The Wage-Productivity Nexus in the UK Economy, An Empirical Investigation.

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Abstract

This study explores the relationship between real wages, labour productivity, the number of hours worked, and the unemployment rate in the United Kingdom at the macroeconomic level by applying time-series econometric techniques. The results obtained suggest a long-term equilibrium relationship existing between real wages and labour productivity whilst unemployment became disconnected from the system. The findings implied that labour productivity has a positive impact on real wages in the long run. Real wages seemingly increased at a rate greater than productivity, this reveals an increase in unit labour costs that stifles employment whilst hindering international competitiveness, ceteris paribus. Ultimately the empirical evidence rejects the efficiency wage theory and shows support for the marginal product theory to some degree.

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1. Introduction

The relationship between real wages and productivity is an area of importance in modern economics. The productivity of labour is a key factor in wage determination within the labour market. From a macroeconomic perspective, to enhance a country's economic climate it is in its interest to increase wages which will consequently improve living standards and reduce poverty. However, a trade-off exists by which inflationary pressure is invited and the international competitiveness of said economy diminishes. This study intends to explore the wage-productivity nexus in the United Kingdom with an empirical approach. The objective is to allow the data to freely demonstrate any patterns and integration through the application of econometric techniques instead of investigating a specific theory. It is advantageous to conduct the investigation in this manner as it allows for findings to be compared with suggested economic theories. Throughout this study there is an intention to find answers to the following questions: a) is there a long-run relationship between real wages and productivity? b) if feasible, how can the short-term/dynamic relationships between these variables be explained? c) will modern econometric techniques shed light on the directions of causality between these variables?

An array of economic literature exists regarding the wage-productivity relationship however none of them observes a sample as large as the one covered in this study or includes recent data in their findings. Generally, a positive bi-variate long-run relationship between real wages and productivity is the main finding of previous studies however drawbacks exist in the methodologies applied to obtain these results. Nonetheless, a combination of these previously employed techniques is applied in a nature which best suits this study.

The following chapter of the study is a detailed review of empirical and international literature concerning wage-productivity relations in various environments. These works of literature provide a framework on how conclusions can be drawn for the hypothesis in question as well as being an outlet for further comparisons and analysis. Chapter 3 is a thorough description of the methodology employed in this study and introduces the data utilised. Chapter 4 interprets and evaluates the empirical findings based on the procedures explained in chapter 3. The final chapter is a summary of the main results and provides a brief suggestion for future studies in this field of research.

2. Literature Review and Theoretical Background

This chapter opens by describing the variables of use throughout the study before a review of other relevant empirical and international literature. An exploration of the possible causal relations amongst the variables is also discussed in this chapter. The economic theory discussed in this section is of importance for comparative purposes as well as potentially supporting any conclusions drawn in the final chapter of this study.

2.1 Underlying Economic Theory

Several wage determination theories are accepted in modern economics, this provides different perspectives regarding the relations between these variables. A common approach to real wages ordinarily refers to the real consumption earning of workers, capturing the actual purchasing power of these workers in the economy. In computation, nominal wages are deflated by the Consumer Price Index (CPI). Conversely, real wages may describe real product wages by which a means to measure the cost of labour is made available. In computation, nominal wages are deflated by the Producer Price Index (PPI). The selection of wage theory is subject to the relationship being explored. To give an example, when firms aim to evaluate their production

costs, product wages are more suited for this purpose. On the other hand, in the situation that union bodies aim to negotiate or bargain for increased wages, it is beneficial for them to use real consumption earnings. Throughout this study the former approach to real wages is utilised, the consumer price index is used to deflate nominal wages with the base year 1900. It can be said that the real wages series used in this study is better suited for analysis with the productivity variable. Furthermore, the series is derived using English daily wage rates which are then averaged allowing the series to represent average real wages per worker.

The most established theory in modern economics regarding wage determination is the marginal productivity theory. In this concept, the remuneration of a worker is equal to the marginal product of the said worker, in other words, labour is paid according to its addition to production. Employers hire workers until the point by which there is no additional marginal product, i.e., a value of zero. Whilst marginal product exceeds marginal cost it is profitable for the employer to increase the size of their workforce and workers receive increased wages. On the contrary, whilst this condition is not met (marginal product succeeds marginal cost) any additional labour hiders total output of the firm due to the law of diminishing returns. Throughout this study, productivity is a portrayal of output per hour of labour input. This information is obtainable through the Bank of England, which provides a ratio of hours worked to total employment in computation. This means that the productivity series is influenced by both hours worked and the level of employment. For instance, if the productivity index exhibits an increase in value this may be a result of a decline in employment with no true addition to output, this may be considered a distortion of the actual measure. From a macroeconomic perspective, it can be said that this theory suggests the hypothesis that productivity influences wages, an idea further discussed in the following sub-chapter.

Another approach to wage determination in modern economics is the efficiency wage theory. This approach proposes that it is advantageous for firms to pay wages above the market equilibrium as labour productivity is subsequently improved through several avenues. Therefore, it can be concluded that this theory suggests the hypothesis that wages influence productivity, an idea discussed in the following sub-chapter. A psychological benefit is a by-product of increased wages, workers become more motivated which strengthens morale within the workforce and in turn becomes more productive. This contrasts with the nature of monopsonist employers where workers may feel exploited or underpaid thus exerting minimal effort in their work. Furthermore, the labour pool is strengthened as higher wages attract experienced and specialised workers which ultimately enhances productivity in the workplace. An increase in labour costs represents a corresponding increase in labour costs therefore factor substitution away from labour towards capital becomes more prevalent. The marginal product of workers may rise as workers aim to display their usefulness and avoid redundancy since firms may intend to cut costs by cutting jobs. However, from another perspective, this approach may dampen the employment rate which may conflict with macroeconomic objectives.

