Optimal Income Taxation in Unionized Labor Markets*

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Abstract

This paper extends the Diamond (1980) model with labor unions to study optimal income taxation and to analyze whether unions can be desirable for income redistribution if income taxes are optimized. Unions bargain with firms over wages in each sector and firms unilaterally determine employment. Optimal unemployment benefits and optimal income taxes are lower in unionized labor markets. Unions raise the efficiency costs of income redistribution, because unemployment benefits and income taxes raise wage demands and thereby generate involuntary unemployment. We show that unions are socially desirable only if they represent (low-income) workers whose participation is subsidized on a net basis. By creating implicit taxes on work, unions alleviate the labor-market distortions caused by income taxation. We empirically verify whether i) participation tax rates are lower if unions are more powerful, and ii) unions are desirable by compiling our own data set with union densities and participation tax rates for 18 sectors in 23 advanced countries. In line with our theoretical predictions, we find that participation tax rates are lower if unions are stronger. Moreover, the desirability condition for unions is never met empirically. Numerical simulations for the Netherlands confirm that unions are not desirable if income taxes are optimized and optimal participation taxes are lower if unions are stronger.

Keywords: optimal taxation, unions, wage bargaining, labor participation
JEL classification: H21, H23, J51, J58

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1 Introduction

Unions play an important role in modern labor markets. Figure 1 plots union membership and coverage rates among three groups of OECD-countries over the period 1960-2011. While union membership has shown a steady downward trend since the early 1980s, the fraction of labor contracts covered by collective labor agreements has decreased by much less and remains high, especially in continental European and Nordic countries. Despite their importance, surprisingly little is known about the impact of unions on the optimal design of redistributive policies. Therefore, this paper aims to study optimal income redistribution in unionized labor markets. It asks two main questions: *'How should the government optimize income redistribution if labor markets are unionized?'* And: *'Can labor unions be socially desirable if the government wants to redistribute income?'* Although some papers have analyzed optimal taxation in unionized labor markets, no paper has, to the best of our knowledge, studied the desirability of unions for income redistribution.

To answer these questions, we extend the extensive-margin models of Diamond (1980), Saez (2002), and Choné and Laroque (2011) with unions. Workers are heterogeneous with respect to their costs of participation and the sector (or occupation) in which they can work. Workers choose whether to participate or not, and supply labor on the extensive margin if they succeed in finding a job. In the baseline version of our model, we abstract from an intensive labor-supply margin.[1] The extensive margin is often considered empirically more relevant compared to the intensive margin, especially at the lower part of the income distribution.[2] Workers within a sector are represented by a union, which maximizes the expected utility of its members. Firm-owners employ a stock of capital and different labor types to produce a final consumption good. Our baseline is the canonical Right-to-Manage (RtM) model of Nickell and Andrews (1983). The wage in each sector is determined through bargaining between firm-owners and unions. Firm-owners, in turn, unilaterally determine how many workers to hire.[3] Finally, there is a redistributive government that sets income taxes, unemployment benefits, and profit taxes to maximize social welfare. Our main findings are the following.

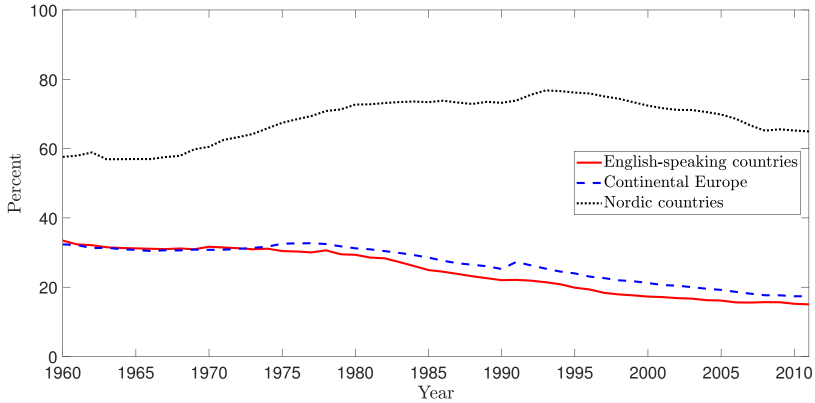
First, we answer the question how income taxes should be set in unionized labor markets. We show that optimal participation taxes (i.e., the sum of income taxes and unemployment benefits) are lower if unions are more powerful.[4] Intuitively, high income taxes and unemployment benefits worsen the inside option of workers relative to their outside option. Hence, higher participation taxes induce unions to bid up wages above market-clearing levels. This results in involuntary unemployment, which generates a welfare loss. Involuntary unemployment creates an implicit tax, which exacerbates the explicit tax on labor participation. Consequently,

[1] In an extension we analyze the case where individuals can choose their occupation, which Saez (2002) refers to as the 'intensive margin' in a model with discrete labor choices.

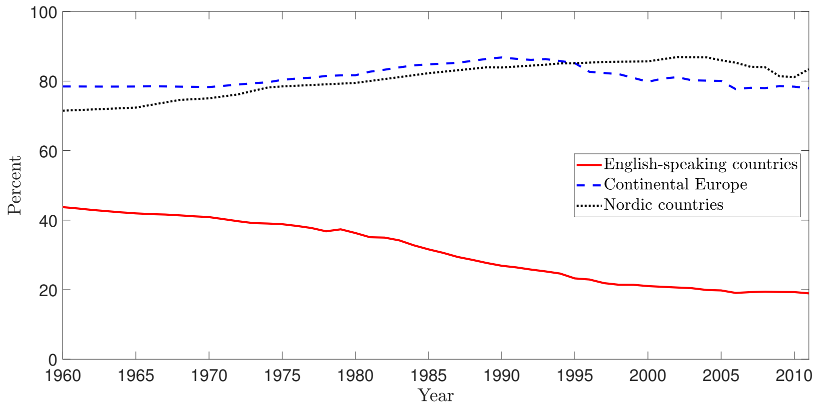
[2] See, for instance, Heckman (1993), Eissa and Liebman (1996), and Meyer (2002).

[3] The RtM-model nests both the monopoly-union (MU) model of Dunlop (1944) and the competitive model as special cases. We also analyze the efficient bargaining (EB) model of McDonald and Solow (1981) in an extension. Together with the RtM-model, these are the canonical union models, see Layard et al. (1991), Booth (1995), and Boeri and Van Ours (2008).

[4] Because participation no longer equals employment if there is involuntary unemployment, Jacquet et al. (2014) and Kroft et al. (2020) prefer the term *employment tax* over the term *participation tax*. In line with most of the literature, we use the term 'participation tax', keeping this caveat in mind.



(a) Union membership



(b) Union coverage

Figure 1: Union membership (a) and union coverage (b). Data are obtained from the ICTWSS Database version 5.1 (ICTWSS, 2016). Membership is measured as the fraction of wage earners in employment who are member of a union, and coverage as the fraction of employees covered by collective labor agreements. Missing observations are linearly interpolated. The countries included are: Australia, Canada, the United Kingdom, the United States ('English-speaking countries'), Austria, Belgium, France, Germany, the Netherlands, Switzerland ('Continental Europe'), Denmark, Finland, Norway and Sweden ('Nordic countries'). Averages are computed using population weights, which are obtained from the OECD database (OECD, 2020).

optimal participation taxes are lowered. It may be optimal to subsidize participation even for workers whose social welfare weight is below average, which never occurs if labor markets are competitive, cf. Diamond (1980), Saez (2002), and Choné and Laroque (2011). Participation subsidies are therefore more likely to be desirable if unions are more powerful.

Second, we answer the question whether unions are desirable for income redistribution. We show that, if taxes are optimally set, and labor rationing is efficient, then unions are desirable if and only if they represent workers with an above-average social welfare weight.[5,6] Intuitively, participation is subsidized on a net basis for these workers, see also Diamond (1980), Saez

[5]Efficient rationing in our model means that the burden of unemployment is borne by the workers with the highest participation costs.

[6]The social welfare weight is defined as the monetary welfare gain of transferring a euro to a worker with a particular income. In the optimal tax system, the average social welfare weight over all workers equals one, since the government ensures that the marginal social value of resources is the same in the public and private sector.

(2002), and Choné and Laroque (2011). Consequently, labor participation is distorted upwards. Unions alleviate the upward distortion in employment by bidding up wages. Hence, involuntary unemployment acts as an implicit tax, which partially off-sets the explicit subsidy on labor participation.[7] Consequently, participation subsidies and labor unions are complementary instruments to raise the net incomes of the low-skilled. The reverse is also true: unions are never desirable if they represent workers with a below-average social welfare weight, since labor participation is then taxed on a net basis.[8] In that case, implicit taxes from involuntary unemployment exacerbate explicit taxes on labor participation.

We compile our own data set of 294 observations in 23 advanced countries and 18 sectors to empirically verify i) whether stronger unions are associated with lower participation tax rates (the sum of income taxes and unemployment benefits as a fraction of the wage), and ii) whether the desirability condition for unions is met. We deploy union densities at the sectoral from the so-called "Jelle Visser Database" as our measure for union power. Moreover, we calculate participation tax rates at the sectoral level using the online tax-benefit calculator of the Organisation for Economic Co-operation and Development (OECD), and by using sectoral wage and employment data from the OECD and the International Labor Organization (ILO). Our analysis demonstrates that unions are indeed associated with lower participation tax rates, as we theoretically predicted. In our sample, average participation tax rates are predicted to be on average about 4%-points lower if union densities are set to zero. Moreover, we find that participation tax rates are always positive, which implies the desirability conditions for unions is not met empirically for any country in our sample.

To further explore the quantitative importance of unions for optimal tax policy, and to study whether an increase in union power is socially desirable, we simulate a structural version of our model for the Netherlands, where in 2015 approximately 79.4% of all employees were covered by collective labor agreements (OECD, 2020). For plausible values of labor-demand and participation elasticities, optimal participation tax rates are on average 7.4 percentage points lower in unionized labor markets than in perfectly competitive labor markets. The reduction in participation tax rates is brought about by lower income taxes and lower unemployment benefits. Furthermore, in most of our simulations raising unions power is not socially optimal provided income taxes are optimized, corroborating our empirical findings. However, this finding is sensitive to the redistributive preferences of the government. It can be overturned if the government attaches a sufficiently large social welfare weight to low-income workers.

We also investigate the robustness of our findings by relaxing a number of important assumptions. Specifically, we study extensions where: i) unions respond to marginal tax rates, ii) labor rationing is not fully efficient, iii) individuals can endogenously choose the sector in which they work, iv) a national union bargains over all sectoral wages with the aim to compress the wage distribution, and v) unions and firms bargain over wages and employment, as in the efficient bargaining model of McDonald and Solow (1981). We show that expressions for op-

[7] This finding echoes the results of Lee and Saez (2012) and Gerritsen and Jacobs (2020), who show that, if labor rationing is efficient, a binding minimum wage raises social welfare if the social welfare weight of the workers for whom the minimum wage binds is above the average.

[8] The net tax on participation is the sum of the participation tax and the implicit tax on labor. As indicated above, it is possible to have an explicit participation subsidy even with a below-average social welfare weight. This is the case if the implicit tax is larger than the explicit subsidy on labor.

timal participation taxes remain the same if sectoral choice is endogenous or a national union bargains over all wages, since we express our tax rules in terms of sufficient statistics. If unions moderate their wage demands in response to higher marginal tax rates, optimal marginal tax rates are reduced if labor participation is subsidized on a net basis or if a higher wage generates redistributional gains. Moreover, optimal taxes are modified to account for implicit taxes under inefficient rationing and implicit labor subsidies under efficient bargaining. We show that our condition for the desirability of unions carries over to the cases where sectoral choice is endogenous, a national union bargains over all wages, and there is efficient bargaining. In contrast, if unions respond to marginal tax rates, the desirability condition for unions is slightly weaker as it depends on both social welfare weights and participation taxes. In addition, the desirability condition becomes tighter if labor rationing is not fully efficient, since the union exacerbates inefficiencies in labor rationing.

The remainder of this paper is organized as follows. Section 2 discusses the related literature. Section 3 outlines the basic structure of the model, characterizes general equilibrium, and discusses the comparative statics. Section 4 analyzes how participation taxes, unemployment benefits, and profit taxes should optimally be set. Section 5 analyzes the desirability of labor unions. Section 6 summarizes the main findings of several robustness checks that are analyzed in the online Appendix. Section 7 empirically studies whether participation tax rates are lower if unions are stronger and whether the desirability condition for unions holds in the data. Section 8 presents our simulations. Section 9 concludes. Finally, the Appendix to this paper contains the proofs and provides additional details on the simulations. An online Appendix contains a number of extensions and proofs of the claims we make in Section 6 and describes the details on the compilation of the dataset that is used Section 7.

2 Related literature

Our paper relates to several branches in the literature. First, there is an extensive literature which analyzes the comparative statics of taxes on wages and employment in union models, see, e.g., Hersoug (1984), Lockwood and Manning (1993), Bovenberg and van der Ploeg (1994), Koskela and Vilmunen (1996), Fuest and Huber (1997), Sørensen (1999), Fuest and Huber (2000), Lockwood et al. (2000), Bovenberg (2006), Aronsson and Sjögren (2004), Sinko (2004), van der Ploeg (2006), and Aronsson and Wikström (2011). In these papers, high unemployment benefits and high income taxes (i.e., high *average* tax rates) improve the position of the unemployed relative to the employed, which raises wage demands and lowers employment. Moreover, high marginal tax rates (for given average tax rates) moderate wage demands and boost employment, since wage increases are taxed at higher rates. If, however, individuals can also adjust their working hours, the impact of higher marginal tax rates on overall employment (i.e., total hours worked) becomes ambiguous (Sørensen, 1999, Fuest and Huber, 2000, Aronsson and Sjögren, 2004, and Koskela and Schöb, 2012). We contribute to this literature by studying optimal taxation rather than deriving comparative statics.

Second, there is a literature on optimal taxation in unionized labor markets to which we contribute. Palokangas (1987), Fuest and Huber (1997), and Koskela and Schöb (2002) analyze models with exogenous labor supply. They show that the first-best optimum can be achieved, provided that the government can tax profits and it can prevent unions from setting above market-clearing wages via income or payroll taxes. First-best cannot be achieved in our model, because labor supply is endogenous and the government does not observe participation costs. Aronsson and Sjögren (2003), Aronsson and Sjögren (2004), and Kessing and Konrad (2006) study labor supply on the intensive margin, which also prevents a first-best outcome. These studies find that the impact of unions on optimal taxes is ambiguous, because higher marginal tax rates moderate wage demands, and thus reduce unemployment, but they also increase labor-supply distortions on the intensive margin.[9] Instead, in our model labor supply responds only on the extensive margin.[10] Consequently, optimal participation taxes are lower because higher taxes induce unions to bid up wages, which generates involuntary unemployment.

Third, our paper is related to Diamond (1980), Saez (2002), and Choné and Laroque (2011), who analyze optimal redistributive income taxation with extensive labor-supply responses. Christiansen (2015) extends these analyses by allowing for imperfect substitutability between different labor types, so that wages are endogenous. These studies show that participation subsidies are optimal for low-income workers with an above-average social welfare weight. We extend these analyses to settings where wages are determined endogenously through bargaining between unions and firm-owners. Our model nests Diamond (1980), Saez (2002), and Choné and Laroque (2011) if labor types are perfect substitutes and it nests Christiansen (2015) if there are no unions. We find that optimal income taxes are less progressive and benefits are lower if unions create involuntary unemployment. In addition, we show that participation subsidies may be optimal even for workers with a below-average social welfare weight. Kroft et al. (2020) reach a similar conclusion in a very general framework, where wages and unemployment rates respond to changes in the tax-benefit system. Our model provides a specific micro-foundation for these wage and unemployment responses, which allows us to analyze the desirability of labor unions if income taxes are optimized.

Fourth, our study is related to Christiansen and Rees (2018), who study optimal taxation in a model with occupational choice and a single union, which is concerned with wage compression. In contrast to our paper, they abstract from involuntary unemployment and focus instead on the misallocation generated by wage compression. They show that unions have an ambiguous effect on optimal taxes, because wage compression alters both the distortions and the distributional benefits of income taxes. In contrast to Christiansen and Rees (2018), we find in an extension of our model that optimal tax rules – expressed in sufficient statistics – do not change if unions are concerned with wage compression.

3 Model

We consider an economy which includes workers, unions, firm-owners, and a government. The basic structure of the model follows Diamond (1980), except that in the baseline we consider

[9] For instance, Aronsson and Sjögren (2004) show that the optimal labor income tax might be either progressive or regressive depending on whether working hours are determined by the union or by workers themselves.

[10] We study an extension with an occupational decision in the online Appendix. Moreover, we also study an extension where unions respond to marginal tax rates in the online Appendix.

a finite number of labor types which are imperfect substitutes in production.[11] Within each sector (or occupation), workers are represented by a single labor union that negotiates wages with (representatives of) firm-owners. The latter exogenously supply capital and produce a final consumption good using the labor input of workers in different sectors. The government aims to maximize social welfare by redistributing income between unemployed workers, employed workers, and firm-owners. We assume that each union takes tax policy as given and does not internalize the impact of its decisions on the government budget.[12]

3.1 Workers

Workers differ in two dimensions: their participation costs and the sector in which they can work. There is a discrete number of I sectors. A worker type $i \in \mathcal{I} \equiv \{1, \cdots, I\}$ can work only in sector i, where she earns wage w_i and pays taxes T_i. We denote by N_i the mass of individuals who can work in sector i. If an individual works, she incurs a monetary participation cost φ, which is private information and has domain $[\underline{\varphi}, \overline{\varphi}]$, with $\underline{\varphi} < \overline{\varphi} \leq \infty$. The cumulative distribution function of participation costs of workers is allowed to vary across sectors and is denoted by $G_i(\varphi)$. We assume that workers cannot switch between sectors in the baseline version of the model and analyze the case with an occupational choice in an extension.

Each worker is endowed with one indivisible unit of time and decides whether she wants to work or not. All workers derive utility from consumption net of participation costs that are modeled as utility costs of working.[13] Their utility function $u(\cdot)$ is increasing and weakly concave. The *net* consumption of an employed worker in sector i with participation costs φ equals labor income w_i minus income taxes T_i and participation costs φ: $c_{i,\varphi} = w_i - T_i - \varphi$. Unemployed workers consume c_u, which equals an unemployment benefit of $-T_u$, hence $c_u = -T_u$. An individual in sector i with participation costs φ is willing to work if and only if

$$u(c_{i,\varphi}) = u(w_i - T_i - \varphi) \geq u(-T_u) = u(c_u). \tag{1}$$

For each sector i, equation (1) defines a cut-off φ_i^* at which individuals are indifferent between working and not working: $\varphi_i^* \equiv w_i - T_i + T_u$. Higher wages w_i, lower income taxes T_i, and lower unemployment benefits $-T_u$ all raise the cut-off φ_i^*, and, thus, raise labor participation in sector i. Workers are said to be *involuntarily* unemployed if condition (1) is satisfied, but they are not employed.

[11]In the extension where unions respond to marginal tax rates, we allow for a continuum of labor types.

[12]Consequently, the government is the Stackelberg leader relative to firms and unions. This assumption seems most natural given that in our model workers are represented by unions at the *sectoral* level (as is the case, for instance, in the Netherlands). The distortions from unions would typically be smaller if they (partly) internalize the impact of their decisions on the government budget constraint, see, e.g., Calmfors and Driffill (1988) and Summers et al. (1993).

