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A three sector model of earnings behaviour

by

D J Mackie

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A THREE SECTOR MODEL OF EARNINGS BEHAVIOUR

CONTENTS

Introduction

This paper discusses some research undertaken in order to improve the properties of the earnings equations in the Bank of England's quarterly macroeconomic model of the UK economy. As such it represents part of a continuing research programme at the Bank aimed at improving the theoretical and empirical properties of the various equations which constitute the labour market of this model.

The labour market in the Bank model is currently disaggregated into three main sectors: the manufacturing sector (which includes those public corporations defined as manufacturers in the 1980 Standard Industrial Classification(SIC)), the non-trading public sector and a sector which incorporates the non-manufacturing private sector and non-manufacturing public corporations. (The last sector is referred to in this paper as the non-manufacturing sector, for ease of exposition.)[1] Although there is a model variable for earnings in public corporations, which plays an important part in ensuring that public sector income is accurately modelled in forecasts and simulations, the level of this variable depends solely on earnings in the non-manufacturing sector (which includes the majority of public corporations).

Most of the quarterly macroeconomic models of the UK economy have a degree of disaggregation in the labour market similar to that in the Bank model while the annual models tend to work with highly aggregate labour markets.[2] (For a survey of the labour markets in the main UK models see Wallis et al (1986).) One possible interpretation of this is that in the short-run interactions between sectors are very important in the wage determination process while in the long run wages are determined entirely by fundamental forces of supply and demand. There can be no doubt, however, that a certain degree of disaggregation provides advantages not only in giving a model a richer dynamic structure but also if the determinants of wages differ markedly across sectors.

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1 It is referred to as the 'other' sector in the Bank of England model manual.

2 An exception to this is the National Institute's quarterly model which has a single aggregate earnings equation. Nevertheless, the National Institute does recognise the importance of intersectoral effects when modelling earnings (see, for example, Foster, Henry and Trinder (1986)).

An important result presented in this paper is that intersectoral effects are important in the wage determination process. Each of the preferred equations has earnings in at least one of the other sectors as an explanatory variable. Other important determinants of nominal earnings in these equations are labour productivity, consumer prices, inflationary expectations, personal sector taxes, and employers' labour taxes, although the last variable only has an effect in the short-run. Another important result is that participants in the labour market who are not currently employed (defined here as the short-term unemployed) do not exert much influence on nominal earnings.

The paper analyses the disaggregated earnings equations as a sub-system of the Bank model and looks at the properties of this sub-system. In particular, the paper considers the issue of homogeneity between nominal earnings and prices and derives the necessary and sufficient conditions for the sub-system to exhibit homogeneity of degree one. These restrictions are imposed and tested. In addition to considering the properties of the earnings sub-system, the paper examines the simulation properties of the equations when they form a part of the larger Bank model.

Section I of the paper discusses the analytical and econometric approach taken; section II presents the estimation results; section III discusses the dynamic properties of the equations and reports some simulation results when the equations are incorporated into the Bank model; and section IV presents some conclusions and suggests areas for future work.

Section I: The Analytical and Econometric Approach

The Bargaining Model

A common approach to deriving a wage equation suitable for estimation is to consider a union bargaining model in which employers and employees bargain about the level of nominal wages and employers set the level of employment unilaterally. The estimated equations reported here lie broadly within this framework. The economic theory underlying this approach is discussed extensively elsewhere (see, for example, Nickell (1982), Nickell and Andrews (1983) and Nickell (1984)) and thus is not repeated in detail here.

The approach in these models is to specify a utility function for the firm and the union and the level of utility which would apply to each participant if no agreement was reached. The resulting wage agreement is usually assumed to be the Nash solution to the bargaining game, although this simply refers to the nature of the equilibrium rather than to the problem of how the equilibrium is actually achieved in a dynamic sense. Nickell (1984) points out that these models suggest equations for the level of nominal wages and the equations presented here are of this form but with earnings rather than wages as the dependent variable. A number of different empirical models suitable for estimation could be derived from this approach depending not only on the specification of the two objective functions and the situation where no agreement is reached, but also on the proxies which are used for the various unobservable variables.

These models tend to consider a single unionised firm or sector; in this paper by contrast we analyse three sectors, all of which are unionised to some extent. The results derived from a model with a single unionised sector can be extended to the case of several unionised sectors as long as there is no collusion between different sectors, ie each sector regards earnings in the other sectors as predetermined when it enters its own bargaining procedure. However, earnings in the other sectors will form an important part of the bargaining process. For a similar assumption see Smith and Holly (1985).

According to the equations presented in the next section the most important determinants of nominal earnings are trend labour productivity, the short-term unemployment rate, consumer prices, inflationary expectations, incomes policies, personal sector income taxes (including National Insurance contributions), and employers' labour taxes. In addition, because of the disaggregated nature of the labour market, each of the earnings equations includes earnings from at least one of the other two sectors as an explanatory variable.

Labour Productivity

A long moving average of actual labour productivity (output per head) is the important variable in these equations for explaining the long-run trend increase in real earnings. The use of an eight quarter moving average is an attempt to remove cyclical influences and proxy trend productivity. However, a drawback of this measure is that any change in productivity will influence earnings whether it represents a change in trend productivity or not. Nevertheless, this approach seems preferable to the rather atheoretical practice of incorporating a time trend. There are alternative measures of productivity which could have been used, for example the capital-labour ratio. Earlier work in this area did investigate the use of a measure of trend productivity derived from the manufacturing production function in the Bank model. However, it did not prove to be as successful as a moving average of output per head. Hall and Henry (1987) consider several different measures of trend productivity in an aggregate earnings equation and they argue that their results provide some grounds for preferring a moving average of output per head as the relevant trend variable.

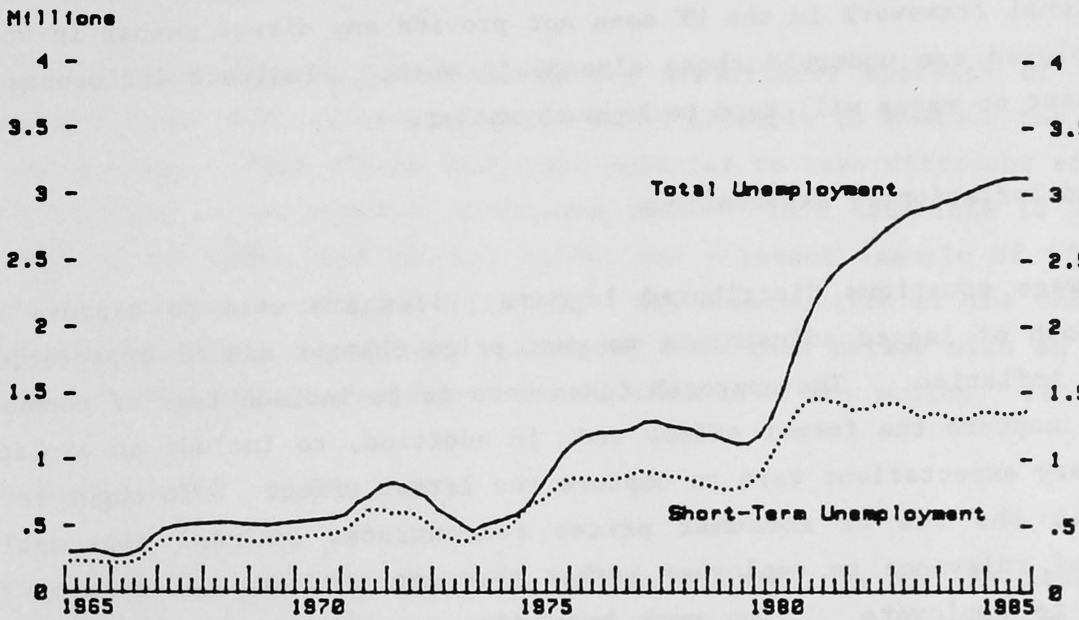
There are several ways in which the inclusion of trend productivity in a wage equation can be justified. In the union bargaining model described in Nickell and Andrews (1983), for example, trend productivity can be used as a proxy for the real wage growth in the economy as a whole which workers might expect if they failed to obtain employment in the unionised firm or sector, and also as a proxy for the "base" level of real wages. Regarding the latter, Nickell and Andrews assume that employees' utility is a function of post-tax real wages relative to a base level of wages which takes account of the growth in real wages over time. In addition, the level of productivity enters as part of the firms' production function. Another approach to the inclusion of trend productivity is contained in the recent paper by Rowlatt (1986) where it forms one of the variables which defines the nominal wage increase considered acceptable by employers and employees and the long-run warranted real wage. The latter variable refers to the real wage considered by employees to be fair in the long-run. It is a function of productivity, the terms of trade and the retentions ratio.

Unemployment

The appearance of unemployment in wage equations has a long history. In the context of a bargaining model the inclusion of unemployment can be justified because a union's utility is likely to be influenced by the conditions in the labour market outside the unionised sector which will affect any workers who fail to find employment in that sector. As the prospects for alternative employment decline employees become less likely to increase the risk of losing their current job by pushing for a large real wage increase. Important relevant variables include both employment in the other sectors and unemployment. On the other hand there may be seniority effects (see, for example, Oswald (1986) and Oswald and Turnbull (1985)) where labour market conditions outside the unionised sector have very little effect on the bargaining position adopted by the union. The use of short-term unemployment (defined as those unemployed for less than 26 weeks) rather than total unemployment is an attempt to have a measure of conditions in the labour market which excludes persons who have ceased to be very active in terms of looking for a job. This does not, of course, imply that all the long-term unemployed are 'voluntarily unemployed'. One possibility is that such persons would accept a job at the going real wage but perceive that the probability of getting a job is relatively low. This could be a consequence of demand side factors, eg firms reducing their demand for the long-term unemployed due to the erosion of their human capital, or to supply side factors, eg the unemployed becoming discouraged from applying for jobs because of the large number of refusals they have received. If the long-term unemployed are largely inactive in the labour market, the union's utility may only be influenced by the number of short-term unemployed, ie those individuals who form the effective competition for other jobs. A number of other researchers have found that the short-term unemployed affect wage behaviour more than the long-term unemployed (see, for example, Layard and Nickell (1986), Hall and Henry (1987), and Nickell (1987)).

FIGURE 1

UNEMPLOYMENT : TOTAL AND SHORT-TERM



The measure of conditions in the labour market used in the equations is the reciprocal of the short-term unemployment rate which gives a non-linear response of earnings to changes in the short-term unemployment rate and a non-constant elasticity.[3] It could be argued that including unemployment in this manner is an alternative to including a structural mismatch variable (for example, the absolute change in the proportion of manufacturing employees in Layard and Nickell (1986)), since this latter variable will reduce the estimated effect of the recent rise in total unemployment on wages. Of

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3 Nickell (1987) presents a number of arguments in support of a non-linear relationship between wages and unemployment. Of course, the term used in the estimation work reported here is not the only manner in which non-linearities could have been introduced.

particular interest, given recent UK experience, is the effect of unemployment on real wages. It could be argued that the UK's recent experience indicates that the unemployment elasticity of real wages is not very large. For example, from 1979 to 1985 real earnings in the manufacturing sector grew by around 2.7% pa while total unemployment increased from 1.1m to 3.1m. This compares with real earnings growth of 2.5% pa from 1963 to 1978 while total unemployment increased from 0.5m to 1.2m. These figures do not appear to be consistent with the traditional Phillips curve. However, if the relevant pressure of demand variable is short-term unemployment rather than total unemployment then there would have been less downward pressure on real earnings over recent years since although short-term unemployment rose sharply in 1980 it has broadly flat since (see Figure 1). Even so, the evidence presented here is that the effect of short-term unemployment on real earnings is also very weak. This result should not seem particularly surprising, despite the voluminous literature on the Phillips curve, because the institutional framework in the UK does not provide any direct manner in which the unemployed can underbid those already in work. Indirect influences of unemployment on wages will tend to be much weaker.

Prices and **Inflationary Expectations**

In many wage equations distributed lags on prices are used to capture the effects both of lagged adjustments to past price changes and of expectations of future inflation. The approach taken here is to include lags of consumer prices to capture the former effect and, in addition, to include an explicit inflationary expectations term to capture the latter effect. It ought to be noted that the use of consumer prices concentrates on real consumption earnings of relevance to employees rather than own product real earnings of relevance to employers. The work here does not investigate whether this distinction is important and further work should consider the issue more fully. (See, for example, Carruth and Oswald (1987) for an analysis of the use of real consumption earnings or the real product wage as the dependent variable in a wage equation.)

A priori, it is likely that price expectations will be important in an earnings equation since wage bargains will be influenced not only by past movements in the cost of living but also by what is likely to happen in the future. There are a number of ways of incorporating expectations of inflation but the method chosen here is to assume that expectations are rational. The equation is estimated by the McCallum errors-in-variables technique using instrumental variables (see McCallum (1976a and 1976b) and for the implementation in a macroeconomic model see Hall and Henry (1985)). The technique can be illustrated (following Blake (1986a)) as follows:

$$W_t = \alpha \; {}_tP^e_{t+1} + \beta Z_t + u_t \qquad \text{(i)}$$

where W_t is earnings, ${}_tP^e_{t+1}$ is the expectation of prices at period t+1 made at period t, Z_t is a vector of other explanatory variables and u_t is a white noise error term. The assumption of rational expectations involves specifying expectations formation as:

$${}_tP^e_{t+1} \equiv E \; (P_{t+1} \mid \Omega_t)$$

$$P_{t+1} = {}_tP^e_{t+1} + \eta_{t+1} \quad \text{and}$$

$$E_t \; (\eta_{t+1}) = 0$$

where Ω_t refers to the information set available at time t and η_{t+1} is another white noise error. The McCallum estimation technique involves replacing ${}_tP^e_{t+1}$ with $P_{t+1} - \eta_{t+1}$ to give an equation appropriate for estimation as:

$$W_t = \alpha \; P_{t+1} + \beta Z_t + u_t - \alpha\eta_{t+1} \qquad \text{(ii)}$$

Given that the error term in equation (ii), $(u_t - \alpha\eta_{t+1})$, is correlated with P_{t+1} the equation must be estimated by instrumental variables with the instruments chosen from Ω_t.

The model actually estimated in this paper is of the form:

$$W_t = \alpha \; {}_tP^e_{t+4} + \gamma \; {}_tP^e_t + \beta Z_t + u_t \qquad \text{(iii)}$$

where the expectation of prices in period t+4 is conditional on Ω_t and the coefficient restriction $\alpha = - \gamma$ is imposed. Under certain circumstances this estimation procedure will induce serially correlated errors. The estimation work reported in the next section does not take account of any potential moving average error process although if it turned out to be important it could lead to inconsistent parameter estimates. Blake (1986a, 1986b) discusses the estimation of rational expectations models with serially correlated errors. The diagnostic test statistics reported later suggest that there is not a serious problem of autocorrelation in the residuals.

Incomes Policies

It is apparent from even the briefest encounter with the literature that there is little agreement regarding how to model incomes policies or even which periods should be considered pertinent. This is an important issue in the estimation of an earnings equation since of the 21 years since 1966, 13 were affected by incomes policies of one sort or another. The most common technique is the use of (1, 0) dummies. A particular coefficient on such a variable would, however, be open to different interpretations, eg it could indicate a severe policy which was very ineffective or a mild policy which was very effective. The use of a single dummy variable has the drawback of restricting the overall effect of all the policies to be identical. On the other hand, using an individual dummy for each policy has the effect of significantly reducing the degrees of freedom available. One way around the degrees of freedom problem is for the researcher to select those periods which, according to his priors, are the most important.

The approach adopted here eschews the traditional approach of using dummy variables and instead uses an index which attempts to measure the severity of each policy. This allows different policies to have different effects while economising on the degrees of freedom used. This technique is discussed in Desai et al (1984) and Whitley (1986) and a recent example of its use in an earnings equation is Rowlatt (1986). The construction of the index proceeds by comparing the stated norm associated with each policy with an estimate of how earnings would have behaved in the absence of the policy; ie

$$\text{Severity index} = \Delta W_t^c - NORM_t \qquad \text{(iv)}$$

where ΔW_t^c is the counterfactual growth in earnings in the absence of the policy and NORM is the rate of growth of earnings desired by the government which is implied by each incomes policy. The simplest approach to proxying ΔW_t^c is to use either ΔW_{t-1} or ΔP_{t-1} and the estimation here uses ΔW_{t-1}. One drawback of this approach is that once an incomes policy has been in effect for a number of quarters ΔW_{t-1} may no longer be a good proxy for ΔW_t^c. An alternative approach which attempts to take account of differing severities of incomes policies is to estimate an equation of the form:

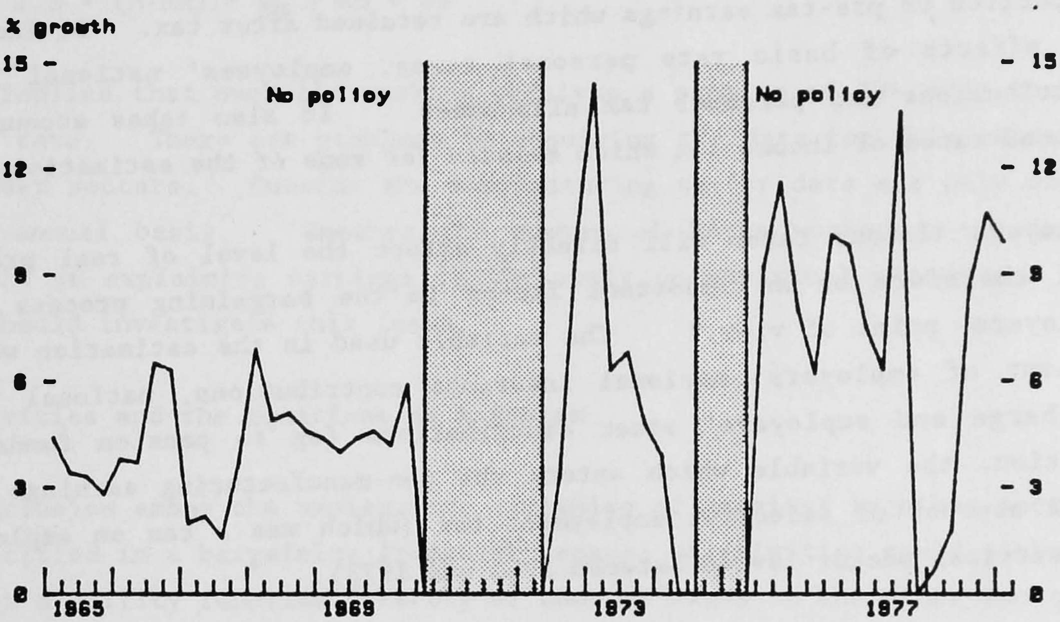
$$W_t = \lambda IP_t * NORM_t + (1 - \lambda\ IP_t)\delta Z_t \qquad \text{(v)}$$

Where IP is a (1, 0) dummy and Z_t is a vector containing the other determinants of earnings. An example of this approach is Wren-Lewis (1985). However, given the number of non-linear constraints which would need to be imposed this method would not be feasible for the equations in this paper.

