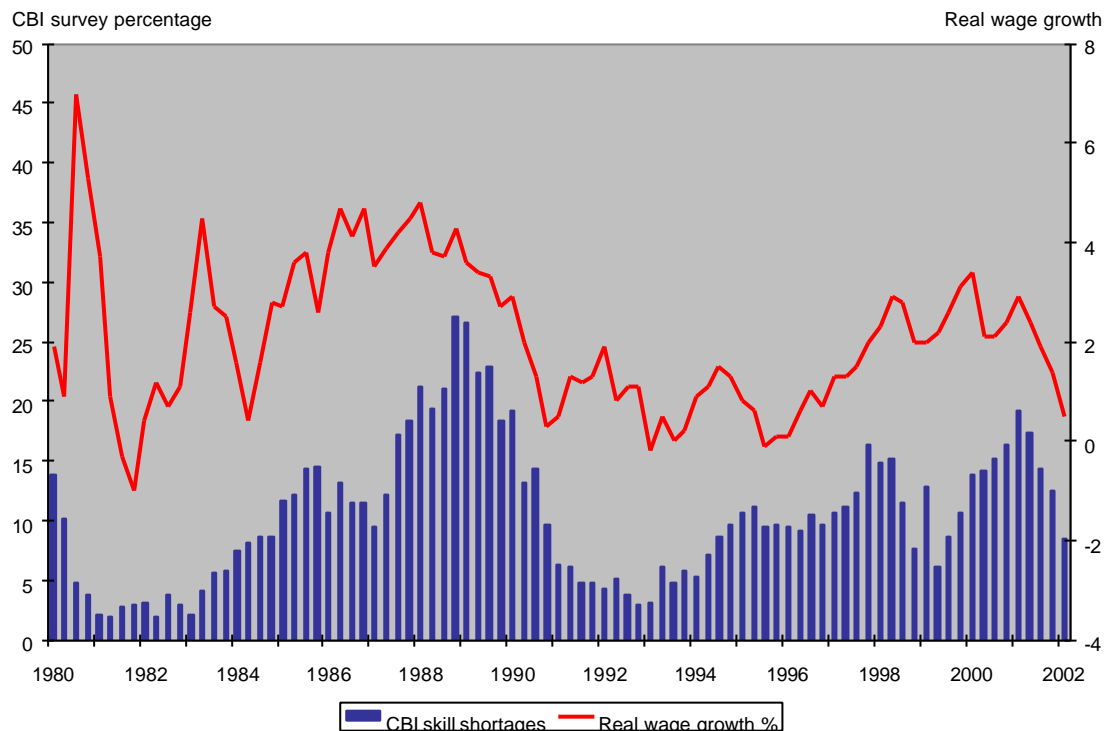
*Figure 12
CBI Skill Shortages and Real Wage Growth; 1971 to 2002, seasonally adjusted*



Source: CBI Industrial Trends Survey; ONS StatBase

The graph shows that there is a strong positive relationship between real wage growth and skill shortages after 1980. Before 1980 this relationship breaks down with real wage growth being much more volatile than post 1980. To examine the relationship between real wage growth and skill shortages more closely I replotted the data from 1980 onwards. Figure 13 below shows real wage growth and skill shortages for the period 1980 to 2002.

Figure 13
CBI Skill Shortages and Real Wage Growth; 1980 to 2002; seasonally adjusted



Source: CBI Industrial Trends Survey; ONS StatBase

The graph shows a strong positive relationship between skill shortages and real wage growth, especially after 1984/85. The data thus appears to support the idea that increased skill shortages will lead to an increase in real wage growth.

5. Estimation and Sample Period

Both of the equations in the above system are overidentified²⁴ and so were estimated by a two-stage least squares (2SLS) procedure. Given that the equations are overidentified 2SLS gives consistent estimates of the equation coefficients. Before this was done a version of the Hausman Specification Error Test was conducted to test for simultaneity between unemployment and real wage growth. This test showed that simultaneity exists between unemployment and real wage growth, and so a system of simultaneous equations is needed to estimate a model. The presence of simultaneity also ensures that 2SLS will

²⁴ See chapter 19 of Gujarati, D. N. *Basic Econometrics*. Third Edition.

give estimators that are consistent and efficient. Without such simultaneity 2SLS will yield estimators that are consistent but not efficient.

My sample period is from 1976 Q1 to 2002 Q1, although my equations are estimated over the period 1986Q1 to 2002 Q1, due to the inclusion of the *stock/GDP* variable in the wage equation, for which, data is not available for the entire sample period²⁵. The rest of the sample period can however, be used to produce a backward forecast for unemployment to see how well the model predicts past variations.

6. Basic Results

6.1. 2SLS Estimates

The equations for the period 1986 Q1 to 2002 Q1 were estimated by 2SLS as follows,

$$WGrowth_t = -29.77 + 0.175UN_t + 0.587WGrowth_{t-1} - 0.295WGrowth_{t-4} + 0.093SkillShortage_t - 0.080SkillShortage_{t-1} + 0.216Stock / GDP_t + 0.643GDPGrowth_t + 0.297GDPGrowth_{t-1} + 0.214GFCF_{t-1}$$

$$UN_t = 0.0646 - 0.034WGrowth_t + 1.180UN_{t-1} - 0.205UN_{t-4} - 0.133GDPGrowth_t + 0.0255r_{t-4}$$

6.2. Real Wage Growth Equation

Table 4 below shows a summary of the results for the 2SLS estimation of the real wage growth equation.

²⁵ This gives a sample of 65 observations, which is generally considered enough for a 2SLS estimation procedure. The presence of a possible structural break in the real wage growth equation also justifies limiting the original sample of 105 observations. This is discussed later.

Table 4
Summary of Real Wage Growth Equation; 1986 to 2002; 2SLS

Variable	Coefficient	s.e	t-value	Sig
<i>Constant</i>	-29.765	5.330	-5.585	0.0000
<i>UN</i>	0.175	0.100	1.745	0.0866
<i>WGrowth_1</i>	0.587	0.080	7.306	0.0000
<i>WGrowth_2</i>	-0.295	0.084	-3.513	0.0009
<i>SkillShortage</i>	0.093	0.023	4.070	0.0002
<i>SkillShortage_1</i>	-0.080	0.023	-3.530	0.0008
<i>Stock/GDP</i>	0.216	0.034	6.328	0.0000
<i>GDPGrowth</i>	0.643	0.121	5.337	0.0000
<i>GDPGrowth_1</i>	0.297	0.141	2.112	0.0392
<i>GECF</i>	0.214	0.056	3.847	0.0003

	Multiple R	R Square	Adjusted R Square	s.e
<i>Equation 1</i>	0.965	0.932	0.921	0.390

	DF	Sum of Squares	Mean Square	F
<i>Regression</i>	9	114.491	12.721	83.440
<i>Residual</i>	55	8.385	0.152	

Table 4 above shows that all the variables are statistically significant at the 1% level, except for one quarter lagged GDP growth, which is significant at 5%, and unemployment, which is significant at the 10% level, with a p-value of 8.7%²⁶. The variables explain a large proportion of the variation in real wage growth, with an adjusted R squared of 0.932. This is quite high considering the volatility of real wage growth over the sample period. The regression is highly statistically significant, with the hypothesis that all coefficients are jointly zero rejected at all significance levels.

The skill shortage variable was statistically significant in nearly all of the alternate specifications that I tried and always had a positive coefficient. Lagged skill shortages was also significant in various specifications and always had a negative coefficient. The coefficient on lagged skill shortages was always less in absolute value than the coefficient

²⁶ It should be noted here that the reported standard errors are not those from the second stage regression of the 2SLS procedure but are corrected standard errors.

on skill shortages. This indicates that the initial effect of an increase in skill shortages is reversed slightly in the next quarter. Other lags of the skill shortages variable were never significant.

GDP growth had the expected sign in the real wage growth equation but the unemployment coefficient was always negative, this is the opposite of what would be expected. The reason for the unemployment variable having a negative coefficient is mostly likely to do with the fact that we are using real wage growth. High levels of unemployment tend to be accompanied by low price level growth and so, given that nominal wages are fixed for some workers high unemployment can result in real wage growth²⁷.

