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The dynamics of public and private sector wages, pay settlements and employment

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Using a new dataset on sector-level earnings, pay settlements and cross-sectoral employment flows in the United Kingdom, and focussing in particular on the private and the public sector, this report addresses three important questions: 1) Which sector leads and which sector follows in terms of earnings determination?, 2) What determines whether there are wage spillovers across sectors?, 3) What is the impact of pay on employment flows? We provide evidence showing that in the long run, wages in the private and the public sector form a persistent relationship. Over time, public sector wages adjust to wages set in the private sector to maintain this relationship. We further find that there can be significant wage spillovers from the public sector to the private sector in the short run. These tend to be somewhat more pronounced for private sectors that are domestically-facing and characterised by low worker bargaining power. Pay rises in the public sectors are also associated with significant employment inflows from other sectors.

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Non-technical summary

This report addresses the important question of how wage growth in the United Kingdom is determined in the long run and whether wage decisions in the public sector can have spillover effects into the private sector. To analyse these questions, we construct a unique new dataset that is made up of macroeconomic data on earnings and pay settlements as well as sector-specific data on settlements and cross-sectoral employment flows.

We find that in the long run, wages in the public and the private sector form a persistent relationship. Over time, public sector wages adjust to wages set in the private sector to maintain this relationship.

Combining evidence from different data sources and modelling techniques, our results highlight the possibility of statistically significant and economically meaningful wage spillovers from the public sector to the private sector in the short run (within a few months or quarters).

The size of wage spillovers depends on a combination of factors. In general, we find that short-run wage spillovers tend to be somewhat larger when the destination sector is less internationally competitive and less productive, with workers' bargaining power playing an additional role.

An analysis of cross-sectoral employment flows suggests that wage growth can act as one possible pull factor to attract labour inflows from other sectors. This appears to be particularly true for the public sector where worker inflows from other sectors increase significantly in wage settlements.

A supplementary analysis of the impact of Pay Review Body (PRB) recommendations on private sector wage dynamics suggests that PRB decisions tend to affect pay more in parts of the private sector that are domestically-facing.

Overall our results suggest that it is important to better understand wage setting processes in the public sector and cross-sectoral interactions. A fifth of the overall workforce in the UK is employed in the public sector. Our findings highlight that wage interactions can have important macroeconomic implications beyond the size of the sector alone. Wage negotiators in the public sector, above all PRB members, and monetary policymakers should therefore be mindful of pay dynamics in the public sector and potential wage spillovers into the private sector. They should also be appraised of the external forces which shape the scale of wage movements in the private sector and recognise their pressures onto public sector wage determination.

Contents

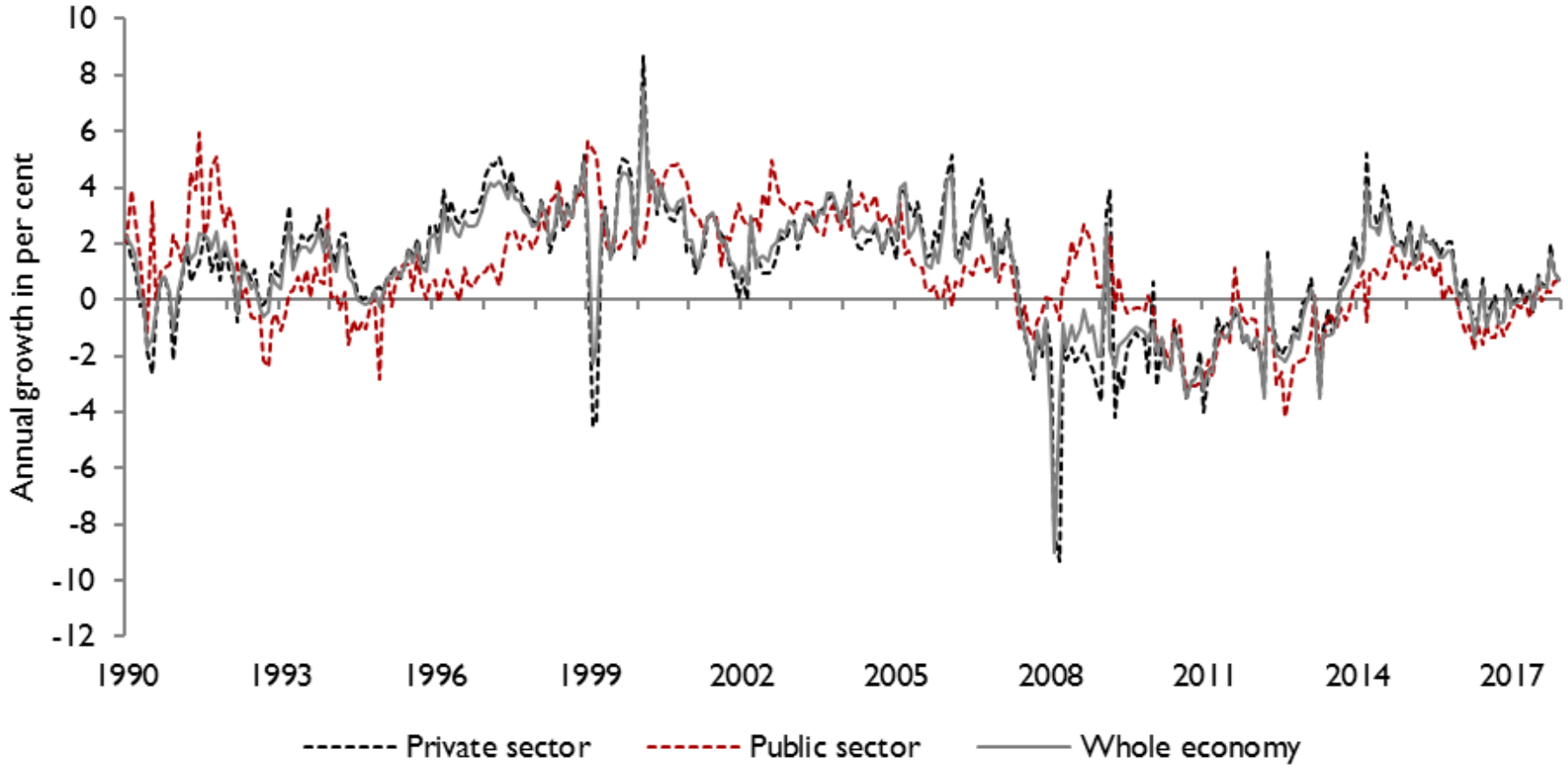
1. Introduction

Real wage growth in the United Kingdom has slowed down considerably over the course of the last three decades (Figure 1). This has been attributed to a number of factors, including low levels of productivity growth, a decline in workers' bargaining power and pay restraint in the public sector. To understand aggregate labour market dynamics, it is important to analyse sector-level developments and interactions in earnings and employment growth between sectors. In this report, we focus in particular on interactions between the public and the private sector.

Figure 1 illustrates that periods of higher public sector earnings growth have over the last three decades alternated with periods of higher private sector wage growth. For instance, the government's decision in 2010 to cap public sector pay and in 2018 to gradually ease pay restraints may have had an effect on pay in the private sector. An analysis of interactions between public and private sector wage growth can also help understand the factors considered by public sector employers. Estimating the impact of public sector pay on pay dynamics in the private sector can inform public sector employers and Pay Review Bodies about the macroeconomic implications of their decisions.

Economic theory posits that in the long run there is a link between nominal wage growth, productivity growth and world price inflation. When exposed to international trade, only the most productive firms tend to enter markets and survive in the face of international competition, as highlighted by Melitz (2003) and the literature on international trade. These firms tend to earn higher profits and are able to pay higher wages. Over time, less productive firms competing with high-productivity firms for workers are forced to adjust their pay levels upwards or exit the market. An implication is that the more open sectors act as wage leaders for the rest of the economy (Lindquist and Vilhelmsson, 2006). Additionally, sectors characterised by strong labour unions may see their wages being set independent of market forces (Freeman and Medoff, 1984). Similarly, if wage setting in one sector, like the public sector, is too generous relative to productivity enhancements in the rest of the economy, this can lead to an inefficient allocation of workers away from private sectors and raise the overall level of wages in the economy (Fernandez-de-Cordoba *et al.*, 2012). Using a model with search and matching frictions, Gomes (2015) shows that unemployment volatility doubles if public sector wages do not respond to the business cycle because more of the unemployed look for jobs in the public sector during recessions, exacerbating the lack of job creation in the private sector. In contrast, the level of wages in the public sector may remain below the long-run equilibrium level set for the whole economy, for instance as a result of fiscal constraint, which could lead to a deterioration in the quality of public services due to a lack of skilled labour. This suggests that over the business cycle, i.e. in the medium run, any mismatch between wages in the public and private sector would be balanced out by worker flows rather than wage spillovers.

Figure 1. Real wage growth



Note: Annual growth in average weekly earnings deflated by the consumer price index. Experimental data before 2000.
Source: ONS, NIESR.

Only if private sector employers compete with the public sector for certain types of workers, i.e. if employment characteristics between the private and public sector are similar, should we observe wage spillovers in the short run.

This report aims to fill some of the existing gaps regarding labour market interactions between sectors of the economy and the determinants of wage spillovers and to test these different hypotheses empirically. After a review of the existing literature (section 2) and an overview of the data we employ (section 3), we address the question of wage leader and follower relationships using aggregate data on average weekly earnings and wage settlements for the public and private sector (Section 4). We estimate a dynamic model that identifies the long-run wage leader as the sector whose wages tend to prescribe wage developments in the long run, i.e. over the course of several years. Short-run spillovers are defined as wage movements in one sector that within a few months are followed by statistically significant wage movements in another sector.

Section 5 then extends our analysis towards the micro level using data on wage settlements in 14 sectors of the economy. For sector-by-sector pairs, we condition wage spillovers on a range of institutional and structural factors to analyse what determines wage responses in one sector to wage movements in another sector.

Next, we estimate wage elasticities of labour flows at the sectoral level in section 6. To do so, we construct a new dataset of cross-sectoral employment movements using information in the Quarterly Labour Force Survey on workers that move job from one quarter to another.

Section 7 provides supplementary estimates for six of the Pay Review Body (PRB) remit groups, namely school teachers, NHS staff, doctors and dentists, prison service staff, armed forces and police, and interactions between PRB pay recommendations and private sector settlements.

Section 8 summarises the main findings and section 9 discusses policy implications of this report.

Key findings

- We find that in the long run, wages in the public and the private sector form a persistent relationship. Over time, public sector wages adjust to wages set in the private sector in order to maintain this relationship.
- Combining insights from different data sources and modelling techniques, we provide further evidence that highlights the possibility of statistically significant and economically meaningful wage spillovers from the public sector to the private sector in the short run (within a few months or quarters).
- The size of short-run wage spillovers depends on a combination of factors but tends to be somewhat larger when the destination sector is less internationally competitive and less productive, with workers' bargaining power playing an additional role.
- An analysis of cross-sectoral employment flows suggests that wage growth can act as an important pull factor to attract labour inflows from other sectors. This appears to be particularly true for the public sector where worker inflows from other sectors correlate significantly with wage settlements.
- An analysis of the impact of Pay Review Body recommendations on private sector wage dynamics suggests that PRB decisions tend to affect pay somewhat more in those private sectors that are more domestically-facing.

2. A review of the existing literature

2.1 Sectoral wage interactions

The existing empirical literature has mainly focussed on the directionality of spillovers between the public and private sector but there is no consensus on which sector dominates the economy-wide wage setting process. For a panel of OECD countries, Afonso and Gomes (2014) find evidence for a short-run impact of public sector wage growth as well as public sector employment on private sector wages. This result is explained by the outside option to unemployed members of the labour force provided by public sector employers which has an effect on private sector wage bargaining. Lamo *et al*. (2012) find considerable heterogeneity across OECD countries with respect to which sector leads or lags. Country-specific studies include Lindquist and Vilhelmsson (2006) who show that the (white collar) private sector leads the wage-setting process in Sweden while Demekas and Kontolemis (2000) find that public sector wage growth dominated wage setting in Greece in the 1970s and 1980s. Camarero *et al*. (2014) highlight substantial differences across euro area countries. It is only in Germany, Belgium and Greece that the public sector sets the level of wages for the rest of the economy, whereas in countries that experienced a housing market bubble in the run-up to the Great Financial Crisis, like Spain and Ireland, the construction sector leads.

There has been little research exploring wage leadership and follower relationships in the UK. Exceptions include the now somewhat dated study by Lee and Pesaran (1993) who analyse wage interactions across sixteen industrial sectors of the UK economy but do not explicitly look at interactions with the public sector. They provide evidence for significant spillovers across sectors while sector-specific wage pressures, like those arising from productivity gains, are only significant for industries outside service-producing sectors.

2.2 Determinants of wage spillovers

It also remains unclear what exactly determines a wage spillover from one sector to another and to what extent employees really tend to move from one sector to another in response to wage differentials. Wage spillovers may be the result of wage bargaining when a union in a given sector benchmarks its desired wage against wages in other sectors, which serve as a 'fallback wage' for workers of the given sector. This may be driven by fairness concerns or because income comparability contributes to individual utility. The degree of labour market segmentation also matters as wage differentials may persistent across sectors if workers tend not to move sector. By contrast, wages may fully equalise if there was complete labour mobility. Latreille and Manning (2000) assess wage spillovers across 88 UK industries and do not find evidence for spillovers to be explained by cross-sectoral worker movements. Instead, wage spillovers are found to be larger within broad industry classifications which to the authors suggests that

institutional factors determine spillovers, like collective agreements spanning across sectors (while covering narrowly defined occupations). Driffield and Taylor (2006) study wage spillovers both across UK regions and manufacturing sectors as well as the role of international openness in the form of foreign direct investment. They find that inter-industry wage spillovers are significant but those that originate in largely foreign-owned sectors are limited to skilled workers, and that there are distinct spatial labour markets.

We are not aware of any work that has analysed the combined effect of international competition, changes in the institutional environment over time and public sector pay policy on labour market interactions across sectors of the economy as this study does.

2.3 Other factors determining wage dynamics

There are eight further areas of our econometric investigation which we largely set to one side. These areas are: wage drift, union bargaining and wage rigidities, unemployment and migration dynamics, the role of business cycles, distributional and political economy issues, measurement concerns, search-theoretic foundations and labour market matching. These are all issues which have direct relevance to our research on the nature of public-private sector wage interaction. Variously, some of these areas have been developed theoretically but there is a gap in the empirical applied econometric evidence. Some are logical caveats to the work we undertake and reported on here. Others are areas which pose substantive topics for research in their own right and are hence beyond the scope of this targeted investigation. Appendix D discusses these areas in more detail and amplifies why they may be empirically important in principle, but why the pragmatic nature of our econometric work either handles them indirectly or justifies why we have not studied them explicitly.

3. Characteristics of UK sectoral labour markets over time

The aim of this section is to provide an overview of key structural changes that have occurred in UK sectoral labour markets in recent decades. It also introduces some important variables the subsequent analysis draws on. Details about data sources and the construction of all variables used in this report are provided in Appendix A.

Figure 2 provides an overview of pay dynamics in the private sector and the public sector, respectively. A frequently used measure of pay is average weekly earnings, which for the public sector and broad private sectors is available from the Office for National Statistics at monthly frequency, including and excluding bonus and arrear payments. Its higher frequency compared to wage data allows detailed analyses of pay dynamics.

An alternative measure of changes in pay is pay settlements. Compared with earnings data, settlements data has the benefit of conveying information about pay excluding bonuses, arrears, and incremental pay rises which cannot be distinguished in aggregate earnings data. Building on data employed in Dolton *et al*. (2011), which we update using individual settlements data from XpertHR (yielding a total of more than 100,000 firm-level observations), we construct a new dataset of sector-level pay settlements. In particular, we aggregate our data for 14 sectors of the economy at quarterly frequency (see Table A1 in the Appendix). The level of aggregation is determined by the availability of settlements data as well as the breakdown of data for other main variables of interest.

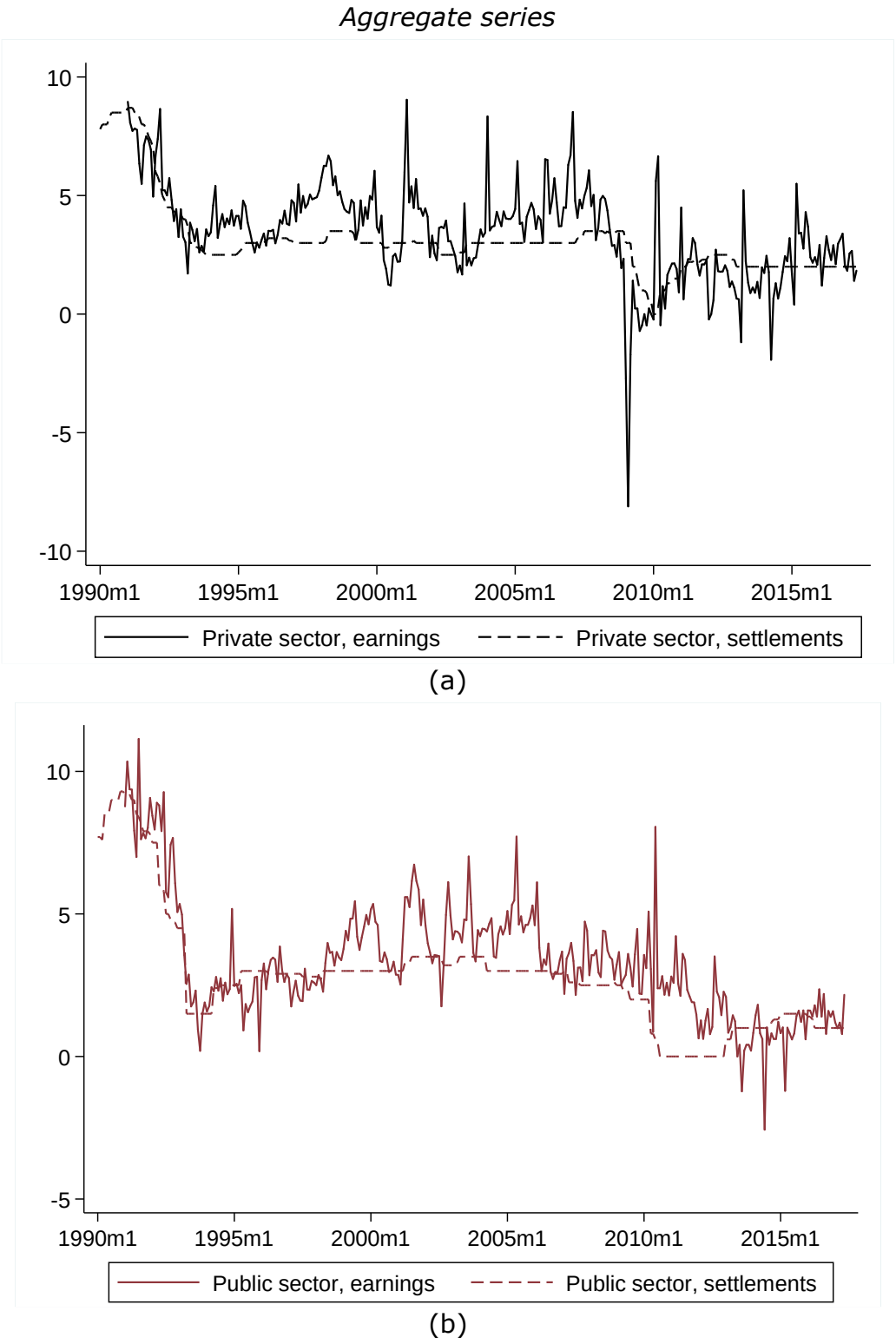
Figure 2 illustrates that that there has been a significant slowdown in pay dynamics on all measures of pay since the 1990s. In particular the Great Recession of 2008-09 is a watershed after which nominal wage growth dropped substantially. The reduction in wage growth in the aftermath of the crisis was more pronounced in the public sector (Figures 2b and d) than in the private sector (Figures 2a and c). Comparing settlements data with earnings data, Figure 2 illustrates that settlements tend to lead average weekly earnings dynamics. This is because the latter also incorporate incremental pay rises making earnings a more sluggish measure of pay dynamics. Figures 2c and d also illustrate that there is considerable variation in pay settlements across sectors, although it is substantially higher in the private sectors than in the public sectors.

Table 1 summarises main characteristics of UK sectoral labour markets for two different periods, 1996 to 2000 and 2011 to 2015, at the beginning and end of our sample.[1] The last three decades saw a well-documented decline of traditional

[1] The periods are chosen to ensure the greatest overlap in terms of data availability. The subsequent analysis uses a sample that stretches to 2016/17.

sectors, in particular manufacturing, while service sectors gained total employment shares.