The incomes policy variables used in the estimation work differ across sectors because ΔW_t^e is proxied by lagged earnings growth for each sector. In addition, the public sector variable takes account of a period of additional pressure on public sector wages, the so-called 'N-1' policy in the early 1970's (see Appendix II for further details).

FIGURE 2

THE STANCE OF INCOMES POLICY FOR THE MANUFACTURING SECTOR



A large value of the index indicates a lot of downward pressure on earnings.

Apart from the need to take account of the periods during which incomes policies were in effect, there are additional problems caused by earnings rising in anticipation of an incomes policy coming into effect and earnings exhibiting a certain amount of catching-up following the ending of a policy. The former problem is ignored here, by assuming that the opportunities for bringing forward wage settlements were quite limited. Catch-up effects are more important, and are alluded to by those who argue that incomes policies only moderated real wage growth in the short-run, if at all. While the dynamic structure of many wage equations will ensure that the level of the real wage will return asymptotically to what it would have been in the absence of an incomes policy, some researchers do include explicit dummy variables to ensure a quicker catch-up of real wages. However, given that it is not at all obvious, a priori, how to model correctly the dynamic effects of an incomes policy, the inclusion of lagged values of the policy variables in the estimation work reported here represents an attempt to allow the data to determine the cumulative effects of a policy. It is possible that there is a simultaneity problem with the incomes policy variable if high earnings growth in any quarter led to a revision to the norm for that quarter. This issue has been investigated by Desai et al (1984) and Whitley (1986) but is ignored in the estimation work reported here.

Taxes

Personal sector taxes will be an important explanatory variable if unions bargain, at least to some extent, in terms of post-tax wages. The variable used in the estimation work is the retentions ratio which measures the proportion of pre-tax earnings which are retained after tax. It incorporates the effects of basic rate personal taxes, employees' national insurance contributions and personal tax allowances. It also takes account of the reduced rates of income tax which existed for some of the estimation period.

Employers' labour taxes will directly affect the level of real profits and will therefore be an important factor in the bargaining process from the employers' point of view.[4] The variable used in the estimation work takes account of employers' national insurance contributions, national insurance surcharge and employers' other contributions (eg to pension funds). In addition, the variable which enters the non-manufacturing earnings equation takes account of selective employment tax (which was a tax on employment in the services sector levied between 1966 and 1973).

Wages, Earnings and Hours

The theory discussed in this section refers to wage settlements while the estimated equations reported in the next section refer to earnings. Other researchers have handled the distinction between wages and earnings in a variety of ways. Rowlatt (1986) mentions that her investigations of the issue of the dependence of manufacturing earnings on hours proved unpromising and the equations she presents have the first difference of earnings as the

4 Strictly speaking the variable used in the estimation work should be called employers' non-earnings labour costs. They are referred to as labour taxes for ease of exposition.

dependent variable without any explicit account being taken of the number of hours worked. In contrast, Holly and Smith (1987) explicitly adjust the Department of Employment manufacturing earnings data to obtain a series for wages. Thus for the manufacturing sector they have:

$$Wm = \frac{WAEM}{1.3 * H - 0.3 * NH}$$

Where WAEM is average earnings in manufacturing;

H is average hours worked in manufacturing;

and NH is normal working hours worked in manufacturing.

This can be rearranged to give:

$$WAEM = 1.3 * (H-NH) * W_m + NH * Wm$$

which implies that overtime working receives a premium of 30% over the normal hourly rate. There are problems in acquiring the data for this exercise for the other sectors. Outside the manufacturing sector data are only available on an annual basis. Whether the number of hours worked is an important variable in explaining earnings is obviously an empirical matter and further work should investigate this issue.

Relativities and the Equations as a System

The inclusion among the explanatory variables of earnings in other sectors can be justified in a bargaining framework because relativities could either enter a union's utility function directly or because wages in the other sectors will affect the utility of those who fail to remain employed in any particular sector. It is because each of the earnings equations includes earnings in one or more of the other two sectors as explanatory variables that they form a simultaneous system. The three earnings equations can be written as a system as follows:

$$AY = BX + U \qquad \text{(vi)}$$

where A and B are matrices of polynomials in the lag operator (L), Y is a vector containing the three earnings variables, X is a vector of predetermined explanatory variables and U is a vector of disturbances. If earnings in each sector were determined totally independently of earnings in the other sectors then A would be a diagonal matrix. However, this is not found to be the case and interaction between different sectors is an important part of the inflationary process. Given the likely simultaneities the following procedure was adopted. The equations were initially estimated as individual structural equations using instrumental variable estimation to ensure consistent, albeit inefficient, estimates of the parameters. Once a parsimonious representation of the data was obtained the equations were then estimated by a systems method to increase the efficiency of the estimates. In the event, none of the preferred equations contain the contemporaneous value of earnings in either of the other two sectors as explanatory variables. It follows that the system is not simultaneous contemporaneously although it is simultaneous in a short-run dynamic sense and in the steady state. Nevertheless, estimating the equations as a system will increase the efficiency of the estimates if the contemporaneous disturbances across the equations are correlated. Apart from the gain in efficiency there is a further advantage in estimating the equations as a system which is that cross-equation parameter restrictions can be imposed.

It is usually considered appropriate that there should be no money illusion in the wage bargaining process, at least in the long run. In the context of the Bank model the long-run homogeneity of degree one of earnings with respect to consumer prices is considered a desirable simulation property so an investigation of this restriction is of some importance. Using the characterisation of the system in equation (vi) the reduced form can be expressed as:

$$Y = A^{-1} BX + A^{-1} U \qquad \text{(vii)}$$

If the polynominals in the lag operator are all solved for $L=1$, then the elements of the matrix $A^{-1}B$ are the static steady state coefficients for each of the predetermined variables. These are the variables of interest when examining the theoretical long-run properties of the equations, rather than the coefficients in the single equation static steady state solutions.

It is the appropriate elements of the matrix $A^{-1}B$ corresponding to prices in the vector X which determines the homogeneity, or otherwise, of earnings with respect to prices in the long run. The cross equation restrictions to be tested are that the three relevant coefficients, which are highly non-linear functions of the elements of the matrix A and of the elements of the column of the matrix B which refers to prices, are each equal to unity. A sufficient but not necessary condition for long-run homogeneity of nominal earnings with respect to prices is that each individual structural equation exhibits homogeneity of nominal earnings with respect to the nominal price terms which appear as explanatory variables (ie consumer prices and other earnings). The appropriate restrictions for this sufficient condition are easy to impose and test in each individual equation. The necessary and sufficient condition for homogeniety requires that the highly non-linear cross equation restrictions are imposed on the system. These restrictions are derived and imposed in the next section when the three equations are estimated as a system.

Section II: The Estimation Results

This section initially presents the results of estimating the three individual structural equations by instrumental variables. The equations were then re-estimated as a system to take account both of the possibility that the contemporaneous residuals in each of the structural equations are correlated and to impose the cross equation restrictions discussed in the previous section. The discusssion in this section concentrates on the static steady state properties of the equations and focuses attention on the systems nature of the earnings equations. The short-run dynamic behaviour of the equations is illustrated in the next section which discusses the simulation properties in the context of the Bank model. The mnemonics used in the equations are consistent with those in the Bank of England model manual.

Manufacturing Earnings

The individual structural equation estimated for manufacturing earnings was derived from an equation of the following general form:

$$\ln WAEM_t = \sum_{i=1}^{4} \alpha_i \ln WAEM_{t-i} + \beta\, LPROM_{t-1}$$

$$+ \sum_{i=0}^{3} \gamma_i\, RSTUR_{t-i} + \sum_{i=0}^{4} \delta_i \ln PC_{t-i}$$

$$+ \sum_{i=0}^{4} \varepsilon_i \ln WAPS_{t-i} + \sum_{i=0}^{4} \phi_i \ln RET_{t-i}$$

$$+ \sum_{i=0}^{4} \lambda_i \ln LABM_{t-i} + \mu\, TDAYWK +$$

$$\eta + \theta\, DEPC_t + \sum_{i=0}^{1} \Psi_i\, IPl_{t-i} \qquad \text{(viii)}$$

where

WAEM is an index of average earnings per head in manufacturing;

$DEPC_t$ is the expectation of inflation over the year beginning in the current quarter;

LPROM is trend productivity in manufacturing;

PC is the price deflator for total consumption;

RET is the employees' retentions ratio;

WAPS is average earnings per head in the non-trading public sector;

LABM is employers' labour taxes;

RSTUR is the reciprocal of the short-term unemployment rate;

IP1 is the incomes policy dummy for manufacturing;

TDAYWK is a dummy for the three day week;

and ln refers to the natural logarithm of the variable. Further details of all the variables used are given in appendix II.

Equation (viii) was estimated with quarterly data from 1966 Q1 to 1983 Q4 using the instrumental variables option on the Time Series Processor (TSP) package. The inflationary expectations term was replaced by actual inflation over the same period and instrumented appropriately. In addition, the contemporaneous terms for prices, other earnings and the reciprocal of the short-term unemployment rate were treated as endogenous variables (see Table 1 for further details).

After a reasonably parsimonious version of equation (viii) was obtained, non-manufacturing earnings (WOO) were included in the equation. The final equation is given as equation (1) in Table 1. A number of test statistics are reported for each equation.[5] Z_1 (4) and Z_2 (4) are both test statistics for residual autocorrelation of up to and including fourth order

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5 For a full discussion of how the test statistics are constructed see Appendix I.

appropriate for the case of instrumental variable estimation. They differ according to how the test statistic is calculated. Z_1 (4) is a likelihood ratio type test calculated in the way suggested by Godfrey (1983) while Z_2 (4) is a modified Lagrange multiplier test calculated in the manner suggested by Breusch and Godfrey (1981). These two tests are not necessarily asymptotically equivalent (see Breusch and Godfrey (op cit)). Both test statistics are distributed χ^2 with 4 degrees of freedom. Z_3 (4) and Z_3 (8) are four and eight period ahead forecasting tests which are distributed $\chi^2(4)$ and $\chi^2(8)$ respectively and Z_4 (ρ) is Sargan's test for the validity of the instruments, which is distributed $\chi^2(\rho)$.

For the forecasting tests reported here the data from 1984 Q1 - 1985 Q4 were put aside at the beginning of the estimation work and not utilised again until the forecasting test statistics were constructed on the basis of the final parsimonious equations. Specifically, the tests were not evaluated at each stage in the specification search and used as a selection criterion. As a result these tests genuinely confront the models with new data (see Harvey (1981)pp 186-7). After the forecasting tests have been performed in this manner the equations were re-estimated over the whole sample period.

Equation (1) is well determined with a standard error of 0.56% and all the variables discussed in section I appear in the equation correctly signed. Both WAPS and WOO enter the equation although neither of them appear contemporaneously. This result contrasts with the recent work of Holly and Smith (1987) who fail to find any significant effect of non-manufacturing earnings in their manufacturing wages equation. The static steady state of the equation is given as:

$$\begin{aligned} \ln WAEM = {} & 0.25842\ LPROM + 0.00104\ RSTUR \\ & + 0.32696 \ln PC + 0.31398 \ln WAPS \\ & + 0.41395 \ln WOO - 0.65128 \ln RET \\ & - 0.27097 \ln LABM - 0.32604 \end{aligned} \qquad \text{(ix)}$$

The equation is slightly over-homogeneous in the static steady state with respect to the nominal price and wage variables with the sum of the coefficients on PC, WAPS and WOO coming to 1.05. A discussion of the appropriate orders of magnitude of the coefficients is better left until the equations are examined as a system to take account of the simultaneity in the static steady state between WAEM, WOO and WAPS. However, there are two important variables in equation (1) which do not enter the static steady state and hence need to be discussed here.

The equation suggests that there is an important role for inflationary expectations in the wage bargaining process. In the static steady state this variable is zero. However, in an economy with a positive inflation rate it is likely to be an important transmission mechanism for inflationary shocks. It is difficult to determine the appropriate size of the coefficient on inflationary expectations a priori. Nevertheless, we can attempt to evaluate its importance, by looking at its impact effect on the level of WAEM. The impact elasticity of manufacturing earnings with respect to inflationary expectations is given by:

0.37676 * DEPC

Thus, if, for example, inflationary expectations are originally at 10% and individuals then expect inflation to rise to 11%, this will increase WAEM by 0.4% in the current period. The inflationary expectations term will have longer run dynamic effects but these are somewhat harder to disentangle analytically.

The equation also suggests that incomes policies have a significant effect on earnings in the short run. As discussed above the inclusion of lagged values of the policy variable was an attempt to allow the data to determine the cumulative effect of a policy and it is interesting to note that the first lag of the incomes policy term is more significant than the contemporaneous term. In the static steady state the incomes policy term would, of course, be zero.

On the issue of residual autocorrelation the results are somewhat inconclusive in that one of the test statistics is marginally significant at the 95% level while the other is insignificant. Appendix I presents some further evidence which suggests that we cannot reject the hypothesis of no residual autocorrelation. If there is any residual autocorrelation it is not of a simple form because the coefficients on each of the four lags of the residuals in an auxilliary regression are not significantly different from zero.

The equation does fairly well on the forecasting test particularly when it is considered that it is quite a demanding test when performed in the way outlined above . The forecast errors (actual minus predicted) from the eight quarter test are:[6]

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6 These forecast errors are the difference between two logarithms. Thus a forecast error of 0.01 can be interpreted as a 1% error on the level of the variable.

	Q1	Q2	Q3	Q4
1984	-0.00457	-0.00793	0.00593	0.00535
1985	0.01269	0.00587	0.00988	0.01182

Although none of these errors are significantly different from zero the equation does show a tendancy to consistently underpredict, at least since mid-1984. One possible explanation for the forecasting errors in the context of this equation is that inflationary expectations have not, in fact, followed inflation down and hence nominal earnings have remained higher than the equation would predict.

It is interesting to note that these forecasting errors are, in fact, relatively small during a period when many would argue that real manufacturing earnings have grown unexpectedly quickly. According to the equation an important part of the explanation for the recent rapid growth in real earnings is the slow feed through of the effects of the rise in labour productivity in the early 1980s. While a certain amount of this increase in productivity was cyclical and part was due to an exceptional amount of labour shedding, it has nevertheless meant that firms could afford high pay settlements.

It was mentioned earlier that a sufficient but not necessary condition for the system as a whole to exhibit homogeneity with respect to prices is for each individual equation to be homogeneous with respect to the nominal price and wage variables. Equation (2) in Table 1 gives the results of imposing single equation homogeneity. The imposition of the constraint is not rejected at the 95% confidence level with a Wald statistic of 1.39 (distributed $\chi^2(1)$). However, the size of some of the coefficients have changed. The static steady state of equation (2) is given as:

$$\begin{aligned} \ln WAEM = {} & 0.33386\, LPROM + 0.00108\, RSTUR \\ & + 0.18410 \ln PC + 0.32971 \ln WAPS \\ & + 0.48616 \ln WOO - 0.57772 \ln RET \\ & + 0.20426 \ln LABM - 1.04578 \end{aligned} \qquad (x)$$

Perhaps the most important change between equation (ix) and equation (x) is that the long-run coefficient on employers' taxes has changed sign. In order to remove a perverse long-run effect from this variable a constraint was imposed so that ln LABM only enters as a first difference. This is given as equation (3) in Table 1 and the Wald statistic for the two restrictions is 2.0

(distributed $\chi^2(2)$). In fact, this restriction on ln LABM is not rejected when imposed on equation (1) with a Wald statistic of 0.34 (distributed $\chi^2(1)$). The static steady state solution of equation (3) is given by:

$$\begin{aligned} \ln WAEM = {} & 0.36415\ LPROM + 0.00096\ RSTUR \\ & + 0.18718 \ln PC + 0.31501 \ln WAPS \\ & + 0.49781 \ln WOO - 0.50182 \ln RET \\ & - 0.98096 \end{aligned} \tag{xi}$$

There is evidence of some residual autocorrelation in equations (2) and (3), although there is disagreement between the test statistics. In addition, equation (3) forecasts the period 1984 Q1-1985 Q4 better than equation (1) with smaller forecast errors through most of this period.