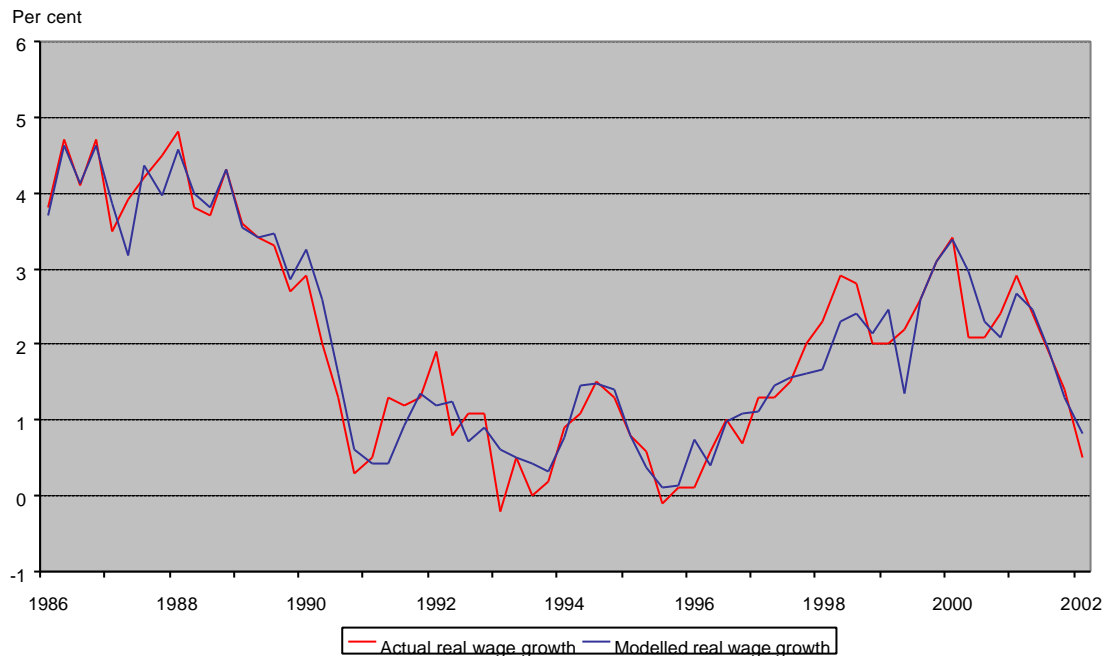
Note the significance of the variable *Stock/GDP* in the above equation. The statistical significance of this variable in the specifications I tried justified reducing the estimation sample in order to include it. Without this variable the wage growth equation was less robust and had much less explanatory power. Although there is some economic justification for the *Stock/GDP* variable being important its significance in the equation is surprising.

I also tested a linear wage equation for structural break in the early 1980's, before which real wage growth can be seen to be much more volatile. I could not reject that there was a structural break between 1980 and 1982 and so felt justified in reducing my estimation sample to start in 1986 Q1. A wage equation over my full sample had considerably less explanatory power and was less robust.

Figure 14 below shows the predicted values obtained from the model against actual real wage growth.

²⁷ This problem emerges from the fact that a complete structural model should consist of a wage, a price, and an unemployment equation.

Figure 14
Real Wage Growth and Modelled Real Wage Growth; 1986 to 2002



The graph above shows that the model performs well considering the volatility of real wage growth. Real wage growth tends to be difficult to model given that it consists of two endogenous variables that are related to each other (nominal wage growth and inflation). The graph above shows that the model performs well and predicts real wage growth very close to actual real wage growth. This can be seen further in Figure 15 below.

Figure 15
Residuals: Real Wage Growth Equation

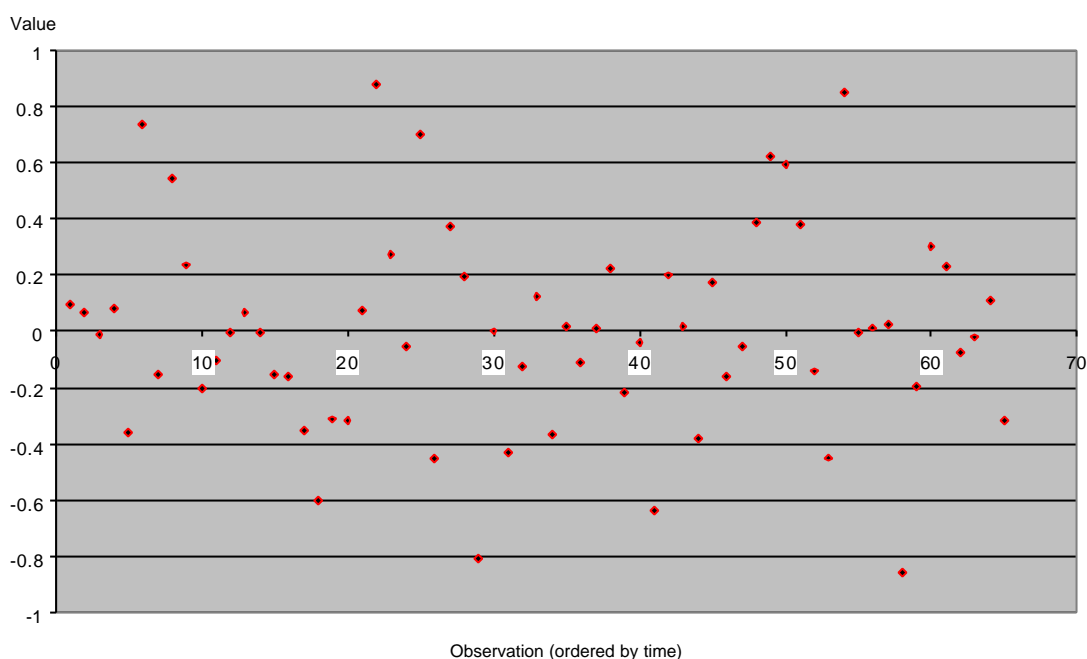


Figure 15 above shows a scatter plot of the residuals for the real wage growth equation. The scatter plot shows that by visual observation the residuals exhibit no autocorrelation and that there are not any obvious outliers. The residuals also fall within a 1-point band either side of zero.

6.3. Unemployment Equation

Table 5 below shows a summary of the results for the unemployment equation. The table show that real wage growth is statistically significant at the 5% level, whilst all other variables, except for the constant, which has a p-value of 0.36, are statistically significant at the 1% level. The model has very high explanatory power with an adjusted R squared of 0.996. It also has a very high F-value of some 3558.760, which means that the regression is highly statistically significant, with the hypothesis that all coefficients are jointly zero rejected at all significance levels. . The residual sum of squares is much lower than that for the wage equation at 1.144. This is as expected given that unemployment is a much less volatile series than real wage growth.

Table 5
Summary of Unemployment Equation; 1986 to 2002; 2SLS

Variable	Coefficient	s.e	t-value	Sig
<i>Constant</i>	0.065	0.070097	0.922	0.3604
<i>WGrowth</i>	-0.034	0.017	-2.051	0.0448
<i>U_1</i>	1.180	0.027	44.415	0.0000
<i>U_4</i>	-0.205	0.027	-7.618	0.0000
<i>GDPGrowth</i>	-0.133	0.042	-3.169	0.0024
<i>r_4</i>	0.026	0.007	3.585	0.0007

	Multiple R	R Square	Adjusted R Square	s.e
<i>Equation 2</i>	0.998	0.997	0.996	0.139

	DF	Sum of Squares	Mean Square	F
<i>Regression</i>	5	344.906	68.981	3558.760
<i>Residual</i>	59	1.144	0.019	

