Public wages, public employment, and business cycle volatility: Evidence from U.S. metro areas *

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Abstract

Based on data from a cross section of U.S. metro areas, we show that public employment correlates negatively with business cycle volatility, hinting at a stabilizing effect of public employment, while public wages correlate weakly and positively with business cycle volatility, hinting at a destabilizing effect of public wages. To explain these stylized facts, we set up a search and matching model with public employment. We show that the model in isolation cannot explain both of these facts simultaneously. However, when we add a role for government purchases in product markets, the model can explain both of these facts.

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Keywords: Job search; public employment; public wages; business cycle; volatility.

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1 Introduction

Based on data for the U.S. at a MSA/NECTA level, we find some puzzling stylized facts about the joint relationships among public wages, public employment, and business cycle volatility.[1] These facts are puzzling insofar as they are at odds with the implications of standard search and matching models. In particular, we find that the relationship between the size of public employment and the volatility of private employment in the U.S. is negative, that is, higher public employment is related to less volatility in private employment over the business cycle (summarized in Figure 1). Meanwhile, higher public wages are related to more volatility in private employment over the business cycle (summarized in Figure 2). We also discuss effects on private wages and private employment – higher public wages are associated with higher private wages and lower private employment, while higher public employment is associated with lower private wages and ambiguously with private employment. We argue that these effects are not compatible with a standard search and matching model with public employment.

This incompatibility occurs because, according to the search model, higher public wages and higher public employment should both crowd out private employment. This is because the public sector acts as a competitor to the private sector in the labor market, so that higher public wages or a greater chance of finding a public-sector job cause the value of unemployment for a worker to rise. This should crowd out private employment and make private employment more responsive to productivity shocks (i.e. increase volatility). This occurs, in turn, because higher public wages or public employment shift the wage curve outward, and higher public wages or public employment also steepen both the wage curve and job creation curve. A steeper wage curve and steeper job creation curve in turn make equilibrium market tightness more sensitive to shocks. This is the same intuition behind the results of Hagedorn and Manovskii (2008), who show that an increase in the flow value of unemployment results in a stronger response of market tightness to shocks. These results are theoretically robust, but they are at odds with our stylized facts, thus constituting a puzzle.

To resolve this puzzle, we apply the approach of Gomes (2015) and add a labor-leisure tradeoff (originally following Baxter and King (1993)), such that the flow value of unemployment is governed by an income effect. This income effect by itself undoes some of the destabilizing effects of public wages or public employment, since now, public wages and public employment

[1] These data are produced by the BEA's Regional Economic Accounts program, augmented by data from the BLS on the unemployment rate. The figures that we present here are for expositional purposes only.

crowd out private consumption, in turn pushing down the flow value of unemployment. However, this effect by itself cannot explain the different relationships that we see in the data. To obtain these different relationships, we note that a significant portion of government consumption comes from intermediate purchases from the private sector. If this intermediate consumption and public employment are complements in the production of government final output, then a higher rate of government employment crowds out private consumption by more than before, causing the flow value of unemployment to fall yet further. This effect is such that, for our calibrated parameter values, a higher rate of public employment actually helps to stabilize private employment. The results from this exercise suggest that it is important to take the structure of government consumption into account when looking at the effects of public wages and public employment on the private sector.

Our results add to a growing literature analyzing the interactions among public wages, public employment, and their private counterparts. For instance, Quadrini and Trigari (2007) set up a partial equilibrium search and matching model similar to ours, but with directed search.[2] They solve the model stochastically, finding that high public wages or public employment should drive up volatility in private employment and in total employment. Taking a different approach, Burdett (2012) sets up a model similar to that of Burdett and Mortensen (1998) but with a public sector. Burdett's model predicts that public employment and public wages should crowd out private employment. More recently, Afonso and Gomes (2014) set up a similar model to that of Quadrini and Trigari (2007), which they then solve stochastically. They find that high public wages should crowd out private employment while raising private wages, while high public employment should crowd out private employment (more than one-to-one) while also raising private wages. All of these results are compatible with our search and matching model without product markets, based on the same intuition governing that model.

Building on this intuition, Gomes (2015) examines the possibility of using procyclical public wages to stabilize business cycles, in a model that contains product markets.[3] We show that Gomes's results are consistent with some of our findings on the stabilizing role of a

[2]Our baseline model features random search. However, we also examine a variant of our model with directed search; most of our results and intuition, particularly on the importance of the labor-leisure tradeoff, are robust to this variation.

[3]In related work, Bradley, Postel-Vinay, and Turon (2015) set up a model with worker-level heterogeneity, which they estimate using British data. They go on to analyze a number of consolidation scenarios, also finding a crowding-out result. Meanwhile, Albrecht, Robayo-Abril, and Vroman (2015) use a similar model to discuss the cross-sectional behavior of wages in Colombian data. In further related work, Caponi (2014) analyzes public wage and employment policies in Italy, finding that differences in public wage and employment policies can account for a large portion of the north-south unemployment differential.

procyclical public wage policy. In particular, we find that the response of public wages to private wages is positive in the data, and this procyclicality can help to stabilize private employment. In addition, our work can be seen as reconciling Gomes's approach with a new set of stylized facts on the effects of public employment.

Our results are related more loosely with results from the business cycle stabilization literature. Some caution is in order since that literature has not in general focused on situations where government consumption is broken down into public employment, public wages, and intermediate consumption. Nonetheless, Galí (1994), Fatás and Mihov (2001), Andrés, Doménech, and Fatás (2008), Reicher (2014), and others find that government spending and some of its components are negatively correlated with volatility in both private output and overall output, and these results echo our results on public employment. However, in a theoretical context, it is difficult but possible to generate a stabilizing effect of government consumption on private output. For instance, Andrés, Doménech, and Fatás (2008) point out that a medium-scale DSGE model with sticky prices and capital adjustment costs still has trouble in replicating the stabilizing effects of government spending on private output, although this problem is alleviated somewhat when rule-of-thumb consumers are inserted into that model, and when that model features a high degree of nominal and real rigidities. In light of this literature, our results suggest that a search and matching approach, augmented with a non-trivial role of the government in product market, can help to alleviate some of these problems without having to add extra rigidities. In addition, our results indicate that it is more generally important to distinguish among the different components of government consumption, since these components can have different theoretical and empirical effects.

2 Stylized facts on public employment and public wages

2.1 Data sources and definitions

In order to establish our set of empirical stylized facts, we use data produced by the BEA's Regional Economic Accounts program, augmented by data from the BLS on the unemployment rate. The data are annual and cover the period from 2001-2013 (on a NAICS basis), at a MSA/NECTA level. Based on these data, we derive the following series. First of all, private employment is calculated as total employment minus employment in government and government enterprises. Next, the private employment rate is calculated by dividing private employment by population. Next, private productivity is calculated by dividing GDP generated by private industries by private employment. Next, the private wage rate is calculated as earnings generated by private industries divided by private employment. Similarly, the public wage rate is calculated as earnings generated by government and government enterprises divided by employment in government and government enterprises. Next, employment shares in the farm, manufacturing, and construction sectors are calculated as the ratios of total farm, manufacturing, and construction employment, respectively, to private employment. Finally, population data are taken as is. Given these data series, all averages and growth rates are calculated using the formulae $a(X_t) = (.5X_t + .5X_{t-1})$ and $g(X_t) = (X_t - X_{t-1})/a(X_t)$, respectively, and then MSA-specific averages and standard deviations are calculated using these averages and growth rates.[4]

Based on these averages, our analysis takes a cross-sectional approach, covering four dependent variables at the MSA level: the log standard deviation of growth in the private employment rate (as a measure of business cycle volatility), the log private wage rate, the private employment rate, and the unemployment rate. For each of these dependent variables, we are interested in the effects of a set of independent variables: the log public wage rate, the public employment rate, log private productivity, the farm, manufacturing, and construction employment shares, and population. We include employment shares and population because these variables are known to be related to volatility. For all of these variables, summary statistics are presented in Table 1, over the sample of MSAs with a complete time series of valid records. Furthermore, Figures 1 and 2 plot log volatility against the public employment rate and the difference between log public wages and log private wages. These plots describe loose correlations that go in opposite directions, but they do not have a causal interpretation.

2.2 The endogeneity of public wages and public employment

To discuss causation, it would be necessary to look at two major issues: the endogeneity of public wages and employment, and the presence of other factors that may drive wages or employment (or volatility). To look at these issues, we specify a model of public wages and employment; this model then allows us to disentangle endogenous movements in these objects from exogenous movements that are likely the result of policy.

[4] Our analysis looks at employment and unemployment separately, since these series come from different data sources and are incompatible with each other.

To see how public wages and public employment vary in response to their private counterparts, we follow Quadrini and Trigari (2007), by positing that public wages or employment are set according to the expressions:

$$\ln W_{git} = \gamma_W \ln W_{pit} + b_w' x_{it} + \ln W_{git}^*, \tag{1}$$

and:

$$E_{git} = \gamma_E E_{pit} + b_e' x_{it} + E_{git}^*, \tag{2}$$

where W_g and E_g denote public wages and public employment, W_g^* and E_g^* denote an exogenously-determined public wage shifter or public employment shifter, γ_W and γ_E give the degree to which private wages or employment feed back into public wages or employment in the cross section, x_t denotes a set of control variables (a constant, sectoral employment shares, and population), and b_w and b_e denote coefficient matrices.

Based on these specifications, we estimate γ_W and γ_E under the assumptions that cross-sectional variation in productivity is unrelated to cross-sectional variation in W_g^* or E_g^* (i.e. that private productivity only directly affects public wages and public employment through their effects on private wages or public employment), that public wages do not respond directly to private employment, and that public employment does not respond directly to private wages. These assumptions allow the use of log private productivity as an instrument for either log private wages or log private employment, in separate two-stage least squares regressions. Based on these regressions, the results in Table 2 indicate that there appears to be some response of public wages to private wages in the cross section, on the order of 0.22. However, there does not appear to be a strong response of public employment to private employment. This latter finding provides support for the common assumption, in business cycle studies, of acyclicality in real government consumption or in public employment.