Non-Manufacturing Earnings

The individual structural equation estimated for non-manufacturing earnings was derived from an equation of the following form:

$$\begin{aligned} \ln WOO_t = {} & \sum_{i=1}^{4} \alpha_i \ln WOO_{t-i} + \beta\ LPROO_{t-1} \\ & + \sum_{i=0}^{3} \gamma_i\ RSTUR_{t-i} + \sum_{i=0}^{3} \delta_i \ln PC_{t-i} \\ & + \sum_{i=0}^{3} \varepsilon_i \ln WAPS_{t-i} + \sum_{i=0}^{3} \phi_i \ln RET_{t-i} \\ & + \sum_{i=0}^{3} \lambda_i \ln LABN + \mu\ TDAYWK + \\ & \eta + \theta\ DEPC + \sum_{i=0}^{1} \psi_i\ IP2_{t-i} \end{aligned} \tag{xii}$$

where

WOO is average earnings per head in the non-manufacturing sector (including the majority of public corporations);

LPROO is trend productivity for the whole economy;

LABN is employers' labour taxes which includes the effects of selective employment tax; and

IP2 is the incomes policy dummy for non-manufacturing.

Equation (xii) was estimated with quarterly data from 1966 Q2 to 1983 Q4 using the instrumental variables option on TSP. The inflationary expectations term was replaced by actual inflation over the same period and instrumented appropriately. In addition, the contemporaneous terms for prices, other earnings and the reciprocal of the short term unemployment rate were treated as endogenous variables (see Table 2 for further details).

After a reasonably parsimonious version of equation (xii) was obtained, manufacturing earnings were included and the final equation is given as equation (4) in Table 2. This equation is rather less well determined than the corresponding equation for manufacturing earnings, with a standard error of 1.5%, and a number of the variables which entered the general form were excluded during the specification search, in particular the reciprocal of the short-term unemployment rate, the employees' retentions ratio, and the incomes policy dummy. In addition, only one of the other earnings terms appears as an explanatory variable. Despite the equation missing some of the important explanatory variables, WOO will be influenced by these variables via the WAEM terms. This will become apparent when we consider the three equations as a system.

The static steady state solution of equation (4) is given as:

$$\ln WOO = 0.29470\ LPROO + 0.36681 \ln PC + 0.63299 \ln WAEM + 0.34728 \ln LABN + 3.55503 \qquad \text{(xiii)}$$

Equation (xiii) is almost exactly homogeneous in the nominal price and wage variables with the sum of the coefficients on PC and WAEM equal to 0.9998. Another feature of this equation is that LABN has a positive coefficient, which in the single equation context is an incorrect sign. The equation does not reject a first difference restriction on the ln LABN terms with a Wald statistic of 0.75 (distributed $\chi^2(1)$). This is given as equation (5) in Table 2. The nominal price homogeneity restriction is not rejected in either equation (4) or (5). Inflationary expectations play a role in the WOO equation but they are less well determined than in the WAEM equation.

There does not appear to be any residual autocorrelation in any of these equations. However, their forecasting performance is rather worse than for the WAEM equation. The forecast errors for equation (4) from the eight quarter test are:

	Q1	Q2	Q3	Q4
1984	-0.02571	-0.02653	-0.04109	-0.02562
1985	-0.03382	-0.04626	-0.01437	-0.03449

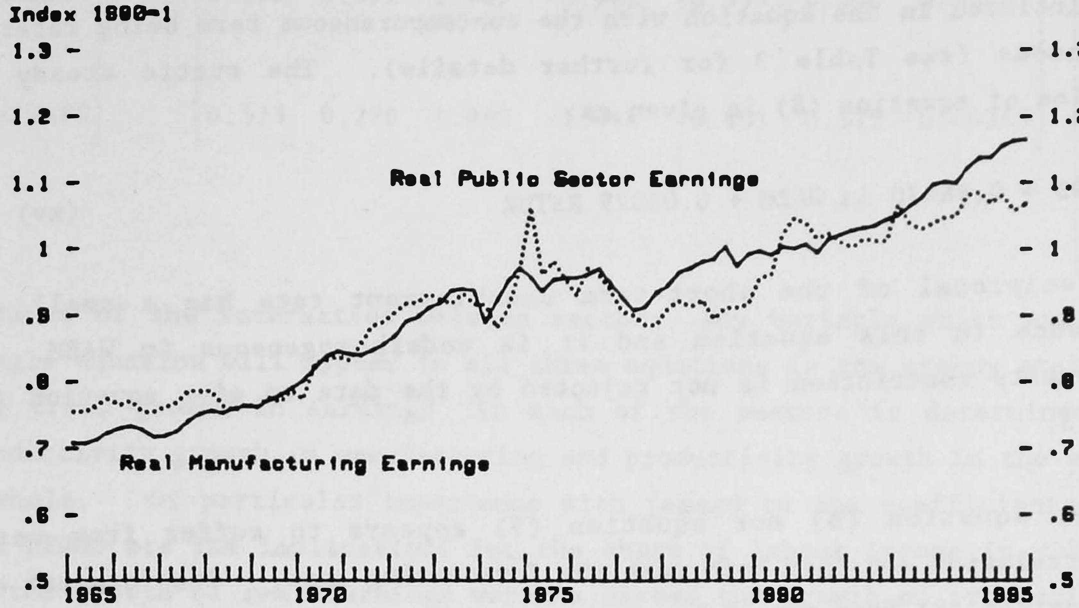
Although none of these forecast errors are significantly different from zero the equation does show a marked tendency to overpredict. This contrasts with the WAEM equation and is much harder to understand given recent UK experience. It may be due to the weight given to WAEM in the WOO equation which leads to a relatively large solution value of WOO over this period.

Non-Trading Public Sector Earnings

Attempts were made to derive an equation for earnings in the non-trading public sector (WAPS) in an analogous manner to the other two earnings equations. However, a specification search beginning from a general form similar to equations (viii) and (xii) did not prove very successful. It is possible that earnings in the public sector depend much more on institutional arrangements than private sector earnings, at least in the short-run. As a consequence of this it is likely to prove difficult to model public sector earnings in a manner comparable to private sector earnings.

FIGURE 3

REAL MANUFACTURING AND PUBLIC SECTOR EARNINGS



In order to derive an equation for WAPS the starting point was the presumption that in the long-run comparability is maintained between WAPS and WAEM. In the short-run there can be substantial deviations from this relationship. Hence, public sector earnings could be modelled in the simplest possible manner as:

$$\alpha_i \text{ (L) ln WAPS}_t = \beta_i \text{ (L) ln WAEM}_t \qquad \text{(xiv)}$$

where α_i (L) and β_i (L) are polynominals in the lag operator. This is similar to the approach taken in the London Business School model (see Budd et al (1984)). The final parsimonious equation for WAPS, given as equation (8) in Table 3, augments equation (xiv) with a number of additional variables. CATCH75 is a dummy variable to take account of a period of exceptionally rapid catch up of public sector earnings during 1975 and CLEGG is a dummy variable to take account of the effects of the Clegg Commission on pay comparability. Apart from all the incomes policies which affected both public and private sectors, the incomes policy variable used in this equation (IP3) additionally takes account of the 'N-1' policy which the Conservative government implemented towards the end of 1970 with regard to public sector wage settlements. It is to be expected that incomes policies would have an important effect on public sector earnings insofar as the government has a direct influence on wage settlements. It is interesting to note that it is the first lag of the incomes policy variable which is important rather than the contemporaneous term; this is also a feature of the manufacturing earnings equation. The reciprocal of the short-term unemployment rate was also included in the equation with the contemporaneous term being regarded as endogenous (see Table 3 for further details). The static steady state solution of equation (8) is given as:

$$\ln WAPS = 0.96470 \ln WAEM + 0.00079\ RSTUR \qquad \text{(xv)}$$

The reciprocal of the short-term unemployment rate has a small direct influence in this equation and it is underhomogeneous in WAEM. The homogeneity restriction is not rejected by the data to give equation (9) in Table 3.

Neither equation (8) nor equation (9) appears to suffer from residual autocorrelation and they both pass the forecasting test. The forecast errors for equation (8) from the eight quarter test are:

	Q1	Q2	Q3	Q4
1984	-0.00043	0.00408	0.03049	0.02173
1985	-0.01718	-0.02033	-0.02621	0.00043

None of the forecast errors are significantly different from zero and, in fact, the forecasting performance of this equation is in some sense better than the WAEM and WOO equations since the errors are both positive and negative rather than being persistently positive or negative.

The Properties of the System

It has been stressed in this paper that the earnings equations in the Bank model need to be examined as a system to take account of the interaction between sectors. Despite the fact that the three preferred final equations do not contain any contemporaneous other earnings terms as explanatory variables, the system is simultaneous in a short-run dynamic sense and in the static steady state. We now consider the matrix of static steady state coefficients (the matrix $A^{-1}B$ in equation (vii) evaluated at L=1). If we consider the three unconstrained equations ((1), (4) and (8)) then the $A^{-1}B$ matrix evaluated at L=1 is as follows:

$$
\begin{bmatrix} \ln WAEM \\ \ln WOO \\ \ln WAPS \end{bmatrix} = \begin{bmatrix} 0.594 & 0.280 & 1.101 & -1.497 & -0.623 & 0.330 & 0.00296 \\ 0.376 & 0.472 & 1.063 & -0.948 & -0.394 & 0.556 & 0.00187 \\ 0.573 & 0.270 & 1.062 & -1.444 & -0.601 & 0.319 & 0.00365 \end{bmatrix} \begin{bmatrix} LPROM \\ LPROO \\ \ln PC \\ \ln RET \\ \ln LABM \\ \ln LABN \\ RSTUR \end{bmatrix}
$$

Because of the interaction between sectors, any variable which appears in a single equation will appear in all three equations in the steady state. Thus the trend growth in earnings in each of the sectors is determined by both productivity growth in manufacturing and productivity growth in the economy as a whole. Of particular importance with regard to the coefficients on LPROM and LPROO are the implications for the share of labour income in value-added. If the growth of real earnings were to exceed the growth of productivity this would lead, ceteris paritus, to a decline in the share of profits in value-added. However, firms might resist such a decline and respond by either increasing prices or reducing employment. Some commentators see such a mechanism as an important part of the explanation of stagflation in the 1970s (see, for example, Bruno and Sachs (1985)). Over the period 1966-1984, manufacturing productivity grew on average by 2.8% pa while whole-economy productivity grew by 2% pa. Over the same period real earnings in the manufacturing, non-manufacturing and public sectors grew by 2.4% pa, 2.1% pa, and 1.9% pa respectively. The coefficients in the above matrix imply that, ceteris paribus, if productivity grew at its historical average then real earnings in the manufacturing, non-manufacturing and public sectors would grow at 2.3% pa, 2.0% pa and 2.2% pa respectively. These figures suggest that in this set of equations there does not appear to be any tension over the division of value-added between labour income and profits. However, larger coefficients on LPROM and LPROO might imply a problem in this respect.

All of the equations are slightly over-homogeneous in consumer prices in the static steady-state. In the WAEM and WAPS equations the retentions ratio has a coefficient larger (in absolute terms) than -1. This implies that personal sector taxes have a very powerful effect on earnings and it could be argued that these coefficients are implausibly large. Employers' taxes have an important effect on WAEM and WAPS although the effect is incorrectly signed in the WOO equation. The reciprocal of the short-term unemployment rate has a very weak effect in all three equations. As mentioned earlier the form of this variable not only implies a non-linear response of earnings to the short-term unemployment rate but in addition the elasticity of the response varies with the short-term unemployment rate. The elasticity of earnings with respect to the reciprocal of the short-term unemployment rate is given by:

$$C_{ij} * RSTUR$$

where C_{ij} is the appropriate element of the $A^{-1}B$ matrix. The following table gives the percentage decline in earnings induced by a rise of 100,000 in short-term unemployment at the levels of employment and unemployment prevailing in 1978 and 1985. It illustrates how the effect of short-term unemployment on earnings has fallen with the rise in short-term unemployment. (Over this period short-term unemployment rose from 0.85m to 1.34m.)

Table 4

	1978	1985
WAEM	-1.12	-0.45
WOO	-0.71	-0.28
WAPS	-1.38	-0.55

Short-term unemployment has the largest influence on public sector earnings. This is perhaps surprising given that the public sector is probably the sector which is insulated the most from market related shocks.

The next system examined corresponds to the equations where price homogeneity is imposed and employers' labour taxes no longer appear in the static steady state solution (equations (3), (7) and (9)). The system looks as follows:

$$\begin{bmatrix} \ln WAEM \\ \ln WOO \\ \ln WAPS \end{bmatrix} = \begin{bmatrix} 0.871 & 0.585 & 1.000 & -1.200 & 0.00293 \\ 0.467 & 0.806 & 1.000 & -0.643 & 0.00157 \\ 0.871 & 0.585 & 1.000 & -1.200 & 0.00377 \end{bmatrix} \begin{bmatrix} LPROM \\ LPROO \\ \ln PC \\ \ln RET \\ RSTUR \end{bmatrix}$$

The coefficients on productivity have increased relative to the unconstrained case and it could be argued that they imply implausibly large effects which may lead to some tension in the division of value-added between labour income and profits. On the other hand the coefficients on the retentions ratio have declined. The coefficients on the reciprocal of the short-term unemployment rate have remained remarkably stable.

Estimating the Earnings Equations as a System

The individual structural equations were estimated by instrumental variables to ensure consistency. However, a gain in efficiency can be attained by estimating the equations in a manner that takes account of any cross equation correlation in the residuals. Furthermore, estimating the three equations as a system allows the imposition of cross-equation restrictions which enables the price homogeneity restriction to be imposed in a more general manner by imposing constraints on the appropriate elements of the $A^{-1}B$ matrix. These constraints are both necessary and sufficient for price homogeneity in the static steady state rather than simply sufficient. The estimation method used was the three stage non-linear least squares option on TSP and the equations chosen to form the system were the three equations (1), (4) and (8).

Because of the nature of the estimation procedure only one diagnostic test statistic is reported. $Z_5(3)$is a likelihood ratio type test for first order residual autocorrelation calculated along the lines suggested by Breusch and Godfrey (1981). It takes account of correlation between the contemporaneous residual for each equation and the lagged residuals from the other two equations, as well as its own lagged residual. It is distributed $\chi^2(3)$.

The results of estimating the unconstrained system are given in equations (10), (15) and (20) in Tables 5, 6, and 7 respectively. In the WAEM and WOO equations the majority of the parameter estimates are similar to those in the individual structural equations and the standard errors of the parameter estimates, in general, decline. In addition, the standard errors of these two equations have declined. In the WAPS equation some of the parameter estimates seem to have changed by a larger degree, although again there is a decline in the standard error of the equation. The static steady state of this system is as follows:

$$
\begin{bmatrix} \ln WAEM \\ \ln WOO \\ \ln WAPS \end{bmatrix} = \begin{bmatrix} 0.633 & 0.227 & 1.076 & -1.416 & -0.403 & 0.221 & 0.0024 \\ 0.399 & 0.373 & 1.059 & -0.893 & -0.254 & 0.363 & 0.0015 \\ 0.600 & 0.215 & 1.020 & -1.341 & -0.382 & 0.209 & 0.0023 \end{bmatrix} \begin{bmatrix} LPROM \\ LPROO \\ \ln PC \\ \ln RET \\ \ln LABM \\ \ln LABN \\ RSTUR \end{bmatrix}
$$

The main characteristics of the system are the same as when the equations were estimated individually; all three equations are over-homogeneous in prices, the coefficients on the retentions ratio are greater than unity (in absolute terms) in the WAEM and WOO equations, the effects of short-term unemployment are very weak and employers' labour taxes are again incorrectly signed in the WOO equation.

In order to derive the necessary and sufficient conditions to ensure homogeneity in the static steady state write the expression AY = BX + U from (vi) more generally as:

$$
\begin{bmatrix} \alpha(L) & \beta(L) & \gamma(L) \\ \delta(L) & \epsilon(L) & 0 \\ \phi(L) & 0 & \lambda(L) \end{bmatrix} \begin{bmatrix} \ln WAEM \\ \ln WOO \\ \ln WAPS \end{bmatrix} = \begin{bmatrix} \mu(L) \\ \eta(L) \\ 0 \end{bmatrix} \begin{bmatrix} LPROM \\ LPROO \\ \ln PC \\ \ln RET \\ \ln LABM \\ \ln LABN \\ RSTUR \end{bmatrix}
$$

(assuming for convenience that U = 0). $\alpha(L)$, $\beta(L)$, $\gamma(L)$, $\delta(L)$, $\epsilon(L)$, $\phi(L)$, $\lambda(L)$, $\mu(L)$ and $\eta(L)$ are all polynomials in the lag operator. For clarity of exposition only the third column of the matrix B is considered which corresponds to ln PC in the vector X. By pre-muliplying the matrix B with the inverse of the matrix A, the three long-run coefficients can be written as:

$$\frac{\varepsilon(L)\ \lambda(L)\ \mu(L)\ -\ \beta(L)\ \lambda(L)\ \eta(L)}{\lambda(L)\ \alpha(L)\ \varepsilon(L)\ -\ \gamma(L)\ \phi(L)\ \varepsilon(L)\ -\ \lambda(L)\ \delta(L)\ \beta(L)} = C_{13} \qquad \text{(xvi)}$$

$$\frac{\alpha(L)\ \lambda(L)\ \eta(L)\ -\ \delta(L)\ \lambda(L)\ \mu(L)\ -\ \gamma(L)\ \phi(L)\ \eta(L)}{\lambda(L)\ \alpha(L)\ \varepsilon(L)\ -\ \gamma(L)\ \phi(L)\ \varepsilon(L)\ -\ \lambda(L)\ \delta(L)\ \beta(L)} = C_{23} \qquad \text{(xvii)}$$

$$\frac{\beta(L)\ \phi(L)\ \eta(L)\ -\ \phi(L)\ \varepsilon(L)\ \mu(L)}{\lambda(L)\ \alpha(L)\ \varepsilon(L)\ -\ \gamma(L)\ \phi(L)\ \varepsilon(L)\ -\ \lambda(L)\ \delta(L)\ \beta(L)} = C_{33} \qquad \text{(xviii)}$$

where C_{ij} refers to the (i, j) element in the matrix $A^{-1}B$. The constraints to be imposed are that $C_{13} = C_{23} = C_{33} = 1$. In order to impose these constraints it is necessary to note that C_{33} is a linear function of C_{13}, ie

$$C_{33} = \frac{-\ \phi(L)}{\lambda(L)}\ C_{13} \qquad \text{(xix)}$$

This implies that the three constraints given in expressions (xvi), (xvii) and (xviii) cannot be imposed as they stand. Rather the constraint $\phi(L) = -\lambda(L)$ replaces expression (xviii) and expressions (xvi) and (xvii) are imposed after substituting $\phi(L) = -\lambda(L)$. The intuitive explanation for this is that the only nominal price variable entering the WAPS equation is WAEM, and if the WAEM equation is homogeneous of degree one with repect to prices then WAPS will be as well if the long-run coefficient on WAEM in the WAPS equation is unity. This will be so if $\phi(L) = -\lambda(L)$.

