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Cyclical and welfare effects of public sector unions in a Real-Business-Cycle model

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Abstract

Motivated by the highly-unionized public sectors, the high public shares in total employment, and the public sector wage premia observed in Europe, this paper examines the importance of public sector unions for macroeconomic theory. The model generates cyclical behavior in hours and wages that is consistent with data behavior in an economy with highly-unionized public sector, namely Germany during the period 1970-2007. The union model is a significant improvement over a model with exogenous public employment. In addition, endogenously-determined public wage and hours add to the distortionary effect of contractionary tax reforms by generating greater tax rate changes, thus producing significantly higher welfare losses.

Keywords: fiscal policy, public wages, public employment, public sector labor unions

JEL Classification: C68, E62, J45, J51

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1 Introduction

The behavior of the labor input is very important for output fluctuations, as Cooley and Prescott (1995) and Kydland (1995) have pointed out.¹ Despite this, real business cycle (RBC) theory has been predominantly focused on the private sector and largely ignored the dynamic general-equilibrium effects of public sector labor choice. This paper adds to earlier research by distinguishing between the two types of hours and argues that the presence of the public sector labor market in European economies generates significant interaction with the private sector labor and capital markets. If public sector labor choice is ignored, then important effects on cyclical fluctuations, as well as on welfare, due to fiscal regime changes, will be missed.

Furthermore, several stylized facts suggest that this labor market is driven by non-competitive arrangements: As reported in Table 1 on the next page, the public sectors in the major European Union (EU) member states are highly unionized, and significantly more so than the respective private sectors.² Therefore, collective bargaining agreements are often used to set public wage rates and employment levels in European economies. Central governments in EU countries are the biggest employers at a national level, with a high public share in total employment. The large share of public employees in total employment could in itself constitute a source of union power, and could explain the positive public sector wage premia over the private sector wages, which are observed in most post-WWII European economies over the period 1970-2008. The Wage Dynamics Network (WDN) 2010 Final Report also emphasizes that wage bargaining institutions are an important determinant of the wage dynamics and wage structure in the EU countries, and the major reason for the existence of

¹In particular, changes in hours account for two-thirds of the movement in US output per person over the business cycle.

²Even though the unionization rates for the EU countries in each sector were calculated in Visser (2003) for only one year, the wide gap in union density between the two sectors indicates that the two labor markets operate in different settings. High unionization rates alone do not necessarily translate into strong unions, but the significance of unions in Europe can be inferred from the generally high coordination, centralization and, in particular, the extensive coverage rate.

the public wage premia.³

Table 1: Labor market facts 1970-2008

Country	Private sector union density	Public sector union density	Coverage rate (2000)	Average publ./priv. compensation	Average publ./priv. employment
Euro Area (2001)	26	N/A	78	1.22	0.22
France (1993)	4	25	95	1.00	0.32
Germany (1997)	22	56	73	1.20	0.17
Italy (1997)	36	43	82	1.30	0.26
Spain (1997)	15	32	80	1.60	0.16
UK (2003)	18	59	36	1.08	0.27
US (2010)	7	35	15	1.08	0.16

Sources: BLS (2011), OECD (2011), Visser (2003)

Additionally, Lane (2003) shows that the public wage bill in OECD countries is pro-cyclical, as opposed to government purchases, which are acyclical. Further empirical work from Lamo, Perez and Schuknecht (2007, 2008) concludes that pro-cyclical discretionary fiscal policy can have important effects on the economy through the unions. In particular, unions act as organized groups that constantly press for an expansion in the government wage bill. Therefore, the presence of interest groups in the public sector imposes a significant constraint on the use of fiscal policy in Europe as a tool for economic stabilization, and thus accentuates cyclical fluctuations.

This paper uses the RBC framework for studying the cyclical properties of European public sector labor markets.⁴ Most of the extensions to the benchmark RBC model, which allow for public employment, however, model public sector labor market variables predominantly as

³Other reasons for the existence of a public sector wage premium, as documented in Ehrenberg and Schwartz (1986) can be due to skill and experience differences: on average, public employees are older and have higher qualification. In addition, females and employees belonging to a minority group receive higher labor compensation compared to the remuneration package for similar duties in the private sector.

⁴In addition the baseline RBC model performance improves significantly when extended to capture specific features of the economy of interest. Some examples include: distortionary taxation (McGrattan 1994),

exogenous, e.g. Finn (1998), Cavallo (2005), and Linnemann (2009). Those models feature a representative household and two sectors - public and private - where labor hours can be supplied. A serious shortcoming in these models is that wage rates in the economy are identical, with public hours approximated by a stationary stochastic process. The absence of an internal propagation mechanism for public employment is a serious limitation in this class of models, particularly when the research focus falls on the interactions between the two labor markets and their relation to the business cycle.

There are few RBC models with endogenous public sector wages and employment. Ardagna (2007), for example, *ex ante* divides total population into capitalists and workers, with workers being either employed in the private or public sector, or unemployed. In addition, both sectors are unionized, and public sector wage is different from the private sector wage rate. Public wage and employment are obtained from the government's maximization problem, where the government profit function is augmented with a term capturing equity considerations. This is at odds with data, which shows that the biggest group of government employees are bureaucrats. Another limitation of Ardagna's (2007) setup is that it assigns each household to a sector and by default excludes further labor reallocation, which is the focus in this paper.

Additionally, there are even fewer RBC models that incorporate endogenously-determined wage and hours in the public sector, and also reflect the importance of public sector unionization for the business cycles in EU countries. Fernandez-de-Cordoba *et al.* (2009, 2012) were the first to develop a Dynamic Stochastic General Equilibrium (DSGE) model with public and private wages being determined in different environments. The private sector wage is determined within a competitive market framework, while the public sector wage is an optimal solution to the union's optimization problem. In addition, the impulse response analysis in Fernandez-de-Cordoba *et al.* (2009, 2012) generates pro-cyclical public wage and hours. Another important finding is the positive co-movement between the two wage rates, and public and private hours. These are all robust patterns have been observed previously government spending (Christiano and Eichenbaum 1992), and productive public investment (Baxter and King 1993).

in the empirical work of Lamo, Perez and Schuknecht (2007, 2008) and Perez and Sanchez (2010).

The model in this paper adopts the public sector union maximization problem from Fernandez-de-Cordoba *et al.* (2009, 2012) and incorporates it into a RBC model with richer tax structure and fiscal policy instruments, *i.e.* Finn (1998), to address new aspects of the economy. In particular, the individual quantitative effect of union optimization can be assessed relative to Finn's (1998) setup with exogenous public hours and a single, competitive wage rate. In addition, the fiscal policy instruments will be specified as the shares of government purchases and investment in output, which allows the government to react to output. The presence of a union in the public sector will thus crowd out the other types of the government spending at the expense of the public sector wage bill, an effect not present in Fernandez-de-Cordoba *et al.* (2009, 2012). Additionally, in contrast to Fernandez-de-Cordoba *et al.* (2009, 2012), who model public employment as output-enhancing, public employment in this paper is a wasteful expenditure from a productive point of view.⁵ Lastly, a government's highly wasteful public wage bill spending is expected to amplify fluctuations in hours, as there will be no direct substitutability/complementarity between private and public hours. In other words, the allocative efficiency will decrease significantly, as a wasteful hour spent working in the public sector receives a higher return relative to a productive hour of work in the private sector.

The analysis in this paper is done at the country level, as taxation and government spending decisions are still to a great extent country-specific for individual EU member states.⁶ This approach differs from Fernandez-de-Cordoba *et al.* (2009, 2012), who analyze the Euro Area as a whole. Germany is the preferred choice for calibration in this paper, as it is the classical example of a large EU economy. Some of the features of the German economy include strong public sector unions, and a large and growing gap between public and private sector union-

⁵This modeling choice is used to reflect the view that the public sector bureaucracy's direct contribution to the national product in the economy is somewhat small.

⁶Furthermore, based on their extensive compilation of case studies, Ebbinghaus and Visser (2000) and Visser (2003) conclude that international unionism is weak, *i.e.* the influence of labor unions in Europe tends to be constrained to the respective countries's borders.

ization, as reported in *The Economist* (2011). Additionally, Germany has a public sector wage premium and public/private employment ratio similar to the EU average.

The study in this paper takes a much wider scope relative to Finn (1998) and at the same time is complementary to Fernandez-de-Cordoba *et al.* (2009, 2012). It includes a complete evaluation of an RBC model with optimizing public sector union, following the widely-accepted methodology in the RBC literature. The union model matches the cyclical fluctuations in the public and private sector labor markets.⁷ Lastly, endogenously-determined public wage and hours will be shown to add to the distortionary effect of contractionary tax reforms and produce significantly higher welfare losses. The union model requires larger changes in tax rates to achieve a pre-specified increase in tax revenue, as compared to Finn’s (1998) model with exogenous public sector hours. Thus, endogenous public hours are quantitatively important for fiscal policy evaluation. Ignoring the interaction between hours and wages leads to a significant underestimation of the welfare effect of tax regime changes.

The paper is organized as follows: Section 2 presents the model setup in the context of the relevant literature. Sections 3 explains the data used and model calibration, and Section 4 solves for the steady-state. Section 5 presents the model solution procedure, discusses the effects of different shocks and the impulse responses of variables across model. Section 6 simulates the competing models and evaluates their properties for the calibrations performed for Germany. Section 7 computes the long-run welfare costs of exogenous tax regime changes, both across models and across countries. Section 8 concludes.

2 Model setup

2.1 Description of the model:

There is a representative household, as well as a representative firm. The household owns the private physical capital and labor, which it supplies to the firm. Hours supplied in the

⁷Additionally, the union also compares well against the empirical autocorrelation and cross-correlation functions generated from an unrestricted Vector Auto Regression (VAR). These results are presented in a technical appendix, which is available upon request.

public sector are decided via a collective agreement between a union and the government. The perfectly-competitive firm produces output using labor, private and public capital. The government uses tax revenues from consumption expenditure, labor and capital income to finance: (1) government consumption, (2) government investment, (3) government transfers, and (4) the public wage bill. The wage rate and hours supplied in the public sector are determined by a utility-maximizing public sector union, as in Fernandez-de-Cordoba *et al.* (2009), subject to the government period budget constraint.

