



Asymmetric nexus between wages and productivity in the context of the global financial crisis

Muhammad Ali Nasir^{a,*}, Junjie Wu^b, Cameron Howes^c, Helen Ripley^b

^a University of Leeds, Leeds, United Kingdom

^b Leeds Beckett University, Leeds, United Kingdom

^c Dandenong City Council, Melbourne, Australia



ARTICLE INFO

Article history:

Received 22 June 2021

Revised 26 February 2022

Accepted 2 April 2022

JEL classification:

E24

E31

E43

E52

E58

E61

E62

D84

Keywords:

Wages

Productivity

Retail sector

Labour market

Nonlinearities

NARDL

ABSTRACT

In the context of the breakdown of the wage-productivity nexus since the 2008–09 Global Financial Crisis, this study analyzes that nexus in the UK by accounting for potential asymmetries and nonlinearities. Employing a NARDL framework and data from 2000Q1 to 2018Q4, our key findings suggest that aggregate productivity and productivity within the retail sector have a significant and positive impact on aggregate wages and wages within the retail sector. However, there are important asymmetries and nonlinearities. The impact of productivity on wages in the retail sector is found to be many times smaller than that of aggregate productivity on aggregate wages across the economy as a whole. Economic growth, inflation and unemployment rates are found to have effects on wage growth over the short term. In the long run, it is productivity that is the sole statistically significant influence on wages. Our findings contribute to the debate on the productivity-wage nexus and have profound implications for the labour market and wage policies.

© 2022 The Author(s). Published by Elsevier B.V.

This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>)

1. Introduction

Decent wages are considered a sign of socio-economic progress and, therefore, wage growth is a crucial part of the public policy debate. In the last two decades, and especially since the 2008–09 Global Financial Crisis, wage growth has been stagnant in developed economies. This stagnation is often associated with lower productivity growth. More empirical evidence is needed to identify the contingent and contextual factors associated with this economic phenomenon. For example, since the 2008–09 Global Financial Crisis, the growth rates of developed economies have been lower than those of developing economies, which have lower levels of income. Moreover, due to the idiosyncratic nature of each sector, it is important to test the wage-productivity nexus not only in aggregate but also at the sectoral level. In addition, there is an argument that the wage increases resulting from policy interventions such as the minimum wage can have negative effects on employee

* Corresponding author.

E-mail address: m.a.nasir@leeds.ac.uk (M.A. Nasir).

effort (see e.g., [Brink et al., 2021](#)). If policy interventions can have a negative effect, then what are the precondition for wage increases that do not reduce the productivity of workers? Following this line of reasoning, does an increase in productivity always lead to an increase in wages? Are there any sectoral differences in this? These questions merit enquiry.

Productivity can affect investors' behavior; specifically, lower labour productivity is associated with less investment intention ([Neira, 2019](#)). However, the evidence on the influence of capital productivity investment on the equity market is conflicting. For instance, [Davis and Madisen \(2008\)](#) empirically show that the relationship between capital productivity and equity returns is stronger than that between labour productivity and equity returns. The specificities of each industrial sector may have a role in this. For instance, [Demetriades et al. \(1998\)](#) suggest that the strength of the financial sector in an economy can have implications for productivity. Looking at the effect of the nexus between productivity and investment in the productivity-wages relationship, one may argue that higher wages can reduce productivity and consequently investment. However, [Riley and Bondibene \(2013\)](#), in their investigation of UK firms, report that there is no significant evidence that the introduction of the national minimum wage in April 1999 increased costs, or changed investment rates, or had detrimental effects on the firms' outcomes after the 2008–09 Global Financial Crisis. Thus, the research evidence indicates that the wages-productivity nexus should not simply be treated as having a negative influence on investors' behavior.

In terms of the wage-productivity nexus, *tournament theory* suggests that wage differences are not only attributed to the marginal productivity of workers but also influenced by the rank orders of the individuals in an organisation (see [Lazear and Rosen, 1981](#); [Connelly et al., 2014](#)). In contrast, the *fair-wage hypothesis* proposed by [Akerlof and Yellen \(1990\)](#) in their seminal study postulates that the fairness of the wages influences the efforts and productivity of the workers. This implies that a productive worker needs to be compensated through a fair wage to sustain productivity. However, studies that have drawn on *tournament theory* and the *fair-wage hypothesis* show mixed findings. For instance, in their study of Belgian firms, [Mahy et al. \(2011\)](#) report that the relationship between wage dispersion and firm productivity is hump-shaped, indicating that the *tournament* effect dominates only up to a certain level. Their findings raise questions about the nexus between wages and productivity, i.e., the relationship may vary among countries and sectors in association with the different working environments. The notion of the *efficiency wage* suggests that workers paid above the market equilibrium wage rate generally perform better, which increases their productivity. Similarly, with regard to the notion of productivity enhancement through the minimum wage, contrary to [Brink et al. \(2021\)](#) argument that the latter has negative effects, [McLaughlin \(2009\)](#), drawing on experience in New Zealand and Denmark, argue that it does play a positive role, though a supportive institutional framework is required.

Some studies show the downsides of increases in productivity. For instance, in a study on China, [Leung \(2001\)](#) argues that productivity can increase economic growth but also inequality. Similarly, [Barigozzi et al. \(2018\)](#) report that higher wages do not always attract the most productive workers; in fact, it can lead to crowding out in the labour market. Moreover, there are contradictory findings on the relationship between wages/bonuses and productivity. For example, on the one hand, [Gill et al. \(2013\)](#) show that the random award of bonuses has no significant effect on productivity. The evidence from Taiwan reported by [Morton \(1998\)](#) indicates there is no significant impact of bonus increase on productivity, though productivity increases firms' profits and bonuses. On the other hand, [Gross et al. \(2015\)](#) show that higher-ability workers reduce their effort if not they are not paid well; and [Caiani et al. \(2019\)](#) argue that the wage increases associated with a monetary union can increase productivity.

In a meta-analysis in which 236 minimum-wage elasticities were estimated from 16 UK studies, [de Linde Leonard et al. \(2014\)](#) find no obvious adverse employment effect. Furthermore, the study by [Stewart \(2012\)](#) shows that the minimum wage does not have much spillover effect and has almost been below the 10th percentile, implying that it has a very small distributional role to play in the economy. This brings us back to productivity growth, and we argue it is a core determinant of wage increases. Since the 2008–09 Global Financial Crisis, there has been stagnation in wages in developed economies; for example, in October 2018, real average weekly earnings in the UK were still below their 2008 peak. This suggests that the last 20 years have been the worst decades for pay growth since the Napoleonic Wars (more than 200 years ago). The Bank of England and other scholars (see [Tenreyro, 2018](#)) assert that this is due to stagnant levels of productivity. According to [Tenreyro \(2018, page 6\)](#), “higher productivity is reliably associated with higher wages” and this is supported by the historical evidence, as depicted in [Fig. 1](#). However, in recent years, the gap between productivity growth and real wage growth has been increasing. In fact, in the last two decades, there seems to have been a divergence between productivity and real wage growth, and this requires exploration.

The process of wage determination is dynamic and continuous, and the underlying factors are changing too. This then creates divergences between the theory of wages and the empirical evidence (see [Rubery, 1997](#)). As such, a re-examination of the nexus between productivity and wages is urgent, especially in relation to its multi-dimensional features.