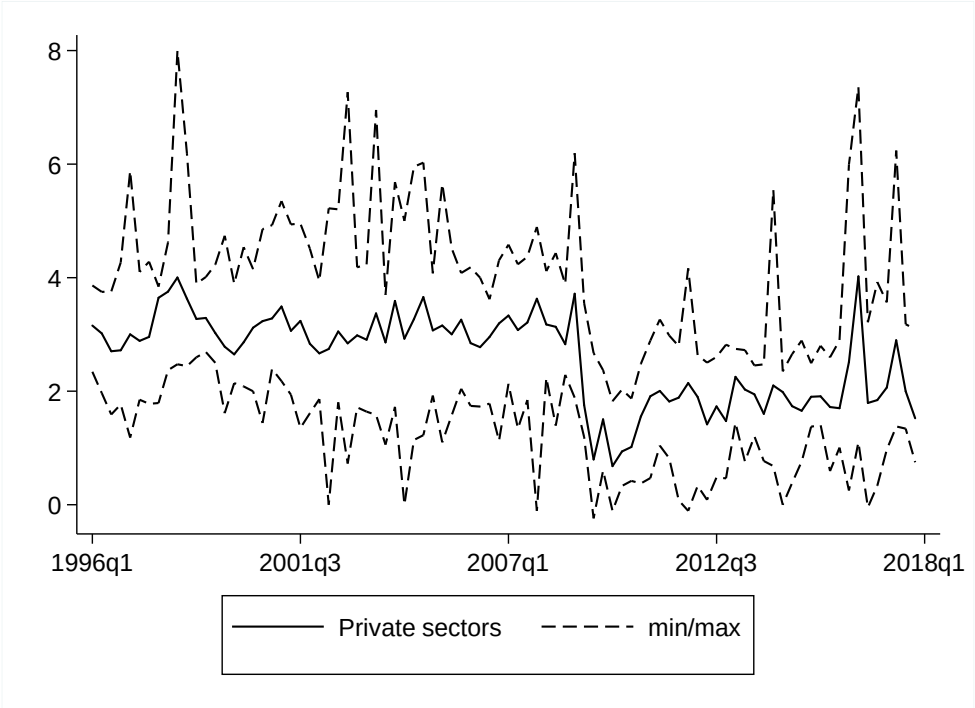
Figure 2. Earnings growth and wage settlements (per cent)



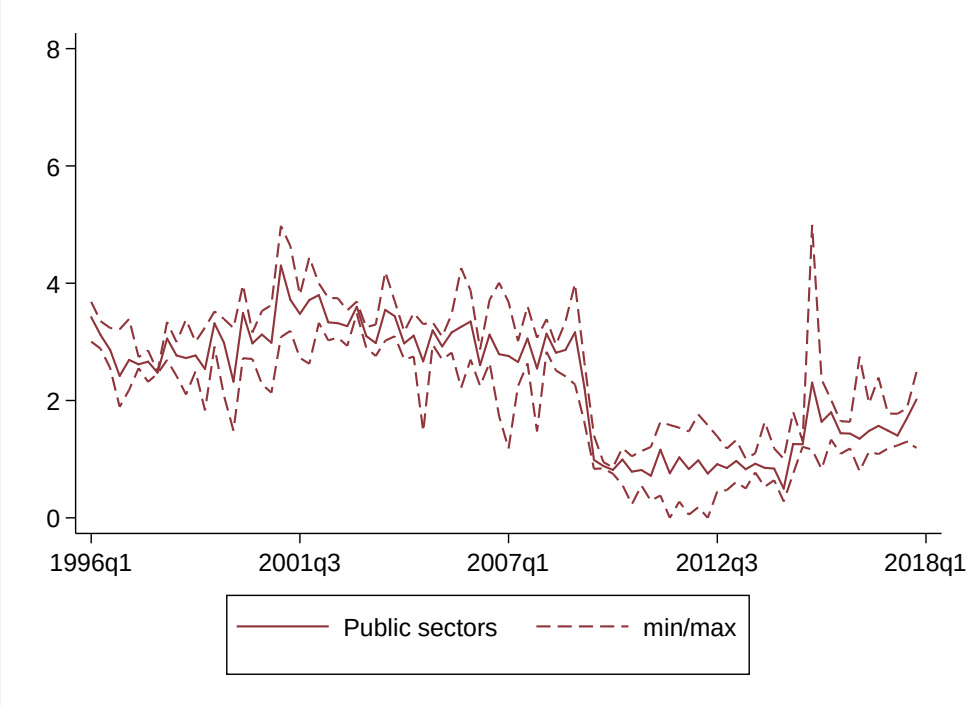
Notes: Public sectors in (d) are public administration and defence, education, and health and social work. Nominal data.
Sources: see Appendix A.

Figure 2 (continued). Earnings growth and wage settlements (per cent)

Sector-level data



(c)



(d)

Notes: Public sectors in (d) are public administration and defence, education, and health and social work. Nominal data.
Sources: see Appendix A.

The rebalancing towards services is also reflected in a greater role for sectors with high shares of public sector employees, i.e. public administration and defence, education, health and social work.[2] The same period saw a broad decline in the share of employees covered by union membership across all sectors of the economy. The predominantly public sectors continue to exhibit the largest degree of union density.

Productivity measured as real output per hour worked varies significantly across sectors. Apart from the relatively small mining and quarrying and utilities sectors, labour productivity is particularly high in manufacturing, finance and business service sectors. By contrast, public sectors as well as trading and hospitality sectors exhibit low average productivity levels but also relatively low productivity growth between the late 1990s and 2010s. There is a high correlation between productivity and openness to trade, measured by the degree of sectoral export dependence and the degree of competition from foreign imports faced by each sector.

Turning to demographics, characteristics of the workforce also vary substantially across sectors. The public sectors tend to employ a larger share of women and older workers compared with most of the private sectors.[3]

Finally, we measure employment flows from one sector to another each quarter using longitudinal Labour Force Survey data. We focus only on direct cross-sectoral movements instead of movements in and out of unemployment or activity. Our flow data therefore applies to a particular subset of workers which is more likely to move up the career path, and receive pay increases, compared to those that undergo a spell of unemployment. From the workers that are employed in two subsequent quarters, around 94 per cent remain employed in the same sector in both quarters. Using similar data, Fontaine *et al.* (2018) document that the probability of private sector employees to transition into unemployment is around 1.6 per cent in a given quarter compared to 0.5 per cent in the much less volatile public sector. For workers that move directly across sectors, we construct a measure of sectoral employment flows in absolute terms (log employment flows) and relative terms (relative to sector employment). This yields a sector network which connects sectors through relative employment flows an is depicted in Figure C1 in the Appendix. The figure shows that cross-sectoral employment flows have become denser since the 1990s indicating that it has become more common for workers to move from one sector to another. To measure the importance of each sector in the network, we construct an index of centrality (see Jackson, 2010, and

[2] Note that information on public sector employment in the Labour Force Survey used to construct public sector shares is self-reported and prone to inaccuracies.

[3] We also obtain sector-level data on average levels of qualification and part-time work. The former does not vary substantially across sectors, presumably because sector categories as defined here are relatively large. The latter is highly correlated with the share of female employees.

Appendix A). Centrality is a measure of the importance of a node in a network. In the present case, sectors can be thought of as nodes in an economy-wide network.

Table 1. Sectoral labour market characteristics

	Employment share		Public sector employees		Union density	
	1996-2000	2011-2015	1996-2000	2011-2015	1996-2000	2011-2015
Agriculture, etc.	0.018	0.013	0.02	0.02	0.11	0.08
Mining & quarrying	0.004	0.004	0.01	0.01	0.34	0.19
Manufacturing	0.181	0.100	0.01	0.01	0.30	0.18
Utilities	0.007	0.013	0.07	0.12	0.58	0.38
Construction	0.070	0.072	0.08	0.05	0.25	0.14
Wholesale & retail	0.156	0.134	0.01	0.01	0.11	0.12
Hotels & restaurants	0.045	0.049	0.05	0.03	0.07	0.04
Transport, communication	0.065	0.086	0.16	0.07	0.37	0.27
Finance	0.042	0.038	0.03	0.02	0.33	0.16
Business activities	0.101	0.124	0.06	0.05	0.10	0.10
Public administration	0.061	0.063	0.95	0.85	0.61	0.51
Education	0.079	0.109	0.83	0.76	0.54	0.52
Health & social work	0.113	0.140	0.60	0.53	0.47	0.41
Other services	0.053	0.052	0.26	0.16	0.19	0.14
Total	1	1	0.22	0.19	0.31	0.23

	Productivity (£/ hour)		Export competition		Import competition	
	1996-2000	2011-2015	1996-2000	2011-2015	1996-2000	2011-2015
Agriculture, etc.	14	14	0.12	0.13	0.29	0.40
Mining & quarrying	173	182	0.88	0.95	0.32	0.95
Manufacturing	27	36	0.34	0.37	0.53	0.84
Utilities	69	74	0.05	0.10	0.03	0.03
Construction	20	26	0.00	0.01	0.00	0.01
Wholesale & retail	21	24	0.04	0.02	0.00	0.00
Hotels & restaurants	14	17	0.10	0.11	0.15	0.15
Transport, communication	31	37	0.21	0.26	0.10	0.11
Finance	38	66	0.30	0.52	0.04	0.06
Business activities	51	48	0.11	0.18	0.05	0.06
Public administration	24	33	0.01	0.01	0.00	0.00
Education	26	30	0.03	0.05	0.01	0.01
Health & social work	19	22	0.00	0.00	0.01	0.01
Other services	20	26	0.06	0.08	0.08	0.11
Total	39	45	0.16	0.20	0.12	0.19

	Share of female workers		Age		Centrality	
	1996-2000	2011-2015	1996-2000	2011-2015	1996-2000	2011-2015
Agriculture, etc.	0.24	0.27	43.5	48.6	0.08	0.06
Mining & quarrying	0.13	0.16	40.9	44.2	0.02	0.02
Manufacturing	0.28	0.25	39.5	43.6	0.85	0.64
Utilities	0.25	0.21	38.9	42.9	0.04	0.10
Construction	0.10	0.13	39.9	43.1	0.31	0.39
Wholesale & retail	0.51	0.51	36.9	40.1	1.00	0.75
Hotels & restaurants	0.63	0.57	33.8	35.2	0.25	0.21
Transport, communication	0.25	0.24	39.9	43.2	0.38	0.47
Finance	0.55	0.47	36.0	40.2	0.19	0.14
Business activities	0.43	0.45	39.8	43.3	0.70	1.00
Public administration	0.47	0.52	40.0	43.9	0.18	0.30
Education	0.72	0.73	43.1	44.3	0.23	0.38
Health & social work	0.82	0.80	41.0	43.6	0.39	0.52
Other services	0.54	0.55	38.8	41.3	0.34	0.29
Total	0.43	0.42	39.4	42.7	0.35	0.38

Sources: see Appendix A.

A node is considered relatively central if it shares strong connections, here measured using cross-sectoral labour flows, with other sectors that are themselves well connected. Manufacturing, wholesale and retail, and business service sectors tend to be the most central sectors within the UK labour market. But centrality has also shifted since the 1990s with manufacturing becoming less important in the network than it used to be and business services and public sectors gaining importance.

4. Wage leadership

4.1 Modelling sectoral wage dynamics

A simple two-sector model

To illustrate how cross-sectoral wage interlinkages may come about, we follow Lindquist and Vilhelmsson (2006) and assume as a starting point that there are two sectors A and B in each of which a representative firm produces output using a Cobb-Douglas production function

(1) $y_t^i = a_t^i (l_t^i)^{\theta^i} \quad 0 < \theta^i < 1$

where y_t^i is output produced by sector $i \in \{A, B\}$ in period t. For illustrative purposes, labour l_t^i is assumed to be the only factor of production alongside technology a_t^i. Technological change is assumed to follow a trend-stationary process

(2) $a_t^i = \tau_1^i + \tau_2^i a_{t-1}^i + \tau_3^i t + \varepsilon_t^i \quad 0 < \tau_2^i < 1, \tau_3^i > 0, \varepsilon_t^i \sim N(0, \sigma^i)$

Firms maximise profits subject to equation (1) and (2)

(3) $\Pi_t^i = P_t^i y_t^i - W_t^i l_t^i$

where P_t^i is the price of output y_t^i and W_t^i is the nominal wage paid in sector i. The first-order condition for the profit maximising firm in sector i yields the equilibrium wage assuming for simplicity perfectly competitive markets for output and labour inputs

(4) $W_t^{i^*} = P_t^i \theta^i a_t^i (l_t^i)^{\theta^i - 1}$

Equation (4) shows that in perfectly competitive markets, nominal wages in a given sector should reflect productivity enhancements in that sector as well as price levels. In the long run, we would expect workers to move across sectors, productivity enhancements to be shared across the economy and demand for output to adjust, i.e. labour and product markets to clear, such that wages in the economy are driven by aggregate productivity levels and equalise

(5) $W_t^{A^*} = W_t^{B^*}$

In the short run however, various frictions may prevent wages from equalising. Wage differentials may arise if one of the sectors experiences more frequent productivity changes, ε_t^i, than the other sector.[4] This would make this sector the productivity and ultimately, over time, the wage leader. Hence this sector would be setting the wage level that will be reached in other sectors of the economy gradually over time, once workers move and sector-level wages adjust.[5]

In addition, workers may temporarily be able to negotiate higher wages in one sector. This sector would then set the benchmark wage which wages in the other sector may follow for some time. For instance, wages in sector A may serve as a benchmark for wages in sector B such that actual wages in sector B temporarily deviate from market wages.

To structure ideas, one could think of cross-sectoral wage dynamics to be driven by the process captured in equation (6) in which the current level of wages in a given sector B is a weighted average of past wages in that sector W_{t-1}^B, the equilibrium wage $W_t^{B^*}$ defined by equation (4) and current wages set in the rest of the economy W_t^A:

$$(6)\ W_t^B = W_{t-1}^B \left[\frac{{W_t^{B^*}}^{\delta_2} {W_t^A}^{1-\delta_2}}{W_{t-1}^B} \right]^{\delta_1},\ 0 < \delta_1 < 1, 0 < \delta_2 < 1$$

Equation (6) suggests that there can be considerable persistence in wages (presence of past wages), wage spillovers across sectors (a role for other sectors' wages in the dynamic relationship) as well as convergence towards a long-run equilibrium. In the long run, wages in all sectors would be expected to return to their equilibrium rates defined by equations (4) and (5) as workers move across sectors, new technologies are adopted across the economy and demand adjusts.

In reality, various other factors affect the wage setting process and wage dynamics are richer than in the simple theoretical example outlined above. We necessarily abstract from many of such complications in the following analysis.

A more realistic description of the labour market

Developing a comprehensive theoretical framework to provide a more realistic description of the sectoral labour market lies outside the scope of this report. An empirical analysis of labour market interactions nevertheless needs to investigate and control for the most important of these factors. The contribution of this report therefore lies in bringing together various theoretical arguments that are likely to explain labour market interactions in the UK in the last three decades and test them in a coherent empirical set-up.

[4] In this example, we assume productivity changes can be positive or negative.

[5] For the sake of clarity we abstract here from differences in worker characteristics.

The idea that more open sectors tend to be more productive has been underpinned by research on the impact of trade on heterogeneous firms. Melitz (2003) shows theoretically that exposure to trade means only the most productive firms engage in international competition offering them more profit opportunities. Higher potential returns in this class of economic models also induces the establishment of more productive firms. This leads to an increase in aggregate productivity. Increased labour demand by more productive firms (or sectors) and newly established high-productivity firms lead to an overall increase in real wages which forces the least productive firms to shut down. In other words, more productive firms (and sectors) start paying higher wages when exposed to international competition, and other sectors follow or are being replaced over time. In our analysis, we consider sector-level productivity measures as determinants of wage growth and also account for openness to international trade through import or export competition.

Labour market institutions can shield sectors from international competition, leading to deviations of wages from their equilibrium determined by productivity enhancements. Freeman and Medoff (1984) show theoretically that high levels of unionisation act like a labour market monopoly and generate wage mark-ups. At the same time, unions may take into account the wider state of the macroeconomy and lower wage pressures to preserve employment levels. Unionisation in the UK has dropped significantly since the 1980s (see section 3). Brown and Wadhwani (1990) fail to find significant effects on wages and employment in the immediate aftermath of labour market reforms. Nickell (1997) shows that the link between institutions and labour market outcomes is rather complex and depends very much on the type of labour market reform and country characteristics. Blanchard and Wolfers (2000) show that labour market institutions, like the degree of union density, play an important role in how macroeconomic shocks are transmitted through the economy. Bowdler and Nunziata (2007) find that there is a significant, positive link between inflation and union density. They argue that this is the result of a pass-through from stronger wage pressure to labour costs and prices or because central banks conduct inflationary monetary policy in response to higher rates of unemployment associated with union power. Hantzsche *et al*. (2018) estimate that sectors with more flexible labour market institutions, like construction, tend to see smaller wage adjustments to financial shocks compared to more rigid sectors but a larger response takes place along other adjustment margins, in particular sector-level employment. Our analysis uses union density as one measure of workers' bargaining power and wage growth determinant.

The public sector in the United Kingdom is characterised by particularly strong levels of unionisation (see section 3). But public sector wages may not only deviate from overall productivity developments because of workers' bargaining power. Public spending decisions feed directly into hiring and pay of public sector staff. This can explain why in countries like Greece, Belgium and Germany, where the public sector plays a relatively more important role, public sector wages provide a benchmark for the rest of the economy (Demekas and Kontolemis, 2000;

Camarero *et al.*, 2014). In contrast, the recent episode of fiscal austerity in the UK has been characterised by stringent restraints on public sector pay awards.

Finally, to better understand wage dynamics it is important to account for the composition of the workforce (Verdugo, 2016). If a large share of low-skilled, low-paid workers exits employment during a recession this may be reflected in aggregate sector-level wages as a wage increase or wage rigidity and mask individual wage decreases for those workers that remain employed. We control in particular for differences in the gender balance and average age across sectors and over time.

An empirical representation

To account for equations (5) and (6) and differences in labour market characteristics between sectors and over time in our empirical specification, we follow Lindquist and Vilhelmsson (2006) and Lamo *et al.* (2012) and for the private and public sector set up an equation of log wage changes in error correction form. We model the nominal wage dynamics of sector A and possible interactions with sector B using the following general model:

(7) $\Delta w_t^A = \pi_0^A + \alpha^A[w_{t-1}^A - \beta^A w_{t-1}^B - \mu] + \sum_{i=1}^{L} \pi_i^A \, \Delta w_{t-i}^A + \sum_{j=1}^{L} \pi_{j,B}^A \, \Delta w_{t-j}^B + C_t{}' \pi_c^A + \varepsilon_t^A$

where monthly changes of log wages in sector A, Δw_t^A, are explained by up to L lagged wage changes in that sector. Wage series are allowed to be cointegrated, i.e. to converge to a long-run equilibrium over time. The equilibrium is defined by the relationship in log levels of both sectors' wages, and a wedge μ, $[w_{t-1}^A - w_{t-1}^B - \mu]$. The wedge μ can be attributed to a different composition of employment across sectors and institutional differences which may lead to higher wage levels.[6] Δw_t^B are changes in sector B's log wages which may influence wage setting in A and matrix C_t contains other sector-specific and macroeconomic variables that may affect sector A's wages in the short run with weights π_c^A, such as inflation and productivity. π_0^A is the constant term and ε_t^A is the error term capturing wage innovations that result from unobserved short-term deviations of wages from equilibrium.[7]

Similarly, wages in sector B may converge to a long-run equilibrium defined by sectors A's wages and in the short run may depend on own lags, lagged wage growth in sector A and control variables:

(8) $\Delta w_t^B = \pi_0^B + \alpha^B[w_{t-1}^B - \beta^B w_{t-1}^A - \mu] + \sum_{i=1}^{L} \pi_i^B \, \Delta w_{t-i}^B + \sum_{j=1}^{L} \pi_{j,A}^B \, \Delta w_{t-j}^A + C_t{}' \pi_c^B + \varepsilon_t^B$.

[6] The wedge, μ, may vary over time if the relative composition of the workforce changes. We address this issue in the form of a robustness check.

[7] As a robustness check, we also estimate a specification that explicitly controls for sector-level productivity growth.

Long-run wage leadership

Testing for long-run wage leadership amounts to testing whether wages of sector A are long-run forcing or 'weakly exogenous' to the long-run equation, i.e. provide a benchmark to which wages of sector B tend to converge, and *vice versa* for sector B. In practice, this means testing whether $\alpha^A = 0$, while at the same time $\alpha^B < 0$. If both hold, sector A would be considered the wage leader in the long run, and sector B the wage follower. The case $\alpha^B < 0$ and $\alpha^A < 0$, on the other hand, would imply a bi-directional leadership in the long run.

Conditional Granger causality

To test for short-run wage leadership, we employ the concept of Granger causality: sector B is considered a short-run wage leader if its short-run movements can explain the short-run movements of sector A's wages. It could come about as a result of wage bargains that are considered indicative for the rest of the economy or of government policy. For that to hold, the hypothesis $\pi^A_{1,B} = \pi^A_{2,B} = \ldots = \pi^A_{L,B} = 0$ would need to be rejected at statistically significant levels.

Causality in a statistical sense may not necessarily imply economic causality. For instance, this may be true, if the fact that wage changes in one sector precede wage changes in another sector are mere data artefacts. Our cross-sectoral dataset allows us to condition spillovers on a number of factors and thereby puts us into a position to make more rigorous causal statements. To do so, we estimate equations of short-run wage changes for each sector controlling for wage changes in other sectors and interacting these wage changes in other sectors with a number of conditioning factors. In the present example with two sectors these include factors that allow spillovers to vary over time, such as over calendar months. In the next section we consider a panel dimension of this framework in which factors will be allowed to vary across sectors as well.