Unemployment describes the situation in which individuals that are of working age are actively seeking work but are unable to find a job. Generally, the unemployment rate is obtained through the ratio of those unemployed and the total number of people in the workforce. This variable serves as a key indicator in observing a country's economic climate. In the United Kingdom, two approaches exist when measuring unemployment, namely the Claimant Count (CC) and the Labour Force Survey (LFS). The Claimant Count is a figure that indicates the number of individuals receiving benefits (the Jobseekers allowance as an example). The Labour Force Survey is conducted based on standards outlined by the International Labour Organisation (ILO) every quarter to determine the structure of the labour market and thus the unemployment

rate. These methods of calculating the unemployment rate account for the many types of unemployment, such as structural, frictional, demand-deficient, and voluntary unemployment. The unemployment series applied in this study is obtained through the feedback of the Labour Force Survey and then expressed as a proportion of the total UK workforce. In recent years, due to the changes in criteria for receiving unemployment benefits, a widening disparity has emerged between the results of the Claimant Count and Labour Force Survey. The Claimant Count to an extent is an underestimate of unemployment as it is viewed as an underestimate of true unemployment as several individuals claiming benefits consider finding a job counteracting since they can maintain a sufficient standard of living through allowances. Moreover, since the Labour Force Survey is consistent with international standards, the series has a high degree of comparability which may be of interest in further studies with other economies.

The hours worked measure describes the average weekly hours worked in the United Kingdom, adjusted for part-time work, holidays, stoppages, and sicknesses. In theory, this is a very important variable to observe as a rise in productivity may be the outcome of an increased number of hours worked. Therefore, any increases in real wages due to productivity may also be a direct or indirect product of hours worked. Furthermore, an increase in the number of hours worked may portray the scarcity of labour

2.2 International and Empirical Literature Review

An article authored by Wakeford (2004) explores the relationship between labour productivity, real wages, and unemployment in South Africa. Wakeford's study is classified as an empirical investigation at the macroeconomic level as modern time series econometric techniques are employed on nationwide data. Ultimately, the study concludes that a long-term correlation is

present between real wages and labour productivity whilst unemployment fails to demonstrate a significant impact on the model and thus cannot be a part of the relationship. The long-run elasticities produced by the empirical results suggest that the findings of Wakeford can be interpreted as follows: a one per cent increase in productivity tends to lead to a 0.58 per cent increase in real wages. In addition to this, the findings illustrate that labour productivity has risen at a faster rate than real wages which are plausibly due to technological advancements in South Africa. This consequently promotes labour substitution towards capital in the workplace, an early suggestion that efficiency wage theory may be of substance in this context. Many similarities exist between the empirical methodology employed by Wakeford and the procedures intended for use in this study. Following a preliminary data analysis, evidence of a structural break emerges, and the dataset is subsequently divided into two sub-periods (1983 – 2002 period and 1990 – 2002 period). The severe recession endured by South Africa during this period is a reason suggested by the author to explain the structural changes in the economy. This became an advantageous property of Wakeford's study as the model coefficients from the differing sub-periods can be compared to further understand the behaviour of the model. The author implements a dummy variable to capture the effect of the structural changes in South Africa. Next, the degree of integration of the dataset is assessed by utilising the Augmented Dickey-Fuller test followed by the Johansen (1988) multivariate test for integration. Upon successfully detecting cointegration within the data, Error Correction Models (ECMs) are generated with aim of explaining the short-term dynamics and long-term equilibrating mechanism. Overall, the literature demonstrates an array of strengths, mainly the robustness of the empirical findings and the credibility of the sources of data. The study can conclude the empirical findings that pose an answer to the investigation, exploring the relationship between variables. Wakeford finalises by discussing the concept of Granger causality in addition to

labour's share of gross output, specifically discussing how an increase in wages cannot necessarily be attributed to economic growth.

Goh (2009) empirically investigated the existence of a link between productivity, wages, and unemployment at the macroeconomic level in Malaysia accomplished using time-series econometric techniques. Alike existing literature in this field, the investigation aimed to address these questions, i) is there a long-run relationship between productivity and real wages, ii) what are the short-term relationships among these variables, iii) will statistical techniques explain ant directional causality between the variables? The findings of Goh verify the fact that a long-run equilibrium relationship between real wages and productivity was present in the sample whereas unemployment disconnects from the final model. The results inferred labour productivity positively influences real wages in the long run. Be that as it may, the rate of increase in real wages sustained in the model seemingly exceeds the increase in productivity which in turn is recognised as an upsurge in unit labour costs. The author puts a special emphasis on the threat this poses to international competitiveness. The paper additionally found a positive short-run causal flow from productivity to real wages, supporting the marginal productivity theory. The empirical methodology employed begins by applying unit root tests, namely the Augmented Dickey-Fuller and Phillips-Perron tests whilst assuming no structural breaks. The paper critically considers the possibility of structural breaks however results formed from the Bai, J & Perron, P (1998) structural break test were inconclusive. Despite this, the findings of the paper remained consistent with alternate specifications which account for structural breaks. The Johansen cointegration test was then applied from which cointegrating vectors were identified within the system. Error Correction Models were then estimated to reconcile the long-run equilibrium following short-run disequilibrium, this enabled tests for dynamic causality. Overall, the results of the study yielded much useful information regarding

the relationship between the variables as well as discussing potential implications on the economy.

