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António Afonso
Pedro Gomes

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António Afonso
European Central Bank,
ISEG/TULisbon and UECE

Pedro Gomes
Universidad Carlos III de Madrid
and IZA

ABSTRACT

Interactions between Private and Public Sector Wages[*]

We examine the interactions between public and private sector wages per employee in OECD countries. The growth of public sector wages and of public sector employment positively affects the growth of private sector wages. Moreover, total factor productivity, the unemployment rate and the degree of urbanisation are also important determinants of private sector wage growth. With respect to public sector wage growth, we find that it is influenced by fiscal conditions in addition to private sector wages. We then set up a dynamic labour market equilibrium model with two sectors, search and matching frictions and exogenous growth to understand the interaction mechanisms. The model is quantitative consistent with the main estimation findings.

Corresponding author:

António Afonso
European Central Bank
Directorate General Economics
Kaiserstrasse 29
D-60311 Frankfurt am Main
Germany
E-mail: antonio.afonso@ecb.europa.eu

1   Introduction

The relevance of public wages for total government spending has increased gradually over the past decades in several European countries. Apart from the importance that such a budgetary item has for the development of public finances and for attaining budgetary objectives[1], public sector employment and wages play a key role in the labour market. In this context, the main objective of this paper is to study one aspect of the relation between fiscal policy and the labour market, namely the interaction between private and public sector wages.

First, we analyse the interactions between the wages in the two sectors empirically. We examine the determinants of private sector wage growth, paying attention to the role of public sector wage and employment growth, as well as other market related variables. Additionally, we look at the determinants of public sector wage growth. Although there is evidence of some pro-cyclicality of public wages (Lamo, Pérez, and Schuknecht (2008)), their developments may be less aligned with those of the private sector. For instance, public wages can also depend on the fiscal position. In fact, Poterba and Rueben (1995) and Gyourko and Tracy (1989) find that fiscal conditions affect wages of public employees at a local level. Moreover, they might be used as an instrument for income policies, thus they can depend on political factors such as the political alignment of the ruling party or election cycles. For instance, Matschke (2003) finds evidence of systematic public wage increases prior to a federal election in Germany.

We develop our analysis for OECD countries for the period between 1973 and 2000. We carefully discuss the econometric issues involved, particularly the problem of endogeneity, and how we subsequently address them. In a nutshell, we find that a number of variables affect private sector wage growth, for instance: changes in the unemployment rate (negative relationship), total factor productivity growth and changes in the urbanisation rate. Moreover, public sector wages and employment growth also affect private sector wage growth. A 1%

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[1]According to the European Commission, the average share of public wages (compensation of employees) in general government total spending was around 23 per cent in 2007 for the European Union, that is, around 11 percent of GDP. Interestingly, the public wages-to-total government spending ratio was 28 per cent in 2006 in the US.

increase in public sector wages raises the wages in the private sector by 0.3 percent. Public sector wage growth seems to respond mainly to private sector wage growth, but also to the budget balance, the tax wedge and the position of the countries in the political spectrum.

Second, we set up a dynamic two-sector labour market equilibrium model in order to understand the interaction mechanisms. The model, that features search and matching frictions in the labour market and exogenous growth, captures the essence of the interaction between the wages in the two sectors. The government determines wage increases depending on the expected growth rate of private sector wages and an error correction that depends on the public-private wage differential. The long-run growth rate is determined in the private sector and then spreads out to the public sector, but similar to other models that address this issue, we also find that public sector wages and employment affect private sector wages.[2]

Public sector wages and employment impinge on private sector wages via three channels. First, they affect the outside option of the unemployed, either by increasing the probability of being hired (public sector employment) or by increasing the value of being employed in the public sector (public sector wages). Therefore, they put pressure on wage bargaining. Second, they both crowd out private sector employment which, due to the presence of diminishing marginal productivity of labour, raises the average productivity. Finally, both public wages and employment have to be financed by an increase in taxes, which will also affect the wages paid by the firm. In addition, the model also features the effects from private sector wages to public sector wages in response to technology shocks. Re-doing the empirical exercise with simulated data, yields very similar coefficients to the ones estimated for the OECD countries.

The paper is organised as follows. In Section 2 we present the empirical setting and in Section 3 we report and discuss the results. In Section 4 we present the theoretical model. Section 5 summarises the main findings of the paper.

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[2]See, for instance, Holmlund and Linden (1993), Algan, Cahuc, and Zylberberg (2002), and Ardagna (2007).

2 Empirical framework

In this section, we estimate the determinants of both private sector and public sector wages. Our underlying idea is to estimate two different wage functions that link private and public wages, while carefully addressing the problem of endogeneity between the two.

Most papers provide an aggregate perspective of the relation between the two wages focussing on wage levels per employee (see, for instance, Nunziata (2005), Jacobson and Ohlsson (1994) and Friberg (2007)). However, we prefer to model the growth rates of real compensation per employee to assess the behaviour of the two variables in the short run. Since we have annual data, the use of growth rates eliminates the low frequency movements, but preserves the movements at business cycle frequency, which we are more interested in uncovering (Abraham and Haltiwanger (1995)).

In the long-run it is natural that the two variables are cointegrated with a slope coefficient of one, if not one would observe a constant divergence of the wages in the two sectors. [3] This does not exclude differences in the levels of the wages, but simply that these differences do not show a trend. In fact, we observe a public sector wage premium or a gap, either due to different skills composition of employment or because of barriers between the two sectors.

2.1 Empirical specification for private sector wages

Our baseline wage function for the developments in private sector salaries is given by

$$\omega_{it}^p = \alpha_i + \delta^p \omega_{it-1}^p + \theta^p X_{it}^p + \pi^p Z_{it}^p + \kappa^p E_{it-1} + \mu_{it}. \tag{1}$$

In (1) the index i ($i = 1, ..., N$) denotes the country, the index t ($t = 1, ..., T$) indicates the period, α_i stands for the individual effects to be estimated for each country i, and it is assumed

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[3]This is supported by preliminary panel regressions between public and private wages (in logs) where the estimated coefficient is between 0.97 and 1.02. Additionally, cointegration analysis for each country supports such long-term relation between private and public sector wages.

that the disturbances μ_{it} are independent across countries. ω_{it}^p is the growth rate of the real compensation per employee in the private sector.

X_{it}^p is a vector of macroeconomic variables that might be endogenous to private sector wage growth. This vector includes the growth rate of real compensation per employee in the public sector, ω_{it}^g; the growth rate of the consumer price index, growth rate of total factor productivity, change in the unemployment rate, change in urbanization rate, growth rate of the per worker average hours worked, growth rate of the countries' terms of trade, change in the tax wedge and the growth rate of public employment. The latter can also positively impinge on the growth rate of private sector wages if higher labour demand in the public sector pushes private sector wages upwards.

On the other hand, Z_{it}^p is a vector of institutional exogenous variables. It includes the change in union density, an index of bargaining coordination, the change in benefit duration and the change in the benefit replacement ratio. Previous work by Nunziata (2005) concluded that these institutional variables are important determinants of the level of wages. While union density should contribute to increase wages, the benefit replacement rate and duration affect the outside option of workers and may also influence their wages. Additionally, if the bargaining process is centrally coordinated it is likely to restrain private sector wage growth. Finally, we include an index of central bank independence to capture potential credibility effects on inflation expectations as well as a variable that measures the change in education attainment of the working age population to control for composition effects.

Finally, E_{it-1} in (1) is defined as the percentage difference between public and private sector wages - the public wage premium or gap:

$$E_{it-1} = \ln\left(\frac{w_{it-1}^g}{w_{it-1}^p}\right) \times 100. \tag{2}$$

where w^g and w^p are respectively the nominal public and private per employee wage in levels. This term can be interpreted as an error correction mechanism. There are two ways through

which public sector wages can affect private sector wages. There is the direct effect, captured in θ^p, in equation (1), and there is the indirect effect through the error correction mechanism of magnitude κ^p. If the ratio of public-to-private wages increases, private sector wages may rise in order to correct the wage differential downwards. This can be seen both as a demonstration effect stemming from the public sector or a catching up effect in salaries implemented in the private sector. Therefore, κ^p is expected to be positive.