In addition, we look at the behavior of public wages and public employment over time. These estimates are derived under the assumption that shocks to local real public wages and public employment are unrelated to aggregate real private wages and aggregate private employment. In doing this, we follow a set of assumptions similar to those made by Steinsson and Nakamura (2014) when they estimate local military spending multipliers, though we had less luck in estimating local cyclical sensitivities to a precise degree. When use this instrumentation strategy, we arrive at a response of real public wages to real private wages shown in Table 2 on the order of 0.36, which is slightly larger than the cross-sectional response. Furthermore, we arrive at a response of public employment to private employment on the order of 0.012, which suggests that public employment is acyclical or even slightly procyclical. Altogether, however, we find that our time-series estimates present the same basic picture as our cross-sectional estimates: slight procyclicality in public wages, with much less cyclicality in public employment.

2.3 The likely effects of public wages and public employment

To the extent that our identifying assumptions are valid, then the cross-sectional results presented in Table 2 make it possible to estimate the effects of the purged public wage and employment shifters W_g^* and E_g^* on volatility, private wages, private employment, and unemployment. Such a set of regression results is presented in Table 3, while a set of results based on un-purged data is presented in Table 4 for reference. Both sets of results confirm the impressions given by Figures 1 and 2, in that they show that higher public employment seems to be associated with less business cycle volatility, while higher public wages are associated with more business cycle volatility. Also, interestingly, a larger manufacturing or construction share of private employment appears to be associated with a more volatility, while there is no clear association between population and volatility. Taken together, these results point toward a positive statistical effect of public wages on the volatility of private employment.

These results also show that higher public wages seem to be associated with higher private wages, as shown by Afonso and Gomes (2014) using aggregate U.S. time series data, while higher public wages are associated with lower private employment and higher total rate of unemployment. Meanwhile, higher public employment seems to be associated with lower private wages, is associated ambiguously with private employment, and is associated with a lower total rate of unemployment. The result on private employment seems sensitive to whether or not the data are purged, although both sets of results suggest far from perfect one-to-one crowding out. Altogether, these results suggest that a larger public sector is not uniformly contractionary or expansionary–public wages and public employment have differing effects on log volatility, private wages, private employment, and total unemployment.

3 A theoretical model

Motivated by these stylized facts, we construct a search and matching model in general equilibrium, which we analyze for its steady state properties. This follows standard practice in the labor search literature. Importantly, our model does not rely on any short-run Keynesian model elements, such as sticky prices or rule-of-thumb consumers.

3.1 Household behavior

In our model, households trade on the goods market in order to maximize the present discounted value of utility H_t, subject to a sequence of budget constraints which apply at the household level. Households pool all of their consumption and income among their members.

The household's utility function takes the form:

$$H_t = \widetilde{E_t} \int_0^\infty e^{-\rho i} \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} + v(G_{t+i}) - \overline{b}(E_{g,t+i} + E_{p,t+i}) \right] di, \tag{3}$$

where $\widetilde{E}$ denotes the expectation operator; ρ is a discount rate; C_{t+i} denotes consumption with a preference parameter σ; $v(G_{t+i})$ is a monotonic, increasing function in real government consumption G_{t+i}, such that preferences are separable in government consumption and private consumption; and $E_{g,t+i}$ and $E_{p,t+i}$ denote public and private employment, with a marginal disutility given by $\overline{b}$. The budget constraints take the form:

$$C_{t+i} + T_{t+i} + B_{t+i+di} = (1 + r_{t+i}di)B_{t+i} + W_{g,t+i}E_{g,t+i} + W_{p,t+i}E_{p,t+i} + \Pi_{p,t+i}, \tag{4}$$

for consumption C_{t+i}, taxes T_{t+i}, bondholdings B_{t+i} which yield a return r_{t+i}, public wages and employment $W_{g,t+i}$ and $E_{g,t+i}$, private wages and employment $W_{p,t+i}$ and $E_{p,t+i}$, and firm profits $\Pi_{p,t+i}$.

Maximization proceeds in a standard way. First, denoting the Lagrange multiplier on the budget constraint by Λ_{t+i}, the first-order conditions to the maximization problem imply that, in the steady state:

$$\Lambda = C^{-\sigma}. \tag{5}$$

Furthermore, the flow value of nonemployment or unemployment in consumption units is denoted by by b, which equals $\bar{b}/\Lambda$. In equilibrium, then, b is given by:

$$b = \bar{b}C^{\sigma}. \tag{6}$$

Additionally, r in the steady state equals ρ.

This setup endogenizes the flow value of nonemployment in a way that is compatible with the rest of the dynamic general equilibrium literature. As a special case, setting σ to zero gives the "standard" search and matching calibration, which implies a risk-neutral, acyclical flow value of nonemployment. Meanwhile, setting σ to a larger value (such as one) gives an interpretation of this value as representing leisure in the presence of risk aversion, in line with the business cycle literature and with Gomes (2015).

3.2 The labor market

3.2.1 The environment

Production takes place in a search and matching economy, divided into the private and public sectors. Workers search in both sectors at once, and eventual placement in a sector occurs randomly. (In other words, this is a random search model.) Apart from the inclusion of a public sector, this is a standard textbook search and matching economy. In this economy, economic rents are discounted at a rate ρ or equivalently in the steady state, r; private matches are destroyed at a rate λ_p; public matches are destroyed at a rate λ_g; hires from unemployment into private employment occur at a rate p_p; hires from unemployment into public employment occur at a rate p_g; workers in private matches are paid a wage W_p; workers in public matches are paid a wage W_g; matches produce output at a rate of productivity π; and unemployed workers experience a flow value b. Firms and workers take the actions of the government as exogenous to their own decisions.

3.2.2 Steady state flows and hiring costs

First of all, matches and employment outflows must be equal in the steady state. Given a Cobb-Douglas matching function over total vacancies V and searchers U, this implies:

$$V^a U^{1-a} = \lambda_g E_g + \lambda_p E_p. \tag{7}$$

Given tightness $\theta = V/U$ and $U = 1 - E_g - E_p$, and substituting these into the previous expression, this equation can be written as:

$$\theta^a (1 - E_g - E_p) = \lambda_g E_g + \lambda_p E_p. \tag{8}$$

In addition, the average cost of hiring a worker $c(\theta)$ is given by a coefficient $\overline{c}$ divided by the job finding rate (matches per vacancy), such that:

$$c(\theta) = \overline{c}\theta^{1-a}. \tag{9}$$

Furthermore, steady-state job-finding rates are given by the equations:

$$p_g = \frac{\lambda_g E_g}{1 - E_g - E_p}, \tag{10}$$

and

$$p_p = \frac{\lambda_p E_p}{1 - E_g - E_p}, \tag{11}$$

which in turn implicitly pin down private employment.

3.2.3 Value functions and private wages

The value functions for workers in public and private matches in the steady state, measured in output units, are given by the two equations:

$$rV_p = W_p - \lambda_p (V_p - V_u), \tag{12}$$

and:

$$rV_g = W_g - \lambda_g (V_g - V_u), \tag{13}$$

where V_p denotes the value of being in a private match, and V_g denotes the value of being in a public match. Furthermore, workers engage in undirected or random search; in this case, the value of unemployment for a worker is given by:

$$rV_u = b + p_p(V_p - V_u) + p_g(V_g - V_u), \tag{14}$$

while the value of employment for a firm in the private sector is given by:

$$rV_j = \pi - W_p - \lambda_p V_j. \tag{15}$$

Firms can hire workers at a marginal cost $c(\theta)$; free entry implies that the value of a filled job should equal the cost of filling that job, such that:

$$V_j = c(\theta). \tag{16}$$

The value of an unfilled vacancy is zero.

Since these hiring costs create quasi-rents, employed workers and firms Nash bargain over these rents, in order to determine wages. In this bargaining process, workers have a bargaining weight β over the match surplus, while firms have a bargaining weight $1 - \beta$. This implies that the surplus is split according to the formula:

$$\beta V_j = (1 - \beta)(V_p - V_u). \tag{17}$$

Based on these value functions and bargaining equation, the equilibrium private wage is given by the wage equation:

$$W_p = \beta\pi + \frac{r + \lambda_g}{r + \lambda_g + p_g(\theta)}\left[(1 - \beta)b + \beta c(\theta)p_p(\theta)\right] + \frac{(1 - \beta)p_g(\theta)}{r + \lambda_g + p_g(\theta)}W_g, \tag{18}$$

with p_p and p_g marked as functions of θ. This wage equation (or wage curve) functions like a labor supply equation.[5] Furthermore, free entry in vacancy posting implies that labor demand evolves according to the job creation equation:

$$\pi - W_p = (r + \lambda_p)c(\theta). \tag{19}$$

The intersection between these two equations pins down θ and W_p, and implicitly by way of

[5] Notice that if we assume that there is no public sector and set $\lambda_g = 0$ and $p_g = 0$, the wage equation reduces to the classical textbook wage equation. See Caponi (2014) for more discussion.

flow rates, private employment.

3.3 Government production and fiscal policy

Following the setup of Quadrini and Trigari (2007), the government hires workers and pays them according to a rule-of-thumb fiscal reaction function. We assume that the public employment shifter E_g^* and the public wage shifter W_g^* are set exogenously, according to political considerations, and that the government sets its policies according to the equations:

$$\ln W_g = \gamma_W \ln W_p + \ln W_g^*, \tag{20}$$

and:

$$E_g = \gamma_E E_p + E_g^*. \tag{21}$$

These are the same reaction functions found in the empirical section, with the exogenous control variables omitted.