Hall (1986) conducted an empirical investigation using aggregate UK data by applying the two-step Engle and Granger (1987) procedure and concluded that real wages, productivity, and unemployment form a cointegrated system. A study by Alexander (1993) may be seen to serve as a more formal and in-depth take on Hall's work. The paper examined the relationship between real wages, productivity, and unemployment covering the 1955 – 1991 period. Evidence emerges to suggest the presence of a structural break in the year 1979 therefore Alexander reasoned it necessary to split the sample into two sub-periods. The findings of the study demonstrate a significant contrast between the sub-periods wherein the period until 1979 unemployment was classed as a central variable which was caused by both wages and productivity. On the contrary, in the period after 1979, the findings of Alexander suggest a bivariate relationship between real wages and productivity prevails whilst unemployment seemingly becomes dissociated from the system. Alexander attributes the severe change in pattern to policies introduced by Margaret Thatcher, the UK Prime Minister of the time. The Johansen cointegrating vector autoregression (1988) procedure was applied to observe the long-run relationship of the models. Following this, the Granger causality approach was incorporated to understand the causal links within the model.

Throughout this chapter, the empirical findings of the existing literature have been outlined and connected with economic theory to some degree. Despite the array of similarities among existing papers, one may argue that several important aspects have been disregarded. This study intends to add value to the existing value by also observing the average weekly hours worked in the economy alongside real wages, labour productivity, and unemployment. This will be

accomplished by applying econometric methodologies which will produce robust results. This is beneficial as the study will be in an informed position to infer causation. Furthermore, this study will utilise the most recent data available combined with historical information in a way that a dataset can be assembled to avoid small sample issues.

2.3 Hypothesised Causality

The direction of Causal Relation	Expected Nature	Interpretation
Real Wages → Productivity	+	Supports Efficiency Wage theory
Real Wages → Unemployment Rate	+	Increasing labour costs promotes factor substitution away from capital
Real Wages → Hours Worked	+	Workers are incentivised to increase hours worked to maximise wage earnings
	-	Fewer hours are required to work to earn as much prior to the increase and be able to maintain a similar standard of living
Productivity → Real Wages	+	Supports Marginal Product theory, implemented through bonuses and performance-related wages
Productivity → Unemployment Rate	-	Improved output per worker increases a firm's profitability, encouraging them to increase the workforce and exploit economies of scale
	+	Reduced labour demand as the workforce is more efficient (positive output effect on employment)
Productivity → Hours Worked	-	Improved efficiency reduces the demand for labour
Unemployment Rate → Real Wage	-	Surplus labour weakens union power
Unemployment Rate → Productivity	+	Less productive workers are released, and workers increase efforts to avoid dismissal
Unemployment Rate → Hours Worked	-	Aggregate hours worked diminishes due to a reduced size of the workforce
	+	Number of hours worked rises due to scarcity of labour
Hours Worked → Real Wages	+	Strengthened effect of union bargaining for increased, fairer wages or compensation for workers
Hours Worked → Productivity	+	Over time there is an improvement to worker efficiency and specialisation is promoted
Hours Worked → Unemployment Rate	-	Increased opportunity for work, positive output effect on employment

Table 2.3: Hypothesised causal relations existing amongst variables (follows the structure of Wakeford, 2004, p. 113).

The table above lists all possible hypothesised relations between real wages, productivity, hours worked and unemployment in the United Kingdom. The expected nature of these relations is suggested in the table along with an interpretation based on economic theory.

A change in real wages within an economy may positively impact productivity, as taught in the theory of efficiency wages. To elaborate, the cost of a worker losing their job has increased so to avoid redundancy or being released they become more productive. Furthermore, in the case of unemployment, the rate may rise as labour costs increase consequently promoting factor substitution away from capital. Firms aim to minimise costs therefore they cut the size of their workforce. There is likely to be a contrasting dual impact on hours worked because of increased real wages. Firstly, workers may be incentivised to maximise their earnings by increasing the number of hours they work. Conversely, they can maintain a given standard of living or income whilst working fewer hours. This allows for more time to be allocated to leisure ultimately improving national happiness and inducing economic development (the extent to which this occurs is not discussed in this study). Therefore, it can be concluded that real wages should primarily have a positive impact on productivity, unemployment, and real wages.

An increase in productivity is advantageous for real wages, supporting the marginal product theory. As workers become more productive their output per hour increases also facilitating an increase in the marginal product of a firm, therefore, they have the resources to better wages. Additionally, this may be reflected in performance-related wages as union bodies and worker associations negotiate for higher/fairer wages. For the impact of productivity on unemployment there are two hypothesised causal relations. Firstly, there is the case that due to an increase in labour productivity the profitability of a firm also rises therefore they may be encouraged to increase the size of their workforce to further exploit economies of scale. On the other hand,

there may be a reduced demand for labour as the workforce has become more efficient. Lastly, the impact of productivity on hours worked is negative as the more efficient workforce reduces the demand for as many hours to be worked. The overall effect of productivity is ambiguous and cannot easily be predicted.

The impact of more unemployment is detrimental to real wages, and the bargaining influence of union bodies is weakened. These bodies become less able to justify high wages therefore they may be forced to accept a fall in the wage rate. The nature of the relation between unemployment on productivity is positive because the less efficient workers tend to be released first. For this reason, they are encouraged to improve their productivity to avoid becoming unemployed. In terms of the impact of increasing unemployment on the number of hours worked, this measure may contract due to the size of the workforce also contracting. The overall impact of unemployment on the other variables cannot be predicted with certainty.