2.2 Households

There is an infinitely-lived representative household in the model economy, and no population growth. The household maximizes the following expected utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^h, G_t^c, N_t^h), \quad (2.2.1)$$

where E_0 is the expectation operator as of period 0; C_t^h , G_t^c and N_t^h are household's consumption, per household consumption of government services, and hours worked by the household at time t , respectively. The parameter β is the discount factor, $0 < \beta < 1$. The instantaneous utility function $U(., ., .)$ is increasing in each argument and satisfies the Inada conditions. Following Finn (1998), the CRRA form for utility is:

$$U(C_t^h, G_t^c, N_t^h) = \frac{[(C_t^h + \omega G_t^c)^\psi (1 - N_t^h)^{(1-\psi)}]^{(1-\alpha)} - 1}{1 - \alpha}, \quad (2.2.2)$$

where $(\alpha > 1)$. The parameter ψ is the weight of consumption in utility, $0 < \psi < 1$, and $0 < 1 - \psi < 1$ is the weight in the utility function that the household puts on leisure. Government consumption is a substitute to private consumption, and the degree of substitutability is measured by ω , where $0 \leq \omega \leq 1$.

The household has an endowment of one unit of time in each period t , which is split between work, N_t^h and leisure, L_t^h , so that

$$N_t^h + L_t^h = 1. \quad (2.2.3)$$

The household can supply hours of work in the public sector, N_t^{gh} , or in the private one, N_t^{ph} , with $N_t^h = N_t^{ph} + N_t^{gh}$. The wage rates per hour of work in private and public sector

are denoted by w_t^p and w_t^g , respectively. The household chooses N_t^{ph} only; public hours will be endogenously chosen by the government, so N_t^{gh} will be taken by the household as given, as in Fernandez-de-Cordoba *et al.* (2012).

The representative household saves by investing in private capital I_t^h . As an owner of capital, the household receives interest income $r_t K_t^{ph}$ from renting the capital to the firms; r_t is the return to private capital, and K_t^{ph} denotes private capital stock in the beginning of period t . As in Finn (1998), the household receives capital depreciation allowance in the amount of $\tau^k \delta^p K_t^{ph}$, where τ^k is the capital income tax rate and $0 < \delta^p < 1$ is the depreciation rate of private physical capital.

Finally, the household owns all firms in the economy, and receives all profit (Π_t^h) in the form of dividends. The household's budget constraint is

$$(1 + \tau^c)C_t^h + I_t^h \leq (1 - \tau^l)[w_t^p N_t^{ph} + w_t^g N_t^{gh}] + (1 - \tau^k)r_t K_t^{ph} + \tau^k \delta^p K_t^{ph} + G_t^t + \Pi_t^h, \quad (2.2.4)$$

where τ^c, τ^l are the proportional tax rates on consumption and labor income, respectively, and G_t^t is the per household transfer from the government.

The household's private physical capital evolves according to the following law of motion

$$K_{t+1}^{ph} = I_t^h + (1 - \delta^p)K_t^{ph}. \quad (2.2.5)$$

The representative household acts competitively by taking prices $\{w_t^p, r_t\}_{t=0}^\infty$, tax rates $\{\tau^c, \tau^l, \tau^k\}$, policy variables $\{w_t^g, N_t^{gh}, G_t^c, G_t^i, G_t^t\}_{t=0}^\infty$ as given, and chooses allocations $\{C_t^h, N_t^{ph}, I_t^h, K_{t+1}^{ph}\}_{t=0}^\infty$ to maximize Equation (2.2.1) subject to Equations (2.2.2)-(2.2.5), and initial condition for private physical capital, K_0^{hp} .

The optimality conditions from the household's problem, together with the transversality condition (TVC) for private physical capital, are as follows⁸

$$C_t: \left[(C_t^h + \omega G_t^c)^\psi (1 - N_t^h)^{(1-\psi)} \right]^{-\alpha} \psi (C_t^h + \omega G_t^c)^{\psi-1} (1 - N_t^h)^{(1-\psi)} = \Lambda_t (1 + \tau^c) \quad (2.2.6)$$

⁸Detailed derivations are provided in a companion Technical Appendix (available upon request).

$$N_t^p: \left[(C_t^h + \omega G_t^c)^\psi (1 - N_t^h)^{(1-\psi)} \right]^{-\alpha} (1 - \psi) \left[\frac{C_t^h + \omega G_t^c}{1 - N_t^h} \right]^\psi = \Lambda_t (1 - \tau^l) w_t^p \quad (2.2.7)$$

$$K_{t+1}^p: \beta E_t \Lambda_{t+1} \left[(1 - \tau^k) r_{t+1} + \tau^k \delta^p + (1 - \delta^p) \right] = \Lambda_t \quad (2.2.8)$$

$$\text{TVC: } \lim_{t \rightarrow \infty} \beta^t \Lambda_t K_{t+1}^p = 0, \quad (2.2.9)$$

where Λ_t is the Lagrange multiplier on the household's budget constraint. The household equates marginal utility from consumption with the marginal cost imposed on its budget. Private hours are chosen so that the disutility of an hour work in the private sector at the margin equals the after-tax return to labor. Next, the Euler equation describes the optimal capital accumulation rule. The last expression is the TVC, which guarantees that the model equilibrium is well-defined by ruling out explosive solution paths.

2.3 Firms

Following Finn (1998), there is also a representative private firm in the model economy. It produces a homogeneous final product using a production function that requires private and public physical capital, K_t^p , K_t^g respectively, and labor hours N_t^p . The production function is as follows

$$Y_t = A_t (N_t^p)^\theta (K_t^p)^{1-\theta} (K_t^g)^\nu, \quad (2.3.1)$$

where A_t measures the total factor productivity in period t ; $0 < \theta, (1 - \theta) < 1$ are the productivity of labor and private physical capital, respectively. Parameter $\nu \geq 0$ measures the degree of increasing returns to scale (IRS) that public capital has on output.

The representative firm acts competitively by taking prices $\{w_t^p, r_t\}_{t=0}^\infty$ as given. Accordingly, K_t^p , and N_t^p are chosen every period to maximize firm's static aggregate profit,

$$\Pi_t = A_t (N_t^p)^\theta (K_t^p)^{1-\theta} (K_t^g)^\nu - r_t K_t^p - w_t^p N_t^p. \quad (2.3.2)$$

In equilibrium, profit is zero. In addition, labor and capital receive their marginal products

$$w_t^p = \theta \frac{Y_t}{N_t^p}, \quad (2.3.3)$$

$$r_t = (1 - \theta) \frac{Y_t}{K_t^p}. \quad (2.3.4)$$

2.4 Government budget constraint

The government purchases goods, G_t^c , invests in public capital G_t^i , distributes transfers G_t^t , hires labor N_t^g , and sets the public sector wage rate w_t^g . Public capital evolves according to the following law of motion

$$K_{t+1}^g = G_t^i + (1 - \delta^g)K_t^g, \quad (2.4.1)$$

where $0 < \delta^g < 1$ is the linear depreciation rate on government physical capital.

Total government expenditure, $G_t^c + G_t^i + w_t^g N_t^g + G_t^t$, is financed by levying proportional taxes on consumption, capital and labor income. Thus, the government budget constraint is

$$G_t^c + G_t^i + w_t^g N_t^g + G_t^t = \tau^c C_t + \tau^k r_t K_t^p - \tau^k \delta^p K_t^p + \tau^l \left[w_t^p N_t^p + w_t^g N_t^g \right]. \quad (2.4.2)$$

Government takes market prices $\{w_t^p, r_t\}_{t=0}^\infty$ and allocations $\{N_t^p, K_t^p\}$ as given.

The following six policy instruments, $\{\tau^c, \tau^k, \tau^l, \frac{G_t^c}{Y_t}, \frac{G_t^i}{Y_t}, \frac{G_t^t}{Y_t}\}$, will be exogenously set. In particular, $\frac{G_t^c}{Y_t}, \frac{G_t^i}{Y_t}$ will follow stochastic processes. Thus, public consumption and investment will respond to both exogenous shocks and output. (K_{t+1}^g will be exogenously determined as well, subject to the initial condition K_0^g and the law of motion for G_t^i .) Government transfers-to-output ratio $G^{ty} \equiv \frac{G_t^t}{Y_t}$ will be fixed,⁹ but the level of public transfers will vary with output. All three tax rates $\{\tau^c, \tau^k, \tau^l\}$ will be kept constant. Finally, the pair $\{N_t^g, w_t^g\}$ will be determined as an optimal solution from a collective bargaining problem between the government and a public sector union, which is described in the next subsection.

2.5 Government sector union objective function

In contrast to Finn's (1998) model, which features a single wage rate w_t and exogenous public employment, modeled as an AR(1) process, here the two variables will be obtained as optimal choices from an explicit objective function maximization, as in Fernandez-de-Cordoba *et. al*

⁹The fixed government transfers/output ratio is to be interpreted as an "implied" one, as it will be set so that the model matches the long-run wage and employment ratios, as it will be shown in the following sections.

(2012):

$$\max_{w_t^g, N_t^g} \left[(N_t^g)^\rho + \eta (w_t^g)^\rho \right]^{1/\rho}, \quad (2.5.1)$$

where $\eta > 0$ is the relative weight put on wages, and ρ is the parameter determining the constant elasticity of substitution between wages and hours, $\frac{1}{1-\rho}$. Hence, the pair $\{N_t^g, w_t^g\}$ solves (2.5.1) s.t (2.4.1)-(2.4.2) and the processes for the other policy instruments.¹⁰

The interaction between the public sector union and the government is as follows: the wage bill in the public sector, modeled as a residual spending item that balances the budget constraint in every period, is distributed between wages and hours according to the union utility function (2.5.1) specified above. Additionally, government period budget constraint serves the role of a labor demand function, which will be subject to shocks, resulting from innovations to total factor productivity and the fiscal shares.¹¹ Now the problem in the public sector is a standard representation used in union literature, where a labor union maximizes utility, constrained by a stochastic labor demand curve. In addition to producing endogenous public wage and public hours, this optimization problem generates a public sector wage that features a positive premium over the private sector one. Therefore, at least part of this premium can be justified by the gains from unionization in the public sector. In equilibrium, a positive linear relation exists between the public wage rate and public sector hours ("a contract curve")

$$N_t^g = \eta^{\frac{1}{\rho}} w_t^g. \quad (2.5.2)$$

The contract curve defines the set of allocations $\{w_t^g, N_t^g\}$, generated as an outcome of the collective bargaining between the government and the union. Since the union optimizes over both the public wage and hours, the outcome is efficient. The solution pair is at the intersection point of the contract curve, and the labor demand curve (government budget constraint).