The results of imposing the three constraints are given in equations (11), (16) and (21).[7] These restrictions are rejected by the data with a Wald statistic of 10.55 (distributed $\chi^2(3)$). The particular problem appears to be the restriction on the WAPS equation. Imposing this restriction on its own gives a Wald statistic of 8.30 (distributed $\chi^2(1)$). This is an interesting result given that the data accepted this restriction in the individually estimated structural equation (see equation 9 in Table 3). The explanation for this is that the increase in efficiency brought about by the systems estimation has increased the ability of the data to reject any particular restriction.

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7 In order to impose the constraints, the expressions (xvi) and (xvii) (after subsituting $\phi(L) = -\lambda(L)$) have to be solved as a set of simultaneous equations in two of the parameters selected as the parameters to be constrained.

When price homogeneity is imposed on the three equations the long-run coefficients on employers' labour taxes become incorrectly signed. Imposing first differences gives equations (13), (18) and (23) with a static steady state solution given as:

$$\begin{bmatrix} \ln \text{WAEM} \\ \ln \text{WOO} \\ \ln \text{WAPS} \end{bmatrix} = \begin{bmatrix} 0.864 & 0.577 & 1.000 & -1.141 & 0.00350 \\ 0.461 & 0.800 & 1.000 & -0.609 & 0.00187 \\ 0.864 & 0.577 & 1.000 & -1.141 & 0.00519 \end{bmatrix} \begin{bmatrix} \text{LPROM} \\ \text{LPROO} \\ \ln \text{PC} \\ \ln \text{RET} \\ \text{RSTUR} \end{bmatrix}$$

Although the price homogeneity and first-differencing of employers' labour taxes restrictions are jointly rejected by the data, with a Wald statistic of 15.06 (distributed $\chi^2(5)$), the steady state coefficients look quite reasonable with the exception of the productivity terms which it could be argued imply implausibly large effects since the sum of the coefficients on LPROM and LPROO exceed unity in all three equations.

Imposing restrictions on the long-run consumer price coefficients in just the WAEM and WOO equations and allowing the long-run coefficient in the WAPS equation to be determined freely is not rejected by the data with a Wald statistic of 0.91 (distributed $\chi^2(2)$). These are given as equations (12), (17) and (22).

The final equations chosen at this stage are equations (14), (19) and (24) in tables 5, 6 and 7 respectively. In addition to price homogeneity being imposed for the long-run coefficients on prices in the WAEM and WOO equations, employers' labour taxes only enter as first differences. Thus there is only a short-run effect from a shock to employers' taxes. The Wald statistic for these four restrictions is 4.00 (distributed $\chi^2(4)$). The static steady state solution to equations (14), (19) and (24) is given as:

$$\begin{bmatrix} \ln WAEM \\ \ln WOO \\ \ln WAPS \end{bmatrix} = \begin{bmatrix} 0.700 & 0.492 & 1.000 & -1.241 & 0.0022 \\ 0.376 & 0.752 & 1.000 & -0.666 & 0.0012 \\ 0.659 & 0.463 & 0.942 & -1.169 & 0.0020 \end{bmatrix} \begin{bmatrix} LPROM \\ LPROO \\ \ln PC \\ \ln RET \\ RSTUR \end{bmatrix}$$

The important features of this system relative to the unconstrained case (see page 26) is that the retentions ratio effect is smaller and the productivity effect larger. However, the effect from productivity is smaller than in the system reported on page 24. The unemployment effects remain broadly unchanged.

Section III: The Dynamic Properties of the Earnings Equations

In order to examine the dynamic properties of the earnings equations a version of the system consisting of equations (14), (19) and (24) was re-estimated over the whole data period available (ie 1966 Q2 - 1985 Q4) to give the equations presented in Table 8. The purpose of re-estimating the equations over an extended data set was to make use of the data reserved previously for the forecasting tests. The static steady state solution is given as:

$$\begin{bmatrix} \ln WAEM \\ \ln WOO \\ \ln WAPS \end{bmatrix} = \begin{bmatrix} 0.764 & 0.385 & 1.000 & -1.071 & 0.00207 \\ 0.287 & 0.701 & 1.000 & -0.402 & 0.00078 \\ 0.723 & 0.364 & 0.946 & -1.013 & 0.00180 \end{bmatrix} \begin{bmatrix} LPROM \\ LPROO \\ \ln PC \\ \ln RET \\ RSTUR \end{bmatrix}$$

The static steady state is broadly similar to the system estimated over the shorter data period. This system of equations is stable with all the eigenvalues lying within the unit circle. The mean lag of the system is just over 5 quarters.[8]

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8 I am grateful to Stephen Hall for the use of one of his programs to calculate the eigenvalues of the system.

An important concept when considering the dynamic properties of the system is the dynamic steady state given by these equations. In order to derive the dynamic steady state consider the $A^{-1}B$ matrix given in equation (vii) without solving for L=1 as in the case of the static steady state. This derivation ignores the constant terms, the dummy variables and the incomes policy variables. The justification for ignoring the latter is that, in the dynamic steady state, this variable may well be zero either due to the absence of an incomes policy at all or because $\Delta W_t^e = NORM_t$ in equation (iv). Furthermore, it is assumed that future prices are known with certainty, ie ${}_tP_{t+4}^e = P_{t+4}$, and that the retentions ratio and the short-term unemployment rate both remain constant over time. The system can be written as:

$$\begin{bmatrix} \alpha(L) & \beta(L) & \gamma(L) \\ \delta(L) & \varepsilon(L) & 0 \\ \phi(L) & 0 & \lambda(L) \end{bmatrix} \begin{bmatrix} \ln WAEM \\ \ln WOO \\ \ln WAPS \end{bmatrix} = \begin{bmatrix} \theta(L) & 0 & \mu(L) & \psi(L) & \rho(L) \\ 0 & \tau(L) & \eta(L) & 0 & 0 \\ 0 & 0 & 0 & 0 & \omega(L) \end{bmatrix} \begin{bmatrix} LPROM \\ LPROO \\ \ln PC \\ \ln RET \\ RSTUR \end{bmatrix}$$

where

$\alpha(L) = 1 - 0.70303L$

$\beta(L) = -0.11248L$

$\gamma(L) = -0.09746L^3$

$\delta(L) = -0.64931L + 0.51531L^2$

$\varepsilon(L) = 1 - 0.52103L - 0.26790L^2 + 0.14580L^3$

$\phi(L) = -0.84812L + 0.57611L^3 + 0.65085L^4 - 1.12210L^5 + 0.36764L^8$

$\lambda(L) = 1 - 0.40128L - 0.32025L^3 + 0.11879L^4$

$\theta(L) = 0.12427L$

$\mu(L) = 0.31342L^{-4} - 0.31342 + 0.28980L - 0.19746L^2$

$\psi(L) = -0.17415L$

$\rho(L) = 0.00035$

$\tau(L) = 0.19850L$

$\eta(L) = 0.15871L^{-4} - 0.15871 + 0.81003L - 0.58716L^2$

$\omega(L) = 0.00053 - 0.00188L + 0.00129L^2$

and L^i is the lag operator and L^{-i} is the lead operator.

The method used to derive the dynamic steady state equations involved multiplying the matrix B with the transpose of the adjoint of the matrix A. This leaves the vector of earnings variables being pre-multiplied by a diagonal matrix with the determinant of A down the diagonal.[9] Then the method outlined in Currie (1981) was applied to the semi-reduced form to give the dynamic steady state solution as follows:

$$\begin{bmatrix} \ln WAEM \\ \ln WOO \\ \ln WAPS \end{bmatrix} = \begin{bmatrix} 0.76 & 0.38 & 1.00 & -1.07 & 0.0021 & -8.05 & -5.11 & 3.08 \\ 0.29 & 0.70 & 1.00 & -0.40 & 0.0008 & -2.70 & -5.23 & 3.29 \\ 0.72 & 0.36 & 0.95 & -1.01 & 0.0018 & -7.66 & -4.85 & 2.85 \end{bmatrix} \begin{bmatrix} LPROM \\ LPROO \\ \ln PC \\ \ln RET \\ RSTUR \\ \pi_1 \\ \pi_2 \\ \pi_3 \end{bmatrix}$$

where $\pi_1 = \ln\left(\frac{MPRO}{LEMF}\right)_t - \ln\left(\frac{MPRO}{LEMF}\right)_{t-1}$

$$\pi_2 = \ln\,(GDPO/(LE + LSE + LHMF))_t - \ln\,(GDPO/(LE + LSE + LHMF))_{t-1}$$

$$\pi_3 = \ln PC_t - \ln PC_{t-1}$$

The coefficients on the levels terms are the same as in the static steady state but in addition there are growth effects with non zero coefficients on π_1, π_2 and π_3. What these coefficients imply is that the level of earnings in the dynamic steady state will be lower if trend productivity growth is higher and higher if the rate of price inflation is higher. Currie (op cit) discusses whether such growth effects are desirable and suggests that in some instances the coefficients on the π terms should be constrained to be zero. In this example it would be very laborious to derive these coefficients analytically so no attempt has been made to test the coefficient restrictions which would need to be imposed. Furthermore, Patterson and Ryding (1984) question whether such constraints are, in fact, desirable since they are likely to lead to important changes in the dynamic structure of the equations.

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9 I am grateful to the Mathematical Techniques Group in the Bank for solving this problem.

The Simulation Properties

Another way of examining the dynamic properties of the earnings equations is to incorporate them into the Bank model and to run some simulation experiments. These simulation exercises take the form of examining how the model behaves in response to a shock to one or more of the exogenous variables where the solution path of the model after the shock has been administered is compared to a base case. The results of these simulations may indicate whether the growth effects identified in the dynamic steady state solution are important in practice. These simulations do not, of course, isolate the dynamic properties of the earnings sub-system independently of the dynamic properties of the rest of the model, neither do they have any particular policy prescriptions. Rather, they simply illustrate the marginal properties of the Bank model. Nevertheless, they are informative and assist in determining whether the equations should ultimately form part of the Bank model.

Prior to discussing the simulation results two issues need to be addressed. The first concerns how the inflationary expectations term in the WAEM and WOO equations is handled in the current solution suite for the Bank model. Given that the equations were estimated assuming rationally formed expectations they should really be embedded into a model which has an appropriate forward looking solution suite. However, this is not the case with the current Bank model so that as an approximation, inflationary expectations are modelled as a distributed lag of inflationary expectations and actual inflation, although it is recognised that this method does lose an important transmission mechanism for inflationary shocks.

The second issue concerns the specification of the short-term unemployment equation. Research in the Bank has found that it is quite difficult to estimate an equation for short-term unemployment which has acceptable theoretical and empirical properties. As a consequence of this a rather simple equation was used in these simulations to model changes in short-term unemployment conditional upon changes in total unemployment. The equation used is:

$$\Delta_1 LUST_t = \underset{(6.33)}{0.744}\, \Delta_1 LU_t - \underset{(1.88)}{0.221}\, \Delta_1 LU_{t-1} \qquad \text{(xx)}$$

Sample period 1968 Q1 - 1979 Q4. SEE 28.89.Durbin Watson 1.76.t statistics in parentheses.

Although this equation does not have a long-run solution in levels it nevertheless provides an acceptable equation for simulation purposes. Hopefully, future work in this area will be able to provide a better equation.

The simulation results are now discussed. Three exogenous shocks were considered; an increase in world prices, a cut in personal sector income tax and an increase in government current expenditure. All the simulations were run on a ten year simulation base with the exchange rate constrained throughout.

An Increase in World Prices

In this simulation all world prices (including world unit labour costs) are raised 2% above the base throughout. A shock of this sort primarily feeds into UK domestic inflation via the unit value indices for imports which in turn feed into manufacturers' wholesale prices. The transmission into domestic prices occurs fairly slowly with manufacturers' wholesale prices fully reflecting this increase in world prices only after about four years. There is a further one year lag before consumer prices rise above the base to the full extent of the initial shock (ie 2%). Whole economy average earnings initially respond more slowly than consumer prices with a consequent small decline in real earnings. After about three years, however, average earnings overshoot prices slightly and there is a small increase in real earnings until the final year of the simulation when whole economy real earnings are almost unchanged relative to the base (see Figure 4). The different sectors respond at different rates to the price shock with the fastest sector being non-manufacturing which responds slightly more quickly than the manufacturing sector over the first five years of the simulation (see Figure 5). The non-manufacturing earnings equation has the largest impact elasticity with respect to consumer prices (0.81 compared to 0.29 for manufacturing). Earnings in the non-trading public sector are the slowest to respond since the price shock only feeds in indirectly via manufacturing earnings. Furthermore, although during the course of the simulation non-trading public sector earnings appear to catch up with manufacturing earnings, by the end of the simulation period they reach only 93% of the response of manufacturing earnings. This is very close to the long run response of 0.95 given on page 30.

INCREASE IN WORLD PRICES

FIGURE 4
PRICES AND AVERAGE EARNINGS. % DIFFERENCES FROM BASE

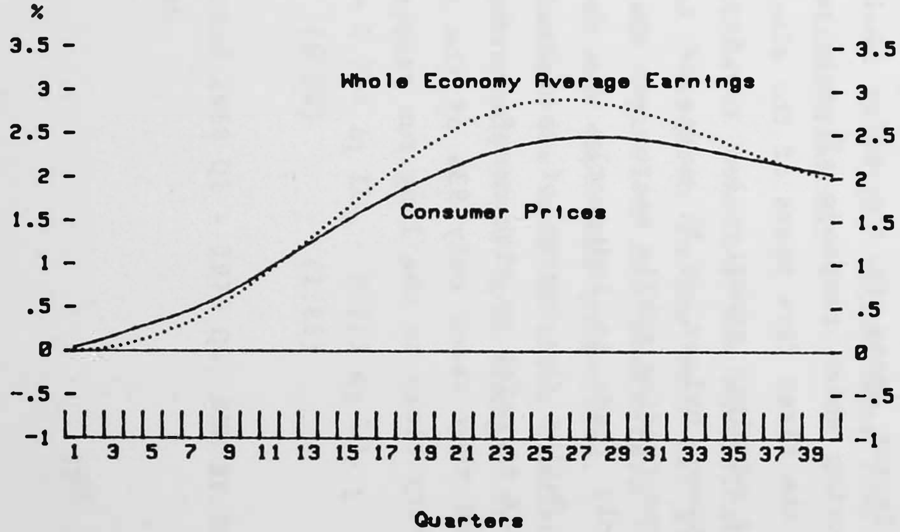


FIGURE 5
RELATIVE RESPONSE IN EARNINGS % DIFFERENCES FROM BASE

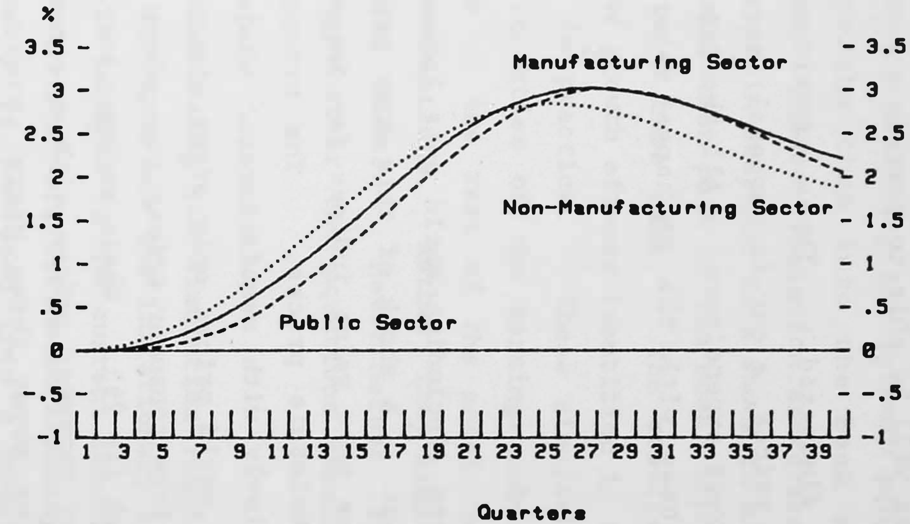


FIGURE 6
GDP % DIFFERENCES FROM BASE.