A change in hours worked within the economy will have a positive impact on real wages. This may be a result of the increased strength in the bargaining power of union bodies and worker associations as they negotiate fairer wages or compensation. A rise in the number of hours worked will also have a positive impact on productivity as workers are becoming better at their jobs over time therefore their output per hour is rising. On the other hand, there is an undesirable impact on the unemployment rate again due to the positive output effect. The hypothesised overall impact of increased hours worked should generally have a positive impact on the other variables.

Evidently, the relations amongst the variables at measure are complicated and the direction of causality cannot be predicted with full certainty. The remainder of this study intends to decipher

the true correlations with the support of econometric analysis. The causality between real wages and productivity may be of importance for policy decisions within an economy. To elaborate, if real wage rising (possibly due to union bargaining) stimulates rises in productivity at the same time labour substitution pressures (to capital) may dampen the size of the workforce. This is an undesirable circumstance and the argument that union bodies can negatively impact unemployment is raised.

3. Data and Methodology

3.1 Methodology

This section outlines the strategies applied to the wage-productivity paradox with justification. The initial cause of action is a visual examination of each variable in the series. A graphical display of the series is advantageous for various reasons including identifying trends and correlations and observing for evidence of structural breaks. Additionally, correlograms were generated for the series, the autocorrelation parameter was of significance as it supported the hypothesis of cointegration within the series. These preliminary observations are imperative to developing a framework for further time-series statistical analysis. In this investigation, real wages, productivity, and average hours worked had the natural logarithm applied to ensure unit free variables thus their coefficients could be interpreted as elasticities, a common economic practice (see Goh, 2009 also Wakeford, 2004). The unemployment rate is given annually in percentage form, remaining untransformed in this study.

Subsequently, unit root tests were applied to determine the degree of integration, or stationarity of the series. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) procedures were run parallel, in this fashion the result of one test is verified by the other. Generally, a stationary dataset is time-invariant and covers specific criteria: i) constant mean, ii) constant standard deviation, and iii) no seasonality effects. This test is necessary to avoid a spurious regression,

the case by which the model produces misleading evidence of a linear relationship. Ultimately, this discredits the results of the empirical analysis as they cannot be used for hypothesis testing. The hypothesis of the tests is defined as follows: H_0, the presence of a unit root (non-stationary) therefore H_1, rejects the null (stationary).

On the assumption that the variables are stationary at the first difference, in other words, found to be integrated of order 1, the Johansen (1988) cointegration test for a multivariate system is applied. This procedure is necessary to capture a long-run relationship among variables. The nature of the Johansen test is favourable over alternate approaches like the Engle-Granger (1987) for several reasons. Firstly, in this study, a four-variable system is used with no specific definition of a dependent variable, the Johansen test can detect multiple cointegrating vectors as well as consider each variable as endogenous. Furthermore, the Johansen test requires a lag order specification to be used in the Vector Autoregression (VAR), in this study the lag order is determined by the Akaike Information Criterion (AIC). To determine the number of possible cointegrating equations trace tests and maximum eigenvalues is applied to the system.

If the series are cointegrated, they exhibit a long-run relationship, implying there is a relation that can be combined linearly. Theoretically, despite any short-run economic shocks causing the individual series to move into disequilibrium, there would be convergence over time towards the long-run equilibrium. It is necessary to produce a Vector Error Correction Model (VECM) in this circumstance. This explains the short-term dynamics in addition to the equilibrating (adjustment) mechanism for the long run.

Granger causality tests are then employed to understand the direction of causality between variables within the model. This is a concept of causality based on prediction, 'If X Granger

causes Y then past values of X should contain information helping to predict Y beyond the information contained in past values of Y alone' (Anil Seth (2007) Granger causality. Scholarpedia, 2(7):1667). To identify any Granger causality amongst the variables, they must be modelled in the VECM by which a single period lagged error correction term is embedded. Cointegration in this circumstance confirms Granger causality. The following error correction models were estimated:

$$\Delta \ln LRW_t = \alpha_0 + \sum_{i=1}^{n} \alpha_1 \Delta \ln LRW_{t-1} + \sum_{i=1}^{n} \alpha_2 \Delta \ln LPROD_{t-1} + \sum_{i=1}^{n} \alpha_3 \Delta \ln LHW_{t-1} + \lambda_1 ECT_{t-1} + \varepsilon_t$$

$$\Delta \ln LPROD_t = \alpha_4 + \sum_{i=1}^{n} \alpha_5 \Delta \ln LPROD_{t-1} + \sum_{i=1}^{n} \alpha_6 \Delta \ln LRW_{t-1} + \sum_{i=1}^{n} \alpha_7 \Delta \ln LHW_{t-1} + \lambda_2 ECT_{t-1} + \varepsilon_t$$

$$\Delta \ln LHW_t = \alpha_8 + \sum_{i=1}^{n} \alpha_9 \Delta \ln LHW_{t-1} + \sum_{i=1}^{n} \alpha_{10} \Delta \ln LRW_{t-1} + \sum_{i=1}^{n} \alpha_{11} \Delta \ln LPROD_{t-1} + \lambda_3 ECT_{t-1} + \varepsilon_t$$

An error correction term signified as $\lambda_n ECT_{t-1}$ describes the nature of the long-run relationship as the coefficient, λ_n, represents the speed of adjustment to restore the equilibrium. The term also signifies any convergence or long-term causality amongst the dependent variable and explanatory variables.

The complete methodology explained in this chapter is conducted on the dataset for the entire range dating from the year 1866 to 2016. The econometric procedures are executed using EViews 12.