¹⁰The public sector union should be taken as an aggregation of smaller unions who operate at federal and state/local levels, who maximize the same objective function over local government period budget constraint. The coalition of workers is large at a regional level, and thus able to influence the public sector wage rate. Still, local unions are small relative to the size of the economy, hence w^p is taken as given. Nonetheless, both wage rates will be determined within the system, so there will be some feedback effect from public to private wage.

¹¹The balanced budget assumption is thus important in the model setup. Since the wage bill is a residual, if the wage rate is increased, then hours need to be decreased.

Next, Eq. (2.5.2) is plugged back into (2.4.2) to obtain a solution for the public sector wage:

$$w_t^g = \eta^{-\frac{1}{2\rho}} \left[\frac{\tau^c C_t + \tau^k r_t K_t^p - \tau^k \delta^p K_t + \tau^l w_t^p N_t^p - G_t^c - G_t^t - G_t^i}{1 - \tau^l} \right]^{\frac{1}{2}}. \quad (2.5.3)$$

Optimal public hours are obtained by substituting (18) into (17) to obtain

$$N_t^g = \eta^{\frac{1}{2\rho}} \left[\frac{\tau^c C_t + \tau^k r_t K_t^p - \tau^k \delta^p K_t + \tau^l w_t^p N_t^p - G_t^c - G_t^t - G_t^i}{1 - \tau^l} \right]^{\frac{1}{2}}. \quad (2.5.4)$$

Both public sector wage and hours will be negatively related to government consumption and investment, and positively related to tax revenue from consumption, capital income and private sector labor income. Public hours and the wage rate are directly affected by fiscal policy variables: a decrease in government consumption, for example, will have a direct positive effect on both public hours and wages, and thus on the household's income. Such effect are empirically observed in Lano, Perez, and Schuknecht (2008). In the model, the crowding-out effect of government spending will generate important differences from earlier literature. This makes it relevant for the analysis of the impulse responses to fiscal shares shocks and for the long-run welfare effects of fiscal policy. These effects will be discussed at length in the following sections.

2.6 Stochastic processes for the policy variables

The exogenous stochastic variables are the total factor productivity A_t , and the policy instruments $\frac{G_t^c}{Y_t}, \frac{G_t^i}{Y_t}$ are assumed to follow AR(1) processes in logs, in particular

$$\ln A_{t+1} = (1 - \rho_a) \ln A_0 + \rho_a \ln A_t + \epsilon_{t+1}^a, \quad (2.6.1)$$

where $A_0 = A > 0$ is steady-state level of the total factor productivity process, $0 < \rho_a < 1$ is the first-order autoregressive persistence parameter and $\epsilon_t^a \sim iidN(0, \sigma_a^2)$ are random shocks to the total factor productivity progress. Hence, the innovations ϵ_t^a represent unexpected changes in the total factor productivity process.

The stochastic process for the government consumption/output share $\{\frac{G_t^c}{Y_t}\}$ is

$$\ln \left(\frac{G_{t+1}^c}{Y_{t+1}} \right) = (1 - \rho_c) \ln \left(\frac{G_0^c}{Y_0} \right) + \rho_c \ln \left(\frac{G_t^c}{Y_t} \right) + \epsilon_{t+1}^c, \quad (2.6.2)$$

or

$$\ln G_{t+1}^{cy} = (1 - \rho_c) \ln G_0^{cy} + \rho_c \ln G_t^{cy} + \epsilon_{t+1}^c, \quad (2.6.3)$$

where $\frac{G_0^c}{Y_0} > 0$ is the steady-state public consumption/output ratio, $0 < \rho^c < 1$ is the first-order autoregressive persistence parameter and $\epsilon_t^c \sim iidN(0, \sigma_c^2)$ are random shocks to government consumption/output share. the innovations ϵ_t^c represent unexpected changes in government consumption/output share.

The stochastic process followed by the government investment/output share $\{\frac{G_t^i}{Y_t}\}$ is

$$\ln \left(\frac{G_{t+1}^i}{Y_{t+1}} \right) = (1 - \rho_i) \ln \left(\frac{G_0^i}{Y_0} \right) + \rho_i \ln \left(\frac{G_t^i}{Y_t} \right) + \epsilon_{t+1}^i, \quad (2.6.4)$$

or

$$\ln G_{t+1}^{iy} = (1 - \rho_i) \ln G_0^{iy} + \rho_i \ln G_t^{iy} + \epsilon_{t+1}^i, \quad (2.6.5)$$

where $\frac{G_0^i}{Y_0} > 0$ is the steady-state public investment/output ratio, $0 < \rho^i < 1$ is the first-order autoregressive persistence parameter and $\epsilon_t^i \sim iidN(0, \sigma_i^2)$ are random shocks to government investment/output share. the innovations ϵ_t^i represent unexpected changes in government investment/output share.

Additionally, in Finn (1998), public hours will also follow an AR(1) process:

$$\ln N_{t+1}^g = (1 - \rho_n) \ln N_0^g + \rho_n \ln N_t^g + \epsilon_{t+1}^n, \quad (2.6.6)$$

where $N_0^g = N^g > 0$ is the steady-state public employment, $0 < \rho^n < 1$ is the first-order autoregressive persistence parameter and $\epsilon_t^n \sim iidN(0, \sigma_n^2)$ are random shocks to government employment. the innovations ϵ_t^n represent unexpected changes in government employment.

2.7 Decentralized competitive equilibrium

Given the fixed value of government transfers/output ratio G^{ty} , the exogenous processes followed by $\{A_t, G_t^{cy}, G_t^{iy}\}_{t=0}^\infty$, tax rates $\{\tau^c, \tau^l, \tau^k\}$, and initial conditions for the state variables

$\{A_0, G_0^{cy}, G_0^{iy}, K_0^{ph}, K_0^g\}$, a decentralized competitive equilibrium (DCE) is defined to be a sequence of allocations $\{C_t^h, N_t^{ph}, N_t^{gh}, I_t^{ph}, K_{t+1}^{ph}, K_{t+1}^g\} \forall h$, and prices $\{r_t, w_t^p, w_t^g\}_{t=0}^\infty$ such that (i) the representative household maximizes utility; (ii) the stand-in firm maximizes profit every period; (iii) government objective function is maximized subject to the government budget constraint being satisfied in each time period; (iv) all markets clear.

3 Data and model calibration

Both the model in this paper and Finn (1998) are calibrated for German data at annual frequency. Both the data set and steady-state DCE relationships of the models will be used to set the parameter values, in order to replicate certain features of the reference economy. In German data, $n^g/n^p = 0.17$, and $w^g/w^p = 1.20$. The weight on public wages, η , as well as government transfers/output ratio g^{ty} will be set so that the steady-state wage and employment ratios in the model match the corresponding data averages. The curvature parameter of the union's CES maximization function was set to a standard value, $\rho = -1$, as in Fernandez-de-Cordoba *et al.* (2010).¹² The average effective tax rates in EU countries were obtained from McDaniel's (2009) dataset.¹³ Over the period studied, the German economy is characterized by a low average capital income tax rate, $\tau^k = 0.16$, and a relatively high labor income tax rate, $\tau^l = 0.409$. The labor share, $\theta = 0.71$, was computed as the average ratio of compensation of employees in total output. Private and public capital depreciation rates, $\delta^p = 0.082$ and $\delta^g = 0.037$, respectively, were approximated from the EU Klems Database as the average ratio of gross fixed capital formation and the corresponding value of fixed capital stock (both in constant 1995 prices) over the 1970-2007. The discount rate $\beta = 0.973$ was calibrated from the steady-state Euler equation. The parameter describing the curvature of the household's utility function was set to $\alpha = 2$. As in Kydland (1995), the weight on consumption, $\psi = 0.296$, was set equal to the average steady-state total hours of work in data as a share of total hours available. Parameter value $\omega = 0.099$, was calibrated using the MRS and data averages. The public capital share value, $\nu = 0.0233$, is set equal

¹²A robustness check on the curvature parameter was performed with $\rho = [-5, -4, -3, -2, -0.5]$, which did not produce any significant difference in the results obtained, as parameter η adjusted accordingly.

¹³McDaniel's approach was preferred to the one used by Mendoza *et al.* (1984) and the subsequent updates due to the more careful treatment of property and import taxes.

to the average public investment/output ratio. Persistence and innovation volatility of the stochastic processes, as well as the AR(1) process for public employment in Finn (1998), were estimated using OLS.¹⁴ Table 2 below summarizes the model parameters for Germany.

Table 2: Model Parameters

Param.	Value	Definition	Source
β	0.973	Discount factor	Calibrated
θ	0.710	Labor income share	Data average
δ^p	0.082	Depreciation rate on private capital	Data average
δ^g	0.037	Depreciation rate on government capital	Data average
α	2.000	Curvature parameter of the utility function	Set
ψ	0.296	Weight on consumption in utility	Set
ν	0.023	Degree of increasing returns to scale of public capital	Set
ρ	-1.000	Curvature parameter of the union's maximization function	Set
ω	0.099	Weight on government services in household's consumption	Calibrated
τ^c	0.148	Effective tax rate on consumption	Data average
τ^k	0.160	Effective tax rate on capital income	Data average
τ^l	0.409	Effective tax rate on labor income	Data average
A	1.000	Steady-state level of total factor productivity	Set
ρ^a	0.943	AR(1) parameter total factor productivity	Estimated
ρ^c	0.976	AR(1) parameter government consumption/output ratio	Estimated
ρ^i	0.853	AR(1) parameter government investment/output ratio	Estimated
ρ^n	0.915	AR(1) parameter government employment (Finn's model)	Estimated
σ_a	0.013	SD of total factor productivity innovation	Estimated
σ_c	0.016	SD of government consumption/output share innovation	Estimated
σ_i	0.023	SD of government investment/output share innovation	Estimated
σ_n	0.016	SD of government employment innovation (Finn's model)	Estimated

¹⁴Total factor productivity parameters, $\rho^a = 0.943$ and $\sigma^a = 0.013$, were estimated using the logged and linearly detrended Solow residual series, obtained from the model's aggregate production function and data.