The government combines the output of its own workers with output that it purchases from the private sector, in order to produce a final government consumption good. We assume that government production is Leontief, such that the government purchases ψ units from the private sector for every unit of gross output it produces, at a rate of productivity π. This means that the government purchases $\psi\pi E_g$ additional units of output, such that when government final consumption is measured in private output units, government consumption is given by:

$$G = [\pi - c(\theta)\lambda_g] E_g + \psi\pi E_g. \tag{22}$$

The government also balances its budget, such that tax revenues equal the wage bill plus intermediate government consumption. This implies:

$$T = W_g E_g + \psi\pi E_g. \tag{23}$$

3.4 Closing the model

Closing the model requires deriving equilibrium values of firm profits and private consumption. On the firm side, steady-state profits to private firms are given by:

$$\Pi_p = [\pi - W_p]\, E_p - c(\theta)\, [E_p - (1 - \lambda_p)E_p]\,. \tag{24}$$

Furthermore, steady-state net lending B equals zero.

Substituting these conditions and the government's budget constraint into the households' budget constraint, and then solving for steady-state values under the assumption of market clearing, gives private consumption as a function of private and public employment, such that:

$$C = [\pi - c(\theta)\lambda_p]\, E_p - \psi \pi E_g. \tag{25}$$

Through this mechanism, fluctuations in private and public employment affect private consumption, which then can affect the outside option b.

4 Theoretical results: the search and matching block

We argue that the search and matching block of our model has trouble generating a contractionary and destabilizing effect of public wages while also generating a stabilizing effect of public employment. First we present some analytical results, and then we provide some graphical intuition.

4.1 Solving for E_p

In what follows, we focus on the search and matching block of the model, which is equivalent to setting σ, γ_W, and γ_E to zero. When we do this, we find that the search and matching block of the model has trouble explaining all of our empirical results. In particular, we find that a higher rate of public employment or public wages should result in lower private employment, higher private wages, and more volatility, where we treat volatility as corresponding with the sensitivity of steady-state private employment to productivity given by $d\ln(E_p)/d\ln(\pi)$.

To understand this requires first solving for private employment. To do this, combining the wage equation (18) with the job creation equation (19) gives an expression linking the endogenous objects c, p_p, and p_g together such that:

$$-(1-\beta)\pi + \frac{r+\lambda_g}{r+\lambda_g+p_g}\left[(1-\beta)b + \beta c p_p\right] + \frac{(1-\beta)p_g}{r+\lambda_g+p_g} W_g + (r+\lambda_p)c = 0. \tag{26}$$

By substituting in the flow rates from equations (10) and (11), it becomes possible to solve for the equilibrium value of E_p. The equilibrium value of E_p can be obtained, after some algebra, by solving the linear equation:

$$\alpha_p E_p = \alpha_c + \alpha_g E_g, \tag{27}$$

the coefficients to which are given by:

$$\begin{aligned} \alpha_p &= (r+\lambda_g)\left[\beta c \lambda_p + (1-\beta)\pi - (r+\lambda_p)c - (1-\beta)b\right]; \\ \alpha_c &= (r+\lambda_g)\left[(1-\beta)\pi - (r+\lambda_p)c - (1-\beta)b\right]; \\ \alpha_g &= \lambda_g\left[(1-\beta)\pi - (r+\lambda_p)c - (1-\beta)W_g\right] - \alpha_c. \end{aligned} \tag{28}$$

This forms part of a nonlinear system along with with equations (8) and (9), which pin down θ and c.

4.2 Understanding the first-order (level) effects of E_g and W_g

To understand the first-order effects of E_g and W_g, we first look at the special case of a symmetric calibration, where $\lambda_g = \lambda_p$ and where $W_g = W_p$. Looking at the effects of public employment, differentiating the composite labor market equilibrium condition (27) with respect to E_g implies:

$$\frac{dE_p}{dE_g} = \frac{\alpha_g}{\alpha_p} + \varpi \frac{dc}{dE_g}, \tag{29}$$

for some constant ϖ. However, since under the symmetric calibration, $\alpha_g = -\alpha_p$, then the derivative of E_p with respect to E_g is given by:

$$\frac{dE_p}{dE_g} = -1 + \varpi \frac{dc}{dE_g}. \tag{30}$$

Next, we need to look at $\frac{dc}{dE_g}$. To do this, first, we rearrange equation (9) to express c as a function of E_p and E_g, such that:

$$c = \bar{c} \left(\frac{\lambda_g E_g + \lambda_p E_p}{1 - E_p - E_g} \right)^{\frac{1-a}{a}}. \tag{31}$$

Differentiating this expression with respect to E_g implies that:

$$\frac{dc}{dE_g} = \eta \left[1 + \frac{dE_p}{dE_g} \right], \tag{32}$$

for some coefficient η. Combining this equation with equation (30) implies:

$$\frac{dE_p}{dE_g} = -1 + \varpi\eta \left[1 + \frac{dE_p}{dE_g} \right]. \tag{33}$$

Solving this expression for $\frac{dE_p}{dE_g}$ implies that $\frac{dE_p}{dE_g} = -1$, and that $\frac{dc}{dE_g} = 0$. This is a situation of perfect crowding out. Furthermore, differentiating (8) implies that $\frac{d\theta}{dE_g} = 0$, and differentiating the vacancy posting equation (19) implies that $\frac{dW_p}{dE_g} = 0$. These results imply that public employment should crowd out private employment by one-to-one without having an effect on private wages.

Next, we turn to the effects of public wages. Implicitly differentiating the vacancy posting condition (19) implies that the derivative of W_p with respect to W_g is given by:

$$\frac{dW_p}{dW_g} = -(r + \lambda_p) \frac{dc}{dW_g}. \tag{34}$$

To investigate this derivative, it is necessary to look at $\frac{dc}{dW_g}$. To do this, differentiating the expression (31) with respect to W_g implies that:

$$\frac{dc}{dW_g} = \eta \frac{dE_p}{dW_g}, \tag{35}$$

for the same positive value of η from above. Substituting this into the expression (34) implies:

$$\frac{dW_p}{dW_g} = -(r+\lambda_p)\eta\frac{dE_p}{dW_g}. \tag{36}$$

Turning to the calculation of this derivative, differentiating equation (27) with respect to W_g, after some algebra, implies:

$$\alpha_p\frac{dE_p}{dW_g} + \left[E_p(r+\lambda_g)\beta\lambda_p + (1-E_p)(r+\lambda_g)(r+\lambda_p) - E_g r(r+\lambda_p)\right]\eta\frac{dE_p}{dW_g} = 0. \tag{37}$$

This expression implies that, for non-pathological calibrations, $\frac{dE_p}{dW_g} < 0$, which in turn implies that $\frac{dW_p}{dW_g} > 0$.

4.3 Understanding the second-order (volatility) effects of E_g and W_g

Taken together, these results show that an increase in E_g or W_g should be expected to increase the outside option of employed workers, in turn putting downward pressure on private employment. In addition, this increase in the outside option can be expected to increase the amount of volatility faced by the economy, where volatility is proxied by $d\ln(E_p)/d\ln(\pi)$. This derivative is given by:

$$\frac{d\ln(E_p)}{d\pi} = \frac{(r+\lambda_g)(1-\beta)(1-E_p) - r(1-\beta)E_g}{E_p\alpha_p}, \tag{38}$$

which for non-pathological calibrations, is positive.

After taking derivatives of this derivative, the effect of public employment on business cycle volatility is given by:

$$\begin{aligned}\frac{d}{dE_g}\left[\frac{d\ln(E_p)}{d\pi}\right] = &-\frac{r(1-\beta)}{E_p\alpha_p} - \left[\frac{(r+\lambda_g)(1-\beta) - r(1-\beta)E_g}{E_p^2\alpha_p}\right]\frac{dE_p}{dE_g} \\ &- \left[\frac{(r+\lambda_g)(1-\beta) - r(1-\beta)E_g}{E_p\alpha_p^2}\right](r+\lambda_g)(\beta\lambda_p - (r+\lambda_g))\frac{dc}{dE_g},\end{aligned} \tag{39}$$

which in principle is ambiguous. However, as a special case, focusing on a symmetric calibration gives:

$$\frac{d}{dE_g}\left[\frac{d\ln(E_p)}{d\pi}\right]=\frac{(r+\lambda_g)(1-\beta)-r(1-\beta)(E_g+E_p)}{E_p^2\alpha_p}>0, \tag{40}$$

which implies that higher public employment should result in higher private sector business cycle volatility.

Next, we look at the effect of public wages on business cycle volatility. This is given by:

$$\begin{aligned}\frac{d}{dW_g}\left[\frac{d\ln(E_p)}{d\pi}\right]=&-\left[\frac{(r+\lambda_g)(1-\beta)-r(1-\beta)E_g}{E_p^2\alpha_p}\right]\frac{dE_p}{dW_g}\\&-\left[\frac{(r+\lambda_g)(1-\beta)-r(1-\beta)E_g}{E_p\alpha_p^2}\right](r+\lambda_g)(\beta\lambda_p-(r+\lambda_g))\frac{dc}{dW_g},\end{aligned} \tag{41}$$

which is in principle ambiguous, even under the symmetric calibration. However, when $a=1$ and hence $\frac{dc}{dW_g}=0$, the fact that $\frac{dE_p}{dW_g}<0$ implies that $\frac{d}{dW_g}\left[\frac{d\ln(E_p)}{d\pi}\right]$ is positive, for non-pathological calibrations. This implies that higher public wages could destabilize private employment, as we show later on in our simulations. This result and the previous result, taken together, imply that the search and matching block of the model, taken as a whole, cannot be expected in general to generate a stabilizing effect of public employment and a destabilizing effect of public wages at the same time.

4.4 The cyclical behavior of equilibrium unemployment and vacancies

Our analytical results can be supported by graphic intuition. To this end, Figures 3 and 4 plot wage curves in $\{W_p,\theta\}$ space for the calibrated model, and for models where E_g and $\ln(W_g)$ are increased slightly from their calibrated values, by 0.03.[6] These plots show log market tightness against the log private wage. The results from both of these exercises show that an increase in public employment or public wages induces an increase in workers' outside options, which in turn pushes the wage curve outward. These shifts also push the market equilibrium into a region where both the wage curve and job creation curve are *steeper*. These steeper curves are more sensitive to outward shifts caused by increases in π, which means that market tightness is more volatile.