[13]This is a slight abuse of terminology, since we assume that individuals who are *involuntarily* unemployed do *not* incur these costs. Nevertheless, we prefer to use the term 'participation costs' rather than 'costs of working', to stay close to the literature on optimal taxation with extensive-margin labor-supply responses. For analytical convenience, we model participation costs as a pecuniary cost rather than a utility cost, see also Choné and Laroque (2011). Utility is then a function of consumption net of participation costs. Whether participation costs are modeled as pecuniary or a utility costs has no bearing on our results.

3.2 Firms

There is a unit mass of firm-owners, who inelastically supply K units of capital, and employ all types of labor to produce a final consumption good.[14] The production technology is described by a production function:

$$F(K, L_1, \cdots, L_I), \quad F_K(\cdot), F_i(\cdot) > 0, \quad F_{KK}(\cdot), F_{ii}(\cdot), -F_{Ki}(\cdot) \leq 0. \tag{2}$$

Here, the subscripts refer to the partial derivatives with respect to capital and labor in sector i. We assume that capital and labor have positive, non-increasing marginal returns. Moreover, capital and labor in sector i are co-operant production factors ($F_{Ki} \geq 0$).[15] We do not make specific assumptions regarding the complementarity of different labor types. In a number of special cases, we invoke the assumption that labor markets are independent.

Assumption 1. (Independent labor markets) *The marginal product of labor in sector i is unaffected by the amount of labor employed in sector $j \neq i$, i.e., $F_{ij}(\cdot) = 0$ for all $i \neq j$.*

Under Assumption 1, there are no spillover effects between different sectors in the labor market.[16]

Profits Π equal output minus wage costs:

$$\Pi = F(K, L_1, \cdots, L_I) - \sum_i w_i L_i. \tag{3}$$

Firm-owners maximize profits, while taking sectoral wages w_i as given. The first-order condition for profit maximization in each sector i is given by:

$$w_i = F_i(K, L_1, \cdots, L_I). \tag{4}$$

Firms demand labor until its marginal product is equal to the wage. The labor-demand elasticity ε_i in sector i is defined as $\varepsilon_i \equiv -F_i(\cdot)/(L_i F_{ii}(\cdot)) > 0$.[17]

Firm-owners consume their profits net of taxes. Their utility is given by $u(c_f) = u(\Pi - T_f)$, where T_f denotes the profit tax. The profit tax is non-distortionary, as it affects none of the firms' decisions.

[14] Alternatively, we could assume that there are sector-specific firms producing a single, final consumption good. As long as the government is able to observe (and tax) profits of all firms, none of our results change. The same is true if firm-ownership would be equally shared among workers or, in case of unequal ownership, if profits can be taxed and rebated to employed and unemployed workers in a lump-sum way.

[15] Firms only respond to unions' wage demands by reducing labor demand (a move along the labor-demand curve), since the production technology is given. In future research, it would be interesting to also analyze endogenous labor-saving (capital-augmenting) technological change, see e.g., Acemoglu (2002) or Loebbing (2022), which would yield a shift of the labor-demand curve.

[16] Such spillover effects may also occur with an occupational-choice margin. We return to this point in more detail below.

[17] If Assumption 1 holds, then the demand for labor in sector i depends only on the wage in sector i (i.e., $L_i = L_i(w_i)$, where $L_i'(\cdot) = 1/F_{ii}(\cdot)$) and the labor-demand elasticity ε_i depends only on L_i.

3.3 Unions and labor-market equilibrium

All workers in sector i are organized in a union, which aims to maximize the expected utility of its members.[18] We characterize labor-market equilibrium in sector i using a version of the Right-to-Manage (RtM) model due to Nickell and Andrews (1983). In this model, the wage w_i is determined through bargaining between the union in sector i and (representatives of) firm-owners. Individual firm-owners in each sector take the negotiated wage w_i as given and have the 'right to manage' how much labor to employ. The RtM-model nests both the competitive equilibrium (CE) as well as the monopoly-union (MU) model of Dunlop (1944) as special cases.

Because union members differ in their participation costs, we have to make an assumption on labor rationing: which workers become unemployed if the wage is set above the market-clearing level? In most of what follows, we assume that labor rationing is efficient (cf. Lee and Saez, 2012, Gerritsen, 2017, and Gerritsen and Jacobs, 2020).

Assumption 2. (Efficient Rationing) *The incidence of involuntary unemployment is borne by the workers with the highest participation costs.*

If labor markets are competitive, there is no involuntary unemployment and Assumption 2 is trivially satisfied. However, if there is involuntary unemployment, there is no reason to believe that only individuals with the highest participation costs bear the burden of unemployment, see also Gerritsen (2017). The assumption of efficient rationing clearly biases our results in favor of unions and will be relaxed in Section 6.

Let $E_i \equiv L_i/N_i$ denote the employment rate for workers in sector i. Under Assumption 2, workers with participation costs $\varphi \in [\underline{\varphi}, \hat{\varphi}_i]$, where $\hat{\varphi}_i \equiv G_i^{-1}(E_i)$, are employed, whereas those with participation costs $\varphi \in (\hat{\varphi}_i, \overline{\varphi}]$ are not employed. Workers with participation costs $\varphi \in (\hat{\varphi}_i, \varphi_i^*]$ are involuntarily unemployed, since they prefer to work but cannot find employment. Workers with participation costs $\varphi \in (\varphi_i^*, \bar{\varphi}]$ do not participate ('voluntary unemployment'). Because participation is voluntary, the fraction of workers willing to participate is weakly larger than the rate of employment: $E_i = G_i(\hat{\varphi}_i) \leq G_i(\varphi_i^*)$. If union i maximizes the expected utility of its members, and labor rationing is efficient, the union's objective function can be written as:

$$\Lambda_i = \int_{\underline{\varphi}}^{\hat{\varphi}_i} u(c_{i,\varphi})\mathrm{d}G_i(\varphi) + \int_{\hat{\varphi}_i}^{\overline{\varphi}} u(c_u)\mathrm{d}G_i(\varphi) = E_i\overline{u(c_i)} + (1 - E_i)u(c_u), \tag{5}$$

where $\overline{u(c_i)} \equiv \int_{\underline{\varphi}}^{\hat{\varphi}_i} u(c_{i,\varphi})\mathrm{d}G_i(\varphi)/E_i$ denotes the average utility of employed workers in sector i.

To characterize equilibrium, we employ a version of the RtM-model that allows for any degree of union power. This is graphically illustrated in Figure 2. The competitive equilibrium (CE) lies at the intersection of the labor-supply curve and the labor-demand curve. The monopoly-union (MU) outcome, in turn, lies at the point where the union's indifference curve is tangent to the labor-demand curve. Any point on the bold part of the labor-demand curve corresponds to an equilibrium in the RtM-model. The higher (lower) is union power, the closer is the outcome

[18] The qualitative predictions of the model are robust to changing the union objective as long as the union cares about *both* wages and employment, and as long as the negotiated wage extends to the non-union members. For example, we could allow for different degrees of union membership across workers with different participation costs.

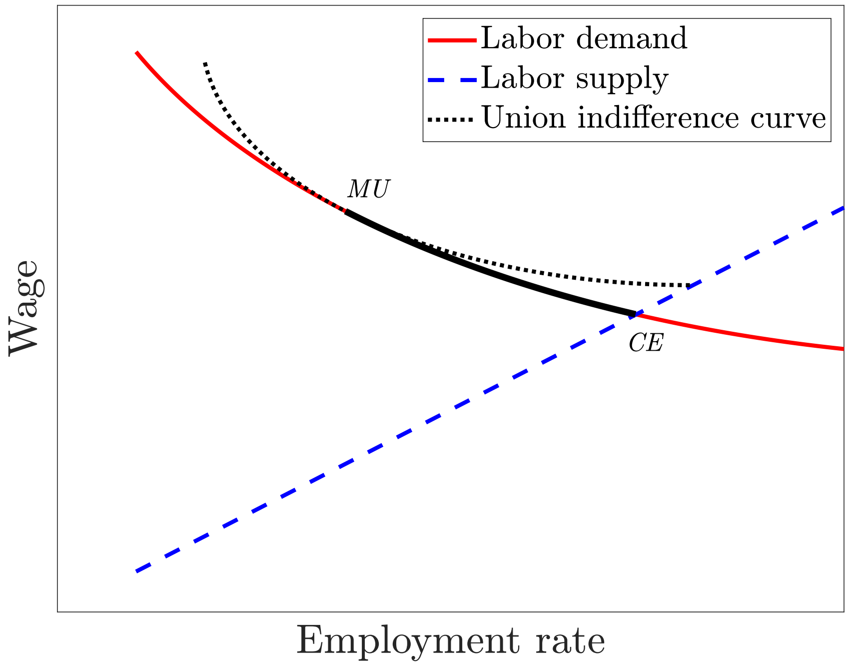


Figure 2: Labor-market equilibria in the Right-to-Manage model

to the monopoly-union (competitive) outcome. Therefore, the monopoly-union outcome and the competitive outcome represent the two polar cases in our analysis.

We refer to the monopoly-union (MU) model if the union in sector i has full bargaining power. In this case, the union chooses the combination of the wage w_i and the rate of employment E_i, which maximizes its objective (5) subject to the labor-demand equation (4). This leads to the following (implicit) wage-demand equation for each sector i:

$$1 = \varepsilon_i \frac{u(\hat{c}_i) - u(c_u)}{\overline{u'(c_i)} w_i}, \tag{6}$$

where $u(\hat{c}_i)$ denotes the utility of the marginally employed worker (i.e., the worker with participation costs $\hat{\varphi}_i$), and $\overline{u'(c_i)}$ is the average marginal utility of employed workers in sector i. If the union has full bargaining power, it demands a wage w_i in sector i such that the marginal benefit of raising the wage for the employed with one euro (on the left-hand side) equals the marginal cost of higher unemployment (on the right-hand side). The marginal cost of setting the wage above the market-clearing level equals the elasticity of labor demand multiplied with the marginal worker's monetized utility gain of finding employment as a fraction of the wage: $\frac{u(\hat{c}_i) - u(c_u)}{\overline{u'(c_i)} w_i}$. Importantly, because rationing is efficient, the costs of setting a higher wage depend only on the utility loss of the marginally employed workers, since they lose their jobs first following an increase in the wage. Furthermore, equation (6) implies that an increase in either the income tax T_i or the unemployment benefit $-T_u$ raises wage demands. Intuitively, higher income taxes T_i or unemployment benefits $-T_u$ make the outside option of not working more attractive relative to the inside option of working.

The polar opposite case is the competitive outcome, where unions have no bargaining power at all. In this case, the wage is driven to the point where the marginally employed worker is indifferent between participating and not participating (i.e., $u(\hat{c}_i) = u(c_u)$) and labor demand equals labor supply for each sector i:

$$E_i = G_i(\varphi_i^*). \tag{7}$$

Since there is no involuntary unemployment, we have $\hat{\varphi}_i = \varphi_i^* = w_i - T_i + T_u$. A reduction in either the income tax T_i or the unemployment benefit $-T_u$ leads to higher employment and, through the labor-demand equation (4), to a lower wage. The reduction in the wage and the increase in employment comes about through an increase in labor participation, rather than through a reduction in the union's wage demand.

A common approach to characterize the labor-market equilibrium for an intermediate degree of union power is to solve the Nash bargaining problem between the union and the firm. Here, we choose a different approach. Rather than using bargaining weights, we introduce a *union power parameter* $\rho_i \in [0, 1]$, which directly determines which equilibrium is reached in the wage negotiations. In particular, we modify the wage-demand equation (6) and characterize labor-market equilibrium for each sector i as:

$$\rho_i = \varepsilon_i \frac{u(\hat{c}_i) - u(c_u)}{\overline{u'(c_i)}w_i}. \tag{8}$$

The union power parameter ρ_i determines which point on the labor-demand curve between *MU* and *CE* is reached in the wage negotiations. If $\rho_i = 1$, the outcome corresponds to the equilibrium in the MU-model. If $\rho_i = 0$, the outcome corresponds to the CE. Consequently, $\rho_i \in (0, 1)$ corresponds to any intermediate degree of union bargaining power in the RtM-model. The higher (lower) is ρ_i, the higher (lower) is the negotiated wage.

In what follows, union power ρ_i is treated as policy-invariant. In Section 1 of the online Appendix, we derive that there is a direct relationship between our measure of union power ρ_i and the union's Nash-bargaining parameter in the RtM-model. Hence, we can use either parameter to rationalize any point on the labor-demand curve in equilibrium. However, treating the Nash-bargaining parameter as fixed leads to technical complications that we circumvent. For this reason, we prefer to characterize equilibrium and derive the optimal tax results using our measure of union power.

3.4 Government

The government is assumed to maximize a social welfare function $\mathcal{W}$:

$$\mathcal{W} \equiv \sum_i \psi_i N_i (E_i \overline{u(c_i)} + (1 - E_i)u(c_u)) + \psi_f u(c_f), \tag{9}$$

where ψ_f is the Pareto weight that the government attaches to firm-owners and ψ_i is the Pareto weight that the government attaches to individuals who work in sector i. We assume throughout that Pareto weights are lower for workers in sectors where wages are higher. By attaching the same Pareto weight to all workers within the same sector, this government objective respects the union's objective by imposing the same preferences for income redistribution within a sector.[19]

The informational assumptions in our model are as follows. The government observes the employment status of all workers, all sectoral wages, and firm profits. However, individual participation costs φ are private information, as in Diamond (1980), Saez (2002), and Choné and Laroque (2011).[20] This assumption is the most natural one to make, as in reality the government lacks the information to redistribute income between workers who have the same income but different participation costs. The non-observability of participation costs also implies that the government is unable to distinguish workers who are voluntarily unemployed and those who are involuntarily unemployed. In particular, only workers with participation costs $\varphi \in (\hat{\varphi}_i, \varphi_i^*]$ are involuntarily unemployed, while workers with participation costs $\varphi \in (\varphi_i^*, \bar{\varphi}]$ are voluntary unemployed. To distinguish both types of workers thus requires information on the participation costs φ of each worker. Therefore, if participation costs are realistically not observable, then tax policy cannot be conditioned on φ. Hence, the assumption that participation costs are not observable implies the government needs to resort to distortionary taxes and transfers to redistribute income and optimal tax policy can at best implement a second-best allocation.[21]

In line with our informational assumptions, the government can set income taxes T_i, as well as a profit tax T_f to finance an unemployment benefit $-T_u$ and an exogenous revenue requirement R. The government's budget constraint is given by:

$$\sum_i N_i(E_i T_i + (1 - E_i)T_u) + T_f = R. \tag{10}$$

3.5 Equilibrium and behavioral responses

General equilibrium with unions is defined as follows.

Definition 1. *An equilibrium with unions consists of wages w_i and employment E_i in each sector i such that, for given union power ρ_i and taxes T_i, T_u, and T_f:*

1. *For all sectors i, firms maximize profits:*

$$w_i = F_i(\cdot). \tag{11}$$

2. *For all sectors i, wages and employment satisfy the wage-demand equation of unions:*

$$\rho_i \int_{\underline{\varphi}}^{G_i^{-1}(E_i)} u'(w_i - T_i - \varphi)\mathrm{d}G_i(\varphi)F_{ii}(\cdot)N_i + \big(u(w_i - T_i - G_i^{-1}(E_i)) - u(-T_u)\big) = 0, \tag{12}$$

3. *The government runs a balanced budget as given by equation (10).*

Equations (11) and (12) determine equilibrium wages and employment in each sector i as a function of union power, unemployment benefits, and income taxes in all sectors. Without additional structure on the production function, it is generally not possible to derive the comparative

[19]Conflicting government and union objectives would introduce unnecessary complications, from which we like to abstain.

[20]This assumption is the analogue of the non-observability of earning ability in the Mirrlees (1971) model.

[21]A first-best allocation can be implemented only if participation costs φ would be fully verifiable and tax policy can be conditioned on participation costs φ. See Section 2 in the Online Appendix for details.

statics of a change in union power or income taxes on equilibrium wages and employment rates. However, if labor markets are independent (i.e., if Assumption 1 holds), equilibrium in sector i does not depend on union power or income taxes in other sectors.[22] In that case, we can write $E_i = E_i(T_i, T_u, \rho_i)$ and $w_i = w_i(T_i, T_u, \rho_i)$ for all sectors i. Appendix A shows that an increase in union power ρ_i, income taxes T_i, or the unemployment benefit $-T_u$ raises the equilibrium wage w_i and lowers the equilibrium employment rate E_i in sector i.

Before turning to the optimal tax problem, we make the following assumption in most of what follows.

Assumption 3. (No income effects at the union level) *The equilibrium wage and employment in sector i respond symmetrically to an increase in the income tax T_i or an increase in the unemployment benefit $-T_u$: $\frac{\partial w_i}{\partial T_i} = -\frac{\partial w_i}{\partial T_u}$ and $\frac{\partial E_i}{\partial T_i} = -\frac{\partial E_i}{\partial T_u}$.*

Under Assumption 3, giving both the employed and the unemployed an additional euro does not affect equilibrium wages and employment rates.[23] This assumption is made solely for analytical convenience, as none of our results critically depend on it, see Appendix B.2 and C.1. If Assumptions 1 and 3 hold, the equilibrium wage and employment in sector i depend only on union power and the participation tax $T_i - T_u$ in sector i. The behavioral responses are given in the following Lemma.

Lemma 1. *If Assumptions 1 (independent labor markets), 2 (efficient rationing), and 3 (no income effects at the union level) are satisfied, then the comparative statics of an increase in the participation tax $T_i - T_u$ on equilibrium wages and employment rates in each sector i are given by:*

$$\frac{\mathrm{d}E_i}{\mathrm{d}(T_i - T_u)} = \frac{\rho_i E_i \overline{u_i''} N_i F_{ii} + \hat{u}_i'}{\rho_i E_i \overline{u_i''}(F_{ii}N_i)^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} < 0, \tag{13}$$

$$\frac{\mathrm{d}w_i}{\mathrm{d}(T_i - T_u)} = \frac{(\rho_i E_i \overline{u_i''} N_i F_{ii} + \hat{u}_i')F_{ii}N_i}{\rho_i E_i \overline{u_i''}(F_{ii}N_i)^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} > 0, \tag{14}$$

where we ignored function arguments to save on notation, and $G_i' \equiv G_i'(E_i)$.

Proof. See Appendix A. □

According to Lemma 1, an increase in the participation tax (resulting from either an increase in the income tax or the unemployment benefit) raises the union's wage demand, which reduces labor demand, and thus lowers employment.

4 Optimal taxation

The government optimally chooses participation taxes $T_i - T_u$, the unemployment benefit $-T_u$, and profit taxes T_f to maximize social welfare (9), subject to the government budget constraint

[22] With independent labor markets, one can also show that the equilibrium is unique if the union objective is concave in E_i after substituting $w_i = F_i(\cdot)$ and $\hat{\varphi}_i = G^{-1}(E_i)$. If that is the case, the first-order condition (6) of the monopoly union's maximization problem is both necessary and sufficient.

[23] This is an assumption on the individual utility function $u(\cdot)$ that is always satisfied if $u(\cdot)$ is linear. Appendix A shows that income effects at the union level are also absent if $u(\cdot)$ is of the CARA-type. We are not aware of other utility functions for which this assumption holds.