4 Solving for the steady-state

Once model parameters were obtained, the unique steady-state of the system was computed numerically for the Germany-calibrated model. Results are reported in Table 3 below.

Table 3: Data averages and long-run solution

	Description	GE Data	Finn GE	Union GE
c/y	Consumption-to-output ratio	0.590	0.576	0.576
i/y	Investment-to-output ratio	0.210	0.212	0.212
g^c/y	Gov't consumption-to-output ratio	0.189	0.189	0.189
g^i/y	Gov't investment-to-output ratio	0.023	0.023	0.023
g^t/y	Gov't transfers-to-output ratio	0.170	0.047	0.047
k^p/y	Private capital-to-output ratio	2.350	2.350	2.350
k^g/y	Public capital-to-output ratio	0.630	0.630	0.630
$w^p n^p/y$	Priv. labor share in output	0.710	0.710	0.710
$w^g n^g/y$	Public wage bill-to-output ratio	0.130	0.146	0.145
$r k^p/y$	Capital share in output	0.290	0.290	0.290
n^g/n^p	Public-private employment ratio	0.170	0.205	0.170
w^g/w^p	Public-private employment ratio	1.200	1.000	1.200
n^p	Private sector employment	0.253	0.210	0.211
n^g	Public sector employment	0.043	0.043	0.036
η	Relative weight on public wage rate	-	N/A	31.63
$\tilde{r}$	After-tax net return to capital	0.036	0.028	0.028

Note that the public transfers share, g^{ty} , and the relative weight attached to public wages, η are set so that the wage and hours ratios match the corresponding data averages.¹⁵ In addition, the steady-state values for hours in data are approximated by splitting the average hours, expressed as a share of total available hours of work, according to the average hours

¹⁵In this model, the implied η cannot be interpreted directly, but should rather be regarded as containing a scaling factor, as n^g and w^g differ in magnitude (due to the normalization of the time endowment to unity). Therefore, once this is accounted for, i.e. when η is normalized by w^g/n^g , the "corrected" parameter, $\bar{\eta}$, equals 0.998 for Germany. In other words, wage rate and hours are equally-weighted in the generalized Stone-Geary union utility function, as typically assumed in the trade union literature.

ratio.¹⁶ In Finn (1998), public hours are set to match the corresponding data average.

Overall, the long-run solutions of both models are good approximations to the data averages. The steady-state real after-tax real interest rate, net of depreciation, delivered by the two models, *i.e.* $\tilde{r} = (1 - \tau^k)(r - \delta^p)$, is close to the average real interest rate on 10-year bonds, which is taken as a proxy for the return to private physical capital in the model. Both models capture the public wage bill share of GDP in Germany. Furthermore, public sector labor income is also a significant share relative to capital in Germany.

Across models, several important differences can be noted: in steady-state, Finn (1998) produces a slightly higher level of total hours and lower public sector wages, compared to the model with the public sector union. This is due to the additional constraint imposed in the union model on the steady-state public-private hours and wages ratio. Model dynamics out of the steady-state are investigated in the following section.

5 Model solution and impulse responses

Since there is no closed-form general solution for the model in this paper, a typical approach followed in the RBC literature is to log-linearize the stationary DCE equations around the steady state, where $\hat{x}_t = \ln x_t - \ln x$, and then solve the linearized version of the model. The linearized DCE system can be represented in the form of first-order linear stochastic difference equations as in King, Plosser and Rebello (1999):

$$\mathbf{A}E_{t+1}\hat{\mathbf{x}}_t = \mathbf{B}\hat{\mathbf{x}}_t + \mathbf{C}\epsilon_t \quad (5.0.1)$$

where $\mathbf{A}, \mathbf{B}, \mathbf{C}$ are coefficient matrices, ϵ_t is a matrix of innovations, and $\hat{\mathbf{x}}_t$ is the stacked vector of state (also called 'predetermined') variables, $\hat{\mathbf{s}}_t = \left[\hat{a}_t \quad \hat{g}_t^{cy} \quad \hat{g}_t^{iy} \quad \hat{k}_t^p \quad \hat{k}_t^g \right]'$, and control variables, $\hat{\mathbf{z}}_t = \left[\hat{y}_t \quad \hat{c}_t \quad \hat{i}_t \quad \hat{n}_t \quad \hat{n}_t^p \quad \hat{n}_t^g \quad \hat{w}_t^p \quad \hat{w}_t^g \quad \hat{\lambda}_t \quad \hat{g}_t^c \quad \hat{g}_t^i \quad \hat{g}_t^t \quad \hat{r}w_t \quad \hat{r}l_t \right]'$. Klein's (2000) generalized eigenvalue decomposition algorithm was used to solve the model.

¹⁶In this way hours/employment data averages are made comparable in magnitude with the corresponding theoretical variables in the union model.

Using the model solution, the impulse response functions (IRFs) were computed to analyze the transitional dynamics of model variables to a surprise innovation to either productivity, or government consumption. The effects of total factor productivity (TFP) and fiscal shocks to the government purchases in a model with public sector union are different compared to Finn (1998), particularly when the behavior of labor market variables and the labor reallocation is given close scrutiny.¹⁷

5.1 The Effect of a positive productivity shock

Figure 1 shows the impact of a 1% surprise TFP innovation on the economy with public sector union and Finn’s setup. The impulse responses are expressed in log-deviation from the variables’ original steady-states in the model economy calibrated to annual German data. There are two main channels through which the TFP shock affects the model economy. A higher TFP increases output directly upon impact. This constitutes a positive wealth effect, as there is a higher availability of final goods, which could be used for private and public consumption, as well as investment. From the rules for the government spending, investment and transfers in levels, a higher output translates into higher level of expenditure in each of the three categories. In turn, there is also a feedback effect from government investment to output through public capital, which comes with a one-period lag. This indirect effect is quite small. Meanwhile, the positive TFP shock increases both the marginal product of capital and labor, hence the real interest rate (not pictured) and the private wage rate increase. The household responds to the price signals and supplies more hours in the private sector, as well as increasing investment. This increase is also driven from both the intertemporal consumption smoothing and the intra-temporal substitution between private consumption and leisure. In terms of the labor-leisure trade-off, the income effect (“work more”) produced by the increase in the private wage dominates the substitution effect (“work less”). Furthermore, the increase of private hours expands output even further, and thus both output and government spending categories increase more than the amount of the shock upon impact. Over time, as private physical capital stock accumulates, marginal product of capital falls, which decreases the incentive to invest. In the long-run, all variables return to their old

¹⁷IRFs for a public investment share shock are quantitatively small, and are thus not presented here. Those are available upon request.

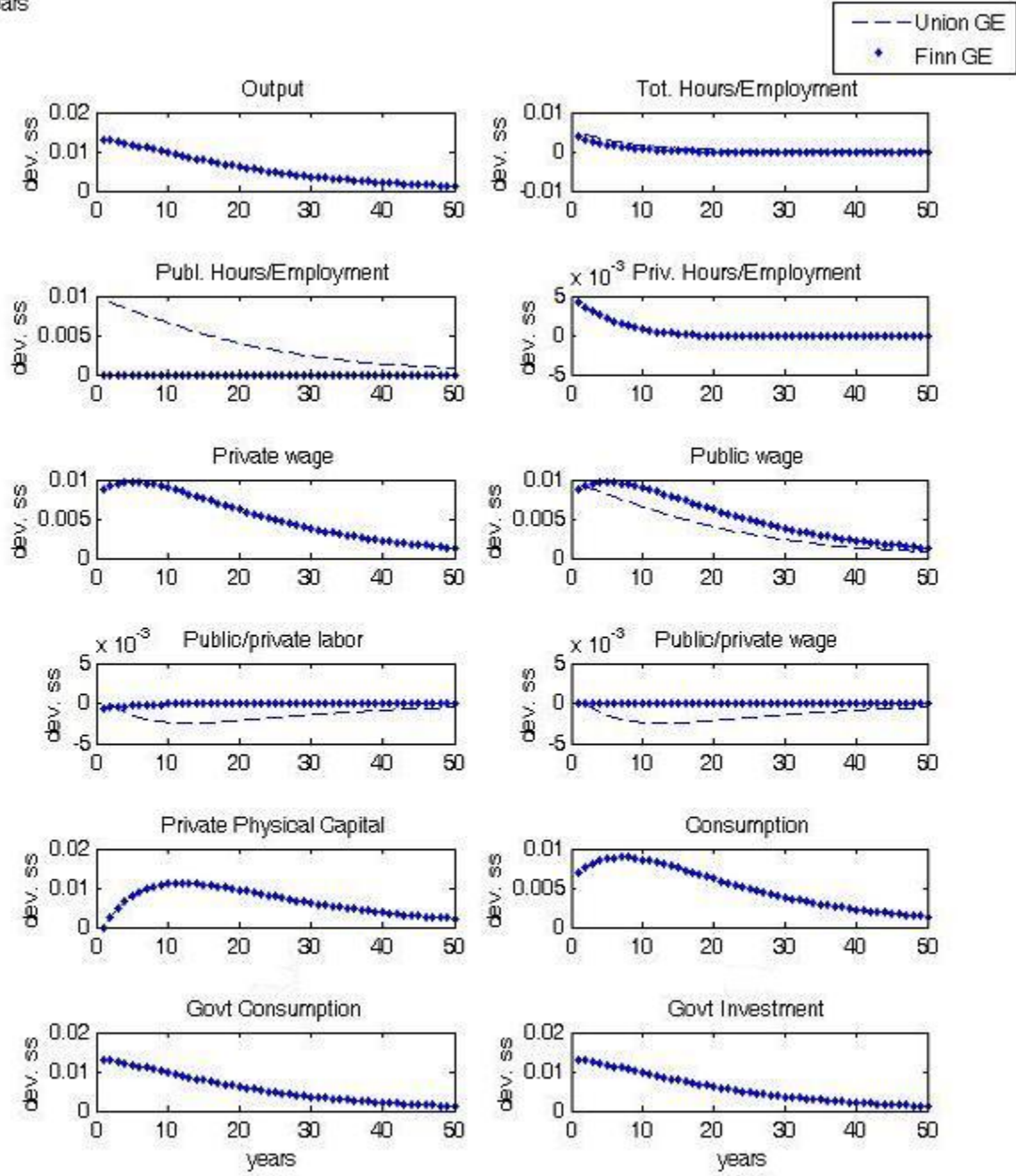
steady-state values. Due to the highly-persistent TFP process, the effect of the shock is still present after 50 periods.