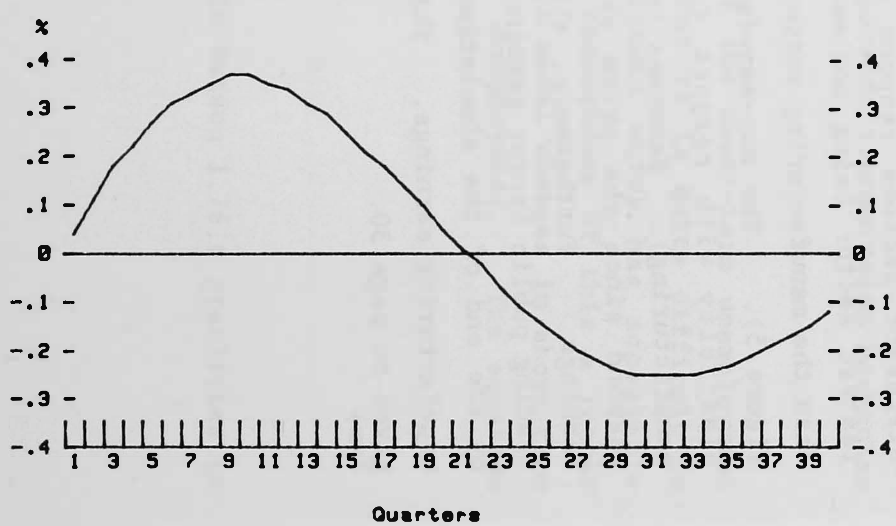
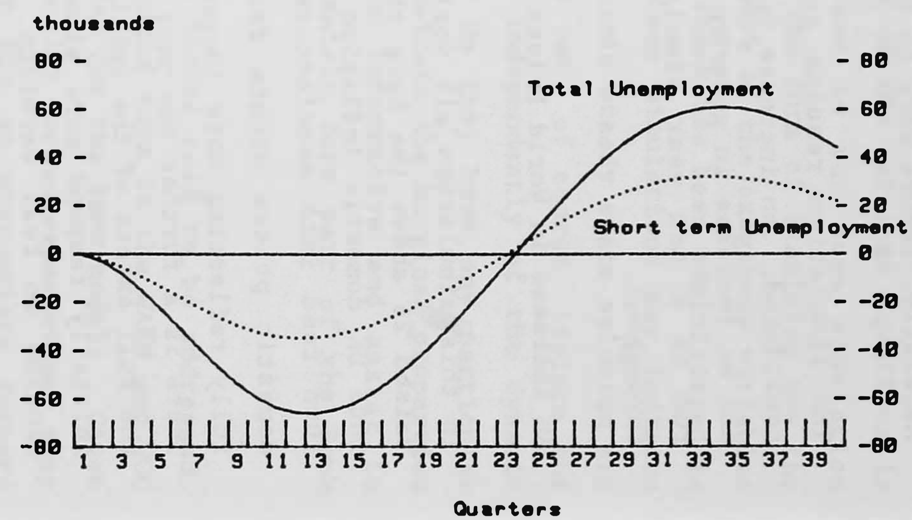


FIGURE 7
UNEMPLOYMENT. LEVELS DIFFERENCES FROM BASE



It is important to know the degree to which domestic prices in the model are homogeneous with respect to world prices in the long run. A plausible simulation property, with the exchange rate constrained, would be homogeneity of degree one so that an x% increase in all world prices would eventually lead to an increase of x% in UK domestic prices. This simulation suggests that the model does in fact have this property. This follows from the proposition that homogeneity of degree one in the individual price and earnings equations in the model is a sufficient but not necessary condition that the model as a whole will exhibit homogeneity of degree one if the exchange rate is constrained. Consumer prices increase relative to the base by more than 2% after about six years but turn down again after about eight years and end the simulation period exactly 2% above the base.

It ought to be noted that this simulation property is very sensitive to the assumption made about the exchange rate. If the exchange rate is allowed to be determined endogenously by the model then consumer prices respond with a more marked cyclical pattern rising to about 3 1/4% above the base after about seven years and declining to about 1 1/2% below the base at the end of ten years. The simulation base is too short to determine whether this cycle will eventually damp down or not. This suggests that there may be some problems with the properties of the exchange rate equation currently in the Bank model rather than with the domestic wages and prices sectors. This is the reason why in this paper we report the simulation properties of the model with the exchange rate constrained to the base.[10]

Turning to the real side of the economy, domestic output never deviates by more than 1/2% from the base (see Figure 6). Initially GDP is slightly above the base as the initial beneficial shock to competitiveness increases exports and reduces imports. However, as domestic prices respond, the expansionary effect from net trade declines and GDP falls below the base after about six years. Investment responds initially to the increase in activity but eventually falls below the base. Consumers' expenditure remains broadly unchanged for about seven years as an increase in expenditure on consumer durables from about the third year broadly offsets a decline in expenditure on non-durables. However, after about eight years expenditure on consumer

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10 The property that, in this simulation, there is more of a cyclical pattern in domestic prices and earnings when the exchange rate is determined endogenously is also a feature of the version of the model reported in Patterson et al (1987).

durables also falls below the base. Expenditure on non-durables is below the base throughout primarily due to inflationary losses on liquid assets and wealth. The increase in expenditure on consumer durables, relative to the base, is partly due to lower real interest rates which affects this category of consumption directly and lower nominal interest rates, brought about by a lower PSBR, which affects consumption via mortgage lending.

Initially both total unemployment and short-term unemployment fall below the base as output expands (see Figure 7). After about four years the former declines by around 60,000 while the latter declines by around 30,000. After just over five years both rise above the base as the stimulus to domestic output is reversed.

A Cut in Personal Sector Income Tax

In this simulation the basic rate of personal sector income tax (TRY) is reduced by 2 1/2% percentage points. At 1986 Q1 levels, a change in TRY from 30% to 27 1/2% would lead to a change in the retentions ratio from 0.73 to 0.75, ie after the tax reduction 75% of persons' pre-tax earnings are retained as post-tax earnings.[11]

It was mentioned earlier that the retentions ratio term has a very powerful effect in the earnings equations and this property is very apparent from this simulation. The reduction in taxes generates a downward movement in nominal earnings and prices which, at least during the period under consideration, does not show any sign of slowing down. At the end of the ten year period whole economy average earnings are just over 7 1/4% below the base while consumer prices are just over 4 1/2% below the base (see Figure 8). Because earnings respond directly to the tax cut and prices respond with a lag there is a decline in real pre-tax earnings throughout. However, because of the direct effects of the tax cut, real personal disposable income is higher than the base throughout.

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11 The percentage points change in the retentions ratio is not the same as that for the basic rate of tax due to the former variable also taking account of national insurance contributions and personal tax allowances.

One reason why the responses of earnings and prices do not appear to flatten out very quickly is the very weak Phillips curve effect in these equations. Over the course of the simulation, short-term unemployment is significantly different from the base (see Figure 11) but this seems to put very little upward pressure on earnings. By the end of the simulation, short-term unemployment is about 250,000 lower than in the base which corresponds to a change in the short-term unemployment rate from 4.68% in the base to 3.77% in the simulation. At this short-term unemployment rate the changes induced in this simulation would, ceteris paribus, lead to an increase in real earnings of about 1% for the manufacturing and non-trading public sectors and about 1/2% for the non-manufacturing sector.

There is another important mechanism in the Bank model which contributes to the failure of nominal earnings and prices to stablise to any great extent. Real earnings decline in this simulation relative to the base and because there is a real wage term in the manufacturing labour demand schedule this will lead to firms taking on more employees even for given output. This reduction in manufacturing productivity in turn puts downward pressure on real earnings. (Productivity in manufacturing is 3 1/4% below the base by the end of the simulation but this, of course, includes other effects on productivity besides the real wage effect on labour demand.) The fall in nominal earnings, relative to the base, is larger than the decline in productivity so that unit labour costs in manufacturing decline relative to the base. This ensures that the decline in productivity does not lead to any upward pressure on prices. This property, along with the weak Phillips' curve effect, seems to suggest that self-perpetuating cycles can be generated in the Bank model where a cut in real earnings leads to an increase in the demand for labour, lower productivity and still lower real earnings. In addition, both output and employment are raised.

This simulation illustrates the potential tensions in the model regarding the division of value-added between labour income and profits, since the sum of the coefficients on the productivity terms exceeds unity in the WAEM and WAPS equations. Because nominal earnings decline in this simulation, relative to the base, by more than the decline in productivity there is a decline in labour's share of value-added and firms respond by reducing prices and increasing employment. Because the model is broadly linear, an increase in the rate of personal sector income tax would lead to a rise in nominal earnings larger than the increase in productivity which would lead to upward pressure on prices and a decline in employment as firms resist labour's

CUT IN INCOME TAX

FIGURE 8

PRICES AND AVERAGE EARNINGS. % DIFFERENCES FROM BASE.

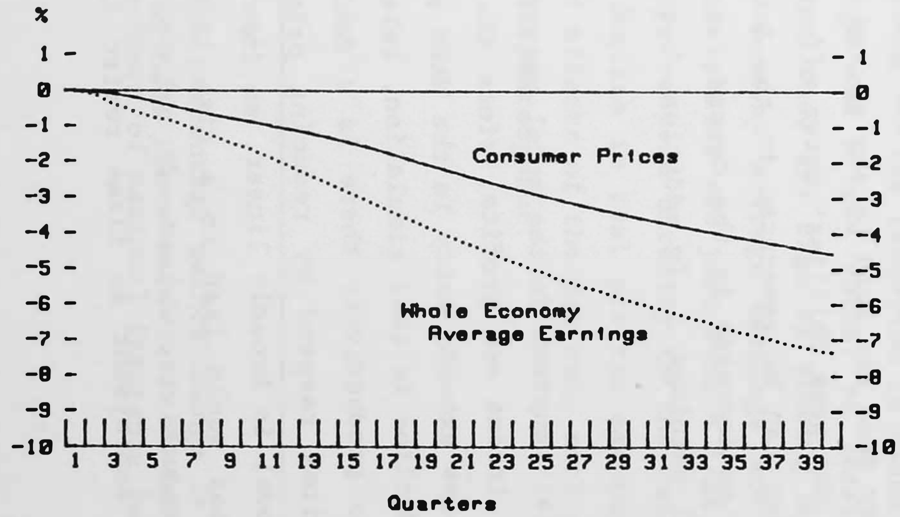


FIGURE 9

RELATIVE RESPONSE IN EARNINGS % DIFFERENCES FROM BASE.

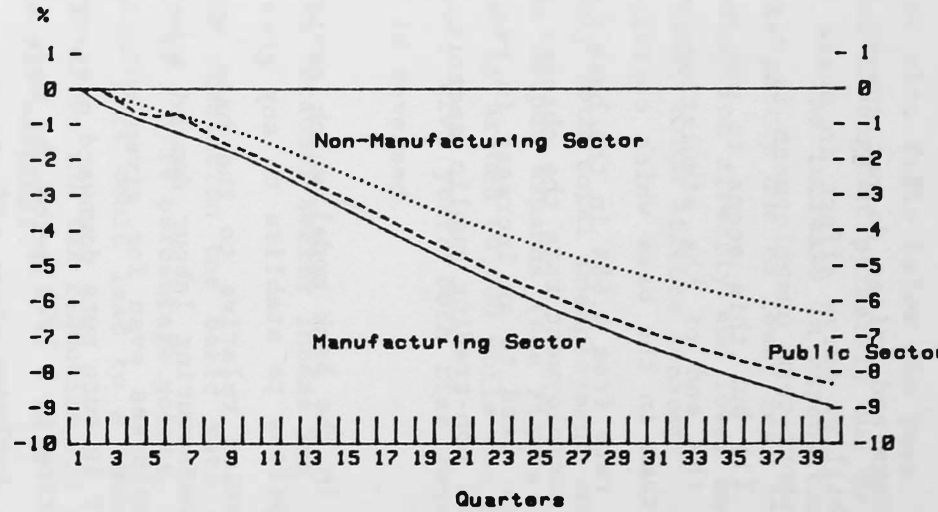


FIGURE 10

GDP % DIFFERENCES FROM BASE.

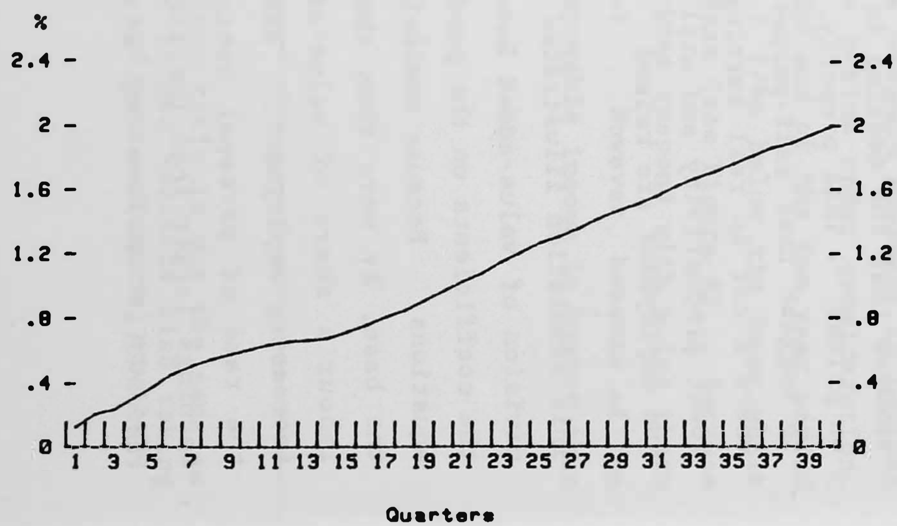
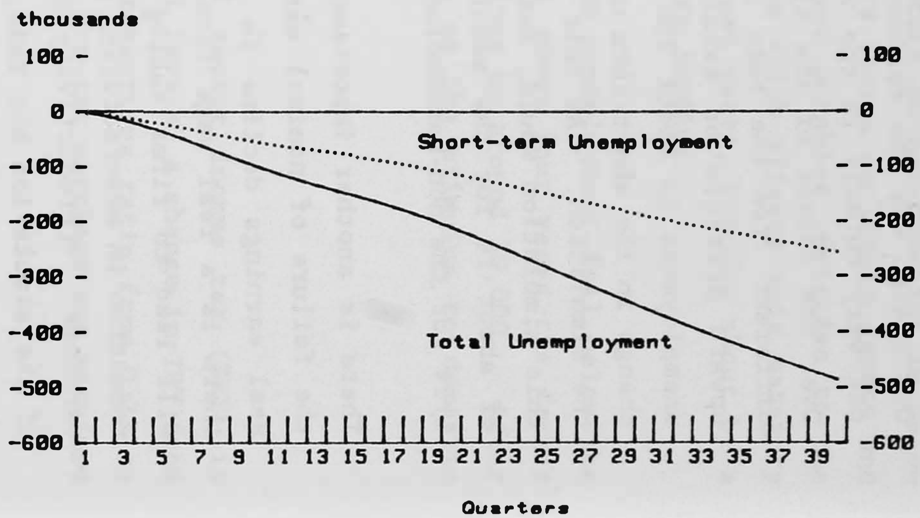


FIGURE 11

UNEMPLOYMENT. LEVELS DIFFERENCES FROM BASE.



attempt to increase its share of value-added. This simulation does illustrate a problem in using a moving average proxy for trend productivity where changes in productivity which do not represent true changes in trend productivity lead to important repercussions in the rest of the model.

The different sectors respond at different rates to the shock (see Figure 9). The quickest response is in the manufacturing sector because it is this equation which directly responds to the increase in the retentions ratio.

Turning to the real side of the economy GDP is above the base throughout, ending the simulation period 2% above (see Figure 10). The increase in real personal disposable income brought about directly by the tax cut and the increase in persons' real liquid assets and real financial wealth caused by the fall in prices all contribute to higher consumers' expenditure. Exports are higher than the base throughout due to the depreciation in the real exchange rate (a decline in prices with a fixed nominal exchange rate). Despite the improvements in competitiveness imports are above the base for the first six years due to the effects of the increase in domestic demand. By the end of the simulation, however, the competitiveness effect slightly outweighs the demand effect and imports end the simulation period about 1/4% below the base.

An Increase in Government Expenditure

In this simulation government current expenditure is increased by £400 m (1980 prices) per quarter throughout. There is a very small inflationary effect in this simulation with consumer prices only around 3/4% above the base after ten years (see Figure 12). However, about 2/3 of this increase in prices is due to an increase in local authority receipts of rates which in the model finances a part of the increase in government current expenditure.

This simulation again illustrates how weak the Phillips curve effect is in these equations. Early on in the simulation the level of short-term unemployment is almost 70,000 lower than in the base which corresponds to a change in the short-term unemployment rate from around 4.57% to 4.32%. At this level of the short-term unemployment rate the changes induced by this simulation would, ceteris paribus, lead to an increase in the real wage of 1/4% for the manufacturing and non-trading public sectors and about 0.1% for the non-manufacturing sector.

INCREASE IN GOVERNMENT EXPENDITURE

FIGURE 12

PRICES AND AVERAGE EARNINGS. % DIFFERENCES FROM BASE.