Given the differences in levels of productivity between firms ([Chakrabarti and Lahkar, 2017](#)) and sectors, a question arises: is (greater) productivity translated into (higher) wages in a similar pattern across different sectors? The evidence on the nexus between productivity and wages is mixed and varies among countries and sectors. For instance, in a study on Singapore, [Freddy \(2011\)](#) reports a negative impact of labour productivity on wages in the wholesale and retail sectors, though the study investigates the wholesale and retail sectors in combination, which may have obscured any differences between the two. Interestingly, a negative impact of productivity on wages is at odds with economic theory, though some studies report such an effect. In a study focusing on China, [Dosi et al. \(2020\)](#) obtain the opposite results: the elasticities of real wages to productivity levels are positive both at the firm and the sectoral levels. However, in their study on the OECD countries, [Sharpe and Ugucioni \(2017\)](#) report that the wages in most countries grow more slowly than productivity.

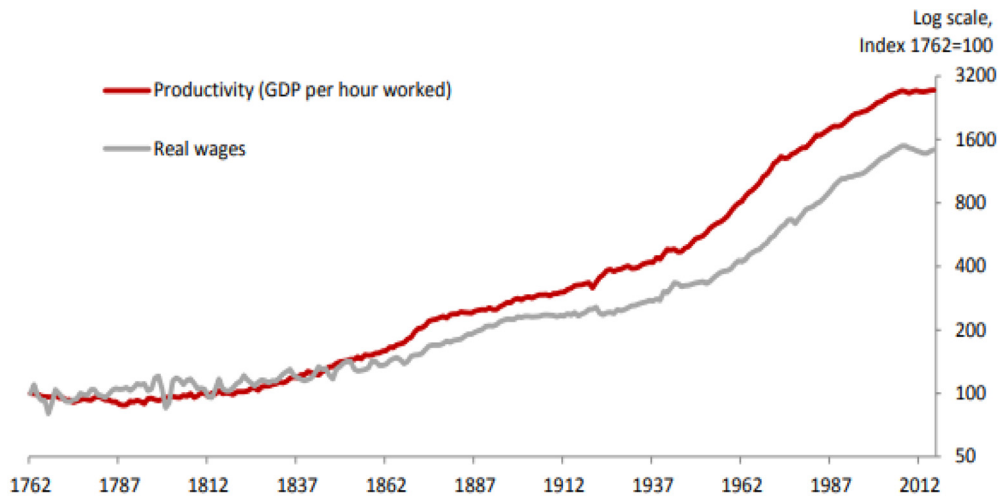


Fig. 1. Labour productivity and real wages. sources: Thomas and Dimsdale (2017) and Teneyro (2018).

Similar findings are reported in a study by the OECD (2018), employing data on 24 OECD countries, which shows that there is a decoupling of wages from productivity - a manifestation of a falling share of wages in GDP; furthermore, the growth in low and medium wages lags behind the growth in average wages. In the context of the nexus between low wages and productivity, Ciarli et al. (2018) investigate the question of the benefits of productivity growth for low-wage workers in the UK and their results suggest that the wage elasticity to industry-level productivity is relatively small and negative, though statistically significant.

Specifically in relation to the UK, the evidence suggests that productivity has been particularly low in low-wage industries and lower compared with international standards (see e.g., Forth and Aznar, 2018). While the stagnation of productivity growth is a critical issue, a second issue is whether productivity growth is manifested in wage growth. Exploring whether the productivity-wage nexus is alive, Brocek (2020) argues that although the relationship between labour productivity growth and real wage growth persists in the UK, it has weakened since the 2008–09 Global Financial Crisis. On the basis of regression analysis, Brocek (2020) reports that the relationship is weaker for low-paid jobs, and, in fact, it is negative in the wholesale and retail sectors. This implies that productivity may lead to a decrease in wages, which is indeed counterintuitive and somewhat against the prevailing economic wisdom. However, this study employed a linear regression approach and so could not account for any nonlinearity and asymmetries in the productivity-wage relationship. In our study, the nonlinearity in the wage-productivity nexus will be addressed. Furthermore, Waldman (1996) points out that the wage-productivity relationship could be asymmetric, as the current employer may acquire information about existing workers' productivity but that information is not available to potential employers. Therefore, this might raise another question, i.e., whether there is an asymmetry in the relationship between wages and productivity, and the present study will also highlight the issue of asymmetry in the productivity-wage relationship.

Contrary to the notion that the impact of productivity on real wages has diminished, the study by Castle, 2014 argues that, since 1860, there has been a constant relationship between productivity and wages. In a comparative study of the UK and the US, Pessoa and Reenen (2013) report that there is some evidence of a minor decoupling of productivity and wages in the US, where productivity grew about 13% more than compensation from 1972 to 2010; however, overall, there is not much difference between the two countries. Their result also suggests that the real issue is inequality. The analysis by Tuckett (2017) also concludes that there is a link between productivity and wages in the UK; however, productivity growth does not lead to wage growth at the industry level. These findings call for more empirical tests. Furthermore, in addition to productivity, the inflation rate and unemployment rate are also considered to be potential determinants of wages, though the results vary and are debatable (e.g., Castle and Hendry, 2009; Nielsen, 2009). Consequently, in our study, inflation rate and unemployment rate are control variables.

Our study contributes to the understanding of the wage-productivity nexus in multiple ways. First, it analyzes the wage-productivity nexus at the aggregate level by incorporating nonlinearities and asymmetries and considering long- and short-term differences. Second, we focus on the wage-productivity nexus in the retail sector to capture sectoral particularity. The rationale for selecting the retail sector is that it is an important part of the UK economy, employing over 3 million people, with £437 bn sales in 2020, accounting for 5.2% of the national economy (Hutton, 2021). Third, the unique features of our study, i.e., analysing the impact of economic growth, inflation and unemployment on wage growth both in aggregate and at an industry level (the retail sector) between 2000Q1 and 2018Q4, and employing a NARDL framework, allow us to confidently suggest that aggregate productivity and retail-sector productivity have a significant and positive impact on aggregate and retail-sector wages. Nevertheless, there are important asymmetries and nonlinearities in the wage-productivity nexus,

e.g., the effect of productivity on wages in the retail sector being many times smaller than the impact of aggregate productivity on aggregate wages. The economic growth, inflation and unemployment rates are also found to have an influence on wage growth, although only in the short term. In the long term, it is only productivity that has an effect. Our findings provide fresh knowledge about the productivity-wage nexus, and the new knowledge should have profound implications for the labour market and policy settings.

The paper proceeds as follows: Section 2 elaborates on the research methodology and the NARDL framework. Section 3 presents and discusses the empirical findings. Section 4 concludes and highlights the policy implications.

2. Methodology

2.1. Empirical model

A nonlinear auto-regressive distributed lag (NARDL) framework is employed to estimate and analyze the effects on wages of productivity growth and other potential determinants, namely economic growth, unemployment and inflation. The reason for employing the nonlinear framework is to capture the nonlinearity and asymmetry in the nexus between productivity and wages. In the light of theories of wage rigidity (Stiglitz, 1984), wages might be sticky and downward rigid. This might imply that a decrease in productivity might not reduce wages in the same proportion as an increase in productivity will increase wages. Hence the relationship between productivity and wages would be asymmetric and nonlinear - something that is often not considered.

This relationship can be specified as follows:

$$Wages_t = +\beta_{wag}Wages_{t-i} + \beta_{Prod}(Prod)_{t-i} + \beta_{GDP}GDP_{t-i} + \beta_{Inf}INF_{t-i} + \beta_{unemp}Unemp_{t-i} + e_t \quad (1)$$

where wages ($Wages_t$) are determined by their past values (the persistence element in wage growth, $Wages_{t-i}$), productivity ($Prod$), output or GDP growth (GDP), labour market outlook in terms of slack or spare capacity ($Unemp$), and inflation (INF).