An observational equivalence is noted in the responses of most of the model variables across the two models. Public sector labor dynamics, however, is quite distinct: In Finn (1998), public hours stay fixed at their steady-state, and public wage transition is identical to the private wage one. In the model with collective bargaining, however, there is the additional effect of an increase in productivity leading to an increase in income and consumption. Higher income and consumption lead to larger tax revenue. The growth in government revenue exceeds the increase in the fiscal spending instruments; therefore, the additional funds available for the wage bill lead to an expansion in both public sector wage and hours. The effect on total hours in Germany is very small.¹⁸ In addition, the model with collective bargaining in this paper generates an interesting dynamics in the wage and hours ratio, which is not present in Finn (1998). The two wage rates, as well as the two types of hours move together, making the model consistent with the empirical evidence presented in Lamo, Perez and Schuknecht (2007, 2008).

Overall, the endogenous public sector hours model shows an important difference in the composition of household's labor income with the public sector share increasing at the expense of private sector labor income. At aggregate level, however, this distributional effect disperses, as output and consumption dynamics are identical across models. Another important observation to make is that the TFP shocks, being the main driving force in the union model, induce pro-cyclical behavior in public wage and hours. In the German model economy, the shock effects are smaller and variables reach their peak response much more rapidly. This means the impulse effect wears off much faster but the transition period can still take up to 100 years. This illustrates the important long-run effects of TFP shocks in the labor markets, and particularly on the wages- and hours ratios.

¹⁸Still, the increase in hours is much greater in magnitude compared to the responses reported in Fernandez-de-Cordoba *et al.* (2009, 2010).

Figure 1: Impulse Responses to a positive 1% productivity shock in Germany
years

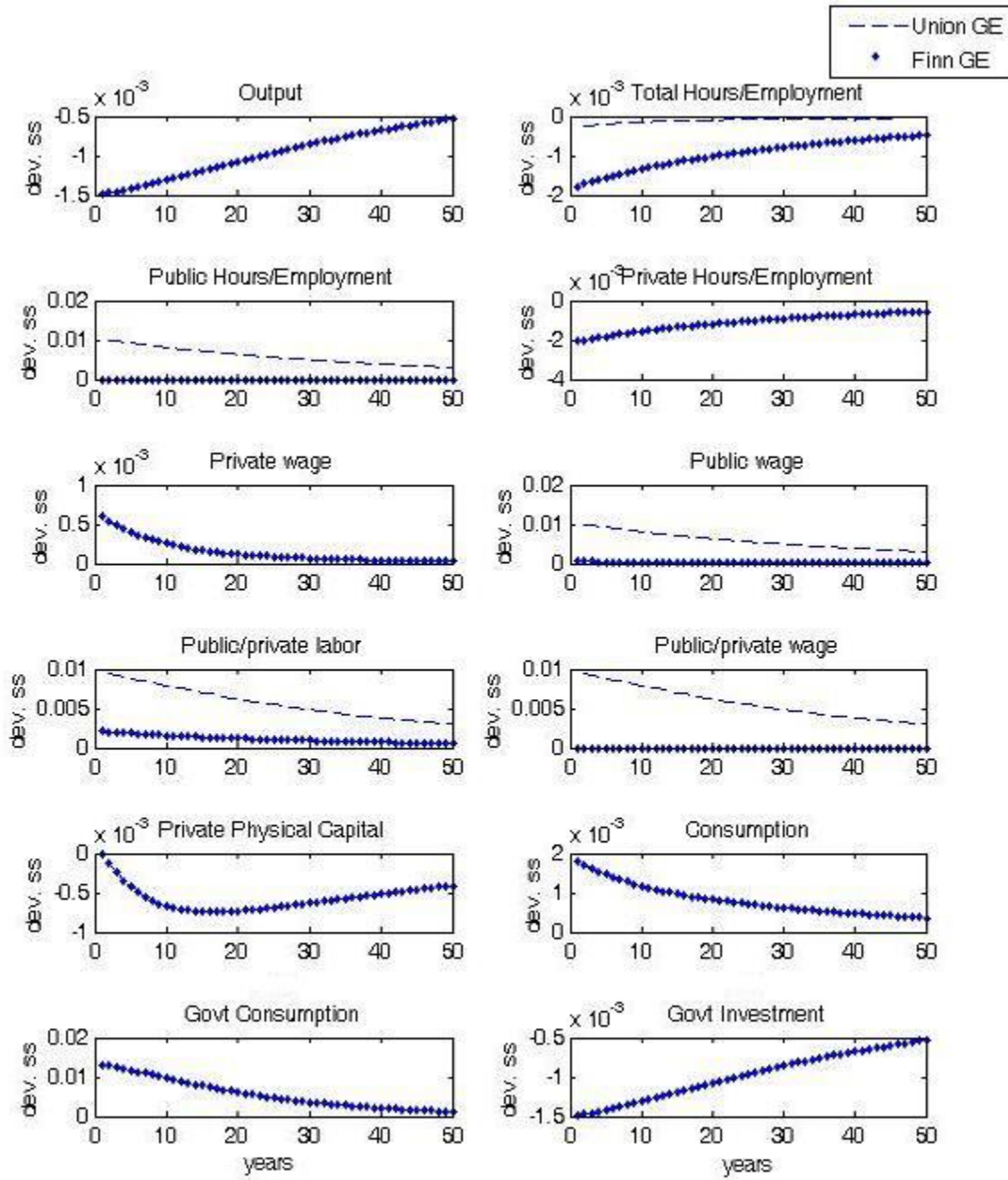


5.2 The effect of a negative government consumption share shock

The second scenario is an exogenous restrictive fiscal policy, which is an unexpected decrease in the government consumption/output ratio. The impulse response functions for this scenario are reported in Figure 2. The results are similar to those obtained from a standard RBC model. The plots show that a negative government consumption shock partially crowds-in private consumption, as public consumption is only an imperfect substitute for private consumption from the household's point of view. This creates a significant positive welfare effect in the model economy as the decrease in the government consumption ratio frees additional resources that could be directed to private use. The increase in consumption at the expense of a drop in investment, triggers a decrease in private sector hours through the marginal rate of substitution between consumption and leisure. In other words, the increase in consumption, resulting from the positive wealth effect, decreases the need to supply labor, so the household enjoys more leisure. The decrease in labor input leads to a fall in output, and an increase in the private wage. Since government expenditure categories follow output, public consumption, investment, and government transfers (not presented) also fall. Over time, all variables return to their old-steady states.

Those common responses are typical in the RBC literature but in the presence of a union in the public sector, the fall in labor supply leads to a lower tax revenue, while the increase in consumption increases the tax revenue. The other spending categories also decrease, thus leaving more funds available for the public sector wage bill. The effect on public hours is very pronounced, when total hours responses are compared across models. Furthermore, the model with public sector union generates a realistic labor reallocation from private to public sector meaning that in times of fiscal restraint, government jobs become more attractive. In a model with exogenous public employment, public sector hours stay fixed at their steady-state value and do not respond to fiscal shocks. The effect of a decrease in the government consumption/output ratio in Finn (1998) leads to a significant underestimation in total hours. Additionally, the model with public sector union could again address the relative labor income share evolution, which is the product of the public-private wage and employment ratios. The results in this subsection differ from those in Fernandez-de-Cordoba *et al.* (2009, 2010) in important ways: The negative shock to the fiscal instruments

Figure 2: Impulse Responses to a negative 1% government consumption/output share shock in Germany



creates a substitution effect and leads to the crowding-in of the public wage bill. In other words, even under a regime of fiscal tightening, public employment and the public wage are increased, *i.e.* shocks to the government consumption share make public wage and hours behave counter-cyclically.

6 Model simulation and goodness-of-fit evaluation

This section compares the theoretical second moments of the simulated data series with their empirical counterparts, with special attention paid to the behavior of public sector hours and wages. Table 4 on the next page summarizes the empirical and simulated business cycle statistics for the two models calibrated for Germany.¹⁹

In the German data, relative consumption volatility exceeds one, as the available series does not provide a breakdown into consumption of non-durables and consumption of durables. Durable products behave like investment, and vary much more than non-durables, while model consumption corresponds to non-durable consumption. Since a major force in all the three models is consumption smoothing, as dictated by the Euler equation, both models under-predict consumption volatility and investment variability. Across models, private sector employment and private wage also vary less compared to data. Total employment in German data varies less than either private or public employment due to the smaller variation in the number of self-employed individuals. It is evident from Table 5 that the model with public sector union underestimates public wage volatility, but matches public employment quite well. Finn’s model captures the volatility of public employment due to the fact that it is modeled as an exogenous stochastic process to mimic public hours time series behavior.

Both models capture the high contemporaneous correlations of main variables with out-

¹⁹Using the model solutions, shock series were added to produce simulated data series. The length of the draws for the series of innovations was 138, and the simulation was replicated 1000 times. Natural logarithms were taken, and then all series were run through the Hodrick-Prescott filter with a smoothing parameter equal to 100. The first 100 observations were then excluded, and the average standard deviation of each variable and its correlation with output were estimated across the 1000 replications.