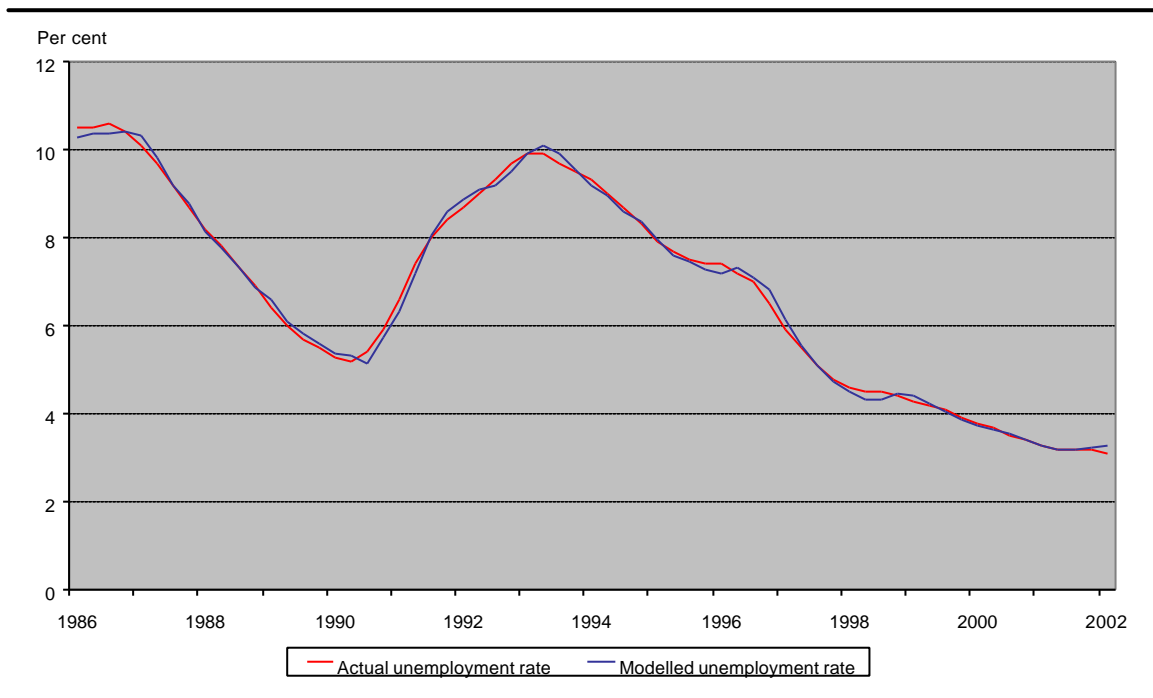
The skill shortage variable was never statistically significant in any of the alternate specifications that I tried, but did always have a negative sign as was expected. This corresponds with DfES research that concludes that, although there is a negative relationship between skill shortages and unemployment “in statistical terms, this relationship is relatively weak”²⁸. The system of equations above ensures that changes in skill shortages do affect unemployment but this is through their effect on real wage growth. The exclusion of skill shortages from the unemployment equation is therefore supported by both statistical and economic arguments.

The inclusion of the interest rate variable is not generally supported by economic theory as entering into unemployment equations, but as other authors have found, this variable was statistically significant in all model specifications. For this reason it has remained, even though it has no strong theoretical foundation. The sign of the coefficient is as would be expected.

²⁸ See [13].

The unemployment equation was estimated over the period 1986 Q1 to 2002 Q1 but predicted values can be produced for the whole sample period 1976Q1 to 2002 Q1, as the unemployment equation does not include the *Stock/GDP* variable. The two graphs below in figures 16 and 17 show that the model has better predicted power over 1986 to 2002 than over the entire period. This could be due to the structural break discussed earlier but is most likely due to the model being estimated over the later period.

Figure 16
Unemployment Rate and Modelled Unemployment Rate; 1986 to 2002



In Figure 17 below the pre 1986 predicted values are essentially a backward forecast, made using the recorded values of the variables in the unemployment equation to predict the level of unemployment. This can then be compared to the actual level. This backward forecast performs very well over this large period picking up the main trend in the unemployment rate. The inclusion of lagged unemployment in the unemployment equation does however mean that the ability to produce a backwards forecast should not be overstated, as the lagged value of unemployment will be doing a lot of the work when producing this forecast.

Figure 17
Unemployment Rate and Modelled/Forecast Unemployment Rate; 1977 to 2002

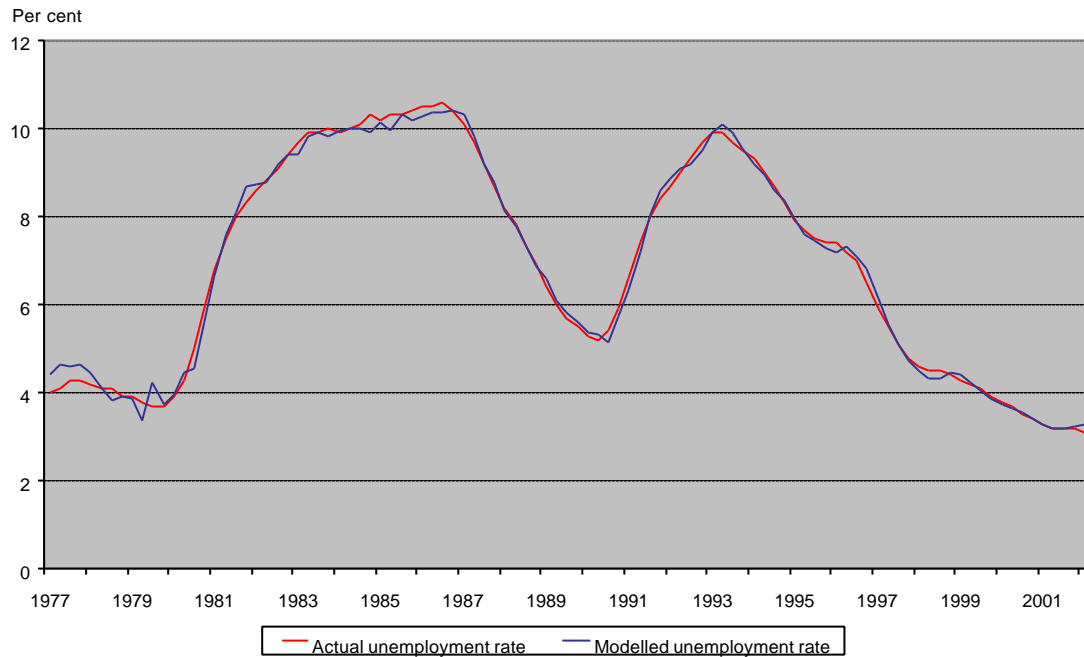
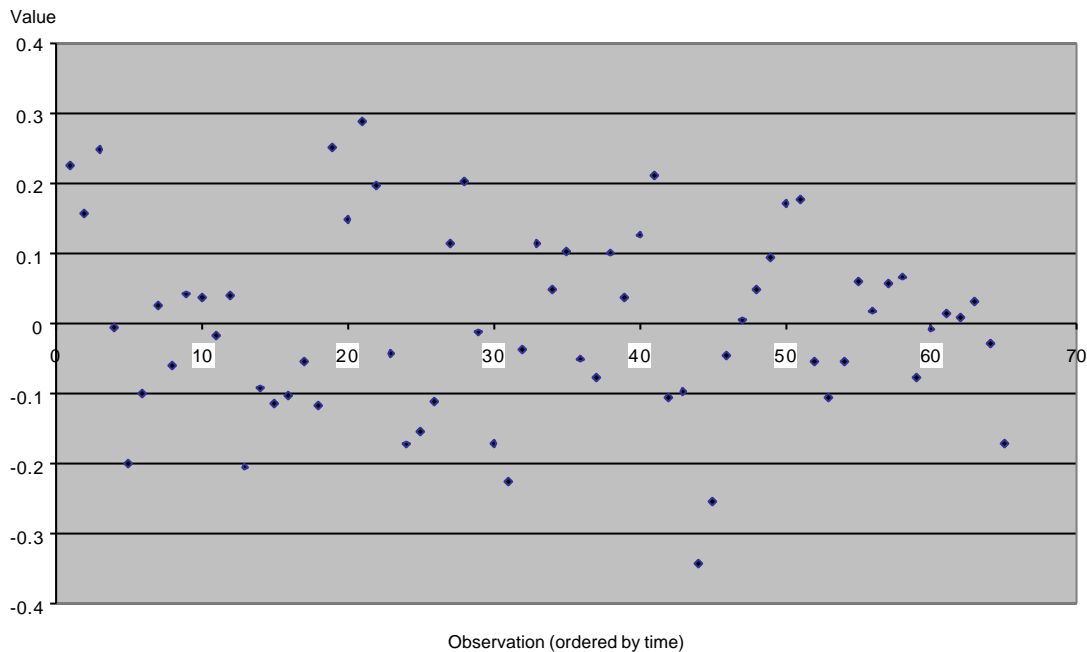


Figure 18 below shows a scatter plot of the residuals for the unemployment equation and shows that the residuals for the estimated equation show no obvious autocorrelation or outliers. The graph also shows that the unemployment equation performs better than the real wage growth equations with the residuals within a 0.4-point band either side of zero. The better performance of the unemployment equation is also outlined by the residual sum of squares for the equations. The residual sum of squares for the unemployment equation is only 1.144 compared to a residual sum of squares for the real wage growth equation of 8.385. This is not surprising given the variation of real wage growth.

Figure 18
Residuals: Unemployment Equation; 1986 to 2002



A scatter plot of the residuals over the full sample period, including the backwards forecast shows, as does figure 17 above, that the model performs better over the estimation period than over the forecast period.