(10), while taking into account the behavioral responses to tax policy. We characterize optimal tax policy in terms of elasticities and social welfare weights.[24] Social welfare weights of employed workers in sector i and the firm-owners are denoted by $b_i \equiv \psi_i \overline{u'(c_i)}/\lambda$ and $b_f \equiv \psi_f u'(c_f)/\lambda$, where λ is the multiplier on the government budget constraint. The social welfare weight of the unemployed is given by the weighted average of the social welfare weights of the unemployed $\psi_i u'(c_u)/\lambda$ in each sector i:

$$b_u \equiv \frac{\sum_i N_i(1-E_i)\psi_i u'(c_u)/\lambda}{\sum_i N_i(1-E_i)}. \tag{15}$$

The social welfare weight measures the monetized increase in social welfare resulting from a one unit increase in income. The following Proposition characterizes optimal tax policy.

Proposition 1. *Suppose Assumptions 2 (efficient rationing) and 3 (no income effects at the union level) hold, then the optimal unemployment benefit $-T_u$, profit taxes T_f, and participation taxes $T_i - T_u$ are determined by:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{16}$$

$$b_f = 1, \tag{17}$$

$$\sum_j \omega_j \left(\frac{t_j + \tau_j}{1-t_j}\right)\eta_{ji} = \omega_i(1-b_i) + \sum_j \omega_j (b_j - b_f)\kappa_{ji}, \quad \forall i, \tag{18}$$

where

$$\omega_i \equiv \frac{N_i E_i}{\sum_j N_j}, \quad \omega_u \equiv \frac{\sum_i N_i(1-E_i)}{\sum_j N_j}, \quad t_j \equiv \frac{T_j - T_u}{w_j}, \quad \tau_j \equiv \frac{\psi_j(\hat{u}_j - u_u)}{w_j \lambda} = \frac{\rho_j b_j}{\varepsilon_j}, \tag{19}$$

$$\eta_{ji} \equiv -\left(\frac{\partial E_j}{\partial(T_i - T_u)}\frac{w_i - (T_i - T_u)}{E_j}\right)\frac{w_j(1-t_j)}{w_i(1-t_i)}, \tag{20}$$

$$\kappa_{ji} \equiv \left(\frac{\partial w_j}{\partial(T_i - T_u)}\frac{w_i - (T_i - T_u)}{w_j}\right)\frac{w_j}{w_i(1-t_i)}. \tag{21}$$

ω_i and ω_u are the shares of employed workers in sector i and the unemployed, t_j is the participation tax rate in sector j, τ_j is the union wedge in sector j, η_{ji} and κ_{ji} are the elasticities of employment and wages in sector j with respect to the participation tax $T_i - T_u$ weighted with relative net wages.

Proof. See Appendix B.1. □

Equation (16) states that a weighted average of the social welfare weights of the employed and unemployed workers equals one.[25] This is a well-known result in optimal tax theory. Intuitively, the government uniformly raises transfers to all individuals until the marginal utility benefits of a higher transfer (left-hand side) are equal to the unit marginal costs (right-hand side).[26] Unless the utility function $u(\cdot)$ is linear, and the government attaches equal Pareto weights to workers in all sectors, i.e., $\psi_i = \psi_f = 1$, there will be at least one sector where $b_i < 1$.

[24] We also implicitly characterize the optimal tax system in terms of the model's primitives in Appendix C.1.

[25] If there are income effects at the union level, i.e., if Assumption 3 does not hold, this equation is slightly modified, see Appendix B.2 for details.

[26] This confirms Jacobs (2018), who shows that the marginal cost of public funds equals one in the policy optimum even under distortionary taxation.

Depending on the redistributive preferences of the government, there may also be employed workers whose social welfare weight is above one, see also Diamond (1980), Saez (2002), and Choné and Laroque (2011). In the remainder, we refer to workers for whom $b_i > 1$ as low-income, or low-skilled workers. If the utility function is concave, then typically the unemployed have the highest social welfare weight. Given that the social welfare weights are on average equal to one, this implies that $b_u > 1$.

Condition (17) for optimal profit taxes states that the government taxes firm-owners until their social welfare weight equals one. Since the profit tax is non-distortionary, the government raises profit taxes until it is indifferent between raising firm-owners' consumption with one unit and receiving a unit of public funds.

Equation (18) gives the first-order condition with respect to the participation tax $T_i - T_u$. The left-hand side gives the marginal costs in the form of larger labor-market distortions, whereas the right-hand side gives the marginal distributional benefits (or losses) of higher participation taxes in sector i. At the optimum, the distortionary costs of raising the participation tax in sector i are equated to the distributional gains over all sectors.

The overall distortion of the participation tax in sector i is given by the sum over all sectors of the total tax wedge in sector j multiplied by the weighted (cross) elasticity of employment in sector j with respect to the participation tax in sector i. The total tax on labor participation in sector j equals $t_j + \tau_j$ and consists of the explicit tax on participation t_j and the union wedge $\tau_j \equiv \psi_j(\hat{u}_j - u_u)/(w_j\lambda) = \rho_j b_j/\varepsilon_j$. A reduction in employment reduces social welfare by government revenue from the participation tax $T_j - T_u$, and it lowers social welfare through the union wedge τ_j, which is the monetized loss in social welfare as a fraction of the wage if the marginal worker in sector i loses employment. Unions generate welfare losses by bidding up wages above the market-clearing level. As a result, the marginal worker (i.e., the employed worker with the highest participation costs) is no longer indifferent between working and not working. Therefore, τ_j acts as an *implicit* tax on labor participation. The union wedge τ_j is proportional to union power ρ_j and inversely related to the labor-demand elasticity ε_j. Hence, $\tau_j = 0$ if either labor markets are competitive so that the union has no bargaining power ($\rho_j = 0$), or if labor demand is infinitely elastic ($\varepsilon_j \to \infty$). In the latter case, unions refrain from demanding a wage above the market-clearing level, since doing so would result in a complete breakdown of employment.

The main insight from Proposition 1 is that – *ceteris paribus* social welfare weights and behavioral responses – optimal participation taxes are lower if unions are stronger (i.e., if union wedges τ_j are larger). Intuitively, the tax system is not only geared toward income redistribution, but also aims to reduce involuntary unemployment generated by unions bidding up wages above the market-clearing level. Lower participation taxes induce unions to moderate their wage demands, and this alleviates the welfare costs of involuntary unemployment.

A higher participation tax in sector i raises wages demanded by unions in sector i. *Ceteris paribus,* this leads to a decrease in employment in sector i. Moreover, the change in the participation tax in one sector has implications for both employment and wages in all other sectors. If labor types are complementary (i.e., $F_{ij}(\cdot) > 0$ for $i \neq j$), then the decrease in employment in sector i lowers marginal productivity, and thus labor demand, in all other sectors $j \neq i$.

Consequently, both employment and wages in all other sectors are reduced. The reduction in employment is larger if the (weighted) cross elasticity η_{ji} of employment in sector j with respect to the participation tax in sector i is larger. If the sum of the explicit and implicit tax on participation is positive (negative), i.e., $t_j + \tau_j > 0$ (< 0), then a higher participation tax in sector i exacerbates (alleviates) labor-market distortions in sector j. The total wedge on labor participation $t_j + \tau_j$ is weighted by the employment elasticity in sector j with respect to the participation tax in sector i (η_{ji}). Therefore, if η_{ji} is large, optimal participation taxes are lower. This is in line with the findings from Diamond (1980) and Saez (2002).

The right-hand side of equation (18) gives the sum of the marginal distributional benefits over all sectors of a higher participation tax in sector i. An increase in the participation tax directly redistributes income from workers in sector i to the government. The associated welfare effect is proportional to $1 - b_i$, which captures the rise in government revenue minus the monetized utility loss of workers if they need to pay more taxes. Furthermore, the increase in the participation tax in sector i redistributes income from firm-owners (whose social welfare weight equals b_f) to workers in sector i (whose social welfare weight equals b_i) if the wage w_i increases. Intuitively, if an increase in the participation tax in sector i raises the wage in that sector, then the wage increase yields desirable distributional benefits if the social welfare weight of workers exceeds that of firm-owners in sector i, i.e., if $b_i > b_f$. In addition, there are indirect redistributional consequences in all other sectors $j \neq i$, because wages in all other sectors are affected if participation taxes in sector i are raised. The total impact on social welfare due to general-equilibrium effects on the wage structure is obtained by summing these effects over all sectors. If the social welfare weight of workers in sector j is larger than that of firm owners, i.e., $b_j > b_f$, then the reduction in the wage in sector j due to higher participation taxes in sector i is socially costly. However, if the social welfare weight of workers in sector j is smaller than that of firm-owners, i.e., $b_j < b_f$, the reduction in the wage in sector j is welfare-enhancing. This indirect welfare effect is weighted by the wage elasticity in sector j with respect to the participation tax in sector i (κ_{ji}).

Our main finding – optimal participation taxes are lower in unionized labor markets – holds *for given social welfare weights and behavioral responses.* Clearly, both social welfare weights and behavioral responses are endogenous to the tax system. As such, our result should not be interpreted as a comparative statics exercise of the optimal participation tax with respect to union power, since then the endogeneity of behavioral responses and social welfare weights should be taken into account as well. An increase in union power only leads to a reduction in optimal participation taxes if the 'direct' impact of a larger union wedge τ_i is sufficiently large to off-set any 'indirect' impacts on elasticities and social welfare weights.[27] Furthermore, in our numerical simulations we take the endogeneity of social welfare weights and behavioral responses into account and they never overturn the direct impact of higher union power on optimal participation taxes.

Four final remarks are in order. First, it might be optimal in unionized labor markets to subsidize participation even for workers with a below-average social welfare weight, i.e., for

[27] An example with a closed-form solution for the optimal participation tax that depends in an ambiguous way on union power is available from the authors upon request.

whom $b_i < 1$. This never occurs if labor markets are competitive, see Diamond (1980), Saez (2002), and Choné and Laroque (2011). To see this, suppose labor markets are independent so that all cross effects of wages and employment with respect to participation taxes are zero ($\eta_{ji} = \kappa_{ji} = 0$ for all $j \neq i$) and substitute $b_f = 1$ in equation (18):

$$\left(\frac{t_i + \tau_i}{1 - t_i}\right) \eta_{ii} = (1 - b_i)(1 - \kappa_{ii}). \tag{22}$$

Under weak regularity conditions, a higher participation tax leads to a less than one-for-one increase in the wage: $\kappa_{ii} < 1$, see Lemma 1. The sign of the total wedge on employment, i.e., the sum of the participation tax and the union wedge, in sector i thus equals the sign of $1 - b_i$. Like in Diamond (1980), Saez (2002), and Choné and Laroque (2011), we find that it is optimal to subsidize participation, i.e., setting $t_i < 0$, for low-income workers with an above-average social welfare weight, i.e., if $b_i > 1$. However, and in contrast to these papers, in unionized labor markets subsidizing participation can also be optimal for workers with a below-average social welfare weight ($b_i < 1$). This occurs if the welfare cost of involuntary unemployment is high, so that the implicit tax τ_i is large. Intuitively, explicit subsidies on participation can be desirable to offset the distortions from implicit taxes on participation even if $b_i < 1$. The reason is that participation subsidies are not only used for income redistribution, but also to off-set downward distortions in employment generated by labor unions. A high union wedge could therefore rationalize participation subsidies even for workers with a below-average social welfare weight. In a general framework, Kroft et al. (2020) also show that the optimal participation tax can be negative for workers whose social welfare weight is below-average if wages and unemployment are endogenous to tax policy. Through the lens of their model, unions can be seen as a micro-foundation for these wage and employment responses.[28]

Second, optimal participation taxes are higher – ceteris paribus – if the government has Rawlsian social preferences, and only cares for the non-working poor, i.e., if $b_i = 0$ for all i, and $b_u = b_f$.[29] In that case, the union wedge $\tau_i = 0$ for all i. Intuitively, with a maximin criterion, the government does not value the cost of involuntary unemployment among individuals who want to work. As a result, the union wedge τ_i disappears from the left-hand side in equation (18). As the costs of participation distortions are lower, optimal participation taxes are higher – ceteris paribus.

Third, the formula for the optimal participation tax simplifies considerably if labor markets

[28] Equation (10) in Kroft et al. (2020) is closely related to our optimal tax formula (18) from Proposition 1. For the case without spillover effects, our analysis differs in two subtle ways. First, in their benchmark model, Kroft et al. (2020) set the social welfare weight of firm-owners equal to zero (an assumption that is relaxed in their online Appendix), while in our model the welfare weight of firm-owners is denoted by b_f. Second, while in our model individuals differ in their fixed costs of working, Kroft et al. (2020) assume individuals differ in their search costs. Consequently, labor participation depends on the *expected* utility gain from working and not, as in our model, on the realized income difference. This latter difference enables Kroft et al. (2020) to substitute out for the impact of taxes on wages and employment probabilities using the (matrix) ratio of macro and micro *participation* responses to taxation, which then gives equation (11) in their Proposition 1. This last step simplifies the empirical implementation of their optimal tax formula, but we cannot make this last step due to the difference in modeling participation decisions.

[29] To prevent firm-owners from becoming the poorest group in society, the Rawlsian government drives the welfare weight of the capital owners down to the welfare weight of the unemployed. Given that the unemployed and the firm-owners have the same utility function, they then obtain the same net income.

are competitive – irrespective of whether wages are exogenous or endogenous. It is shown in Appendix B.3 that with competitive labor markets, the optimal tax formula (18) coincides with the one derived by Saez (2002). The optimal tax formula is then given by

$$\frac{t_i}{1-t_i} = \frac{1-b_i}{\pi_i}, \tag{23}$$

where $\pi_i \equiv \frac{G_i'(\varphi_i^*)\varphi_i^*}{G_i(\varphi_i^*)}$ is the participation elasticity, which measures the percentage increase in the fraction of participants in sector i following a one-percent increase in the net payoff from working $\varphi_i^* = w_i - (T_i - T_u)$. If labor demand is infinitely elastic (i.e., if labor types are perfect substitutes in production), equations (18) and (23) coincide. In this case, unions always refrain from demanding above market-clearing wages. Furthermore, the optimal tax formula (23) that is derived in Saez (2002) also holds if labor types are imperfect substitutes in production and there are no unions. The same result is derived as well in Christiansen (2015). If labor markets are perfectly competitive, labor-demand considerations are irrelevant for the characterization of optimal participation tax rates.[30]

Fourth, earlier studies on (optimal) taxation in unionized labor markets have explicitly considered restrictions on profit taxation, either to prevent a first-best outcome or to analyze rent appropriation by unions.[31] If profit taxation is restricted, e.g., due to political-economy reasons or profit-shifting opportunities, the social welfare weight of firm-owners is below the average over all (employed and unemployed) workers: $b_f < 1$. If labor markets are independent, this calls for a higher participation tax *ceteris paribus*, see equation (18) and set $\kappa_{ji} = \eta_{ji} = 0$ if $i \neq j$. A higher participation tax puts upward pressure on the wage, cf. Lemma 1.[32] This redistributes income from firm-owners to workers. The latter is more desirable (or less costly) if profit taxation is more severely restricted. The finding that income taxes are adjusted to indirectly redistribute income from firm-owners to workers has been established as well in Fuest and Huber (1997) and Aronsson and Sjögren (2004).

5 Desirability of unions

The previous Section analyzed the optimal tax-benefit system in unionized labor markets. In this Section we ask the question: can it be socially desirable to allow workers to organize themselves in a union? And, if so, under which conditions? The following Proposition answers both questions.

Proposition 2. *If Assumption 2 (efficient rationing) is satisfied, and taxes are set optimally, then increasing union power ρ_i in sector i raises social welfare if and only if the social welfare weight of the workers in sector i is above-average, i.e., it exceeds one: $b_i > 1$.*

Proof. See Appendix C.1. □

[30] See also Diamond and Mirrlees (1971a,b), who show that optimal tax formulas are the same in partial as in general equilibrium *provided* markets are competitive. Saez (2004) refers to this finding as the 'tax-formula result'.

[31] See, among others, Fuest and Huber (1997), Koskela and Schöb (2002), and Aronsson and Sjögren (2004).

[32] Lemma 1 assumes there are no income effects at the union level. However, a higher participation tax also raises the equilibrium wage if there are income effects at the union level, see Appendix A.

According to Proposition 2, unions are desirable if they represent low-income workers for whom $b_i > 1$. To understand why, suppose that the tax-benefit system is optimized and union power in sector i is marginally increased: $\mathrm{d}\rho_i > 0$. The increase in union power leads to a higher wage and a lower employment rate in sector i, see Appendix A. Moreover, it also reduces employment and wages in other sectors j if labor types are complements in production. All the effects on employment and wages, in turn, can be perfectly offset by combining the increase in union power ρ_i with a lower income tax T_i. If the tax system is optimized, a marginal change in income taxes does not change social welfare. If the joint policy reform of raising union power and changing the income tax offsets the change in the wage and employment rate in sector i, labor-market outcomes in all other sectors j will be unaffected as well. The reduction in the income tax T_i transfers income from the government (with social welfare weight 1) to workers in sector i (whose social welfare weight is b_i). An increase in union power ρ_i is therefore welfare-enhancing if and only if $b_i > 1$.

The fundamental reason why unions can raise social welfare if the tax-benefit system is optimized is that it might be optimal for the government to subsidize participation when participation costs are not observable. This, in turn, leads to upward distortions in employment. To see this, suppose that there are no unions, i.e., $\rho_i = 0$ for all i. According to equation (23), if $b_i > 1$, then participation is optimally subsidized (i.e., $T_i < T_u$), see also Diamond (1980) and Saez (2002). Consequently, labor participation is distorted upwards: too many low-skilled workers decide to participate. Unions alleviate this distortion by offsetting the explicit subsidy on participation with an implicit tax τ_i on participation. As such, unions can meaningfully complement the tax-benefit system.

The result from Proposition 2 is related to Hungerbühler and Lehmann (2009), who study optimal non-linear taxation in a matching framework. They find that increasing the worker's bargaining power leads to higher social welfare if the latter is below the level prescribed by the Hosios (1990) condition. Intuitively, raising the worker's bargaining power puts upward pressure on wages, which partly alleviates the downward distortion on wages brought about by positive marginal tax rates. By contrast, in our framework, unions can be useful to alleviate upward distortions in employment generated by participation subsidies.

Proposition 2 is also related to the findings of Lee and Saez (2012) and Gerritsen and Jacobs (2020), who show that a similar role can be played by minimum wages. Unlike the tax system, both unions and a binding minimum wage can raise the income of low-skilled workers and simultaneously reduce employment, which is desirable if participation is distorted upwards. An important difference between unions and a minimum wage is that unions, unlike a minimum wage, respond to changes in the tax system. Moreover, a minimum wage only generates unemployment at low income levels.

Unions are never desirable if the government has Rawlsian social preferences and only cares about individuals who are least well-off. In our framework, these are the (voluntarily or involuntarily) unemployed, because participation is voluntary. As a result, the social welfare weight of all employed individuals is zero: $b_i = 0$ for all i. Proposition 2 then immediately implies that an increase in union power always lowers social welfare if the government is Rawlsian. Intuitively, by generating additional involuntary unemployment, unions make it more costly to redistribute towards the unemployed. A Rawlsian government therefore always prefers competitive over unionized labor markets.