[6] These figures are based on simulations of our calibrated model. The calibration excercise is fully explained in the next section of the paper.

These results depend on the same mechanism by which an increase in b results in higher volatility, as shown by Hagedorn and Manovskii (2008). Their model does not feature public employment or public wages. After removing these features and solving for c, the wage curve and job creation curve can be written as:

$$W_p = \beta\pi + (1-\beta)b + \beta\bar{c}\theta, \tag{42}$$

and:

$$W_p = \pi - (r+\lambda_p)\bar{c}\theta^{1-a}. \tag{43}$$

The intersection between these two equations pins down θ and W_p, and implicitly by way of flow rates, private employment.

To see how the volatility of this system evolves, taking log deviations (hatted) from an initial steady state gives:

$$W_p\hat{W}_p = e^{\pi}_{WC}\hat{\pi} + e^{\theta}_{WC}\hat{\theta}, \tag{44}$$

and:

$$W_p\hat{W}_p = e^{\pi}_{JC}\hat{\pi} + e^{\theta}_{JC}\hat{\theta}, \tag{45}$$

where the semi-elasticities denoted by e are given by: $e^{\pi}_{WC} = \beta$; $e^{\theta}_{WC} = \beta\bar{c}\theta$; $e^{\pi}_{JC} = 1$; and $e^{\theta}_{JC} = -(r+\lambda_p)\bar{c}\theta^{1-a}(1-a)$. The intersection between these curves is given at the point where:

$$\hat{\theta} = \frac{e^{\pi}_{JC} - e^{\pi}_{WC}}{e^{\theta}_{WC} - e^{\theta}_{JC}}\hat{\pi}. \tag{46}$$

(This formula also holds for elasticities, if one were to divide every element in this ratio by W_p.) This close relationship between (semi-)elasticities and cyclical sensitivities implies that the sensitivity of the system to perturbations in π is a function of the slopes of the wage and job creation curves.

An increase in the outside option can be shown to increase volatility in the simplified model through the following thought experiment. In particular, if b were to increase, then θ would fall. This would in turn cause both e^{θ}_{JC} and e^{θ}_{WC} to fall (or for the job creation curve and wage curve to become steeper), which would increase the sensitivity of $\hat{\theta}$ to $\hat{\pi}$. In other words, an increase in the value of unemployment increases volatility because a higher outside option causes the job creation curve and wage curve to become steeper and hence more sensitive to shifts caused by movements in productivity. In this sense, an increase in public wages or public employment in our full model has similar effects to an increase in the flow value of unemployment.

5 Calibrating the model

5.1 Calibrating the main parameters

In order to solve this puzzle, we next add product markets to the model, and for this, we rely on a calibrated model. We also use the calibrated model to simulate the effects of different fiscal policy reaction functions. We calibrate our model to match aggregate data at a monthly frequency, where possible. These calibration targets are shown in Table 5. Based on cross-sectional averages from our dataset from 2001 to 2013, we target public employment as a share of total employment of 15.79 percent, and we target an unemployment rate of 6.73 percent. Based on JOLTS data for separations minus quits from 2001 to 2013, we target a rate of private separations λ_p of 1.84 percent per month, and we target a rate of public separations λ_g of 0.77 percent per month. We target these numbers because our model omits on-the-job search, which comprise the majority of quits. For other parameters, we use standard values from the literature. For instance, we target a discount rate of four percent per year, or 0.33 percent per month. We also normalize productivity π to one, without loss of generality. Finally, we calibrate γ_W and γ_E to their time-series elasticities of 0.3644 and 0.0124, respectively, based on the results from Table 2.

There are also some parameters for which direct evidence is difficult to find; for these parameters, we use the literature as a guide. For instance, we target a Nash bargaining weight β of 0.5, which is in keeping with the rest of the literature. Also, we vary the matching function parameter a between one (a special case of theoretical interest) and 0.4 (a more standard case). We choose this value of 0.4 to follow Elsby and Michaels (2013) and Petrongolo and Pissarides (2001). We also vary the consumption parameter σ between zero (the standard search and matching calibration) and one (a standard calibration from the business cycle literature). We also vary the outside option b (or equivalently the hiring cost c). In our baseline setup, we target a replacement rate b/W_p of 0.8342, based on a value of c equivalent to 0.14 times the quarterly wage per worker. We choose this value to follow Elsby and Michaels (2013), Silva and Toledo (2009), and Hall and Milgrom (2008). This is a larger value than that used by Shimer (2005) but it is within the range used within the search and matching literature. Furthermore, this larger value is compatible with the estimates of Chodorow-Reich and Karaboulis (2015), in which the outside option includes leisure and home production. Such an interpretation, as shown by Hagedorn and Manovskii (2008), produces more business cycle volatility, which helps the model to better fit the data. Given this controversy, we also look at larger and smaller replacement rates.

5.2 Calibrating the public wage premium and government demand parameter ψ

There are two additional parameters to calibrate, and those are the steady state public wage premium and the share of outside government purchases in overall government purchases. The problem is that our baseline dataset suggests that the public wage premium is unrealistically large. In fact, the summary statistics presented in Table 1 suggest that public employees are compensated at a rate about 1.42 times as much that of private employees (geometric mean across regions) or about 1.44 times (arithmetic mean across regions). However, most previous studies of the public wage or compensation premium, such as those of Katz and Krueger (1991), Borjas (2002), and Falk (2012a, 2012b) find a significantly smaller premium once they control for worker characteristics, most notably education. However, the estimates of Falk are only for the federal wage and compensation premiums, while we are more interested in a premium that takes federal, state, and local employment into account. Given this, and given that the average size of the public wage premium is an important target for our model, we estimate how large the overall government wage premium is for a typical person based on data from the CPS. We do this in Appendix A, and we arrive at a gross compensation premium of 1.0337.

Finally, we calculate the government's demand for output from the private sector, in private worker-productivity-equivalents. To derive this, we note that, based on aggregate NIPA tables, the share of government consumption and gross investment that does not come from value added, as a share of measured value added, equals 0.587. However, this captures government demand measured in public worker-wage-equivalents. To express this in private worker-productivity-equivalents, we correct this by the observed ratio of the wages of public workers to private workers. This gives a target for the ratio of ψ to the private wage W_p of

0.848, which gives a value of ψ of 0.840. This represents the government's demand for the output of private workers, valued at those workers' productivity levels.

6 Simulations based on the calibrated model

6.1 Simulating the effects of public wages and public employment

To confirm that the hypothesized relationships among E_g, W_g, and volatility hold for our full version of the model, we turn to simulation evidence. For the calibrated model, we numerically calculate the following derivatives: the derivative of private employment with respect to the public employment shifter, the derivative of log private wages with respect to the public employment shifter, the derivative of private employment with respect to the log public wage shifter, the derivative of log private wages with respect to the log public wage shifter, the derivative of log private employment with respect to log productivity (our proxy for volatility), and the derivatives of that derivative with respect to the public employment and log public wage shifters. We report these cross-derivatives normalized by the derivative of log private employment with respect to log productivity, so that these cross-derivatives have an interpretation as the derivative of log volatility. In all cases, we vary starred values E_g^* and $\ln W_g^*$ to make our results analogous to the econometric exercise in Table 3.

6.2 Comparing models with and without the income effect channel

As seen in Table 6, model variants (1) ($\sigma = 0; a = 1$), (2) ($\sigma = 0; a = 0.4$), and (3) ($\sigma = 1; a = 0.4$) correspond fairly closely with the cases discussed under the symmetric calibration. In model variant (1), c does not vary; model variant (2) adds c; and model variant (3) adds the income effect channel.

In model variant (1), an increase in the public employment shifter strongly crowds out private employment as under the analytical results, though the calibrated parameter values now imply that this crowding out is slightly stronger than one-to-one. Furthermore, an increase in the public wage shifter crowds out private employment, as under the symmetric calibration. Taking this model and endogenizing c, as in model variant (2), now implies less crowding out, while an increase in the public employment shifter slightly increases private wages. This effect was zero under the symmetric calibration. However, the positive effect of the public wage shifter on private wages still holds, as under the symmetric calibration. This exercise suggests that the analytical results provide a useful set of predictions that hold in the more complex model, and that the simple model still has trouble in matching the stylized facts.

Next, taking this model and turning on the income effect channel ($\sigma = 1$), as in model variant (3) now implies that higher public employment crowds out private employment by somewhat less, while slightly decreasing private wages. These effects now all point in the same direction as their corresponding regression results. Importantly, an increase in public employment decreases private wages and helps to stabilize private employment over the business cycle. This effect is caused by the combination of two channels working in conjunction. The first channel is what Gomes (2015) refers to as the Business Cycle Wealth Effect. Under this channel, an increase in public employment or public wages cause private employment E_p and private consumption C to fall, which in turn decreases b. This undoes some of the destabilizing effects of public employment or public wages. The second channel comes from the additional term $\psi \pi E_g$ governing consumption, which amplifies the first channel in response to public employment. This channel occurs because public employment and public intermediate consumption are complements, so that, for instance, public employees require pens, paper, and coffee to produce final output. The combination of these two channels is strong enough to generate a realistic stabilizing effect of public employment, without undoing the destabilizing effect of public wages.[7] As a result, model variant (3) can generate effects that are compatible with the stylized facts, and this occurs through an interaction between the labor market block and product market block of the model.

6.3 The effects of cyclical public wage and employment policies

Given the success of the baseline calibration in matching our stylized facts, we then pose the question: What are the model-implied effects of different stabilization policies, proxied by γ_E and γ_W, on business cycle volatility? To see the effects of these parameters on business cycle volatility, Table 7 shows the simulated derivatives for the benchmark calibration, along with simulated derivatives for four alternative calibrations. These calibrations all target the same steady states as the benchmark calibration. Meanwhile, results for a whole range of

[7] This result requires a large enough value of psi–for instance, results for $\psi = 0$ (not shown) still show a muted destabilizing effect for public employment.

these coefficients are given in Figure 4.