Given that these factors are theoretically perceived and often empirically shown to be the determinants of overall earnings, earnings in the retail sector ($Wages.Ret$) should also be influenced by the same set of factors, particularly productivity in the retail sector ($Prod.Ret$). Hence, the relationship for wages in the retail sector can be specified as follows:

$$Wages.Ret_t = +\beta_{wag.Ret}Wages.Ret_{t-i} + \beta_{Prod.Ret}(ProdRet)_{t-i} + \beta_{GDP}GDP_{t-i} + \beta_{Inf}INF_{t-i} + \beta_{unemp}Unemp_{t-i} + e_t \quad (2)$$

The novelty of the employed NARDL approach is that it takes the asymmetries and nonlinearities into account in the relationship between earnings and their determinants. The NARDL cointegration approach is based on the seminal work by Shin et al. (2011), which has its roots in the contributions by Pesaran and Shin (1999) and Pesaran et al. (2001). To start with, we can specify Eqs. (1) and (2) in the following long-run model of aggregate wages and wages in the retail sector:

$$Wages_t = a_0 + a_1Prod_t^+ + a_2Prod_t^- + a_3GDP_t + a_4INF_t + a_5Unmp_t + e_t \quad (3)$$

and

$$Wages.Ret_t = a_0 + a_1Prod.Ret_t^+ + a_2Prod.Ret_t^- + a_3GDP_t + a_4INF_t + a_5Unmp_t + e_t \quad (4)$$

where $Wages_t$ is overall wages in the economy for all sectors and $Wages.Ret_t$ are wages in the retail sector, and the determinants are as specified for Eqs. (1) and (2), and $a = (a_0 - a_5)$ is a cointegrating vector of long-run parameters of the relationship. In Eq. (3), $Prod_t^+$ and $Prod_t^-$ are partial sums of positive and negative changes in productivity on aggregate, and similarly in Eq. (4) $Prod.Ret_t^+$ and $Prod.Ret_t^-$ in the retail sector. These can be specified as follows:

$$Prod_t^+ = \sum_{i=1}^t \Delta Prod_i^+ = \sum_{i=1}^t \max(\Delta Prod_i, 0) \quad (5)$$

and

$$Prod_t^- = \sum_{i=1}^t \Delta Prod_i^- = \sum_{i=1}^t \min(\Delta Prod_i, 0) \quad (6)$$

In the light of economic theory and the above-presented specification Eqs. (3) and ((4)), the relationship between wages and productivity is expected to be positive (a_1). However, a_2 captures a potential negative relationship between wages and productivity, indicating the impact of a decrease in productivity on wages. A symmetric relationship would imply that the negative shock will generate a negative response, and hence estimates of a_2 are expected to have negative signs. Furthermore, we may also expect that an increase in a positive shock to productivity may have a greater impact on wages than a negative shock i.e., $a_1 > a_2$. This implies downward wage rigidity, which could be reflected in wage stickiness. Concomitantly, the long-run relationship presented in Eqs. (3) and (4) is expected to reflect an asymmetric pass-through. At this juncture, we can frame Eqs. (3) and (4) in a NARDL setting (see Shin et al., 2011; Pesaran and Shin 1999; Pesaran et al., 2001) as follows:

$$\begin{aligned} \Delta Wages_t = & a + \beta_1 Wages_{t-1} + \beta_2 Prod_{t-1}^+ + \beta_3 Prod_{t-1}^- + \beta_4 GDP_{t-1} + \beta_5 INF_{t-1} + \beta_6 Unemp_{t-1} \\ & + \sum_{i=1}^p \theta_i \Delta Wage_{t-i} + \sum_{i=0}^q (\theta_i^+ \Delta Prod_{t-i}^+ + \theta_i^- \Delta Prod_{t-i}^-) + \sum_{i=0}^s \gamma_i \Delta GDP_{t-i} + \sum_{i=0}^v \delta_i \Delta INF_{t-i} \\ & + \sum_{i=0}^w \Omega_i \Delta Unemployment_{t-i} + e_t \end{aligned} \tag{7}$$

and

$$\begin{aligned} \Delta Wages.Ret_t = & a + \beta_1 Wages.Ret_{t-1} + \beta_2 Prod.Ret_{t-1}^+ + \beta_3 Prod.Ret_{t-1}^- + \beta_4 GDP_{t-1} + \beta_5 INF_{t-1} \\ & + \beta_6 Unemp_{t-1} + \sum_{i=1}^p \theta_i \Delta Wage_{t-i} + \sum_{i=0}^q (\theta_i^+ \Delta Prod_{t-i}^+ + \theta_i^- \Delta Prod_{t-i}^-) + \sum_{i=0}^s \gamma_i \Delta GDP_{t-i} \\ & + \sum_{i=0}^v \delta_i \Delta INF_{t-i} + \sum_{i=0}^w \Omega_i \Delta Unemployment_{t-i} + e_t \end{aligned} \tag{8}$$

Where all the variables are as defined earlier, p, q, s, v and w are lag orders, and $a_1 = -\beta_2/\beta_1$ $a_2 = -\beta_3/\beta_1$ are the long-run impacts of an increase/decrease in productivity on wages (Eq. (7)), and the impact of an increase/decrease in productivity on wages in the retails sector (Eq. (8)). In Eq. (7), $\sum_{i=0}^q \theta_i^+$ measures the short-run impacts of an increase in productivity on wages,

whereas $\sum_{i=0}^q \theta_i^-$ measures the short-run impacts of a decrease in productivity on wages. Similarly, in Eq. (8) $\sum_{i=0}^q \theta_i^+$ measures the short-run impacts of an increase in retail-sector productivity on retail wages, whereas $\sum_{i=0}^q \theta_i^-$ measures the short-run impacts of a decrease in productivity on retail wages. Concomitantly, we capture the asymmetric long-run as well as the asymmetric short-run relationship between wages and productivity.

The implementation of the NARDL framework entails the following steps. First, we perform the unit root test to determine the order of integration of the underlying data series for all the variables. It is worth acknowledging that the ARDL approach to cointegration is valid whether the series are $I(0)$ or $I(1)$; however, it is still important to perform a unit root test to confirm that there is no $I(2)$ variable. This is an important aspect to consider, as $I(2)$ invalidates the computation of F -statistics to test the cointegration (Ibrahim, 2015). We perform the ADF unit root test with a structural break to find the order of integration. Thereafter we estimate Eqs. (7) and (8) using the OLS method.

After the estimation of our NARDL model, we apply the bounds testing approach proposed by Pesaran et al. (2001) and Shin et al. (2011) to test for the presence of cointegration among underlying data series. In so doing, we perform the Wald F -test with the null hypothesis, $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$.

In the final step of the analysis, we examine the long- and short-run asymmetries in the relationship between wages and productivity, and we also discuss the impact of other explanatory variables in the model. For wages specifically, we derive the asymmetric cumulative dynamic multiplier effects of a 1% change in productivity at aggregate as well as sector levels i.e. OP_{t-1}^+ and OP_{t-1}^- as:

$$m_h^+ = \sum_{j=0}^h \frac{\partial y_{t+j}}{OP_{t-1}^+}, \quad m_h^- = \sum_{j=0}^h \frac{\partial y_{t+j}}{OP_{t-1}^-}, \quad h = 0, 1, 2, \dots \tag{9}$$

A point to note here is that as $h \rightarrow \infty$, $m_h^+ \rightarrow a_1$ and $m_h^- \rightarrow a_2$.