In addition, one can assess the cyclicality of private wages. If the coefficient on the change in the unemployment rate is negative this implies a pro-cyclical behaviour of private wages. While the idea of wage counter-cyclicality was put forward by Keynes (1939), empirical results actually produce evidence of both pro-cyclical and counter-cyclical private sector behaviour. Abraham and Haltiwanger (1995) offer several arguments for the possibility of both outcomes.

2.2   Empirical specification for public sector wages

We also estimate an equation for public sector real wage growth. The baseline wage function for the developments of public sector salaries can be assessed with the following specification:

$$\omega_{it}^g = \beta_i + \delta^g \omega_{it-1}^g + \theta^g X_{it}^g + \pi^g Z_{it}^g + \kappa^g E_{it-1} + \eta^g F_{it}^g + \zeta^g P_{it}^g + \mu_{it}. \tag{3}$$

We consider that government wages can respond to the same variables as private wages, except for the average hour worked per worker, central bank independence and the growth rate of public employment growth. Indeed, the hours worked in the public sector are more standardized than in the private sector, and the central bank independence is more relevant for the private sector. X_{it}^g also includes the growth rate of private sector wages. Additionally, F_{it} includes fiscal variables, such as the general government budget balance as a percentage of GDP and the general government debt-to-GDP ratio. P_{it} contains the political variables, which consist of the percentage of votes for left wing parties and a dummy variable for parliamentary election years. While the variables in F_{it} are endogenous, we consider the variables in P_{it} as exogenous. β_i stands for the individual effects to be estimated for each country i.

Similar to the specification for the private sector wages, κ_g now measures to what extent public wages correct the imbalances of the long-term relation between the two. In this case, increases in the public-to-private wages ratio can produce a future reduction in public sector wages, implying an expected negative value for κ_g.

While one would expect that recent fiscal developments may impinge on the public sector wages per employee, this hypothesis seems less relevant for the development of private sector wages. On the other hand, if one expects the unemployment rate to impinge negatively on the development of private sector wages, this effect may be mitigated in the case of public sector wages, given the higher rigidity of the labour force in the government sector and a possible higher degree of unionisation.

2.3 Econometric issues

There are two main econometric issues when estimating the wage functions (1) and (3). The first issue is the presence of endogenous variables, particularly the simultaneous determination of public and private sector wage growth. To deal with this, we estimate each equation separately and instrument all the endogenous variables by the remaining pre-determined variables and two lags of all variables. We compute the Sargan over-identifying test to assess the validity of the instruments. As we are using the lagged variables as instruments, what we are essentially doing is predicting the value of the regressors based on past information. Thus, the interpretation of the coefficients should be, for instance, the effect of expected public sector wage growth on the growth rate of private sector wages.

Although our distinction between endogenous and exogenous variables is arbitrary, we run a Hausman test to examine the exogeneity of each block of variables.

The second econometric issue is that the regressors and the error term are correlated, because we allow for a country specific error and include a lagged dependent variable. Although we also tried the Arellano and Bond GMM estimator, our preferred methodology is a simple panel 2SLS estimation. First, the Arellano and Bond methodology implies estimating

the equation in first differences (of growth rates) which adds a lot of noise to the estimates. Furthermore, as Nickell, Nunziata, and Ochel (2005) point out, the bias created by the presence of a lagged dependent variable in panel data tends to zero if we have a long time series component. As we have close to 30 time observations for most countries in the sample, we proceed with the estimation with a panel 2SLS. We also include country fixed effects.

3   Estimation results and discussion

3.1   Data

We study this issue in a panel framework for eighteen OECD countries, covering essentially the period between 1973 and 2000.[4]

For the employment and wage data our main data source is the OECD Economic Outlook database, the European Commission database AMECO and the Labour Market Institutions Database used in Nickell, Nunziata, and Ochel (2005) and expanded by Nickell (2006). Private sector wages are defined as total compensation of employees minus compensation of government employees. Private sector wages per employee are defined as private compensation of employees divided by private sector employees (total employment minus government employees minus self-employed persons).[5] We compute the real wages per employee using the consumption price deflator.

Using aggregate data has its limitations. On the one hand, it ignores the composition of public and private employment, in particular with respect to the skills level of employment and age. On the other hand, it is difficult to get a completely clean identification strategy. Despite these problems we still think using aggregate data is an advantage. First, no other type of data would allow for such a long time span for so many countries. Second, the identification using lags as instruments has been used quite successful in several studies, for instance by

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[4]Given data availability, the countries used in the empirical analysis are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom and United States. See the Appendix for details and sources.

[5]This approach is also used by Lamo, Pérez, and Schuknecht (2008)

Nickell, Nunziata, and Ochel (2005) and Nunziata (2005). To control, as far as possible, for the skills composition of the workforce we also consider the educational attainment on the basis of the average years of schooling.

The share of government employment in total employment increased for most countries in the 1980s, while there was an even more generalised decline after the beginning of the 1990s. Regarding real wages per employee an upward trend occurred for most countries, both for private and public wages. In addition, although the ratio of public-to-private wages per employee is relatively constant, it has followed an upward path for the majority of European countries since the beginning of the 1990s.[6]

3.2   Private wage determinants

The first two columns of Table 1 report the results for the growth rate of the real private sector wages per employee. One can observe that the growth rate in public sector wages affects their private counterpart both directly and through the error correction model. Both coefficients are positive and statistically significant. A 1 percent increase in real public sector wage growth increases private sector real wage growth by 0.3 percent. The growth rate of public employment also has a positive and significant effect on the growth rate of nominal private sector wages. A 1 per cent increase in public sector employment increases private sector wage growth by close to 0.2 percent.

The change in the unemployment rate exerts a negative effect on private sector wages growth. In other words, private sector wages have a pro-cyclical behaviour: a 1 percentage point increase in the unemployment rate reduces the growth rate of private sector wages by around 0.5 percentage points. On the other hand, such a growth rate increases with total factor productivity growth.

The inflation rate does not affect the growth rate of real private sector wages per employee,

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[6]See Afonso and Gomes (2008) for a more detailed assessment of the data trends.

Table 1: Determinants of the real growth rate of wages per employee (1973-2000)

	Private sector				Public sector			
	(1)		(2)		(3)		(4)	
Lagged dependent variable	0.120**	(2.46)	0.140***	(3.23)	0.243***	(5.07)	0.246***	(5.60)
Error correction component	0.034**	(2.47)	0.038***	(2.91)	-0.097***	(-5.35)	-0.094***	(-6.49)
Growth rate of public sector wages	0.304***	(4.72)	0.325***	(5.41)				
Growth rate of private sector wages					0.730***	(4.43)	0.562***	(5.14)
Δ Unemployment rate	-0.501***	(-2.97)	-0.451***	(-3.57)	0.218	(0.79)		
Inflation rate	-0.005	(-0.10)			-0.015	(-0.21)		
Growth rate of TFP	0.349***	(2.78)	0.361***	(2.94)	-0.175	(-0.85)		
Δ Urbanization rate	0.873	(1.58)	0.888*	(1.71)	-1.000	(-1.14)		
Growth rate of terms of trade	0.031	(0.64)			-0.005	(-0.08)		
Growth rate of hours per worker	-0.604	(-0.96)						
Growth rate of public employment	0.229**	(2.09)	0.231***	(3.07)				
Tax wedge	0.187	(1.42)			-0.562**	(-2.29)	-0.455**	(-2.43)
Budget balance					0.102	(1.61)	0.113**	(2.28)
Government debt					0.003	(0.24)		
Δ Union density	0.001	(1.03)			-0.001	(-0.45)		
ΔBargaining coordination	1.975	(1.60)			-1.210	(-0.60)		
Δ Benefit duration	-4.567*	(-1.84)	-3.894*	(-1.65)	1.032	(0.26)		
Δ Benefit replacement rate	-0.018	(-0.55)			0.019	(0.39)		
Δ Education	0.392	(0.35)			-1.130	(-0.66)		
Central bank independence	-2.416***	(-3.33)	-2.530***	(-3.96)				
Election year					-0.171	(-0.59)		
% Left wing votes					0.069*	(1.81)	0.057*	(1.68)
Observations	437 (18)		440 (18)		437 (18)		437 (18)	
R^2	0.380		0.381		0.228		0.263	
Sargan test[#]	40.1 (0.15)		44.6 (0.28)		42.2 (0.09)		49.2 (0.24)	
Overidentifying restrictions	32		40		31		43	
Hausman test (Exogenous)[&]	5.56 (0.99)		3.10 (0.96)		4.08 (1.00)		0.68 (1.00)	
Hausman test (Endogenous)[$]	20.29 (0.26)		28.5 (0.00)		2555.4 (0.00)		23.7 (0.00)	