The first alternative calibration (1) represents a situation in which public wages and public employment are perfectly acyclical. Under such a situation, the derivative of private employment with respect to log productivity increases substantially. This means that the business cycle becomes significantly more volatile for the private sector in comparison with our benchmark scenario. This implies that even current stabilization policies, though incomplete in their scope, do seem to result in more stable business cycles.

The second alternative calibration (2) represents a situation in which log public wages adjust one-to-one with log private wages. This alternative calibration results in much less volatile business cycles than either the benchmark or (1). This implies that Gomes's (2015) suggestion to allow public wages to vary procyclically should result in significant business cycle stabilization. The reason that such a policy would help to stabilize business cycles is that the distortions to the bargaining process that arise through government employment policies are allowed to vary more procyclically, and this variation acts to make the value of unemployment (and hence bargained wages) vary more procyclically.

The third alternative calibration (3) represents a situation in which public employment adjusts proportionately with private employment. This alternative calibration results in less volatile business cycles than the situation (1) in which public employment does not adjust. This prediction of the model results from crowding out–if productivity increases, then private employment rises. But, if in response, public employment rises, then crowding out dampens the rise in private employment. As a result, a responsive public sector could help to stabilize private employment, though for reasons that are not compatible with standard intuition. However, the desirability of such policies would depend on how government output enters into the preferences of households (the shape of v and any possible nonseparabilities), which would require us to add more assumptions to the model.

The fourth alternative calibration (4) represents a situation in which public employment and public wages adjust proportionately with private employment and wages. This is a calibration that is compatible with balanced growth. This calibration delivers predictions that are in line with the predictions of alternative calibrations (2) and (3) relative to (1). Under this calibration, business cycle volatility falls drastically in comparison with (1) or with the benchmark, implying that there could be significant possibilities for procyclical public sector wage and employment policies to stabilize the private economy. In conjunction with the same results depicted in Figure 4, these results suggest that one way for public authorities to stabilize the business cycle would be to allow public employment and public wages to covary *positively* with their private counterparts.

6.4 Effects of the public wage premium W_g/W_p and outside option b

Next, we investigate the role of the steady state public wage premium W_g/W_p. While our estimates point toward this premium being relatively small, the role of W_g in the analytical results suggests that the size of this wage premium may have some effect. To investigate this problem, Table 8 displays simulated derivatives for different steady state calibrations. In particular model variant (1) features no wage premium, such that $W_g/W_p = 1$, and model variant (2) features a wage premium doubled relative to its baseline value, such that $W_g/W_p = 1.067$. These two counterfactuals indicate that the baseline results are not sensitive to the exact level of the wage premium, except with respect to the effect of the public employment shifter on log volatility. This stabilizing effect reverses sign when the wage premium is large.

The other major parameter which might be expected to affect our results is the outside option b, which in our calibration strategy is closely linked with c. This parameter has an important effect on volatility. To examine the effects of this calibration choice, model variants (3) and (4) depict situations in which c/W_p is set to either half or twice its calibrated value. While a smaller value for c or a larger value for b does not affect the qualitative results of the model relative to the baseline calibration, a larger value for c or a smaller value for b also undoes some of the stabilizing effects of public employment.

7 Random vs. directed search

We discuss one more issue related to specification, and that is the specification of random search versus directed search. We find that if we were to specify our model as a directed search model, then the effects of public wages on private wages would disappear. However, our results on volatility would survive. To examine this set of issues, first we present a re-specified model using directed search, and then we present a set of computational results from our directed search model.

7.1 The directed search model

Under directed search, unemployed searchers can choose every period whether or not to search for a private job or a public job. They cannot search for both at the same time. Therefore, there are two separate pools of unemployed searchers: the private unemployed (denoted by U_p) and the public unemployed (denoted by U_g), such that $U_p + U_g = U$, or:

$$U_p = 1 - E_p - E_g - U_g. \tag{47}$$

Workers move freely between these pools. Denoting the value functions of unemployed private workers and unemployed public workers as $V_{u,p}$ and $V_{u,g}$, respectively, free movement implies that the utility of belonging to one of these pools satisfies $V_{u,p} = V_{u,g} = V_u$, so that all unemployed workers have a value of unemployment given by V_u.

Since in every period, workers may freely choose in which pool to search, the expected gains to searching in either pool must be equal, which implies:

$$\frac{\lambda_p E_p}{U_p}(V_p - V_u) = \frac{\lambda_g E_g}{U_g}(V_g - V_u), \tag{48}$$

the derivation of which is given in Appendix B. In turn, a series of algebra steps similar to those used to derive the wage equation implies that:

$$\left[\frac{\lambda_p E_p}{\lambda_g E_g}\frac{U_g}{U_p}(r + \lambda_g + p_g) + p_p\right]\frac{\beta}{1-\beta}c = W_g - b. \tag{49}$$

Furthermore, equation (8) no longer holds; this equation is replaced by:

$$\theta_p^a(1 - E_g - E_p - U_g) = \lambda_p E_p, \tag{50}$$

where θ_p is market tightness in the private sector. The associated marginal hiring cost is given by:

$$c = \overline{c}\theta_p^{1-a}. \tag{51}$$

All other value functions and equilibrium relationships hold, as before. Appendix B lists these relationships in detail, and it also gives a fuller description of the model.

7.2 Results from the directed search model

The results from this model are shown in Table 9, in a format analogous to that of Table 6. Within Table 9, model variants (1) through (3) correspond with directed-search equivalents of the random-search model variants (1) through (3). Comparing both of these tables, model variant (1) ($\sigma = 0; a = 1$) gives the same results across both specifications. This result makes sense because the modifications to the model come through modifications to the tightness equation (8), which feeds through into hiring costs. However, when $a = 1$, tightness does not affect hiring costs, and so the model has the same equilibrium as under random search. This equilibrium features a strong degree of crowding out in response to both public employment and public wages.

Interestingly, moving to model variant (2) ($\sigma = 0; a = 0.4$) does not change this result. In this model variant, our simulations suggest that private employment and private wages respond exactly the same way to public employment and public wages as they do in model variant (1). While it is difficult to derive this result in closed form, this suggests that adding directed search to a model will make it difficult to replicate the positive effect of public wages on private wages. However, our main point remains, in that this version of the model runs into the same problems as the random-search model.

However, model variant (3) still features a strong income effect channel. This channel implies that anything that reduces private employment will also reduce private wages, by way of a lower flow value of unemployment. Because of this effect, this model variant still cannot explain the positive correlation between public wages and private wages, although it generates a stabilizing effect for public employment. Altogether, these results imply that a directed search model can match most of (but not all of) our main stylized facts, particularly when that model features an interaction between product markets and the flow value of unemployment.

8 Conclusion

By looking at a cross section of U.S. metro areas, we have established a few stylized facts related to the effects of public employment and public wages. Our findings suggest that a high rate of public employment is associated with relatively little crowding out in private employment, while a high rate of public employment is associated with low private wages and with less business cycle volatility. Meanwhile, high public wages are associated with low private employment, with high private wages, and with high business cycle volatility. We argue that these facts can match the predictions of a standard search and matching model augmented with a public sector, so long as that model also allows for government policies to affect product markets, resulting in an endogenous flow value of unemployment. Such a mechanism is necessary to match the behavior of private wages after an increase in public employment, and such a mechanism also makes it possible for higher public employment to stabilize the business cycle. However, the main mechanisms underlying the effects of public wages seem to work through standard search and matching channels.

While these results appear to be mostly robust to different empirical and theoretical strategies, our results suggest several avenues for future work. First of all, on the empirical side, there remains much to be done in estimating the government wage or compensation premium at the individual level, particularly for state and local workers, and in linking these estimates with geography in a way that cross-sectional variation in the public wage premium could be examined. There is also work to be done in precisely estimating the local sensitivity of public wages and public employment to private wages and private employment, so as not to run into problems with weak instruments. Such exercises could help add to the broader understanding of how public wages and employment behave in the United States. Furthermore, on the theoretical side, additional work could help link our results to the DSGE literature. Such a link would entail setting up (and then simulating) a model that features a rich set of macro rigidities, along with additional sources of shocks. Since these models feature richer product markets than the ones we have investigated, these models are well-suited to explain the broader macroeconomic effects of public wage and employment policies.

A Appendix: Estimating the government compensation premium

To estimate the government compensation premium, we follow Falk (2012a) in estimating the following regression using earnings per hour from 2001 to 2013 as reported in the following year's March Current Population Survey (CPS):

$$\ln W_{i,t} = \gamma_{G,t} \mathbb{1}_{G,i,t} + b_G' X_{i,t} + \varepsilon_{i,t}, \tag{A.1}$$

where $W_{i,t}$ is earnings per hour; $\mathbb{1}_{G,i,t,t}$ is an indicator variable equal to one if a worker worked in the government sector in time t and zero otherwise; $\gamma_{G,t}$ is the effect of public employment on log wages in time t; $X_{i,t}$ is a vector of control variables including time dummies, seven categories for educational attainment (unknown, through grade 6, through grade 11, a high school diploma or equivalent, an associate's degree, a bachelor's degree, or anything beyond a bachelor's degree), five racial categories (unknown, white, black, native American, and anything else), state dummies, coded sex, and a third-degree polynomial in age; b_G is a vector of coefficients; and $\varepsilon_{i,t}$ is a white noise error term. In estimating this regression, we restrict our sample to native-born US citizens who lived in one of the fifty states or DC, reported usual hours of work strictly greater than 34 per week, worked strictly more than 51 weeks, were strictly over 15 years in age, were wage and salary workers, and reported wage and salary income for that year. Unfortunately, we are not able to adequately control for occupation (which is endogenous to the choice of sector) or metro area, since these things are badly measured in our dataset, and our sample is too small to adequately control for metro area. This is particularly unfortunate since this hinders a proper cross-sectional comparison between the BEA and the CPS datasets. We also do not control for firm size, since this is also endogenous to the choice of sectors.