We term the approach of making spillovers dependent on conditioning factors 'conditional Granger causality'. More specifically, we augment the regression framework as follows. For each time period, we interact the lagged wage change in sector B (the 'other' sector) with a set of conditioning factors (collected in matrix F^A_t) to assess if wages in sector A are affected in the statistical sense:

$$(9)\ \Delta w^A_t = \alpha^A[w^A_{t-1} - \beta^A w^B_{t-1} - \mu] + \sum_{i=1}^{L} \pi^A_i \, \Delta w^A_{t-i} + \sum_{j=1}^{L} \pi^A_{j,B} \, \Delta w^B_{t-j}$$

$$+ \sum_{j=1}^{L} (\Delta w^B_{t-j} \times F^A_t)' \pi^A_{j,B\times F} + F^{A\prime}_t \pi^A_{j,F} + C_t{}' \pi^A_{j,c} + \varepsilon^A_t .$$

Statistically significant parameters $\pi^A_{j,B\times F}$ would imply that the size of the short-run wage spillover from sector B to sector A depends on the values that conditioning factors take.

4.2 Long-run wage leadership

We employ aggregate data on average weekly earnings in the private and public sector to test for long-run wage leadership. We proceed in two steps. First, we estimate a general model of equations (7) and (8) and then impose restrictions to estimate both equations separately.

A general form of equations (7) and (8) is estimated to establish a) whether there is indeed a long-run relationship between both sectors' wages, b) which sector acts as the long-run leader and whether there are spillovers from one sector to another in the short run under different assumptions about the form of dynamics in the long run and short run. This amounts to estimating a vector error correction model for both earnings series. We refer the reader to textbooks like Hamilton (1995) and Pesaran (2015) for methodological details that underlie these standard macroeconometric techniques. Technical Appendix B1 also provides a summary of the methodological approach.

In particular, we test for a long-run (cointegrating) relationship between public and private average weekly earnings series using the Johansen approach. To do so, we have to specify whether our empirical specification includes constant and trend terms, in the short-run and long-run part of equations (7) and (8). This is usually done on the basis of available theory. To remain objectively agnostic, we estimate a range of different specifications, from one that allows for trend and constant terms in both parts of the equation to a fully constrained specification. The testing procedure asks whether a system of equations that includes a cointegrating (long-run) equation is significantly different from a constrained system that does not include a cointegrating equation. It starts with a test for zero cointegrating equations (matrix $\alpha\beta'$ with a rank of zero, where vector α collects long-run adjustment parameters α^A, α^B, and vector β collects parameters governing the long-run relationship, i.e. β^A, β^B, μ). It then proceeds with a test for at most one cointegrating equation (matrix $\alpha\beta'$ with a rank of 1). Only if both hypotheses are rejected, would the Johansen procenture proceed to test the hypothesis of the rank=2. In the present case of only two potentially endogenous dependent variables, private and public sector wages, a rejection of the hypotheses that rank=0 and rank=1 and an acceptance of the hypothesis that the rank=2 would imply that both series of interest are stationary and therefore cannot form a stable cointegrated relationship.

Table 2. Vector error correction results

	(1) unrestricted trend	(2) restricted trend	(3) unrestricted constant	(4) restricted constant	(5) no trend or constant
Johansen cointegrating rank test (trace statistic, 5% critical value in brackets)					
Rank 0	12.5* (18.2)	31.1 (25.3)	23.0 (15.4)	26.1 (20.0)	15.3 (12.5)
Rank 1	3.4* (3.7)	4.8* (12.3)	0.9* (3.8)	2.6* (9.4)	2.2* (3.8)
Error correction term					
Private sector series	0.02	-0.01	-0.01	-0.02*	-0.02
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
Public sector series	-0.06**	-0.07***	-0.06***	-0.05***	-0.08***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
Sum of short-run coefficients					
Public to private	-0.024*	0.176	0.043	0.078*	0.438**
	(0.08)	(0.10)	(0.11)	(0.10)	(0.04)
Private to public	-0.527	-0.616	-0.391	-0.416	-0.394
	(0.18)	(0.15)	(0.17)	(0.16)	(0.18)
Model selection (information criteria)					
AIC	-15.9	-15.9	-15.9	-15.9	-15.9
HQIC	-15.5	-15.5	-15.5	-15.6	-15.5
SBIC	-15.0	-15.0	-15.0	-15.0	-15.0

Note: Dependent variables are aggregate public and private average weekly earnings series excluding bonuses and arrears. Monthly frequency. Number of monthly lags: 13 (determined by information criteria which are based on a simple vector autoregression of public and private sector average weekly earnings series, see Table C1 in the Appendix). Rank 1 indicates that there is a long-run equilibrium relationship between the private and public sectors' log wage levels. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Information criteria indicate the fit of each model with lower values reflecting a better fit. AIC: Akaike information criterion, HQIC: Hannan and Quinn information criterion, SBIC: Schwarz's Bayesian information criterion.

Results are reported in the top panel of Table 2. Most of the evidence confirms that there is indeed a long-run equilibrium relationship between both sectors' wages. For model specifications (2) to (5), i.e. all specifications apart from the most general specification, the hypothesis of rank=0 is rejected (the value of the test statistic lies above the 5 per cent critical value, first row of Table 2). In contrast, the values of the trace statistics for a test of the hypothesis of cointegration (rank=1) lie comfortly below 5 per cent critical values (second row of Table 2). This means that parameters associated with the long-run part of equations (7) and (8), α^A, β^A, α^B, β^B, μ, are statistically significant. The most general specification (1) allows there to be a quadratic trend in the level of both sectors' wages. In the absence of extreme rates of inflation, this specification is unlikely to apply in practice. The Johansen test for cointegration cannot reject the hypothesis of no cointegration at 5 per cent levels (the trace statistic of 12.5 lies below the relevant critical value of 18.2). However, the test statistic associated with the hypothesis of cointegration (rank=1) is very close to the relevant critical value albeit marginally smaller, leading us to conclude that for the general specification (1) the evidence from a Johansen test of cointegration is ambiguous.

Given the acceptance of either the hypothesis of the rank=0 or the hypothesis of the rank=1, we do not proceed testing whether the rank=2.[8] Information criteria reported at the bottom of Table 2 suggest a very similar fit across different model specifications.

Another indication for whether a stable long-run relationship exists between public and private sector wages is to test whether one or both of the sectors' wage series tend to converge to a joint equilibrium. We proceed by testing which sector reacts to deviations of wages from a long-run relationship (the long-run follower) and which sector does not respond, i.e. exhibits weakly exogenous wage dynamics (the long-run wage leader). Results from the vector error correction estimation are reported in the middle panel of Table 2. They show that under all specifications, including the general specification (1), long-run adjustment parameters (α in the notation above, i.e. the error correction term) are statistically significant for public sector wage series. The hypothesis that parameters are zero cannot be rejected for private sector wage series. In other words, this suggests that in a system of wage equations, private sector wages tend to move independently while public sector wage series gradually adjust over time to a common equilibrium defined by wages in the private sector. Private sector wages are long-run forcing while public sector wages respond endogenously. This suggests that the private sector acts as the wage leader in the long run while public sector wage setters tend to follow private sector wage developments gradually over time.

A disadvantage of the vector error correction approach is that it is not very flexible in accommodating a number of additional features that may play a role in public and private wage setting, such as the conditioning factors of equation (9). We therefore follow Lamo *et al.* (2012) and estimate equations (7) and (8) separately for the private and public sector. We also account for bonus and arrear payments which can constitute an important form of pay in particular in the private sector. To do so, we follow Lamo *et al.* (2012) and impose the restriction $w_{t-1}^{A} = w_{t-1}^{B} + \mu^{A}$, i.e. $\beta^{A} = \beta^{B} = 1$. A departure from this relation would imply that inflation has an effect on relative wages which we rule out.[9] We estimate equations (7) and (8) by OLS which are consistent with specification (4) in Table 2 allowing for a constant term in the long-run part of the equation.[10] Newey-West standard errors are

[8] To additionally confirm that public and private average weekly earning series are non-stationary, we conduct a series of Dickey-Fuller unit root tests which fail to reject the hypothesis that either of the series contain a unit root.

[9] To confirm the validity of this assumption, we estimate a long-run equation for public and private sector wage series allowing for a linear trend and constant term (case A), for a constant term and no trend (case B) and no constant term and no trend (case C). Parameter estimates for private sector wages (keeping public sector wages as dependent variable) are: 1.176 (case A), 1.119 (case B), 1.017 (case C). The hypothesis that the estimate is different from 1 is rejected for cases B and C and accepted with a p-value of 0.2 for case A. If bonus and arrear payments are accounted for, the hypothesis is rejected in all three cases.

[10] In what follows, we consider (4) the preferred specification. Information criteria (bottom of Table 2) confirm that all five specifications fare similarly well in fitting the data, with marginal preference being given to

computed for inference to account for potentially serially correlated error terms ε_t^A, ε_t^B.

Table 3. Results from sector-specific regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Including bonuses, arrears:	yes	yes	yes	yes	no	no	no	no
Sector:	Private sector		Public sector		Private sector		Public sector	
Long-run endogeneity	0.011	0.026	-0.04***	-0.036**	-0.012	0.005	-0.032**	-0.024*
(ECM term)	(0.02)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Short-run causality	0.122***	0.108***	0.055*	0.068*	0.031	0.024***	-0.001	0.006**
(other sector, p-value)	*(0.00)*	*(0.00)*	*(0.06)*	*(0.06)*	*(0.13)*	*(0.01)*	*(0.96)*	*(0.03)*
Other sector *								
January		0.308***		-0.030		0.176***		-0.128*
		(0.10)		(0.05)		(0.05)		(0.07)
February		0.078		-0.010		0.064		0.005
		(0.14)		(0.05)		(0.08)		(0.09)
March		-0.126		0.075**		-0.009		-0.010
		(0.15)		(0.04)		(0.06)		(0.09)
April		0.014		-0.003		0.075		0.267***
		(0.20)		(0.05)		(0.07)		(0.10)
May		0.083		0.099		-0.020		-0.129**
		(0.08)		(0.07)		(0.05)		(0.06)
June		0.240***		-0.292		0.045		0.091
		(0.07)		(0.23)		(0.06)		(0.07)
July		0.121		0.396*		-0.018		0.027
		(0.08)		(0.20)		(0.07)		(0.08)
August		0.248***		0.184**		-0.004		0.100
		(0.06)		(0.09)		(0.06)		(0.09)
September		0.139**		0.151		0.012		-0.167**
		(0.07)		(0.12)		(0.05)		(0.07)
October		0.159***		-0.033		-0.073*		0.020
		(0.05)		(0.10)		(0.04)		(0.07)
November		0.086		0.095		0.092***		-0.019
		(0.10)		(0.08)		(0.03)		(0.08)
December		-0.057		0.182*		-0.056		0.018
		(0.11)		(0.11)		(0.08)		(0.07)
RPI inflation	0.117**	0.112**	0.026	0.034	0.033*	0.019	-0.018	-0.003
	(0.05)	(0.05)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)
Observations	316	316	316	316	196	196	196	196
R-squared	0.805	0.890	0.627	0.661	0.555	0.610	0.659	0.709

Note: Monthly frequency. Lagged annual changes in the other sector's log wages serve as regressor. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. P-values from a test of joint significance in italics.

We consider two specific cases: one in which average monthly wage growth in one sector is affected by annual wage growth in the other sector up to the month prior to the month under consideration; and one specification in which spillovers from

specification (4) (smaller Hannan and Quinn criterion). As a robustness check, we also estimate the main specifications including a linear trend term (see section 4.4).

the other sector's annual wage growth depend on the time within the calendar year. The latter specification accounts for the fact that spillovers may vary by calendar month depending on whether a month falls into a typical pay review period or not, i.e. times of the year when employees' performance and pay are re-assessed. From an estimation point of view this means estimating equation (9) using dummy indicator variables for each month as conditioning factors F.

Table 3 reports results for the case of annual wage growth spillovers and average weekly earnings series including bonuses and arrears (columns 1-4) and excluding bonuses and arrears (columns 5-8). The first two rows of the upper panel report estimates of the long-run adjustment parameter, i.e. error correction term, for each earnings series. Results confirm that private sector wages are long-run forcing for whole-economy wage dynamics, i.e. act as leaders. By contrast, error correction term estimates for the public sector are negative and statistically significant confirming that public sector wages tend to converge towards an equilibrium set by the private sector in the long run. These results hold independent of whether bonus and arrear payments are taken into account.

Using estimates of the long-run adjustment parameter, α, it is possible to calculate the half-life of deviations from the long-run equilibrium.[11] Suppose there is a 1 per cent increase in private sector wages. How long does it take on average for public sector wages to reduce the long-run wage gap to 0.5 per cent, holding everything else constant? Estimates of the adjustment parameter range from -0.08 to -0.024, depending on the estimation approach and whether bonus payments and arrears are taken into account.

This yields a range of half-life estimates from 8 months to 29 months. In other words, it can take between 8 months and 2½ years to halve an existing long-run wage gap between the public and the private sector. This may be because public sector employers and Pay Review Bodies need time to identify wage gaps in real time. It may also be because wage differentials have to build up enough for skill shortages to emerge and bite before the process is being reversed. The estimates reflect a cycle in which public sector wage growth dominates for 2 to 6 years, reverses and private sector wage growth becomes stronger in relative terms until the process starts again, as illustrated also by Figure 1 in the introduction. Suppose it takes 3 years for a 3 per cent wage differential to build up and the half life is 1½ years. It would then take 3 years for the differential to reduce to just over half a percentage point, yielding close to a six-year cycle.

[11] The half-life is calculated as $\log(0.5) / \log(1 + \alpha)$.

4.3 Short-run wage spillovers

Turning next to the question of short-run spillovers, we proceed again in two steps. We first analyse whether past wage movements in a given sector can explain wage growth in the other sector using the more general vector error correction approach. We then use the single equation method to allow potential wage spillovers to vary over the calendar year as described in the previous section.

Short-run results for the VECM approach are reported in the lower panel of Table 2. We find that for the specifications (2) to (5), the coefficient for spillovers from the public to the private sector is positive, albeit only statistically significant at the 10 and 5 per cent level, respectively, for the more restrictive model specifications (4) and (5). A positive coefficient indicates that public sector wage changes feature in private sector earnings determination with a positive weight. The most general model specification (1) yields a negative estimate for the spillover term that is significant at the 10 per cent level. The VECM approach delivers insignificant results for short-run spillovers from the private to the public sector. This may suggest that wage setting in the public sector is relatively slow in adjusting to private sector wage dynamics.

To explore further the possibility of short-run wage spillovers from the public sector to the private sector, we next turn to the single equation results reported in Table 3. The row labelled 'short-run causality' reports the sum of coefficients that correspond to wage changes in the respective 'other' sector alongside p-values from a test of joint significance. Columns (1), (3), (5), (7) report average results for the effect of lagged *annual* wage growth in a given sector on monthly wage dynamics in the respective other sector. The remaining columns allow for these spillovers to vary over the calendar year, possibly as a result of cyclical wage setting behaviour which tends to play an important role in particular in the private sector. Our findings confirm the possibility that there can be sizeable spillovers from the public to the private sector in the short run (columns (1), (2), (6)). The impact of annual public sector wage growth on monthly private sector wage dynamics is larger than month-on-month results reported in Table 2 given the lags with which earnings data becomes available in real time. Effects are also more significant when differences in spillovers over the calendar year are explicitly accounted for (columns (2) and (6)). This is confirmed by statistically significant interactions between lagged public sector wage growth and dummy indicators for individual calendar months in the bottom panel of Table 3. What is more, spillovers are economically more significant when bonus payments and arrears are taken into account as indicated by larger spillover coefficients in columns (1) and (2) relative to column (6). This suggests that private sector employers react to pay pressures from the public sector predominantly by increasing bonuses.

Taken together, evidence from employing different modelling approaches (VECM estimation, single equation estimation, interaction terms) and different variable definitions (monthly vs annual change, including and excluding bonus and arrear payments) suggests that private sector employers adjust regular *and* non-regular

pay in response to wage shocks emanating from the public sector, for instance to retain skilled staff. To illustrate, our estimates of short-run public-to-private spillovers ranging from -0.02 to 0.4 (average of around 0.1 across specifications)[12] imply that a 1 per cent increase in annual public sector wage growth leads to an increase of around 0.1 per cent, and up to 0.4 per cent in average nominal pay in the private sector. This appears to be a sizeable and economically meaningful estimate. With a public sector employment share of 20 per cent, the direct impact of a 1 per cent increase in public sector pay on whole-economy labour costs is 0.2 per cent. Also accounting for spillovers into the private sector, and abstracting from potential productivity improvements in the short run, the overall impact on unit labour costs increases to 0.3 per cent on average, and may reach up to 0.5 per cent. In contrast, short-run spillovers from the private sector to the public sector are smaller as public sector pay adjusts more gradually over time.[13]

4.4 Robustness checks

We conduct a number of robustness checks to corroborate our findings about long-run wage leadership and short-run spillovers.

Aggregate settlements data. We first check whether our results for short-run spillovers hold for pay settlements which are free from bonus and arrear payments and incremental pay rises. To do so, we use aggregate public and private sector settlements data from XpertHR, which is reported as 3-month rolling average growth (private sector) and 12-month rolling average growth (private and public sector). Results are reported in Table 4. Findings confirm results for average weekly earnings series: there is a significant impact of lagged public sector pay settlements on settlements in the private sector, independent of the model specification and despite the fact that settlements do not account for bonus payments. The response of public sector settlements to changes in private sector pay in the short run is not statistically significant.

Alternative specifications: Table 3 reports results for a specification in which monthly changes in earnings in one sector depend on annual changes in the other sector. This is motivated by the fact that annual wage growth is often considered as a benchmark. To confirm the robustness of our results, we re-estimate the model using lagged monthly changes in the source sector as the independent variable. Tables C3 and C4 in the Appendix report results which confirm long-run findings about private sector leadership while short-run findings are more volatile but are replicated for earnings series including bonuses and arrears. Weaker findings of short-run spillovers when using lagged monthly wage changes may

[12] Taken from Tables 2 and 3 (short-run causality, private sector wage equations).

[13] The sample size differs between earnings series including bonuses and arrears compared to series excluding both because the former is partly constructed using the ONS' experimental series stretching back to 1990. Table C2 in the Appendix confirms that differences in results are not much driven by the longer sample.

result from the fact that earnings data is only published with a lag and therefore not observed by wage setters in real time.

Additional control variables: One concern might be that cross-sectoral wage dynamics pick up general business cycle and macroeconomic trends. We therefore ran a number of robustness checks that include additional control variables. These include CPI inflation instead of RPI inflation, GDP growth, the unemployment rate and sector-level productivity growth. By including these additional economy-wide variables, we control for the impact of macroeconomic shocks on wage dynamics, such as the financial crisis of 2008-09. Tables C5 to C7 and C9 in the Appendix confirm the robustness of our findings when these additional controls are included.

Table 4. Results for aggregate settlements series

	(1)	(2)	(3)	(4)
Sector:	Private sector	Private sector	Private sector	Public sector
Dependent variable:	3m average	3m average	3m average	12m average
Short-run causality	0.12***	0.20***	0.20**	0.29
(other sector, p-value)	(0.00)	(0.00)	(0.03)	(0.13)
* months	no	no	yes	no
RPI inflation	0.18***	0.30***	0.30***	-0.07
	(0.05)	(0.06)	(0.06)	(0.08)
Observations	314	314	314	305
R-squared	0.884	0.848	0.852	0.657

Note: Pay settlements. Monthly frequency. Column 1 controls for lagged 3-month own sector settlements; columns 2-4 control for 12-month own sector settlements. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Trend terms and changes in the composition of employment: Another concern regarding the long-run relationship we imposed is that the long-run gap between private and public sector wage levels, i.e. parameter μ in equation (7), is varying as a result of structural changes. These changes can arise if the relative composition of the workforce, i.e. relative skills, gender balances, age, etc., move gradually over time. Specifications (1) and (2) of our VECM accounts for a trend relationship in the cointegrating equation capturing potential linear changes in the relative composition of the workforce in an agnostic way. In Table C8 in the Appendix, we include a linear trend term in single-sector wage equations and find that it affects pay growth in a statistically significant way. However, controlling for a linear time trend (similar to specifications (1) and (2) of the VECM reported in Table 2), yields similar results for short-term wage spillovers (short-run causality). Evidence for public sector wages error-correcting towards a joint equilibrium with the private sector becomes weaker, but only if bonus and arrear payments are excluded. Much empirical work has focussed on estimating the size of the public sector wage premium, accounting for relative characteristics of respective workforces (e.g. Disney and Gosling, 1998; Cribb *et al.*, 2014). While for our analysis we are not interested in the exact size of the pay differential, our results on long-run wage leadership and followership may depend on variations in the pay differential over time. We therefore construct a proxy for changes in the relative composition of public relative to private sector workforces. Details are explained in Appendix A. This yields an index of the composition of private relative to public

sector employment which is plotted in Figure C2 in the Appendix. Table C9 in the Appendix shows that time-varying compositional differences have a significant effect on equilibrium wages relevant for the public sector (column 2). Yet even when we account for compositional changes, our finding of long-run public sector followership remains significant.