3.2 Data

This study utilises annual data with coverage from 1866 to 2016 (150 observations). The dataset was gathered from the Bank of England, 'a millennium of macroeconomic data' a reputable source of information for economic statistics regarding the UK. The series of interest are averaged indices for real consumption earnings labour productivity, and labour hours worked. Additionally, the annual unemployment rate is measured. Real wages reflect the real consumption earnings of workers, attained by applying a Consumer Price Index (CPI) deflator with the base year 1900. This adjustment allows this variable to capture the real purchasing power of workers. Labour productivity is given as an annual average of aggregate output and total employment computed using GDP at factor cost with the base year 2013. The unemployment rate is given as a proportion of the total UK workforce annually. Throughout this study the notation used to represent these variables is as follows: i) LRW: Log Real Wages (index), ii) LPROD: Log Productivity (index), iii) LHW: Log Hours Worked (index), iv) UR: Unemployment Rate (percentage).

4. Empirical Results

Before the application of any econometric analysis, it is beneficial to study the existing properties of the data for which expectations can be shaped. graphical analysis and summary statistics help to identify suggestions of correlation over time.

4.1 Preliminary Data Analysis

Figure 4.1 is a time series display of all the variables being observed in this study. LRW exhibits a generic trend with minimal shocks, the most rapid growth was experienced during the 1950-2000 period. The post-war economic climate is characterised by heightened real GDP growth, a period of low global inflation, and political stability, facilitating increasing real wages. The productivity series follows a trend like that of real wages with minimal shocks

however demonstrates a lesser magnitude of growth overall. Increased government expenditure in the post-war period enhanced human capital and thus labour productivity. Additionally, technological advancements improved the efficiency of the workforce. Across the 150-year timeframe, hours worked have expectedly declined, in simple terms the UK became more productive so there was no need to work as many hours as before. The unemployment rate exhibits several aggressive fluctuations throughout the series, peaking in 1932 when 15% of the population was unemployed. The climate of the economy following the second world war promoted high inward migration which eradicated labour shortages, hence why unemployment around 1945 was at its lowest.

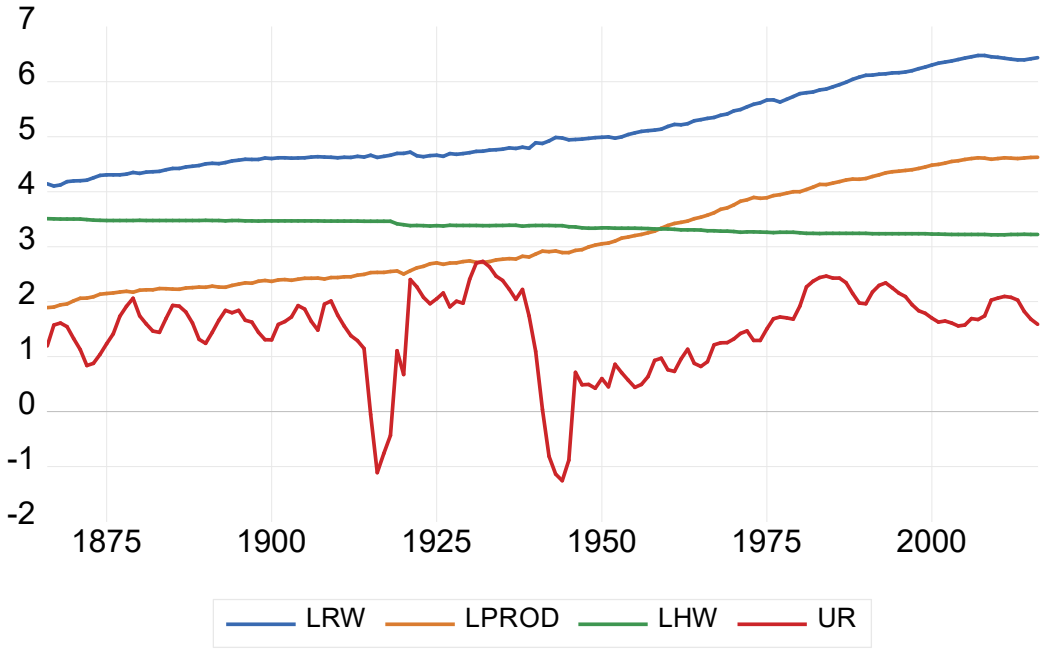

Figure 4.1: Log of Real Wages (LRW), Log of Productivity (LPROD), Log of Hours Worked (LHW), and the Unemployment Rate (UR) for the period 1866-2016 in the UK. Source: Bank of England.

4.2 Empirical Results

Testing for the presence of a unit root

	ADF		PP	
	In levels	In first difference	In levels	In first difference
LRW	-0.925528	-3.148443**	-1.059499	-11.28139**
LPROD	-2.945054	-3.073790**	-1.248011	-10.51897**
LHW	-2.141678	-5.340753**	-2.067829	-9.348714**
UR	-1.572636	-10.17152**	-1.419890	-10.03478**

Table 4.1: Unit Root Test results in level and at first differences.
Augmented Dickey-Fuller test specification: $\Delta x = \beta_0 + \beta_1 x_{t-1} + \sum_{i=1}^{T} \beta_2 \Delta x_{t-i} + \varepsilon_t$
Phillips-Perron test specification: $x_t = \beta_0 + \beta_1 x_{t-1} + \varepsilon_t$

As discussed in the previous sub-chapter, much meaningful information was gathered from the preliminary analysis. The graphical observation illustrated trends in the series suggesting a non-stationary series. Additionally, the correlograms for each variable displayed a declining autocorrelation parameter in level, a further suggestion of non-stationarity. The estimation of the ADF test included a constant and time trend in levels for LRW, LPROD, and LHW but later uninvolved the trend in the first differences for these variables. No constant or time trend was included for UR in level or first difference. The lag length for the ADF test was determined by the AIC criterion (0-13 lags). Regarding the PP test, the lag truncation for the Bartlett Kernel was based on the Newey-West adjusted variance estimators. Using the MacKinnon (1991) critical values, '**' denotes rejection of the null hypothesis (non-stationary data) at the 5% level. The table of results concludes that the series is I(1), that is, non-stationary in level but stationary in first differences. Here the absolute values of the t-statistic exceeded their respective critical value therefore considered statistically significant. Figures 4.1 and 4.2 depict the first differenced graphs of the variables, it is clear now that there is very much stationary. The series are mean reverting, therefore is no apparent trend and a more constant mean and variance exist.