Proposition 2 holds irrespective of whether there are income effects at the union level or whether labor markets are independent or not, see Appendix C.1. Perhaps surprisingly, the result also generalizes to a setting where profits cannot be fully taxed, in which case $b_f < 1$. Hence, a restriction on profit taxes does not provide an additional reason why an increase in union power could be welfare-enhancing. The reason is that income taxes can already be used to raise wages and thereby indirectly redistribute from firm-owners to workers. As such, for the result in Proposition 2 to hold, it is important that income taxes are optimized.[33] The optimal tax-benefit system takes the indirect redistribution from firm-owners to workers into account. This explains why *ceteris paribus* income taxes are higher when profit taxation is restricted (i.e., when b_f is low), see Proposition 1. Unions are not helpful to achieve more income redistribution from firm-owners to workers over and above what can already be achieved via the tax-benefit system. Therefore, provided income taxes are optimized, the only role of labor unions is to offset upward distortions in employment generated by participation subsidies.

We can also use our model to determine the optimal union power ρ_i in each sector i. Unlike tax policy, union power is not typically considered an instrument over which policymakers have direct control.[34] Nevertheless, if such policy instruments are available, then they should ensure that union power satisfies the conditions in the next Corollary.

Corollary 1. *If Assumption 2 (efficient rationing) is satisfied, and taxes and transfers are set optimally, then the optimal degree of union power $\rho_i^* \in [0,1]$ ensures that the social welfare weight of workers in sector i becomes equal to one: $b_i = 1$. If that is not feasible, $\rho_i^* = 1$ if $b_i > 1$ and $\rho_i^* = 0$ if $b_i < 1$.*

According to Corollary 1, for workers with an above-average social welfare weight (i.e., $b_i \geq 1$), the power of the union representing them should optimally be increased until $b_i = 1$. However, if this is not feasible (which can happen if workers have low wages w_i or if the utility function is linear), the next best thing to do is to make the labor union a monopoly union, i.e., to set $\rho_i^* = 1$.[35] For workers with a below-average social welfare weight ($b_i < 1$), the government would like to lower the power of the union representing them. However, the government cannot decrease union power below the competitive level.

A disadvantage of Proposition 2 is that it is written in terms of social welfare weights, which are generally endogenous as they depend on the entire allocation.[36] Moreover, assessing whether

[33] Political-economy reasons can explain why the income tax is sub-optimal, either by imposing additional constraints on the tax system or by generating a misalignment between the social welfare function and the political objective function. If that is the case, unions can be welfare-enhancing by either alleviating the constraints on the tax system or reducing the misalignment.

[34] It is not obvious how the government can set union power. In this context, Hungerbühler and Lehmann (2009, p.475) remark that: "Whether and how the government can affect the bargaining power is still an open question". They suggest that changing the way how unions are financed and regulated can affect their bargaining power.

[35] In this case, the constraint $\rho_i^* \leq 1$ becomes binding. See Appendix C.2 for details.

[36] The only instance where social welfare weights are exogenous is if the utility function is linear. However, it is always possible to make the social welfare weights exogenous at will by considering a monotone transformation of $u(\cdot)$ that makes the individual utility function linear and to (locally) describe the government's preference for income redistribution using Pareto weights ψ_i.

the condition holds requires invoking political judgments regarding the desirability of income redistribution, i.e., on the exact value of b_i. However, it is possible to judge the desirability of unions while refraining from making such political judgments. The main idea is that the increase in union power ρ_i can be combined with a set of tax adjustments such that net incomes of all workers in the economy remain unaffected, hence the distribution of utilities is kept constant in the tax reform.[37] As a result, the desirability condition for unions from Proposition 2 can be expressed solely in terms of behavioral responses, fiscal externalities, and union wedges, as the next Proposition demonstrates.

Proposition 3. *If Assumption 2 (efficient rationing) is satisfied, and taxes are set optimally, then a net-income neutral increase in union power ρ_i raises social welfare if and only if*

$$\sum_j N_j(t_j + \tau_j)w_j \mathrm{d}E_j^i > 0, \tag{24}$$

where $\mathrm{d}E_j^i$ is the change in employment in sector j induced by a joint increase in union power ρ_i in sector i and a tax reform $\{\mathrm{d}T_k^i\}_k$ that keeps all net incomes in all sectors the same. The changes in employment in all sectors j are given by

$$\mathrm{d}E_j^i = \frac{\partial E_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial E_j}{\partial T_k^i}\mathrm{d}T_k^i. \tag{25}$$

The tax reform $\{\mathrm{d}T_k^i\}_k$ can be found by solving, for all j,

$$\frac{\partial w_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial w_j}{\partial T_k^i}\mathrm{d}T_k^i - \mathrm{d}T_j^i = 0. \tag{26}$$

Proof. See Appendix C.3. □

Proposition 3 can again be understood by starting from a small increase in union power ρ_i in sector i. Such an increase raises the wage in sector i, and lowers wages in other sectors $j \neq i$, if labor types are complements in production. The net-income neutral tax reform offsets the impact on net wages by combining the increase in ρ_i with a tax reform $\{\mathrm{d}T_k^i\}_k$ that keeps all net incomes constant. This tax reform can be found by solving equation (26), which is obtained by setting $\mathrm{d}(w_j - T_j) = 0$ for each sector j. Provided the social welfare weight of firm-owners equals one (i.e., provided the profit tax is optimized), the only welfare-relevant effect of the joint increase in union power and the tax reform goes via changes in employment rates, $\mathrm{d}E_j^i$, as given by equation (25). The associated welfare impact consists of the fiscal externality $t_j w_j = T_j - T_u$ and the union wedge $\tau_j w_j$.

The total impact of the combined increase in ρ_i and the tax reform $\{\mathrm{d}T_k^i\}_k$ on employment in different sectors is generally ambiguous. The increase in union power raises the wage and lowers employment in sector i. Keeping the net wage $w_i - T_i$ in sector i fixed thus requires increasing the income tax T_i, which further lowers employment in sector i. In other sectors, both employment and wages go down following the increase in ρ_i if labor types are complements

[37] Such tax reforms have been analyzed as well by Gerritsen and Jacobs (2020) in the context of minimum wages.

in production. Hence, keeping net wages $w_j - T_j$ in other sectors fixed requires decreasing T_j, which raises employment in other sectors. Equation (24) states that an increase in union power ρ_i in sector i is desirable if and only if the sum of the fiscal externality and the union wedge over all sectors is positive.

It is shown in Appendix C.3 that the impact of a rise in union power in sector i on employment in sector $j \neq i$ is zero in sectors where wages are determined competitively or if labor markets are independent. Furthermore, the effect is negligible if the production function can be approximated well by a second-order Taylor expansion. If $\mathrm{d}E_j^i = 0$ for $j \neq i$ and $\mathrm{d}E_i^i < 0$, then according to Proposition 3 an increase in union power ρ_i raises social welfare if and only if employment in sector i is upward distorted on a net basis, i.e., if the sum of the explicit and implicit tax are negative: $t_i + \tau_i < 0$. Because the union wedge is non-negative, this condition requires that participation is subsidized, i.e., $T_i < T_u$. In reality, as we will demonstrate below, participation is taxed for all workers in OECD countries. Hence, if the tax system in these countries is optimized, and spillover effects between different sectors are small, an increase in union power unambiguously lowers social welfare. We get back to this point in more detail in Sections 7 and 8.

6 Summary of extensions

In the online Appendix accompanying this paper, we investigate the robustness of our results by relaxing some of the key assumptions in our model. i) We study how our main results are affected if unions respond to marginal tax rates. ii) We analyze the consequences of inefficient rationing. iii) We study endogenous occupational choice, or the 'intensive margin' as in Saez (2002). iv) We analyze a single, national union that bargains with firm-owners over the entire *distribution* of wages. v) We analyze sectoral unions that bargain with firms over wages *and* employment, as in the efficient bargaining model of McDonald and Solow (1981). This Section summarizes the main results from these extensions. More details and the proofs of all claims made here can be found in the online Appendix.

6.1 Union responses to marginal tax rates

So far, we have assumed that the government sets the tax liability T_i in each sector directly, which unions subsequently take as given. However, if the government sets a tax *schedule* $T(w_i)$, rather than a tax liability T_i in each sector, unions will anticipate that a higher wage affects the tax liability. Hence, the marginal tax rate will also determine wage demands of the union. The extension in this subsection derives how our main results are affected if the government optimizes a tax schedule and unions respond to marginal tax rates. See also Section 3 in the online Appendix.

To study this extension, it is more convenient to work with a continuum, rather than a discrete set of sectors (or occupations), which gives rise to a continuous income distribution. Like before, sectors are indexed by $i \in \mathcal{I} = [0, 1]$ and ordered in such a way that wages $w(i)$ are increasing in i.[38] To maintain tractability, we invoke Assumption 1, which guarantees

[38] Because this extension employs a continuum of sectors, i shows up as a function argument instead of a

that there are no spillover effects between different sectors.[39] Within each sector, workers are represented by a union that maximizes the expected utility of its members, as in the baseline. Unions bargain with firm-owners over wages and firms unilaterally determine employment. We again parameterize union power in each sector with a parameter $\rho(i)$ so that we allow for any equilibrium in the Right-to-Manage model. The modified wage-demand equation, which is the counterpart of equation (8), then reads as:

$$\rho(i)(1-T'(w(i))) = \varepsilon(i)\frac{u(\hat{c}(i))-u(c_u)}{u'(c(i))w(i)}. \tag{27}$$

There is one key difference relative to the baseline. Labor-market outcomes are affected by changes in the marginal tax rate $T'(w(i))$: the left-hand side of equation (27) is multiplied by the net-of-tax rate. Intuitively, unions only care about demanding higher wages if this leads to higher after-tax earnings. Consequently, a higher marginal tax rate reduces wage demands, which induces firms to hire more workers. The negative (positive) impact of the marginal tax rate on the equilibrium wage (employment rate) is referred to in the literature as the wage-moderating effect of a higher marginal tax rate.[40,41] In Appendix 3 of the online Appendix, we characterize optimal profit taxes, unemployment benefits, and the optimal tax schedule on labor income $T(\cdot)$ using the tax-perturbation approach.[42] The first two results from Proposition 1 generalize immediately. However, optimal income taxes now need to take into account two additional, welfare-relevant effects.

First, a higher marginal tax rate at w' raises the employment rate at this income level due to the wage-moderating effect of a higher marginal tax rate. This alleviates labor-market distortions from the explicit tax $t(w')$ on labor participation, and the implicit tax $\tau(w')$ from unions bidding up wages above the market-clearing level. Intuitively, if unions moderate wage demands in response to a higher marginal tax rate, employment increases, and this is welfare-improving if employment is distorted downwards, i.e., if $t(w') + \tau(w') > 0$.

Second, as the marginal tax rate moderates wages at income level w', income is redistributed among workers, firm-owners, and the government. In particular, if wages are lowered, firm-owners receive higher profits, workers see their after-tax income reduced, and the government experiences a reduction in tax revenue (provided that $T'(w') > 0$). The welfare effect of this additional redistribution is ambiguous and depends on whether $b(w') \gtrless 1$. A redistribution of one unit of income from the worker to the firm owner yields a welfare effect of $1 - b(w')$, since firm-owners have a social welfare weight of 1 (in the optimum). The subsequent reduction in tax payments of this worker with $T'(w')$ units yields a welfare effect of $T'(w')(b(w') - 1)$. As

subscript.

[39]See Sachs et al. (2020) for a derivation of the optimal non-linear tax schedule in a competitive framework with a continuum of wages and spillover (general-equilibrium) effects.

[40]The negative (positive) impact of the marginal tax rate on the equilibrium wage (employment rate) is derived in the context of unions by Hersoug (1984), but also holds when there are matching frictions (Pissarides, 1985), or when firms pay efficiency wages (Pisauro, 1991). See Lehmann et al. (2016) for empirical evidence, and Kroft et al. (2020) and Hummel (2021) for the implications for optimal taxation.

[41]Sometimes, this effect is referred to as the wage-moderating effect of 'tax progressivity'. Indeed, if marginal tax rates increase, while average tax rates remain fixed, a higher marginal tax rate also raises the progressivity of the tax system, since a tax system is progressive only if the average tax rate increases in income.

[42]The tax-perturbation approach is also employed by, Saez (2001), Golosov et al. (2014), Gerritsen (2016), and Jacquet and Lehmann (2021), among many others.

both effects are proportional to $1 - b(w')$, there is a redistributional gain (loss) due to wage moderation at w' if $b(w') < 1$ ($b(w') > 1$).

Wage-moderation effects of marginal tax rates thus trigger two welfare-relevant effects: they alleviate (exacerbate) labor-market distortions if labor participation is taxed (subsidized) on a net basis, and they generate redistributional gains (losses) if $b(w') < 1$ ($b(w') > 1$). These welfare effects are related. Loosely speaking, the government typically only provides transfers to employed workers that exceed the unemployment benefit, i.e., sets $t(w) < 0$, if these workers have an above-average social welfare weight, i.e., if $b(w) > 1$. Therefore, we conjecture that, compared to the baseline, wage-moderation effects tend to reduce (raise) optimal marginal tax rates if employment is distorted upwards (downwards) – *ceteris paribus*. However, we are not sure whether the ceteris paribus condition holds, since the optimal marginal tax schedule is dependent on all social welfare weights, the entire income distribution, and participation distortions at all income levels. Only a more elaborate quantitative analysis can give a more definitive answer to the question how wage-moderation effects affect optimal participation taxes, which is beyond the scope of the current paper.[43]

Turning to the desirability of unions, we find that an increase in union power raises social welfare if the union represents workers with an above-average social welfare weight and/or represents workers whose labor participation is subsidized on a net basis. Hence, our desirability condition carries over in slightly modified form. Intuitively, an increase in union power at income level w boosts wage demands and reduces employment at w. This results in a welfare gain i) if participation is distorted upwards on a net basis (our first effect discussed above), and/or ii) if the wage increase is associated with a positive redistributional gain (our second effect discussed above). A positive redistributional gain requires that $b(w) > 1$. Therefore, we view our adjusted desirability condition as only slightly weaker, since an above-average social welfare weight generally also implies that labor participation is distorted upwards (see, e.g., Diamond, 1980).

Moreover, we can derive a sufficiency condition for the desirability of unions: an increase in union power at income level w raises social welfare if participation is distorted upwards on a net basis ($t(w) + \tau(w) < 0$) *and* the social welfare weight of the workers represented by the union is above-average ($b(w) > 1$). Conversely, a sufficient condition for unions not to be desirable is that workers pay positive participation taxes ($t(w) > 0$) and have a below-average social welfare weight ($b(w) < 1$).[44] Given that we empirically find that participation taxes are never negative (see the next section), the desirability condition also implies that a necessary condition for unions to be desirable is that the social welfare weight of the workers that are represented by the union is above average, i.e., $b(w) > 1$. Hence, Proposition 2 largely carries over to the current setting.

In the baseline, without union responses to marginal tax rates, social welfare weights and net participation taxes at a particular income level are tightly linked.[45] The reason is that both

[43] See Kroft et al. (2020) and Hummel (2021) for an analysis of the quantitative implications of the wage-moderating effect for optimal taxes.

[44] This sufficiency condition only requires that participation taxes are positive, since implicit taxes from unions are always weakly positive (i.e., $\tau(w) \geq 0$). Hence, a positive participation tax is sufficient to guarantee downward distortions on participation.

[45] From equation (22), net participation taxes are negative if and only if the social welfare weight is above

participation distortions and distributional effects are proportional to $1 - b(w)$. Therefore, only knowledge of social welfare weights is required to judge whether an increase in union power raises social welfare, cf. Proposition 2. However, if unions respond to marginal tax rates, such a tight link between social welfare weights and net taxes on participation no longer exists. This is because participation taxes at each income level are determined by the entire optimal non-linear tax schedule, which depends on all social welfare weights, the income distribution, and participation distortions at all income levels. Therefore, judging whether an increase in union power raises social welfare generally requires knowledge of both participation taxes and social welfare weights.

6.2 Inefficient rationing

We have deliberately biased our findings in favor of unions by assuming that labor rationing is efficient: the burden of involuntary unemployment is borne by the workers with the highest participation costs. However, there are neither theoretical nor empirical reasons to expect that labor rationing is always efficient, see Gerritsen (2017) and Gerritsen and Jacobs (2020). In this extension, we relax the assumption of efficient rationing. For analytical convenience, this extension assumes that labor markets are independent and there are no income effects at the union level. See also Section 4 in the online Appendix.

We follow Gerritsen (2017) and Gerritsen and Jacobs (2020) by defining a rationing schedule that specifies the probability that workers find employment in sector i for a given sectoral employment rate E_i and a given participation threshold φ_i^* in sector i. The probability of finding a job in sector i increases in employment E_i and decreases if labor participation rises, i.e., if φ_i^* is higher. Consequently, it is possible that a worker with lower participation costs (a higher surplus from work) is unemployed, while a worker with higher participation costs (lower surplus from work) has a job.

We show that Proposition 1 for optimal taxes generalizes to a setting with inefficient labor rationing with two modifications. First, with a general rationing scheme, the union wedge τ_i no longer measures the monetized utility loss of a *marginal* worker losing her job, but the expected utility loss of *all rationed workers*, i.e., the workers who lose their job if the wage is marginally increased. Second, in addition to the union wedge, there is a distortion associated with the inefficiency of the rationing scheme. The more inefficient is the rationing scheme, the *higher* should be the optimal participation tax – *ceteris paribus* – compared to the case with efficient rationing. The intuition is similar to Gerritsen (2017): if wages are above the market-clearing level and rationing is inefficient, some workers will be unemployed that have a higher surplus from work than some of the workers who are employed. By setting a higher participation tax, the workers with the lowest surplus from work opt out of the labor market. This, in turn, increases the employment prospects of the workers with a larger surplus from work. Consequently, the government replaces involuntary unemployment by voluntary unemployment, which reduces the inefficiency of labor-market rationing.

In addition, the desirability condition for unions in Proposition 2 is modified to account for inefficient rationing. In particular, an increase in union power is less likely to be desirable

average.

than in the case with efficient rationing. The implicit tax on labor caused by unions not only alleviates possible upward distortions in labor supply, it also generates more inefficiencies in labor rationing. Hence, the desirability condition for unions becomes tighter. Unions can be desirable only if the social welfare weight b_i in sector i is sufficiently above the average of one so as to compensate for the larger inefficiencies in labor rationing.

6.3 Endogenous sectoral choice

We abstracted from an intensive margin of labor supply for the following reasons. First, including an intensive margin requires us to take a stance on whether working hours are determined by the worker, the union, or some combination. Second, we also need to know the incidence of involuntary unemployment: does it fall on the intensive margin, the extensive margin, or both? We are neither aware of good theoretical models nor empirical evidence on the joint determination of hours worked and the incidence of involuntary unemployment on the intensive and extensive margin. Therefore, in this extension (studied in Section 5 of the online Appendix), we follow Saez (2002) and model the 'intensive margin' by letting workers optimally choose the sector in which they want to work. As before, we assume that there are no income effects at the union level.