5. Determinants of wage spillovers

Having established that there can be significant wage spillovers across sectors in the short run, we confirm previous findings (e.g. Lee and Pesaran, 1993) but with a particular emphasis on interactions between the public sector and the private sector. Most existing work stops at this point but we aim to understand what drives cross-sectoral wage spillovers. Theory provides little guidance. The simple model outlined in section 4.1 and international trade theory suggest that over time wages in the economy tend to adjust to wages in more productive and internationally open sectors. Whether this holds in the short run is far from clear. Institutional factors may also play a role. If collective agreements cover occupations across sectors then wage changes would automatically apply to several sectors (Latreille and Manning, 2000). In contrast, pay differentials between the public and the private sector may be balanced through employment flows as workers move to high-paying sectors. It may however be that certain sectors compete for workers with particular characteristics. In that case, if there was a shock to wages in one sector, competing sectors may aim to retain workers by adjusting their wages in response. Wages in other sectors may also be relevant to wage setting in a given sector if fairness concerns play a role or workers gain utility if wages are comparable across sectors (see discussion in Driffield and Taylor, 2006). We therefore test whether differences in productivity, openness to trade, employment and institutional characteristics can explain cross-sectoral wage spillovers. To do so, we employ a dataset containing average pay settlements in 14 sectors of the economy at quarterly frequency. This provides us with considerable variation in cross-sectoral wage interactions.

5.1 Identifying spillover determinants

We define pay spillovers as before as the impact of lagged changes in one sector's pay on changes in pay in another sector. To identify the average magnitude of spillovers, previous work has considered as a determinant of wage growth in a given sector the weighted average of wage growth in all other sectors.[14] To do so, a distance (or 'contiguity') measure is constructed that pre-defines how closely sectors are related with each other. Lee and Pesaran (1993) use the proportion each sector contributes to the aggregate wage bill to define sector weights, while Latreille and Manning (2000) and Driffield and Taylor use industry classifications.

[14] The macroeconomic and spatial literature refers to this approach as global vector autoregression, originally proposed by Pesaran *et al*. (2004).

Using pre-defined distance matrices therefore relies on assumptions about the determinants of spillovers. Latreille and Manning (2000) also experiment with cross-sectoral employment flows to measure the proximity of sectors but do not find that these are significant in explaining cross-sectoral wage spillovers. It is possible to remain agnostic about spillover determinants and estimate equations separately for each sector pair or consider a data-dependent rule to construct contiguity weights (Gross, 2013) but the economic cause of spillovers would remain unclear.

We therefore follow a different path and estimate the relative importance of different spillover channels using interactions between lagged pay growth and sector characteristics. To do so, we adapt equation (9) to a panel set-up where settlements of sector i in quarter t depend on lagged settlements in sector i, lagged settlements in sector $j \neq i$ and sector-specific as well as macroeconomic controls collected in matrix C_t^i:

(10) $\Delta w_t^i = \pi^i \Delta w_{t-1}^i + \pi^j \Delta w_{t-1}^j + (\Delta w_{t-1}^j \times F_t^{ji})' \pi^{jF} + C_t^{i\prime} \pi^C + \varepsilon_t^i$

We let spillovers depend on conditioning factors F_t^{ij} which are specific to each sector pair (i,j) and may vary over time. More specifically, we now define conditioning factors by the distance between sectors with respect to various sector characteristics.

Let V_t^i be a matrix that collects characteristics of sector i and V_t^j be a matrix collecting characteristics of sector j. Distance is then defined as the difference between characteristics of sector j – the 'shock sector' – and characteristics of sector i – the 'recipient sector':

(11) $F_t^{ji} = V_t^j - V_t^i$

We consider the following sector characteristics: share of public sector employees, union density, share of female employees, average worker age, labour productivity in logs, degree of export and import competition faced by sectors, and the centrality of sectors in a network defined by cross-sectoral labour flows.

We further include these characteristics directly as control variables for each sector i alongside sector-specific time trends. We also control for inflation and the unemployment rate, and the average economy-wide settlement weighted by each sector's employment share. The latter term accounts for the fact that spillovers from one sector to another may pass through third sectors. The cross-sectional dimension of our panel is made up by pairing each sector with each other sector, yielding $14 \times 14 - 14$ sector pairs.

5.2 Spillover estimates

Table 5 reports results for all sector pairs (columns 1-4). In order to analyse specific spillover channels relevant to the public sector, we consider the subset of sector pairs for which the three sectors with a majority of public sector employees

are spillover recipients, i.e. public administration and defence, education and health and social work (columns 5, 6). Finally, we consider a subset of sector pairs that consists of all 11 predominantly private sectors as recipients of spillovers originating in the three predominantly public sectors (columns 7, 8). Table 5 focuses on estimates of spillover determinants, i.e. estimates of coefficients π^{jF} in equation (10). Results for a baseline specification including control variables are available in Table C10 in the Appendix which shows that settlements tend to be larger in sectors with higher rates of unionisation, a higher share of males, a younger workforce and higher export competition while sector-specific measures of productivity employed here are not statistically significant. Settlements also respond to inflation and unemployment.

Table 5. Spillover determinants

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All sectors				Public sector as spillover recipient		Spillovers from public to private sectors	
Settlement spillover	0.00	0.01	0.01	0.00	0.00	0.01	-0.03	-0.16
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.04)	(0.12)
* Public		-0.12***	-0.12***	-0.14***				
		(0.03)	(0.03)	(0.03)				
* Union density		0.12***	0.11**	0.10**		0.03		0.53**
		(0.04)	(0.04)	(0.05)		(0.05)		(0.22)
* Female share		0.10***	0.10***	0.11***		0.03		0.32***
		(0.03)	(0.03)	(0.03)		(0.03)		(0.10)
* Age		0.00	0.00	0.00		-0.01**		-0.00
		(0.00)	(0.00)	(0.00)		(0.00)		(0.01)
* Export competition		0.11***	0.10**			-0.02		0.64***
		(0.04)	(0.05)			(0.06)		(0.18)
* Import competition		0.02	0.03			0.05		0.06
		(0.03)	(0.03)			(0.05)		(0.10)
* Productivity			0.00	0.03***		0.01		-0.03
			(0.01)	(0.01)		(0.02)		(0.06)
* Centrality		-0.01	-0.01	-0.03		-0.03		0.01
		(0.02)	(0.02)	(0.02)		(0.03)		(0.08)
R-squared	0.540	0.543	0.543	0.543	0.773	0.779	0.478	0.487
Observations	12,259	12,077	12,077	12,077	2,712	2,673	2,277	2,244
Sector pairs	182	182	182	182	39	39	33	33

Note: Sector-level pay settlements. Coefficients for interactions between other sector's lagged settlement and conditioning factors are reported. Estimated specifications further control for lagged own-sector settlements, share of public sector employees (columns 1-4), union density, female share, age, export competitiveness, import competitiveness, centrality, CPI inflation, unemployment rate, lagged average settlement, constant term, sector time trends. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

The first row of Table 5 shows that unconditional settlement spillovers are zero on average. This does not come as a surprise given that the estimate averages over sectors with very different characteristics. With spillovers being zero on average, we cannot exclude the possibility that in some instances spillovers are negative, i.e. a wage increase in one sector is followed by a smaller wage increase, or even decrease, in another sector. It is also possible that spillover effects are asymmetric, something that our linear set-up would not be able to pick up and that is best left for future analysis.

When interpreting the economic significance of these results, it is worth bearing in mind that in our sample settlements in a given sector tend not to change very often and very much from one quarter to the next. The median quarterly change in settlements across sectors and time is -0.03 percentage points, the 25th percentile is -0.4 percentage points, the 75th percentile is 0.4 percentage points and the standard deviation is 0.9 percentage points. This is also illustrated by Figure C3 in the Appendix.

Turning to average spillover results across private and public sectors (columns 2-4), we find that spillovers that originate in sectors that only employ public sector employees tend to be smaller by 0.1 percentage points of annual pay growth than spillovers from sectors with a 0 per cent share of public sector employees. This is indicated by significantly negative coefficients of 0.1 for the interaction between wage spillovers and the relative share of public sector employees. Across all sectors, spillovers are therefore larger between more similar private sectors than if they originate in the public sector.

The significantly positive coefficient for interactions between wage spillovers and union density in columns 2-4 of Table 6 suggests that spillovers are significantly larger if they originate in sectors with a higher share of unionised workers and impact less unionised sectors. In general, sectors with higher union density tend to reach higher pay settlements than less unionised sectors (see Table C10 in the Appendix).

Our estimates suggest that sectors characterised by lower bargaining power somewhat benefit from these higher settlements in the form of pay spillovers: the spillover of a 1 per cent pay rise in the source sector on pay in another sector is 0.01 percentage points higher for each 10 percentage point increase in union density differentials.

Similarly, spillovers are larger, the higher the share of female workers in the shock sector compared to the recipient sector, as suggested by a significantly positive interaction term between spillovers and the female share. The spillover is 0.01 percentage points higher for each 10 percentage point increase in the difference regarding the share of female workers.

We also find that on average, spillovers tend to originate in sectors that face stronger competition for exports, as suggested by the significantly positive

interaction between wage spillovers and our measure of export competition. For each 10 percentage points that the spillover source sector's measure of export competition is larger than the recipient sector's equivalent, the larger is the wage spillover by 0.01 percentage points. Openness to trade tends to be highly correlated with measures of productivity, as also discussed in section 3. This may explain why including both measures of trade openness – our indicators of export and import competition – and shock sector productivity does not yield significant effects for productivity (column 3) but excluding openness measures does (column 4). Export and import competition are also highly correlated, explaining the insignificant result for the latter measure.

How central a sector is in terms of cross-sectoral employment flows appears to have little bearing on wage spillovers, and neither does average worker age. The interaction terms for wage spillovers and our centrality measure or age are not statistically significant.

Focussing next on determinants of spillovers into the public sectors, we obtain less significant results (column 6 of Table 5). This is in line with findings for aggregate series and corroborates our conclusion that in the short run, wage setting in the public sector is very much shielded from private sector wage dynamics. The only variable for which we estimate a significant coefficient is age: public sector wage negotiators appear to take pay dynamics in relatively younger sectors somewhat into account.

An important question for wage setters in the public sector is how their decisions affect and potentially distort wage setting in the private sector. The average estimate for settlement spillovers from the public to the private sector remains statistically indifferent from zero (first row, columns 7-8), contrasting our findings for aggregate earnings data. This may suggest that characteristics of the particular source sector may matter.

Indeed, we find that public pay settlements have a larger impact on less unionised private sectors compared to private sectors with higher bargaining power as well as on sectors with a relatively small share of female employees. Interaction terms between spillovers from predominantly public sectors to predominantly private sectors and union density as well as differences in the share of female workers are positive and statistically significant (column 7). The larger the difference between highly unionised public sectors and impacted private sectors is, the larger is the pay spillover. The average level of union density in predominantly public sectors is between 40 and 50 per cent; average union density in the economy as a whole was around 20 per cent between 2011 and 2015 (Table 1). Spillovers of a 1 per cent increase in public sector pay into private sectors with a union density that lies 10 percentage points below the average are estimated to reach 0.05 per cent, holding all else equal, compared to on average zero spillovers.[15] This would

[15] Union density is given on a scale from 0 to 1, settlements are given in per cent. A 1 per cent increase in public sector pay has a spillover of zero on the average private spillover. Using the estimated interaction coefficient for

hold, for example, for domestically-facing wholesale and retail industries and constitutes an economically meaningful contribution to settlement adjustments over time. Similarly, the larger the difference between public and private sectors in terms of gender balance, the larger the pay spillover, potentially capturing the impact of unobservable workforce characteristics that tend to be correlated with the share of female workers.

We also estimate a positive and statistically significant coefficient for an interaction between pay spillovers and export competition suggesting that sectors that are less open to trade than others follow public sector pay dynamics more, such as domestically-facing services sectors. The average degree of export competition in the economy is 20 per cent, that in the public sector is close to zero (i.e. the average difference being minus 20 percentage points). Spillovers of a 1 per cent increase in public sector pay into sectors with average export shares are negligible. By contrast, the spillover would be 0.06 percentage points larger in sectors with an export share in total demand of only 10 per cent, like hospitality. To put this in context, the average pay settlement was 1½ per cent per annum between 2011 and 2015.

Pay settlements are determined by a number of factors of which pay spillovers are only one. While individual spillover determinants may have only small economic effects on the size of spillovers and thus, overall pay settlements, in practice different spillover determinants would be expected to reinforce each other.

union density, that spillover is larger by 0.005 percentage points for each 1 per cent increase in union density away from the average.

6. Cross-sectoral employment flows

6.1 Modelling employment flows

Economic theory of a fallback wage suggests that wage spillovers should be stronger if workers have the option of moving to sectors paying this alternative wage. This implies that there are substantial cross-sectoral employment movements. As a final check, we therefore analyse the determinants of cross-sectoral employment flows. To do so, we employ data on quarterly transitions of workers directly from one sector to another. As pointed out above, this means we focus on people that are more likely to progress upwards in their career and hence receive a pay rise as they change jobs. It also implies that we are capturing predominantly labour supply decisions as we would expect labour demand to be met both through employment within a sector and outside the sector (as well as unemployed and inactive workers). As explained in section 3, the number of workers we identify in the Labour Force Survey as those that move sector from one equarter to another is relatively small. Subsequent results therefore apply to a subset of employment flows in the economy.

Our empirical approach closely follows the sector-pair analysis of pay spillovers. For each sector pair, we regress log cross-sector employment flows from one quarter to the next on settlements in the destination sector as well as other characteristics of the destination and of the source sector. Given that settlements in the destination sector may themselves be driven by cross-sectoral employment flows, we adopt an instrumental variable approach to isolate the impact of exogenous wage changes on labour movements.

We denote the log of the number of workers (in 1,000s) moving from sector i to sector j in a given quarter, m_t^{ij}. We write cross-sectoral employment flows as a function of past flows as well as pull and push factors:

$$(12)\ m_t^{ij} = \beta_0^{ij} + \beta_1 m_{t-1}^{ij} + \beta_2 \Delta \widehat{w}_t^j + C_t^{j\prime}\beta_3 + C_t^{i\prime}\beta_4 + \beta_5 C_t^m + \varepsilon_t^{ij}$$

$\Delta \widehat{w}_t^j$ is the predicted change in settlements of the recipient sector which is obtained from a first-stage regression of settlement changes on a number of instruments. Instruments used to estimate $\widehat{w}_t^j$ include destination-sector specific characteristics (also used as controls in second-stage estimation) as well as economy-wide macroeconomic indicators of economic growth, price inflation and weighted average settlements. Given that the share of individual sectors in economy-wide indicators is small but the state of the macroeconomy is an important settlement driver (see Table C10 in the Appendix), we consider these macroeconomic measures as sufficiently exogenous to identify destination sector settlement changes. Estimates of β_2 in equation (12) reflect the wage elasticity of cross-sectoral employment flows. We also include source sector settlement changes Δw_t^i as an additional control variable.

Matrix C_t^j contains other pull factors that may make workers move to sector j. We include the destination sector's union density, share of public sector employees and female workers, average age, export and import competition, and productivity. Push factors, that may make workers leave sector i are collected in matrix C_t^i and include the source sector's characteristics using the same set of variables as for the destination sector.

We further control for economy-wide GDP growth (C_t^m) as a proxy for changes in labour demand and sector-pair fixed effects β_0^{ij}. ε_t^{ij} is the error term.

6.2 Estimates of employment flow determinants

As before, we report results for three subsets of the data (Table 6): for all sector combinations (i, j) (column 1), for all combinations in which one of the three public sectors (public administration and defence, education and health and social work) is the destination of labour flows (column 2), and for all combinations with private sectors as destination sectors for flows out of the public sector (column 3). Sargan tests reported at the bottom of the table confirm the validity of instruments used in the estimation.

We find that overall, changes in settlements in the destination sector act as a significant pull factor, as indicated by positive and statistically significant coefficients for 'Settlement j' in Table 6 (columns 1-2). A 1 percentage point increase in a given sector's settlement increases direct worker flows into that sector by around 5 per cent (more details about how estimates translate into absolute numbers below). This result is driven by the pull public sector settlement changes exert, as indicated by column 2. A 1 percentage point increase in the settlement of a public sector, relative to the previous quarter, raises worker flows into the public sector by 10 per cent. Changes in settlements in the private sector cannot explain worker flows from the public to the private sector however (insignificant coefficients for 'Settlement j' in column 3).

Sectors that are relatively more protected, like highly unionised sectors, see a lower employment turnover and worker inflows and outflows are inhibited. This is suggested by significantly negative coefficients for union density variables in column 1 (for source and destination sectors) and column 3 (for destination sectors). Various other control variables are also statistically significant but do not warrant a detailed discussion.[16]

[16] When restricting source and destination sectors to a subset of our sample in columns 2 and 3, we have to rely on a smaller number of observations making our results less robust to outliers. This can explain why some coefficients, like for import competition are estimated to be relatively large.

Table 6. Determinants of cross-sectoral employment flows (log)

	(1) All sectors	(2) Public sectors as recipients	(3) Flows from public to private sectors
Lagged flow ij	0.15***	0.16***	0.09***
	(0.02)	(0.04)	(0.03)
Settlement i	0.01	0.02	0.00
	(0.01)	(0.01)	(0.02)
Settlement j	0.05***	0.10*	-0.02
	(0.02)	(0.05)	(0.02)
GDP growth	-0.00	-0.01	0.01
	(0.00)	(0.01)	(0.01)
Union density i	-2.65***	-1.08	1.54*
	(0.56)	(0.95)	(0.89)
Union density j	-1.92***	1.94	-4.43***
	(0.56)	(1.49)	(1.30)
Public i	-0.64		
	(0.57)		
Public j	-0.09		
	(0.57)		
Female i	4.35***	5.06***	5.68***
	(0.60)	(1.09)	(1.05)
Female j	1.72***	0.84	1.22
	(0.59)	(1.50)	(1.22)
Age i	0.01	0.03	0.07*
	(0.02)	(0.03)	(0.04)
Age j	-0.00	0.07	0.10***
	(0.01)	(0.05)	(0.03)
Export competition i	1.03**	2.00***	
	(0.47)	(0.75)	
Export competition j	0.49	12.15***	0.92
	(0.56)	(3.50)	(0.60)
Import competition i	-1.57***	-2.00***	68.73***
	(0.28)	(0.49)	(26.64)
Import competition j	-1.18***	46.96*	-3.46***
	(0.29)	(24.66)	(0.47)
Productivity i	-0.07	0.14	-0.14
	(0.11)	(0.17)	(0.18)
Productivity j	-0.19	1.01***	-0.25
	(0.12)	(0.37)	(0.21)
Constant	0.32	-12.35***	-8.89***
	(1.22)	(2.77)	(2.21)
R-squared	0.108	0.115	0.132
Observations	8,205	2,041	1,471
Pairs	173	39	31
Sargan p-value[(a)]	0.821	0.891	0.094

Note: Log quarterly flow of employment across sectors. Settlements data are in per cent. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. (a) Null hypothesis: instruments are valid.

Considering log employment flows as the dependent variable means sector pair observations drop out in quarters when labour flows are zero. This reduces the sample size and the number of total sector pairs given that direct cross-sectoral flows tend to be small in absolute terms and frequently zero for smaller sectors. It may also bias results because it constrains the sample to positive movements.

Table 7. Determinants of cross-sectoral employment flows (absolute)

	(1) All sectors	(2) Public sectors as recipients	(3) Flows from public to private sectors
Lagged flow ij	0.24***	0.32***	0.18***
	(0.03)	(0.07)	(0.03)
Settlement i	0.02	0.05	-0.01
	(0.03)	(0.05)	(0.05)
Settlement j	0.23***	0.64**	0.00
	(0.08)	(0.30)	(0.09)
GDP growth	-0.00	-0.07**	0.05*
	(0.02)	(0.03)	(0.03)
Union density i	-3.96***	1.58	-0.26
	(1.49)	(2.73)	(2.70)
Union density j	-1.93	8.18	-1.12
	(1.74)	(5.21)	(3.25)
Public i	-4.08**		
	(1.84)		
Public j	-3.22*		
	(1.88)		
Female i	12.55***	15.34***	10.57**
	(2.29)	(4.52)	(4.12)
Female j	5.65***	-5.49	7.86**
	(2.10)	(9.17)	(3.86)
Age i	0.01	-0.00	0.27*
	(0.05)	(0.09)	(0.16)
Age j	-0.01	0.42**	0.07
	(0.04)	(0.18)	(0.09)
Export competition i	3.52**	3.37	
	(1.53)	(3.23)	
Export competition j	2.26	47.34***	6.39**
	(1.73)	(15.49)	(3.06)
Import competition i	-4.51***	-6.72***	245.65***
	(0.88)	(1.42)	(83.69)
Import competition j	-1.90***	163.78	-3.86***
	(0.70)	(120.40)	(1.08)
Productivity i	-0.26	0.36	-1.09
	(0.29)	(0.57)	(0.75)
Productivity j	-0.44	3.68**	-0.40
	(0.32)	(1.70)	(0.58)
Constant	0.75	-40.55***	-19.02**
	(4.08)	(11.21)	(9.25)
R-squared	0.259	0.224	0.108
Observations	12,792	2,826	2,376
Pairs	182	39	33
Sargan p-value[(a)]	0.093	0.804	0.040

Note: Absolute flow of employment in thousand across sectors. Settlements are data in per cent. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. (a) Null hypothesis: instruments are valid.