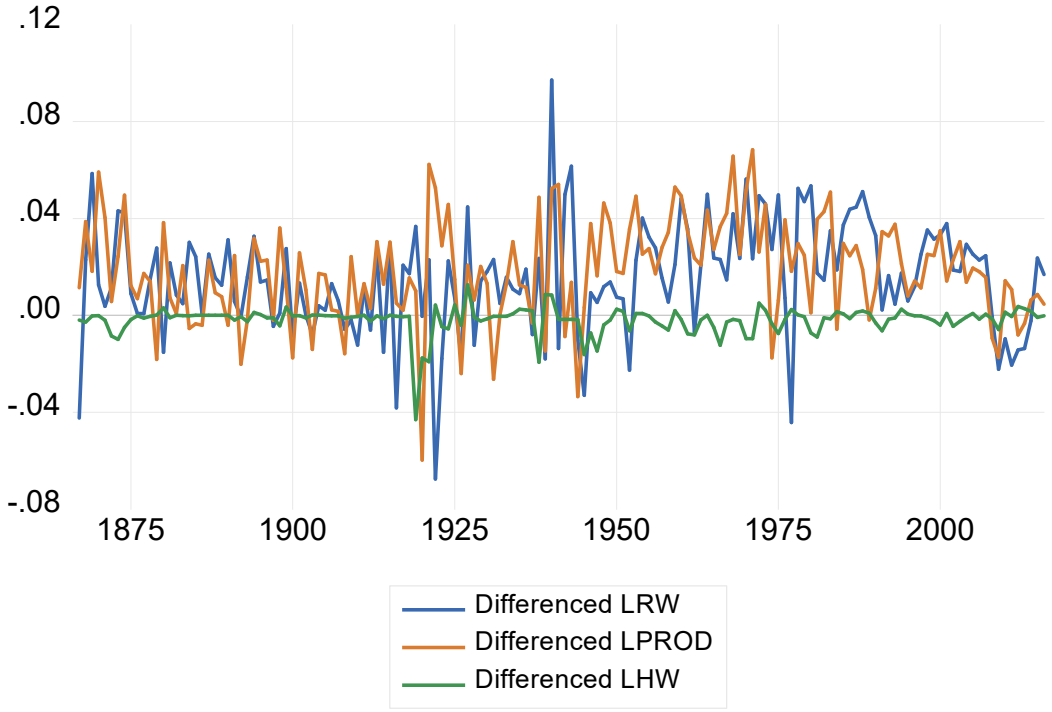

Figure 4.1: First differenced graph of LRW, LPROD, and LHW.

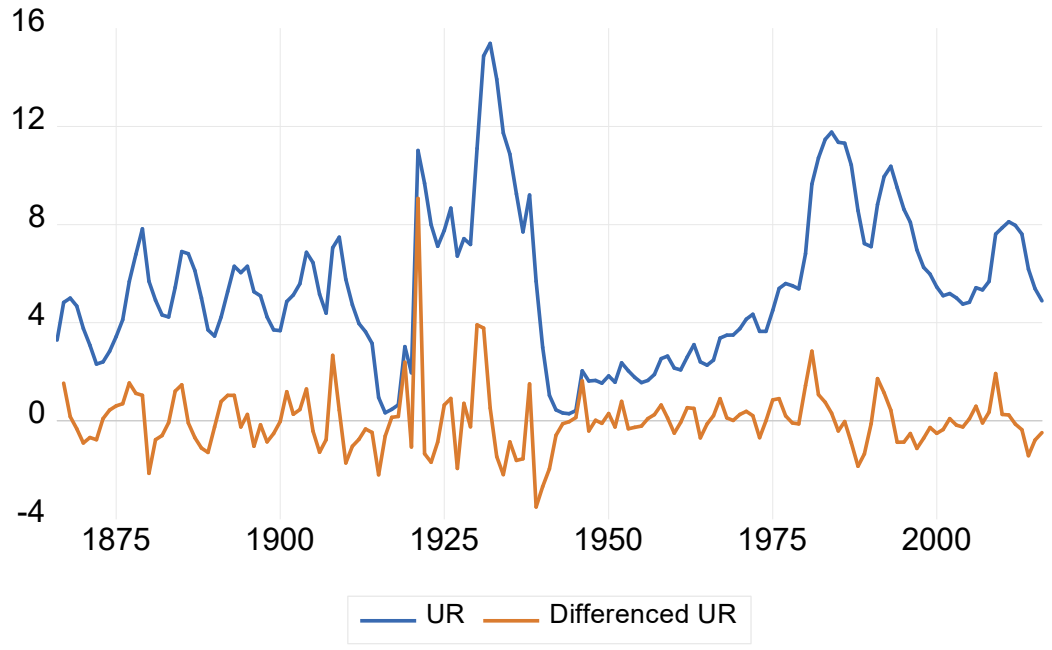

Figure 4.2: First differenced graph of UR.