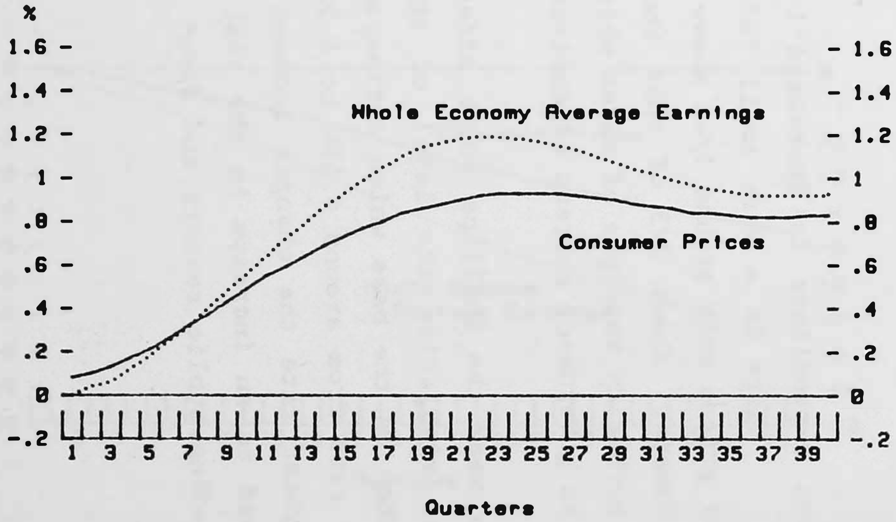


FIGURE 13

RELATIVE RESPONSE IN EARNINGS. % DIFFERENCES FROM BASE.

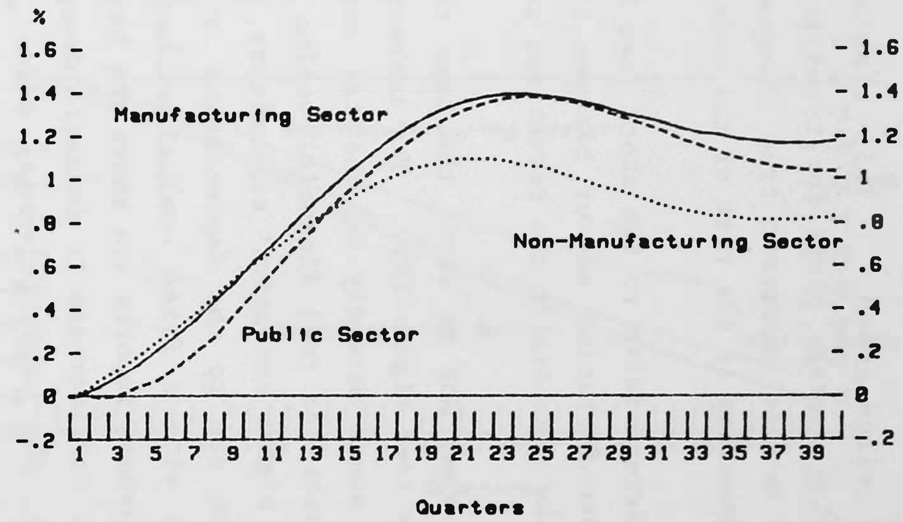


FIGURE 14

GDP % DIFFERENCES FROM BASE.

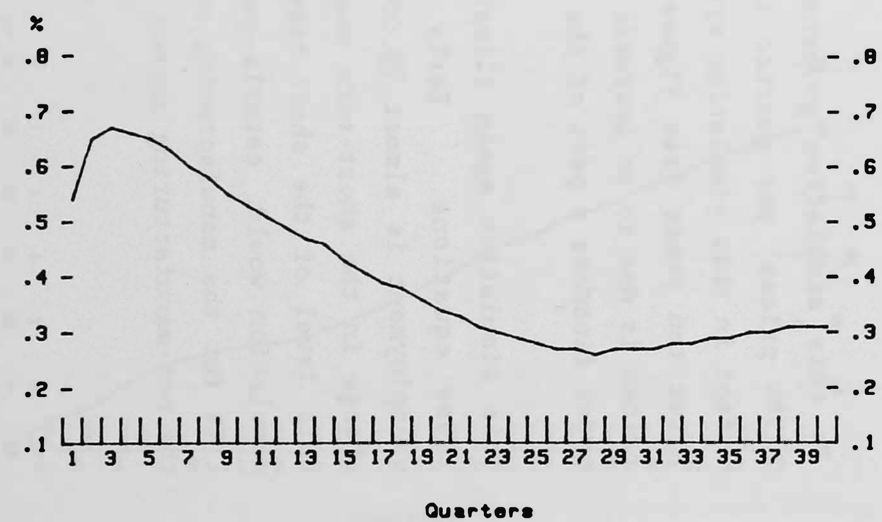
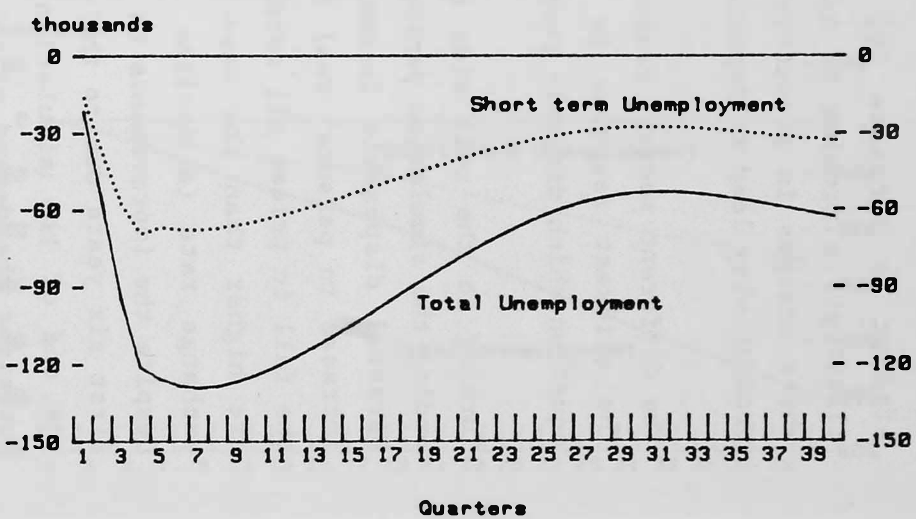


FIGURE 15

UNEMPLOYMENT. LEVELS DIFFERENCES FROM BASE.



The level of GDP is higher than the base throughout the simulation period although there is considerable crowding out as the simulation proceeds (see Figure 14). The reason for this crowding out is an appreciation in the real exchange rate, which occurs due to the small rise in domestic prices with the exchange rate constrained, which depresses output in the manufacturing and non-manufacturing sectors. In addition, the increase in the PSBR puts upward pressure on nominal interest rates.

Section IV: Conclusions and Suggestions for Further Work

The aim of the research reported here was to improve the earnings equations in the Bank of England macroeconomic model of the UK economy. However, as with any research project there remain many issues which require further investigation. This section draws some conclusions from the work already undertaken and discusses how future work might proceed.

The equations presented in this paper appear to be an adequate representation of earnings in the three disaggregated sectors with plausible theoretical and empirical properties. Although the system of equations is not contemporaneously simultaneous, there are nevertheless important intersectoral effects and as a consequence the equations have a fairly rich dynamic structure. Other variables found to be important in determining nominal earnings are labour productivity, consumer prices, inflationary expectations, personal sector taxes and employers' labour taxes, although the last variable only has an effect in the short-run. An important result of this research is that short-term unemployment does not have a very powerful effect on earnings.

The intersectoral effects in these equations may imply a certain amount of nominal inertia in the inflationary process. Since earnings in each sector depend on lagged earnings in the other sectors as well as lagged prices, a shock to prices may take longer to feed through fully to earnings than if earnings simply depended on past prices. This, along with the small effect from short-term unemployment and the large increases in labour productivity in the early 1980s, may provide part of the explanation of why the growth of nominal earnings has remained relatively high recently despite falls in inflation.

One question which is often asked of a disaggregated labour market is whether there is a leading sector. There are two ways in which this notion might be interpreted. The first is that within any annual wage round a particular sector might temporally lead the other two sectors. This would occur if an annual wage round existed as a well defined phenomenon and different groups of employees settled at the same time each year. However, the model presented here does not really address this issue. The second possible interpretation of the notion of a leading sector is that a particular sector might respond more quickly to a shock than the other sectors. With this interpretation the leading sector may vary according to the nature of the shock. Thus, in the equations presented in Table 8 the manufacturing sector is the leading sector in response to a shock to personal sector taxes because the manufacturing earnings equation is the only equation which directly includes the retentions ratio as an explanatory variable. The simulations reported earlier indicate that the non-manufacturing sector is the leading sector in response to a shock to prices. This property can also be seen from the coefficients on consumer prices in the WAEM and WOO equations. The public sector will lead very slightly in response to an unemployment shock with a slightly larger impact elasticity than in the manufacturing sector. Finally, perhaps surprisingly the manufacturing sector will lead in response to an incomes policy shock because the incomes policy variable enters the manufacturing earnings equation contemporaneously (as well as lagged once) whilst only occurring with a lag in the public sector equation.

The simulations reported here illustrate the dominance of the cost-push approach to pricing behaviour in the Bank model. With the exchange rate constrained the two main channels through which demand pressures can affect prices are via short-term unemployment influencing earnings and employed factor utilisation rates affecting manufacturing margins, and it has been amply demonstrated that the former effect is very weak in the equations reported here.

As has been mentioned earlier, an important feature of these equations is the influence of productivity on real earnings. If the sum of the coefficients on the two productivity terms in the equations exceeds unity then a balanced increase in productivity of 1% will lead to real earnings rising by more than 1%. It might be considered desirable to impose restrictions on the equations to ensure that shares in value-added remain constant in the steady state. However, it is not really feasible to impose the necessary and sufficient conditions in the way that price homogeneity has been imposed because the two sets of restrictions would become extremely complicated. Further work could investigate the imposition of sufficient conditions to ensure constant shares in value-added which could probably be imposed along with the price homogeneity restrictions.

The estimated equations suggest that there is an important role for inflationary expectations in the wage bargaining process. Apart from price expectations a disaggregated labour market could also incorporate sectoral wage expectations, ie earnings in any one sector will not only be influenced by expectations of price inflation but also by expectations of earnings in the other two sectors. This is something which could be investigated further.

One issue which has received a certain amount of attention recently in the literature is the appropriate role of corporate profits in determining wage behaviour. Carruth and Oswald (1987) find empirical evidence that profits (real profits per unit of capital stock) have a direct influence on real product wages. They argue that this result is consistent with microeconomic industrial relations data (see, for example, Gregory et al (1985, 1987)). The model presented by Rowlatt (1986) also includes a term in profits (real profits per unit of private sector output) which has a significant effect in her preferred equation. In contrast, Hall and Henry (1987) failed to find any empirical support for the inclusion of a real profits term in an aggregate earnings equation. The evidence on this issue is, at this stage, rather inconclusive and would hence warrant some further research which could be carried out within the context of the disaggregated model presented here.

Finally, there has been some discussion of the effect of the housing market on wages (see, for example, articles by John Muellbauer in the Financial Times on 23/10/86 and 23/12/86) but this has yet to influence the main macroeconomic modellers to any great extent. However, it is something that requires further investigation.

TABLE 1: Manufacturing Earnings
Dependent Variable is ln $WAEM_t$

	Equation (1) Unconstrained equation	Equation (2) Price homogeneity imposed	Equation (3) Price homogeneity and Δ_1 on ln LABM imposed
ln $WAEM_{t-1}$	0.67329 (13.16)	0.69397 (14.45)	0.69804 (14.64)
$LPROM_{t-1}$	0.08443 (2.40)	0.10217 (3.21)	0.10996 (3.62)
$RSTUR_t$	0.00034 (3.14)	0.00033 (3.12)	0.00029 (3.18)
ln PC_{t-1}	0.29836 (3.22)	0.24709 (3.02)	0.24732 (3.03)
ln PC_{t-2}	-0.19154 (2.60)	-0.19075 (-)	-0.19080 (-)
ln $WAPS_{t-3}$	0.10258 (4.50)	0.10090 (4.44)	0.09512 (4.43)
ln RET_{t-1}	-0.21278 (3.96)	-0.17680 (4.01)	-0.15153 (5.05)
ln $LABM_t$	-0.85272 (3.71)	-0.80191 (3.56)	-0.84516 (3.87)
ln $LABM_{t-1}$	0.76419 (3.24)	0.86442 (3.93)	0.84516 (-)
ln WOO_{t-1}	0.13524 (2.95)	0.14878 (3.35)	0.15032 (3.39)
Constant	-0.10652 (0.39)	-0.32004 (1.60)	-0.29621 (1.50)
DEPC	0.37676 (5.71)	0.31189 (8.61)	0.29256 (11.06)
$IP1_t$	-0.02942 (1.06)	-0.03728 (1.39)	-0.03816 (1.43)
$IP1_{t-1}$	-0.17558 (5.16)	-0.16567 (5.03)	-0.15405 (5.25)
TDAYWK	-0.05678 (9.16)	-0.05730 (9.27)	-0.05818 (9.58)
SEE	0.00565	0.00565	0.00564
Z_1 (4)	6.76	8.67	8.66
Z_2 (4)	10.70	12.33	12.38
Z_3 (4)	4.37	4.67	4.53
Z_3 (8)	9.35	8.53	8.01
Z_4 (6)	8.28	9.37	9.76
Wald statistics for linear restrictions		1.39 ($\chi^2(1)$)	2.00 ($\chi^2(2)$)

For footnotes see page 55

TABLE 2: Non-Manufacturing Earnings

Dependent Variable is ln WOO_t

	Equation (4) Unconstrained equation	Equation (5) Δ_1 on ln LABN imposed	Equation (6) Price homogeneity imposed	Equation (7) Price homogeneity and Δ_1 on ln LABN imposed
ln WOO_{t-1}	0.38042 (3.11)	0.38274 (3.14)	0.38036 (3.15)	0.39265 (3.22)
ln WOO_{t-2}	0.20302 (1.63)	0.21073 (1.70)	0.20298 (1.65)	0.22190 (1.80)
ln WOO_{t-3}	-0.24130 (1.97)	-0.21260 (1.81)	-0.24132 (1.99)	-0.18839 (1.66)
$LPROO_{t-1}$	0.19387 (1.39)	0.23307 (1.77)	0.19372 (1.42)	0.28215 (2.47)
ln PC_{t-1}	0.89975 (3.67)	0.95240 (4.02)	0.90001 (3.75)	0.95321 (4.00)
ln PC_{t-2}	-0.65844 (3.05)	-0.65792 (3.06)	-0.65824 (-)	-0.68699 (-)
ln $WAEM_{t-1}$	0.82467 (4.60)	0.79338 (4.53)	0.82463 (4.65)	0.77674 (4.45)
ln $WAEM_{t-2}$	0.40825 (2.25)	-0.45799 (2.67)	-0.40842 (2.29)	-0.46911 (2.73)
ln $LABN_t$	-0.78838 (1.66)	-0.95369 (2.19)	-0.78956 (1.80)	-0.90454 (2.09)
ln $LABN_{t-1}$	1.01684 (2.30)	0.95369 (-)	1.01686 (2.32)	0.90454 (-)
Constant	2.33871 (3.65)	2.49595 (4.07)	2.34096 (4.31)	2.28728 (4.18)
DEPC	0.13410 (1.64)	0.13743 (1.69)	0.13442 (2.03)	0.09414 (1.66)
Z_1 (4)	5.75	6.36	5.68	6.52
Z_2 (4)	7.56	8.22	7.44	8.74
Z_3 (4)	9.38	12.15	8.87	12.01
Z_3 (8)	12.79	15.71	12.31	15.71
Z_4 (6)	6.00	6.60	6.00	6.88
SEE	0.01528	0.01524	0.01516	0.01533
Wald statistics for linear restrictions		0.75 ($\chi^2(1)$)	0.00004 ($\chi^2(1)$)	1.29 ($\chi^2(2)$)

For footnotes see page 55

TABLE 3: Non-Trading Public Sector Earnings
Dependent Variable is ln $WAPS_t$

	Equation (8) Unconstrained equation	Equation (9) Price homogeneity imposed
ln $WAPS_{t-1}$	0.33730 (3.03)	0.34973 (2.87)
ln $WAPS_{t-3}$	0.39078 (3.35)	0.41075 (3.23)
ln $WAPS_{t-4}$	-0.13348 (1.24)	-0.14942 (1.27)
ln $WAEM_{t-1}$	0.98941 (6.89)	1.04859 (6.83)
ln $WAEM_{t-3}$	-0.78462 (2.84)	-0.86699 (2.92)
ln $WAEM_{t-4}$	-0.58295 (1.82)	-0.58123 (1.65)
ln $WAEM_{t-5}$	1.16782 (4.89)	1.19936 (4.59)
ln $WAEM_{t-8}$	-0.39857 (4.34)	-0.41079 (-)
$RSTUR_t$	0.00259 (1.47)	0.00428 (2.96)
$RSTUR_{t-1}$	-0.00497 (1.90)	-0.00728 (3.22)
$RSTUR_{t-2}$	0.00270 (2.14)	0.00384 (3.56)
$IP3_{t-1}$	-0.19701 (2.66)	-0.20061 (2.47)
Constant	0.81701 (4.24)	0.69727 (3.66)
CATCH75	0.068191 (3.28)	0.06596 (2.89)
CLEGG	0.04358 (3.59)	0.04136 (3.12)
Z_1 (4)	3.52	4.24
Z_2 (4)	4.47	5.55
Z_3 (4)	3.37	2.53
Z_3 (8)	8.57	8.20
Z_4 (4)	3.27	4.23
SEE	0.01813	0.01992
Wald Statistics for linear restrictions		2.07 ($\chi^2(1)$)