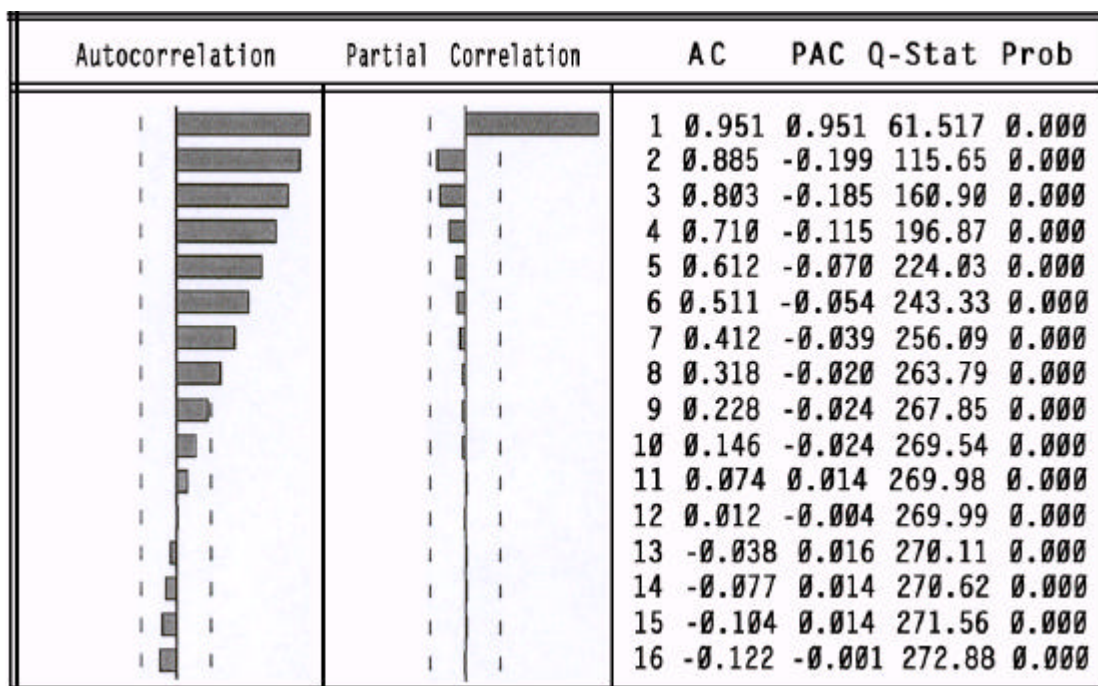
7. Model Evaluation and Diagnostics

One of the problems that emerge when looking at time series data is the implication of nonstationarity and cointegration. Casual observation of the unemployment series, in figure 9 above, suggests that the series may be nonstationary. To test the unemployment time series for nonstationarity an autocorrelation function (ACF) was produced, this is shown below in figure 19.

Figure 19 shows the correlogram for up to 16 lags (4 years). The main feature of the correlogram is that it starts of at a very high value of 0.951 and tapers of gradually over further lags. At lag 8 (2 years) the autocorrelation coefficient is still 0.318, implying that there is some correlation between unemployment levels two years apart. The correlogram is therefore indicative that the time series is nonstationary. Figure 8 above also shows that all the coefficients up to lag 8 are individually statistically significance (statistically

different from zero in a 5% two-sided hypothesis test). The Ljung-Box Q-statistics are also highly significant with p-values of practically zero for all lags.

Figure 19
Unemployment Autocorrelation and Partial Correlation Function; 1986 to 2002



An Augmented Dickey-Fuller (ADF) unit root test on unemployment also indicated that the unemployment series was nonstationary. The ADF test statistic was -2.001254 with the MacKinnon critical values for rejection of the hypothesis of a unit root of -3.5328 at the 1% level and -2.5903 at the 10% level. The absolute value of the ADF test statistic is therefore less than the MacKinnon absolute critical value and the hypothesis of stationary is rejected²⁹.

We can therefore conclude that the unemployment time series is nonstationary. In modelling time series nonstationarity has to be generally considered but as Hsiao [23] notes, “in a structural equation approach what one needs worry about are the classical issues of identification and estimation, non nonstationarity and cointegration”. Given that I have adopted a structural approach to my model the nonstationarity of the unemployment

²⁹ These results are from a test equation with 2 lagged differences and a constant (intercept). Test equations with other orders of lagged differences still rejected stationarity.

series is not an issue³⁰, all that needs to be considered are the issues of identification and simultaneity bias³¹.

Table 6 below shows the diagnostic results for the estimated system above. The first 8 lines show the diagnostic test for the separate equations, whilst the following three lines show the tests for the whole system. The single equation tests consist of an error autocorrelation test, a normality test, a heteroscedasticity test, and an autoregressive conditional heteroscedasticity test (ARCH). The system tests are then vector tests of the same type, excluding the ARCH test. A Vector Portmanteau test was also reported but is only a valid test in a VAR (Vector Autoregression).

Table 6
Diagnostic Results for 2SLS Estimation

U	:AR 1- 2 F(2, 51) =	19.812	[0.0000] **
Wgrowth	:AR 1- 2 F(2, 51) =	1.0557	[0.3554]
U	:Normality Chi^2(2)=	0.026099	[0.9870]
Wgrowth	:Normality Chi^2(2)=	1.4692	[0.4797]
U	:ARCH 1 F(1, 51) =	2.5196	[0.1186]
Wgrowth	:ARCH 1 F(1, 51) =	0.17257	[0.6796]
U	:Xi^2 F(22, 30) =	1.4446	[0.1725]
Wgrowth	:Xi^2 F(22, 30) =	0.60327	[0.8884]
<hr/>			
Vector	AR 1-2 F(8,104) =	2.9736	[0.0049] **
Vector	normality Chi^2(4) =	1.9347	[0.7478]
Vector	Xi^2 F(66, 96) =	1.0376	[0.4297]

As can be seen above the model performs well in all but the error autocorrelation test for the unemployment equation and the vector autocorrelation test. The nonstationarity of the unemployment series could be causing the model to fail this diagnostic test, even so, it is possible to handle the complication of the error term being autocorrelated by using an alternative estimation technique to 2SLS. Using Zellner's seemingly unrelated regressions (SURE) estimation technique to estimate the coefficients in my system of equations the problem of autocorrelated errors can be resolved.

³⁰ I also estimated an equation similar to my model with the second difference of unemployment, which is stationary, as an endogenous variable instead of unemployment, the results were very similar.

³¹ See section 5.

8. SURE Regression Estimates

Table 7 below present results for the real wage growth equation from the SURE estimates of the simultaneous system above. It can easily be seen that the results differ only very slightly to those of the 2SLS estimation show above in table 4. The coefficients are very close to those of the 2SLS estimations, but the SURE estimates are more efficient, with lower standard errors and hence higher t-statistics.

Table 7
Summary of Real Wage Growth Equation; 1986 to 2002; SURE

Variable	Coefficient	s.e	t-value	Sig
<i>Constant</i>	-29.725	4.787	-6.210	0.0000
<i>UN</i>	0.193	0.089	2.178	0.0315
<i>WGrowth_1</i>	0.596	0.073	8.159	0.0000
<i>WGrowth_2</i>	-0.299	0.076	-3.926	0.0001
<i>SkillShortage</i>	0.095	0.021	4.584	0.0000
<i>SkillShortage_1</i>	-0.079	0.021	-3.819	0.0002
<i>Stock/GDP</i>	0.212	0.031	6.869	0.0000
<i>GDPGrowth</i>	0.629	0.111	5.690	0.0000
<i>GDPGrowth_1</i>	0.285	0.128	2.225	0.0281
<i>GFCF</i>	0.220	0.050	4.430	0.0000

	Multiple R	R Square	Adjusted R Square	s.e
<i>Equation 1</i>	0.965	0.932	0.921	0.391

	DF	Sum of Squares	Mean Square	F
<i>Regression</i>	9	114.491	12.721	83.403
<i>Residual</i>	55	8.389	0.152	

The largest change in the coefficient estimates is that on unemployment, which increases from 0.175 to 0.193, the other changes are of a much smaller magnitude. This change in the unemployment coefficient means that in the SURE regression unemployment is significant at the 5% level whereas in the 2SLS estimation it was only significant at the 10% level. The residual sum of squares increases slightly for the SURE estimation from

8.385 to 8.389 but this has no real effect on the explanatory power of the regression, measure by its R-squared or F-statistic.

Table 8 below reports the results of the SURE estimation of the unemployment equation. As with the real wage growth equations the SURE estimates are very close to the 2SLS estimates and again the SURE estimation is more efficient with lower standard error. All the t-values are higher except for the real wage growth variable, which falls slightly, as the coefficient falls in absolute value. The p-value of the wage growth variable increases from 0.0448 in the 2SLS estimation to 0.0510 in the SURE estimation.