To model endogenous sectoral choice, we assume that all workers draw a vector of participation costs $\boldsymbol{\varphi} \equiv (\varphi_0, \varphi_1, \cdots, \varphi_I)$ indicating how costly it is to work in each sector i. Based on their participation costs, individuals optimally choose in which sector (or: occupation) to look for a job. We assume that the probability $p_i \in [0, 1]$ that an individual finds employment in sector i can be written as a reduced-form function of the participation taxes in all sectors $p_i(\boldsymbol{\varphi}, T_1 - T_u, \cdots, T_I - T_u)$. If the individual is unsuccessful in finding a job in his/her preferred sector, she cannot move to another sector but instead becomes unemployed. We extend our notion of efficient rationing to this environment by assuming that, if there is involuntary unemployment, individuals who are indifferent between choosing sector i and another sector (possibly non-employment) do not find a job if wages in sector i are set above the market-clearing level.[46]

We demonstrate that Proposition 1 generalizes to a setting where workers can switch between occupations with two modifications. First, the union wedge τ_i no longer captures the utility loss of the marginal worker, but instead captures the average utility loss of all workers who lose their job if employment in sector j is marginally reduced – like in the case with inefficient rationing, see above. Second, the employment and wage responses η_{ji} and κ_{ji} remain sufficient statistics, but they not only capture 'demand interactions' through complementarities in production (as in the baseline model), but also 'supply interactions' through occupational choice. Moreover, the desirability condition for unions in Proposition 2 generalizes completely to an environment with occupational choice. The reason is that if labor rationing is efficient, individuals who are marginally indifferent between two sectors will not switch between sectors if there is involuntary unemployment. Therefore, the welfare effects of a combined increase in union power and a tax reform that leaves the wage unaffected are the same as before.

[46]Our notion of efficient rationing is similar to Lee and Saez (2012), but we extend it to multiple sectors.

6.4 National unions

In our baseline model, bargaining takes place at the sectoral level. Each sectoral union faces a trade-off between employment and wages, but does not care about the overall *distribution* of wages. There is, however, ample empirical evidence that a higher degree of unionization is associated with lower wage inequality.[47] How do our results for optimal taxes and the desirability of unions change if unions care about the entire distribution of wages?

To answer this question, Section 6 of the online Appendix analyzes a model where a single union bargains with firm-owners over *all* wages in all sectors, while firms (unilaterally) determine employment, as in the RtM-model. To maintain tractability, we assume efficient rationing and we assume away income effects at the union level. The union maximizes the sum of all workers' expected utilities. Since the utility function $u(\cdot)$ is concave, the union has an incentive to compress the wage distribution. We explicitly solve the Nash-bargaining problem between unions and firms to characterize labor-market equilibrium. To maintain comparability with our previous findings, we assume that firm-owners are risk neutral. It should be noted that a national union does not necessarily find it in its best interest to bargain wages in *all* sectors above the market-clearing level. This is because an increase in the wage for high-skilled workers depresses the wages for low-skilled workers. A national union may therefore refrain from demanding an above market-clearing wage for high-skilled workers.

We demonstrate that Proposition 1 carries over fully to a setting with a national union bargaining over the entire wage distribution. The reason is that the optimal tax rules in Proposition 1 are expressed in terms of sufficient statistics for the employment and wage responses η_{ji} and κ_{ji}. Hence, a different bargaining structure gives rise to different elasticities, but the optimal tax formulas remain the same. We derive the counterpart of Proposition 2 for the desirability of a national union bargaining over all wages. In particular, we show that increasing power of a national union raises social welfare if and only if weighted average social welfare weight of workers in sectors with involuntary unemployment exceeds the average social welfare weight of all (employed and unemployed) workers.

6.5 Efficient bargaining

The baseline assumed that bargaining takes place in a Right-to-Manage setting. This bargaining structure generally leads to outcomes that are not Pareto efficient (McDonald and Solow, 1981). This inefficiency can be overcome if unions and firm-owners bargain over both wages *and* employment.[48] Therefore, we explore whether our results generalize to a setting with efficient bargaining (EB), as in McDonald and Solow (1981). For simplicity, we assume efficient rationing, independent labor markets, and no income effects at the union level. See also Section 7 in the online Appendix.

[47] See, for instance, Freeman (1980, 1993), Lemieux (1993, 1998), Machin (1997), Card (2001), DiNardo and Lemieux (1997), Card et al. (2004), Visser and Checchi (2011), and Western and Rosenfeld (2011).

[48] We consider the EB-model less appealing for two reasons. First, the assumption that firms and unions can write contracts on both wages *and* employment is problematic with national or sectoral unions, since individual firm-owners then need to commit to employment levels that are not profit-maximizing (Boeri and Van Ours, 2008). Oswald (1993) argues that firms unilaterally set employment, even if bargaining takes place at the firm level. Second, employment is higher in the EB-model compared to the competitive outcome, since part of firm profits are converted into jobs. This property of the EB-model is difficult to defend empirically.

The key feature of the EB-model is that any potential labor-market equilibrium (w_i, E_i) in sector i lies on the *contract curve*, which is the line where the union's indifference curve and the firm's iso-profit curve are tangent:

$$\frac{u(w_i - T_i - \hat{\varphi}_i) - u(-T_u)}{E_i \overline{u'(w_i - T_i - \varphi)}} = \frac{w_i - F_i(\cdot)}{E_i}. \tag{28}$$

Intuitively, if the equilibrium wage and employment level are on the contract curve, then it is impossible to raise either union i's utility while keeping firm profits constant, or vice versa. Which labor contract (w_i, E_i) is negotiated depends on the power of union i relative to that of the firm. We model union i's power as its ability to bargain for a wage that exceeds the marginal product of labor with a rent-sharing rule.[49] In stark contrast to the RtM-model, an increase in union power will not only result in a higher wage, but also in *higher* employment. Intuitively, unions can use their power to bargain both for a higher wage and a higher employment rate. Moreover, and also in contrast to the RtM-model, there is now a labor-demand distortion: the wage exceeds the marginal product of labor. As a result, there will be an implicit subsidy on labor demand.

We show that Proposition 1 generalizes to a setting with efficient bargaining with one important modification. The larger is the implicit subsidy on labor demand, the higher is the optimal participation tax – *ceteris paribus*. Therefore, the impact of unions on optimal participation taxes has become ambiguous with efficient bargaining, in contrast to our findings with the RtM-model. On the one hand, employment is too low, because unions generate involuntary unemployment (as captured by the union wedge τ_i), which calls for lower participation taxes. On the other hand, employment is too high, because unions generate implicit subsidies on labor demand in the EB-model, which calls for higher participation taxes. Furthermore, we demonstrate that the desirability condition of Proposition 2 remains the same in the EB-model. Therefore, the question whether unions are desirable or not does not depend on the bargaining structure. Intuitively, also in the EB-setting, unions will generate more *involuntary* unemployment if they are more powerful. Hence, an increase in union power is desirable only if labor participation (and not employment) is distorted upwards, just like in the RtM-model.

7 Empirical analysis

According to Proposition 1, more powerful unions should be associated with lower participation tax rates. Moreover, Proposition 3 gives a necessary condition for the desirability of unions in a sector: if taxes are optimized, unions are desirable only if participation is subsidized on a net basis.[50] Furthermore, according to Proposition 2 unions are only desirable for workers with the lowest incomes, who feature the highest (above-average) social welfare weights. In this Section, we empirically verify whether more powerful unions are associated with lower participation tax rates, whether participation is subsidized, and whether unions are stronger among the lower

[49] If unions have zero bargaining power, the outcome in the EB-model coincides with the competitive equilibrium. If, on the other hand, union i has full bargaining power, it can offer a contract which leaves no surplus to firm-owners.

[50] Participation is typically only subsidized on a net basis if social welfare weights are above-average, that is, for the low-income workers, see equation (22).

income groups. We so by compiling our own data set with 294 country-sector observations on union densities, wages, and participation tax rates from 23 OECD countries and 18 sectors.

7.1 Data

This Section summarizes the construction of our data set of union densities, wages, and participation tax rates at the sectoral level. Unfortunately, micro data on individual union membership are scarce. Therefore, our primary unit of observation is the sector level.[51] An important advantage of using sectoral data is that it allows us to include many countries. All details can be found in online Appendix 8. We use union densities at the sectoral level from the OECD Bargaining and Trade Union Data. To calculate participation tax rates, we use the online tax-benefit calculator from the OECD. Making these calculations requires information on the earnings of workers at the sectoral level. We obtain the earnings data from the STAN database from the OECD and the Statistics on Wages Database of the ILO.

7.1.1 Union densities

Our analysis uses sectoral union density as a measure for union power. Union density measures the percentage of (employed) workers who are member of a labor union. Our assumption is that if union densities are larger, then unions are more powerful. To the best of our knowledge, this is the only available union variable that is consistently measured across countries and across sectors.[52]

Data on union density come from the "Jelle Visser database", which is officially referred to as the Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts (Visser, 2019).[53] This panel data set spans 55 countries over the time-period 1960-2018 and contains union densities at the sectoral level. However, many observations are missing, since union densities are not measured every year, not for every country, and not for every sector. To obtain a more complete data set, we pool the observations on union membership for each country-sector over a 10-year time window.[54] Doing so gives us a coverage of union densities at the sectoral level of approximately 75%. The reference year of each country is the latest year for which data on sectoral union densities are available.

Our final sample contains 23 countries. Table 1 in Appendix 8 lists the countries that are included.

[51] For the US, however, we are able to use micro-data from the CPS to calculate union densities by income level. By using union densities by income level, we can cross-check our findings obtained from sectoral data. We indeed confirm all results for the US. Since no additional insights are obtained from this analysis, we relegated it to Section 8 from the online Appendix.

[52] Alternatively, one may use union coverage by sector as measure for union power, see also Figure 1. Such a measure would also take into account that in some countries, collective labor agreements are extended to the entire sector. However, to our knowledge, no data on union coverage are available at the sectoral level.

[53] This database forms the basis of the OECD Bargaining and Trade Union Data. We employ version 6.1 of the database (2019), which is the latest version that contains data on union membership at the sectoral level.

[54] This procedure rests on the assumption that union membership rates are only slow-changing over time, which is empirically the case.

7.1.2 Wages

Data on wages of workers at the sectoral level are obtained mainly from the STAN (Structural Analysis) industry database from the OECD (OECD, 2022d). The STAN database covers sectoral data for OECD countries at the International Standard Industrial Classification of All Economic Activities (ISIC4) 2-digit level from 1970-2021. The wage refers to gross wages and salaries for employees, excluding employer contributions, for example for social insurance and pensions. Moreover, by focusing on the wage bill minus employer contributions, this wage measure corresponds most closely to the gross earnings variable in the OECD tax-benefit calculator. Of the 23 countries that we include in our final sample (see Table 1 in Appendix 8), the OECD STAN database does not contain sectoral wage data for Switzerland, Japan, South Korea, New Zealand, and Turkey. For these countries, we rely on the Statistics on Wages Database of the ILO (2022d). This database contains mean monthly gross earnings of employees measured in local currency units at the ISIC4 1-digit level, which are multiplied with 12 to obtain yearly figures. Furthermore, the STAN wage data cover fewer sectors than the ILO data for Australia. Therefore, we also use the ILO wage data for Australia to obtain more observations.

In all our calculations, wages are measured per full-time equivalent worker per year. The STAN data provide the total wage bill at the sectoral level. In addition, data on full-time equivalent employment are available for seven countries (Austria, Spain, France, Italy, Netherlands, Norway, and the United States). For these countries, we calculate the wage per full-time equivalent worker in each sector. For the 16 remaining countries, only data on total employment are available. We translate wages per worker to full-time equivalents by means of a country-sector specific part-time factor, which is defined as the ratio of average weekly hours worked relative to the statutory length of the working week in that country. We rely on data from the OECD and the ILO to compute the sectoral part-time factor, see online Appendix 8 for more details.

To merge the sectoral union densities from the ICTWSS-database and the sectoral wage data from the STAN and ILO databases, a concordance between the sectoral classifications of each database is employed. Table 2 in Appendix 8 shows the sectoral mapping between all data sets. The data set with union densities and wages ultimately consists of observations during the period 2014-2018. Given that the coverage of sectoral union densities and wage data is incomplete, we obtain a cross section of countries with 294 observations spread out over 23 countries and 18 sectors.[55]

7.1.3 Participation tax rates

We employ the OECD tax-benefit web calculator to compute participation tax rates for all 294 country-sector observations in our data (OECD, 2022c). To do so, we first calculate the sum of taxes paid minus transfers received at the household level if the primary earner is full-time employed at the sectoral wage. Subsequently, we calculate the sum of taxes paid minus transfers received at the household level when the primary earner is unemployed and entitled to social-

[55]The sectors are: Agriculture, Industry*, Services*, Mining, Manufacturing, Utilities, Construction, Trade, Transport and communication, Hotels and restaurants, Finance, Real estate and business services, Commercial services*, Social services, Public administration, Education, Health care, and Other services, where an asterisk refers to an aggregated sector.

assistance benefits (in the baseline) or unemployment benefits (in the robustness check).[56] In line with our theoretical definition, the participation tax rate is defined as the difference between taxes paid minus transfers received when the primary earner is employed and unemployed, expressed as a fraction of gross earnings of the primary earner. The total net tax burden in work is the sum of the income tax and social-security contributions minus family benefits, and in-work tax credits.[57] The total tax burden for households where the primary earner is out of work is based on the same tax items except that we account for social-assistance benefits (in the baseline) or unemployment benefits (in the robustness check).

We use the default settings of the tax-benefit calculator and focus on a two-earner couple with two dependent children. The earnings of the primary earner are taken to the sector-specific yearly full-time equivalent wage. Regarding the secondary earner, we assume positive assortative mating such that there is a perfect correlation between earnings of primary and secondary earners. We calculate the secondary earner's income by multiplying the primary earner's income with a country-specific ratio that is computed based on average monthly earnings and total employment by gender, which are obtained from ILO (2022a,b,c). See online Appendix 8 for details.[58]

7.2 Descriptive statistics

Before diving into our empirical exploration, this Section provides some descriptive statistics of our data set. Table 4 in Appendix D gives the means, standard deviations, minima and maxima broken down by country and sector. On average, the union density is 27% in our sample. The participation tax rate is on average 37%. Moreover, Table 4 reveals that all countries set positive participation tax rates. Furthermore, participation tax rates can sometimes be as high as 100% in sectors where earnings are very low. Figure 9 in Appendix D also provides scatter plots of participation tax rates against union densities for all countries.

Figure 3 gives the (unweighted) average union density and average participation tax rate by country. The countries with low union densities are, for example, the United States (11%), France (11%), Hungary (11%), and New Zealand (14%).[59] At the high end of union densities, we find the Scandinavian countries: Finland (63%), Sweden (63%), and Denmark (68%).

There is substantial cross-country heterogeneity in average participation tax rates. They are highest in Denmark (64%), Japan (50%), and Germany (49%), followed by Australia (47%), Austria (46%), and Canada (45%). On average, participation tax rates are lowest in Turkey (21%), Spain and Sweden (25%), and Slovakia (26%).

[56] Because our theoretical model is static, it is not obvious if the empirical counterpart of income in non-employment includes only social assistance or also unemployment benefits (which only have a limited duration). Therefore, we decided to calculate the participation tax rate at each country-sector observation twice.

[57] We set the housing benefits (e.g., rent assistance) to zero, since we do not want to distinguish between renters and home-owners.

[58] Specifically, the fraction is calculated as the product of average monthly earnings of females multiplied by total female employment divided by the product of average monthly earnings of males multiplied by total male employment. In our data set, this fraction is always between 0 and 1 (see Table 3 in Appendix 8) and captures differences in labor participation, unemployment rates, working hours and hourly wages (e.g., due to labor-market discrimination) between females and males.

[59] Despite low union densities in France, union coverage is very large, around 98%, because collective labor agreements are extended to entire sectors in the economy, see also OECD (2022b).

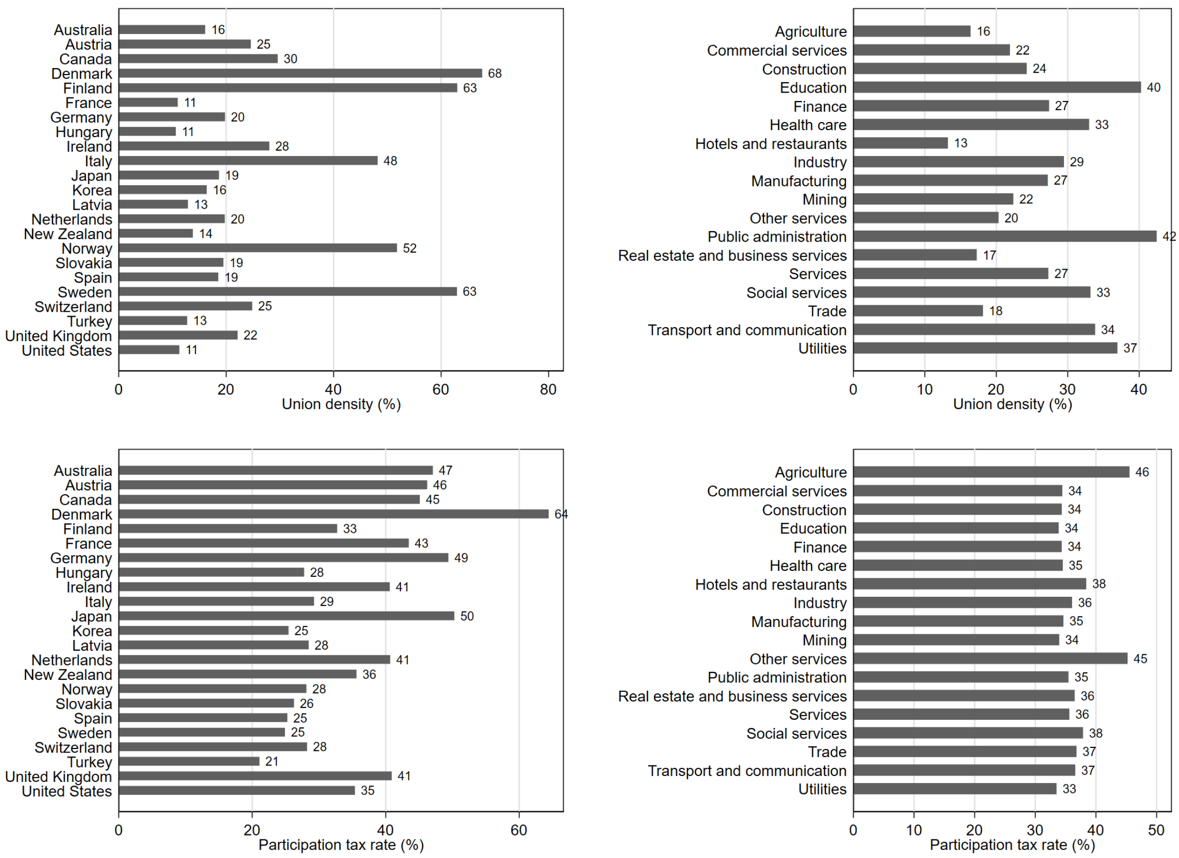


Figure 3: Average union densities and participation tax rates across countries and sectors

Similarly, Figure 3 breaks down our data across sectors. Clearly, there is quite some variation in union densities across sectors. Not surprisingly, Hotels and restaurants (13%) and Agriculture (16%) are the sectors that have on average very low union densities. At the same time, Public Administration (42%), Education (40%), and Utilities (37%) are the sectors that are most strongly unionized.

There is much less variation in participation tax rates across sectors: most sectors feature a participation tax rate of around 35-40%. The sectors with – on average – the lowest wages, Agriculture and Other Services, feature substantially higher participation tax rates, since unemployed workers in these sectors receive large income support relative to their earnings.

7.3 Analysis

We start by exploring whether union densities and participation tax rates are negatively associated, in line with the prediction from Proposition 1. Figure 4 gives a scatter plot of participation tax rates against union densities in our data set. At first sight, there does not seem to be much of an association between participation tax rates and union densities. Indeed, the coefficient of a simple regression of participation tax rates on union densities (0.003, s.e. 0.035) is not significantly different from zero. However, this correlation may be driven by substantial cross-country heterogeneity, as we documented above.