2.2. Data

We collect the data on aggregate wages, productivity, inflation, unemployment, and economic growth, and on wages and productivity in the retail sector. The data on wages is the average weekly earnings at the aggregate and the sector (retail) levels. Inflation is taken to be the consumer price index - the official measure used by the Bank of England for its inflation targeting and monetary policy. The unemployment rate is the seasonally adjusted rate of unemployment based on the definition of unemployment given by the International Labour Organisation (ILO). Economic growth is GDP growth expressed as quarter-on-quarter percentage change, seasonally adjusted. Based on the data availability and the focus of our paper the period covers 2000Q1–2018Q4. The sample size is ample and sufficient for the chosen approach.¹All data are collected from the Office for National Statistics (ONS).

3. Empirical findings and discussion

3.1. Descriptive statistics and unit root testing

First, we perform the descriptive statistical analysis (Table 1) to gain some insights into the characteristics of the underlying dataset.

Table 1
Descriptive statistics.

	Growth	Inflation	Productivity% Δ	Productivity Retail% Δ	Unemployment	Wages	Wages. Retail
Mean	0.436	2.051	0.199	0.554	5.813	425.066	257.426
Median	0.500	2.100	0.215	0.520	5.300	437.500	258.165
Maximum	1.500	4.800	1.877	3.394	8.400	527.000	347.330
Minimum	-2.200	0.000	-1.745	-3.024	4.000	306.000	186.000
Std. Dev.	0.591	1.130	0.577	1.411	1.325	61.523	44.935
Skewness	-2.239	0.369	-0.578	0.009	0.711	-0.327	0.174
Kurtosis	10.159	2.802	4.732	2.844	2.006	1.954	1.995
Jarque-Bera	225.772	1.848	13.371	0.076	9.532	4.820	3.581
Prob.	0.000	0.397	0.001	0.963	0.009	0.090	0.167

Productivity growth on average is high in the retail sector, though it is also quite volatile, as manifested in the high standard deviation. Inflation averages around 2%, which is the target of the Bank of England. Economic growth on average is around 0.5% quarterly and unemployment averages 5.8%, suggesting modest slack in the labour market. Interestingly, wages in the retail sector are on average lower than the aggregate level, indicating that this is a low-wage sector. The Jarque-Bera test for the normality of data suggests that except for unemployment, productivity and economic growth, the null of the normal distribution is not rejected at the 5% level of confidence. This is a common feature of economic data, where variables like growth and unemployment usually show non-normality, and it also provides the rationale for our use of a framework that accounts for nonlinear behavior in the dataset.

Next, we perform the unit root test to determine the order of integration of the series. The chosen approach is the ADF unit root test in consideration of the structural break in the data series. Accounting for a structural break is important to achieve reliable estimates. For the detail, see Perron (1989, 2006), Hansen (2001) and more recently Nasir et al. (2018), Nasir and Simpson (2018), Nasir and Vo (2020), and Nasir (2021). We determine the data break endogenously rather than exogenously - in simple terms, we let the data speak. In so doing, we choose the alternative to minimise and maximise options to allow for the evaluation of one-sided alternatives. This produces different critical values for the final Dickey-Fuller test statistic and tests with greater power than the non-directional alternatives.² The ADF is applied to test for the unit root in the presence of a break with both innovative outliers (IO) and additive outliers (AO).³ To choose the optimal number of lags for the ADF test, we use the Schwarz information criterion (SIC), which is particularly appropriate in the presence of a structural break (Asghar and Abid, 2007). The results of the ADF test with a structural break are presented in Table 2:

The results of the ADF unit root test with the structural break, including innovation and additive outliers summarised above, suggest that for most of the variables, the null of 'no unit root' cannot be rejected at the 5% level of statistical significance. However, at the first difference, all the series are found to be stationary, i.e. $I(1)$. For productivity at the aggregate and sector levels, there is a break in the period around the 2008–09 Global Financial Crisis. This is in line with the general perception that since the crisis, productivity growth has been sluggish in the UK.

After unit root testing, we obtain the estimation of the NARDL model Eqs. (7) and ((8)) for the productivity-wage nexus at the aggregate and sector levels, and the results are presented and explained below.

3.2. Productivity-wage nexus at the aggregate and sector levels

We employ the bound testing approach to cointegration. Following Narayan and Narayan (2005) for selecting the critical values and Narayan (2005) for Upper Critical Bound (UCB) and Lower Critical Bound (LCB), we argue the approaches are more appropriate for the small samples ($T = 30$ to $T = 80$). The results are presented in Table 3:

The bound testing shows that the critical values of the F -statistics are greater than the upper bound at the 95% level of confidence. In fact, the results are significant at the 99% level, showing very strong evidence of cointegration in the aggregate as well as the sector wages models Eqs. (7) and ((8)). This implies that there is a long-run relationship among these variables, and, hence, we can proceed with the estimation for further analyzes. The results of NARDL for the wage-productivity nexus at the aggregate and sector levels are presented in Table 4.

¹ Furthermore, this study focuses on the Pre-Covid-19 period, though further analysis can be done on the impact of Pandemic which is beyond the scope of this study.

² See, Zivot and Andrews (1992), Banerjee et al. (1992) and Vogelsang and Perron (1998) for discussion and support of this practice.

³ See Fox (1972) and Tsay (1988). Fox (1972) pioneered the notion of considering outliers within time series, assuming an AR structure with Gaussian noise. The two overarching categories of outliers are defined as the "additive outliers (AO)" where a single point is affected, and "innovative outliers (IO)" where an innovation to the process affects both an observation and the subsequent series. In essence, Fox's approach is actually a likelihood ratio criterion which involves comparing the estimated error for an observation with the estimated standard error of that discrepancy. In terms of the break dynamics: the *innovational outlier* (IO) model implies that the break occurs gradually, with the breaks following the same dynamic path as the innovations, whereas under the *additive outlier* (AO) model, it is assumed the breaks occur immediately.

Table 2

. ADF test with a structural break: additive and innovative outliers.

Variables	ADF Test Statistic (IO)	P-Values	ADF Test Statistic (AO)	P-Values	Break-Date
At Level					
Wages	-2.967	0.965	-3.829	0.631	2005Q2
Productivity	-7.344*	< 0.01	-6.740*	< 0.01	2008Q2
GDP	-5.606**	0.015	-5.697**	0.011	2007Q4
Inflation	-4.891	0.100	-5.046	0.070	2013Q4
Unemployment	-4.885	0.102	-3.738	0.685	2008Q2
Wages. Retail	-5.375**	0.029	-5.529**	0.018	2003Q2
Productivity. Retail	-3.295	0.896	-3.414	0.851	2011Q3
1st Difference					
Wages	-14.503*	< 0.01	-15.946*	< 0.01	2007Q1
Productivity	-7.795*	< 0.01	-7.980*	< 0.01	2005Q4
GDP	-11.674*	< 0.01	-11.913*	< 0.01	2009Q2
Inflation	-7.568*	< 0.01	-7.551*	< 0.01	2016Q3
Unemployment	-6.278*	< 0.01	-6.468*	< 0.01	2009Q2
Wages. Retail	-18.344	< 0.01	-17.390*	< 0.01	2014Q4
Productivity. Retail	-8.778*	< 0.01	-9.017*	< 0.01	2009Q2

***Vogelsang (1993) asymptotic one-sided p -values.

* 1% level of significance.

** 5% level of significance.

Table 3

. Bounds test for nonlinear cointegration.