To check the robustness of our results and gain a better understanding of the economic significance of our results, we re-estimate equation (6) using absolute labour flows (in thousand workers) as the dependent variable. Table 7 confirms that our results remain qualitatively unchanged.

We can use the estimates provided in Table 7 to calculate absolute flow movements in response to changes in settlements. For instance, a 1 percentage point increase in public sector settlements, according to these estimates, increases the flow into the public sector each quarter by around 600 workers (or by around 2,400 per annum), as suggested by a coefficient estimate of 0.6 for destination sector settlements in column 2 of Table 7. To illustrate the economic significance of our estimates, Table 8 reports the average number of people that move into the three main public sectors each quarter. The average quarterly inflow into the public administration sector, for instance, is 9,600 workers from the professional services sector, 4,500 from the wholesale and retail sector and 8,700 from the health and social work sector. Each quarter, 6,700 employees previously employed in the professional services sector find employment in the education sector and 10,700 employees move from the wholesale and retail sector into health and social work. An additional quarterly inflow of 600 workers in response to a 1 percentage point public sector settlement increase in one quarter relative to the previous quarter is therefore an economically meaningful, policy-relevant quantity.

Table 8. Average quarterly employment flows (in thousand)

	Destination sector:	Public administration	Education	Health & social work
Source sector:	Agriculture, etc.	0.5	0.7	0.7
	Mining & quarrying	0.2	0.1	0.2
	Manufacturing	3.1	2.7	4.5
	Utilities	0.4	0.1	0.3
	Construction	3.1	1.3	1.7
	Wholesale & retail	4.5	6.4	10.7
	Hotels & restaurants	1.9	5.3	6.9
	Transport, communication	2.9	2.0	2.6
	Finance	2.2	0.9	1.7
	Business activities	9.6	6.7	9.7
	Public administration		5.4	12.1
	Education	4.1		8.3
	Health & social work	8.7	9.0	
	Other services	3.4	5.6	5.8

Source: Authors' calculations based on Labour Force Survey, see Appendix A.

7. Supplementary PRB remit group-specific results

This section presents supplementary results that apply directly to recommendations made by Pay Review Bodies for six of their remit groups: school teachers, NHS staff, doctors and dentists, prison staff, armed forces and police.

7.1 Data

We use data provided by the Office of Manpower Economics on annual pay recommendations made by Pay Review Bodies for each of the six aforementioned remit groups. We allocate annual data to quarters of the calendar year according to the publication dates of PRB annual reports. Employing a quarterly dataset allows a more thorough analysis of pay dynamics and interactions with the private sectors. Figure 3 plots the time series we obtain for six PRBs. It shows that PRBs tend to follow each other in their pay recommendations fairly closely.

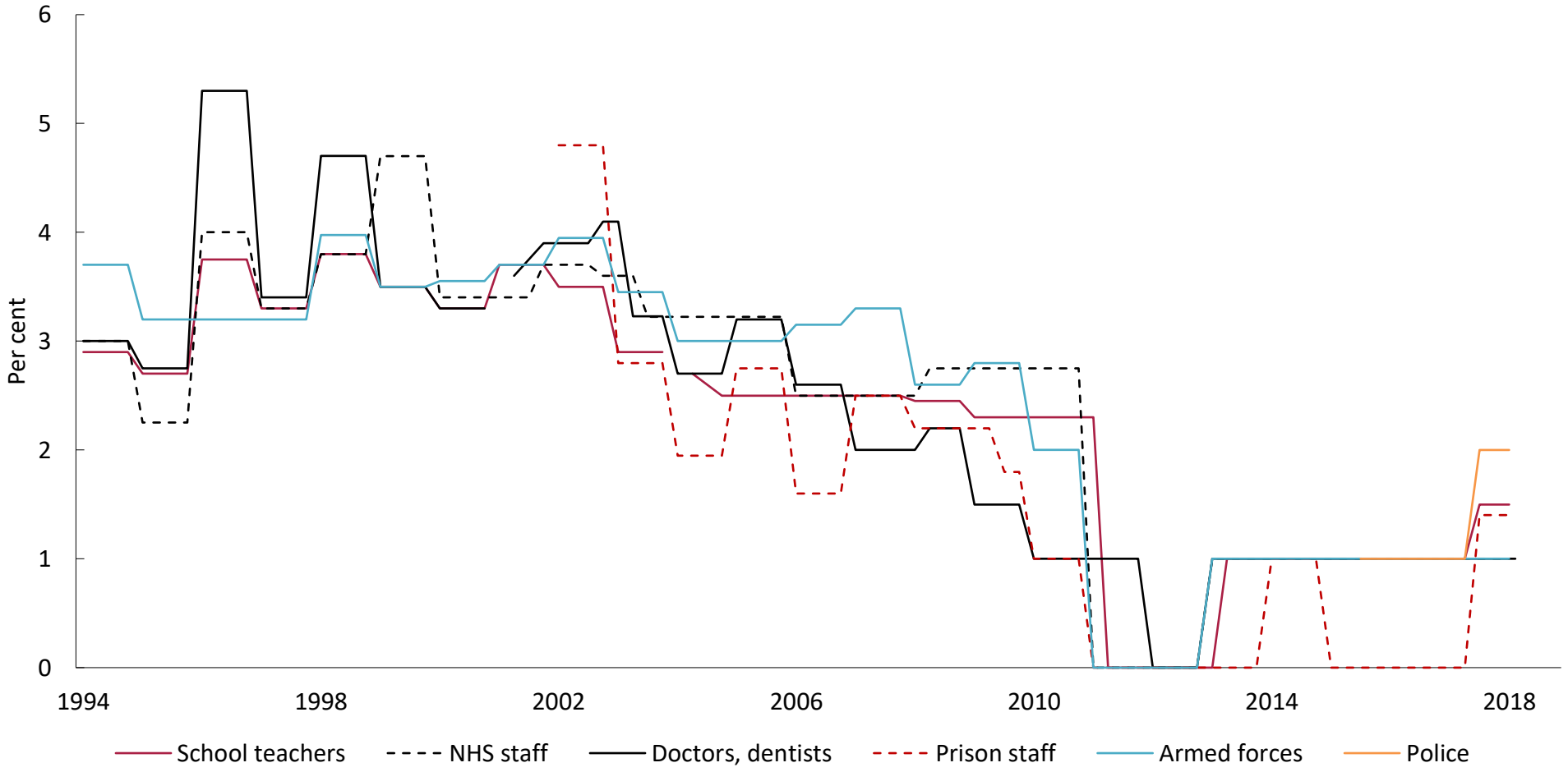
We then merge our data on PRB recommendations with the sector-level settlements dataset used in Section 5 of this report. This allows us to analyse interactions between PRB decisions and private sector wage dynamics. Because we are not able to identify settlements that were struck by non-PRB employers in the broad public sectors public administration, education, health and social work, we have to exclude these sectors from our analysis and replace them with PRB remit group data.

Table 9. Characteristics of PRB remit groups

	Number of employees ('000)		PRB decision (per cent)		Share of female employees		Age (years)	
	1996-2000	2011-2015	1996-2000	2011-2015	1996-2000	2011-2015	1996-2000	2011-2015
School teachers	185	405	3.5	0.7	0.60	0.70	39	39
NHS	1094	1344	3.8	0.6	0.82	0.82	40	43
Doctors, dentists	91	169	4.0	0.8	0.38	0.48	38	39
Prison service	35	32		0.2	0.14	0.25	40	44
Armed forces	96	72	3.5	0.6	0.05	0.07	33	35
Police	163	172		1.0	0.15	0.27	37	39

To obtain data on employment characteristics for each of the six PRB remit groups, we make use of occupational information in the Labour Force Survey. Following Dolton *et al.* (2015), we construct summary statistics at quarterly frequency for occupations that match those of the remit groups. While we may not be able to identify all the workers of a particular remit group, for instance because not a representative sample of members of the armed forces is surveyed in the LFS, we are confident that demographic imformation for samples reported in Table 9 closely approximates true PRB remit group demographics.

Figure 3. Pay Review Body recommendations



Source: OME, see Appendix A.

Table 9 summarises descriptive statistics for two periods at the beginning and end of our sample. It shows that NHS staff make up the largest remit group while the number of prison officers in the representative Labour Force Survey is very small. NHS staff are characterised by the highest share of females; the armed forces exhibit a small but growing share of female employees. Apart from the armed forces which have a large number of young members, the age distribution is relatively narrow amongst public sector employees.

To better compare PRB remit groups with private sectors despite the lack of available data, we extrapolate making the following additional assumptions. We assume that import and export competition for remit groups is zero. We also assume union density and productivity growth for school teachers equals that in the education sector, for NHS and doctors/dentists it equals union density and productivity growth in the health care sector and for prison staff and police we set variables equal to measures for general public administration.

7.2 Determinants of wage spillovers into and out of PRB remit groups

In order to determine the factors that make PRBs consider other sectors' wages in their decision-making as well as the determinants of spillovers of PRB recommendations into the private sector, we follow the empirical approach outlined in Section 5 of this report. For each sector pair that contains a PRB remit group as potential spillover recipient j as well as for sector pairs that contain PRB remit groups as spillover source i and any of the private sectors as spillover recipients j, we estimate equation (10), conditioning wage spillovers on the difference between source sector characteristics and recipient sector characteristics.

Results are reported in Table 10. PRB decisions are more persistent by construction than private sector settlements given there is only one decision a year that applies to the whole 'sector'. This is shown by a larger coefficient for the lagged dependent variable (columns 1-3) compared to sector results reported in columns 4-6 (and Table C11).

The list of control variables reported at the bottom of Table 10 in columns 1-3 suggests that a higher estimate of union density increases average settlements amongst remit groups, by 0.1 to 0.3 percentage points for each 10 percentage point difference in union density relative to the sample average. Average age has a negative effect on PRB pay awards while the impact of the sector-specific gender balance (female worker share) is ambiguous and interacts with other controls included. PRBs appear to respond to the business cycle, as indicated by significantly negative coefficients for unemployment, but not as much as wage negotiators in the private sector where the coefficient for unemployment is larger in absolute terms in columns 4-6.

Table 10. Spillover determinants: PRB remit group results

	(1)	(2)	(3)	(4)	(5)	(6)
	PRB remit groups as spillovers recipients			Spillovers from PRB remit groups to private sectors		
Lagged settlement	0.74***	0.74***	0.75***	0.26***	0.26***	0.26***
	(0.01)	(0.01)	(0.00)	(0.04)	(0.04)	(0.04)
Lagged spillover	0.00	0.01*	0.01	-0.14***	-0.14***	-0.02
	(0.00)	(0.01)	(0.01)	(0.02)	(0.04)	(0.07)
* Union density (diff)		0.01	-0.01		-0.00	-0.03
		(0.01)	(0.01)		(0.12)	(0.15)
* Female worker share (diff)		0.03***	0.02**		-0.02	-0.02
		(0.01)	(0.01)		(0.03)	(0.05)
* Age (diff)		-0.00**	-0.00		-0.00	-0.00
		(0.00)	(0.00)		(0.00)	(0.00)
* Export competition (diff)			-0.04**			0.44**
			(0.02)			(0.17)
* Import competition (diff)			-0.00			0.05
			(0.02)			(0.08)
* Log earnings (diff)			0.01			-0.00
			(0.01)			(0.03)
Controls:						
Average lagged settlement	-0.00	-0.00	-0.01	-0.03	-0.03	-0.03
	(0.01)	(0.01)	(0.01)	(0.04)	(0.04)	(0.04)
Union density	1.32***	1.51***	2.67***	1.30	1.28	1.44
	(0.30)	(0.28)	(0.36)	(1.48)	(1.57)	(1.61)
Female worker share	-0.01	0.06	0.43***	-1.52	-1.54	-1.36
	(0.08)	(0.08)	(0.12)	(1.18)	(1.19)	(1.12)
Age	-0.03***	-0.03***	-0.03***	-0.08**	-0.08**	-0.07**
	(0.01)	(0.01)	(0.01)	(0.03)	(0.03)	(0.03)
Export competition				1.29	1.29	1.97
				(1.19)	(1.18)	(1.30)
Import competition				-0.38	-0.39	-0.67
				(0.43)	(0.43)	(0.54)
Productivity growth				-0.00	-0.00	-0.00
				(0.00)	(0.00)	(0.00)
Inflation	0.00	-0.00	-0.02***	0.20***	0.20***	0.21***
	(0.00)	(0.00)	(0.00)	(0.03)	(0.03)	(0.03)
Unemployment	-0.09***	-0.09***	-0.08***	-0.39***	-0.39***	-0.39***
	(0.00)	(0.00)	(0.00)	(0.04)	(0.04)	(0.04)
Constant	2.58***	2.52***	1.29***	9.50***	9.53***	9.05***
	(0.32)	(0.33)	(0.42)	(1.52)	(1.54)	(1.53)
Sector trends	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,374	6,334	5,738	3,450	3,450	3,450
Number of sector pairs	95	95	95	59	59	59
R-squared	0.920	0.920	0.930	0.471	0.471	0.474

Note: Fixed Effects regression. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

We do not find a statistically significant response to productivity growth. This may suggest that PRBs do not consider it in their decisions but the result is also driven

by the fact that we are unable to measure productivity amongst PRB remit groups directly and instead rely on measures of productivity growth in the three broad sectors with the largest share of public sector employees, i.e. public administration, education and health and social work. Unlike private sector pay decisions, PRB recommendations appear not to take inflation dynamics into account, as suggested by insignificant or small and negative coefficients for the inflation variable in columns 1-3.

Turning to factors that make PRBs respond to settlements in other private sectors (interaction terms reported in columns 1-3), we find that PRB decisions are somewhat dependent on wage dynamics in sectors with a large share of female employees and domestically-facing sectors. The former is shown by the statistically significant positive coefficient for interactions between other sectors' settlements and the female share: a 10 percentage point larger differential in the share of female employees between sectors, increases average spillovers across these sectors by 0.002-0.003 percentage points. The latter is shown by the negative coefficient for interactions between settlements and the difference in export competition in column 3: a 10 percentage point differential in export competition increases spillovers into PRB settlements by 0.004 percentage points (noting that the average differential is negative given our assumption of zero export competition faced by PRB workers themselves).

When interpreting the economic significance of results, it is again worth bearing in mind that settlements tend to be very persistent over time. This holds in particular for PRB decisions. The median quarterly change in settlements is zero, as is the 25th and 75th percentile. The standard deviation of quarterly PRB settlement changes is only 0.4 percentage points.

PRB decisions appear to be negatively correlated with private sector settlements, as indicated by the negative sign on PRB decisions in private sector settlements equations (columns 4-6). This finding appears to be driven by what happens in sectors that are more open to international competition: their settlements are negatively correlated with PRB decisions - the interaction between export competition and PRB decisions in column 6 is estimated to be positive and significant. In fact, including such interactions renders lagged PRB decisions insignificant in private settlements equations. This means that PRB decisions can have a positive spillover effect into more domestically-facing private sectors.

Observations on PRB decisions have been allocated to the quarter when reports were published but decisions may have well been made sometime before the publication dates. While most relevant dependent variables are lagged by one quarter in the present analysis, in particular other sectors' settlements, it might be that information about these variables will not yet have been known in real time to PRB panel members. Table C11 in the Appendix reports results from a robustness check that lags independent variables by another quarter. Results are largely robust to this alternative specification.

8. Summary of findings

To analyse labour market dynamics in the economy as a whole it is important to understand possible interactions in wage setting processes between main sectors of the economy, in particular between the private and the public sector. Using a unique new dataset combining earnings and settlements data at the macroeconomic and sectoral level, we test which sector leads and which sector lags in terms of how earnings have been determined in the UK labour market over the last three decades.

We find that in the long run, wages in the public and the private sector form a persistent relationship. Using various model specifications and measures of wage growth, our results consistently show that over time, public sector wages adjust to wages set in the private sector to maintain this relationship. Economic theory suggests that this may be due to the fact that the private sector tends to be more productive and open to international trade (see descriptive statistics provided in Table 1).

Theory is less clear about wage spillovers from one sector to another in the short run. While wage differentials may be balanced through labour flows rather than wage adjustments, in particular if explained by productivity differentials, it may well be that wage growth spills over temporarily, for example if sectors compete for certain types of workers or certain sectors set a benchmark wage that is then also adopted in other sectors. Building on limited evidence for the UK to date (exceptions include Lee and Pesaran, 1993; Latreille and Manning, 2000; Driffield and Taylor, 2006), we analyse short-run wage spillovers between sectors of the economy. Our results highlight in particular the possibility of significant and economically meaningful wage spillovers in the short run from the public sector to the private sector. We cannot rule out that pay awards in the public sector temporarily provide a boost to pay growth in parts of the private sector.

To explore spillover dynamics in more detail, we examine some of the possible determinants of whether wages in one sector respond to wage changes in another sector. While the economic role of individual spillover determinants is small, our results shed some light on interlinkages between sectors of the economy. Results from our sector-by-sector analysis suggest, for instance, that wage growth in the public sector is followed by a somewhat stronger wage adjustment in parts of the private sector that are characterised by a low degree of union density and that are more domestically-facing compared to the rest of the private sector. We find similar linkages across sectors for PRB decisions. Sectors that share these characteristics are the hospitality sector (hotels and restaurants), wholesale and retail sectors, other services sectors that include entertainment services, personal service activities and activities of membership organisations and to some extent business services.

In contrast, we wage dynamics in the public sector tend to be largely shielded from wage developments in the private sector in the short run. The data does not

give a clear indication as to which sectors wage negotiators in the public sectors have in the past paid particular attention to.

One argument for why there may be wage spillovers from one sector to another is competition for workers in a particular segment of the labour market. We therefore checked whether pay rises in one sector impact on cross-sectoral employment flows. While overall direct cross-sectoral worker flows are small, we find that pay rises in a given sector can help attract workers from other sectors. This appears to be particularly true for the public sector.

We show that our main results hold under different model specifications and using different types of pay data, including average weekly earnings and pay settlements. Our analysis is nevertheless constrained by the availability of data, in particular at the sector level. Future work may benefit from further disaggregation, in particular of data on sector-level employment characteristics, trade openness and institutional peculiarities. As longer time series of wage and employment data become available, dynamic processes and sectoral interactions can be analysed in more detail. Another caveat of our analysis is that there may be unobservables driving some of our results, in particular in terms of labour market institutions and public sector pay policies which future work could explicitly take into account.

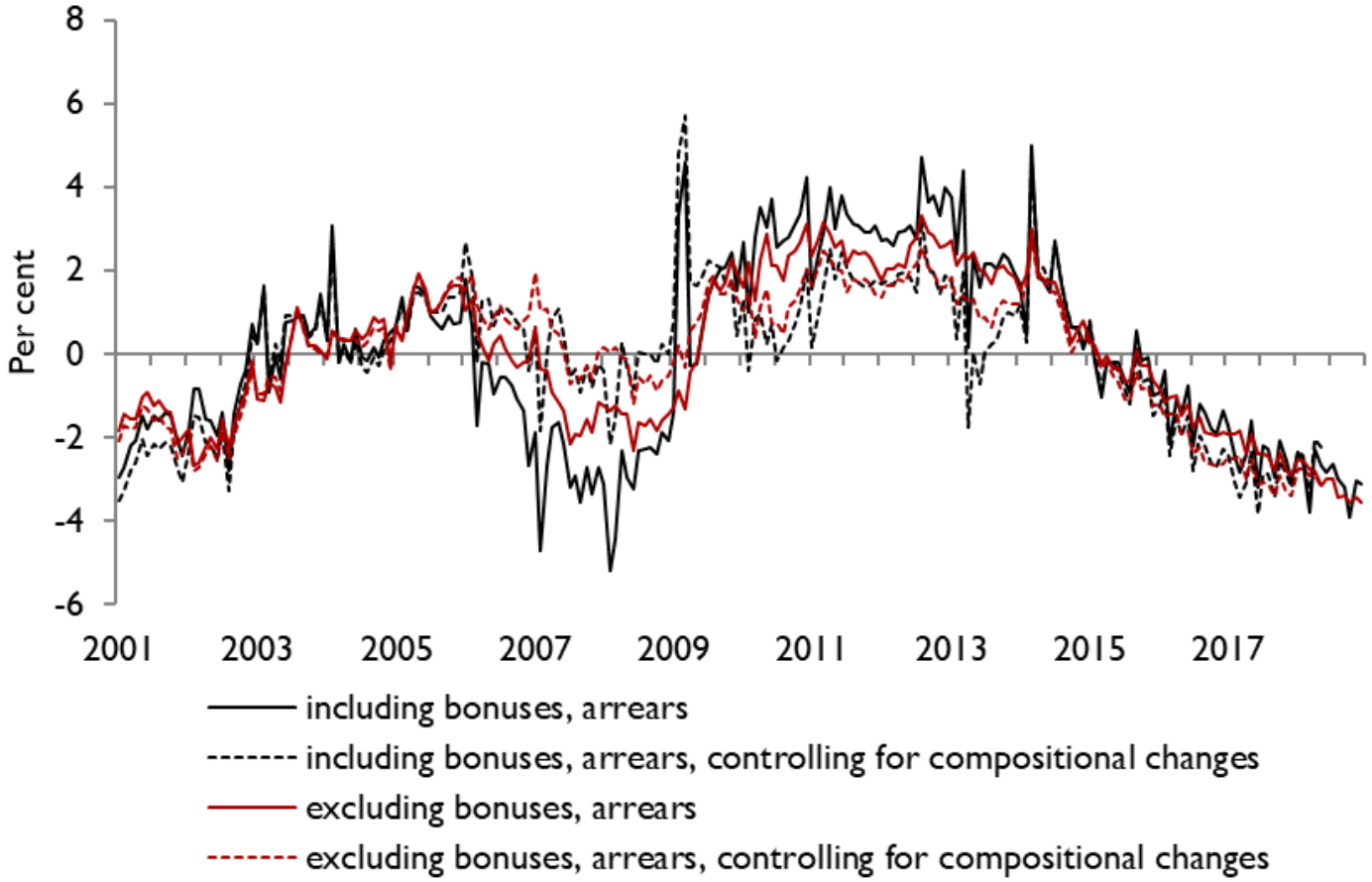
9. What do findings mean for policymakers and Pay Review Bodies?