To control for the unobserved, sector-invariant heterogeneity between countries (e.g., in pref-

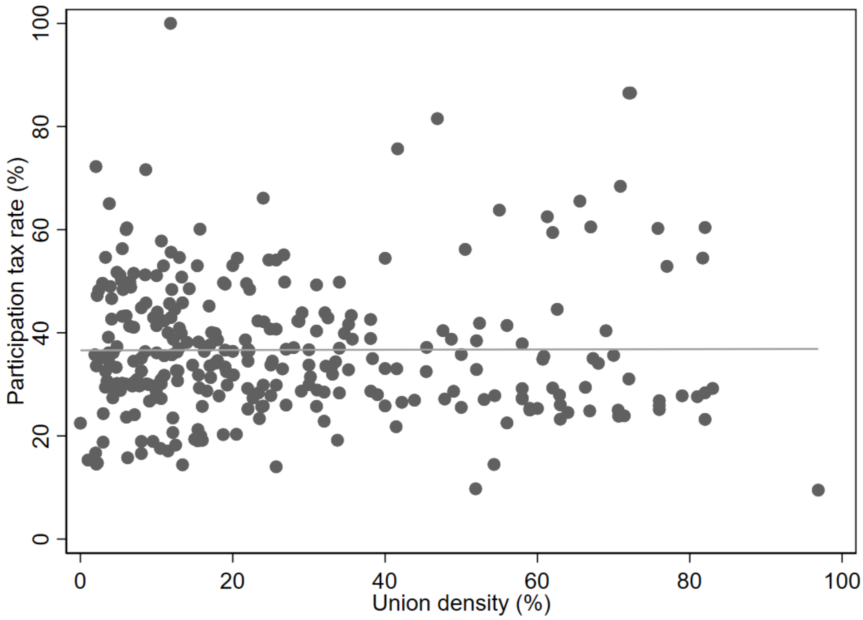


Figure 4: Participation tax rates and union densities

Table 1: Fixed-effects regressions of participation tax rates on union densities

Variable	Coefficient	Standard error	t-value
Union density	-0.142	0.039	-3.62
Constant	37.0	2.14	17.3
R^2	0.60	R^2 adj.	0.57

Country-fixed effects included, United States is the reference country

erences for income redistribution), we also run a country-fixed effects regression of participation tax rates on union densities. Table 1 gives the regression results. Now, the coefficient on the union density is -0.14 and is statistically significant at the 1-percent level. Our estimate implies that a one-percentage point increase in union density is associated with a 0.14 percentage-point decrease in the participation tax rate. This association is in line with the prediction from Proposition 1: higher union densities are associated with lower participation tax rates. Evaluated at the mean union density of 27%, participation tax rates would be on average about 4 percentage points lower if there were no unions, which is a reduction in participation tax rates of 11% on average.[60]

Next, we verify empirically if the desirability condition is met. According to Proposition 3, unions can be desirable only if employment is distorted upwards as a result of participation subsidies. Clearly, the desirability condition is never met in our data, as can be verified upon inspection of Table 4 and the scatter plot in Figure 4. Participation tax rates are positive in all sectors and all countries under consideration. This empirical observation implies that unions are not a socially desirable complement to the tax system to redistribute income in any country or sector in our data set if participation taxes would be optimally set.[61]

[60]This result should be interpreted with caution, because our results cannot be given a causal interpretation, since we do not exploit exogenous variation union density.

[61]As a Corollary, our analysis also implies that the desirability condition for minimum wages – as derived by

According to Proposition 2, unions would be desirable only for the lowest income groups, since they have the highest social welfare weights for standard social welfare functions, see also Proposition 2.[62] With our data, we can verify whether union power – as measured by union density – is indeed largest for the workers with lower incomes and lowest for high-income workers. In Figure 5, we plot union densities against wages, where sectoral wages are taken relative to their national average to account for the fact that wages are measured in national currencies. A clear positive correlation is visible between union densities and wages. Moreover, this correlation survives in a country-fixed effects regression of union densities on relative wages, see Table 2. A one percentage-point increase in the wage relative to the national average is associated with a 0.12 percentage points higher union density. Hence, it appears that unions are actually strongest in sectors where wages are relatively high.[63] This finding corroborates our earlier result that unions are not a socially desirable complement to the redistributive tax system if taxes are optimally set. Unions are on average most powerful among the higher income groups, while they should be most desirable for the lower income groups.

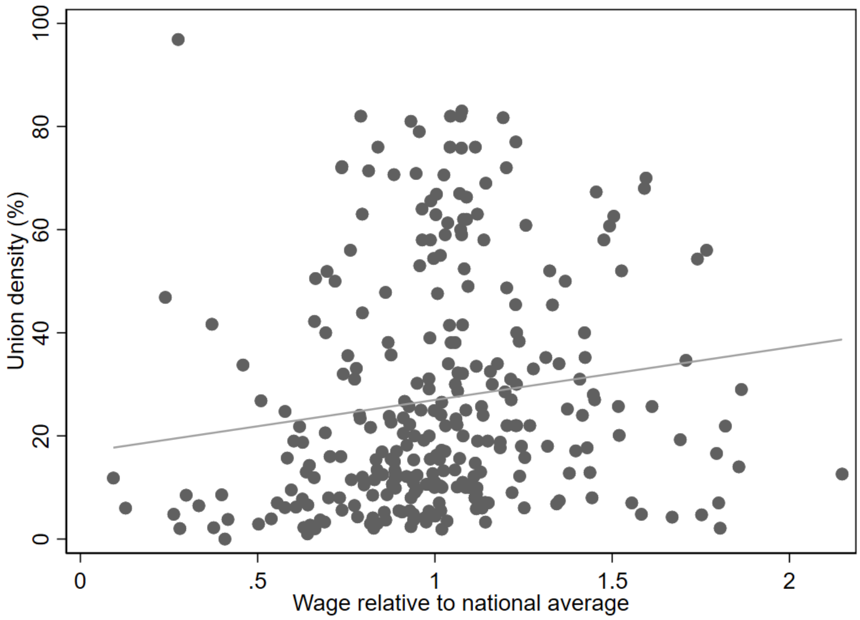


Figure 5: Union densities and wages

7.4 Robustness

As a robustness check, we also compute participation tax rates using unemployment benefits rather than social-assistance benefits, see online Appendix 8.5. Average participation tax rates

Gerritsen and Jacobs (2020) – is rejected empirically. The logic is similar: minimum wages are not a socially desirable complement to the optimal tax system because there are no upward distortions in employment resulting from participation subsidies.

[62]We assume declining Pareto weights with income, which can be rationalized by many theories of redistributive justice or inequality aversion in a social welfare function. Declining private marginal utility of income can also generate declining social welfare weights.

[63]Again, this finding should be interpreted with caution because the correlation might be driven by reverse causality: wages might also be high partly as a result of strong unions.

Table 2: Fixed-effects regressions of union density on relative wages

Variable	Coefficient	Standard error	t-value
Relative wage	11.5	2.45	4.70
Constant	-0.74	4.03	-0.18
R^2	0.68	R^2 adj.	0.65

Country-fixed effects included, United States is the reference country

are 68% based on unemployment benefits, compared to an average of 37% in the baseline. Participation tax rates based on unemployment benefits are, on average, much higher, because in many countries social-assistance benefits are means tested on partner income, while unemployment benefits are only linked to past earnings. Redoing the analysis with this alternative measure for the participation tax rate strengthens our main findings. Indeed, the country-fixed effects regression of participation tax rates on union densities returns an even smaller coefficient of -0.17 (significant at 1%-level), suggesting that participation tax rates are lower if union densities are higher, see Table 6 in online Appendix 8.5. Moreover, nowhere are participation tax rates negative, like in the baseline. Hence, the desirability condition for unions is still not satisfied.

A potential concern is that for some individuals or household types at the bottom of the income distribution, participation taxes could be lower than in our data, in which case the desirability condition could be met. Indeed, most wage levels in our sample are substantially above guaranteed minimum incomes. Some countries, for example the United States, may target in-work tax credits especially at the working poor, which would lower their participation tax rates, and thus would potentially make unions (more) desirable. To address this concern, we calculate participation taxes for a household where one individual is full-time employed at the minimum wage, and the second individual is not employed. Data on minimum wages are obtained from OECD (2022a) for a selection of 16 out of our 23 countries. For the remaining countries, we set the income of the household to 25% of average earnings.[64] We maintain the other assumptions of the baseline; the couple has two children, is not entitled to housing benefits, and receives social assistance when out of work.[65] Figure 6 shows the cross-section of participation tax rates for these workers. For most countries, participation tax rates at minimum-income levels are substantially higher (66%) compared to the average participation tax rate (37%), see Table 4 of Section 8 in the online Appendix. Participation tax rates for Austria, Norway, Spain, and Sweden are (close to) 100%. The international outlier is the United States, where the participation tax rate at minimum income levels is only 7%. Hence, the desirability condition for unions is still never met as participation taxes remain positive, even at very low earnings levels.

[64] The Table does not include Italy as the OECD tax benefit calculator does not return meaningful participation taxes at this low income level.

[65] As explained above, with unemployment benefits participation tax rates would be substantially higher, in which case the desirability condition would be even more difficult to meet.

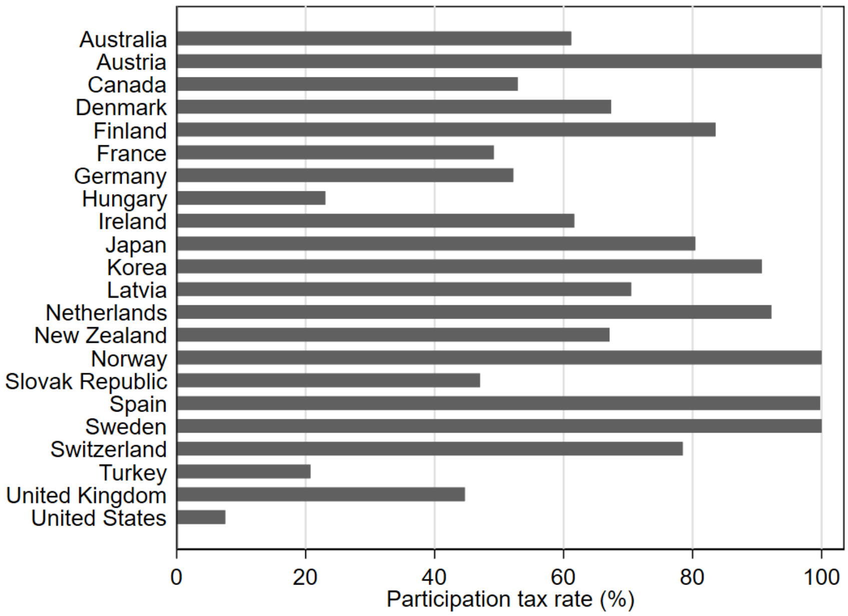


Figure 6: Participation tax rates for minimum-wage earners

8 Simulations

In this final Section, we analyze how the presence of unions affects the optimal tax-benefit system and study the desirability of unions in a structural version of the model that is calibrated to the Netherlands The main difference with the previous section is that we now explicitly specify a social welfare function and numerically solve for optimal taxes. We can thus explore whether unions can meaningfully complement an optimal tax-benefit system – for a well-defined social welfare function – instead of assessing the desirability of unions under the *current* tax-benefit system. The reason for choosing to calibrate our model to the Netherlands is that the RtM-model we use throughout this paper shares important features with the actual bargaining process between unions and employers in the Netherlands.[66]

8.1 Calibration

To calculate the optimal tax-benefit system and to study the desirability of unions, we calibrate a structural version of our baseline model where income effects at the union level are absent and labor rationing is efficient (cf. Assumptions 2 and 3). We allow for spillover effects between different sectors as labor types are complements in aggregate production, but abstract from the extensions presented in Section 6. After discussing the data, we present the functional forms for the social welfare function, the utility function, the production function, the distribution of participation costs, and explain how the parameters of our model are calibrated.

[66] Unions and representatives of firms bargain over wages (mainly) at the sectoral level. Employment is subsequently determined unilaterally by firms. Furthermore, in 2015, the year of our calibration, 79.4% of all employees are covered by collective labor agreements (OECD, 2020).

8.1.1 Data

Most of our data come from Statistics Netherlands, which provides information on employment and average wages for $I = 65$ industries based on the two-digit NACE industry classification (Statistics Netherlands, 2020c). Consequently, we have more income levels than in the STAN data of our empirical analysis.[67] To correct for differences in hours worked and part-time jobs, we express sectoral employment L_i in full-time equivalents. Aggregate employment is slightly above 5.8 million full-time equivalents. The average sectoral wage w_i is the yearly wage for an employee who works full time.[68] It varies between €27,600 (catering services) and €89,500 (mineral extraction), with an average of €44,777. By having a relatively large number of sectors, we are able to approximate the income distribution reasonably well, while maintaining the sectoral structure of the model. We combine sectoral data on wages and employment with a number of labor market aggregates, in particular the labor income share of 75.2% (Statistics Netherlands, 2020b), the labor force participation rate of 70.2% and the involuntary unemployment rate of 6.9% (Statistics Netherlands, 2020a).

To calibrate the primitives of our structural model, we also need information on income taxes and unemployment benefits in the current tax-transfer system. Instead of using the OECD online tax-benefit calculator to compute participation taxes for a specific household type, we calculate income taxes T_i by multiplying annual labor earnings w_i by the average tax rate that applies at that income level. The average tax rates are obtained from Quist (2015), who uses detailed, micro-level data from the CPB Netherlands Bureau of Economic Policy Analysis to compute the average tax liability for individuals throughout the income distribution, based on all taxes, tax credits, and tax rebates that are applicable for each individual.[69] For a detailed discussion of the data and which taxes are included, see Quist (2015). The average yearly social assistance benefit $-T_u$ paid to the non-employed is set at €12,223. This figure is based on the weighted average benefit of €961 for singles (14% of recepients) and €1,372 for couples (86% of receipients) (Rijksoverheid, 2016).

8.1.2 Social welfare function

We assume a utilitarian social welfare function, by setting the Pareto weight of workers in each sector i and firm-owners to one: $\psi_i = \psi_f = 1$. Moreover, without much loss of generality we can simplify the analysis considerably by letting profits flow directly to the government's budget. Neither capital nor firm-owners play an important role in our analysis. What ultimately matters in our calibration is the difference between the government revenue requirement and the profit

[67] Specifically, the STAN data has 17 income levels for the Netherlands, see Table 4. An important advantage of the STAN data is that we could include many more countries.

[68] As in our empirical analysis from Section 7, the annual gross wage includes all taxes and social-security contributions levied at the individual, which are typically withheld by firms, but it does not include the social-security contributions and employment subsidies levied at firms.

[69] By computing averages over all demographic groups at each income level, this approach differs from the OECD online tax-benefit calculator, where a tax liability is computed for a specific household type based on particular demographic characteristics. This explains why the numbers for the participation taxes are not directly comparable and why in Section 7 we also conduct robustness exercises by computing participation tax rates based on unemployment benefits and for minimum-wage earners alone.

tax, i.e., $R - T_f$, and not the composition over R and T_f.[70] This short-cut implies that we do not need to obtain empirical measures for the level of the profit tax as it would simply translate into a different value for the revenue requirement.

8.1.3 Utility function

We assume a utility function with a constant coefficient of absolute risk-aversion $\theta > 0$ (CARA):

$$u(c - \varphi) = -\exp(-\theta(c - \varphi))/\theta. \tag{29}$$

Since the labor union maximizes the expected utility of its members, θ also captures the willingness of unions to tolerate more unemployment when demanding higher wages. The CARA utility function ensures that income effects at the union level are absent, cf. Assumption 3. Hence, an increase in the benefit level has the same effect on the wage demanded by the union as an increase in the tax level with the same amount.

The parameter θ measures the concavity in the utility function and thereby determines the social preference for income redistribution. The larger is θ, the stronger is the government's inequality aversion. We set $\theta = 0.139$ in the baseline to make sure the average participation tax rate in the optimal tax system is roughly equal to (income-weighted) average participation tax rate of 58% in the calibrated economy.[71] In Section 9 of the online Appendix, we explore the sensitivity of our results with respect to θ.

8.1.4 Production function

To allow for interdependent labor markets with general-equilibrium effects on the wage structure, we assume the following CES production function, which is defined over aggregate capital K and labor L_i in each sector i:

$$Y = F(K, L_1, \cdots, L_I) = AK^{1-\alpha} \left(\sum_i a_i L_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\alpha\sigma}{\sigma-1}}, \tag{30}$$

where $\sigma > 0$ is the constant elasticity of substitution between different labor types, and $\alpha \in (0, 1)$ is the aggregate labor share. The latter is set at the empirically observed value of $\alpha = 0.757$, which is obtained from Statistics Netherlands (2020b). We harmlessly normalize $AK^{1-\alpha} = 1$. A different value for this composite parameter would only change the coefficients a_i, which are used to match data on wages in each sector i.

We calibrate σ to match the employment-weighted average labor-demand elasticity. The

[70] The government is indifferent between taxing firm profits or setting a lower revenue requirement if firm-owners have a linear utility function. Moreover, in the optimum, the government is indifferent between a marginally higher profit tax and a marginally lower revenue requirement, since the social welfare weight of firm-owners is one.

[71] This value is considerably higher than the average participation tax rate computed using the OECD online tax-benefit calculator for two main reasons (see Table 4). First, Quist (2015) uses averages at each income level containing all demographic groups, whereas in our calculations the OECD tax-benefit calculator is based on two-earner couples that have fewer entitlements to income-support programs due to means-testing on household income. Second, Quist (2015) includes all income-support programs, including rent assistance, which we have set to zero in the OECD tax-benefit calculator.

labor-demand elasticity in each sector i is given by (see Appendix E.1 for the derivation):

$$\varepsilon_i = \frac{\sigma}{1 + \phi_i(\sigma(1-\alpha) - 1)}, \tag{31}$$

where $\phi_i \equiv w_i L_i / \sum_j w_j L_j$ is the labor share of sector i in aggregate labor income. We draw on Lichter et al. (2015) who conduct an extensive meta-analysis of labor-demand elasticities. They find an average wage elasticity of labor demand of around 0.55. However, this average contains numerous short-run estimates and we think of our model as describing the economy's long-run equilibrium. Therefore, we use their long-run estimates to account for changes in, e.g., technology and substitution across labor types. Of all studies that explicitly estimate a long-run elasticity of labor demand, the average equals 0.70. We calibrate $\sigma = 0.672$ to match an employment-weighted average labor-demand elasticity of $\bar{\varepsilon} = 0.70$. Since the labor-demand elasticity governs the trade-off between employment and wages at the union level, we conduct several robustness checks with respect to the labor-demand elasticity in Section 9 of the online Appendix.

The productivity shifters a_i can be calculated from the labor-demand equation by using data on employment L_i and wages w_i in each sector i – given the values of α and σ:

$$w_i = F_i(\cdot) = \alpha a_i Y^{\frac{1-(1-\alpha)\sigma}{\alpha\sigma}} L_i^{-\frac{1}{\sigma}}, \tag{32}$$

where aggregate output follows from $Y = \sum_i w_i L_i / \alpha$.