Dependant variable	f -statistics	lower bound (95%)	upper bound (95%)	conclusion
Aggregate wages	8.716*	3.11	4.31	Cointegration
Wages in the retail sector	30.349	3.11	4.31	Cointegration

* 1% level of significance, ** 5% level of significance, ***10% level of significance.

The estimation results summarised in Table 4 show that in the short run (Panel A), the lagged values of the wages ($wages_{t-1}$) have a negative and statistically significant impact on present wages. This implies an adjustment of wages due to past-period earnings and in wage-setting, which means that the increase in the wages in the previous periods lead to a lesser increase in the current period. Positive productivity shocks, $Productivity_t^+$, have a strong positive impact on wages, which is in line with evidence that greater productivity leads to higher wages (e.g., Dosi et al., 2020; Brocek, 2020) and the fair-wage hypothesis that the productive worker needs to be compensated through a fair wage to sustain productivity. However, the findings are contrary to the notion that productivity increases and wages have a negative association (Freddy, 2011; Brink et al., 2021). Negative shocks, $Productivity_t^-$, also have a positive impact on wages in the short run. As we expected and discussed earlier, the impact of positive shocks is greater in magnitude, suggesting wage stickiness and supporting the wage stickiness theory, which is intuitive. *To the best of our knowledge, this is the first study that has reported this asymmetry in the context of productivity shocks.* Among the other variables, GDP and inflation have a positive effect, while unemployment has a lagged negative impact. The short-term estimates of lagged wages and productivity suggest a short-term negative impact of productivity on wages, as well as a persistent element. GDP, inflation and employment also have a positive impact, though the results vary with lag. The results for wages in the retail sector are by and large similar and hence contrary to the study by Freddy (2011), who found that productivity increase does not have a positive impact on wages. However, it is noteworthy that the impact of productivity within the retail sector is smaller, which implies that the gains from productivity might not be passed on to workers in that sector to the same degree as in other sectors. On the theoretical grounds, it means that the fair-wage hypothesis and the notion of efficiency wage are not very explicit in the retail sector. Nonetheless, inflation also shows a negative and statistically significant impact, indicating that a higher rate of inflation suppresses wage growth in the retail sector. This could particularly be the case when the price hikes are not reflected in mark-ups but result in a reduction in the real wages.

The long-run estimates (Panel B) are interesting. A positive productivity shock ($Productivity^+$) has a very strong and significant positive impact on wages but a negative shock to productivity ($Productivity^-$) does not have a negative impact on wages over the long term. This clearly suggests wage stickiness manifested in an asymmetric relationship between wages and productivity, despite the impact of a negative shock being smaller in magnitude than that of a positive productivity shock. The notion that there has been decoupling between productivity and wages (Pessoa and Reenen, 2013) is not supported by our findings rather the findings are in line with the evidence on persistence in the relationship (Castle, 2014; Tuckett, 2017). Over the long term, GDP and inflation have a positive impact on wages while unemployment has a negative impact. However, these factors are not significant in the long run, and the magnitude is smaller than the impact of overall productivity on aggregate wages. With regard to other factors, GDP has a positive impact on wages whereas inflation and unemployment have negative impacts, which suggests that economic growth does lead to an increase in wages, while inflation and unemployment constrain wage growth. In the comparison between aggregate and retail sectors, the results are

Table 4
 . NARDL estimation of wages at the aggregate and sector levels.

Wages: Aggregate				Wages: Retail Sector			
Panel A: Short-Run Estimates							
Variables	Coefficient	T-states.	Prob.	Variables	Coefficient	T-states.	Prob.
$Wages_{t-1}$	-0.457**	-3.203	0.023	$WagesRet_{t-1}$	-0.147	-1.287	0.202
$Productivity_{t-1}^+$	1.105*	3.622	0.000	$\times ProductivityRet_{t-1}^+$	0.203**	2.003	0.049
$\times Productivity_{t-1}^-$	0.513*	5.391	0.000	$\times ProductivityRet_{t-1}^-$	0.122	1.755	0.084
GDP_{t-1}	0.003	0.835	0.407	$\times GDP_{t-1}$	0.001	0.663	0.509
$\times Inflation_{t-1}$	0.0009	0.891	0.376	$\times Inflation_{t-1}$	-0.005*	-3.374	0.001
$Unemployment_{t-1}$	-8.72E-05	-0.086	0.931	$\times Unemployment_{t-1}$	-0.0009	-0.771	0.443
$\Delta wages_{t-1}$	-0.464*	-3.119	0.003	$\Delta wages.Ret_{t-1}$	-0.700*	-6.210	0.000
$\Delta wages_{t-2}$	-0.363**	-2.616	0.011	$\Delta wages.Ret_{t-2}$	-0.826*	-9.456	0.000
$\Delta wages_{t-3}$	-0.204***	-1.878	0.065	$\Delta wages.Ret_{t-3}$	-0.756*	-8.988	0.000
$\Delta Productivity_{t-1}^+$	-0.472	-1.389	0.170				
$\Delta Productivity_{t-1}^-$	-0.685**	-2.164	0.035				
$\Delta Productivity_{t-2}^+$	-0.915*	-2.782	0.007				
$\Delta Productivity_{t-2}^-$	-0.699**	-2.270	0.027				
ΔGDP_t	0.004***	1.762	0.083				
ΔGDP_{t-1}	0.004***	1.781	0.080				
ΔGDP_{t-2}	0.003	1.257	0.214				
ΔGDP_{t-3}	0.005**	2.452	0.017				
$\Delta Unemployment_t$	0.017*	2.804	0.007				
Constant	2.658*	3.203	0.002				
Panel B: Long-Run Estimates							
$Productivity^+$	2.416*	17.854	0.000	$Productivity.Ret^+$	1.374*	3.311	0.001
$Productivity^-$	1.123*	3.631	0.000	$Productivity.Ret^-$	0.825	0.921	0.360
GDP	0.007	0.710	0.480	GDP	0.012	0.575	0.566
$Inflation$	0.002	0.976	0.333	$Inflation$	-0.039	-1.216	0.228
$Unemployment$	-0.0001	-0.084	0.932	$Unemployment$	-0.006	-0.624	0.534
Panel C: Diagnostic Testing							
R^2	0.998				0.995		
Durban Watson	2.111				1.775		
ECT	-0.457*		0.000		-0.147*		0.000
Jarque-Bera test.	1.533		0.464		1.701		0.427
Breusch-Godfrey LM test	1.940		0.378		1.527		0.465
Breusch-Pagan-Godfrey test	19.559		0.358		14.623		0.101
White test	28.711		0.052		14.118		0.118
Ramsey REST Test	0.2955		0.589		1.852		0.178

Note: White heteroscedasticity-consistent standard errors and covariance. Optimal lag selection is based on AIC.

\times interpreted as $Z_t = Z_{t-1} + \Delta z$.

* 1% level of significance.

** 5% level of significance.

*** 10% level of significance.

consistent with the short-run estimates. Productivity gains are translated into higher wages in the retail sector in the long run but not by the same magnitude as in the national economy. Inflation also seems to affect real wage growth.