Table 4: Business Cycle Statistics Germany, 1970-2007

	GE Data	Finn (1998)	Public Sector Union
$\sigma(y)$	0.0154	0.0165	0.0165
$\sigma(c)/\sigma(y)$	1.11	0.56 [0.49,0.62]	0.56 [0.49,0.62]
$\sigma(i)/\sigma(y)$	3.57	2.30 [2.24,2.36]	2.30 [2.24,2.36]
$\sigma(n^p)/\sigma(y)$	1.05	0.45 [0.40,0.50]	0.45 [0.40,0.49]
$\sigma(n^g)/\sigma(y)$	1.06	0.91 [0.69,1.13]	1.27 [0.98,1.56]
$\sigma(n)/\sigma(y)$	0.73	0.38 [0.33,0.43]	0.39 [0.38,0.40]
$\sigma(w^p)/\sigma(y)$	1.16	0.63 [0.59,0.68]	0.63 [0.59,0.68]
$\sigma(w^g)/\sigma(y)$	3.50	0.63 [0.59,0.68]	1.19 [0.92,1.47]
$corr(c, y)$	0.80	0.85 [0.79,0.92]	0.85 [0.79,0.92]
$corr(i, y)$	0.85	0.99 [0.98,0.99]	0.99 [0.98,0.99]
$corr(n^p, y)$	0.60	0.89 [0.84,0.93]	0.89 [0.85,0.94]
$corr(n^g, y)$	0.11	-0.05 [-0.29,0.20]	0.19 [0.04,0.43]
$corr(n, y)$	0.60	0.84 [0.78,0.91]	0.97 [0.97,0.98]
$corr(w^p, y)$	0.60	0.95 [0.92,0.97]	0.94 [0.93,0.97]
$corr(w^g, y)$	0.35	0.95 [0.92,0.97]	0.19 [0.04,0.43]
$corr(n, n^p)$	0.92	0.90 [0.86,0.95]	0.88 [0.79,0.92]
$corr(n, n^g)$	0.43	0.28 [0.06, 0.51]	0.27 [0.05,0.49]
$corr(n^p, n^g)$	0.12	-0.15 [-0.38,0.08]	-0.21 [-0.44,0.02]
$corr(n^p, w^p)$	0.21	0.70 [0.59,0.81]	0.71 [0.61,0.81]
$corr(n^g, w^g)$	-0.38	0.03 [-0.22,0.28]	1.00 [1.00,1.00]
$corr(n^g, w^p)$	0.20	0.03 [-0.22,0.28]	0.45 [0.26,0.64]
$corr(n^p, w^g)$	0.34	0.70 [0.59,0.81]	-0.21 [-0.44,0.02]
$corr(w^p, w^g)$	0.48	1.00 [1.00,1.00]	0.45 [0.26,0.65]

put relatively well. Moreover, public sector variables are also pro-cyclical, but not as much as the models predict: Finn (1998) even predicts that public employment is countercyclical. Nevertheless, the model with the public union captures the co-movement between labor market variables, as well as their contemporaneous correlations with output quite well, compared to the alternative. The German data, as well as the model with public sector

union, provide some support to the "private sector wage-leader" hypothesis: that public sector wages follows those in the private sector but only moderately so. The dimension where the union model fails, however, is the correlation between public sector hours and wages: in the German data, it is negative, while the union model predicts a perfect positive linear relationship. The reason is that the empirical correlation can be interpreted as showing the net effect of supply and demand factors, while the model concentrates exclusively on the supply-side forces. Next, the empirical correlation between wages also well-captured by the model with collective bargaining. In other words, empirical public sector wage follows the private sector wage to a much lesser degree. A failure of the model with public sector union is the predicted negative correlation between the two types of hours.²⁰ Furthermore, it is a well-known fact (e.g. Prescott 1986, Hansen 1992) that the RBC model captures private sector labor market dynamics only imperfectly.

Overall, the model with the public sector union captures the labor market dynamics in Germany, addressing dimensions that were ignored in earlier RBC models. Thus, an optimizing union in the public sector proves to be an important ingredient in RBC models when studying European labor markets with strong public sector unions. To assess the welfare cost of fiscal policy in the presence of public sector union, several fiscal experiments were performed and are reported in the following section.

7 Welfare evaluation of fiscal regime changes

The goal of this section is to quantify the importance of endogenously-determined public sector hours for fiscal policy, relative to Finn's setup with exogenously-fixed public hours. Additionally, the explicit welfare analysis complements earlier studies in Finn (1998) and Fernandez-de-Cordoba *et al.* (2009, 2012). To understand the adjustment mechanisms after an exogenous change in fiscal policy, each tax rate in the two models is varied over the $[0, 1]$ interval. Since all three tax rates were exogenously-specified, Schmitt-Grohe and Uribe (1997) show that for a wide class of RBC models, and plausible values for model parameters,

²⁰To a certain extent, this is an artifact of the way fiscal instruments were specified. The prediction of the model along this dimension greatly improves if government consumption and investment follow AR(1) processes in levels, and thus do not react to output.

a unique long-run solution exists. When tax rates are plotted against tax revenues, Laffer curves (Laffer 1974) appear: in both Finn and the public sector union model, an inverted U-shape relationship is observed between labor and capital income tax rates and total tax revenues. Thus, there are pairs of tax rates that generate the same level of tax revenue. In general, increasing tax rates could lead to either an increase or a decrease in total tax revenue, depending on which side of the Laffer curve the economy is situated. For the German model economy, however, both setups place Germany on the left side of the labor and capital tax Laffer curve, as seen in Figs. 3-4. Furthermore, a change in a tax rate affects the tax receipts from other tax bases as well, by influencing steady-state allocations and prices. Therefore, to gain an additional insight of the effect of fiscal policy in the steady state, total tax revenue is broken down into individual tax revenues corresponding to the tax bases, and plotted as a function of each individual tax rate in Figs. 3-5, for both the public union model and Finn.

The shape of the capital tax Laffer curve, for example, presents an interesting case: an increase in τ^k leads to a negligible marginal increase in total tax revenue, since total tax revenue is essentially flat in the $\tau^k \in [0, 0.5]$ range, and for $\tau^k \in [0.5, 1]$ total revenue is negatively related to capital income tax rate.²¹ The German economy features a low rate of capital income taxation, $\tau^k = 0.16$, thus the economy is situated safely away from the downward sloping segment of the Laffer curve. The reason for the flat Laffer curve is clearly seen from the breakdown in individual tax revenues as a function of capital income tax rate: All increases in capital income tax revenue are offset by corresponding decreases in labor income and consumption tax revenue. Since τ^c and τ^l are held fixed while τ^k is varied, the fall in labor income and consumption tax revenue is entirely driven by the shrinking tax bases. Across models, union framework features only slightly higher capital income and consumption revenue, and lower labor income tax revenue for each τ^k , as compared to Finn's setup.

On the other hand, labor income tax rate places Germany much closer to the peak of the labor tax Laffer curve, but still far away from the downward-sloping segment. Thus, the

²¹Uhlig and Trabandt (2010) find a similarly-shaped capital tax Laffer curve in an RBC model without public employment, calibrated to the EU-15 data.

government could increase tax revenue by increasing τ^l . The computed total tax revenue-maximizing τ^l is approximately 50% in the union model, and 55% in Finn. As demonstrated in Fig. 4, the difference in computed total tax revenue with respect to labor income tax in the union model and Finn is due to the difference in the steady-state public and private hours, as well as the wage rates in the two models: Finn's model, featuring a single wage rate and fixed public employment, generates both a higher total tax revenue and a higher labor income tax revenue Laffer curve, as compared to the union model.

Lastly, for the consumption tax rate, no Laffer curve is observed: within a realistic range, Fig. 5 shows no negative relationship between τ^c and tax revenue.²² Across models, the exogenous public hours in Finn produce a slightly flatter total tax revenue curve as a function of τ^c . In particular, the important difference across the setups is a steeper labor income tax revenue curve in the union model vs. a flatter labor income tax revenue curve in Finn's model. The slope of the labor tax revenue curve is determined by the elasticity of hours with respect to changes in the tax rate. In both models, a higher τ^c decreases the labor wedge, $(1 - \tau^l)/(1 + \tau^c)$. However, the response in hours is larger in the case of the union model, which features endogenous public sector hours, as compared to Finn's setup, where n^g is held.

After characterizing and comparing the shapes of the Laffer curves in both models, this section proceeds to welfare-evaluate the effects of different tax regimes. This is achieved through several normalized fiscal policy experiments. In all of the experiments, a combination of tax rate changes will be specified so that total tax revenue is kept constant. The general usefulness of this approach is that it separates tax and spending issues. In the framework considered in this paper, however, public sector labor income appears on both

²²The reason for this is as follows: In the model parameterizations $\alpha > 1$, thus the income effect dominates the substitution effect: when τ^c increases, labor supply and capital stock increase while consumption falls. Note that the increase in private hours and capital, driven by the increase in consumption tax rate does not translate into an increase in the corresponding tax revenue category. In addition, a higher τ^c leads to lower steady-state consumption, but a higher consumption revenue. As argued in Trabandt and Uhlig (2010), a consumption tax Laffer curve arises if $\alpha < 1$, so that after an increase in τ^c , the substitution effect dominates the income effect and hours and capital stock fall together with consumption. In the union model, public employment also falls, driven by the fall in tax revenue. In the borderline case, when $\alpha = 1$ (log-utility), the two effects offset one another. Again, no consumption tax Laffer curve occurs.