For footnotes see page 55

TABLE 5: System Estimation: Manufacturing Earnings
Dependent Variable is ln WAEM

	Equation (10) Unconstrained equation	Equation (11) Cross equation homogeneity imposed on all three equations	Equation (12) Cross equation homogeneity imposed on lnWAEM and lnWOO
ln $WAEM_{t-1}$	0.67606 (15.67)	0.68926 (16.23)	0.68117 (16.00)
$LPROM_{t-1}$	0.08932 (3.05)	0.10070 (3.56)	0.09753 (3.48)
$RSTUR_t$	0.00035 (3.69)	0.00036 (3.80)	0.00035 (3.70)
ln PC_{t-1}	0.29436 (3.69)	0.24559 (3.36)	0.26810 (3.64)
ln PC_{t-2}	-0.19539 (2.89)	-0.18853 (2.86)	-0.19228 (2.93)
ln $WAPS_{t-3}$	0.10021 (5.12)	0.10374 (5.28)	0.10294 (5.36)
ln RET_{t-1}	-0.19983 (5.27)	-0.17961 (5.02)	-0.18909 (5.24)
ln $LABM_t$	-0.84974 (4.21)	-0.79900 (3.98)	-0.82142 (4.12)
ln $LABM_{t-1}$	0.79279 (3.85)	0.88585 (4.50)	0.85036 (4.36)
ln WOO_{t-1}	0.13925 (3.53)	0.14995 (-)	0.14579 (-)
Constant	-0.13630 (0.63)	-0.32856 (1.86)	-0.24342 (1.39)
DEPC	0.35681 (9.06)	0.31651 (11.44)	0.33320 (11.37)
$IP1_t$	-0.02885 (1.19)	-0.03556 (1.48)	-0.03202 (1.35)
$IP1_{t-1}$	-0.17013 (6.06)	-0.16783 (5.92)	-0.16908 (6.01)
TDAYWK	-0.05650 (10.32)	-0.05698 (10.31)	-0.05663 (10.34)
SEE	0.00502	0.00509	0.00505
Z_5 (3)	4.88		
Wald Test for Restrictions		10.55 ($\chi^2(3)$)	0.91 ($\chi^2(2)$)

For footnotes see page 55

TABLE 5: CONTINUED

	Equation (13) Cross equation homogeneity imposed on all three equations and Δ_1 imposed on ln LABM and ln LABN	Equation (14) Cross equation homogeneity imposed on lnWAEM and lnWOO and Δ_1 imposed on ln LABM and ln LABN
ln $WAEM_{t-1}$	0.69114 (16.13)	0.67973 (15.97)
$LPROM_{t-1}$	0.11229 (4.13)	0.10165 (3.82)
$RSTUR_t$	0.00029 (3.59)	0.00033 (4.00)
ln PC_{t-1}	0.24222 (3.29)	0.26930 (3.65)
ln PC_{t-2}	-0.18341 (2.76)	-0.19188 (2.93)
ln $WAPS_{t-3}$	0.09754 (5.08)	0.10231 (5.35)
ln RET_{t-1}	-0.14832 (5.63)	-0.18026 (6.16)
ln $LABM_t$	-0.86241 (4.37)	-0.84313 (4.35)
ln $LABM_{t-1}$	0.86241 (-)	0.84313 (-)
ln WOO_{t-1}	0.15251 (-)	0.14646 (-)
Constant	0.29363 (1.66)	-0.23072 (1.33)
DEPC	0.29588 (13.33)	0.32802 (12.46)
$IP1_t$	-0.03664 (1.51)	-0.03212 (1.35)
$IP1_{t-1}$	-0.15432 (5.86)	-0.16573 (6.23)
TDAYWK	-0.05836 (10.63)	0.05706 (10.57)
SEE	0.00514	0.00505
Z_5 (3)	6.88	5.78
Wald Test for Restrictions	15.06 ($\chi^2(5)$)	4.00 ($\chi^2(4)$)

For footnotes see page 55

TABLE 6: System Estimation: Non-Manufacturing Earnings

Dependent Variable is $\ln WOO_t$

	Equation (15) Unconstrained equation	Equation (16) Cross equation homogeneity imposed on all three equations	Equation (17) Cross equation homogeneity imposed on lnWAEM and lnWOO
ln WOO_{t-1}	0.37154 (3.36)	0.37690 (-)	0.37446 (-)
ln WOO_{t-2}	0.19339 (1.72)	0.19428 (1.72)	0.19518 (1.73)
ln WOO_{t-3}	-0.25092 (2.27)	-0.25190 (2.28)	-0.25093 (2.27)
$LPROO_{t-1}$	0.15780 (1.27)	0.15957 (1.29)	0.16214 (1.31)
ln PC_{t-1}	0.86829 (3.93)	0.84176 (3.89)	0.84631 (3.91)
ln PC_{t-2}	-0.60728 (3.18)	-0.61094 (3.20)	-0.61373 (3.21)
ln $WAEM_{t-1}$	0.80831 (5.00)	0.80677 (4.98)	0.80859 (4.99)
ln $WAEM_{t-2}$	-0.37576 (2.31)	-0.35687 (2.25)	-0.35988 (2.26)
ln $LABN_t$	-0.82589 (1.92)	-0.74167 (1.85)	-0.75208 (1.87)
ln $LABN_{t-1}$	1.04967 (2.62)	1.04629 (2.61)	1.05228 (2.62)
Constant	2.47773 (4.37)	2.33623 (4.71)	2.34537 (4.72)
DEPC	0.19037 (3.20)	0.17705 (3.43)	0.17679 (3.42)
SEE	0.01387	0.01388	0.13888
Z_5 (3)	4.88		
Wald test for restrictions		10.55 ($\chi^2(3)$)	0.91 ($\chi^2(2)$)

For footnotes see page 55

TABLE 6: CONTINUED

	Equation (18) Cross equation homogeneity imposed on all three equations and Δ_1 imposed on ln LABM and ln LABN	Equation (19) Cross equation homogeneity imposed on lnWAEM and lnWOO and Δ_1 imposed on ln LABM and ln LABN
ln WOO_{t-1}	0.38643 (-)	0.38512 (-)
ln WOO_{t-2}	0.22311 (1.96)	0.22016 (1.93)
ln WOO_{t-3}	-0.18476 (1.76)	-0.18366 (1.75)
$LPROO_{t-1}$	0.28285 (2.68)	0.28211 (2.68)
ln PC_{t-1}	0.90474 (4.15)	0.90588 (4.15)
ln PC_{t-2}	-0.63640 (3.28)	-0.63798 (3.29)
ln $WAEM_{t-1}$	0.73325 (4.61)	0.73616 (4.63)
ln $WAEM_{t-2}$	-0.42638 (2.72)	-0.42568 (2.71)
ln $LABN_t$	-0.90183 (2.26)	-0.90937 (2.28)
ln $LABN_{t-1}$	0.90183 (-)	0.90937 (-)
Constant	2.29915 (4.56)	2.30322 (4.57)
DEPC	0.13521 (2.91)	0.13568 (2.92)
SEE	0.01414	0.01414
Z_5 (3)	6.88	5.78
Wald test for restrictions	15.06 ($\chi^2(5)$)	4.00 ($\chi^2(4)$)

For footnotes see page 55

TABLE 7: System Estimation: Non-Trading Public Sector Earnings

Dependent Variable is ln $WAPS_t$

	Equation (20) Unconstrained equation	Equation (21) Cross equation homogeneity imposed on all three equations	Equation (22) Cross equation homogeneity imposed on lnWAEM and lnWOO
ln $WAPS_{t-1}$	0.37838 (4.10)	0.43848 (4.55)	0.38103 (4.14)
ln $WAPS_{t-3}$	0.35267 (3.68)	0.35395 (3.45)	0.35380 (3.70)
ln $WAPS_{t-4}$	-0.12690 (1.40)	-0.14630 (1.51)	-0.12567 (1.39)
ln $WAEM_{t-1}$	0.89908 (8.05)	0.92627 (7.77)	0.89441 (8.02)
ln $WAEM_{t-3}$	-0.64976 (2.86)	-0.70297 (2.91)	-0.63292 (2.79)
ln $WAEM_{t-4}$	-0.65174 (2.41)	-0.68393 (2.36)	-0.66612 (2.47)
ln $WAEM_{t-5}$	1.14804 (5.70)	1.17519 (5.47)	1.14430 (5.70)
ln $WAEM_{t-8}$	-0.37048 (4.93)	-0.36068 (-)	-0.37054 (4.94)
$RSTUR_t$	0.00081 (0.88)	0.00210 (2.43)	0.00073 (0.80)
$RSTUR_{t-1}$	-0.00237 (1.66)	-0.00395 (2.81)	-0.00225 (1.59)
$RSTUR_{t-2}$	0.00154 (2.04)	0.00245 (3.36)	0.00147 (1.96)
$IP3_{t-1}$	-0.18034 (2.96)	-0.16567	-0.18452 (3.04)
Constant	0.84472 (5.24)	0.64464 (4.12)	0.84049 (5.22)
CATCH75	0.06480 (3.68)	0.05815 (3.10)	0.06376 (3.64)
CLEGG	0.04072 (3.97)	0.03472 (3.22)	0.04050 (3.96)
SEE	0.01539	0.03472	0.01540
Z_5 (3)	4.88		
Wald statistics for restrictions		10.55 ($\chi^2(3)$)	0.91 ($\chi^2(2)$)

For footnotes see page 55

TABLE 7: CONTINUED

	Equation (23) Cross equation homogeneity imposed on all three equations and Δ_1 imposed on ln LABM and ln LABN	Equation (24) Cross equation homogeneity imposed on lnWAEM and lnWOO and Δ_1 imposed on ln LABM and ln LABN
ln $WAPS_{t-1}$	0.43786 (4.54)	0.38030 (4.13)
ln $WAPS_{t-3}$	0.35218 (3.43)	0.35306 (3.70)
ln $WAPS_{t-4}$	-0.14543 (1.50)	-0.12201 (1.36)
ln $WAEM_{t-1}$	0.92301 (7.74)	0.89027 (7.99)
ln $WAEM_{t-3}$	-0.71398 (2.95)	-0.63607 (2.81)
ln $WAEM_{t-4}$	-0.67740 (2.34)	-0.66733 (2.47)
ln $WAEM_{t-5}$	1.18582 (5.51)	1.15078 (5.74)
ln $WAEM_{t-8}$	-0.36205 (-)	-0.37148 (4.95)
$RSTUR_t$	0.00212 (2.45)	0.00069 (0.75)
$RSTUR_{t-1}$	-0.00401 (2.86)	-0.002215 (1.57)
$RSTUR_{t-2}$	0.00249 (3.40)	0.00145 (1.94)
$IP3_{t-1}$	-0.16229 (2.50)	-0.18400 (3.04)
Constant	0.64848 (4.14)	0.84155 (5.23)
CATCH75	0.060488 (3.22)	0.06532 (3.72)
CLEGG	0.03497 (3.24)	0.04091 (4.01)
SEE	0.01649	0.01540
Z_5 (3)	6.88	5.78
Wald statistics for restrictions	15.06 ($\chi^2(5)$)	4.00 ($\chi^2(4)$)

For footnotes see page 55

TABLE 8: Earnings Equations Used in Simulations. Estimated as a System with Cross Equation Homogeneity Imposed on lnWAEM and lnWOO and Δ_1 Imposed on ln LABM and ln LABN

Dependent Variable	$\ln WAEM_t$	$\ln WOO_t$	$\ln WAPS_t$
Independent Variables			
$\ln WAEM_{t-1}$	0.70303 (16.83)	0.64931 (4.08)	0.84812 (7.67)
$\ln WAEM_{t-2}$		-0.51531 (3.28)	
$\ln WAEM_{t-3}$			-0.57611 (2.56)
$\ln WAEM_{t-4}$			-0.65085 (2.43)
$\ln WAEM_{t-5}$			1.12210 (5.71)
$\ln WAEM_{t-8}$			-0.36764 (5.06)
$\ln WOO_{t-1}$	0.11248 (-)	0.52103 (-)	
$\ln WOO_{t-2}$		0.26790 (2.34)	
$\ln WOO_{t-3}$		-0.14580 (1.42)	
$\ln WAPS_{t-1}$			0.40128 (4.45)
$\ln WAPS_{t-3}$	0.09746 (5.00)		0.32025 (3.35)
$\ln WAPS_{t-4}$			-0.11879 (1.36)
$LPROM_{t-1}$	0.12427 (5.52)		
$LPROO_{t-1}$		0.19850 (1.87)	
$\ln PC_{t-1}$	0.28980 (3.98)	0.81003 (3.66)	
$\ln PC_{t-2}$	-0.19746 (3.00)	-0.58716 (2.96)	

TABLE 8: CONTINUED

Dependent Variable Independent Variables	$\ln WAEM_t$	$\ln WOO_t$	$\ln WAPS_t$
$\ln RET_{t-1}$	-0.17415 (5.95)		
$\Delta_1 \ln LABM_t$	-0.73941 (3.88)		
$\Delta_1 \ln LABN_t$		-1.00289 (2.49)	
$RSTUR_t$	0.00035 (4.27)		0.00053 (0.56)
$RSTUR_{t-1}$			-0.00188 (1.28)
$RSTUR_{t-2}$			0.00129 (1.68)
$IP1_t$	-0.03189 (1.31)		
$IP1_{t-1}$	-0.16210 (5.97)		
$IP3_{t-1}$			-0.17604 (2.93)
TDAYWK	-0.05754		
CATCH75			0.06364 (3.63)
CLEGG			0.03949 (3.88)
Constant	-0.08783 (0.56)	1.69394 (3.60)	0.85411 (5.35)
DEPC	0.31342 (12.48)	0.15871 (3.34)	
SEE	0.00518	0.01470	0.01559

For footnotes see page 55

Footnotes to Table 1

The estimation was performed on quarterly data from 1966 Q1 - 1983 Q4 using the instrumental variables option on TSP. The additional instruments were Δ_4 ln PC_{t-1}, Δ_4 ln PC_{t-2}, Δ_4 ln $PFO\$_t$, Δ_4 ln $WULC_t$, Δ_4 ln WPC_t, Δ_4 ln EER_{t-1}, Δ_4 $ERUK_{t-1}$ and RUR_{t-1}. In addition, the general form included ln WOO_{t-1}, ln $WAPC_{t-1}$, ln WPC_t and ln EER_{t-1} in the instrument set. See Appendix II for definitions of these variables. t-statistics in parentheses.

Footnotes to Table 2

The estimation was performed on quarterly data from 1966 Q2 - 1983 Q4 using the instrumental variables option on TSP. The additional instruments were Δ_4 ln PC_{t-1}, Δ_4 ln PC_{t-2}, Δ_4 ln $PFO\$_t$, Δ_4 ln $WULC_t$, Δ_4 ln WPC_t, Δ_4 ln EER_{t-1} and Δ_4 $ERUK_{t-1}$. In addition, the general form included ln $WAPC_{t-1}$, ln WPC_t, ln EER_{t-1}, ln $PPOX_{t-1}$ and RUR_{t-1} in the instrument set. t-statistics in parentheses.

Footnotes to Table 3

The estimation was performed on quarterly data from 1966 Q2 - 1983 Q4 using the instrumental variables option on TSP. The additional instruments were RUR_{t-1}, $RSTUR_{t-3}$, $RSTUR_{t-4}$, $RSTUR_{t-5}$, $RSTUR_{t-6}$. t-statistics in parentheses.

Footnotes to Tables 5, 6 and 7

The estimation was performed on quaterly data from 1966 Q2 - 1983 Q4 using the non-linear three stage least squares option on TSP. The additional instruments were RUR_{t-1}, $RSTUR_{t-4}$, $RSTUR_{t-5}$, $RSTUR_{t-6}$, $\Delta_4 lnPC_{t-1}$, $\Delta_4 lnPC_{t-2}$, $\Delta_4$lnPFO\$, $\Delta_4$lnWULC, $\Delta_4$lnWPC, $\Delta_4 lnEER_{t-1}$, $\Delta_4 ERUK_{t-1}$. t statistics in parentheses.

Footnotes to Table 8

The estimation was performed on quarterly data from 1966 Q2 - 1985 Q4 using the non-linear three stage least squares option on TSP. For the additional instruments see footnote to Table 5. t statistics in parentheses.

Appendix I The Calculation of the Diagnostic Test Statistics

This appendix discusses the calculation of the test statistics reported in this paper. All the tests are appropriate for instrumental variable estimation.

Consider a model specified as

$$Y = X B_0 + U_0 \tag{1a}$$

$$U_0 \sim N(0, \sigma_0^2 I)$$

where Y and U_0 are both n dimensional vectors, X is an $n \times k$ matrix of both endogenous and exogenous explanatory variables, and B_0 is a k dimensional parameter vector. In addition, define Z to be an $n \times m$ matrix of instruments consisting of both included and excluded exogenous variables. Many diagnostic tests can be set up as tests by variable addition which involves estimating an auxillary regression of the form (see Godfrey (1983) and Pagan (1984)):[12]

$$Y = X B_1 + TA + U_1 \tag{2a}$$

$$U_1 \sim N(0, \sigma_1^2 I)$$

where T is an $n \times p$ matrix of test variables and A is a p vector of parameters. Define the associated residual vectors for equations (1a) and (2a), as

$$\hat{U}_0 = Y - X \hat{B}_0$$

and

$$\hat{U}_1 = Y - X \hat{B}_1 - T\hat{A}$$

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12 For a comparable discussion of testing by variable addition in a similar context see Wallis et al (1986).

and the error variance for equation (1a) as

$$\hat{\sigma}_0^2 = (n - k)^{-1} \hat{U}_0' \hat{U}_0$$

Z_1 (ρ) is a likelihood ratio type test for residual autocorrelation of up to and including order ρ. It is calculated by making T a matrix containing the first ρ lags of the residual vector from equation (1a). The test statistic is constructed as (see Godfrey (1983)):

$$\phi_1 = \frac{(S_R - S_{UR})}{\hat{\sigma}_0^2} \tag{3a}$$

Where

$$S_R = \hat{U}_0' Z (Z' Z)^{-1} Z' \hat{U}_0$$

$$S_{UR} = \hat{U}_1' Z (Z' Z)^{-1} Z' \hat{U}_1$$

This is distributed asymptotically $\chi^2(\rho)$ under the null hypothesis and large values of ϕ_1 reject the hypothesis of no residual autocorrelation. An important point to note in this procedure is that equations (1a) and (2a) must be estimated using the same set of instruments. Since in this case the elements of T cannot be part of the instrument set for equation (1a) this equation has to have a sufficient number of instruments to allow equation (2a) to be estimated since the lagged residuals will not be part of the instrument set for equation (2a) either.