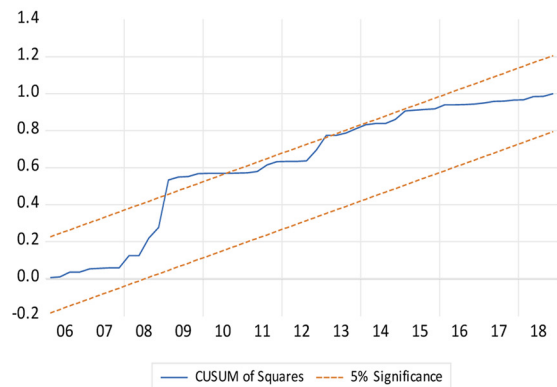
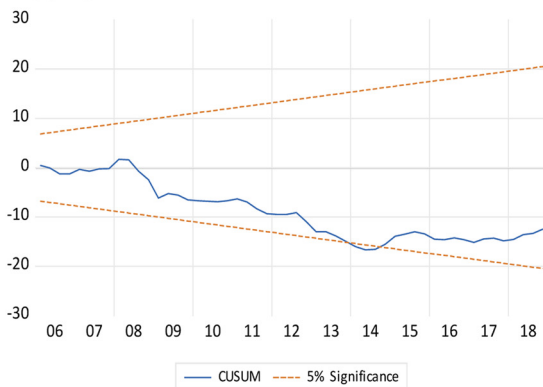
Diagnostic testing is performed for both of the models and the results are reported in Panel C. There are no issues of autocorrelation (DW and Breusch-Godfrey LM tests) or heteroscedasticity (Breusch-Pagan-Godfrey test and White test). The Jarque-Bera test also suggests that there is no non-normality issue of residuals. The null hypothesis of no autocorrelations, no heteroscedasticity and normality are not rejected. The negative and significant values of the error correction term (ECT) indicate the stability of the model. Lastly, the Ramsey REST test shows that the null of no misspecification cannot be rejected at a statistical level of significance. Therefore, both models are correctly specified.

To further test the stability of the estimates, we perform the CUSUM and CUSUMSQ tests (Fig. 2).

Parameter stability tests for aggregate wages and retail-sector wages show that the CUSUM and CUSUMSQ graphs remain within the 5% significance bounds, which indicates the stability of the estimation. After the stability test, we perform the NARDL multiplier analysis of the impact of productivity shocks on wages (both in aggregate and within the retail sector) and the results are presented in Fig. 3:

The results of the multiplier test of productivity on wages show that in response to a 1% increase in productivity, there is a gradual and persistent increase in wages (about a 2% increase by the end of 12 quarters). This implies that a unit increase in productivity can lead to more than a unit increase in wages. However, a negative productivity shock has a negative impact, which is, however, smaller than that of the positive impact (it is only about 1%). This finding suggests that on an upswing in productivity, the positive shock can lead to more than a unit increase in wages, whereas on a downswing in productivity, there is downward wage rigidity, which makes the relationship between productivity and wages asymmetric, and the negative effects on wages do not increase more than the loss in productivity. Interestingly, retail-sector productivity

Aggregate



Retail Sector

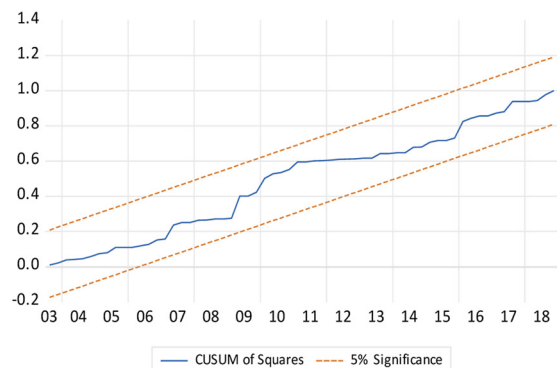
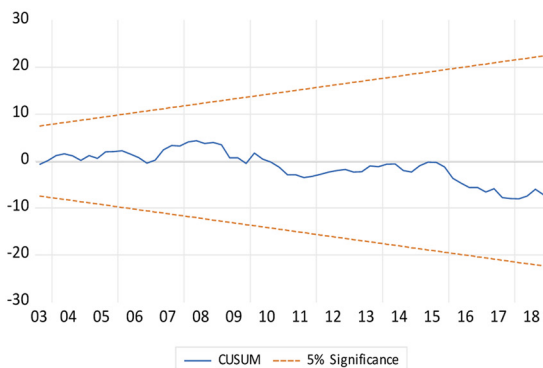


Fig. 2. CUSUM and CUSUMSQ parameter stability test for aggregate wages and wages in the retail sector.

has a fairly symmetric impact on retail-sector wages, although the positive impact is slightly greater than the negative impact. Nonetheless, the impact of productivity on wages in the retail sector is found to be less than unity, contrary to the wage-productivity nexus at the aggregate level. Overall, over 12 quarters, a positive shock of a 1% increase in productivity in the retail sector leads to only about a 0.62% increase in wages; however, regarding a negative shock, a 1% decrease in productivity leads to about a 0.42% reduction in wages. This implies that in the retail sector, productivity gains are not fully passed on to workers; in other words, workers are not compensated for the increase in their productivity. Concomitantly, the debate on the decoupling of productivity and wage growth on which there is contrasting evidence (e.g., [Pessoa and Reenen, 2013](#), [Castle, 2014](#); [Tuckett, 2017](#)) as we discussed earlier, shall account for the underlying crucial sectoral difference.

4. Conclusion and policy implications

The nexus between productivity and wages has been widely debated, particularly since the 2008–09 Global Financial Crisis. In this context, slow productivity growth is blamed for the depressed wages in developed economies in recent years. We argue that it is vital to evaluate the wage-productivity nexus from multiple perspectives, as it is dynamic and multifaceted. Accordingly, our study re-examines this nexus by incorporating the nonlinearities and asymmetries in this relationship and contrasting the overall (aggregate, national) productivity-wage nexus with that of the retail sector in the United Kingdom. While productivity is known to be an important determinant of wage growth at the aggregate level, through robust analyzes our results provide a comprehensive understanding of the relationship between wages and levels of productivity, not only establishing that there is an asymmetric and nonlinear relationship between productivity and wages but also adding fresh evidence that positive productivity shocks of unit magnitude can lead to more than a unit increase in wages. Furthermore, negative productivity shocks can lead to a comparatively small reduction in real wages, implying that wages see downward rigidities in the face of negative productivity shocks. Our findings also prove that productivity still generally acts as a major contributor to wages, even after the Global Financial Crisis.

Our results further show that there are crucial short- and long-term differences in the impact of productivity shocks. Specifically, the impact of productivity on aggregate wages is more profound in the long term than in the short term.