8.1.5 Distribution of participation costs

We impose the following functional form for the distribution of participation costs, which is assumed to be common across all sectors i:

$$G(\varphi) = \frac{\gamma\varphi^{\zeta}}{1 + \gamma\varphi^{\zeta}}, \tag{33}$$

where $\gamma, \zeta > 0$. The reason for choosing this functional form is twofold. First, because participation costs are defined on the interval $\varphi \in [0, \infty)$, full employment is never optimal. This prevents boundary solutions in each sector that could, for instance, occur if $G(\varphi)$ is iso-elastic (so that the participation elasticity is constant) and one considers large tax reforms, such as those from the current to the optimal tax-benefit system. Second, equation (33) generates participation elasticities that are declining in income, in line with empirical evidence, see Hansen (2021) for references. To see this, note that the participation elasticity can be written as

$$\pi_i \equiv \frac{G'(\varphi_i^*)\varphi_i^*}{G(\varphi_i^*)} = \frac{\zeta}{1 + \gamma(\varphi_i^*)^{\zeta}}, \tag{34}$$

where $\varphi_i^* = w_i - T_i + T_u$ is the net gain from working. The latter is larger for individuals who earn a higher net wage $w_i - T_i$.

The parameter ζ is calibrated to match an average participation elasticity of $\bar{\pi} = 0.25$. This value is in line with common empirical estimates, but somewhat higher than estimates for the participation elasticity for the Netherlands. In particular, Mastrogiacomo et al. (2013)

documents estimates ranging from 0.10 to 0.16. The reason for choosing a higher value is twofold. First, estimates of the participation elasticity with respect to the unemployment benefit are typically larger. Gercama et al. (2020) estimate a value for this elasticity of around 0.30 for the Netherlands. Second, other extensive margins (e.g., schooling and retirement) may also result in a higher participation elasticity. Because of its importance for the optimal tax-benefit system (especially in the absence of unions), we investigate the robustness of our results with respect to the participation elasticity in Section 9 of the online Appendix.

The average participation elasticity is given by

$$\bar{\pi} = \sum_i \left(\frac{N_i}{\sum_j N_j}\right)\pi_i = \zeta \sum_i \left(\frac{N_i}{\sum_j N_j}\right)\left[1 - \frac{\gamma(\varphi_i^*)^\zeta}{1+\gamma(\varphi_i^*)^\zeta}\right] = \zeta\left[1 - \frac{\sum_i N_i G(\varphi_i^*)}{\sum_j N_j}\right], \quad (35)$$

where the last term in brackets equals one minus the aggregate participation rate, as obtained from Statistics Netherlands (2020a). For an average participation elasticity of 0.25, this gives a value of $\zeta = 0.25/(1-0.702) = 0.839$.

The parameter γ determines how many individuals decide to participate in the labor market. We calibrate this parameter to match the aggregate participation rate. Because we only have data on employment $L_i = N_i E_i$, and not on labor force sizes N_i or sectoral employment rates E_i, the parameter γ needs to be calibrated jointly with the degree of union power, as the latter also affects the employment rate.

8.1.6 Union power

Given that there are no direct empirical counterparts of union power ρ_i, neither in the aggregate, nor at the sectoral level, we assume that union power is the same across all sectors: $\rho_i = \rho$ for all i and that, in line with our theoretical analysis, all unemployment observed in the data is caused by unions. The higher the degree of union power ρ, the further away the equilibrium is from the labor-supply curve, and the higher is the unemployment rate, see Figure 2.

We calibrate the value for ρ, joint with γ, such that the unemployment and participation rates in our model match the data. Doing so requires, first, solving the union wage-demand equation (8) for employment E_i for each sector i:

$$\rho\left(\frac{\int_0^{G^{-1}(E_i)} u'(w_i - T_i - \varphi)\mathrm{d}G(\varphi)}{E_i}\right)\frac{w_i}{\varepsilon_i} = u(w_i - T_i - G^{-1}(E_i)) - u(-T_u). \quad (36)$$

Parameters $\rho = 0.215$ and $\gamma = 0.229$ are then chosen in such a way that the involuntary unemployment rate equals 6.9% and the aggregate participation rate equals 70.2% based on data from Statistics Netherlands (2020a). The size of the labor force in each sector i then follows residually from $N_i = L_i/E_i$. We will conduct robustness checks for different values of union power ρ in Section 9 of the online Appendix.

8.1.7 Revenue requirement

The final parameter that needs to be calibrated is the revenue requirement R. Given our assumption that profits flow to the government budget, R follows directly from the budget constraint

$$R=\sum_i N_i(E_iT_i+(1-E_i)T_u)+(1-\alpha)\sum_i w_iL_i/\alpha. \tag{37}$$

The revenue requirement equals approximately 36.8% of GDP. Although this number appears high, it includes all capital income, as captured by the last term of equation (37). Correcting for the capital share of $1-\alpha=0.243$, the revenue requirement equals 12.5% of GDP, which is close to non-redistribution government spending in the Netherlands of approximately 10% of GDP (Jacobs et al., 2017).

All simulation inputs are summarized in Table 3. Figure 10 in Appendix E.3 plots participation rates, employment rates, and unemployment rates by earnings level in the baseline economy. Sectoral participation rates range from 59.7% (at the lowest wage) to 83.4% (at the highest wage). The sectoral employment rates are between 47.5% and 83.1%, implying that sectoral unemployment rates range from 20.4% (at the lowest wage) to 0.4% (at the highest wage). Figure 11 in Appendix E.3 plots the participation elasticity and the labor-demand elasticity by income level. The participation elasticity declines from 0.34 at the lowest income level to 0.14 at the highest income level. There is little variation in the labor-demand elasticities, which range from 0.67 to 0.72. As can be seen from equation (31), the variation in labor-demand elasticities across sectors is driven solely by the labor shares ϕ_i, which turn out to only have a limited impact.

Table 3: Baseline calibration

Parameter	Value	Calibration target
CARA	$\theta=0.139$	Avg. participation tax rate 58.3%
Labor income share	$\alpha=0.757$	Labor income share 75.7%
Elasticity of substitution	$\sigma=0.672$	Labor-demand elasticity $\bar{\varepsilon}=0.697$
Union power	$\rho=0.215$	Unemployment rate 6.9%
Participation curvature	$\zeta=0.839$	Participation elasticity $\bar{\pi}=0.25$
Participation shifter	$\gamma=0.229$	Participation rate 70.2%
Revenue requirement	$R/Y=0.368$	Government budget constraint

8.2 Optimal taxes and the desirability of unions

The numerical methods for solving the optimal tax system are described in Appendix E. Figure 7 shows the optimal participation tax rates $t_i=(T_i-T_u)/w_i$ in the calibrated economy with unions. The figure also plots the optimal participation tax rates if labor markets are competitive, which are obtained by setting $\rho=0$, and the participation tax rates in the current tax system.[72] To facilitate comparison, all participation tax rates are plotted against *current* income.

Comparing the first two lines from Figure 7 shows our most important finding: optimal participation tax rates are substantially lower in unionized labor markets than in competitive labor markets. The average participation tax rate with unions equals approximately 58.3%, as

[72] We prefer a 'pure' comparative statics exercise by *only* changing the degree of union power from its value in the calibrated economy to zero (competitive labor markets), while not recalibrating the parameter γ to match the aggregate participation rate. If we would do this, labor force sizes $N_i=L_i/E_i$ would change as well, which complicates the comparison of optimal tax systems with and without unions. Nevertheless, if we recalibrate γ, we obtain very similar conclusions as in the main text.

it is calibrated to be the same as in the current tax system. By contrast, if labor markets are competitive (i.e., if $\rho = 0$), the average optimal participation tax rate equals approximately 65.8%. Unions lower the optimal participation tax rates on average by approximately 7.4 percentage points. This reduction is brought about both by a reduction in income taxes and a reduction in the non-employment benefit. On average, income taxes are approximately €1,310 lower in unionized than in competitive labor markets. The optimal non-employment benefit with unions equals approximately €12,560, close to its current value of around €12,223. However, if labor markets are competitive, the optimal non-employment benefit is higher and equals approximately €14,534. The reason why participation tax rates are optimally lower with unions is the presence of the union wedge τ_i. The government optimally lowers participation taxes to moderate union wage demands and to reduce involuntary unemployment.

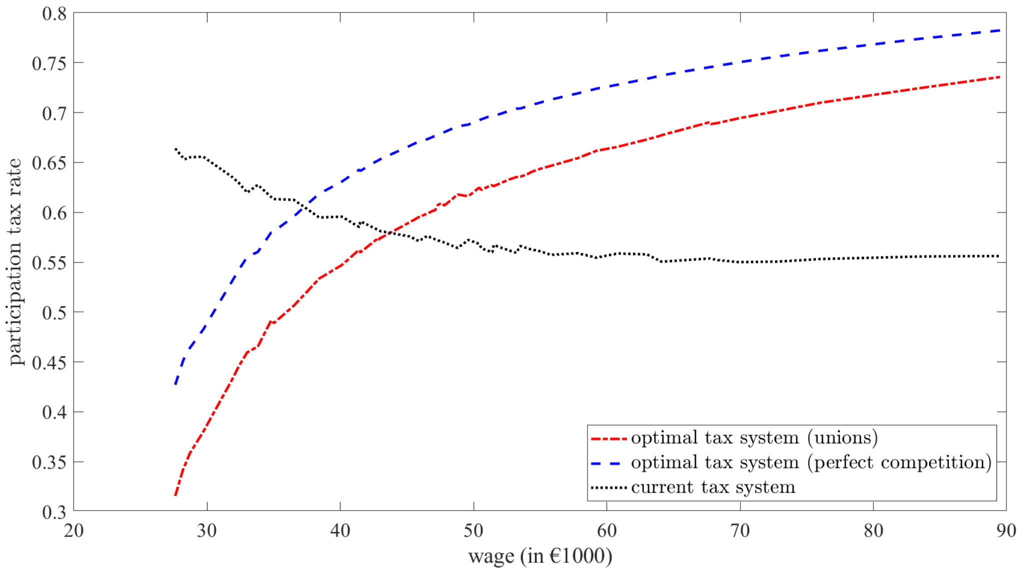


Figure 7: Optimal participation tax rates (baseline)

There is a substantial discrepancy between the current tax system and the optimal tax system, as can be seen from Figure 7. Income taxes for low-income individuals exceed the taxes that would be set by a utilitarian government. This finding confirms earlier research on optimal taxes for the Netherlands in Zoutman et al. (2013). Using the inverse optimal tax approach, Jacobs et al. (2017) demonstrate that the social welfare weights implied by the current tax system in the Netherlands are much larger for the middle-income groups than for the low- and high-income groups, presumably for political-economy reasons. Hence, the current government does not optimize a social welfare function with smoothly declining social welfare weights as in our model.[73]

In Section 7 we document that stronger unions are empirically associated with lower participation tax rates. In particular, a reduction in union density from approximately 20% (the average union density in the Netherlands) to zero is associated with a 2.8 percentage-point

[73]It is perhaps surprising that participation tax rates at the current tax system are *declining* in income. The reason is quite mechanical. Participation taxes consist of both income taxes and social assistance benefits. In our model, the latter do not vary with earnings. Consequently, if they are expressed as a fraction of the wage, they are lower for high-income earners.

reduction in the participation tax rate, cf. Table 1. This number is not directly comparable to the 7.4 percentage-point reduction brought about by unions that is documented in Figure 7 for at least three reasons. First, while we can use the structural version of our model to study the causal impact of union power on optimal participation taxes, our estimates from Section 7 do not exploit any exogenous variation in union power and cannot be given a causal interpretation. Second, Figure 7 studies the impact of unions on the *optimal* tax-benefit system, whereas our empirical analysis studies the association between union density and participation tax rates in the *current* tax-benefit system. As discussed above, the current and optimal tax-benefit system differ substantially from each other. However, if we were to calculate optimal participation taxes with and without unions under the assumption that the current tax-transfer system is optimized, we are still confident that optimal participation taxes would be lower with unions than without, as is also demonstrated in the robustness analysis where we vary the degree of inequality aversion, see Section 9 in the online Appendix. Third, our numerical simulations assume that all unemployment is caused by unions demanding wages that are above market-clearing levels. This may create an upward bias for the difference between optimal taxes in unionized and competitive labor markets. Nevertheless, despite these caveats, both findings suggest that stronger unions reduce (optimal) participation tax rates.

Turning to the desirability of unions, Figure 8 plots the social welfare weights against current labor income at the optimal tax system in unionized and in perfectly competitive labor markets. Given that the tax system is optimized, the average social welfare weight in both cases equals one, cf. Proposition 1. Moreover, the concavity in the utility function ensures that the social welfare weights are monotonically declining in income. As can be seen from the figure, the social welfare weight for the unemployed workers (whose wage equals zero) exceeds one and is higher if there are unions. The reason is that the optimal unemployment benefit is lower (i.e., €12,560 with unions versus €14,534 without unions). Furthermore, employed workers in *all* sectors have a social welfare weight that is smaller than the average of one. Hence, there are no employed individuals whose social welfare weight exceeds one.[74] Proposition 2 then immediately implies that if the tax system is optimized, an increase in union power in any sector of the Dutch economy reduces social welfare. Even starting from a competitive labor market, introducing a union for low-income workers is not socially desirable. A utilitarian government would always prefer to increase the net incomes of low-skilled workers directly by reducing taxes (or increasing subsidies) rather than indirectly by increasing the bargaining power of the union representing them. The finding that unions cannot meaningfully complement an optimal tax-benefit system is consistent with the findings from Section 7 that, as a result of positive participation taxes, the desirability condition for unions is not met.

In Section 9 of the online Appendix, we investigate the sensitivity of our results by studying the desirability of unions and optimal participation tax rates in unionized labor markets for different assumptions on the labor-demand and participation elasticity, union power, and the degree of inequality aversion. Quantitatively, the results change for different assumptions on the main behavioral elasticities. Nevertheless, we find that, in all cases, unions reduce optimal participation tax rates, and increasing union power does not raise social welfare, with one

[74] Recall from Section 8.1.1 that the lowest level of positive earnings in the data is €27,600.

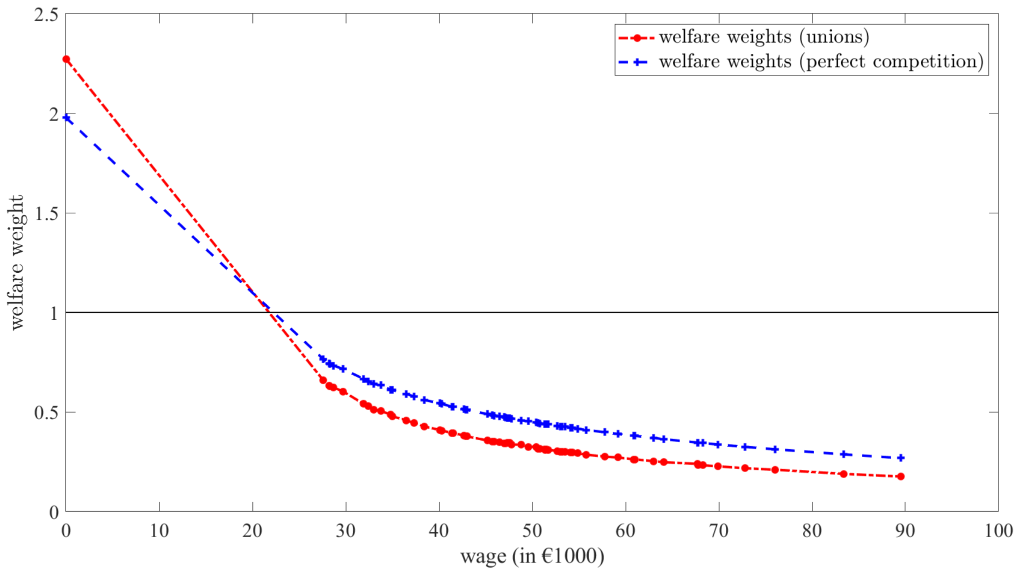


Figure 8: Social welfare weights (baseline)

exception. In particular, a very substantial reduction in inequality aversion brings the social welfare weights of unemployed and employed workers closer to each other and raises the social welfare weight of low-skilled workers above the average of one.[75] In that case, participation is optimally subsidized and an increase in union power representing workers at the bottom of the income distribution is welfare-improving. However, a much lower inequality aversion reduces optimal participation tax rates to 27.8% (on average), which is much lower than the optimal participation tax rate of 58.3% (on average) in the calibrated economy. Therefore, unions can only be desirable for social preferences for income redistribution that deviate substantially from redistributive preferences that would rationalize the current tax-benefit system. Hence, the results from this Section corroborate our findings from the empirical analysis: stronger unions are associated with lower participation tax rates and, given that participation is typically taxed (both in the current and in the optimal tax system), unions cannot be used to alleviate upward distortions in labor participation.

9 Conclusion

The aim of this paper has been to answer two questions concerning optimal income redistribution in unionized labor markets. Our first question was: *'How should the government optimize income redistribution if labor markets are unionized?'* Our answer is that the optimal tax-benefit system is less redistributive than in competitive labor markets. Intuitively, the tax system is not only used to redistribute income, but also to alleviate the distortions induced by unions. Lower income taxes and lower benefits motivate unions to moderate their wage demands, which results in less involuntary unemployment. We show that participation taxes should be lower

[75] There could also be non-welfarist motives why the social welfare weights of low-income workers are raised relative to the social welfare weight of the non-employed. This would be the case, for instance, if the working poor are considered more deserving or if work is a merit good. We abstract from this in our analysis.

the larger are the welfare gains from reducing involuntary unemployment. Therefore, it may be optimal to subsidize participation even for workers with a below-average social welfare weight, which cannot happen if labor markets are competitive (see, e.g., Diamond, 1980, Saez, 2002, and Choné and Laroque, 2011). We collect data on participation tax rates and union densities – a proxy for union power – from 18 sectors in 23 OECD countries. In line with our theoretical predictions, we find there is a negative association between participation tax rates and union densities. Furthermore, we simulate a structural version of our model, which is calibrated to the Netherlands. Our simulations suggest that optimal participation tax rates are substantially lower if unions are more powerful.

Our second question was: *'Can labor unions be socially desirable if the government wants to redistribute income?'* Our answer is that increasing the power of the unions representing workers with an above-average social welfare weight is welfare-enhancing, while the opposite holds true for workers with a below-average social welfare weight. Since Diamond (1980), it is well known that participation is optimally subsidized for workers with an above-average social welfare weight, i.e., they receive an income transfer that exceeds the unemployment benefit. Consequently, participation for these workers is distorted upwards, which results in *overemployment*. By bidding up wages, unions create implicit taxes on employment, which reduce the upward distortions from participation subsidies. Whether unions are desirable thus depends critically on whether low-income workers are subsidized or taxed on a net basis. We calculate participation taxes throughout the income distribution and find that they are always positive in nearly all OECD countries. Our data thus reveal that unions are not a desirable complement to the tax system to redistribute income if participation taxes are optimized. Moreover, in our simulations, we find that increasing union power typically lowers social welfare, but this finding is sensitive to the government's preference for income redistribution. Hence, increasing union power would typically not be socially desirable, as it would only exacerbate labor-market distortions.

We have made some assumptions that warrant further research. First, we assumed throughout the paper that the government is the Stackelberg leader relative to firms and unions. However, unions may internalize some of the macro-economic and fiscal impacts of their decisions in wage negotiations, see also Calmfors and Driffill (1988). Second, we have abstracted from labor supply on the intensive (hours, or effort) margin. For future research, it would be interesting to study a setting where unions and the government interact strategically and labor supply also responds on the intensive margin. Third, one may study optimal taxation and the desirability of unions with endogenous (directed) technical change. Firms may not only respond to unions' wage demands by reducing labor demand, but also by investing in labor-saving (capital-augmenting) technology, see e.g., Acemoglu (2002) or Loebbing (2022). Fourth, we assumed that firms act competitively by taking wages as given in their labor demand. Future research could fruitfully explore how unions could alleviate monopsony power of firms in the labor market.