Cointegration Tests

Having obtained the degree of integration for the series, the Johansen multivariate cointegration test is then applied to identify any long-term cointegrating vectors in the model. The assumption enforced is a linear deterministic trend and intercept in the cointegrating equation. A maximum lag order of 2 is determined by the AIC criterion. Johansen and Juselius (1990) suggest that the test is applied to the series in level, namely the non-stationary series. The null hypothesis is defined as no cointegrating vectors within the model. Provided a cointegrating equation exists, selected error correction models will be estimated.

Hypothesized No. of CE(s)	Trend and Intercept in CE, No Intercept in VAR			
	λ_{trace} statistics	5% critical value	λ_{max} statistics	5% critical value
None**	80.58922	63.87610	37.69066	32.11832
At most 1	42.89856	42.91525	20.60472	25.82321
At most 2	22.29384	25.87211	17.67406	19.38704
At most 3	4.619773	12.51798	4.619773	12.51798

Table 4.2: Johansen Multivariate Cointegration Test Results

Table 4.2 is the output of the test; the trace and maximum eigenvalue statistics are generated for comparison alongside their respective critical value. In instances by which the test statistics exceed that of the critical value the null hypothesis is rejected, denoted by '**' at the 5% level. The test concludes that the possibility of there being no cointegrating equations is rejected at the 5% level. The normalised long-term equilibrium vector is estimated to be Z = LRW + 1.096433LPROD (0.08673) – 0.937640LHW (0.97259) – 0.007137UR (0.00513) where the standard error is given in parentheses. The coefficient of the LPROD term has a standard error of 0.08673 and therefore can be classed as statistically significant at the 1% level in this context. The same can be said for the coefficient of the term LHW, which has a standard error equal to 0.97259. On the other hand, the coefficient of the UR term has a standard error of 0.00513 and

is insignificant at the 1% level. Given this, there is enough evidence to conclude that the unemployment rate is not a part of the long-term relationship.

Hypothesized No. of CE(s)	Trend and Intercept in CE, No Intercept in VAR			
	λ_{trace} statistics	5% critical value	λ_{max} statistics	5% critical value
None**	50.96601	42.91525	25.86244	25.82321
At most 1	25.10357	25.87211	19.07786	19.38704
At most 2	6.025709	12.51798	6.025709	12.51798

Table 4.3: Johansen Multivariate Cointegration Test REPEAT

Table 4.3 is a table of results from a repeat methodology of the Johansen test in this case testing for a relationship between LRW, LPROD and LHW. Again, the test concludes that the possibility of there being no cointegrating equations is rejected. The normalised long-term equilibrium vector is estimated to be Z = LRW + 1.165670LPROD (0.06449) + 2.679553LHW (0.65420) where the standard error is given in parentheses. The coefficient of the terms LPROD and LRW have standard errors of 0.06449 and 0.65420 respectively, therefore are classed as statistically significant. When interpreting the long-run cointegrating equation of the Johansen test the signs attached to each coefficient should be reversed. LRW is the target variable therefore it can be said that for every 1 per cent increase in productivity, wages rise by 1.16570 per cent in the long term. Additionally, in the case of LHW, for every 1 per cent increase in hours worked, wages rise by 2.679553 per cent in the long term.

Error Correction Models

As previously discovered, cointegration exists within the series therefore it is practical for Error Correction Models (ECM) to be estimated. As a result, the short term or dynamic causality within the model can be tested for and understood. The ECM generated follows the specification outlined in chapter 3.1.

Table 4.4 reports the result of the ECM estimations. The coefficient of each variable is stated followed by the standard error in parentheses below. The DLRW model is the model of interest in this case and is significant and passes conventional tests of robustness such as being non-heteroskedastic. In this model, the error correction term is negative and significant at the 5% level. This implies that there is a convergence from short term disruptions toward long term equilibrium. The value of the coefficient was estimated to be -0.192461, this implies that a previous period deviation from the long-run equilibrium is corrected in the current period at an adjustment speed of 19.2%. The mechanism can be interpreted as follows: A one per cent increase in LRW results in an increase in LRW by 0.06 per cent in the following period. A one per cent increase in LPROD will lead to a 0.22 decline in LRW in the following period. A one per cent increase in LHW will lead to a 0.11 decline in LRW in the following period. To observe the short-run causality running from productivity or hours worked to real wages the WALD test is used. In the case of productivity, the null hypothesis that the coefficient of its lagged term DLPROD(-1) is equal to zero was rejected (chi-square probability = 0.0137), and therefore significant at the 5% level. This implies that there is a short-run causality running from productivity to real wages. In the case of hours worked, the null hypothesis that the coefficient of its lagged term DLHW(-1) is equal to zero could be rejected (chi-square probability = 0.7101), and therefore insignificant at the 5% level. This implies that there is no short-run causality running from hours worked to real wages.

When evaluating the DLPROD model, to observe any long-run causality the coefficient of the error correction term must be negative, and the standard error of this term must be significant at the 5% level. In this case, the value of the coefficient is negative (-0.033452), and the standard error (0.03045) is significant therefore it can be concluded that there is some form of long-run causality running from real wages and hours worked to productivity. In other words,

there is a convergence from short term disruptions toward long term equilibrium. The value of the coefficient has been estimated to be -0.033452, this suggests that a previous period deviation from the long-run equilibrium is corrected in the current period at an adjustment speed of 3.2%. Using the coefficient values provided in Table 4.4, the mechanism can be interpreted as follows: a one per cent increase in LRW results in a decrease in LPROD by 2.1 per cent in the following period. A one per cent increase in LPROD results in a 12.94 per cent in LPROD in the following period. A one per cent increase in LHW will lead to a 17.04 per cent decline in LPROD in the following period. The WALD test is again used to observe the short-run causality running from real wages or hours worked towards productivity. In the case of real wages, the null hypothesis that the coefficient of its lagged term DLRW(-1) is equal to zero was not rejected (chi-square probability = 0.7897) and therefore insignificant at the 5% level. This suggests that there is no short-run causality running from real wages to productivity. In the case of hours worked, the null hypothesis that the coefficient of its lagged term DLHW(-1) is equal to zero was rejected (chi-square probability = 0.5891). Again, this is a suggestion that there is no short-run causality running from hours worked to productivity. The results drawn from the error correction model for productivity may be considered poorly specified. The model does not pass the test for no serial correlation and no heteroskedasticity. The residuals are also not normally distributed. This questions the robustness of this model and thus the usefulness of the findings.