This report analyses in detail how wages are determined in the public sector, including Pay Review Body remit groups, relative to the private sector, and assesses how public sector pay decisions affect pay in the rest of the economy as well as cross-sectoral employment flows. Its results are therefore of direct relevance to Pay Review Bodies, and other bodies like HM Government and public and private sector institutions tasked to monitor labour market and price dynamics, in particular the Bank of England. The aim of this section is to discuss in detail potential policy implications of reported findings. We put a particular emphasis on current discrepancies between public sector pay and its long-run levels as well as on labour market interactions between sectors. At the most basic level, this report highlights the economic forces at work in the determination of wages in different industries. Crudely, this means that PRB members need to be cogniscent of more than the course and trends of economic aggregates in weighting the determinants of wage uplift and this may impact on their recommendations to government.

Our main finding that there is evidence that in the long run, wages in the public and the private sector form a persistent relationship with public sector wages adjusting to wages set in the private sector over time to maintain this relationship, has important practical implications. It suggests that abstracting from short-term fluctuations caused by wage bargaining or government pay policy, wage dynamics in the public sector over time gradually converge with whole-economy wage developments, for a given skillset and demographic characteristics. This means that to retain staff of required skill levels, public sector pay should aim not to deviate for too long from private sector pay trends. A logical implication of this finding is that PRB members should recognise that the forces of wage pressures at work in the economy are subject to external forces, like productivity developments in the private sector, international trade and competition.

The current episode of public sector pay restraint is significant because it marks the longest period of sustained downward pressure on public sector pay in recent history. Using the finding that public sector wages tend to form a common relationship with private sector wages in the long run, it is possible to determine the deviation of public sector wages from their equilibrium. The methodology is described in section B2 of the Appendix. Figure 4 plots four different estimates of the public-private sector wage gap based on different measures of earnings including and excluding bonuses and arrears and controlling for compositional changes in private sector relative to public sector employment.

Figure 4. Estimate of the public-private sector wage gap



Note: The methodology is explained in section B2 of the Appendix.

Estimates show that during the last 20 years the public sector wage gap was sometimes positive and sometimes negative. Most recently, Figure 4 suggests that a period with a persistently negative wage gap followed one with a persistently positive wage gap. From 2009 until around 2014, the level of public sector wages was some 2 to 4 per cent higher than suggested by the long-run equilibrium determined by private sector wage dynamics. This is mainly because private sector wage growth collapsed during the Great Recession of 2008-9. The government reacted by putting a wage freeze in place in 2010 which was subsequently replaced by a 1 per cent annual cap on wage growth in the public sector. As a result, the public sector wage gap turned gradually negative reaching around 3½ per cent in December 2018. In recent months, public sector wage restraint was somewhat relaxed but given that earnings growth in the private sector has picked up in the face of historically high employment, the public sector wage gap has remained largely unchanged.

Past experience suggests that this process will reverse at some point in the near future. Given the duration and magnitude of the current public-private sector wage gap there is a risk, however, that skill shortages in certain areas of the public sector, like the National Health Services, intensify as high-skilled workers, like senior health administrators, seek employment in higher paid private sector jobs. Our results suggest that pay differentials can play an important role for cross-sectoral employment flows when the destination sector is the public sector.

Public sector wage setters therefore face a difficult trade-off between skill shortages as a result of pay differentials and the affordability of pay rises. With a public sector paybill of around £180 billion, closing a public-private sector wage gap of around 3½ per cent would cost around £6 billion per annum, or a quarter of a percentage point of GDP. Fully eliminating existing pay differentials is therefore likely to involve difficult compromises.

This report also highlights the possibility that pay rises in the public sector can lead to short-term spillovers into the rest of the economy. This may be beneficial if it improves the quality of pay in sectors with particularly vulnerable workers. While wage spillovers may arise for different reasons, we provide evidence that suggests that public sector spillovers are somewhat larger into sectors that are predominantly domestically-facing and characterised by low worker bargaining power, such as the hospitality, wholesale and retail services sectors.

While this report focuses predominantly on cyclical dynamics of sectoral labour markets it also sheds light on structural changes that have taken place in the UK labour market over the last three decades. The result of worker flows across sectors has been that some sectors lost a significant share of their workforce, like manufacturing. Other sectors, like business and communication services, have gained importance as employers, as did sectors with a large share of public sector employees. At the same time, unionisation rates have fallen substantially. At the aggregate level this has only partly been offset by an increase in the employment

share of traditionally highly unionised sectors. Our results suggest that lower union density not only means that wage settlements are on average lower than in the past. We also find that lower union density may have facilitated interactions between sectors in the form of pay spillovers and employment flows. This is because the role of unions in shielding sector-level employees from outside economic shocks has diminished. Stronger cross-sectoral labour market interactions than in the past imply that in the face of economic disruptions it is easier for workers to move job across sectors and for wages to adjust. But stronger interactions may also mean that the macroeconomy as a whole becomes more volatile if wage and employment changes in one sector feed more easily through to the rest of the economy.

To conclude, our results suggest that it is important to better understand wage setting processes in the public sector and cross-sectoral interactions. A fifth of the overall workforce in the UK is employed in the public sector. Our findings highlight that wage interactions can have important macroeconomic implications. Wage negotiators in the public sector, policymakers at HM Treasury and the Bank of England and, above all, the PRB members making recommendations on public sector pay uplift should therefore pay close attention to pay dynamics in the public sector and wage spillovers into the private sector.

References

Afonso, A., & Gomes, P. (2014). Interactions between private and public sector wages. *Journal of Macroeconomics*, *39*, 97-112.

Altonji, J. and Devereux, P. (2000). 'Is there nominal wage rigidity? Evidence from panel data', *Research in Labor Economics*, vol. 19, pp. 313–50.

Anderton, R., Hantzsche, A., Savsek, S., & Tóth, M. (2017). Sectoral wage rigidities and labour and product market institutions in the Euro Area. *Open Economies Review*, *28*(5), 923-965.

Aukrust, O. (1970). PRIM I: a model of the price and income distribution mechanism of an open economy. *Review of Income and Wealth*, *16*(1), 51-78.

Barwell, R.D. and Schweitzer, M. 'The incidence of nominal and real wage rigidities in Great Britain, 1978-1998.', *Economic Journal*, 117, F553-F569.

Bell, D., Nickell, S. and Quintini, G. (2002) 'Wage equations, wage curves and all that'*, Labour Economics*, 341-360.

Blanchard, O., Katz, L., 1999. Wage dynamics: reconciling theory and evidence. NBER Working Paper No. 6924, (February), Cambridge, MA.

Blanchard, O., & Wolfers, J. (2000). The role of shocks and institutions in the rise of European unemployment: the aggregate evidence. *The Economic Journal*, *110*(462), C1-C33.

Blanchflower, D.G., Oswald, A.J., 1994. *The Wage Curve*. MIT Press, Cambridge, MA.

Bobeica, E., Ciccarelli, M., & Vansteenkiste, I. (2019). The link between labor cost and price inflation in the euro area. *ECB Working Paper Series*, 2235, February 2019.

Bound, J., Brown, C., Duncan, G. and Rodgers, W. (1989). 'Measurement error in cross-sectional and longitudinal labor market surveys: results from two validation studies', NBER Working Paper, no. 2884.

Bowdler, C., & Nunziata, L. (2007). Trade union density and inflation performance: Evidence from OECD panel data. *Economica*, *74*(293), 135-159.

Brown, W., & Wadhwani, S. (1990). The economic effects of industrial relations legislation since 1979. *National Institute Economic Review*, *131*(1), 57-70.

Camarero, M., D'Adamo, G., & Tamarit, C. (2014). Wage leadership models: A country-by-country analysis of the EMU. *Economic Modelling*, *44*, S2-S11.

Card, D. and Hyslop, D. (1997). 'Does inflation ''grease the wheels of the labor market?'', in (C. Romer, and D. Romer, eds.), *Reducing Inflation: Motivation and Strategy*, Chicago: University of Chicago Press.

Cribb, J., Emmerson, C., Sibieta, L. (2014). Public sector pay in the UK. Institute for Fiscal Studies Report, R97.

Demekas, D. G., & Kontolemis, Z. G. (2000). Government employment and wages and labour market performance. *Oxford Bulletin of Economics and Statistics*, *62*(3), 391-415.

Disney, R., & Gosling, A. (1998). Does it pay to work in the public sector?. *Fiscal Studies*, *19*(4), 347-374.

Dolton, P., Lin, L., Makepeace, G., & Tremayne, A. (2011). An In-depth Assessment of the Impact of the Recession on the Distribution of Pay Settlements and Earnings. *report to the Low Pay Commission*, *11*(6).

Dolton, P., Makepeace, G., & Marcenaro-Gutierrez, O. (2015). Public sector pay in the UK: quantifying the impact of the review bodies. *The Manchester School*, *83*(6), 701-724.

Driffield, N., & Taylor, K. (2006). Wage spillovers, inter-regional effects and the impact of inward investment. *Spatial Economic Analysis*, *1*(2), 187-205.

Dunlop, J. (1938). 'The movement of real and money wage rates', *Economic Journal*, vol. 48, pp. 413–34.

Fernández-de-Córdoba, G., Pérez, J. J., & Torres, J. L. (2012). Public and private sector wages interactions in a general equilibrium model. *Public Choice*, *150*(1-2), 309-326.

Fontaine, I., Galvez-Iniesta, I., Gomes, P., Vila-Martin, D. (2018). Labour market flows: accounting for the public sector. Working paper.

Freeman, R. B., & Medoff, J. L. (1984). *What Do Unions Do?* Basic Books, New York.

Gomes, P. (2015). Optimal public sector wages. *The Economic Journal*, *125*(587), 1425-1451.

Gross, M. (2019). Estimating GVAR weight matrices. *Spatial Economic Analysis*, *14*(2), 219-240.

Hamilton, J. D. (1995). *Time Series Analysis.* Economic Theory. II, Princeton University Press, USA, 625-630.

Hantzsche, A., Savsek, S., & Weber, S. (2018). Labour market adjustments to financing conditions under sectoral rigidities in the euro area. *Open Economies Review*, *29*(4), 769-794.

Holmlund, B. (1986) 'Centralized wage setting, wage drift and stabilization policies under trade unionism', *Oxford Economic Papers*, 243-258.

Jackson, M. O. (2010). *Social and Economic Networks*, Princeton University Press.

Kahn, S. (1997). 'Evidence of nominal wage stickiness from microdata', *American Economic Review*, vol. 87, pp. 993–1008.

Knotek, E., Zaman, S. (2014). On the relationships between wages, prices, and economic activity. *Economic Commentary*, Federal Reserve Bank of Cleveland, 2014-14, August 2014.

Lamo, A., Pérez, J. J., & Schuknecht, L. (2012). Public or private sector wage leadership? An international perspective. *The Scandinavian Journal of Economics*, *114*(1), 228-244.

Latreille, P. L., & Manning, N. (2000). Inter-industry and Inter-occupational Wage Spillovers in UK Manufacturing. *Oxford Bulletin of Economics and Statistics*, *62*(1), 83-99.

Lee, K. C., & Pesaran, M. H. (1993). The role of sectoral interactions in wage determination in the UK economy. *The Economic Journal*, *103*(416), 21-55.

Lindquist, J., & Vilhelmsson, R. (2006). Is the Swedish central government a wage leader?. *Applied Economics*, *38*(14), 1617-1625.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, *71*(6), 1695-1725.

Messina, J., Strozzi, C., and Turunen, J. (2009) 'Real wages over the business cycle: OECD evidence from the time and frequency domains', *Journal of Dynamic and Control*, 33, 1183-1200.

Nickell, S. (1997). Unemployment and labor market rigidities: Europe versus North America. *Journal of Economic Perspectives*, *11*(3), 55-74.

Nickell, S. and Quintini, G. (2003). 'Nominal rigidity and the rate of inflation', *Economic Journal*, vol. 113, pp. 762–81.

Office for Budget Responsibility (2019). *Economic and fiscal outlook*. March 2019.

Ordine, P. (1996) 'Wage drift and minimum contractual wage: Theoretical interrelationship and empirical evidence for Italy', *Labour Economics*, 2, 335-357.

Ormerod, C and Ritchie, F. (2007) 'Linking ASHE and LFS: can the main earnings sources be reconciled?', *Economic and Labour Market Review*, 1(3), 24-31.

Peneva, E. V., & Rudd, J. B. (2017). The Passthrough of Labor Costs to Price Inflation. *Journal of Money, Credit and Banking*, *49*(8), 1777-1802.

Pesaran, H., Schuermann, T., Weiner, S. (2004). Modelling regional interdependencies using a global error-correcting macroeconometric model. *Journal of Business and Economics Statistics*, 22, 129-162.

Pesaran, M. H. (2015). *Time Series and Panel Data Econometrics*. Oxford University Press.

Phelps-Brown, E.H. (1962) 'Wage Drift', *Economica*, 29, 116, 339-356.

Pissarides, C. (2009) The unemployment volatility puzzle: is wage stickiness the answer?', *Econometrica*, 77(5), 1339-1369.

Smith, J. (2000). 'Nominal wage rigidity in the United Kingdom', *Economic Journal*, vol. 110, pp. C176–95.

Verdugo, G. (2016). Real wage cyclicality in the Eurozone before and during the Great Recession: Evidence from micro data. *European Economic Review*, *82*, 46-69.

Visser, J. (2015). ICTWSS Data base. Version 5.0. Amsterdam: Amsterdam Institute for Advanced Labour Studies AIAS, October 2015.

Wallerstein, M. (1999) 'Wage setting institutions and pay inequality in advanced industrial societies', *American Journal of Political Science*, 43(3) 649-680.

Appendix

A Data sources and variables

Earnings data

Source: Office for National Statistics Average Weekly Earnings

Average weekly earnings, public and private sector aggregates as well as selected broad private sectors (manufacturing, construction, finance and business services, wholesaling/ retailing/ hotels/ restaurants), monthly frequency, 2000-2017, including and excluding bonuses and arrears. For 1990 to 2000 experimental data from the same source including bonuses and arrears is merged with the remainder of the dataset.

Aggregate wage settlements

Source: XpertHR

Wage settlements at monthly frequency for private and public sector aggregates, 1990-2017.

Sector-level settlements data

Sources: Dolton *et al.* (2011), Confederation of British Industry, Incomes Data Service, Incomes Data Research, XpertHR, Office of Manpower Economics

Table A1. Sector definition

1. Agriculture, hunting, forestry, fishing
2. Mining, quarrying
3. Manufacturing
4. Electricity, gas, water supply
5. Construction
6. Wholesale, retail
7. Hotels, restaurants
8. Transport, storage, communication
9. Financial intermediation
10. Real estate, renting, business services
11. Public administration, defence
12. Education
13. Health, social work
14. Other community, social, personal services

Data on individual pay settlements is aggregated at the sector level using SIC1992 sector classifications to ensure consistency also with control variables. We consider 14 sectors:

We aggregate individual data on basic pay increases and pay freezes at quarterly frequency using information on the number of employees covered, the agreed duration of the settlement and the date at which the settlement became effective. Period covered: 1971-2018.

Annual data on Pay Review Body recommendations were provided by the OME and allocated to quarters of the year using publication dates of PRB annual reports.

Employment share

Source: Office for National Statistics Quarterly Labour Force Survey

We calculate the sector employment share by multiplying total employment data (ONS) with the number of QLFS respondents in work by sector (using the sector definitions in Table A1).

Share of public sector employees

Source: Office for National Statistics Quarterly Labour Force Survey

Calculated using self-reported information on public sector employment in the QLFS.

Union density

Sources: Trade Union Membership Statistics provided by HM Government, database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts (ICTWSS, Visser 2015)

Union density is defined as trade union membership divided by the number of employees by sector. We use data from multiple issues of Trade Union Membership Statistics. Where possible, gaps are filled using the ICTWSS dataset and otherwise linearly interpolated.

Productivity

Source: Office for National Statistics Labour productivity dataset

Defined as output per hour, seasonally adjusted. Current prices data deflated using GDP deflator.

Export and import competition

Source: Office for National Statistics Supply and Use Tables

Export competition is defined as the share of total exports of goods and services over total final demand using information from the combined use matrix for products and related to industries using product codes.

Import competition is defined as the share of total imports of goods and services over total domestic output of products at basic prices using information from the supply table for products and related to industries using product codes.

Period covered: 1997-2016.

Share of female employees and average age

Source: Office for National Statistics Quarterly Labour Force Survey

Averaged across individuals in work where information on sectors is available.

Cross-sectoral employment flows and centrality

Source: Office for National Statistics Quarterly Labour Force Survey, 2-quarter longitudinal tables, own calculation

Using the QLFS panel dimension, we measure at quarterly frequency the number of people that are employed in two subsequent quarters but for which information about the sector of employment differs across both quarters. We therefore focus on a subset of movers which directly find a new job in a different sector without going through a period of unemployment. It is important to note that these might be workers that move up the career ladder and pay progression.

Taking all cross-sectoral employment flows together, this yields a network in which sectors are connected using employment flows. To formally measure the importance of individual sectors in the network, we employ the concept of centrality. Centrality is a measure of the importance of a node in a network. In particular, we use the concept of eigenvector centrality. It is calculated by first constructing an adjacency matrix $A = (a_{v,t})$ that captures the strength of connections between each node v and all other nodes t. For instance, if there is no connection between v and t then $a_{v,t} = 0$, and $a_{v,t} > 0$ otherwise. The greatest eigenvector λ of this matrix yields a measure of centrality x_v such that the

centrality (or importance in the network) of each node is a function of the centralities of its neighbours:

$$x_v = \frac{1}{\lambda}\sum a_{v,t}\, x_t$$

In the present case, the connections between the sectors are weighted by the share of labour passing from one sector to another each period.

Index of the employment composition of the public relative to the private sector

To construct the index, we use information in ONS Average Weekly Earnings statistics about the fraction of overall earnings increases Δw_t^j due to changes in the composition of employment Δc_t^j, for both the public and the private sector $j \in \{A, B\}$.

$$\Delta w_t^j = \Delta w_t^{j^*} + \Delta c_t^j$$

where $\Delta w_t^{j^*}$ is the wages contribution. We back out the fraction of log wage levels that can be explained by changes in the employment composition Δc_t^j. For each sector j and an arbitrary starting value, we calculate a levels series capturing employment composition c_t^j. We then construct an index of changes in the relative composition of employment by subtracting counterfactual log public sector wages from counterfactual log private sector wages and normalise to 0 in May 2000 to yield an index of changes in the relative employment composition:

$$\Delta\text{Composition index} = \Delta(c_t^A - c_t^B)$$

B Technical appendix

B1 Vector error correction model[17]

To transform equations (7) and (8) into a VECM, we write it in vector form as follows. Let $\mathbf{w_t}$ be a (2×1) column vector containing log wages in each sector at time t, such that $\mathbf{w_t} = \begin{bmatrix} w_t^A \\ w_t^B \end{bmatrix}$. First differences are written as $\Delta\mathbf{w_t} = \mathbf{w_t} - \mathbf{w_{t-1}}$.

Let $\boldsymbol{\alpha}$ be a (2×1) column vector containing the two speed-of-adjustment parameters, such that $\boldsymbol{\alpha} = \begin{bmatrix} \alpha^A \\ \alpha^B \end{bmatrix}$.

Let $\boldsymbol{\beta}$ be a (4×1) column vector containing the parameters which govern the long-run relationship between w_t^A and w_t^B, such that $\boldsymbol{\beta} = \begin{bmatrix} \beta^A \\ \beta^B \\ \mu_{LR} \\ \gamma_{LR} \end{bmatrix}$. This is known in the literature as the 'cointegrating vector'.

Let $\widetilde{\mathbf{w}}_t$ be a (4×1) column vector containing wages in each sector, a constant (normalised to 1), and the time variable t, such that $\widetilde{\mathbf{w}}_{t-1} = \begin{bmatrix} w_{t-1}^A \\ w_{t-1}^B \\ 1 \\ t \end{bmatrix}$.

Let $\boldsymbol{\eta_{t-p}}$ be a (2×2) matrix containing the short-run coefficients for wages in sectors A and B at time $t-p$, such that $\boldsymbol{\eta_{t-p}} = \begin{bmatrix} \pi_i^A & \pi_{j,B}^A \\ \pi_{i,A}^B & \pi_j^B \end{bmatrix}, i = j = p$.