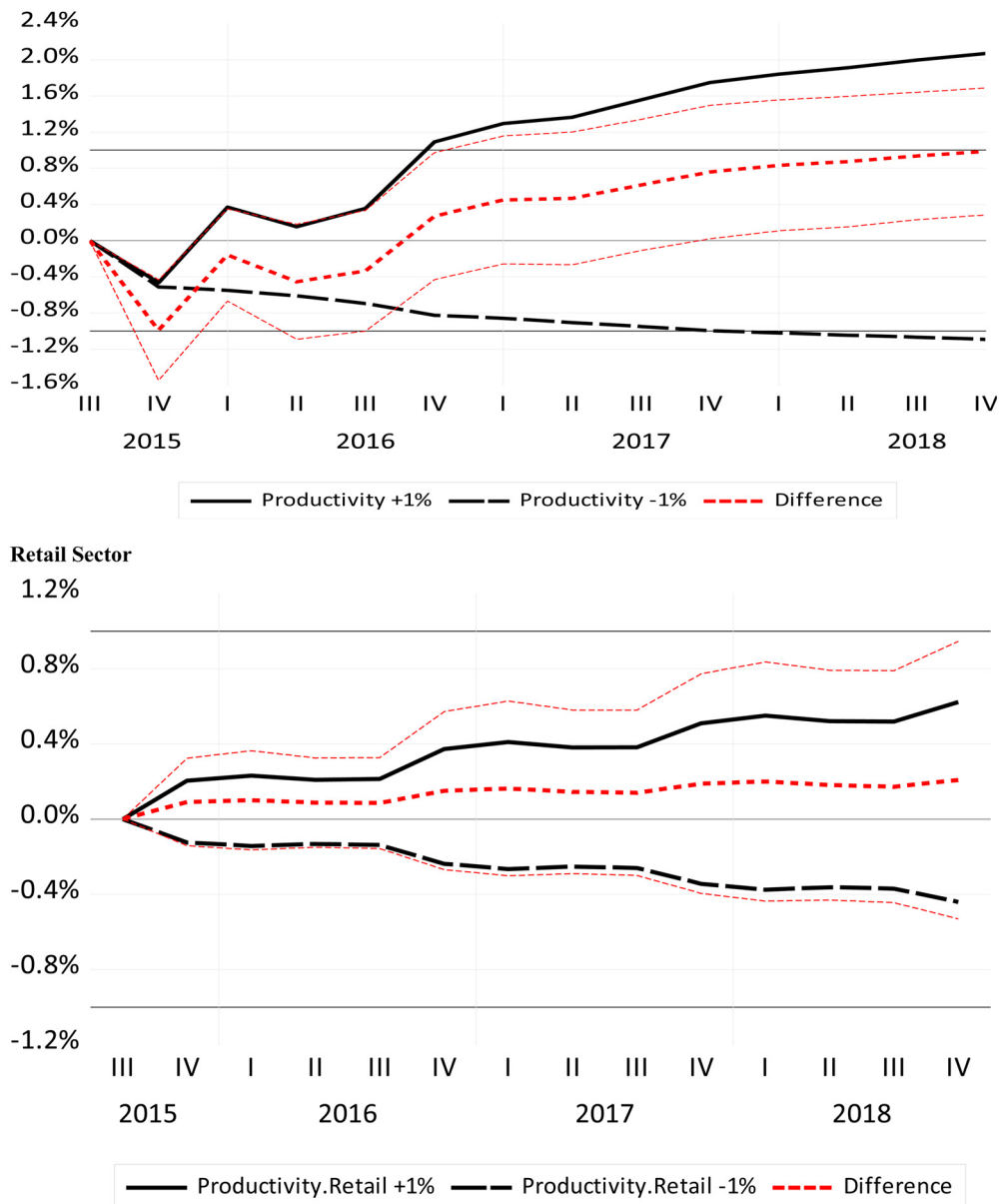


Fig. 3. NARDL cumulative multiplier effects of aggregate and retail-sector productivity and response of aggregate wages and wages in the retail sector.

Therefore, the benefits of productivity in increasing wages should be assessed over the long term. As such, in a policy setting, a long-term approach is more appropriate. Among other variables of interest, economic growth, inflation, and unemployment can also influence productivity at the aggregate level, where the impact of unemployment is negative, while economic growth and inflation have positive impacts. The effects of economic growth and inflation are positive but not statistically significant, implying that economic growth does not always lead to an increase in wages. This could be why, despite some growth, the wage increases are not proportionate and lag behind economic growth, particularly since the Global Financial Crisis.

The sectoral analysis leads us to conclude that although the impact of productivity on wages within the retail sector is positive, it is much smaller than at the aggregate level. This is a clear indication of crucial sector-wise differences. These differences could be due to low skill levels and bargaining power of employees in the retail sector, and the competitive market conditions and profit margins in the sector. The results also suggest that unemployment and inflation have a negative impact on wages in the retail sector and this negative impact is greater than that at the aggregate level. Once again, retail-sector wages seem to be more vulnerable to negative shocks, which has adverse social implications, particularly since this sector is a large employer in the British economy.

The empirical findings contribute to the debate on the wage-productivity nexus and have profound policy implications. Irrespective of the notion that the productivity-wages nexus has been broken since the 2008–09 Global Financial Crisis, the focus of public policy should be on increasing productivity within all sectors, as this should lead to higher wages. There has undoubtedly been only sluggish productivity growth since the 2008–09 Global Financial Crisis, and more recently the ongoing COVID-19 pandemic crisis has seen productivity take a nosedive. A policy to revive productivity growth is vital for wage growth. Furthermore, it is also important to consider the sectoral differences, as some of the low-skill and low-wage sectors, such as the retail sector, may not fully compensate their employees for increases in their productivity. A regulatory or policy response might be needed to overcome this, perhaps through focusing on the living wage and national minimum wage. This would take into account the limitations of the market mechanism in delivering productivity gains to workers in various sectors of the economy. The subject study has a couple of limitations and future research can take them into account. First, future research can focus on the other sectors of the economy. Second, there has been a global pandemic i.e., COVID-19 which has affected all aspects of the economy including productivity, further research can focus on the impact of the Pandemic on the wages-productivity nexus.