In order to arrive at a public wage premium based on these regressions, we then calculate an arithmetic public wage premium for each year t based on the sample analogue to following formula:

$$W_t^{pr} = \frac{\mathbb{E}\left(\exp\left(\gamma_{G,t} + \varepsilon_{i,t}\right) | \mathbb{1}_{G,i,t} = 1\right)}{\mathbb{E}\left(\exp(\varepsilon_{i,t}) | \mathbb{1}_{G,i,t} = 0\right)}. \tag{A.2}$$

This estimate of the arithmetic wage premium explicitly includes exponentiated error terms $\varepsilon_{i,t}$ which have a smaller variance for government workers than for private workers, because of the way that wages are bargained. This is important since Jensen's inequality implies that this wage compression should push the arithmetic government wage premium down below the geometric wage premium given by $\exp(\gamma_{G,t})$.

A time series of geometric and arithmetic means for the estimated object W_t^{pr} can be found in Table A1. This table shows that, over the course of our sample, the average government worker earns a wage 0.931 times as large as the that of the average comparable private worker, and that this ratio is somewhat smaller than that estimated using a geometric mean. Furthermore, this table shows that this ratio seems to have trended slightly upward over time, particularly during the Great Recession. This is in line with the idea that public wages only partially adjust in response to movements in private wages, since private wages were sluggish during that time. Furthermore, some additional checks reveal that our low estimates for the public wage ratio are caused by the presence of state and local workers in our sample. In fact, running the wage regression but separately controlling for federal or state and local workers yields an arithmetic mean federal wage premium of 1.150 and an arithmetic mean state and local wage premium of 0.879 (not shown). These results are much more in line with those of Falk (2012a).

However, it is important to point out that this measured wage premium excludes supplements to wages and salaries, particularly health care and pension benefits. This is an important omission, because as Falk (2012b) points out, a larger share of federal compensation than private compensation comes in the form of these supplements. In fact, using data provided in Table 1 of Falk (2012b), total compensation for full time federal workers, excluding paid leave, exceeds wages by a ratio of 1.461, while a similar ratio for private workers is given by 1.316. When we apply these ratios to the wage premium for the total government, thereby implicitly assuming that the government sector as a whole behaves like the federal sector in this respect, we arrive at a government compensation premium of 1.034 (or 1.0337). This suggests that the average government worker likely does earn a modest premium over a comparable private worker, though the exact size of this premium depends on the systematic ways in which the total government sector might differ from the federal sector with respect to benefits.

B Appendix: The directed search model

This appendix lists the reduced-form equations to the directed search version of the model, along with derivations where necessary. There are two separate pools of unemployed searchers: the private unemployed (denoted by U_p) and the public unemployed (denoted by U_g), such that $U_p + U_g = U$, or:

$$U_p = 1 - E_p - E_g - U_g. \tag{B.1}$$

Workers move freely between these pools. Denoting the value functions of unemployed private workers and unemployed public workers as $V_{u,p}$ and $V_{u,g}$, respectively, free movement implies that the utility of belonging to one of these pools satisfies $V_{u,p} = V_{u,g} = V_u$, so that all unemployed workers have a value of unemployment given by V_u.

Writing out these value functions gives:

$$rV_{u,p} = b + \frac{\lambda_p E_p}{U_p}(V_p - V_u), \tag{B.2}$$

and:

$$rV_{u,g} = b + \frac{\lambda_g E_g}{U_b}(V_g - V_u), \tag{B.3}$$

which in turn implies:

$$\frac{\lambda_p E_p}{U_p}(V_p - V_u) = \frac{\lambda_g E_g}{U_g}(V_g - V_u). \tag{B.4}$$

where the value functions V_u, V_p, and V_g are derived the same way as before, and with p_p and p_g taking on their same meanings as hazard rates relative to U.

The challenge is to make something useful out of this expression. To do this requires first combining the equations for V_g and V_u from the main text, to yield:

$$(r + \lambda_g + p_g)(V_g - V_u) = W_g - b - p_p(V_p - V_u). \tag{B.5}$$

Then, combining the free-movement condition for searchers eliminates the $V_g - V_u$ term, such that:

$$\left[\frac{\lambda_p E_p}{\lambda_g E_g}\frac{U_g}{U_p}(r+\lambda_g+p_g)+p_p\right](V_p-V_u)=W_g-b. \tag{B.6}$$

In turn, Nash bargaining over wages implies:

$$\left[\frac{\lambda_p E_p}{\lambda_g E_g}\frac{U_g}{U_p}(r+\lambda_g+p_g)+p_p\right]\frac{\beta}{1-\beta}c=W_g-b, \tag{B.7}$$

or after eliminating U_p:

$$\left[\frac{\lambda_p E_p}{\lambda_g E_g}\frac{U_g}{1-E_p-E_g-U_g}(r+\lambda_g+p_g)+p_p\right]\frac{\beta}{1-\beta}c=W_g-b. \tag{B.8}$$

This is the "extra" equation in the directed-search model that pins down how the unemployment pool is split into U_p and U_g.

To deal with the splitting of the vacancy pool requires some relabeling. Now private hiring is a function of private tightness $\theta_p = V_p/U_p$, such that:

$$\theta_p^a(1-E_g-E_p-U_g)=\lambda_p E_p, \tag{B.9}$$

with the associated marginal hiring cost for the private sector given by:

$$c=\bar{c}\left(\frac{\lambda_p E_p}{1-E_p-E_g-U_g}\right)^{\frac{1-a}{a}}. \tag{B.10}$$

All other value functions and equilibrium relationships hold, as before, in more or less their usual forms. These are:

$$C=(\pi-c(\theta_p)\lambda_p)E_p-\psi\pi E_g, \tag{B.11}$$

$$b=\bar{b}C^{\sigma}, \tag{B.12}$$

$$W_p=\beta\pi+\frac{r+\lambda_g}{r+\lambda_g+p_g}\left[(1-\beta)b+\beta c(\theta_p)p_p\right]+\frac{(1-\beta)p_g}{r+\lambda_g+p_g}W_g, \tag{B.13}$$

$$\pi-W_p=(r+\lambda_p)c(\theta_p), \tag{B.14}$$

$$p_g=\lambda_g E_g/(1-E_p-E_g), \tag{B.15}$$

and:

$$p_p = \lambda_p E_p/(1 - E_p - E_g), \tag{B.16}$$

along with the two fiscal reaction functions:

$$\ln W_g = \gamma_W \ln W_p + \ln W_g^*, \tag{B.17}$$

and:

$$E_g = \gamma_E E_p + E_g^*. \tag{B.18}$$

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Table 1: Summary statistics for observables

	Mean	**Std.**	**Min.**	**Max.**
Log private wage W_p	3.66	0.16	3.26	4.39
Private employment rate E_p	0.478	0.079	0.232	0.690
Log private prod. π	-2.74	0.20	-3.26	-2.03
Log public wage W_g	4.02	0.14	3.72	4.53
Public employment rate E_g	0.0896	0.0422	0.0365	0.3508
Unemployment rate U	0.0672	0.0193	0.0323	0.2108
Farm share	0.0228	0.0220	0.0003	0.1521
Mfg. share	0.1059	0.0597	0.0156	0.4194
Constr. share	0.0712	0.0163	0.0266	0.1309
Population (m)	0.621	1.243	0.060	12.765

This table features the cross-sectional sample mean, standard deviation, minimum, and maximum for the main observables. Note that to make private productivity comparable to the private or public wage, one should add ln(1000) to log private productivity. Source: BEA, BLS, and authors' calculations.

Table 2: Regression results: likely effects of private wages or employment on public wages or employment

	Cross-sectional		Time-series	
	Log pub. wage	**Pub. empl.**	**Log pub. wage**	**Pub. empl.**
Log private wage	0.222		0.364	
(std.)	0.062		0.016	
Private employment		-0.087		0.012
(std.)		0.078		0.005
Farm share	0.208	-0.169		
(std.)	0.343	0.132		
Mfg. share	-0.912	-0.211		
(std.)	0.135	0.045		
Constr. share	-1.499	-0.415		
(std.)	0.515	0.181		
Population (m)	0.018	-0.006		
(std.)	0.007	0.002		
N	306	306	8,381	8,381
First-stage F	1,067	61.9	4,175	6,291

This set of regressions captures the likely effects of private wages and private employment on public wages and employment, using log private productivity as an instrument for either private wages or private employment, in levels for the cross-sectional elasticities. For the time-series elasticities, two-year first differences are taken, with aggregate first-differences taken as instruments. The dependent variables are the log public wage W_g and public employment per capita E_g. The independent variables are the log private wage W_p, the private employment rate E_p, the shares of farm, manufacturing, and construction employment in private employment, and population (independent variables), at an MSA or NECTA level. The data are cross-sectional averages taking the average of period t and $t-1$ observations, in accordance with the timing assumptions used to derive growth rates. Coefficient estimates are followed by standard errors, and the row of the table lists the number of observations (N). Source: BEA, BLS, and authors' calculations.

Table 3: Regression results: effects of public wages and employment, purged

	Log vol.	Log priv. wage	Priv. empl.	Unempl.
Log public wage shifter	0.476	0.092	-0.139	0.042
(std.)	0.130	0.032	0.031	0.009
Public employment shifter	-1.395	-0.266	-0.010	-0.164
(std.)	0.360	0.080	0.098	0.026
Log private prod.	0.091	0.651	0.167	-0.006
(std.)	0.099	0.029	0.019	0.005
Farm share	1.079	-0.058	-0.696	0.313
(std.)	0.727	0.135	0.205	0.074
Mfg. share	1.280	0.174	0.135	0.019
(std.)	0.430	0.064	0.076	0.021
Constr. share	6.509	-1.909	-1.022	-0.040
(std.)	1.259	0.351	0.305	0.087
Population (m)	0.027	0.012	-0.004	0.002
(std.)	0.009	0.005	0.002	0.0004
R^2	0.254	0.868	0.378	0.298
N	306	306	306	306

This set of regressions captures the unconditional cross-sectional statistical relationships among a set of dependent variables and independent variables. The dependent variables are the log standard deviation of the growth rate of private employment per capita (log volatility), the log private wage W_p, private employment per capita E_p, and the unemployment rate U. The dependent variables are the log public wage shifter W_g^*, the public employment shifter E_g^*, the log private productivity level, the shares of farm, manufacturing, and construction employment in private employment, and population (independent variables), at an MSA or NECTA level. The data are cross-sectional averages taking the average of period t and $t-1$ observations, in accordance with the timing assumptions used to derive growth rates. Furthermore, the shifters are derived by "purging" log public wages and public employment of the effects of private wages and employment, employment shares, and population, using the coefficients in Table 2. Coefficient estimates are followed by robust standard errors, and the bottom two rows of the table list the R-squared values of each regression and the number of observations (N). Source: BEA, BLS, and authors' calculations.