Table 8
Summary of Unemployment Equation; 1986 to 2002; SURE

Variable	Coefficient	s.e	t-value	Sig
<i>Constant</i>	0.065	0.066481	0.980	0.3292
<i>WGrowth</i>	-0.029	0.015	-1.973	0.0510
<i>U_1</i>	1.183	0.025	47.516	0.0000
<i>U_4</i>	-0.206	0.025	-8.162	0.0000
<i>GDPGrowth</i>	-0.139	0.039	-3.530	0.0006
<i>r_4</i>	0.024	0.007	3.597	0.0005

	Multiple R	R Square	Adjusted R Square	s.e
<i>Equation 2</i>	0.998	0.997	0.996	0.139

	DF	Sum of Squares	Mean Square	F
<i>Regression</i>	5	344.906	68.981	3574.684
<i>Residual</i>	59	1.139	0.019	

The residual sum of squares of the SURE regression is slightly less than that of the 2SLS regression at 1.139 compared with 1.144 but this is relatively unimportant considering the very high R-squared and F-statistic of both estimates.

It should be noted here that although changes in the coefficient estimates are small, these changes do have implications later when estimating the impact and long-run multiplier of the system.

9. Implications of equations

9.1. Impact and Long Run Responses

In order to determine the effect of skill shortages on real wage growth and unemployment we first have to calculate the reduced-form equations of the system above. These reduced-form equations express unemployment and real wage growth (the endogenous variables) solely as a function of the exogenous (predetermined) variables and the stochastic disturbance terms. With these reduced-form equations we can calculate reduced-form coefficients, which will be non-linear combinations of the structural coefficients estimated above.

The reduced-form of the system of equations above is the following³²,

$$WGrowth_t = \mathbf{p}_0 + \mathbf{p}_1 UN_{t-1} + \mathbf{p}_2 UN_{t-4} + \mathbf{p}_3 GDPGrowth_t + \mathbf{p}_4 r_{t-4} + \mathbf{p}_5 WGrowth_{t-1} + \mathbf{p}_6 WGrowth_{t-4} + \mathbf{p}_7 SkillShortage_t + \mathbf{p}_8 SkillShortage_{t-1} + \mathbf{p}_9 Stock / GDP_t + \mathbf{p}_{10} GDPGrowth_{t-1} + \mathbf{p}_{11} GFCF_{t-1} + v_t$$

and

$$UN_t = \mathbf{I}_0 + \mathbf{I}_1 WGrowth_{t-1} + \mathbf{I}_2 WGrowth_{t-4} + \mathbf{I}_3 SkillShortage_t + \mathbf{I}_4 SkillShortage_{t-1} + \mathbf{I}_5 Stock / GDP_t + \mathbf{I}_6 GDPGrowth_t + \mathbf{I}_7 GDPGrowth_{t-1} + \mathbf{I}_8 GFCF_{t-1} + \mathbf{I}_9 UN_{t-1} + \mathbf{I}_{10} UN_{t-4} + \mathbf{I}_{11} r_{t-4} + w_t$$

The reduced-form coefficients above are the impact, or short-run multipliers of the system. The reduced-form coefficients, such as $\mathbf{p}_1, \mathbf{I}_1$, give the immediate impact on real wage growth or unemployment (the endogenous variables) of a change in a given exogenous variable.

The reduced-form above also shows that the structural model estimated above is overidentified. There are 16 structural coefficients, but there are 24 reduced-form coefficients, and so 24 equations with which to estimate them. Due to this, a unique estimation of the parameters in the model cannot be obtained by OLS; hence we have to use 2SLS to estimate the structural coefficients. 2SLS will provide us with one estimate per parameter.

³² See appendix for detail.

We can now calculate the impact response on real wage growth and unemployment of a one-unit increase in the skill shortages variable using the 2SLS estimates of the coefficients³³.

For real wage growth the impact response is,

$$p_7 = \frac{a_4}{1 - a_1 b_1} = \frac{0.093}{1 - (0.175 \times -0.034)} = 0.09245$$

For unemployment the impact response is,

$$I_3 = \frac{b_1 a_4}{1 - a_1 b_1} = \frac{-0.034 \times 0.093}{1 - (0.175 \times -0.034)} = -0.00314$$

The above impact responses imply that a one-unit (one-percentage point) increase in the skills shortage variable leads to an immediate 0.09245-unit increase in real wage growth (%) and a 0.00314-unit fall in the unemployment rate (%). The direction of these two responses is as expected prior to analysis. Graphs of the skills shortage data against real wage growth and unemployment both show relationships in the same direction as these impact responses.

We can now also calculate the long-run response of real wage growth and unemployment to increases in skills shortages. In long-run equilibrium³⁴,

$$(1 - p_5 - p_6)WGrowth^* = p_0 + (p_1 + p_2)UN^* + (p_3 + p_{10})GDPGrowth^* + p_4 r^* + (p_7 + p_8)SkillShortage^* + p_9 Stock / GDP^* + p_{11}GFCF^*$$

and

$$(1 - I_9 - I_{10})UN^* = I_0 + (I_1 + I_2)WGrowth^* + (I_3 + I_4)SkillShortage^* + I_5 Stock / GDP^* + (I_6 + I_7)GDPGrowth^* + I_8 GFCF^* + I_{11} r^*$$

Therefore

$$WGrowth^* = \frac{p_0}{1 - p_5 - p_6} + \left(\frac{p_1 + p_2}{1 - p_5 - p_6} \right) UN^* + \left(\frac{p_3 + p_{10}}{1 - p_5 - p_6} \right) GDPGrowth^* + \left(\frac{p_4}{1 - p_5 - p_6} \right) r^* + \left(\frac{p_7 + p_8}{1 - p_5 - p_6} \right) SkillShortage^* + \left(\frac{p_9}{1 - p_5 - p_6} \right) Stock / GDP^* + \left(\frac{p_{11}}{1 - p_5 - p_6} \right) GFCF^*$$

³³ Responses for the SURE estimation will be reported and discussed later.

³⁴ See appendix.

and

$$UN^* = \frac{I_0}{1 - I_9 - I_{10}} + \left(\frac{I_1 + I_2}{1 - I_9 - I_{10}} \right) W\text{Growth}^* + \left(\frac{I_3 + I_4}{1 - I_9 - I_{10}} \right) \text{SkillsShortage}^* + \left(\frac{I_5}{1 - I_9 - I_{10}} \right) \text{Stock / GDP}^* \\ + \left(\frac{I_6 + I_7}{1 - I_9 - I_{10}} \right) \text{GDPGrowth}^* + \left(\frac{I_8}{1 - I_9 - I_{10}} \right) \text{GFCF}^* + \left(\frac{I_{11}}{1 - I_9 - I_{10}} \right) r^*$$

The long-run coefficients on skills shortages for real wage growth and unemployment are thus the following respectively,

$$\frac{p_7 + p_8}{1 - p_5 - p_6} = \frac{0.09245 - 0.07953}{1 - 0.5835 + 0.2933} = 0.01820$$

$$\frac{I_3 + I_4}{1 - I_9 - I_{10}} = \frac{-0.00314 + 0.00270}{1 - 1.1730 + 0.2038} = -0.01429$$

These long-run coefficients imply that following a one-percentage point increase in skills shortages the overall long-run effect on real wage growth is a 0.0182-percentage point increase and on unemployment a 0.01429-percentage point decrease.

9.2. Comparison of 2SLS and SURE Estimates

As noted above the differences in the estimated coefficients of the 2SLS and SURE estimates are minimal, the differences in the impact and long-run responses are greater and are of more importance when quantifying the effect of skill shortages on real wage growth and unemployment. Table 9 below shows a comparison of the impact and long-run responses to a one-percentage point increase in skill shortages for the estimated 2SLS and SURE equations.

Table 10
Comparison of 2SLS and SURE Responses to a one-percentage point Increase in Skill Shortages

Response	Variable	2SLS	SURE
<i>Impact</i>	<i>Wgrowth</i>	0.09245	0.09447
	<i>UN</i>	-0.00314	-0.00274
<i>Static Long-run</i>	<i>Wgrowth</i>	0.01820	0.02258
	<i>UN</i>	-0.01429	-0.01624

The table above shows that the impact and long-run responses of real wage growth to a one-percentage increase in skill shortages differ very little between the 2SLS and SURE estimates. Both the SURE and 2SLS estimates show an impact response that is greater than the long-run response, with the effect on increased real wage growth on unemployment reducing the effect of an increase in skill shortages in the long-run. The SURE estimation implies a slightly larger response than the 2SLS estimation. The SURE estimation produces a greater impact response of 0.09447 compared to 0.09245 and a greater long-run response of 0.02258 compared to 0.01820. This implies that the 2SLS estimation procedure may underestimate the impact of skill shortages on real wage growth.