Let $\boldsymbol{\theta}$ be a $(2 \times N)$ matrix containing the N elements $\boldsymbol{\pi}_{\mathbf{C}}^{\mathbf{A}}$ along with the N *elements* of $\boldsymbol{\pi}_{\mathbf{C}}^{\mathbf{B}}$, such that $\boldsymbol{\theta} = \begin{bmatrix} \pi_{C,1}^{A} \dots \pi_{C,N}^{A} \\ \pi_{C,1}^{B} \dots \pi_{C,N}^{B} \end{bmatrix}$.

Let $\boldsymbol{y_t}$ be a $(N \times 1)$ column vector containing the N control macroeconomic variables C_t, such that $\boldsymbol{y_t} = \begin{bmatrix} C_t^1 \\ \vdots \\ C_t^N \end{bmatrix}$.

Let $\boldsymbol{e_t}$ be a (2×1) column vector containing the error terms for sectors A and B, such that $\boldsymbol{e_t} = \begin{bmatrix} e_t^A \\ e_t^B \end{bmatrix}$.

Equations (7) and (8) can then be written in vector form as follows:

(B1)

[17] We thank Eric Dale for his contributions to this section.

$$\begin{bmatrix}\Delta w_t^A\\ \Delta w_t^B\end{bmatrix}=\begin{bmatrix}\alpha^A\\ \alpha^B\end{bmatrix}[\beta^A\ \beta^B\ \mu_{LR}\ 0]\begin{bmatrix}w_{t-1}^A\\ w_{t-1}^B\\ 1\\ t\end{bmatrix}+\sum_{p=1}^{L}\begin{bmatrix}\pi_p^A & \pi_{p,B}^A\\ \pi_{p,A}^B & \pi_p^B\end{bmatrix}\begin{bmatrix}\Delta w_{t-p}^A\\ \Delta w_{t-p}^B\end{bmatrix}+\begin{bmatrix}\pi_{\mathrm{C},1}^{\mathrm{A}}\dots\pi_{\mathrm{C,N}}^{\mathrm{A}}\\ \pi_{\mathrm{C},1}^{\mathrm{B}}\dots\pi_{\mathrm{C,N}}^{\mathrm{B}}\end{bmatrix}\begin{bmatrix}C_t^1\\ \vdots\\ C_t^N\end{bmatrix}+\begin{bmatrix}e_t^A\\ e_t^B\end{bmatrix}$$

Using vector notations, this can be collapsed to:

(B2)

$$\mathbf{\Delta w_t}=\boldsymbol{\alpha\beta'}\tilde{\mathbf{w}}_{\boldsymbol{t-1}}+\sum_p\boldsymbol{\eta_{t-p}}\mathbf{\Delta w_{t-p}}+\boldsymbol{\theta y_t}+\boldsymbol{e_t}$$

Before the hypothesis of long-run wage leadership can be tested, we determine the number of lags L using information criteria. For average weekly earnings series excluding bonuses and arrears, Table C1 reports the optimal number of lags.[18]

We then need to verify that there is in fact a relationship between wages in both sectors. This amounts to testing whether $\mathrm{w_t^A}$ and $\mathrm{w_t^B}$ are cointegrated, i.e. there is a linear combination of $\mathrm{w_t^A}$ and $\mathrm{w_t^B}$ that is stationary while both processes individually are non-stationary (unit root processes). This is established using the Johansen testing procedure.

Let Φ be a (2×4) matrix defined as $\Phi\equiv\alpha\beta'$. If sectors A and B are cointegrated then the rank of matrix Φ will be equal to 1.

The Johansen test is sensitive to the specification of our model. We therefore specify it in a general form and test for a particular specification while testing the rank of Φ at the same time, using maximum likelihood methods.

The most general form of the VECM specified above is

(B3)

$$\mathbf{\Delta w_t}=\boldsymbol{\mu_{SR}}+\boldsymbol{\gamma_{SR}t}+\boldsymbol{\alpha\beta'}\tilde{\mathbf{w}}_{\boldsymbol{t-1}}+\sum_p\boldsymbol{\eta_{t-p}}\mathbf{\Delta w_{t-p}}+\boldsymbol{\theta y_t}+\boldsymbol{e_t}$$

where $\boldsymbol{\mu_{SR}}$ adds constant terms to the short run equation. Remember that $\boldsymbol{\beta}$ contains the constant term $\boldsymbol{\mu_{LR}}$ that applies to the long run equation (the latter being referred to as long-run wedge above) while $\boldsymbol{\gamma_{SR}}t$ (and $\boldsymbol{\gamma_{Lr}}t$ in $\boldsymbol{\beta'}\tilde{\mathbf{w}}_{\boldsymbol{t-1}}$) capture time trends.

The presence of both $\gamma_{SR}\neq 0$ and $\gamma_{LR}\neq 0$ would mean that there is a quadratic trend in the levels of wages and that the cointegrating equations are stationary around a time trend. We remain agnostic and estimate each of the following specifications: 1) unrestricted trend, 2) restricted trend ($\gamma_{SR}=0$), 3) unrestricted constant ($\gamma_{SR}=0$, $\gamma_{LR}=0$), 4) restricted constant ($\gamma_{SR}=0$, $\gamma_{LR}=0$, $\mu_{SR}=0$), 5) no trend ($\gamma_{SR}=0$, $\gamma_{LR}=0$, $\mu_{SR}=0$ and $\mu_{LR}=0$).

[18] Based on this information we set $L=13$.

Once cointegration is established, long-run leadership is determined using the concept of weak exogeneity:

- $\alpha^A = 0, \alpha^B = 0$: There is no long-run relationship between the two sectors; their wages are set independently of one another.
- $\alpha^A = 0, \alpha^B > 0$: Sector A is a wage leader and sector B is a wage follower. Changes to wages in A are made independently and wages in B respond to them.
- $\alpha^A < 0, \alpha^B = 0$: Sector B is a wage leader and sector A is a wage follower. Changes to wages in B are made independently and wages in A respond to them.
- $\alpha^A < 0, \alpha^B > 0$: A bi-directional relationship. Wages in sectors A and B mutually influence each other, such that they both act to correct deviations from equilibrium.

Short-run leadership is established by testing for Granger causality:

- $\pi_{j,B}^A = 0, \pi_{i,A}^B = 0$: A bi-directional short-run relationship. Wages in sectors A and B mutually influence each other in the short run.
- $\pi_{j,B}^A = 0, \pi_{i,A}^B \neq 0$: There are spillovers from sector A to sector B in the short run but not *vice versa*.
- $\pi_{j,B}^A \neq 0, \pi_{i,A}^B = 0$: There are spillovers from sector B to sector A in the short run but not *vice versa*.
- $\pi_{j,B}^A \neq 0, \pi_{i,A}^B \neq 0$: There is no short-run relationship between the two sectors.

B2 Long-run wage gap

The difference between observed levels of wages and their equilibrium level can be interpreted as wage gap. Wage gaps provide an estimate by how much wages in a particular sector would need to increase to eliminate deviations from equilibrium. Large negative deviations from equilibrium can generate recruitment difficulties, whereas large positive deviations may distort labour markets in the rest of the economy. Suppose sector A's wages historically followed wage setting in sector B. An estimate of sector A's wage gap in per cent can be obtained using

(B4) $Gap(w_t^A) = 100 * [w_t^A - w_t^B - \widehat{\mu_{LR}}]$

where $\widehat{\mu_{LR}}$ is the estimated structural wedge between public and private sector wages.

C Additional tables and figures

Table C1. Lag selection

Information criteria:	AIC	HQIC	SBIC
Number of monthly lags:			
Excluding bonuses and arrears	13	13	4
Including bonuses and arrears	16	13	13

Note: Based on a simple vector autoregression of public and private sector average weekly earnings.

Table C2. Results for average weekly earnings including bonuses and arrears: post-2000

	(1)	(2)	(3)	(4)
Sector:	Private sector		Public sector	
Long-run endogeneity	-0.01	0.00	-0.06*	-0.05*
(ECM term)	(0.06)	(0.07)	(0.03)	(0.03)
Short-run causality	0.16***	0.11***	0.05	0.06
(other sector, p-value)	*(0.05)*	*(0.00)*	*(0.04)*	*(0.19)*
Other sector *				
January		0.83***		-0.04
		(0.26)		(0.09)
February		0.37		-0.04
		(0.32)		(0.06)
March		-0.52		0.06
		(0.40)		(0.05)
April		-0.30		-0.00
		(0.32)		(0.07)
May		-0.12		0.19*
		(0.18)		(0.10)
June		0.24*		-0.40
		(0.14)		(0.42)
July		0.08		0.27
		(0.09)		(0.18)
August		0.17*		0.14
		(0.09)		(0.13)
September		0.13**		0.01
		(0.06)		(0.11)
October		0.18**		-0.04
		(0.09)		(0.15)
November		0.27**		0.25
		(0.10)		(0.18)
December		-0.02		0.25*
		(0.19)		(0.13)
Inflation	0.12*	0.08	-0.01	-0.00
	(0.07)	(0.07)	(0.05)	(0.05)
Observations	197	197	197	197
R-squared	0.899	0.915	0.709	0.735

Note: Monthly frequency. Lagged annual changes in the other sector's log wages serve as regressor. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. P-values from a test of joint significance in italics.

Table C3. Results for average weekly earnings including bonuses and arrears: monthly changes in other sector's wages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sector:	Private sector				Public sector			
Specification:	1 lag other	12 lags other	1 lag other	12 lags other	1 lag other	12 lags other	1 lag other	12 lags other
Long-run endogeneity	0.012	0.02	0.008	0.018	-0.05***	-0.037**	-0.05***	-0.04***
(ECM term)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Short-run causality	0.067	1.302***	1.552*	2.904**	-0.004	0.792***	0.168**	1.582***
(other sector, p-value)	*(0.29)*	*(0.02)*	*(0.10)*	*(0.02)*	*(0.88)*	*(0.00)*	*(0.04)*	*(0.00)*
Other sector *								
January			0.414	0.478			0.007	-0.059
			(0.39)	(0.41)			(0.10)	(0.07)
February			0.126	0.245			-0.118**	-0.059
			(0.53)	(0.50)			(0.05)	(0.05)
March			1.145*	1.006			0.022	0.029
			(0.60)	(0.67)			(0.08)	(0.08)
April			-0.306	-0.306			-0.046	0.049
			(0.44)	(0.47)			(0.04)	(0.06)
May			0.025	-0.103			-0.001	0.056
			(0.14)	(0.15)			(0.05)	(0.06)
June			0.245	0.414**			0.101	0.170
			(0.16)	(0.17)			(0.42)	(0.39)
July			-0.065	-0.025			0.230	0.806**
			(0.09)	(0.10)			(0.34)	(0.33)
August			0.252***	0.254**			0.470***	0.080
			(0.09)	(0.11)			(0.13)	(0.17)
September			0.320*	0.158			0.096	0.090
			(0.18)	(0.17)			(0.21)	(0.19)
October			-0.234	0.023			-0.264	-0.204
			(0.17)	(0.20)			(0.36)	(0.41)
November			-0.063	0.015			-0.415	-0.397
			(0.18)	(0.21)			(0.45)	(0.34)
December			-0.307	-0.224			0.087	0.407*
			(0.25)	(0.26)			(0.20)	(0.21)
Inflation	0.118**	0.093*	0.144**	0.119**	0.061	0.019	0.056	0.023
	(0.05)	(0.05)	(0.06)	(0.06)	(0.04)	(0.04)	(0.04)	(0.04)
Observations	316	316	316	316	316	316	316	316
R-squared	0.882	0.89	0.888	0.894	0.610	0.691	0.627	0.719

Note: Monthly frequency. Lagged monthly changes in the other sector's log wages serve as regressor. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. P-values from a test of joint significance in italics.

Table C4. Results for average weekly earnings excluding bonuses and arrears: monthly changes in other sector's wages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sector:	Private sector				Public sector			
Specification:	1 lag other	12 lags other	1 lag other	12 lags other	1 lag other	12 lags other	1 lag other	12 lags other
Long-run endogeneity	-0.00	-0.00	0.00	0.00	-0.02*	-0.00	-0.02*	-0.02
(ECM term)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Short-run causality	-0.053	0.319	-0.612	-0.407	0.013	0.601	-0.78***	-0.418**
(other sector, p-value)	*(0.32)*	*(0.26)*	*(0.31)*	*(0.20)*	*(0.86)*	*(0.81)*	*(0.00)*	*(0.03)*
Other sector *								
January			0.19	0.26			0.14	-0.10
			(0.39)	(0.33)			(0.15)	(0.17)
February			-0.21	-0.27			0.18	0.21*
			(0.17)	(0.19)			(0.12)	(0.12)
March			-0.09	-0.03			-0.12	-0.09
			(0.12)	(0.14)			(0.19)	(0.21)
April			0.16	0.09			-0.03	-0.11
			(0.16)	(0.17)			(0.67)	(0.72)
May			-0.07	-0.16			-0.32	-0.23
			(0.12)	(0.15)			(0.19)	(0.22)
June			-0.02	-0.09			0.54***	0.65***
			(0.23)	(0.25)			(0.20)	(0.23)
July			-0.42**	-0.49**			0.27	0.27
			(0.20)	(0.19)			(0.35)	(0.30)
August			-0.11	-0.19			0.25	0.22
			(0.20)	(0.20)			(0.26)	(0.28)
September			0.18	0.17			-0.70	-0.68
			(0.15)	(0.15)			(0.46)	(0.49)
October			0.02	0.13			0.03	0.01
			(0.12)	(0.18)			(0.28)	(0.31)
November			0.19	0.19			-0.92***	-0.89**
			(0.13)	(0.19)			(0.26)	(0.37)
December			-0.43	-0.46			-0.09	0.16
			(0.32)	(0.35)			(0.32)	(0.33)
Inflation	0.02	0.02	0.01	0.01	-0.01	-0.02	-0.00	-0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Observations	196	196	196	196	196	196	196	196
R-squared	0.366	0.383	0.352	0.530	0.620	0.636	0.654	0.703

Note: Monthly frequency. Lagged monthly changes in the other sector's log wages serve as regressor. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. P-values from a test of joint significance in italics.

Table C5. Results for average weekly earnings: controlling for CPI inflation

	(1)	(2)	(3)	(4)
Sector:	Private sector	Public sector	Private sector	Public sector
Including bonuses, arrears:	no	no	yes	yes
Long-run endogeneity	-0.005	-0.023*	0.012	-0.060***
(ECM term)	(0.01)	(0.01)	(0.03)	(0.02)
Short-run causality	0.026***	0.005**	0.113***	0.053**
(other sector, p-value)	*(0.00)*	*(0.03)*	*(0.00)*	*(0.04)*
CPI inflation	-0.025	-0.011	0.007	0.118**
	(0.02)	(0.02)	(0.06)	(0.05)
Observations	196	196	316	316
R-squared	0.610	0.709	0.889	0.670

Note: Monthly frequency. Lagged annual changes in the other sector's log wages serve as regressor, interactions between monthly changes in other sector's log wages and monthly dummies included. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. P-values from a test of joint significance in italics.

Table C6. Results for average weekly earnings: controlling for GDP growth

	(1)	(2)	(3)	(4)
Sector:	Private sector	Public sector	Private sector	Public sector
Including bonuses, arrears:	no	no	yes	yes
Long-run endogeneity	0.007	-0.024*	0.018	-0.039***
(ECM term)	(0.01)	(0.01)	(0.03)	(0.01)
Short-run causality	0.027***	0.011**	0.153***	0.093**
(other sector, p-value)	*(0.01)*	*(0.04)*	*(0.00)*	*(0.02)*
RPI inflation	0.007	0.000	0.107**	0.036
	(0.02)	(0.02)	(0.05)	(0.04)
GDP growth	0.037***	-0.009	0.138**	-0.062**
	(0.01)	(0.01)	(0.06)	(0.02)
Observations	196	196	316	316
R-squared	0.628	0.709	0.895	0.667

Note: Monthly frequency. Lagged annual changes in the other sector's log wages serve as regressor, interactions between monthly changes in other sector's log wages and monthly dummies included. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. P-values from a test of joint significance in italics.

Table C7. Results for average weekly earnings: controlling for unemployment

	(1)	(2)	(3)	(4)
Sector:	Private sector	Public sector	Private sector	Public sector
Including bonuses, arrears:	no	no	yes	yes
Long-run endogeneity	-0.019	-0.013	0.021	-0.042**
(ECM term)	(0.01)	(0.02)	(0.05)	(0.02)
Short-run causality	0.027***	-0.005**	0.107***	0.062*
(other sector, p-value)	*(0.00)*	*(0.03)*	*(0.00)*	*(0.06)*
RPI inflation	0.038**	0.005	0.112**	0.034
	(0.02)	(0.02)	(0.05)	(0.04)
Unemployment	-0.001***	-0.000	-0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	196	196	316	316
R-squared	0.635	0.713	0.890	0.661

Note: Monthly frequency. Lagged annual changes in the other sector's log wages serve as regressor, interactions between monthly changes in other sector's log wages and monthly dummies included. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. P-values from a test of joint significance in italics.

Table C8. Results for average weekly earnings: controlling for linear trend

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Including bonuses, arrears:	yes	yes	yes	yes	no	no	no	no
Sector:	Private sector		Public sector		Private sector		Public sector	
Long-run endogeneity	0.016	0.042*	-0.04***	-0.04***	-0.003	0.001	0.001	-0.006
(ECM term)	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Short-run causality	0.095**	0.058***	0.038	0.044	0.048*	0.012***	0.039	0.020***
(other sector, p-value)	(0.02)	(0.00)	(0.25)	(0.16)	(0.06)	(0.01)	(0.18)	(0.01)
Other sector *								
January		0.377***		0.013		0.188***		0.064
		(0.11)		(0.05)		(0.05)		(0.06)
February		0.021		-0.034		0.052		0.003
		(0.14)		(0.05)		(0.08)		(0.08)
March		-0.190		0.057		-0.018		-0.001
		(0.16)		(0.04)		(0.06)		(0.09)
April		-0.032		-0.023		0.058		0.242**
		(0.19)		(0.05)		(0.07)		(0.10)
May		-0.003		0.075		-0.036		-0.137**
		(0.08)		(0.08)		(0.06)		(0.05)
June		0.175***		-0.327		0.031		0.087
		(0.07)		(0.23)		(0.06)		(0.06)
July		0.074		0.368*		-0.030		0.039
		(0.07)		(0.20)		(0.08)		(0.07)
August		0.191***		0.151*		-0.017		0.094
		(0.06)		(0.09)		(0.06)		(0.09)
September		0.095		0.113		-0.002		-0.162**
		(0.06)		(0.11)		(0.05)		(0.06)
October		0.105*		-0.070		-0.086*		0.025
		(0.05)		(0.10)		(0.05)		(0.07)
November		0.030		0.061		0.078**		-0.024
		(0.08)		(0.08)		(0.04)		(0.09)
December		-0.143		0.141		-0.072		0.005
		(0.11)		(0.11)		(0.08)		(0.07)
RPI inflation	0.146***	0.154***	0.048	0.050	0.027	0.020	-0.010	-0.001
	(0.05)	(0.05)	(0.05)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)
Trend	-0.002***	-0.003***	-0.001**	-0.001**	0.000	-0.000	-0.002***	-0.003***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	316	316	316	316	196	196	196	196
R-squared	0.887	0.895	0.633	0.665	0.562	0.612	0.699	0.738

Note: Monthly frequency. Lagged annual changes in the other sector's log wages serve as regressor. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. P-values from a test of joint significance in italics.

Table C9. Results for average weekly earnings: controlling for composition and productivity

	(1)	(2)	(3)	(4)
Sector:	Private sector	Public sector	Private sector	Public sector
Including bonuses, arrears:	no	no	yes	yes
Long-run endogeneity	0.00	-0.04***	0.01	-0.06***
(ECM term)	(0.02)	(0.02)	(0.01)	(0.01)
Short-run causality	0.01**	-0.03***	0.01**	-0.02***
(other sector, p-value)	*(0.02)*	*(0.01)*	*(0.02)*	*(0.00)*
RPI inflation	0.02	0.02	0.02	0.02
	(0.02)	(0.02)	(0.02)	(0.02)
Compositional gap (lagged)	0.03	-0.06*		
	(0.03)	(0.03)		
Productivity growth			0.04*	-0.03**
			(0.02)	(0.01)
Observations	196	196	196	196
R-squared	0.614	0.738	0.620	0.742

Note: Monthly frequency. Lagged annual changes in the other sector's log wages serve as regressor, interactions between monthly changes in other sector's log wages and monthly dummies included. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. P-values from a test of joint significance in italics.