Notes: the coefficients are estimated using 2SLS. Endogenous variables: the change in unemployment rate, the change in the urbanisation rate, the growth rate of total factor productivity, inflation rate, growth rate of real per worker private sector wages, growth rate of hours per worker, growth rate of public employment, growth rate of terms of trade, budget balance, government debt and tax wedge. They are instrumented by the remaining pre-determined variables and two lags of all explanatory variables. The t statistics are in parentheses. *, **, *** - statistically significant at the 10, 5, and 1 percent. [#] The null hypothesis of the Sargan overidentification test is that the instruments are uncorrelated with the error term and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of overidentifying restrictions. The p-value is in brackets. [&] The null hypothesis is that the block of institutional variables is exogenous. Under the null, the estimator used is efficient but it is inconsistent under the alternative hypothesis. The consistent estimator would be to consider all variables as endogenous and instrument them with lags. The p-value is in brackets. [$] The null hypothesis is that the block of macroeconomic variables is exogenous. Under the null, the most efficient estimator is fixed effects estimation taking all variables as exogenous. Under the alternative hypothesis the estimates are consistent. The p-value is in brackets.

which supports the idea that agents have rational expectations. Some wage stickiness is captured by the statistically significant lagged dependent variable, while there are no statistically significant effects reported for the terms of trade or for the tax wedge.

Regarding the set of pre-determined explanatory variables (in vector Z), it is interesting to note that the growth rate of real private sector wages is negatively affected by the index of central bank independence. Changes in union density, bargaining coordination, the benefit replacement rate and education do not statistically affect the growth rate of real private sector wages. Moreover, the change in benefit duration has a negative significant coefficient.

In the estimations, the Hausman test clearly supports that the institutional variables block is exogenous and that the variables in the macroeconomic block are endogenous. The Sargan test points to the validity of the instruments.

3.3   Public wage determinants

We now turn to the analysis of the determinants of the growth rate of real public sector wages per employee, which are presented in columns (3) and (4) of Table 1. The estimations pass the Sargan test. When we include all regressors, the p-value of the test is low, albeit above 0.05. In the reduced specification the p-value is around 0.24.

The growth rate of real public sector wages per employee reacts positively to real private sector wages, with a coefficient between 0.6 and 0.7. On the other hand, it responds negatively to an increase in the ratio between public and private sector wages in line with our previous conjecture. Therefore, this correction mechanism adjusts public wages downward when the differential *vis-à-vis* private wages rises. Note that the absolute value of the coefficient is roughly three times higher than the one from the similar error correction component of the coefficient estimated in the private sector model. This means that most of the adjustment is done via public sector wages.

The lagged dependent variable is statistically significant with a magnitude of around 0.24,

denoting a higher degree of wage stickiness than in the private sector. The growth of public sector wages is not affected by any of the market variables. Regarding the explanatory fiscal variables, improvements in the budget balance increase the growth rate of nominal public sector wages. An increase in the budget balance ratio of 1 percentage point translates into an increase of the growth rate of public sector wages of around 0.1 percentage points. Increases in the tax wedge are associated with lower public sector wage growth. In terms of the pre-determined exogenous variables, there is a statistically significant positive effect of the percentage votes for left wing parties.

3.4   Robustness, system estimation

Given that the two wage variables are jointly determined, a more efficient approach is to perform a 3SLS estimation of the system of two equations. The drawback is that, if there is a problem with one of the equations all the parameter estimates are inconsistent. We start the estimation with all variables and then exclude the variables that are not statistically significant. According to the results shown in Table 2, we do not reject the validity of all the instruments at a 5 percent significance level.

We note that the results are close to the estimations of the single equations. The lagged dependent variable is significant in both equations with a higher value in the public sector. In addition, the error correction mechanism is also significant, but its magnitude in the private sector equation is somewhat higher than in the baseline estimation. Interestingly, the magnitude of the direct effects of wage growth in the other sector are also somewhat higher than in the baseline estimations: 0.47 from public to private and 0.88 in the opposite direction.

The change in the unemployment rate, growth rate of total factor productivity, change in the urbanisation rate, growth rate of public sector wages, employment, and Central Bank independence are all significant determinants of private sector wages, with the coefficients having the same magnitude as previous estimates. The estimate of the effect of the budget balance on public sector wage growth is still 0.1, but the percentage of left wing votes is not

significant. The tax wedge is now statistically significant for both private and public sector. [7]

Table 2: System estimation (1973-2000)

	Private sector		Public sector	
	(1)		(2)	
Lagged dependent variable	0.082**	(2.15)	0.166***	(4.27)
Error correction component	0.056***	(4.66)	-0.109***	(-7.55)
Growth rate of public sector wages	0.473***	(8.59)		
Growth rate of private sector wages			0.881***	(8.11)
Δ Unemployment rate	-0.311***	(-2.80)		
Growth rate of total factor productivity	0.276***	(2.61)		
Δ Urbanization rate	1.148**	(2.34)	-1.572**	(-2.26)
Growth rate of public employment	0.172***	(2.59)		
Tax wedge	0.208*	(1.79)	-0.404**	(-2.30)
Budget balance			0.103**	(2.34)
Δ Benefit duration	-3.422	(-1.63)		
Central bank independence	-2.071***	(-3.57)		
Observations	437 (18)		437 (18)	
R^2	0.341		0.310	
Hansen-Sargan test[#]		103.1 (0.057)		

Notes: the coefficients are estimated using 3SLS. Endogenous variables: the change in unemployment rate, the change in the urbanisation rate, growth rate of total factor productivity, inflation rate, growth rate of real per worker public and private sector wages, growth rate of terms of trade, growth rate of hours per worker, change in tax wedge, the growth rate of public employment, budget balance and government debt. These endogenous variables are instrumented by the remaining pre-determined variables and two lags of all explanatory variables. # The null hypothesis of the Hansen-Sargan overidentification test is that the instruments are uncorrelated with the error term and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of overidentifying restrictions (82). The p-values are in brackets.

4   Analytical framework

4.1   The model

The empirical section offered several important conclusions, useful for the setting up of the model. First, the relation between public and private wages is bi-directional, with market

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[7]As an alternative robustness check, we included one lag of all explanatory variables in the regressions. In general, the inclusion of lags does not carry much explanatory power. Indeed, the R-square changes very little from the baseline estimation, and the test that all coefficients of the lagged explanatory variables are jointly equal to zero is not rejected at the 5 percent significance level for both equations. We have also performed estimations with only the subset of European Union and euro area countries, estimations with only macroeconomic variables and a longer sample, GMM Arellano and Bond estimation and also for the nominal wages. See Afonso and Gomes (2008).

forces and productivity having an effect on private sector wage growth, which is then followed by the public sector. Second, developments in the public sector wages caused by, for instance, political issues or by the need of fiscal tightening also affect the private sector wages. Moreover, and in addition to the contemporaneous relation, there is also an error correction mechanism that corrects the gap between the wages in the two sectors. Most of such correction occurs in the public sector.