The SURE estimation of the unemployment equation implies a greater increase in unemployment between the impact and long-run. The SURE impact response is less than that of the 2SLS estimation in absolute terms, at -0.00274 compared to -0.00314 , but the long-run response is greater in absolute terms, at -0.01624 compared to -0.01429 . Both the 2SLS and SURE estimates imply that after an initial small impact response the effect on unemployment in the long-run increases. For the 2SLS estimation the long-run response is about four and a half times the impact response, whereas for the SURE estimation the long-run response is about six times the impact response.

The SURE estimation therefore produces greater long-run responses for both real wage growth and unemployment. In terms of impact responses the real wage growth impact response is greater but the impact response of unemployment is smaller in absolute terms. Both estimation techniques do however produce the same type of effect on unemployment

and real wage growth. A one-percentage point increase in skill shortages causes an overshooting of real wage growth with a large impact response, this response falls by about factor four over the long-run. In terms of unemployment we have a small initial response but a much more significant long-run response.

9.3. Sensitivity Analysis

Table 11 below shows how the impact and long run responses vary when one standard error is added or subtracted from the coefficient estimates. The results are presented for both the 2SLS estimates and the SURE estimates.

Table 11
Sensitivity Analysis of Response to one-percentage point increase in skill shortages; 2SLS and SURE Estimates.

Response	Variable	coefficients minus 1 standard error		coefficients plus 1 standard error	
		2SLS	SURE	2SLS	SURE
<i>Impact</i>	<i>Wgrowth</i>	0.06994	0.07406	0.11546	0.11554
	<i>UN</i>	-0.00354	-0.00328	-0.00196	-0.00162
<i>Static Long-run</i>	<i>Wgrowth</i>	-0.03700	-0.02917	0.10774	0.10230
	<i>UN</i>	0.01998	0.01414	0.04145	0.03537

Table 11 above shows that the impact responses are quite robust always giving the same sign in table 10. The long-run responses are however less robust, although the results are slightly misleading. The long-run responses tend to have the opposite sign to those in table 10, the problem here however, is that we are adding a standard error to each coefficient whilst there is a negative coefficient on real wage growth in the unemployment equation. Such an analysis is complicated by the complexities of computing the long run responses, which are made up of a large number of different estimated coefficients. The robustness of the impact responses is a better indicator of performance³⁵, with the calculated direction of the effect of skill shortages the same as when using the original coefficient estimates.

9.4. Implications

If we use the SURE estimates of the coefficients for the system of equations we have long-run responses to a one-percentage point increase in skill shortages of 0.023-percentage points for real wage growth and -0.016 -percentage points for unemployment. These responses are quite small but they are not insignificant, in order to assess the full effects of skill shortages their variability and level of fluctuation over time is important. Figure 10 and table 3 above showed that skill shortages over the period 1986 to 2002 fluctuated quite dramatically with a range of some 24-percentage points. Sharp fluctuations in the level of skill shortages will have important implications for real wage growth and unemployment. Table 12 below shows descriptive statistics for quarterly and yearly changes of the skill shortages variable.

Table 12
Skill Shortages, Quarterly and Yearly Changes; 1986 to 2002

<i>Skill Shortages</i>	Mean	Median	Std. Dev.	Max	Min	Range
<i>one-quarter change</i>	-0.09	0.30	2.60	6.00	-6.66	12.66
<i>two-quarter change</i>	-0.12	0.03	3.49	7.66	-7.95	15.61
<i>three-quarter change</i>	-0.09	0.32	4.50	9.07	-9.69	18.75
<i>one-year change</i>	0.00	0.96	5.31	11.72	-12.78	24.50
<i>two-year change</i>	0.50	1.93	7.66	17.05	-20.24	37.29

Table 12 above shows that on average over periods of up to one-year skill shortages do not matter, with means close to zero for 1 to 4 quarter changes. The two-year change in skill shortages has a mean of 0.50, which will produce changes in real wage growth and unemployment that are negligible. All that the means imply however is that the level of skill shortages over the period have on average remained constant. This however misses the importance of the fluctuations that occur in skill shortages and their effect on real wage growth and unemployment.

In terms of the importance of skill shortages on real wage growth and unemployment the maximum and minimum columns of table 12 above are most important. Looking at the

³⁵ Remember here that the impact responses are the reduced-form coefficients.

one-year change the maximum increase in skill shortages is some 11.72-percentage points, which occurs between 1987 Q1 and 1988 Q1. Such a movement in skill shortages will lead to, using my SURE estimates, a 0.26-percentage points increase in real wage growth and a 0.2-percentage points fall in unemployment. For the two-year change of skill shortages we see a maximum increase of 17.05, which leads to a 0.4-percentage point increase in real wage growth and a 0.28-percentage point fall in unemployment. Movements in real wage growth and unemployment of this magnitude are significant and even the maximum one-quarter change produces long run movements in real wage growth and unemployment of 0.14 and -0.1 percentage points respectively.

The minimum changes in the table above can be interpreted the same way and give falls in skill shortages as opposed to increases. These also show significant falls in skill shortages, which have significant effects on real wage growth and unemployment. It is clear that the basic responses given in sections 9.1. and 9.2. do not give the full picture of the importance of skill shortages. The large fluctuations in skill shortages over time have important implications for real wage growth and unemployment, producing significant movements in these variables.

10. Skill shortages and unemployment

The skill shortage variable is only present in the real wage growth equation, looking at figure 11 above this might seem unreasonable, as the unemployment rate seems to have a strong inverse relationship with the skills shortage series. The skill shortage variable was however never significant at even the 10% level in any of the alternate specifications tried.

One important point to note here is that, although the skill shortages variable does not enter the unemployment equation, the set up of the model means that skill shortages do affect unemployment. The impact and long-run multipliers calculated above show that the affect of skill shortages on unemployment works in the same direction as the graph in figure 11 above predicts. Skill shortages do not affect unemployment directly they do affect unemployment through their affect on real wage growth. This affect is in the direction that was expected prior to regression analysis. The following discusses why skill

shortages might not have been statistically significant in the unemployment equation even though its effect on unemployment is captured in the model.

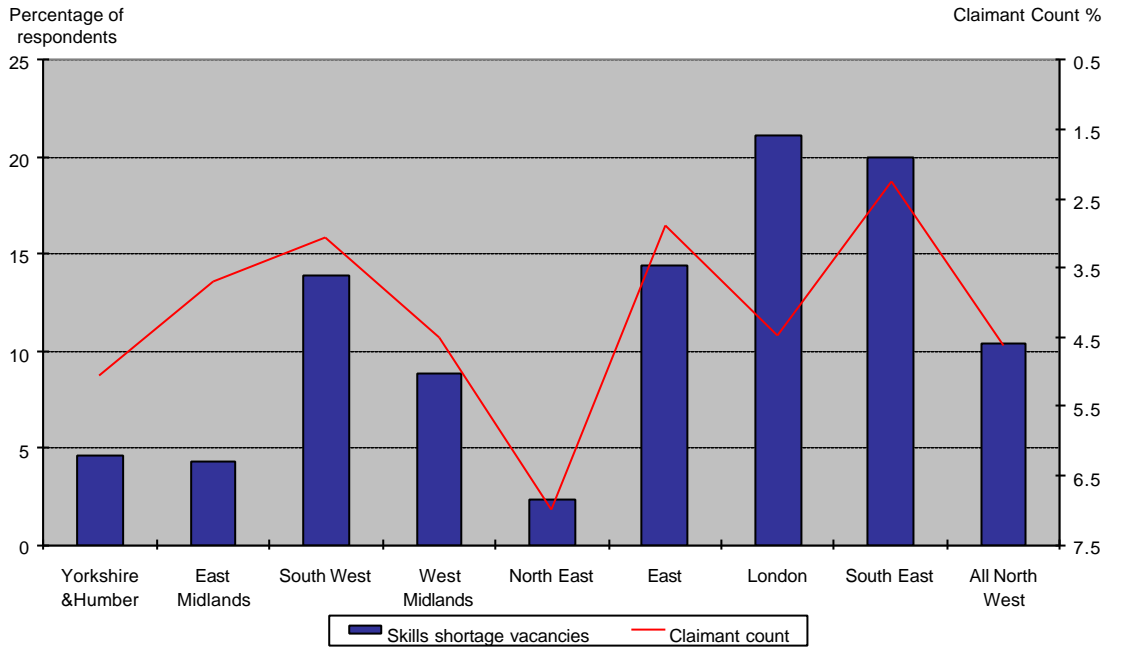
The CBI skill shortages data has limitations, in that firms could be more likely to recognise skill shortages when unemployment is low and labour is scarcer. During periods of high unemployment other factors, such as lack of orders or sales, are likely to be more noticeable in limiting output. This idea can be seen in figure 5 above where it can be seen that the majority of firms in the survey see orders as the main factor limiting sales.