Table C10. Spillover determinants: baseline results

	(1) All sectors	(2) Public sector as spillover recipient	(3) Spillovers from public to private sectors
Lagged settlement	0.26***	0.26***	0.25***
	(0.02)	(0.03)	(0.06)
Settlement spillover	0.00	0.00	-0.03
	(0.01)	(0.01)	(0.04)
Public	-0.76		
	(0.59)		
Union density	2.48***	0.16	3.20*
	(0.72)	(1.74)	(1.77)
Female share	-1.24**	-1.35***	-1.65
	(0.49)	(0.33)	(1.29)
Age	-0.09***	0.08	-0.13**
	(0.02)	(0.05)	(0.05)
Export competition	4.32***	3.98**	3.55**
	(0.77)	(1.86)	(1.67)
Import competition	0.50**	15.73	0.35
	(0.24)	(9.85)	(0.49)
Centrality	-2.24***	-0.15	-2.57***
	(0.20)	(0.20)	(0.53)
Productivity growth	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
CPI inflation	0.19***	0.10***	0.20***
	(0.01)	(0.02)	(0.02)
Unemployment rate	-0.35***	-0.42***	-0.33***
	(0.02)	(0.02)	(0.05)
Lagged average settlement	-0.02	0.06***	-0.01
	(0.02)	(0.02)	(0.07)
Constant	8.73***	4.03***	9.60***
	(0.83)	(1.00)	(2.05)
Sector trends	Yes	Yes	Yes
R-squared	0.540	0.773	0.478
Observations	12,259	2,712	2,277
Sector pairs	182	39	33

Note: Sector-level settlements. No interactions between other sector's lagged settlement and conditioning factors are included. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

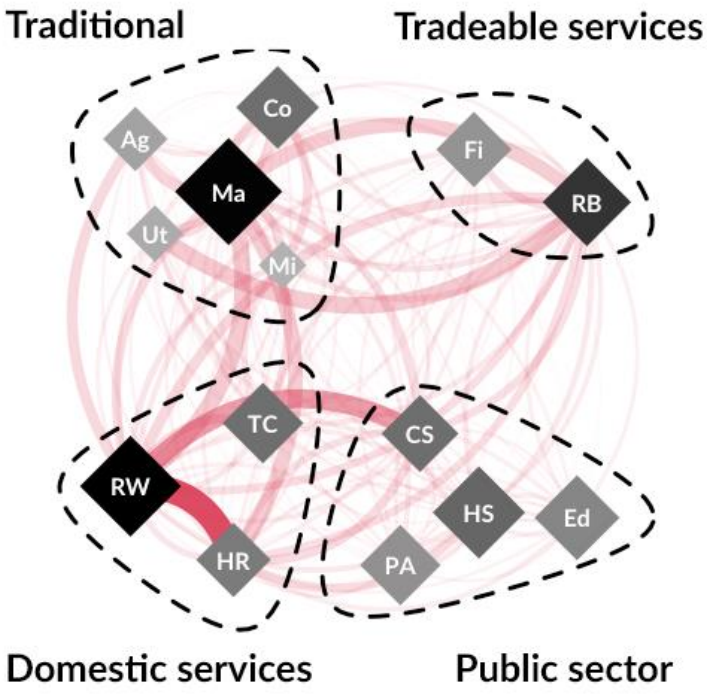
Table C11. Spillover determinants: PRB remit group results (robustness check)

	(1)	(2)	(3)
Lagged settlement	0.73***	0.73***	0.74***
	(0.00)	(0.00)	(0.00)
Lagged spillover	0.00	-0.00	-0.00
	(0.00)	(0.01)	(0.00)
* Union density (diff)		-0.02	-0.04***
		(0.01)	(0.01)
* Female worker share (diff)		0.02*	0.01
		(0.01)	(0.01)
* Age (diff)		-0.00**	-0.00
		(0.00)	(0.00)
* Export competition (diff)			-0.06***
			(0.02)
* Import competition (diff)			0.04
			(0.02)
* Log earnings (diff)			0.01*
			(0.01)
Controls:			
Average lagged settlement	-0.03***	-0.03***	-0.02***
	(0.01)	(0.01)	(0.01)
Union density	1.71***	1.83***	2.94***
	(0.26)	(0.25)	(0.34)
Female worker share	-0.51***	-0.41**	0.08
	(0.17)	(0.17)	(0.21)
Age	-0.03***	-0.03***	-0.03***
	(0.01)	(0.01)	(0.01)
Inflation	-0.00	-0.00	-0.02***
	(0.01)	(0.01)	(0.01)
Unemployment	-0.10***	-0.10***	-0.08***
	(0.01)	(0.01)	(0.01)
Constant	2.59***	2.60***	1.48***
	(0.41)	(0.41)	(0.45)
Sector trends			
Observations	6,300	6,265	5,714
Number of sector pairs	95	95	95
R-squared	0.921	0.922	0.931

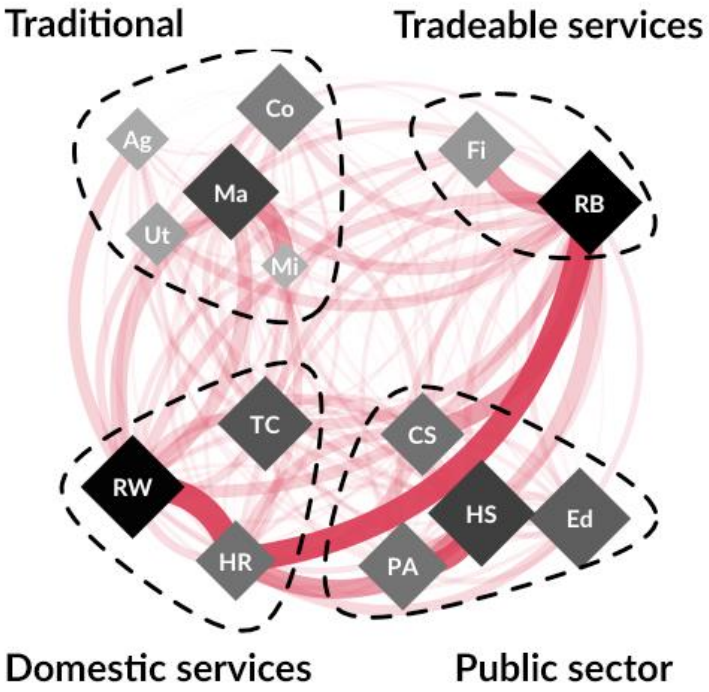
Note: Fixed Effects regression. Regressors lagged by two quarters. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Figure C1. Cross-sectoral employment flows and centrality

1994-1996

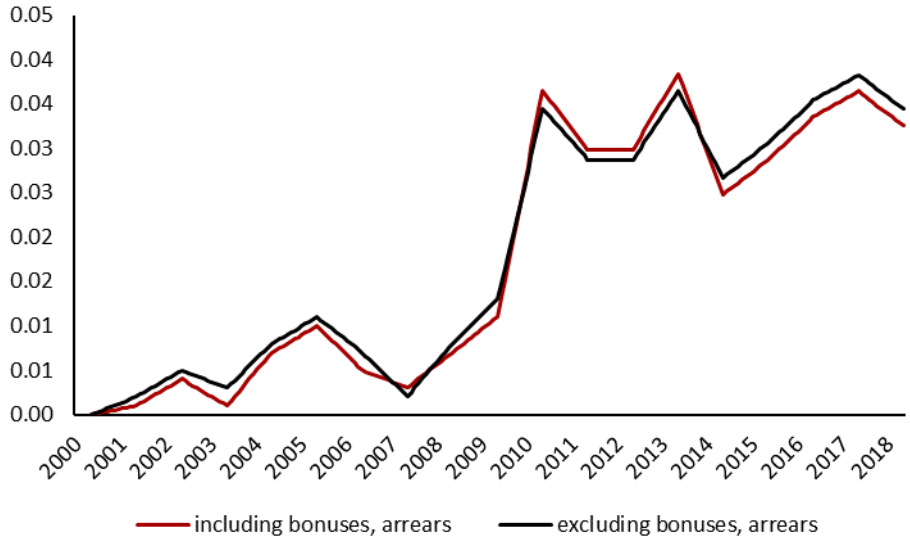


2017-2018



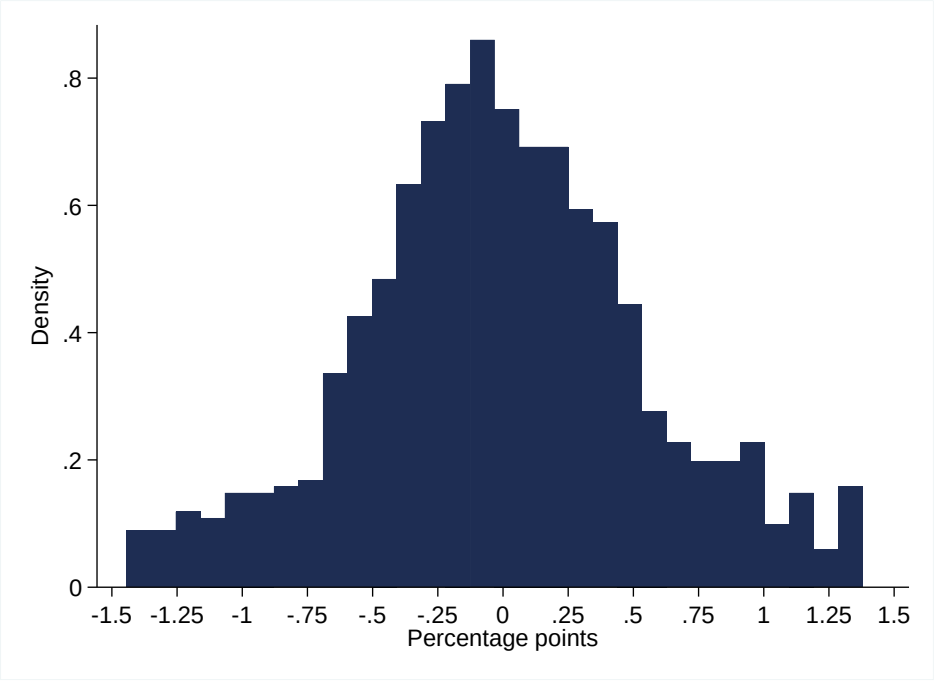
Notes: Sectors – Ag: Agriculture, Mi: Mining & quarrying, Ma: Manufacturing, Ut: Utilities, Co: Construction, RW: Wholesale & retail, HR: Hotels & restaurants, TC: Transport & communication, Fi: Finance, RB: Business services, PA: Public administration, Ed: Education, HS: Health & social work, CS: Other services. Flows depict intensity of quarterly employment flows as a share of total employment in source sector. Diamond area is proportional to sector employment. The darker the colour of the diamond the more central is the sector's position in the network.

Figure C2. Estimated index of the relative composition in private relative to public sector employment



Note: see Appendix A for details on construction.

Figure C3. Distribution of quarterly changes in pay settlements



Note: quarterly settlement changes plotted here range from the 5th to the 95th percentile such that outliers are excluded.

D An overview of factors determining labour market outcomes

In this section, we discuss eight areas of econometric investigation that the report largely sets to one side, either because methodological approaches employed in this report handle them indirectly or because we have not studied them explicitly as they pose substantive topics for research in their own right.

These are the issues of:

- Wage drift
- Union/non-union bargaining and wage setting and
- Wage rigidity
- Unemployment and migration dynamics
- Business cycle dynamics
- Distributional and political economy issues
- Measurement of wages and wage changes.
- Search-theoretic foundations and matching

Wage drift

'Wage drift' has been studied for some time (see Phelps-Brown 1962). It has variously been defined. If pay is rising more than productivity, only part of the rise in pay is brought about by pay awards and collective agreements: a substantial remainder is determined, not at the bargaining head-quarters but at the place of work. This remainder, since it is empirically observed nearly every year and is not under central control, has become known as wage drift.

Wage drift has been mainly a problem of the economies with centralised wage-fixing procedures under full employment, (1); it consists in a rise in the effective rate of pay per unit of labour input that is brought about by arrangements outside the control of the recognised procedures for scheduling wage-rates, (2). In principle, to measure drift we need to compare the actual movement of earnings with the rise that would have come about, at the actual level of activity, from the scheduled provisions alone; but this is hard to do since the counterfactual is difficult to observe.

The propensity for wages in any given occupation or industry to rise is partly conditioned on two main factors:

- The existing structure of the age for wage, promotion and pay advancement schedules which are common in many occupations.
- The mismatch between those leaving an industry and those entering it. Typically those leaving will be on higher experience rated seniority pay – whilst those entering will be younger with less experience.

To a greater or lesser degree, these factors will affect the overall size of the wage bill in any occupation of industry. This will also potentially affect the size of any annual pay uplift which may be agreed in any wage settlement. The implicit

reasoning here may be that a worker may be receiving a de facto wage rise in a year purely as a result of becoming one year more senior in their job and progressing up a pay ladder. This may in turn affect the extent to which their employer feels that they may not need a full cost of living pay rise in that year – as they are already receiving their pay scale rise.

The literature has mainly been concerned with aggregate methods of measuring wage drift in relation to the size of the wage bill and how it relates to productivity. This is not a central concern of our project. But, to the extent that we would wish to relate our findings to productivity then we need to be appraised of the potential importance of the degree to which, specifically public-sector wages may have been lower than cost of living rises expressly because there potentially exists more wage drift in the public sector as a result of career progression wage scales than there is in the private sector. More detailed micro data on institutional and occupational pay structures would need to be analysed in order to investigate this question. By also using settlements data that relates to pay increases given to the lowest adult pay grade and excludes any additional awards beyond basic pay increases, such as incremental rises and merit pay, our approach safeguards against this caveat.

Union/non-union bargaining and wage setting

In most countries the role that decentralised and centralised wage bargaining plays in wage settlements can be crucial. Accordingly, various authors (Holmlund, 1986; Ordine, 1996) have constructed models of the union wage bargaining process which seek to clarify the role of unions in wage settlement determination. Undoubtedly, the importance of these factors varies between the public and private sectors and is very different in different countries. For example, the wage setting process is very decentralised in Italy and Germany, both by sector and local geography. But in the UK in many sectors this is not true and wage settlements are agreed on a wider basis.

A crucial point in the issue of centralised versus decentralised bargaining is to establish the actual weight of insider and outsider factors in the different stages of the bargaining process and to assess empirically the interrelationships between 'wage drift' and the centrally negotiated 'tariff wage'. The relevant insight is then to determine to what extent wage drift offsets changes in the central wage settlements and, consequently, to determine whether there exists a role for centrally negotiated wage policies. Ordine (1996) constructs a simple union bargaining model of this process and seeks to apply it to Italy where this form of dichotomy in the bargaining process is paramount. It is less clear that these factors are so important in the wage setting process in the UK. Accordingly, we set less store in modelling the difference between the forces of local and national bargaining in the UK. Typically, public sector settlements are national settlements which are determined for many public sector occupations by the PRBs in conjunction with central government. Equally, in most national private sector

companies the wage settlement process is mainly a national process. To the extent that there may be regional differences we control for this in our micro settlement data.

In practical terms the Ordine (1996) model only ends up estimating a reduced form econometric model which includes union strength and other regional and sector controls in their econometric model.

To the extent that union strength plays a role in wage bargaining, we can and do control for this in our estimations by the inclusion of sector union trade union membership concentration. We also control for all the other external pressures on wage settlements that Ordine includes in her model. Hence substantively there is no practical difference in the estimation strategy that we adopt.

Wage Rigidity

A third area with a substantial literature relates to wage rigidity and the extent to which either nominal or real wage rates are relatively unresponsive over time, relative to inflation or to macro-economic shocks (see Kahn, 1997; Altonji and Devereux, 2000; Smith, 2000; Barwell and Schweitzer, 2007; and Anderton *et al*., 2017).

The central idea in this literature is that predominantly wages cannot (or do not) get adjusted downwards. In some respects, it is easier to see why nominal wage changes lag behind real wage changes due to either macroeconomic or microeconomic institutional forces.

Barwell and Schweitzer (2007) suggest that the distribution of nominal wage growth in the UK reveals:

- a clear spike in the distribution at zero,
- a clear clustering of observations around the prevailing rate of retail price inflation
  and
- 'fat tails' in the distribution of wage changes - showing a high variance of wage settlements far away from the zero.

Barwell and Schweitzer (2007) argue that the first two of these features of the wage growth distribution are the product of rigidities in wage setting which protect workers from cuts in their nominal and (expected) real wage respectively. They also suggest that a feature of the distribution is largely a by-product of measurement error of various kinds in earnings data (see below). They estimate a model which includes these features on a dataset on pay growth in Great Britain, and find that both nominal and real rigidities are needed to fit the pattern of wage changes seen in these data.

However, what Barwell and Schweitzer (2007) do not study is the extent to which these wage rigidities are different by sector and industry, nor do they distinguish

between micro settlement data and aggregate ONS data on wage growth. We suggest this is a significant topic in its own right which deserves special attention as a separate project.

Unemployment and migration dynamics

Card and Hyslop (1997) argue that labour market institutions tend to prevent nominal wage cuts – even in the face of high unemployment. An implication of this downward rigidity hypothesis is that inflation can ease labour market adjustments by speeding the decline in wages for individuals and markets buffeted by negative shocks.' According to this argument a modest level of inflation may serve to "grease the wheels" of the labour market and reduce frictional unemployment. In sharp contrast, an emerging orthodoxy among many economists and central bankers is that stable aggregate prices reduce labour market frictions and lead to the lowest possible levels of equilibrium unemployment.

Bell *et al*. (2002) examine the relationship between wages and unemployment by region in the UK. They address the following questions. First, is the wage equation a relationship between unemployment and wages or wage changes? Second, is it possible to identify the relationship completely by looking at regional wages and regional unemployment or do regional wages depend on aggregate unemployment as well? Third, is it possible to identify an upward sloping cross-section relationship between wages and unemployment corresponding to a zero migration condition? Finally, are wages influenced only by the current state of the labour market or do contracts lead to wages depending on labour market conditions over the business cycle?

The work of Blanchflower and Oswald (1994) is also relevant in assessing the empirical determinants of the unemployment, wage inflation relationship by region in industry. This 'wage curve' literature is also not emphasized in our report as the focus is not on unemployment dynamics but rather public/private and industry wage uplift spillovers. Although some of the original work of Blanchflower and Oswald (1994) focusses on regional 'wage curves' there has been no emphasis by sector – for the simple reason that the measurement of unemployment by sector is problematic.

Business cycle dynamics

Another area which is overlooked in much of the literature on wage adjustment is the extent to which there is a variation in real wages and wage rises over the business cycle of economic activity. It is fundamentally unclear how much of this can be modelled and the extent to which these cycles vary across sector – or indeed how much of the spillover process between sector wage movements is due to the dynamics of how business cycles spill over from one sector to another.

Messina *et al*. (2009) study real wage dynamics over the business cycle across countries. They find clear effects of cyclicality in real wages and employment and a correlation between the two. They also find a clear role for the degree to which an economy is open to trade and the extent of the role of trade unions. But we know of no work that examines these relationships within a country by industrial sector. To the extent that we incorporate controls for trade unions and degree of openness in our work we have made a significant advance on the literature.

Distributional and political economy issues

One important area which is disguised by the consideration of average wage movements by industry is the extent to which there is a distribution of these wage uplifts over time or by industry. Wallerstein (1999) has studied this question over time across advanced industrial economies from 1980 to 1992. He finds that the most important factors in explaining pay dispersion is the level of wage-setting are:

- The degree of centralisation of collective bargaining, whether this occurs via government involvement in private-sector wage-setting.
- The concentration of unions and the share of the labour force covered by collective bargaining agreements also matter.

He also finds that various political economy measures make a difference. It could be important to replicate this kind of analysis within a country by industry across time.

Measurement of wages and wage changes.

An often-overlooked area of uncertainty about all research on wages, wage increases and wage settlements is the quality and reliability of the data to be used. Too often researchers simply use the main sources of wage data, i.e. the Annual Survey of Hours and Earnings (ASHE) and the Labour Force Survey (LFS) with little regard to the possibility of measurement error in these data. This is despite warnings having been there in the literature for a very long time, see Dunlop (1938).

The differences between the measurement of wages from the UK main surveys, the ASHE and LFS are relatively well know (see Ormerod and Ritchie, 2007). These are namely that ASHE are reported by employers who use payroll data so the earnings should be correct – but the hours worked may not be an accurate reflection of what an individual works. This will mean that measured hourly earnings could easily be quite distorted. Likewise, LFS wages are reported by the individual themselves – but this may easily be subject to memory problems and other kinds of misreporting. They should, however have a better idea of what hours they have actually worked. But again – hourly wages could be mis-measured.

Seldom do labour economists try to reconcile data collected from longitudinal and cross section surveys. A notable exception is the work of Bound *et al*. (1989) – but too seldom do we heed the warnings of the possible inconsistencies in these data. The cautions which surround the measurement of hourly earnings will also clearly affect the measurement of changes in these earnings.

Wage settlements are less likely to be prone to measurement error as they are actual earnings uplift figures. However, what is often less clear is the extent to which the uplift may apply over more than one year – or an uncertain time period - and exactly which workers are to benefit from the uplift.

Again all these issues merit serious further research but, again regrettably have to be left for another separate project.

Search-theoretic foundations and matching

A clear gap in the literature is the investigation of the models of search unemployment frictions and wage dynamics. Pissarides (2009) has set out the theory and provided the micro-foundations of an econometric model of the relationship between the vacancy-unemployment matching function and aggregate wage dynamics. However, what is missing is any investigation of how this model may apply to the sectoral labour market and the extent to which labour market mismatch by sector can be linked to the process of wage change determination. Again, we suggest that this is a topic worthy of separate serious consideration which is outside the scope of this report.