In this section we set up a dynamic labour market equilibrium model that captures the qualitative essence of the interaction between private and public sector wage growth. The purpose is twofold. The first objective is to uncover the transmission mechanisms of fiscal policy through the labour market. The second is to find out if the model with only frictions in the labour market is able to replicate the findings of the empirical section.

The model is an extension of the model by Gomes (2009a). The economy has a public and a private sector and search and matching frictions, along the lines of Pissarides (2000). The unemployed can only search for a job in one sector. There is some micro-econometric evidence on the assumption of directed search between the private and public sector. Blank (1985) finds that sectoral choice is influenced by wage comparison. Heitmueller (2006) is able to quantify this effect and finds that an increase in 1 percent in the wages in the public sector relative to the private sector increases the probability of choosing public sector employment by 1.3 and 2.9 percent respectively for men and for women. The model has several differences from the one in Gomes (2009a), that make it more realistic: it features exogenous growth in the private sector technology; the public sector wage bill is financed through a distortionary labour income taxation; the production function in the private sector has a more general form with diminishing marginal returns and we analyse different fiscal rules for the setting of public sector vacancies and wages, as opposed to discussing the optimal policy.

4.1.1   General setting

Public sector variables are denoted with superscript g while private sector variables are denoted by superscript p. Time is denoted by t. The labour force consists of many individuals $j \in [0, 1]$. A proportion u_t are unemployed, while the remainder are working either in the public (l_t^g) or in the private (l_t^p) sector

$$1 = l_t^p + l_t^g + u_t. \tag{4}$$

The presence of search and matching frictions in the labour market prevents some unemployed individuals from finding work. The evolution of public and private sector employment depends on the number of new matches m_t^p and m_t^g and on separations in each sector. We consider that, in each period, a constant fraction of jobs is destroyed, and this fraction (λ) might be different between the two sectors

$$l_{t+1}^i = (1 - \lambda^i)l_t^i + m_t^i, \ i = p, g. \tag{5}$$

We assume that the unemployed choose in which sector they want to conduct their search, so u_t^i represents the number of unemployed searching in sector i. The number of matches formed in each period is determined by two Cobb-Douglas matching functions:

$$m_t^i = \bar{m}^i {u_t^i}^{\eta^i} {v_t^i}^{1-\eta^i}, \ i = p, g. \tag{6}$$

We define the share of unemployed searching for a public sector job as $s_t = \frac{u_t^g}{u_t}$. From the matching functions we can define the probabilities of vacancies being filled q_t^i, the job-finding rates conditional on searching in a particular sector, p_t^i, and the unconditional job-finding rates, f_t^i:

$$q_t^i = \frac{m_t^i}{v_t^i}, \ p_t^i = \frac{m_t^i}{u_t^i}, \ f_t^i = \frac{m_t^i}{u_t}, \ i = p, g.$$

4.1.2 Households

In the presence of unemployment risk we could observe consumption differences across different individuals. As in Merz (1995), we assume all the income of the household members is pooled so that private consumption is equalised within the household.

The household is infinitely-lived and has preferences over the private consumption good, c_t, and a public consumption good g_t

$$E_0 \sum_{t=0}^{\infty} \beta^t (\ln c_t + \zeta \ln g_t), \tag{7}$$

where $\beta \in (0,\ 1)$ is the discount factor. The budget constraint in period t is given by

$$c_t + B_t = (1 + r_{t-1})B_{t-1} + (1 - \tau_t)w_t^p l_t^p + (1 - \tau_t)w_t^p l_t^g + z_t u_t + \Pi_t. \tag{8}$$

r_{t-1} is the real interest rate from period t-1 to t, and B_{t-1} are the holdings of one period bonds. $(1 - \tau_t)w_t^i l_t^i$ is the wage income from the members working in sector i, net of taxes, being τ the distortinary tax rate. The unemployed members receive unemployment benefits z_t. Finally, Π_t encompasses all lump sum transfers from the firm.

The household chooses consumption and bond holdings to maximize the expected lifetime utility subject to the sequence of budget constraints, taking the public consumption good as given. The solution is the consumption Euler equation:

$$1 = \beta(1 + r_t)E_t\left[\frac{c_t}{c_{t+1}}\right]. \tag{9}$$

4.1.3 Workers

The value to the household of each member depends on their current state. The value of being employed is given by:

$$W_t^i = (1 - \tau_t)w_t^i + E_t \beta_{t,t+1}[(1 - \lambda^i)W_{t+1}^i + \lambda^i U_{t+1}],\ \ i = p, g \tag{10}$$

where $\beta_{t,t+1} = \beta E_t[\frac{c_t}{c_{t+1}}]$ is the stochastic discount factor. The value of being employed depends on the current wage as well as on the continuation value of the job, which depends on the separation probability in each sector. Under the assumption of directed search the agents are either searching in the private or in the public sector. The value functions are given by

$$U_t^i = z_t + E_t\beta_{t,t+1}[p_t^i W_{t+1}^i + (1 - p_t^i)U_{t+1}], \ i = p, g. \tag{11}$$

The value of unemployment depends on the level of unemployment benefits and on the probabilities of finding a job in the two sectors. Optimality implies the existence of movements between the two sectors to guarantee that there is no additional gain of searching in one sector *vis-à-vis* the other

$$U_t^p = U_t^g = U_t. \tag{12}$$

This equality determines the share of unemployed searching in each sector, and the respective expression is implicitly given by

$$\frac{m_t^p E_t[W_{t+1}^p - U_{t+1}]}{(1 - s_t)} = \frac{m_t^g E_t[W_{t+1}^g - U_{t+1}]}{s_t}. \tag{13}$$

The optimal search of public sector jobs increases with the number of vacancies in the public sector and the value of a such a job, which depends positively on the public sector wages and negatively on the separation probability.

4.1.4 Firms

The private sector representative firm hires labour to produce the private consumption good. The production function depends on labour, but part of the resources produced have to be used to pay for the cost of posting vacancies $\varsigma_t^p v_t^p$,

$$c_t = a_t^p(l_t^{p(1-\alpha)} - \varsigma_t^p v_t^p). \tag{14}$$

The technology, a_t^p, has a unit root and grows at an average rate on γ. Its law of motion is given by

$$\ln a_t^p = \ln a_{t-1}^p + \gamma + \epsilon_t^a. \tag{15}$$

The firm's objective is to maximize the present discounted value of profits given by

$$E_t \sum_{k=0}^{\infty} \beta_{t,t+k} [a_{t+k}^p (l_{t+k}^{p(1-\alpha)} - \varsigma_{t+k}^p v_{t+k}^p) - w_{t+k}^p l_{t+k}^p], \tag{16}$$

and faces the law of motion for private sector employment given by

$$l_{t+1}^p = (1 - \lambda^p)l_t^p + q_t^p v_t^p. \tag{17}$$

The firm takes the probability of filling a vacancy, q_t^p, as given. At any given point the level of employment is predetermined and the firm can only control the number of vacancies it posts. The solution to the problem is given by equation (18)

$$\frac{\varsigma^p}{q_t^p} = E_t \beta_{t,t+1} \frac{a_{t+1}}{a_t} [(1 - \alpha)l_{t+1}^{p-\alpha} - \frac{w_{t+1}^p}{a_{t+1}} + (1 - \lambda^p)\frac{\varsigma^p}{q_{t+1}^p}]. \tag{18}$$

The optimality condition of the firm states that the expected cost of hiring a worker must equal its expected return. The benefits of hiring an extra worker is the discounted value of the expected difference between its marginal productivity and its wage and the continuation value, knowing that with probability λ^p the match can be destroyed.