It is only in periods of very low unemployment (early 1970's and early 1990's) when the importance of a lack of skilled labour grows. The negative relationship shown in figure 11 above could therefore be simply due to the way the survey is conducted. In buoyant periods with high growth and strong and growing demand the main factor that limits output, lack of sales or orders, becomes less important and hence firms find that lack of skilled labour becomes an increasingly important factor. In this case the actual level of skill shortages may not actually have increased. As noted above in section 2.1, DfES research suggests that a firm's recognition of skill shortages and internal skill gaps is related to their performance. This supports the idea that skill shortages are more likely to be reported during periods of low unemployment.

The model above predicts that skill shortages affect unemployment through real wage growth and not directly. There is evidence that the model is picking up the true relationship between skill shortages and unemployment. If we look at skill shortages at a regional level in the years of the two Employer Skills Surveys (ESS) (1999 and 2001) we can see that at this level skills shortages show much more correlation with earnings than with unemployment.

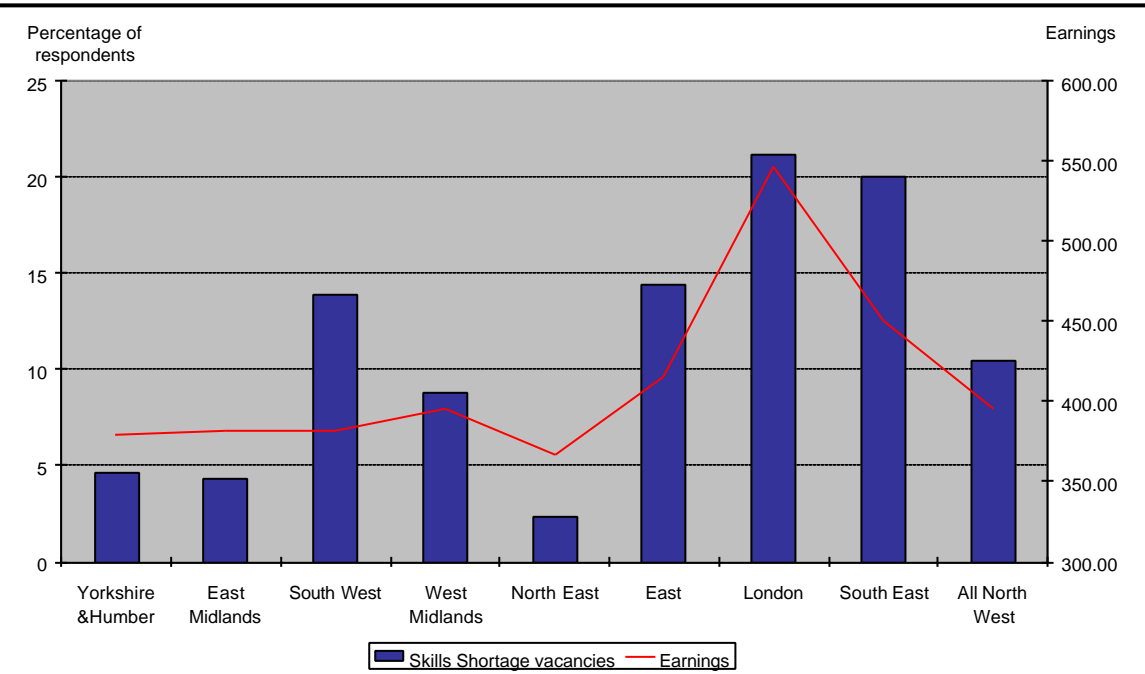
Figures 20 and 21 below shows regional skill shortages plotted against regional unemployment and regional earnings growth for the ESS 1999 (note the inverted unemployment axis).

*Figure 20
Regional Claimant Count and Skill Shortages; ESS 1999*



Source: ESS 1999 (IER/IFF)

*Figure 21
Regional Earnings and Skill Shortages; ESS 1999*



Source: ESS 1999 (IER/IFF)

Regional unemployment does show some correlation with regional skill shortages but this correlation is not as strong as that between regional earnings and skill shortages. This suggests that the model may have picked up the true relationship between earnings, unemployment and skill shortages. The differences in unemployment and earnings across regions is obviously due to a number of factors but the graphs do provide some support for the exclusion of skill shortages from the unemployment equation and support the conclusion that skill shortages affect unemployment through wage growth and not directly.

This conclusion is also supported by DfES research, which concludes that, “There is a negative relationship between the incidence of skill shortage vacancies and the local unemployment rate (i.e. in general, low unemployment rate areas tend to have a higher than average incidence of skill shortage vacancies, and vice versa). However, in statistical terms, this relationship is relatively weak”³⁶. This conclusion emerges, as there are areas where high levels of skill shortages co-exist with high levels of unemployment.

The insignificance of skill shortages in the unemployment equation could therefore be due simply due to data considerations and the type of data being used as a proxy to measure skill shortages. If we assume the data gives an accurate measure of skill shortages, regional data seems to support the model that has been developed above, supporting the conclusion that skill shortages affect real wage growth, which in turn affects unemployment. Hence the inclusion of the skill shortage variable in the real wage equation but not in the unemployment equation is justified.

11. Future research

An alternate modelling technique that was investigated was the use of a vector autoregression (VAR) instead of a simultaneous structural equation approach. The advantage of this approach is that it is not based on *a priori* assumptions about the determinants of real wage growth, unemployment or skill shortages. A VAR approach was tried but with little success. I believe this failure to be due to the weak statistical link between skill shortages and unemployment and also the nonstationarity of unemployment.

³⁶ See [13].

This is in accordance with work by Bosworth *et al* [7] who find no statistically significant link between the unemployment rate and the incidence of skill shortage vacancies. A vector error correction (VEC) model would be more appropriate given the nonstationarity of unemployment and some of the other variables that I have used³⁷.

The recent Employer Skill Surveys have highlighted the importance of regional differences in skill shortages, with regions such as the South East and London with much higher densities of skill shortages than areas such as the North East. The BCC provides a good source of regional skill shortages data that could be used to model its effect on regional wage growth and unemployment. The only problem with using this data is its limited time series and its measure of skill shortages being a much broader and less well defined than those of the Employer Skill Surveys.

One other possible area of future research would be to look at the effect of occupational skill shortages on unemployment and wage growth for that occupation. Following the panel data approach of Haskel and Martin [18], CBI data could be used to investigate the effect of skill shortage variations across industries and their effects on unemployment and wage growth.

12. Conclusions

The model estimated above suggests that increases in skill shortages lead to increased real wage growth and reduced unemployment. The affect on unemployment does not come directly from the increase in skill shortages but via the affect of skill shortages on real wage growth. Due to the relationship between real wage growth and unemployment the long run impact of an increase in skill shortages is less than the impact response in the real wage growth equation. For unemployment the long run response is greater than the impact response.

The 2SLS estimation of the simultaneous model above predicts that a one-percentage point increase in the level of skill shortages will lead to an immediate 0.09245-percentage point increase in real wage growth. In the long run the overall effect is a 0.0182-

³⁷ Some of the variables are also cointegrated.

percentage point increase. In terms of unemployment, a one-percentage point increase in the level of skill shortages will lead to an immediate fall in unemployment of 0.00314, in the long run this impact increases to 0.01429.

SURE estimates of the simultaneous equation model are very close to that of the 2SLS estimation but suggest that the 2SLS estimation may under predict the effect of skill shortages on real wage growth and unemployment. The dynamics suggested by the SURE estimation are also the same as those of the 2SLS estimation.

The model developed above gives a good idea of the magnitude and direction of the effect that skill shortages have on real wage growth and unemployment. This effect is small for both real wage growth and unemployment compared with a variable such as GDP growth but is not however negligible when looking at the fluctuations in skill shortages that occur. Looking at the one-year change of skill shortages we can see a maximum yearly change of 11.72-percentage points, the model predicts that this would produce as much as a 0.26-percentage points increase in real wage growth and a 0.2-percentage points fall in unemployment.