Table 4: **Regression results: effects of public wages and employment, un-purged**

	Log vol.	**Log priv. wage**	**Priv. empl.**	**Unempl.**
Log public wage	0.418	0.147	-0.112	0.039
(std.)	0.128	0.031	0.029	0.009
Public employment	-1.136	-0.323	-0.239	-0.127
(std.)	0.349	0.085	0.081	0.023
Log private prod.	0.012	0.626	0.181	-0.013
(std.)	0.104	0.029	0.019	0.005
Farm share	0.866	-0.115	-0.696	0.291
(std.)	0.745	0.135	0.208	0.075
Mfg. share	1.390	0.233	-0.015	0.025
(std.)	0.448	0.069	0.086	0.021
Constr. share	7.038	-1.803	-1.360	0.001
(std.)	1.263	0.317	0.309	0.083
Population (m)	0.012	0.007	-0.003	0.0005
(std.)	0.010	0.005	0.002	0.0005
R^2	0.240	0.877	0.383	0.254
N	306	306	306	306

This set of regressions captures the unconditional cross-sectional statistical relationships among a set of dependent variables and independent variables, which are not purged of the likely effects of private wages and employment. This is a robustness check to the results presented in Table 3. The dependent variables are the log standard deviation of the growth rate of private employment per capita (log volatility), the log private wage W_p, private employment per capita E_p, and the unemployment rate U. The dependent variables are the log public wage level W_g, public employment per capita E_g, the log private productivity level, the shares of farm, manufacturing, and construction employment in private employment, and population (independent variables), at an MSA or NECTA level. Wages and productivity are equal to private compensation and private GDP per employee, respectively. The data are cross-sectional averages taking the average of period t and $t-1$ observations, in accordance with the timing assumptions used to derive growth rates. Coefficient estimates are followed by robust standard errors, and the bottom two rows of the table list the R-squared values of each regression and the number of observations (N). Source: BEA, BLS, and authors' calculations.

Table 5: **Model calibration, baseline model**

Target	Description	Value	Remarks
W_g/W_p	Gross pub. wage premium	1.0337	CPS data
$E_g/(E_g + E_p)$	Public employment share	0.1579	Cross-sectional mean
U	Unemployment rate	0.0673	Cross-sectional mean
λ_p	Private sep. rate	0.0184	JOLTS nationwide mean
λ_g	Public sep. rate	0.0077	JOLTS nationwide mean
r	Discount rate	0.0033	Target: 4 percent per year
β	Workers' bargaining power	0.5	Standard calibration
c/W_p	Hiring cost	0.42	Target of 0.14/qtr, monthly
b/W_p	Replacement rate	0.8342	Derived from c
ψ/W_p	Govt. demand parameter	0.8476	NIPA, cross-sectional data
π	Productivity	1	Normalization
a	Match elasticity	0.4	Petrongolo and Pissarides (2001)
σ	Consumption utility parameter	1	Log preferences
γ_W	Response of pub. to priv. wages	0.3644	Time-series elasticity
γ_E	Response of pub. to priv. empl.	0.0124	Time-series elasticity

This table lists a set of model calibrations for the baseline random search model calibrated to cross-sectional means (or aggregate means) for U.S. data, from 2001 to 2013. Source: BEA, BLS, and authors' calculations.

Table 6: Implied responses, varying a and σ, baseline model

Object	(1)	(2)	(3)	Data
a	1.0	0.4	0.4	
σ	0.0	0.0	1.0	
Responses to log public wage shifter				
Log volatility	5.393	7.889	3.169	0.476
Log private wages	0.000	0.062	0.052	0.092
Private employment	-0.642	-0.280	-0.235	-0.229
Responses to public employment shifter				
Log volatility	5.719	5.889	-0.809	-0.848
Log private wages	0.000	0.017	-0.060	-0.162
Private employment	-1.120	-1.022	-0.676	*-0.010*
Responses to log private productivity				
Log volatility	-12.002	-11.575	-1.871	*0.091*
Log private wages	1.009	0.932	0.972	0.651
Private employment	0.796	0.347	0.168	0.275

This table lists a set of model calibrations and implied (semi-)elasticities for the baseline random search model calibrated to cross-sectional averages for U.S. data, from 2001 to 2013. Model variant (1) is the baseline model with just the bargaining channel. Model variant (2) adds the tightness channel onto that model. Model variant (3) adds a variable outside option, following the business cycle literature. The fourth column contains analogous values from the data, based on estimates from Table 3, taking the implied labor force participation rate (0.6073) into account. Values in italics are statistically indistinguishable from zero.

Table 7: Sensitivity to public policy changes, varying γ_W and γ_E

Object	Benchmark	(1)	(2)	(3)	(4)
γ_W	0.3644	0.0000	1.0000	0.0000	1.0000
γ_E	0.0124	0.0000	0.0000	0.1875	0.1875
Responses to log public wage shifter					
Log volatility	3.169	3.428	-3.135	3.553	-3.020
Log private wages	0.052	0.051	0.054	0.053	0.056
Private employment	-0.235	-0.233	-0.246	-0.207	-0.218
Responses to public employment shifter					
Log volatility	-0.809	-0.848	-0.713	-1.368	-1.267
Log private wages	-0.060	-0.060	-0.063	-0.053	-0.056
Private employment	-0.676	-0.687	-0.673	-0.609	-0.597
Responses to log private productivity					
Log volatility	-1.871	-3.277	-0.360	-3.415	-0.369
Log private wages	0.972	0.954	1.005	0.951	1.005
Private employment	0.168	0.251	0.018	0.223	0.016

This table lists a set of model calibrations and implied (semi-)elasticities for the random search model calibrated to cross-sectional averages for U.S. data, from 2001 to 2013. Model variant (1) is the baseline model with no response of public wages or public employment to their private counterparts. Model variant (2) adds full adjustment (1:1) in public wages to model (1). Model variant (3) adds full adjustment in public employment to model (1). Model variant (4) adds full adjustment in public wages and public employment to model (1).

Table 8: Sensitivity to steady states, varying W_g/W_p and b/W_p

Object	Benchmark	(1)	(2)	(3)	(4)
W_g/W_p	1.0337	1.0000	1.0674	1.0337	1.0337
c/W_p	0.4200	0.4200	0.4200	0.2100	0.8400
b/W_p	0.8353	0.8867	0.7838	0.8919	0.7220
Responses to log public wage shifter					
Log volatility	3.169	3.566	2.873	2.101	2.715
Log private wages	0.052	0.056	0.049	0.039	0.062
Private employment	-0.235	-0.255	-0.220	-0.355	-0.140
Responses to public employment shifter					
Log volatility	-0.809	-3.286	1.051	-2.299	1.810
Log private wages	-0.060	-0.087	-0.039	-0.050	-0.058
Private employment	-0.676	-0.560	-0.771	-0.500	-0.817
Responses to log private productivity					
Log volatility	-1.871	-2.116	-1.691	-1.143	-1.695
Log private wages	0.972	0.969	0.974	0.978	0.969
Private employment	0.168	0.182	0.156	0.239	0.111

This table lists a set of model calibrations and implied (semi-)elasticities for the random search model calibrated to cross-sectional averages for U.S. data, from 2001 to 2013. Model variant (1) is the baseline model with no public wage premium. Model variant (2) is the baseline model but with double the wage premium. Model variant (3) is the baseline model with the ratio c/W_p set to half its baseline value. Model variant (4) is the baseline model with the ratio c/W_p set to double its baseline value.

Table 9: Implied responses, varying a and σ, directed search model

Object	(1)	(2)	(3)	Data
a	1.0	0.4	0.4	
σ	0.0	0.0	1.0	
Responses to log public wage shifter				
Log volatility	5.393	6.636	-4.573	0.476
Log private wages	0.000	0.000	-0.021	0.092
Private employment	-0.642	-0.642	-0.501	-0.229
Responses to public employment shifter				
Log volatility	5.719	6.944	-0.575	-0.848
Log private wages	0.000	0.000	-0.065	-0.162
Private employment	-1.120	-1.120	-0.695	*-0.010*
Responses to log private productivity				
Log volatility	-12.002	-10.542	3.028	*0.091*
Log private wages	1.009	0.976	1.018	0.651
Private employment	0.796	0.604	0.335	0.275