4.1.5 Private sector wage bargaining

We consider that the private sector wage is the outcome of a Nash bargaining between workers and firms,

$$w_t^p = \arg\max_{w_t^p} (W_t^p - U_t)^b (J_t)^{1-b}, \tag{19}$$

where b is the bargaining power of the unemployed and J_t is the value of the marginal job for the firm, given by the following expression

$$J_t = (1 - \alpha)l_t^{p-\alpha} - w_t^p + E_t\beta_{t,t+1}[(1 - \lambda^p)J_{t+1}]. \tag{20}$$

The Nash bargaining solution is given by:

$$(W_t^p - U_t) = \frac{b(1 - \tau_t)}{1 - b\tau_t}(W_t^p - U_t + J_t). \tag{21}$$

In the presence of distortionary taxes the share of the surplus going to the worker is lower than its bargaining power. The reason is that for every unit that the firm gives up in favour of the worker, the pair lose a fraction τ to the government. So they economise on their tax payments by agreeing a lower wage.

4.1.6 Government

The government produces its consumption good using a linear technology on labour. As in the private sector, the costs of posting vacancies are deduced from production

$$g_t = l_t^g - \varsigma^g v_t^g. \tag{22}$$

It sets a labour income tax to finance the wage bill and the unemployment benefits

$$\tau_t(w_t^p l_t^p) = (1 - \tau_t)(w_t^g l_t^g) + z_t u_t, \tag{23}$$

and the unemployment benefits are given by

$$z_t = z a_t^p. \tag{24}$$

Finally, the government follows a policy for public sector vacancies and public sector wages $\{v_t^g, w_{t+1}^g\}_{t=o}^{\infty}$. We assume the government sets the wage one period in advance, at the time it

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posts the vacancies. As s_t is determined based on the expected vale of both public and private sector wage in $t + 1$, the current period public sector wage only affects the current level of taxes. We assume the following rule for public sector wages:

$$\frac{w_{t+1}^g}{w_t^g} = E_t[\frac{w_{t+1}^p}{w_t^p}] + \kappa[\frac{w_{t-1}^g}{w_{t-1}^p} - 1 - \Psi] + \epsilon_t^w. \tag{25}$$

In every period, the government sets its wage for the next period based on the expected growth of private sector wages and on an error correction mechanism mimicking the public wage premium in (3), that adjusts the differences from the actual to the target public sector wage premium (Ψ). Public sector vacancies are set at their steady state level, designed to target a steady state level of public sector employment

$$v_t^g = \bar{v}^g + \epsilon_t^g. \tag{26}$$

Both public sector vacancies and wages are subject to shocks. We can interpret a shock to wages (ϵ_t^w) as a short-run phenomenon coming from the need of fiscal tightness, because of pressure from the trade union or arising from a change in government.[8]
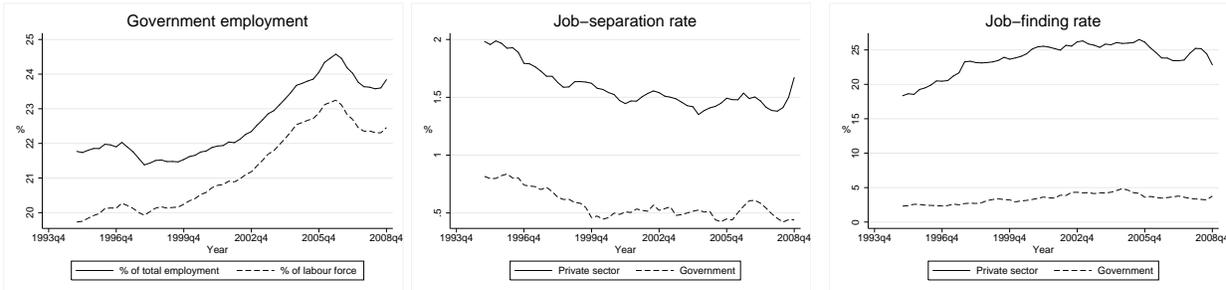
4.2 Calibration

We calibrate the model at a quarterly frequency to be close to the UK economy. Figure 1 shows the level of government employment and the job-separation and job-finding rates in the two sectors. The data are taken from the UK Labour Force Survey.[9]

We calibrate the steady-state public sector vacancies such that the steady-state employment in that sector is 20% of the total labour force. The separation rate in the public sector is set to 1%, half the one in the private sector (2%). The public sector wage is set such that in steady-state, the public sector wage premium is equal to 4%. This value is in line with several empirical estimates (see Gregory and Borland (1999) for an overview of the literature).

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[8]The model written in efficiency units can be found in the Appendix.

[9]See Gomes (2009b) for a detailed study on UK labour market flows.

Figure 1: Evidence for the United Kingdom

Note: The data is taken from the Labour Force Survey. Government employment includes employment in local and central government, health authorities, universities and armed forces.

We also calibrate the two matching functions differently. We set η^p equal to 0.5 as it is common in the literature. In contrast, η^g is set equal to 0.2, which implies that vacancies are relatively more important than the pool of unemployed in the public sector matching. This was the value found in an estimation for the United States by Gomes (2009a). The parameters $\bar{m}^i$ are set in such a way that the duration of a vacancy is 12 weeks for the private sector and 16 weeks for the public sector. These values are taken from two studies for the United Kingdom by the National Audit Office (2009) and the Chartered Institute of Personnel and Development (2009). The latter study also estimates that the average cost of recruiting a worker is between £4600 and £5800. This corresponds to between 10 and 12 weeks of the median income in United Kingdom (£479 according to the ONS). In the public sector, the costs of recruiting are between 20% to 80% lower than for the total economy, depending on occupation category. We therefore set ς^p to be such that the recruitment cost per employee in the private sector is equivalent to wages paid over three-month period and ς^g such that the cost of recruitment per hire in the public sector is 20 percent lower than the private sector.

The unemployment benefit is set around 0.40, which implies a net replacement rate around 0.7 while α is set to 0.3. The discount factor is set to 0.985 and the quarterly growth rate of technology to 0.005, implying a steady-state interest rate of 4 per cent a year. As there is not much empirical evidence on the coefficient of the private sector wage bargaining we set it such that the equilibrium unemployment rate is around 7%, close to the average unemployment rate of the last 20 years in the United Kingdom. The baseline value of κ is set at -0.025,

which implies an annual correction of around -0.10, the value found in the empirical section. Much of the analysis compares the responses of the model with alternative values for the error correction mechanism. Overall, the calibration implies a steady-state overall job-finding rate of 0.23: 0.20 in the private and 0.03 in the public sector.

Finally the standard deviation and the autocorrelation of the shocks are calibrated such that the standard deviations and the autocorrelation of the annual growth rates of public and private wages and public employment are close to the ones from the United Kingdom and from the average of the OECD countries used in the estimation. Table 3 summarises the baseline calibration, the implied steady-state values of the relevant variables and the moments of the growth rates of public sector employment and wages and private sector wages.

Table 3: Calibration

Structural Parameters									
η^p	0.50	ς^p	0.75	$\bar{m}^p$	0.59	λ^p	0.02	γ	0.005
η^g	0.20	ς^g	0.50	$\bar{m}^g$	0.49	λ^g	0.01	β	0.985
α	0.3	$\bar{b}$	0.43	ψ	0.04	z	0.40	κ	-0.05
Steady-state values									
$\bar{f}^p$	0.20	$\bar{q}^p$	1.01	$\bar{u}$	0.07	$\bar{s}$	0.42	$\bar{\tau}$	0.26
$\bar{f}^g$	0.03	$\bar{q}^g$	0.81	$\bar{l}^g$	0.20	$\frac{\bar{w}^g}{\bar{w}^p}$	1.04	$\frac{z}{(1-\bar{\tau})\bar{w}^p}$	0.72
Shocks									
		ρ^w	0.65	ρ^v	0.80	ρ^a	0.70		
		σ_w	0.0054	σ_v	0.0009	σ_a	0.0061		

Moments at annual frequency			
	Model	OECD	UK
Standard deviation			
Private wage growth	0.030	0.030	0.033
Public wage growth	0.030	0.031	0.029
Public employment growth	0.023	0.023	0.021
Autocorrelation			
Private wage growth	0.291	0.451	0.110
Public wage growth	0.375	0.340	0.225
Public employment growth	0.563	0.586	0.511

4.3   Simulation

Figures 2, 3 and 4 show the impulse responses of the private and public wage growth, the public-to-private wage ratio, the tax rate and of the unemployment rate to the three shocks: public sector wages (ϵ_t^w), public sector vacancies (ϵ_t^v), and technology (ϵ_t^a).