Figure 3: Capital tax Laffer curve

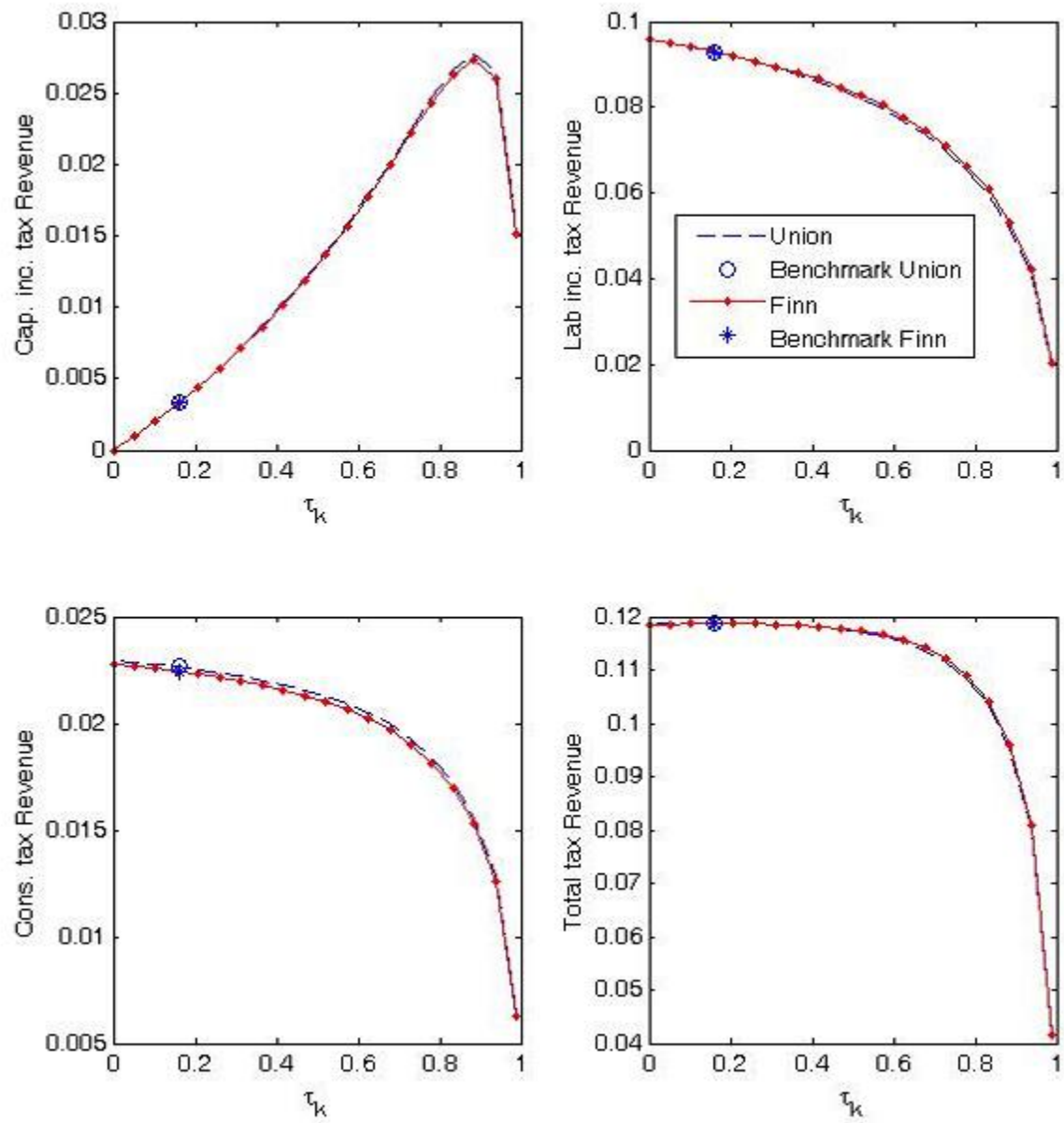


Figure 4: Labor tax Laffer curve

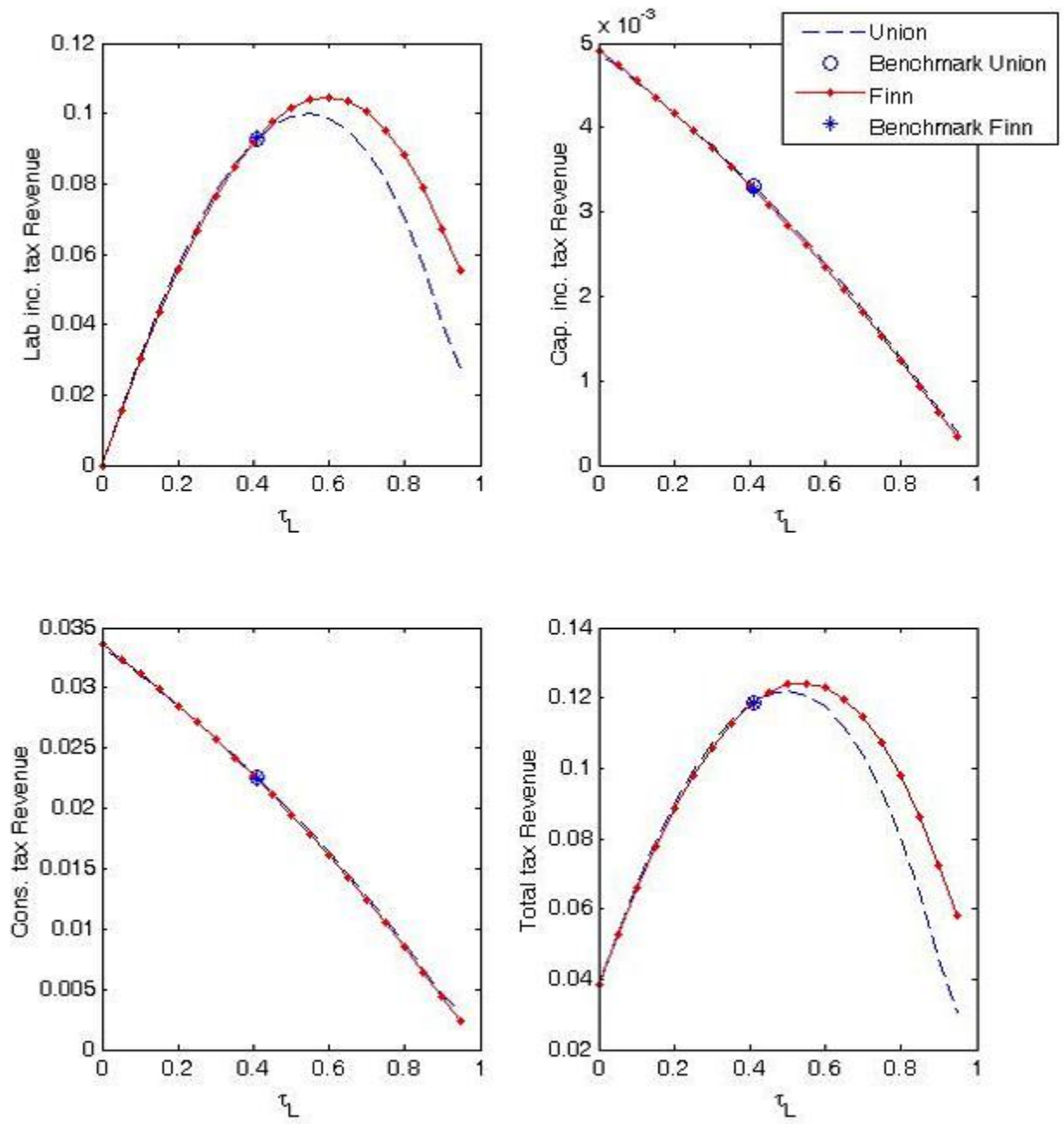
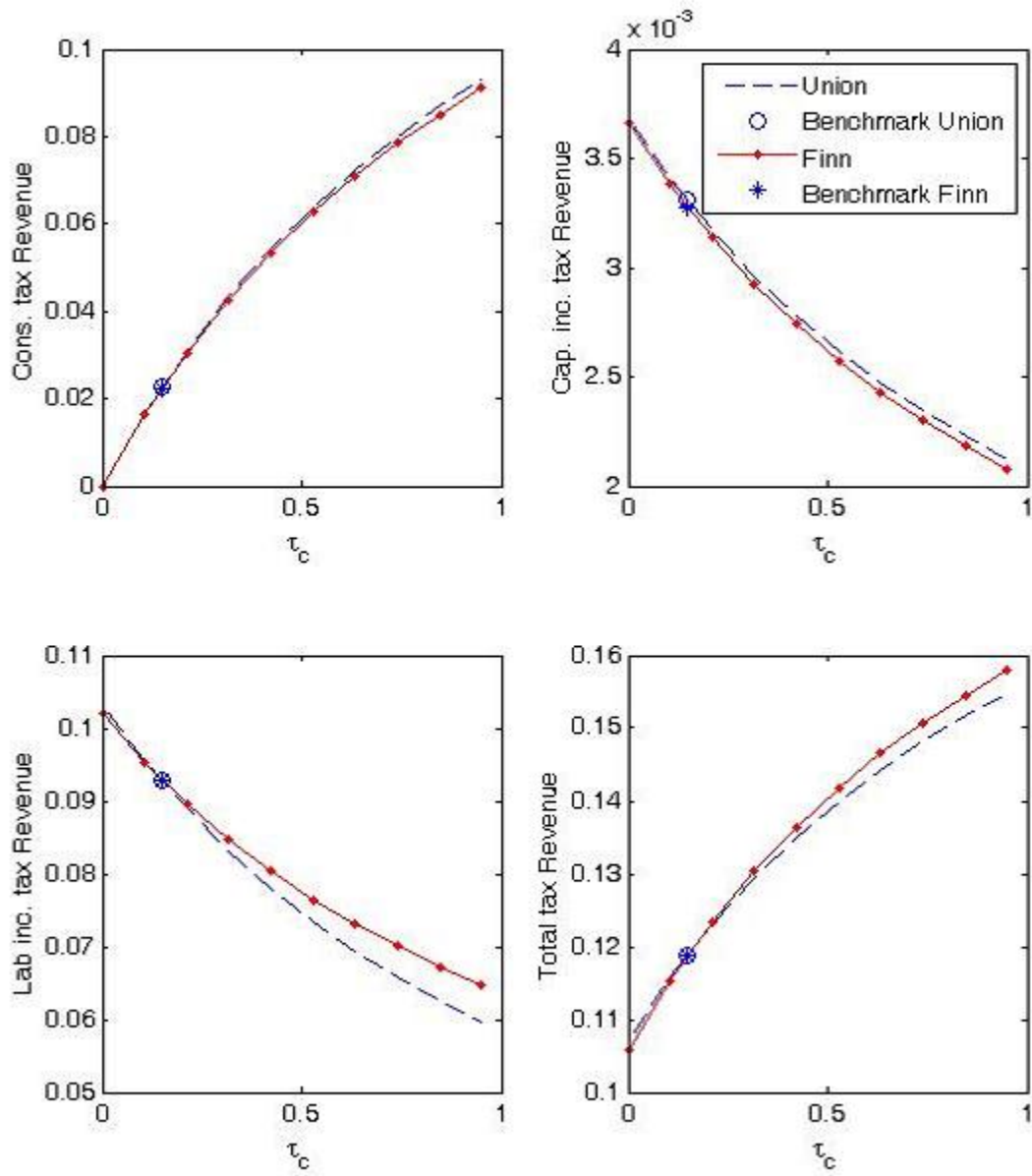


Figure 5: Consumption tax Laffer curve



sides of the government budget constraint. In addition, the substitutability/complementarity of the capital and labor input in the Cobb-Douglas production function, the substitutability between consumption and labor, as well as the substitutability between consumption and investment implies that changes in a single tax rate will affect the tax revenue generated from the other two tax bases.