The concept of latent skill gaps could have important implications for my model. As DfES research points out, firm will often only recognise skill shortages when output demand is strong. As a consequence firms will tend to understate the true level of skill shortages. If we assume that the level of latent skill gaps is consistent over time then this has no implications for my model, simply the absolute level of skill shortages is wrong. If however the amount of latent skill gaps has fluctuated my model could be either over or under predicting the effect of skill shortages.

Even taking account of the possible problems with finding a suitable measure of skill shortages and the problems associated with latent skills gaps the model developed above shows that skill shortages can have important implications for real wage growth and unemployment. The model provides some statistical evidence to support the economic intuition that skill shortages increase real wage growth and reduce unemployment.

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Appendix

Given the following system of equations,

$$WGrowth_t = \mathbf{a}_0 + \mathbf{a}_1 UN_t + \mathbf{a}_2 WGrowth_{t-1} + \mathbf{a}_3 WGrowth_{t-4} + \mathbf{a}_4 SkillShortage_t + \mathbf{a}_5 SkillShortage_{t-1} + \mathbf{a}_6 Stock / GDP_t + \mathbf{a}_7 GDPGrowth_t + \mathbf{a}_8 GDPGrowth_{t-1} + \mathbf{a}_9 GFCF_{t-1} + u_{1t}$$

and

$$UN_t = \mathbf{b}_0 + \mathbf{b}_1 WGrowth_t + \mathbf{b}_2 UN_{t-1} + \mathbf{b}_3 UN_{t-4} + \mathbf{b}_4 GDPGrowth_t + \mathbf{b}_5 r_{t-4} + u_{2t}$$

The reduced-form is as follows,

$$WGrowth_t = \mathbf{p}_0 + \mathbf{p}_1 UN_{t-1} + \mathbf{p}_2 UN_{t-4} + \mathbf{p}_3 GDPGrowth_t + \mathbf{p}_4 r_{t-4} + \mathbf{p}_5 WGrowth_{t-1} + \mathbf{p}_6 WGrowth_{t-4} + \mathbf{p}_7 SkillsShortage_t + \mathbf{p}_8 SkillsShortage_{t-1} + \mathbf{p}_9 Stock / GDP_t + \mathbf{p}_{10} GDPGrowth_{t-1} + \mathbf{p}_{11} GFCF_{t-1} + v_t$$

and

$$UN_t = \mathbf{l}_0 + \mathbf{l}_1 WGrowth_{t-1} + \mathbf{l}_2 WGrowth_{t-4} + \mathbf{l}_3 SkillsShortage_t + \mathbf{l}_4 SkillsShortage_{t-1} + \mathbf{l}_5 Stock / GDP_t + \mathbf{l}_6 GDPGrowth_t + \mathbf{l}_7 GDPGrowth_{t-1} + \mathbf{l}_8 GFCF_{t-1} + \mathbf{l}_9 UN_{t-1} + \mathbf{l}_{10} UN_{t-4} + \mathbf{l}_{11} r_{t-4} + w_t$$

Where

$$\mathbf{p}_0 = \frac{\mathbf{a}_0 + \mathbf{a}_1 \mathbf{b}_0}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{p}_1 = \frac{\mathbf{a}_1 \mathbf{b}_2}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{p}_2 = \frac{\mathbf{a}_1 \mathbf{b}_3}{1 - \mathbf{a}_1 \mathbf{b}_1}$$

$$\mathbf{p}_3 = \frac{\mathbf{a}_1 \mathbf{b}_4 + \mathbf{a}_7}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{p}_4 = \frac{\mathbf{a}_1 \mathbf{b}_5}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{p}_5 = \frac{\mathbf{a}_2}{1 - \mathbf{a}_1 \mathbf{b}_1}$$

$$\mathbf{p}_6 = \frac{\mathbf{a}_3}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{p}_7 = \frac{\mathbf{a}_4}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{p}_8 = \frac{\mathbf{a}_5}{1 - \mathbf{a}_1 \mathbf{b}_1}$$

$$\mathbf{p}_9 = \frac{\mathbf{a}_6}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{p}_{10} = \frac{\mathbf{a}_8}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{p}_{11} = \frac{\mathbf{a}_9}{1 - \mathbf{a}_1 \mathbf{b}_1}$$

$$v_t = \frac{\mathbf{a}_1 u_{2t} + u_{1t}}{1 - \mathbf{a}_1 \mathbf{b}_1}$$

and

$$\mathbf{l}_0 = \frac{\mathbf{b}_0 + \mathbf{b}_1 \mathbf{a}_0}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{l}_1 = \frac{\mathbf{b}_1 \mathbf{a}_2}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{l}_2 = \frac{\mathbf{b}_1 \mathbf{a}_3}{1 - \mathbf{a}_1 \mathbf{b}_1}$$

$$\mathbf{l}_3 = \frac{\mathbf{b}_1 \mathbf{a}_4}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{l}_4 = \frac{\mathbf{b}_1 \mathbf{a}_5}{1 - \mathbf{a}_1 \mathbf{b}_1} \quad \mathbf{l}_5 = \frac{\mathbf{b}_1 \mathbf{a}_6}{1 - \mathbf{a}_1 \mathbf{b}_1}$$

$$\begin{aligned}
I_6 &= \frac{b_1 a_7 + b_4}{1 - a_1 b_1} & I_7 &= \frac{b_1 a_8}{1 - a_1 b_1} & I_8 &= \frac{b_1 a_9}{1 - a_1 b_1} \\
I_9 &= \frac{b_2}{1 - a_1 b_1} & I_{10} &= \frac{b_3}{1 - a_1 b_1} & I_{11} &= \frac{b_5}{1 - a_1 b_1} \\
w_t &= \frac{u_{2t} + b_1 u_{1t}}{1 - a_1 b_1}
\end{aligned}$$

In long-run equilibrium the following must hold,

$$WGrowth_t = WGrowth_{t-1} = WGrowth_{t-4} = WGrowth^*$$

$$UN_t = UN_{t-1} = UN_{t-4} = UN^*$$

$$GDPGrowth_t = GDPGrowth_{t-1} = GDPGrowth^*$$

$$SkillShortage_t = SkillShortage_{t-1} = SkillShortage^*$$

$$Stock / GDP_t = Stock / GDP^*$$

$$GFCF_{t-1} = GFCF^*$$

$$r_{t-4} = r^*$$

$$v_t = 0, w_t = 0$$

Therefore

$$\begin{aligned}
(1 - p_5 - p_6)WGrowth^* &= p_0 + (p_1 + p_2)UN^* + (p_3 + p_{10})GDPGrowth^* + p_4 r^* + (p_7 + p_8)SkillShortage^* \\
&+ p_9 Stock / GDP^* + p_{11} GFCF^*
\end{aligned}$$

and

$$\begin{aligned}
(1 - I_9 - I_{10})UN^* &= I_0 + (I_1 + I_2)WGrowth^* + (I_3 + I_4)SkillShortage^* + I_5 Stock / GDP^* \\
&+ (I_6 + I_7)GDPGrowth^* + I_8 GFCF^* + I_{11} r^*
\end{aligned}$$

Therefore in the long-run,

$$\begin{aligned}
WGrowth^* &= \frac{p_0}{1 - p_5 - p_6} + \left(\frac{p_1 + p_2}{1 - p_5 - p_6} \right) UN^* + \left(\frac{p_3 + p_{10}}{1 - p_5 - p_6} \right) GDPGrowth^* + \left(\frac{p_4}{1 - p_5 - p_6} \right) r^* \\
&+ \left(\frac{p_7 + p_8}{1 - p_5 - p_6} \right) SkillShortage^* + \left(\frac{p_9}{1 - p_5 - p_6} \right) Stock / GDP^* + \left(\frac{p_{11}}{1 - p_5 - p_6} \right) GFCF^*
\end{aligned}$$

and

$$UN^* = \frac{I_0}{1 - I_9 - I_{10}} + \left(\frac{I_1 + I_2}{1 - I_9 - I_{10}} \right) W\text{Growth}^* + \left(\frac{I_3 + I_4}{1 - I_9 - I_{10}} \right) \text{SkillsShortage}^* + \left(\frac{I_5}{1 - I_9 - I_{10}} \right) \text{Stock / GDP}^* \\ + \left(\frac{I_6 + I_7}{1 - I_9 - I_{10}} \right) \text{GDPGrowth}^* + \left(\frac{I_8}{1 - I_9 - I_{10}} \right) \text{GFCF}^* + \left(\frac{I_{11}}{1 - I_9 - I_{10}} \right) r^*$$