Figure 2: Response to a public sector wage shock
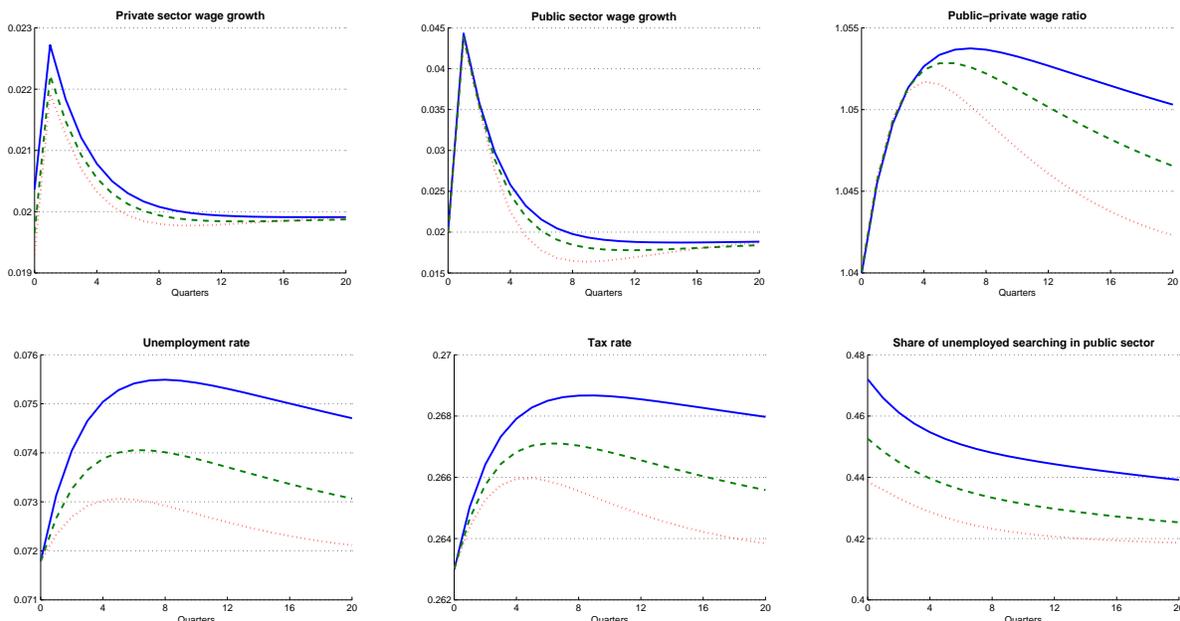
| Private sector wage growth | Public sector wage growth | Public–private wage ratio |
| Unemployment rate | Tax rate | Share of unemployed searching in public sector |

Note: the solid, dashed and dotted lines corresponds to the case where κ is -0.025, -0.05 and -0.10 respectively. The growth rates of wages are expressed in annual terms.

A positive shock to public sector wage growth has a direct spillover effect to the private sector wage growth, mainly through three channels. First, it increases the value of being unemployed because if those individuals are hired by the public sector they get paid more. This effect is amplified because of the endogenous increase of the share of unemployed searching for public sector jobs. Second, as the shock crowds out private sector employment, it raises the marginal productivity and consequently private sector wages. Finally, the increase in the tax rate necessary to finance the wage bill, has two opposite effects. On the one hand, it reduces the match surplus and raises the private sector wage. On the other hand, it reduces the share of the surplus going to the worker, which puts a downward pressure on wages. The contemporaneous and annual elasticity of private wages with respect to public sector wages is around 0.10.[10]

The subsequent dynamics are driven by the error correction mechanism. As the premium of working in the public sector increases relative to the target, there is a correction of public sector

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[10]We have ran simulations with different combinations of parameters: η^p (0.4:0.6), η^g (0.1:0.3), b (0.3:0.6), λ^p (0.01:0.03), λ^g (0.005:0.015), z (0.3:0.5); and this elasticity varied between 0 and 0.3.

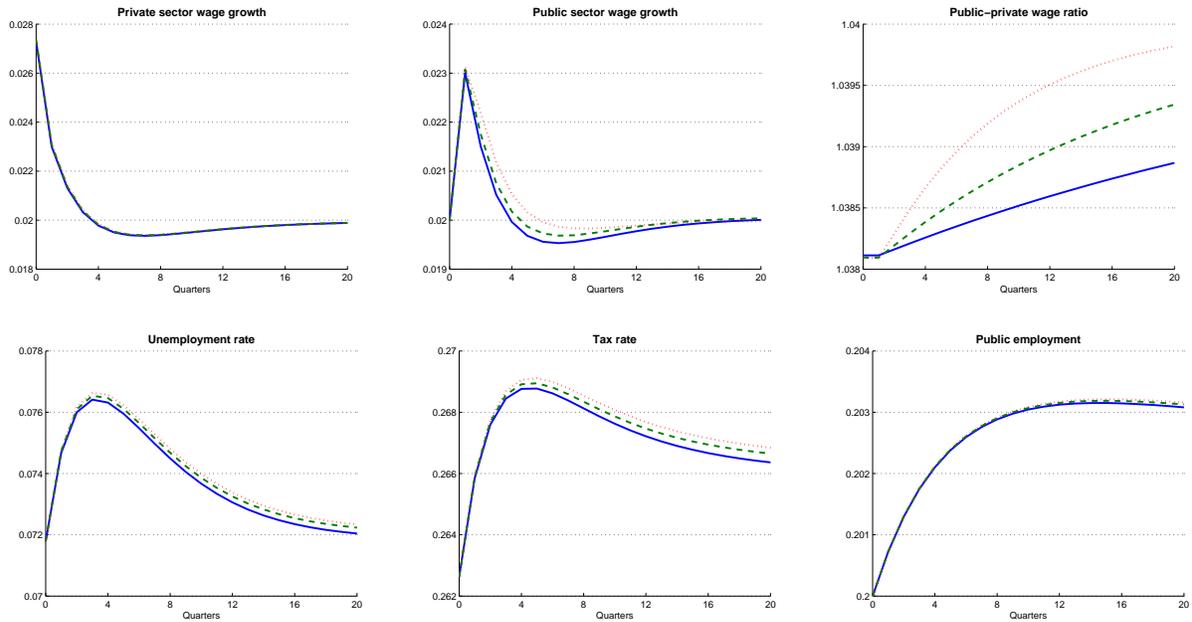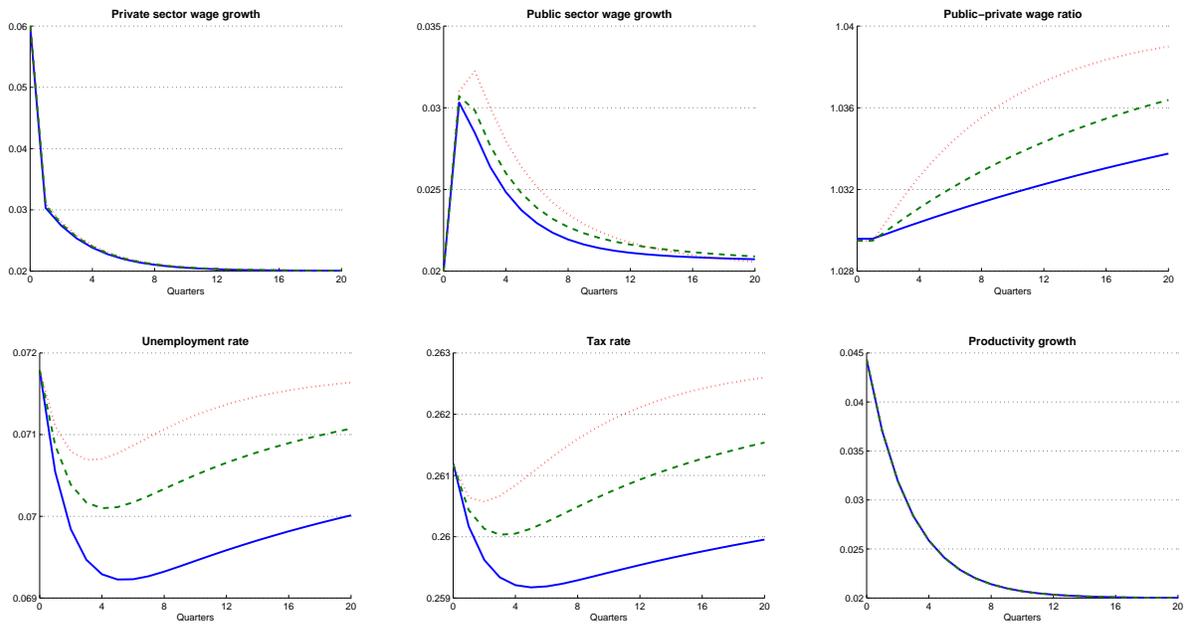## Figure 3: Response to a public sector employment shock