References

- Akerlof, G.A., Yellen, J.L., 1990. The fair wage-effort hypothesis and unemployment. *Q. J. Econ.* 105, 255–283.
- Asghar, Z., Abid, I., 2007. Performance of Lag Length Selection Criteria in Three Different situations. University Library of Munich, Germany MPRA Paper 40042.
- Banerjee, A., Lumsdaine, R.L., Stock, J.H., 1992. Recursive and sequential tests of the unit root and trend-break hypothesis: theory and international evidence. *J. Bus. Econ. Stat.* 10, 271–287.
- Barigozzi, F., Burani, N., Raggi, D., 2018. Productivity crowding-out in labor markets with motivated workers. *J. Econ. Behav. Organ.* 151, 199–218.
- Brocek, F., 2020. Is the link between labour productivity and wage growth still alive in the UK? The Fraser of Allander Institute (FAI). University of Strathclyde, Glasgow available at https://fraserofallander.org/link-labour-productivity-wage-growth-uk/#_ftn1.
- Brink, W., Kuang, X., Majerczyk, M., 2021. The effects of minimum-wage increases on wage offers, wage premiums and employee effort under incomplete contracts. *Account. Organ. Soc.* 89, 101195.
- Caiani, A., Catullo, E., Gallegati, M., 2019. The effects of alternative wage regimes in a monetary union: a multi-country agent based-stock flow consistent model. *J. Econ. Behav. Organ.* 162, 389–416.
- Castle, J.L., Hendry, D.F., 2009. The long-run determinants of UK wages, 1860–2004. *J. Macroecon.* 31 (1), 5–28.
- Chakrabarti, A.X., Lahkar, R., 2017. Productivity dispersion and output fluctuations: an evolutionary model. *J. Econ. Behav. Organ.* 137, 339–360.
- Ciarli, T., Salgado, E., Savona, M., 2018. Do Low-Wage Workers Benefit From Productivity Growth Recovery? ISI Growth, European Union Working Paper 33/2018 June. Available at http://www.isigrowth.eu/wp-content/uploads/2018/06/working_paper_2018_33.pdf.
- Connelly, B.L., Tihanyi, L., Crook, T.R., Gangloff, K.A., 2014. Tournament theory: thirty years of contests and competitions. *J. Manag.* 40 (1), 16–47.
- Davis, E.P., Madsen, J.B., 2008. Productivity and equity market fundamentals: 80 years of evidence for 11 OECD countries. *J. Int. Money Financ.* 27 (8), 1261–1283.
- De Linde Leonard, M., Stanley, T.D., Doucouliagos, H., 2014. Does the UK minimum wage reduce employment? A meta-regression analysis. *Br. J. Ind. Relat.* 52, 499–520.
- Demetriades, P.O., Devereux, M.P., Luintel, K.B., 1998. Productivity and financial sector policies: evidence from South East Asia. *J. Econ. Behav. Organ.* 35 (1), 61–82.
- Dosi, G., Virgillito, M.E., Yu, X., 2020. The wage-productivity nexus in the world factory economy. *World Dev.* 129, 104875.
- Forth, J., Aznar, A.R., 2018. Productivity in the UK's Low-Wage Industries. Joseph Rowntree Foundation available at <https://www.niesr.ac.uk/sites/default/files/publications/ForthAznar%20productivity.pdf>.
- Fox, A.J., 1972. Outliers in time series. *J. R. Stat. Soc. B* 34, 350–363.
- Freddy, L., 2011. Productivity-Wage-Growth Nexus: An Empirical Study of Singapore. University Library of Munich, Germany MPRA Paper 34459.
- Gill, D., Prowse, V., Vlassopoulos, M., 2013. Cheating in the workplace: an experimental study of the impact of bonuses and productivity. *J. Econ. Behav. Organ.* 96, 120–134.
- Gross, T., Guo, C., Charness, G., 2015. Merit pay and wage compression with productivity differences and uncertainty. *J. Econ. Behav. Organ.* 117, 233–247.
- Castle, J., Hendry, D., 2014. The real wage-productivity nexus, CEPR, available at <https://voxeu.org/article/real-wage-productivity-nexus> accessed on 22nd June 2021.
- Hansen, B.E., 2001. The new econometrics of structural change: dating breaks in U.S. labour productivity. *J. Econ. Perspect.* 15 (4), 117–128.
- Hutton, G., 2021. Retail Sector in the UK, Briefing Paper, Number SN06186, 25 May 2021. House of Commons Library Available at <https://researchbriefings.files.parliament.uk/documents/SN06186/SN06186.pdf>.
- Ibrahim, M.H., 2015. Oil and food prices in Malaysia: a nonlinear ARDL analysis. *Agric. Food Econ.* 3 (2), 3–14.
- Lazear, E., Rosen, S., 1981. Rank-order tournaments as optimum labor contracts. *J. Polit. Econ.* 89 (5), 841–864.
- Leung, C.K.Y., 2001. Productivity growth, increasing income inequality and social insurance: the case of China? *J. Econ. Behav. Organ.* 46 (4), 395–408.
- Mahy, B., Rycc, F., Volral, M., 2011. Wage dispersion and firm productivity in different working environments. *Br. J. Ind. Relat.* 49, 460–485.
- McLaughlin, C., 2009. The productivity-enhancing impacts of the minimum wage: lessons from Denmark and New Zealand. *Br. J. Ind. Relat.* 47, 327–348.
- Morton, P.J., 1998. Annual bonuses, employment and productivity change in Taiwan's manufacturing sector. *J. Econ. Behav. Organ.* 37 (4), 481–507.
- Narayan, P.K., 2005. The saving and investment nexus for China: evidence from cointegration tests. *Appl. Econ.* 37 (17), 1979–1990.
- Narayan, P.K., Narayan, S., 2005. Estimating income and price elasticities of imports for Fiji in a cointegration framework. *Econ. Model.* 22 (3), 423–438.
- Nasir, M.A., Simpson, J., 2018. Brexit associated sharp depreciation and implications for UK's inflation and balance of payments. *J. Econ. Stud.* 45 (2), 231–246.
- Nasir, M.A., Vo, X.V., 2020. A quarter century of inflation targeting & structural change in exchange rate pass-through: evidence from the first three movers. *Struct. Chang. Econ. Dyn.* 54, 42–61.
- Nasir, M.A., Naidoo, L., Shahbaz, M., Amoo, N., 2018. Implications of oil prices shocks for the major emerging economies: a comparative analysis of BRICS. *Energy Econ.* Vol. 76, 76–88.
- Nasir, M.A., 2021. Zero lower bound and negative interest rates: choices for monetary policy in the UK. *J. Policy Model.* 43 (1), 200–229.
- Neira, J., 2019. Bankruptcy and cross-country differences in productivity. *J. Econ. Behav. Organ.* 157, 359–381.
- Nielsen, H.B., 2009. Comment on “the long-run determinants of UK wages, 1860–2004”. *J. Macroecon.* 31 (1), 29–34.
- OECD, 2018. Decoupling of Wages from Productivity: What Implications for Public policies? Chapter 2 of the World Economic Outlook. OECD.
- Perron, P., 1989. The great crash, the oil price shock and the unit root hypothesis. *Econometrica* 57, 1361–1401.
- Perron, P., 2006. Dealing With Structural breaks. Palgrave Handbook of Econometrics, Volume 1: Econometric Theory. Palgrave Macmillan UK.
- Pessoa, J.P., Reenen, J.A., 2013. Decoupling of Wage Growth and Productivity Growth? Myth and Reality. Centre for Economic Performance, LSE CEP Discussion Papers dp1246.

- Pesaran, M.H., Shin, Y., Storm, S., 1999. An autoregressive distributed lag modelling approach to cointegration analysis. *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*, Chapter 11. Cambridge University Press, Cambridge.
- Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationship. *J. Appl. Econ.* 16, 289–326.
- Riley, R., Bondibene, C.R., 2013. The Impact of the National Minimum Wage On Firm Behaviour During Recession. National Institute of Economic and Social Research available at <https://www.niesr.ac.uk/publications/impact-national-minimum-wage-firm-behaviour-during-recession>.
- Rubery, J., 1997. Wages and the labour market. *Br. J. Ind. Relat.* 35, 337–366.
- Sharpe, A., Ugucioni, J., 2017. Decomposing the productivity wage nexus in selected OECD countries, 1986–2013. *Int. Prod. Monit.* 32, 25–43 Centre for the Study of Living Standards.
- Shin, Y., Yu, B., Greenwood-Nimmo, M., 2011. Modelling Asymmetric Cointegration and Dynamic Multiplier in a Nonlinear ARDL Framework. Mimeo.
- Stewart, M.B., 2012. Wage inequality, minimum wage effects, and spillovers. *Oxf. Econ. Pap.* 64 (4), 616–634.
- Stiglitz, J. E. 1984. Theories of wage rigidity. NBER Working Paper 1442, available at <https://www.nber.org/papers/w1442> accessed on 22th June 2021.
- Tenreyro, S., 2018. The Fall in Productivity Growth: Causes and Implications. Bank of England available at <https://www.bankofengland.co.uk/speech/2018/silvana-tenreyro-2018-peston-lecture>.
- Thomas, R., Dimsdale, N., 2017. A millennium of UK Data. Bank of England OBRA dataset available at <http://www.bankofengland.co.uk/research/Pages/onebank/threecenturies.asp>.
- Tsay, R.S., 1988. Outliers, level shifts and variance changes in time series. *J. Forecast.* 7 (1), 1–20.
- Tuckett, A. 2017. Does productivity drive wages? Evidence from sectoral data, available at <https://bankunderground.co.uk/2017/03/30/does-productivity-drive-wages-evidence-from-sectoral-data/> accessed on 22nd June 2021.
- Vogelsang, T., Perron, P., 1998. Additional tests for a unit root allowing for a break in the trend function at unknown time. *Int. Econ. Rev.* 39 (4), 1073–1100 (Philadelphia).
- Waldman, M., 1996. Asymmetric learning and the wage/productivity relationship. *J. Econ. Behav. Organ.* 31 (3), 419–429.
- Zivot, E., Andrews, K., 1992. Further evidence on the great crash, the oil price shock, and the unit root hypothesis. *J. Bus. Econ. Stat.* 10 (10), 251–270.