The DLHW model possesses an error correction term that fails to explain a long-run causality running from both real wages and productivity to hours worked. As seen in Table 4.4 the coefficient and standard error of the adjustment speed term are 0.012761 and 0.00788 respectively. These values fail to meet the criteria of being negative and significant at the 5% level. This suggests that a previous period deviation from the long-run equilibrium is corrected

in the current period at an adjustment speed of 1.2%. To observe short-run causality from real wages to hours worked the WALD test was used with the restriction (also the null hypothesis) that the coefficient of the lagged real rages term (DLRW(-1)) was equal to zero. We fail to reject the null hypothesis at the 5% level of significance as the experiment produced a chi-square probability value of 0.1053 therefore, we conclude that there is no short-run causality running from real wages to hours worked. Furthermore, in the case of short-run causality from productivity, the WALD test was again incorporated. The null hypothesis was defined as the value coefficient of the lagged term of productivity (DLPORD(-1)) being equal to zero. In this case, the null hypothesis was rejected at the 5% significance level as the chi-square probability was 0.0223 falling within the critical region. This suggests that there is some degree of short-run causality running from productivity to real wages. Again, the robustness of this model is in doubt as portrayed by tests ran afterwards. The model carries serial correlation as well as being heteroskedastic. In addition to this, the model fails tests to determine whether it is normally distributed. The coefficient values provided in Table 4.4 mean that the vector error correction model can be interpreted as follows: a one per cent increase in LRW leads to a 2.1 per cent decline in LHW in the following period. A one per cent increase in LPROD results in a 5.5 per cent increase in LHW in the following period. Finally, a one per cent increase in LHW will lead to a 29.2 per cent increase in LHW in the following period.

Regressor	Dependent Variable		
	DLRW	DLPROD	DLHW
Constant	0.018435 (0.00239)	0.015900 (0.00253)	-0.002036 (0.00066)
DLRW(-1)	0.064344 (0.07359)	-0.020780 (0.07791)	-0.020188 (0.02016)
DLPROD(-1)	-0.215475 (0.08741)	0.129365 (0.09255)	0.054715 (0.02395)
DLHW(-1)	-0.110766 (0.29800)	-0.170442 (0.31551)	0.292925 (0.08163)
ECM(-1)	-0.192461 (0.02876)	-0.033452 (0.03045)	0.012761 (0.00788)

R^2	0.0256693	0.036702	0.103437
Adjusted R^2	0.236046	0.009943	0.078532
F-Statistic	12.43224	1.371596	4.153326

Table 4.4: Error Correction Models for Real Wages, Productivity, and Hours Worked.

5. Concluding Remarks

The intention of this study was to explore the relationship between real wages, labour productivity, hours worked and unemployment in the UK economy supported by empirical analysis. The nature by which this study was conducted meant that no specific theoretical restriction was attached so that the data could "speak for itself". The findings from this paper may be useful in different ways, either used to compare results with that of another market or provide evidence to support or disprove labour market theories. The findings gathered are useful in describing the relationship between the variables at measure. The key findings of this study are as follows:

- Firstly, a long-term cointegrating equilibrium relationship exists between real wages, productivity, and hours worked across the 150-year period. Unemployment seemingly became disconnected from the system. In the long term, a one per cent increase in productivity is associated with a rise of approximately 1.17 per cent in real wages. Furthermore, a one per cent increase in hours worked is associated with a rise of approximately 2.68 per cent in real wages in the long term. It is important to note that the increase in real wage exceeds that of productivity therefore this reflects a gradual increase in unit labour costs which may dampen unemployment and thus erode the international competitiveness of the economy.
- Secondly, the unemployment rate behaves differently from that proposed by economic theory. A negative relationship between unemployment and real wages is hypothesised and supported by empirical evidence (see Blanchflower and Oswald (1995) international wage curve literature). In this study, the findings suggest that

unemployment becomes unconnected to the long-term equilibrium system meaning that an insider-outsider model of the labour market is more appropriate. This would suggest that unemployment has a minimal effect on wage rates. That being said, it is believed that besides productivity, other labour market variables may have better explanatory power than unemployment in forecasting real wage changes. This is an avenue for future research.

- Thirdly, the econometric results determine the following dynamic (short-term) causal system operates in the labour market: productivity positively impacts real wages, but real wages have no impact on productivity. This supports the marginal productivity theory discussed in chapter 2, whilst evidently rejecting the efficiency wage theory. Additionally, hours worked have no impact on real wages.

In conclusion, at least two other possibilities for further research stem from this body of work. One is it repeat the complete analysis but exploring for the relationship between the variables at a sectoral level. The results found can be compared to this study which is based on aggregation on a national level. It is imperative to understand the wage determination structure in an economy. This study finds that a positive relationship exists between real wages and productivity however no evidence of a relationship between real wages and unemployment. It may be advantageous for future research to detect other variables within the labour market besides productivity that explain changes in the real wage.

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