Note: the solid, dashed and dotted lines corresponds to the case where κ is -0.025, -0.05 and -0.10 respectively. The growth rates of wages are expressed in annual terms.

Figure 4: Response to a technology shock

Note: the solid, dashed and dotted lines corresponds to the case where κ is κ is -0.025, -0.05 and -0.10 respectively. The growth rates of wages and technology are expressed in annual terms.

wages that, after 6 quarters have a growth rate below the long-run value. This adjustment is quicker the higher the magnitude of the error correction coefficient (κ). In addition, an increase in the unemployment rate occurs after the shock.

A positive shock to public sector vacancies initially raises private sector wage growth (see Figure 3). The annual elasticity is around 0.3. Both the tax and the bargaining channel drive the wages up but, additionally, public employment crowds out the employment in the private sector raising the average productivity of workers which serves as a reference for the bargaining process. The increase in the private sector wages reduces the premium paid in the public sector relative to the target, therefore, after the initial period the public sector wages grow above the average to catch up with the private sector.

Regarding a technology shock, depicted in Figure 4, the private sector wage growth increases substantially and contemporaneously, and stays above average for several periods. As the public-private wage premium is reduced, the wages in the public sector grow at a faster pace in the subsequent periods.

4.4   Reconciling the model with the data

The model we set up does not have a straightforward connection with the estimated equation, nor are the elasticities necessarily comparable. The empirical exercise uses annual data and the IV estimation retrieves the effect on the wage growth in one sector of the expected wage growth in the other. In the model, set at a quarterly frequency, we show how the variables respond to unexpected shocks in technology, public sector wages and employment.

In order to reconcile the two, we simulate the model to generate quarterly observations, aggregate data into annual frequency and then perform IV regressions of the type used in section 2. We estimate 5000 regressions with 100 observations each, as well as 1000 regressions with 500 observations. Table 4 shows the results.

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Table 4: IV estimation with simulated data

	Private sector		Public sector	
	Nobs=100 Nreg=5000	Nobs=500 Nreg=1000	Nobs=100 Nreg=5000	Nobs=500 Nreg=1000
Lagged dependent variable	-0.139 (0.083)	-0.058 (0.059)	0.243 (0.090)	0.230 (0.045)
Error correction component	0.018 (0.021)	0.016 (0.010)	-0.103 (0.043)	-0.075 (0.016)
Growth rate of public sector wages	0.192 (0.125)	0.210 (0.073)		
Growth rate of private sector wages			0.697 (0.267)	0.857 (0.159)
Growth rate of TFP	0.807 (0.164)	0.626 (0.111)		
Growth rate of public employment	-0.027 (0.083)	-0.051 (0.042)		
R^2	0.867	0.801	0.294	0.199

Notes: the coefficients are estimated using 2SLS. Endogenous variables: total factor productivity, growth rate of real per worker private and public sector sector wages, growth rate of public employment. They are instrumented by two lags of all explanatory variables. The standard deviation of the estimated coefficients are in parentheses.

In the equation determining the public sector wage growth the three coefficients are very close to the ones estimated for the OECD countries (see Table 1). The error correction mechanism is between -0.08 and -0.10 and the response to expected wages is also around 0.7. Another similar feature is that the R-square of the estimation for the public sector wage growth tends to be quite low.

In the equation determining the private sector wage growth, the coefficient of public sector wages (0.2) and the error correction mechanism (0.02), all have magnitudes similar to the ones we estimated for the OECD countries. The coefficient of total factor productivity growth is slightly bigger, which is expected since it is the only source of fluctuations directly affecting private sector wages in the model. This also translates into a high R-square. The autocorrelation coefficient is slightly negative, which means that for OECD countries there must be some other sources of autocorrelation, perhaps wage stickiness. Still, the difference is relatively small. On the other hand, the estimated coefficient of the growth rate of public employment tends to be close to zero.

5 Conclusion

The purpose of this paper was to analyse the interactions between public and private sector wages per employee in OECD countries, and to uncover the determinants of public and private

sector wage growth. We find that the public sector wage growth is mainly driven by private sector wages and the government budget balance.

Regarding the private sector wage growth, we find that it is influenced by the unemployment rate, total factor productivity and urbanization rate. More important, public sector wages and employment also affect private sector wage growth. The empirical estimates show that a 1 percent increase in public sector wages raises the wages in the private sector by 0.3 percent, while the regressions with simulated data point to an elasticity of around 0.2 percent.

The dynamic labour market equilibrium model that we set up captures the main essence of the interaction between public and private wages, and is quantitatively consistent with the main estimation findings. This is true even if it abstracts from other channels that may be relevant. For instance, higher public sector wages might translate into higher demand, increasing the pressure on the private sector labour market. Alternatively, public sector wage growth may also carry a signal to the private sector about the government's expectations for inflation. In addition, in the presence of on-the-job search, the transmission mechanism of public sector wages can be amplified.

In light of our results, and as discussed in Pedersen et al. (1990), governments could use their role as an employer to reduce public sector wages. This policy, in addition to reducing the tax burden necessary to finance government spending, would have a downward impact on private sector wages, unemployment and, possibly, on inflation. Nevertheless, one has to bear in mind the issue of the composition of public sector employment. It is a known fact that high-skilled workers have a negative premium from working in the public sector (Postel-Vinay and Turon (2007)), which makes it harder for the government to recruit them (Nickell and Quintini (2002)). Therefore, wage moderation for this group could worsen the problem and make retention of high-skilled workers even harder in the public sector.