Following Lucas (1987), the approach taken is to compute the compensatory variation in consumption, the percentage of compensating consumption, ζ , that is to be given to the household to make it indifferent between the two regimes.²³ Three different policies will be examined: a 1% increase in capital income, labor income, and consumption tax rate will be considered. In order to keep total tax revenue constant, whenever a tax rate increases, one of the other two tax rates will be allowed to adjust, holding all other model parameters fixed.²⁴

7.1 Revenue-neutral increase in capital income tax rate

This subsection discusses the steady-state effect of a 1% increase in τ^k , with results presented in Table 5 on the next page. Higher capital income tax rate enters the Euler equation and thus

Table 5: Welfare gains/costs of 1% increase in τ^k in Germany

Model	τ^l fixed, τ^c adjusts	τ^c fixed, τ^l adjusts
Union	$\tau^c = 0.4033 \uparrow (25.52\%)$	$\tau^c = 0.1481$
	$\tau^l = 0.4085$	$\tau^l = 0.5535 \uparrow (14.50\%)$
	$\zeta = -0.2093$	$\zeta = -0.2425$
Finn	$\tau^c = 0.3657 \uparrow (21.76\%)$	$\tau^c = 0.1481$
	$\tau^l = 0.3596$	$\tau^l = 0.5415 \uparrow (13.30\%)$
	$\zeta = -0.1430$	$\zeta = -0.1745$

²³The initial regime for Germany is as described in Section 2, with the calibration and steady state solution presented in Section 3. The value of ζ is calculated for all restrictive fiscal policy scenarios, where a positive (negative) value indicates a welfare gain (loss).

²⁴For example, η and g^{ty} in the union model, and g^{ty} in Finn, are held fixed at the values obtained in the original steady-state computation.

decreases the steady state private capital-to-output ratio. Since total revenue with respect to τ^k is relatively flat in both models, the increase in capital income tax essentially does not change total revenue. Variations in labor income tax rate, or consumption tax rate, however, are very distortionary, as they operate through the marginal rate of substitution. A higher labor-, or a higher consumption tax rate, lower private hours. From the complementarity of hours and capital in the production function, capital stock also falls. Lower levels of labor and capital inputs shrink output, which in turn decreases consumption. This change in steady-state allocation requires additional adjustment in the varying tax rate (τ^l or τ^c) to preserve revenue neutrality. The computational experiment performed shows that in either case, the adjusting tax rate has to change significantly to satisfy the revenue neutrality restriction. Across models, consumption tax is the less distortive instrument. Additionally, the computed welfare cost is higher in the union model by 6.63 % (6.8 % when τ^l varies) due to the endogenous response of public hours, which requires significantly larger tax rate increases in the union model.

7.2 Revenue-neutral increase in labor income tax rate

In this case, an increase in τ^l affects the marginal rate of substitution (MRS) between steady-state hours and consumption. As in the previous subsection, the analysis is split into two sub-cases, with results summarized in Table 6 on the next page. When the consumption tax

Table 6: Welfare gains/costs of 1% increase in τ^l in Germany

Model	τ^k fixed, τ^c adjusts	τ^c fixed, τ^k adjusts
Union	$\tau^k = 0.1603$	$\tau^k = N/A$
	$\tau^c = 0.3862 \uparrow (23.81\%)$	$\tau^c = 0.1481$
	$\zeta = -0.2105$	$\zeta = N/A$
	$\tau^k = 0.1603$	$\tau^k = N/A$
Finn	$\tau^c = 0.35 \uparrow (20.19\%)$	$\tau^c = 0.1481$
	$\zeta = -0.1444$	$\zeta = N/A$

rate is the adjusting rate, a 23.81% increase in τ^c is required in the union model. Again, Finn's setup generates much smaller welfare cost as compared to the union model, as the

setup with exogenous public sector hours requires consumption tax rate to increase by 17% to preserve the initial level of tax revenues.²⁵ In both models, the increase in the consumption tax rate relative to the increase in the labor income tax rate is larger. Therefore, the labor wedge, $(1 - \tau^l)/(1 + \tau^c)$, decreases in both cases, which leads to an increase in private hours. Since hours and private physical capital are complements in the production function, the increase in labor input raises the marginal product of private capital, hence real interest rate will increase as well. The higher return to capital encourages investment, and thus steady-state private capital stock expands. Following the expansion in capital input, output increases as well. In turn, higher output leads to higher consumption. The increase in consumption, however, is dominated by the increase in hours, so long-run welfare decreases relative to the one obtained in the initial steady-state. In addition, in the union model, there is an important feedback effect, which further increases welfare cost. This effect works to increase public hours, as a result of the higher tax revenue. In effect, endogenously-determined public hours add to the allocative distortions in the union model. Public hours enter the MRS condition, and thus necessitate a much larger adjustment in the union economy, as compared to Finn's framework. The presence of endogenously-determined public hours and wages adds 6.6% to the computed welfare loss.

In the second sub-case, when capital income tax rate varies in response to the increase in labor income tax, no reasonable level of τ^k (i.e. $\tau^k \in [-1, 1]$) exists that satisfies the revenue neutrality restriction. This is a straightforward consequence of the relatively flat Laffer curve with respect to the capital income tax rate, as demonstrated in the section on capital tax Laffer curve. Additionally, in both models the share of capital income tax revenue is less than 3%, which is very small when compared to consumption tax revenue share (22%) and labor income tax revenue share (75%). Thus, capital income tax rate is not a suitable instrument for fiscal adjustment, due to its limited ability to affect total tax revenue.

7.3 Revenue-neutral increase in consumption tax rate

The increase in τ^c affects the marginal rate of substitution between steady-state hours and consumption as well; hence, the effect on allocations is qualitatively similar to the one de-

²⁵Note that the higher fall in a tax rate results in a lower level of distortions in the economy.

scribed in the previous section. In the first sub-case of this scenario (Table 7 below), when the labor income tax rate changes to preserve the tax revenue, it needs to increase by 12.73% and 16.96% in Finn and the union model, respectively.

Table 7: Welfare gains/costs of 1% increase in τ^c in Germany

Model	τ^k fixed, τ^l adjusts	τ^l fixed, τ^k adjusts
Union	$\tau^k = 0.1603$	$\tau^k = N/A$
	$\tau^l = 0.5781 \uparrow (16.96\%)$	$\tau^l = 0.4085$
	$\zeta = -0.2404$	$\zeta = N/A$
Finn	$\tau^k = 0.1603$	$\tau^k = N/A$
	$\tau^l = 0.5358 \uparrow (12.73\%)$	$\tau^l = 0.4085$
	$\zeta = -0.1724$	$\zeta = N/A$

This upward change in the labor income tax rate is significantly larger than the increase in consumption tax rate. The resulting decrease in the effective labor wedge, $(1 - \tau^l)/(1 + \tau^c)$, affects labor supply and consumption decisions: the household responds to the dominating income effect and supplies more hours in the private sector. Next, the higher level of labor input in the production function raises both output and the interest rate. The higher return to private physical capital leads to an increase in investment, which adds to the capital stock and expands output. The positive wealth effect then translates into an increase in consumption. However, the higher consumption is offset by the increase in hours, so welfare decreases. Additionally, the increase in hours is higher in the union model, driven by the endogenously-determined public hours, which positively co-move with private hours. Thus the required increases in labor income tax rates produce nearly 6.8% larger welfare losses in the union model, a result attributed to the endogenously-determined public hours.

The case when τ^k is the adjusting tax rate unravels exactly as the case when τ^l increased by 1% and τ^k was the adjusting tax rate. Intuitively, both an increase in τ^c and τ^l decrease the effective labor wedge, thus the resulting adjustments through τ^k are qualitatively similar. Again, there is no feasible capital income tax rate that preserves revenue neutrality.

Overall, the experiments performed in this section uncovered some important limitations

of Finn’s model with exogenous public hours. The presence of endogenously-determined public sector hours and wage rate was shown to generate important interactions, which add to the distortionary effect of taxes. If ignored, the long-run welfare cost of revenue-neutral tax increase policies could be significantly underestimated.

8 Summary and Conclusions

Motivated by the highly-unionized public sectors, the high public shares in total employment, and public sector wage premia observed in most post-WWII European economies, this paper examined the role of public sector unions in a DSGE framework. A strong union, operating in a largely non-market sector was shown to be relevant for business cycle fluctuations, and when evaluating the welfare effects of fiscal policy. Following Fernandez-de-Cordoba *et al.* (2009), an optimizing public sector union was incorporated in a real business cycle model with valuable government consumption and productive public investment. The RBC model generated cyclical behavior in hours and wages that is consistent with data behavior in an economy with highly-unionized public sector, Germany during the period 1970-2007. Overall, the model with collective bargaining in the public sector is an improvement over a similar model with exogenous public employment, namely Finn (1998). In addition, endogenously-determined public wage and hours add to the distortionary effect of contractionary tax reforms and produce greater changes in tax rates to achieve a pre-specified increase in tax revenue and hence significantly higher welfare losses, as compared to Finn’s model. Thus, endogenous public hours are quantitatively important model ingredient when evaluating fiscal policy. In particular, ignoring the positive co-movement between public and private wage and hours leads to a significant underestimation of the welfare effect of tax regime changes.

Data sources: Due to data limitations, the model calibrated for Germany will be for the period 1970-2007, while the sub-period 1970-91 covers West Germany only. For Germany, data on real output per capita, household consumption per capita, gross fixed capital formation per capita, as well as government consumption and population were taken from the World Development Indicators (WDI) database. The OECD statistical database was used to extract the long-term interest rate on 10-year generic bonds, CPI inflation, average annual earnings in the private and public sector, average hours, private, public and total employment in Germany. Public transfers ratio were calculated from the *CES-Ifo* DICE Database (2011). Public and private investment and capital stock

series were obtained from EU Klems database (2009). German average annual real public compensation per employee was estimated by dividing the real government wage bill (OECD 2011) by the number of public employees. Due to data limitations on the average hours worked in each sector, employment statistics were used. To make empirical variables comparable with model variables, employment series in Germany were normalized by total population (obtained from WDI).

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