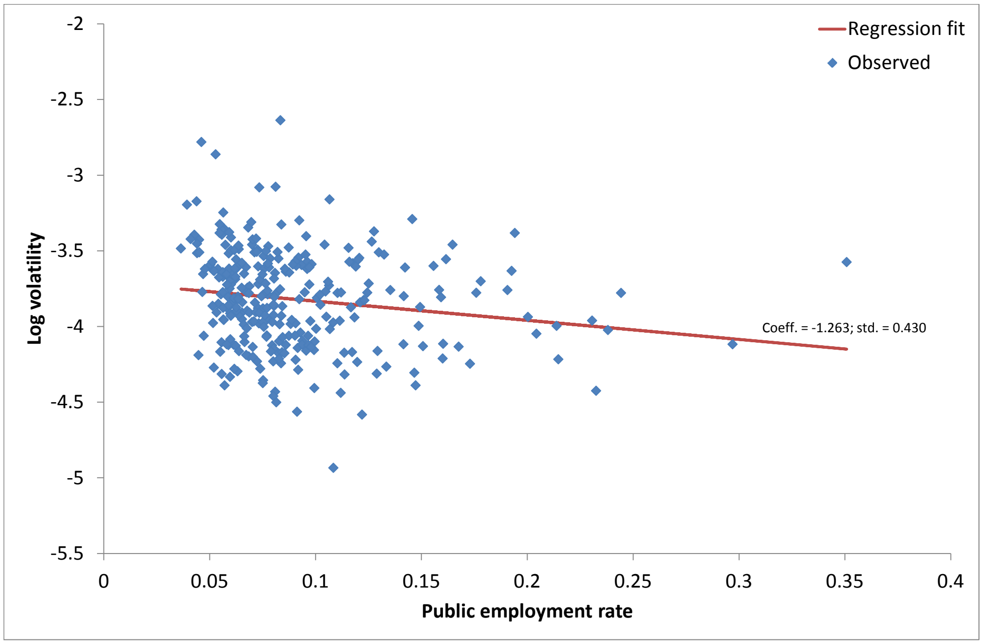
This table lists a set of model calibrations and implied (semi-)elasticities for the baseline directed search model calibrated to cross-sectional averages for U.S. data, from 2001 to 2013. Model variant (1) is the directed search model with just the bargaining channel. Model variant (2) adds the tightness channel onto that model. Model variant (3) adds a variable outside option, following the business cycle literature. The fourth column contains analogous values from the data, based on estimates from Table 3, taking the implied labor force participation rate (0.6073) into account. Values in italics are statistically indistinguishable from zero.

Table A1: Gross public wage premium based on CPS data

Year	Gross wage prem. (Geometric)	Gross wage prem. (Arithmetic)	Gross comp. prem. (Arithmetic)
2001	0.925	0.873	
2002	0.951	0.902	
2003	0.957	0.933	
2004	0.978	0.933	
2005	0.976	0.926	
2006	0.986	0.953	
2007	0.968	0.926	
2008	0.968	0.921	
2009	0.984	0.941	
2010	0.989	0.954	
2011	0.901	0.937	
2012	0.997	0.956	
2013	0.946	0.909	
Mean	0.973	0.931	1.034

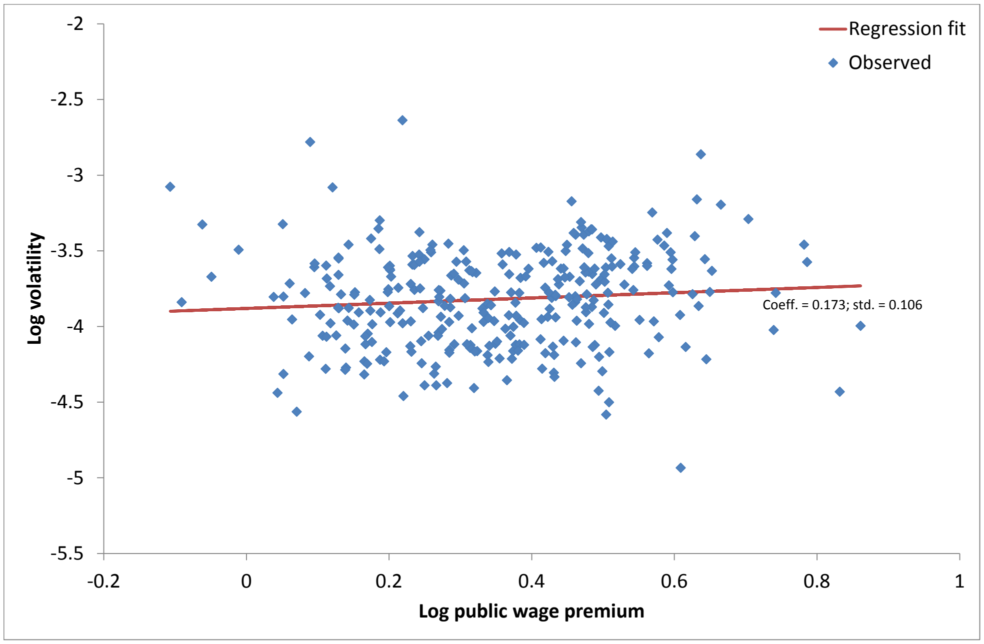
This time series displays the estimated gross public wage premium W_t^{pr} for the years 2001 through 2013, based on CPS data and the authors' calculations. The time-series mean is calculated according to the timing conventions used elsewhere in the paper. The compensation premium is equal to mean wages adjusted using the ratios of federal and private compensation to wages for workers who worked full time, provided by Falk (2012b).

Figure 1: Log public employment rate vs. log volatility



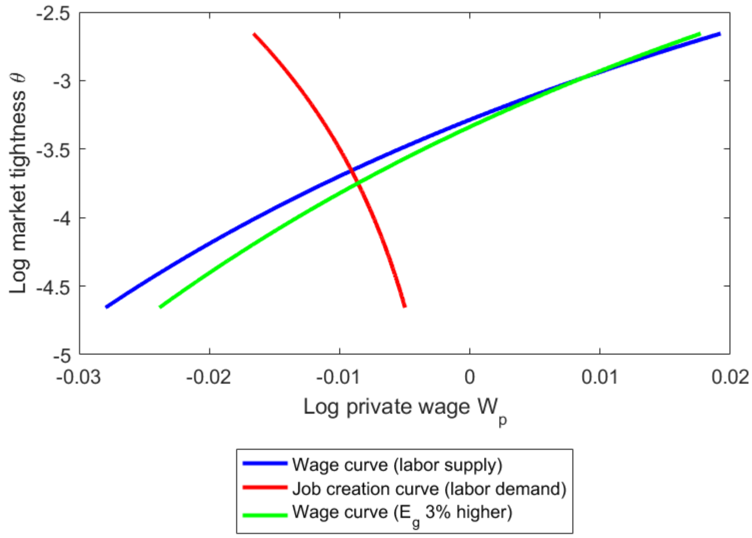
This figure shows the average public employment rate (as a share of population) and log volatility (the log standard deviation of private employment growth) for the metro areas in our full sample. The red line gives the best fit based on an OLS regression. Sample: 2001-2013. Source: BEA and authors' calculations.

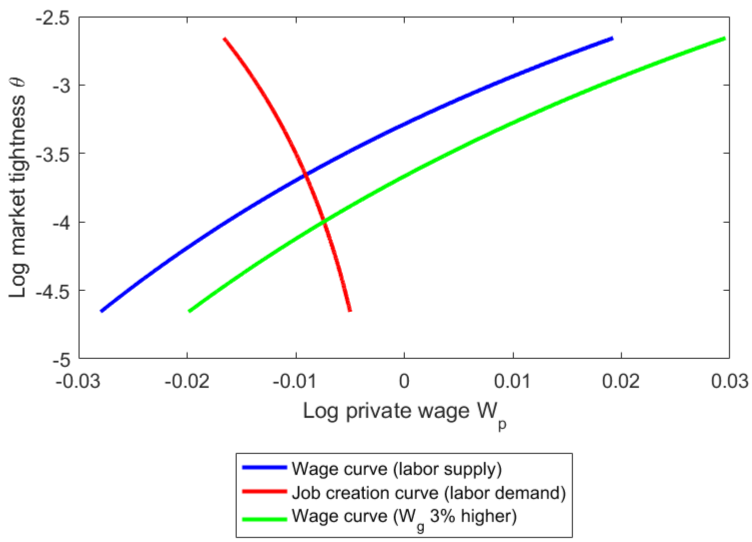
Figure 2: Log public wage premium vs. log volatility



This figure shows the average log public wage premium (relative to private wages) and log volatility (the log standard deviation of private employment growth) for the metro areas in our full sample. The red line gives the best fit based on an OLS regression. Sample: 2001-2013. Source: BEA and authors' calculations.

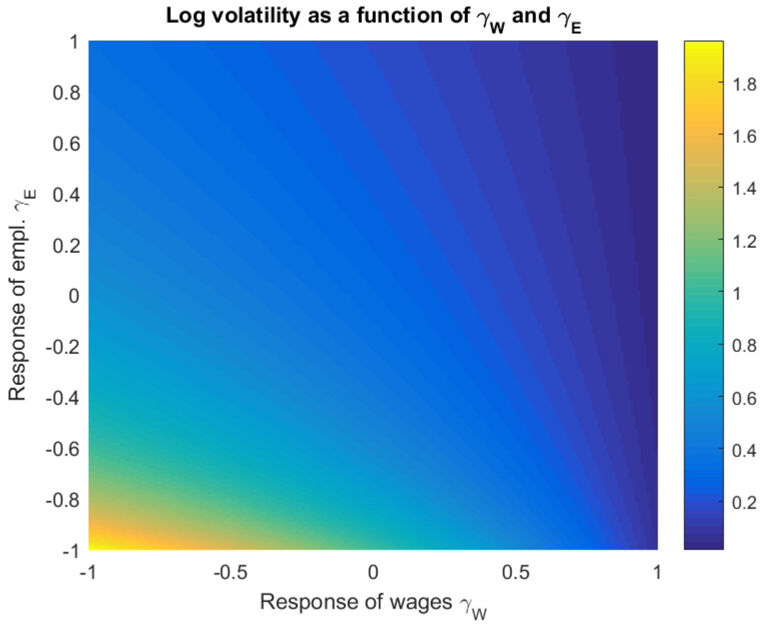
Figure 3: The effects of E_g and W_g on the wage and job creation curves





This figure shows a set of wage curves and job creation curves for the calibrated model, and similar (but steeper) wage curves for higher levels of E_g and W_g.

Figure 4: The effects of γ_E and γ_W on log volatility



This figure shows log volatility (the log derivative of log private employment with respect to log productivity) as a function of γ_E and γ_W, for the model under the baseline calibration.