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Appendix I - Data

Table 5: Summary statistics and sources

	Mean	Standard deviation	Minimum	Maximum	Source
Growth rate of real private sector wages	1.42	2.17	-7.46	9.40	OECD
Growth rate of real public sector wages	1.11	3.13	-8.24	11.06	OECD
Error correction mechanism	7.78	21.26	-50.35	91.89	OECD
Δ Unemployment rate	0.09	1.07	-2.76	5.10	CEP-OECD
Total factor productivity growth rate	1.87	1.53	-2.52	6.34	OECD
Δ Urbanisation rate	0.21	0.25	-0.06	1.60	CEP
Inflation rate	5.85	4.59	0.02	23.23	OECD
Terms of Trade growth rate	-0.12	4.65	-20.30	28.89	BHHS
Hours per worker growth rate	-0.08	0.32	-3.82	3.15	CEP-OECD
Growth rate of public employment	1.38	2.28	-5.76	14.98	OECD
Budget Balance	-2.98	4.35	-15.71	15.37	AMECO - IMF
Government Debt	54.16	28.02	2.31	140.85	AMECO - IMF
Δ Tax wedge	0.24	1.72	-10.28	5.87	BHHS
Δ Union density	-0.21	1.19	-5.90	4.80	CEP
Δ Bargaining Coordination	-0.01	0.08	-0.25	0.20	CEP
Δ Benefit duration	0.01	0.04	-0.21	0.32	CEP
Δ Replacement rate	0.26	3.02	-7.40	24.10	CEP
Δ Education attainment	0.08	0.09	-0.07	0.48	CEP
Central bank independence	0.53	0.21	0.17	0.93	BHHS
Election	0.30	0.46	0	1	Comparative parties dataset
% Left wing votes	36.33	14.36	0	56	Comparative parties dataset

Note: I use two datasets that expand the Labour Market Institutions Database created by Nickell, Nunziata, and Ochel (2005): the BHHS expanded by Baker, Glyn, Howell, and Schmitt (2003) and the Center for Economic Performance CEP- OECD Institutions Data Set by Nickell (2006). The comparatives party dataset was created by Duane Swank and it is available on http://www.mu.edu/polisci/Swank.htm.

Employment and wage variables

The data on public employment and wages is taken from the OECD (Economic Outlook database). For most countries there is information on *Government employment* (EG). To calculate the per employee wage we divide *Government final wage consumption expenditure* (CGW) by *Government employment.* To get the wage in real terms we deflate it using the *Private final consumption expenditure deflator* (PCP).

We also have the value for the *Compensation of employees* (WSSS) and *Total employment* (ET), which refers to the total economy. We define Private sector compensation as the total *Compensation of employees* minus the *Government final wage consumption* (WSSS-CGW). We define the private employment (EP) as *Total employment* minus *Government employment* minus *Self Employed* (ES): EP=ET-EG-ES. The private sector nominal wage per employee is Private sector compensation divided by private sector employees.

For the case of Australia, there is no information on government employment but there is on *Private sector employment* and *Compensation of private sector employees*. In this case, *Government employment* is defined as *Total employment* minus *Private sector employment* and Compensation of public sector employees defined as the value of *Compensation of employees* minus *Compensation of private sector employees*.

Other variables

Benefit replacement rate - Benefit entitlement before tax as a percentage of previous earnings before tax. Source: CEP.

Benefit duration index. Source: CEP.

Coordination index - Captures the degree of consensus between actors in collective bargaining (1 low, 3 high). Source: CEP.

Trade union density - Ratio of total reported union members (minus retired and unemployed) to all salaried employees. Source: CEP.

Educational attainment - Average years of schooling from total population aged 15 and over (taken from Barro and Lee dataset and intrapolated). Source: CEP.

Tax wedge - Payroll tax plus income tax plus the consumption tax rate. Source: BHHS.

Productivity growth - Growth rate of productivity per worker. Source: OECD.

Terms of trade - Growth rate of terms of trade. Source: BHHS.

Urbanisation rate - Percentage of the population living in urban areas (taken from the World Bank World Development Indicators). Source: CEP.

Inflation - Source: OECD.

Unemployment rate - Source: CEP.

Budget Balance - Government balance as percentage of GDP. Source: AMECO European Commission database, complemented with IMF data for early years.

Government debt - Government debt as percentage of GDP. Source: AMECO European Commission database, complemented with IMF data for early years.

Election year - Dummy if there was a parliamentary of presidential election. Source: Comparative parties dataset.

Left wing - Percentage of left with votes of last parliamentary elections. Source: Comparative parties dataset.

Central Bank Independence Index. Source: BHHS

Appendix II - Model in efficiency units

As the technology has a unit root with drift, the model does not have a steady state. There is a balance growth path in which employment, unemployment, vacancies and labour market flows are constant; and in which wages, consumption, the value of employment and unemployment and the value of a job for the firm are growing at rate γ values. We define the variables in efficiency units with tilde (as a ratio of technology),

$$\tilde{w}_t^p = \frac{w_t^p}{a_t}, \ \tilde{w}_{t+1}^g = \frac{w_{t+1}^p}{a_t}, \ \tilde{c}_t = \frac{c_t}{a_t}, \tilde{W}_t^i = \frac{W_t^i}{a_t}, \ \tilde{U}_t^i = \frac{U_t^i}{a_t}, \ \tilde{J}_t^i = \frac{J_t^i}{a_t}, \ \frac{z_t}{a_t} = z, \ \frac{\varsigma_t^i}{a_t} = \varsigma^i.$$

We can re-write the non-stationary equations in efficiency units. The Euler equation becomes:

$$1 = \beta(1 + r_t)E_t[\frac{\tilde{c}_t}{\tilde{c}_{t+1}} \frac{a_{t+1}}{a_t}]. \tag{27}$$

The value functions become:

$$\tilde{W}_t^g = (1 - \tau_t)\tilde{w}_t^g \frac{a_t}{a_{t-1}} + E_t\beta_{t,t+1}\frac{a_{t+1}}{a_t}[(1 - \lambda^g)\tilde{W}_{t+1}^g + \lambda^i\tilde{U}_{t+1}], i = p, g, \tag{28}$$

$$\tilde{W}_t^p = (1 - \tau_t)\tilde{w}_t^p + E_t\beta_{t,t+1}\frac{a_{t+1}}{a_t}[(1 - \lambda^p)\tilde{W}_{t+1}^p + \lambda^p\tilde{U}_{t+1}], i = p, g, \tag{29}$$

$$\tilde{U}_t^i = z + E_t\beta_{t,t+1}\frac{a_{t+1}}{a_t}[p_t^i\tilde{W}_{t+1}^i + (1 - p_t^i)\tilde{U}_{t+1}], i = p, g, \tag{30}$$

$$\tilde{J}_t = (1 - \alpha)l_t^{p-\alpha} - \tilde{w}_t^p + E_t\beta_{t,t+1}\frac{a_{t+1}}{a_t}[(1 - \lambda^p)\tilde{J}_{t+1}]. \tag{31}$$

The first order condition from the firm and the Nash bargaining becomes

$$\frac{\varsigma^p}{q_t^p} = E_t\beta_{t,t+1}\frac{a_{t+1}}{a_t}[(1 - \alpha)l_{t+1}^{p-\alpha} - \tilde{w}_{t+1}^p + (1 - \lambda^p)\frac{\varsigma^p}{q_{t+1}^p}], \tag{32}$$

$$(\tilde{W}_t^p - \tilde{U}_t) = \frac{b(1 - \tau_t)}{1 - b\tau_t}(\tilde{W}_t^p - \tilde{U}_t + \tilde{J}_t). \tag{33}$$

Finally, the equations for the public sector become:

$$\tau_t(\tilde{w}_t^p l_t^p) = (1 - \tau_t)\frac{(\tilde{w}_t^g l_t^g)}{g_t^a} + zu_t, \tag{34}$$

$$\frac{\tilde{w}_{t+1}^g a_t}{\tilde{w}_t^g a_{t-1}} = E_t[\frac{a_{t+1}^p}{a_t^p} \frac{\tilde{w}_{t+1}^p}{\tilde{w}_t^p}] + \kappa[\frac{w_{t-1}^g}{w_{t-1}^p} - 1 - \Psi] + \epsilon_t^{wg}, \tag{35}$$

where

$$g_t^a = \frac{a_t^p}{a_{t-1}^p} = \exp(\gamma + \epsilon_t^a). \tag{36}$$