$Z_2(\rho)$ is a Lagrange multiplier test for residual autocorrelation of up to and including order ρ with the test statistic calculated slightly differently to $Z_1(\rho)$, (see Breusch and Godfrey (1981)). Here the test statistic is expressed as:

$$\phi_2 = n (R_1^2 - R_2^2)$$

Where $R^2{}_1$ is the R^2 statistic of the OLS regression of $\hat{U}_0$ on the instrument set and $R^2{}_2$ is the R^2 statistic of the OLS regression of $\hat{U}_1$ on the instrument set. Again the instrument sets need to be identical for the two regressions. The test statistic is distributed as $\chi^2(\rho)$ under the null hypothesis of no residual autocorrelation.

Breusch and Godfrey state that these two tests will not be asymptotically equivalent unless either certain lagged variables (obtained by transforming the structural equations to eliminate the serial correlation), which do not necessarily enter any of the structural equations, are included in the instrument sets when estimating the structural equations or, alternatively, that there is no correlation between the contemporaneous residual in each structural equation and the lagged residuals in the other structural equations.

A further point about $Z_1(\rho)$ and $Z_2(\rho)$ is that the auxilliary regressions are performed over the whole sample period where the vector of residuals is padded out with ρ zeros at the beginning. This is an alternative procedure to simply omitting the first ρ observations in the auxilliary regressions.

Breusch and Godfrey also raise some important points regarding the instrument sets used to estimate (1a) and (2a). As noted above, equation (1a) has to have a sufficient number of instruments to enable equation (2a) to be estimated. In order for some of these instruments to be valid instruments for the lagged residuals in equation (2a) they must of course be correlated with these residuals. However, for the test statistics presented in Tables 1 to 3 none of the instruments in the instrument sets were chosen specifically because they were correlated with the lagged residuals. The most obvious instrument for a lagged residual is a lagged dependent variable. In view of this, the test statistics have been recalculated where the instrument sets have been expanded to include up to ρ lagged dependent variables. These are reported in Table 1A below. All of the test statistics decline relative to those calculated on the basis of the original instrument sets, with the exception of equation (8), which makes it harder to reject the hypothesis of no residual autocorrelation.

TABLE 1A: Tests for Residual Autocorrelation using an Expanded Instrument set. Original Test Statistics in Parenthesis

	$Z_1(4)$		$Z_2(4)$	
Equation (1)	4.97	(6.76)	8.11	(10.70)
(2)	6.83	(8.67)	9.71	(12.33)
(3)	6.55	(8.66)	9.70	(12.38)
(4)	5.43	(5.75)	6.83	(7.56)
(5)	5.65	(6.36)	7.43	(8.22)
(6)	5.48	(5.68)	6.72	(7.44)
(7)	4.68	(6.52)	5.69	(8.74)
(8)	5.19	(3.52)	6.66	(4.47)
(9)	2.89	(4.42)	4.13	(5.55)

Evans and Patterson (1985) reports the correct form for the Lagrange multiplier test for residual autocorrelation in a model subject to linear restrictions. They demonstrate that homogenous restrictions should be imposed in the auxillary regression of the Lagrange multiplier test even if inhomogenous restrictions apply to the original regression model. However, this result applies to the case where the auxillary equation has the contemporaneous residual vector as the dependent variable, ie in (2a) above Y is replaced by $X\hat{B}_0 + \hat{U}_0$ to give:

$$\hat{U}_0 = X (B_1 - \hat{B}_0) + TA + U_1 \qquad (4a)$$

In this case, as Evans and Patterson demonstrate, a linear restriction $RB_0 = r$ in equation (1a) is replaced by the homogenous restrictions $R(B_1 - \hat{B}_0) = 0$ in equation (4a). But when the auxilliary regression takes the form of (2a) the same restriction is imposed in this equation as in equation (1a), (ie $RB_1 = r$).

Z_3 (ρ) is a ρ period ahead forecasting test. The test statistic is constructed along the lines given for $Z_1(\rho)$ above where equations (1a) and (2a) are both estimated using $n+\rho$ observations and T is an $(n + \rho) \times \rho$ matrix of dummy variables where each element of T is defined as follows

$t_{ij} = 1$ for $i = n+j$; $j = 1$ to ρ

$t_{ij} = 0$ otherwise

(see Godfrey (1983) and Salkever (1976)). The OLS estimates of the elements of A are the prediction errors and the test statistic is calculated as ϕ_1. In this case the elements of the matrix T can enter the instrument sets for equations (1a) and (2a).

$Z_4(\rho)$ is Sargan's test for the validity of the instruments. It is computed as $(T-M)R^2{}_1$ where $R^2{}_1$ is the R^2 statistic in the regression of $\hat{U}_0$ on the instrument set. It is distributed as χ^2 (M-K).

$Z_5(3)$ is a likelihood ratio type test for first order residual autocorrelation in the context of three stage least squares estimation. It is constructed by augmenting the original three equations with the first lag of the residuals from each of the three equations (see Breusch and Godfrey (1981)). Thus the test considers cross correlations in the residuals. The test statistic is constructed as:

$$f(\hat{U}_0)'(S^{-1}Z(Z'Z)^{-1}Z')\ f(\hat{U}_0) - f(\hat{U}_1)'\ (S^{-1}Z(Z'Z)^{-1}Z')\ f(\hat{U}_1)$$

where $f(\hat{U}_0)$ is the stacked vector of residuals from the original system, $f(\hat{U}_1)$ is the stacked vector of residuals from the auxilliary system and S is a consistent estimate of the covariance of the disturbances. The test statistic is distributed as χ^2 with 3 degrees of freedom. An important point to note when doing this test is that the estimator of S must be held constant across the null and maintained hypothesis. The form of ths test is discussed in the TSP manual and the original reference is Gallant and Jorgenson (1979).

The Wald statistics are all calculated using the ANALYZ proceedure on TSP.

Appendix II The Data

CATCH75 — A dummy variable to take account of a period of particularly rapid earnings inflation in the public sector in 1975. It takes the value 1 for the period 1975Q1-1975Q3 and 0 elsewhere.

CLEGG — A dummy variable to take account of the effects of the Clegg Commission on pay comparability on public sector earnings. It takes the value 1 for the period 1980Q1-1981Q1 and 0 elsewhere.

$DEPC_t$ — The expectation of consumer price inflation over the year beginning in period t. It is defined as:

$$DEPC_t = \ln PC_{t+4} - \ln PC_t$$

EER — Effective Exchange Rate Index. 1975=1.

Source: Bank of England Quarterly Bulletin.

ENIH — National Insurance Payments. £mn Seasonally adjusted.

Source: Economic Trends.

ERUK — UK Exchange Rate Against US$. 1980=1.

It is calculated as:

$$ERUK = \frac{2.3267}{\$/£ \text{ rate}}$$

Source: Bank of England Quarterly Bulletin.

IP1 — Incomes Policy Dummy for the Manufacturing Sector.

This is defined as:

$$IP1_t = IPDUM_t\ (((WAEM_{t-1} - WAEM_{t-5})/WAEM_{t-5}) - NORM_t)$$
If $((WAEM_{t-1} - WAEM_{t-5})/WAEM_{t-5}) < NORM_t$ then $IP1_t = 0$.

IPDUM and NORM are based on Whitley (1983, 1986) and are defined as follows:

Period	IPDUM	NORM
1966 Q1 - 1966 Q2	1	0.0350
1966 Q3	1	0.0120
1966 Q4	1	0
1967 Q1	1	0.0125
1967 Q2 - 1968 Q1	1	0
1968 Q2 - 1969 Q4	1	0.0350
1970 Q1 - 1970 Q2	1	0.0450
1970 Q3 - 1972 Q2	0	not applicable
1972 Q3	1	0.0860
1972 Q4	1	0.0270
1973 Q1	1	0
1973 Q2	1	0.0710
1973 Q3	1	0.0700
1973 Q4	1	0.0840
1974 Q1	1	0.0920
1974 Q2	1	0.1050
1974 Q3 - 1975 Q2	0	not applicable
1975 Q3	1	0.1730
1975 Q4 - 1976 Q2	1	0.1380
1976 Q3	1	0.0830
1976 Q4 - 1977 Q2	1	0.0560
1977 Q3	1	0.0850
1977 Q4 - 1978 Q2	1	0.1000
1978 Q3	1	0.0670
1978 Q4 - 1979 Q1	1	0.0500
1979 Q2 - 1985 Q4	0	not applicable

IP2 Incomes Policy Dummy for the Non-Manufacturing Sector.

This is defined as:

$$IP2_t = IPDUM_t\ (((WOO_{t-1} - WOO_{t-5})/WOO_{t-5}) - NORM_t)$$

If $((WOO_{t-1} - WOO_{t-5})/WOO_{t-5}) < NORM_t$ then $IP2 = 0$

IP3 Incomes Policy Dummy for the Non-Trading Public Sector.

This is defined as:

$$IP3_t = IPDUM1_t\ (((WAPS_{t-1} - WAPS_{t-5})/WAPS_{t-5}) - NORM1_t)$$

If $((WAPS_{t-1} - WAPS_{t-5})/WAPS_{t-5}) < NORM_t$ then $IP3 = 0$

where IPDUM1 and NORM1 are identical to IPDUM and NORM respectively except that IPDUM1 and NORM1 take account of the 'N-1' period of pressure on public sector wages which existed between November 1970 and February 1972. The differences are as follows:

Period	IPDUM1	NORM1
1971 Q1	1	0.130
2	1	0.120
3	1	0.110
4	1	0.100
1972 Q1	1	0.090

LABM Employers' Total Labour Costs as a Proportion of Earnings Costs for the Manufacturing Sector.

This is defined as:

LABM = (YWS + YECO + YECN + YECS)/YWS

LABN Employers' Total Labour Costs as a Proportion of Earnings Costs for the Non-Manufacturing Sector.

This is defined as:

LABN = (YWS + YECO + YECN + YECS + TSET)/YWS

which takes account of the Selective Employment Tax.

LE Employees in Employment in the UK. Thousands. Seasonally Adjusted.

Source: Department of Employment Gazette. (Two quarter moving average).

LEG Employment in the Non-Trading General Government Sector including H M Forces. Thousands. Seasonally Adjusted.

Source: Central Statistical Office.

LEMF Employment in the Manufacturing Sector. Thousands. Seasonally Adjusted.

Source: Department of Employment Gazette. (An adjustment is made to the GB figure to take account of Northern Ireland).

LHMF Number Employed in H M Forces. Thousands. Seasonally Adjusted.

Source: Department of Employment Gazette. (Two quarter moving average).

LOTH Employment in the Non-Manufacturing Sector. Thousands. Seasonally Adjusted.

This is defined as:

LOTH = LE + LHMF - (LEG + LEMF).

LPROM Trend Productivity in the Manufacturing Sector. Seasonally Adjusted.

This is constructed as an eight quarter backward looking moving average of the logarithm of output per head in manufacturing (measured as £mn 1980 prices per thousand men).

Source: Manufacturing output is obtained from Economic Trends (This is an index with 1980=100. It is multiplied by 131.2 to obtain £mn 1980 prices). Manufacturing employment is obtained from the Department of Employment Gazette with an adjustment made to the GB figure to account for Northern Ireland.

LPROO	Trend Productivity in the Whole Economy. Seasonally Adjusted.
	This is constructed as an eight quarter backward looking moving average of the logarithm of output per head in the whole economy (measured as £mn 1980 prices per thousand men).
	Source: GDP (output measure) is obtained by multiplying the index contained in Economic Trends by 496.13. Total employment is defined as LE + LSE + LHMF.
LSE	Number of Self-Employed. Thousands. Seasonally Adjusted.
	Source: Department of Employment Gazette. (Two quarter moving average.)
LU	Number Unemployed in the UK excluding School Leavers and Adult Students. Thousands. Seasonally Adjusted.
	Source: Department of Employment Gazette.
LUST	Short Term Unemployed Male and Females up to 26 weeks. Thousands. Seasonally Adjusted.
	In order to obtain a long run of data a number of adjustments were made to the original series: (1) Data prior to 1980 is for Great Britain while for post 1980 it is for the UK. The data for 1979 and before are multiplied by 1.04145 to scale them up. (2) Data prior to October 1982 are not comparable with the data after October 1982 due to the change in the system of counting the unemployed from registrations to claimants. The data from January 1976 to October 1982 are multiplied by 0.96985 to take account of this, (see the article on page S20 of the Department of Employment Gazette December 1982). (3) Data are not available for January 1974 because of the energy crisis and for January 1975 because of industrial action at local offices of the Employment Service Agency. These two figures have been estimated by interpolating between 1973 and 1976 with the growth rates based on what occurred in April and July. (4) The data was seasonally adjusted in two parts (1963 Q3 - 1975 Q2 and 1975 Q3 - 1986 Q2) because there appeared to be a change in the seasonal pattern in mid 1975. This might be related to the exclusion of adult students from the data from October 1975 onwards. (5) The four observations available are for January, April, July and October and the day for which the data are reported tends to be early in the month. In order to obtain an estimate for the middle of a quarter, adjacent observations are weighted together with weights of 0.6 and 0.4.
	Source: Department of Employment and Productivity British Labour Statistics Historical Abstract 1886-1968 and Department of Employment Gazette.
MSCR	Aggregate Married Single and Child Tax Allowances. £mn/Qtr.
	Source: Internal Bank of England Estimate.
NTAM	Number Claiming Married Allowance. Millions.
	Source: Inland Revenue.

NTAS	Number Claiming Single Allowance. Millions. Source: Inland Revenue.
PC	Price Deflator for Total Consumption. 1980=1. Seasonally Adjusted. Source: Economic Trends. Deflating consumers' expenditure at current prices by consumers' expenditure at 1980 prices.
PFO$	World Dollar Price of Oil. 1980=1. Source: Internal Bank of England Estimate.
PPOX	Producer Price of Manufactured Output (excluding Food, Drink and Tobacco). 1980=1. Source: Monthly Digest of Statistics.
RET	Retentions Ratio for Employees. The proportion of pre-tax income retained as post tax income. It is defined as: RET = TAXA + ((TAXB * TRY)/100)/WS where TAXA = 1 - ((TRY/100) + (YJCN/YWS)) and TAXB = (((100 * TARR)/TRY) + MSCR)/(4*((1.45 * NTAM) + NTAS))
RSTUR	The Reciprocal of the Short Term Unemployment Rate. It is defined as: RSTUR = (LE + LSE + LHMF + LU)/LUST.
RUR	The Reciprocal of the Unemployment Rate. It is defined as: RUR = (LE + LSE + LHMF + LU)/LU.
TARR	Reduction in Income Tax due to the Existence of Reduced Rates. £mn. Source: Financial Statement and Budget Report.
TDAYWK	A dummy variable to take account of the 3 day week in 1974. It is 1 in 1974 Q1 and 0 elsewhere.
TRY	Basic Rate of Income Tax. Percentage. Source: Financial Statement and Budget Report.
TSET	Selective Employment Tax Receipts. £mn. Seasonally Adjusted. Source: National Income and Expenditure.

WAEM	Index of Average Earnings in Manufacturing. Seasonally Adjusted.
	The data for 1979 Q3 and 1980 Q1 have been increased by 2.05 per cent and 1.86 per cent respectively to allow for industrial disputes. (See Rowlatt (1986)).
	Source: Department of Employment Gazette.
WAPC	Index of Average Wages in Public Corporations. 1976=100. Seasonally Adjusted.
	Source: Internal Bank of England Estimate.
WAPS	Average Earnings in Non-Trading Public Sector. £ per quarter per man. Seasonally Adjusted.
	Source: Central Statistical office.
WOO	Average Earnings in Non-Manufacturing Sector (including the majority of Public Corporations). £ per quarter per man. Seasonally Adjusted.
	This is defined as: (1000/LOTH) * (YWS - ((LEG - LHMF) * (WAPS/1000) + (LEMF/1000) * (WAEM * 7.09259)))
WS	Average Wages and Salaries. £/qtr per man. Seasonally Adjusted.
	It is defined as:
	WS = (YWS * 1000)/LE
WPC	Consumer Prices for 17 OECD countries. 1980=100. Seasonally Adjusted.
	Source: Internal Bank of England Estimate based on International Financial Statistics.
WULC	Competitors' Normalised Unit Labour Costs in Manufacturing. 1980=1.
	Source: Internal Bank of England Estimate based on IMF data.
YEC	Employers' Contributions (including National Insurance and Private Pension Funds). £mn. Seasonally Adjusted.
	Source: Economic Trends.
YECN	Employers' National Insurance Contributions. £mn. Seasonally Adjusted.
	Source: Central Statistical Office.
YECO	Employers' Other Contributions. £mn. Seasonally Adjusted.
	This is defined as:
	YECO = YEC - YECN

YECS Accruals of National Insurance Surcharge. £mn. Seasonally Adjusted.

Source: Economic Trends.

YJCN National Insurance Contributions Paid by Employees and Self Employed. £mn. Seasonally Adjusted.

This is defined as:

YJCN = ENIH - YECN

YWS Income from Wages and Salaries excluding H M Forces. £mn Seasonally Adjusted.

Source: Economic Trends excluding an estimate of forces pay obtained from the CSO.

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