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A Derivation elasticities

This appendix derives the employment and wage responses to changes in the tax instruments and union power if labor markets are independent and rationing is efficient (i.e., if Assumptions 1 and 2 hold). The labor-market equilibrium conditions are as given by equations (11) and (12). Substituting the labor-demand equation $w_i = F_i(\cdot)$ in equation (12), equilibrium employment in sector i is determined implicitly by the following condition:

$$\Gamma_i(E_i, T_i, T_u, \rho_i) \equiv$$
$$\rho_i \int_{\underline{\varphi}}^{G_i^{-1}(E_i)} u'(F_i(\cdot) - T_i - \varphi)\mathrm{d}G_i(\varphi) F_{ii}(\cdot) N_i + \big(u(F_i(\cdot) - T_i - G_i^{-1}(E_i)) - u(-T_u)\big) = 0. \quad (38)$$

Since labor markets are independent, $F_i(\cdot)$ and $F_{ii}(\cdot)$ depend only on employment $L_i = N_i E_i$ in sector i. Hence, this equation pins down $E_i = E_i(T_i, T_u, \rho_i)$. If the union objective (5) is concave in E_i after substituting $\hat{\varphi}_i = G_i^{-1}(E_i)$ and $w_i = F_i(\cdot)$, it follows that $\Gamma_i(\cdot)$ is decreasing in E_i. The comparative statics can be determined through the implicit function theorem:

$$\frac{\partial E_i}{\partial T_i} = -\frac{\Gamma_{i,T_i}}{\Gamma_{i,E_i}} = \frac{\rho_i E_i \overline{u_i''} F_{ii} N_i + \hat{u}_i'}{\rho_i E_i \overline{u_i''}(F_{ii}N_i)^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} < 0, \tag{39}$$

$$\frac{\partial E_i}{\partial T_u} = -\frac{\Gamma_{i,T_u}}{\Gamma_{i,E_i}} = \frac{-u_u'}{\rho_i E_i \overline{u_i''}(F_{ii}N_i)^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} > 0, \tag{40}$$

$$\frac{\partial E_i}{\partial \rho_i} = -\frac{\Gamma_{i,\rho_i}}{\Gamma_{i,E_i}} = \frac{-E_i \overline{u_i'} F_{ii} N_i}{\rho_i E_i \overline{u_i''}(F_{ii}N_i)^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} < 0. \tag{41}$$

We ignored function arguments to save on notation. The impact on the equilibrium wage w_i follows directly from the labor-demand equation $w_i = F_i(\cdot)$:

$$\frac{\partial w_i}{\partial x} = \frac{\partial w_i}{\partial E_i}\frac{\partial E_i}{\partial x} = F_{ii} N_i \frac{\partial E_i}{\partial x}, \quad x \in \{T_i, T_u, \rho_i\} \tag{42}$$

$$\frac{\partial w_i}{\partial T_i} = \frac{(\rho_i E_i \overline{u_i''} N_i F_{ii} + \hat{u}_i') F_{ii} N_i}{\rho_i E_i \overline{u_i''}(N_i F_{ii})^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} > 0, \tag{43}$$

$$\frac{\partial w_i}{\partial T_u} = \frac{-u_u' F_{ii} N_i}{\rho_i E_i \overline{u_i''}(N_i F_{ii})^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} < 0, \tag{44}$$

$$\frac{\partial w_i}{\partial \rho_i} = \frac{-E_i \overline{u_i'} (F_{ii} N_i)^2}{\rho_i E_i \overline{u_i''}(N_i F_{ii})^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} > 0. \tag{45}$$

If there are no income effects at the union level (cf. Assumption 3), a change in the unemployment benefit has the same impact as an increase in the income tax. Setting $\partial E_i/\partial T_i = -\partial E_i/\partial T_u$ and $\partial w_i/\partial T_i = -\partial w_i/\partial T_u$, it follows that income effects are absent if

$$\rho_i E_i \overline{u_i''} N_i F_{ii} + (\hat{u}_i' - u_u') = 0.$$

If utility is linear, this condition is trivially satisfied. In addition, the condition also holds if utility is of the CARA-type, i.e., $u(c) = -\exp(-\theta c)/\theta$. To see this, substitute $u'(c) = \exp(-\theta c)$ in equation (38) and multiply the expression by $\exp(-\theta T_u)$. The equation then depends on the tax instruments only through the participation tax level $T_i - T_u$.

B Optimal taxation

B.1 Proof Proposition 1

The Lagrangian associated with the government's optimization problem can be written as:

$$\mathcal{L} = \sum_i \psi_i N_i \Big(\int_{\underline{\varphi}}^{G_i^{-1}(E_i)} u(w_i - (T_i - T_u) - T_u - \varphi)\mathrm{d}G_i(\varphi) + \int_{G_i^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G_i(\varphi) \Big) \tag{46}$$
$$+ \psi_f u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i (T_u + E_i(T_i - T_u)) + T_f - R \right).$$

If income effects are absent (cf. Assumption 3), equilibrium wages and employment rates depend only on participation taxes $T_i - T_u$. Using the latter as instruments (instead of income taxes T_i), the first-order conditions are:

$$T_u: \quad -\sum_i \psi_i N_i (E_i \overline{u_i'} + (1 - E_i)u_u') + \lambda \sum_i N_i = 0, \tag{47}$$

$$T_f: \quad -\psi_f u_f' + \lambda = 0, \tag{48}$$

$$T_i - T_u: \quad -N_i E_i (\psi_i \overline{u_i'} - \lambda) + \sum_j N_j E_j \left[\psi_j \overline{u_j'} - \psi_f u_f' \right] \frac{\partial w_j}{\partial (T_i - T_u)}$$
$$+ \sum_j N_j \left[\psi_j (\hat{u}_j - u_u) + \lambda (T_j - T_u) \right] \frac{\partial E_j}{\partial (T_i - T_u)} = 0. \tag{49}$$

To obtain equation (16), divide equation (47) by $\lambda \sum_j N_j$ to find

$$1 = \sum_i \underbrace{\left(\frac{N_i E_i}{\sum_j N_j} \right)}_{\equiv \omega_i} \underbrace{\left(\frac{\psi \overline{u_i'}}{\lambda} \right)}_{\equiv b_i} + \underbrace{\left(\frac{\sum_i N_i (1 - E_i)}{\sum_j N_j} \right)}_{\equiv \omega_u} \underbrace{\left(\frac{\sum_i N_i (1 - E_i) \psi_i u_u'}{\sum_i N_i (1 - E_i) \lambda} \right)}_{\equiv b_u}. \tag{50}$$

Next, divide equation (48) by λ to find equation (17).

To derive equation (18), first define the employment and wage elasticities as:

$$\eta_{ji} \equiv - \left(\frac{\partial E_j}{\partial (T_i - T_u)} \frac{(w_i - (T_i - T_u))}{E_j} \right) \frac{w_j (1 - t_j)}{w_i (1 - t_i)}, \tag{51}$$

$$\kappa_{ji} \equiv \left(\frac{\partial w_j}{\partial (T_i - T_u)} \frac{(w_i - (T_i - T_u))}{w_j} \right) \frac{w_j}{w_i (1 - t_i)} \tag{52}$$

Then, divide equation (49) by $\lambda \sum_i N_i$, use the definitions of the employment shares and the union wedge $\tau_j \equiv \frac{\psi_j (\hat{u}_j - u_u)}{w_j \lambda} = \frac{\rho_j b_j}{\varepsilon_j}$, and rewrite to find:

$$\sum_j \omega_j \frac{(t_j + \tau_j)}{(1 - t_j)} \eta_{ji} = \omega_i (1 - b_i) + \sum_j \omega_j (b_j - b_f) \kappa_{ji}. \tag{53}$$

Note that this result holds irrespective of whether profits are optimally taxed (i.e., $b_f = 1$) or not (i.e., $b_f < 1$).

B.2 Allowing for income effects

If there are income effects at the union level, changes in the unemployment benefit $-T_u$ affect equilibrium employment E_i and wages w_i not only through their impact on participation taxes $T_i - T_u$. Therefore, we write $E_i = E_i(T_1 - T_u, \cdots, T_I - T_u, T_u)$ and $w_i = w_i(T_1 - T_u, \cdots, T_I - T_u, T_u)$. In this case, only the first-order condition for the optimal unemployment benefit (i.e., the counterpart of equation (47)) has to be modified:

$$\begin{aligned} T_u : &- \sum_i \psi_i N_i (E_i \overline{u_i'} + (1 - E_i) u_u') + \lambda \sum_i N_i \\ &+ \sum_i N_i E_i \Big[\psi_i \overline{u_i'} - \psi_f u_f' \Big] \frac{\partial w_i}{\partial T_u} + \sum_i N_i \Big[\lambda (T_i - T_u) + \psi_i (\hat{u}_i - u_u) \Big] \frac{\partial E_i}{\partial T_u} = 0 \end{aligned} \tag{54}$$

Divide this expression by $\lambda \sum_i N_i$ to find

$$\begin{aligned} &- \sum_i \frac{N_i E_i}{\sum_i N_i} (b_i + \frac{(1 - E_i)}{E_i} \psi_i u_u' / \lambda) + 1 \\ &+ \sum_i \frac{N_i E_i}{\sum_i N_i} \Big[b_i - b_f \Big] \frac{\partial w_i}{\partial T_u} + \sum_i \frac{N_i E_i}{\sum_i N_i} \Big[(T_i - T_u) + \psi_i (\hat{u}_i / \lambda - u_u / \lambda) \Big] \frac{\partial E_i}{\partial T_u} \frac{1}{E_i} = 0 \end{aligned} \tag{55}$$

Next, substitute $\omega_i \equiv \frac{N_i E_i}{\sum_i N_i}$, $\omega_u \equiv \frac{\sum_i N_i (1 - E_i)}{\sum_j N_j}$, $b_i \equiv \frac{\psi_i \overline{u_i'}}{\lambda}$, $b_u \equiv \frac{\sum_i N_i (1 - E_i) \psi_i u_u' / \lambda}{\sum_i N_i (1 - E_i)}$ and rewrite:

$$\begin{aligned} &- \sum_i \omega_i b_i - \omega_u b_u + 1 \\ &+ \sum_i \omega_i \Big[b_i - b_f \Big] \frac{\partial w_i}{\partial T_u} + \sum_i \omega_i \Big[(T_i - T_u) + \psi_i (\hat{u}_i / \lambda - u_u / \lambda) \Big] \frac{\partial E_i}{\partial T_u} \frac{1}{E_i} = 0 \end{aligned} \tag{56}$$

To proceed, substitute $b_f = 1$ and $\tau_i = \frac{\psi_i (\hat{u}_i - u_u)}{\lambda w_i}$:

$$\sum_i \omega_i b_i + \omega_u b_u = 1 + \sum_i \omega_i \Big[b_i - 1 \Big] \frac{\partial w_i}{\partial T_u} + \sum_i \omega_i \Big[(T_i - T_u) + \tau_i w_i \Big] \frac{\partial E_i}{\partial T_u} \frac{1}{E_i} \tag{57}$$

This relationship generalizes equation (16). If there are income effects at the union level, a simultaneous increase in the unemployment benefit $-T_u$ and all income taxes T_i that leaves participation taxes unchanged does *not* leave labor-market outcomes unaffected. The welfare-relevant effects are captured by the last two terms on the right-hand side of equation (57). A change in the equilibrium wage in sector i indirectly redistributes income between workers in that sector (whose social welfare weight is b_i) and firm-owners (whose social welfare weight is one). In addition, a change in the employment rate in sector i affects social welfare through the participation tax $T_i - T_u$ and the union wedge $\tau_i w_i$. The government has to take into account these responses when deciding on the optimal benefit $-T_u$.

Equation (57) can be simplified considerably if labor markets are independent. In that case, we can use the property $\frac{\partial E_i}{\partial x_i} = \frac{\partial E_i}{\partial w_i} \frac{\partial w_i}{\partial x_i}$ for $x_i \in \{T_u, T_i - T_u\}$, where $\partial E_i / \partial w_i = 1/(N_i F_{ii}(\cdot))$ is the slope of the labor-demand curve. Equation (57) can then be written as

$$\sum_i \omega_i b_i + \omega_u b_u = 1 + \sum_i \omega_i \left[b_i - 1 \right] \frac{\partial w_i}{\partial T_u} + \sum_i \omega_i \left[(T_i - T_u) + \tau_i w_i \right] \frac{\partial E_i}{\partial w_i} \frac{\partial w_i}{\partial T_u} \frac{1}{E_i} \tag{58}$$

$$\sum_i \omega_i b_i + \omega_u b_u = 1 + \sum_i \left(\omega_i \left[b_i - 1 \right] + \omega_i \left[(T_i - T_u) + \tau_i w_i \right] \frac{\partial E_i}{\partial w_i} \frac{1}{E_i} \right) \frac{\partial w_i}{\partial T_u} \tag{59}$$

If labor markets are independent, the term in brackets on the right-hand side can be obtained from the first-order condition with respect to $T_i - T_u$:

$$\omega_i(1 - b_i) + \omega_i \left[(T_i - T_u) + \tau_i w_i \right] \frac{1}{E_i} \frac{\partial E_i}{\partial (T_i - T_u)} + \omega_i(b_i - 1) \frac{\partial w_i}{\partial (T_j - T_u)} = 0 \tag{60}$$

$$\left(\omega_i \left[b_i - 1 \right] + \omega_i \left[(T_i - T_u) + \tau_i w_i \right] \frac{1}{E_i} \frac{\partial E_i}{\partial w_i} \right) \frac{\partial w_i}{\partial (T_i - T_u)} = -\omega_i(1 - b_i), \tag{61}$$

where we imposed independent labor markets and again used the property $\frac{\partial E_i}{\partial x_i} = \frac{\partial E_i}{\partial w_i} \frac{\partial w_i}{\partial x_i}$. We then arrive at the following condition:

$$\sum_i \omega_i b_i + \omega_u b_u = 1 - \sum_i \omega_i (1 - b_i) \frac{\partial w_i / \partial T_u}{\partial w_i / \partial (T_i - T_u)} \tag{62}$$

$$\sum_i \omega_i b_i + \omega_u b_u = 1 - \sum_i \omega_i (1 - b_i) \iota_i, \tag{63}$$

where $\iota_i \equiv \frac{\partial w_i}{\partial T_u} / \frac{\partial w_i}{\partial (T_i - T_u)}$. Appendix A shows that $\iota_i = 0$ if the utility function $u(\cdot)$ is linear, i.e., $u(c) = c$ or if the utility function is of the CARA-type, i.e., $u(c) \equiv -\frac{1}{\theta} \exp[-\theta c]$.

B.3 Optimal participation tax with perfect competition

To derive an expression for the optimal participation tax with competitive labor markets (i.e., $\rho_i = 0$ for all i), we reformulate the optimal tax problem. Instead of taking the impact of the tax instruments on labor-market outcomes into account through the reduced-form equations $E_i = E_i(\cdot)$ and $w_i = w_i(\cdot)$, we substitute $w_i = F_i(\cdot)$ and make the equilibrium employment rate in each sector an additional choice variable in the government's optimization problem. The labor-market equilibrium condition $G_i(F_i(\cdot) - (T_i - T_u)) = E_i$ for each i then enters the optimal tax problem explicitly as a constraint. The Lagrangian associated with the government's optimization problem is then given by:

$$\begin{aligned} \mathcal{L} = & \sum_i \psi_i N_i \left(\int_{\underline{\varphi}}^{G_i^{-1}(E_i)} u(F_i(\cdot) - (T_i - T_u) - T_u - \varphi) \mathrm{d}G_i(\varphi) + \int_{G_i^{-1}(E_i)}^{\overline{\varphi}} u(-T_u) \mathrm{d}G_i(\varphi) \right) \\ & + \psi_f u(F(\cdot) - \sum_i F_i(\cdot) N_i E_i - T_f) + \lambda \left(\sum_i N_i (T_u + E_i(T_i - T_u)) + T_f - R \right) \\ & \sum_i \mu_i \left[G(F_i(\cdot) - (T_i - T_u)) - E_i \right]. \end{aligned} \tag{64}$$

The first-order conditions with respect to $T_i - T_u$ and E_i are:

$$T_i - T_u : \qquad N_i E_i(\lambda - \psi_i \overline{u_i'}) - \mu_i G_i' = 0, \tag{65}$$

$$E_i : \qquad \lambda N_i (T_i - T_u) - \mu_i + N_i \sum_j F_{ji} \left[N_j E_j (\psi_j \overline{u_j'} - \psi_f u_f') + \mu_j G_j' \right] = 0. \tag{66}$$

If the profit tax is optimally set, $\psi_f u_f' = \lambda$, and hence, $b_f = 1$. The first-order condition (65) then implies that the term in brackets in equation (66) that is summed over j equals zero. Next, use equation (65) to substitute for μ_i in equation (66), divide the equation by λN_i, and use the property $E_i = G_i$. Rearranging gives the result stated in the main text:

$$\frac{t_i}{1-t_i} = \frac{1-b_i}{\pi_i}, \qquad \pi_i \equiv \frac{G_i'(\varphi_i^*)\varphi_i^*}{G_i(\varphi_i^*)}, \tag{67}$$

where $\varphi_i^* = w_i - (T_i - T_u)$ is the participation threshold.

C Desirability of unions

C.1 Proof Proposition 2

To determine how an increase in union power affects social welfare, we set up the optimal tax problem while taking the labor-market equilibrium conditions explicitly into account as constraints, rather than deriving our results in terms of sufficient statistics. The reason for doing so is that this approach allows us to directly derive the welfare effect of an increase in union power. The maximization problem for the government is:

$$\begin{aligned}
\max_{T_u, T_f, \{T_i - T_u, w_i, E_i\}_{i=1}^I} \mathcal{W} = & \sum_i \psi_i N_i \bigg(\int_{\underline{\varphi}}^{G_i^{-1}(E_i)} u(w_i - (T_i - T_u) - T_u - \varphi) \mathrm{d}G_i(\varphi) \\
& + \int_{G_i^{-1}(E_i)}^{\overline{\varphi}} u(-T_u) \mathrm{d}G_i(\varphi) \bigg) + \psi_f u(F(\cdot) - \sum_i w_i N_i E_i - T_f), \\
\text{s.t.} \qquad & \sum_i N_i (T_u + E_i(T_i - T_u)) + T_f = R, \\
& w_i = F_i(\cdot), \quad \forall i, \\
& \rho_i \int_{\underline{\varphi}}^{G_i^{-1}(E_i)} u'(w_i - (T_i - T_u) - T_u - \varphi) \mathrm{d}G_i(\varphi) F_{ii}(\cdot) N_i \\
& + u(w_i - (T_i - T_u) - T_u - G_i^{-1}(E_i)) - u(-T_u) = 0, \quad \forall i.
\end{aligned} \tag{68}$$

By using the labor-demand equations to substitute for wages $w_i = F_i(\cdot)$, the corresponding Lagrangian is given by:

$$\begin{aligned}
\mathcal{L} = & \sum_i \psi_i N_i \left(\int_{\underline{\varphi}}^{G_i^{-1}(E_i)} u(F_i(\cdot) - (T_i - T_u) - T_u - \varphi) \mathrm{d}G_i(\varphi) + \int_{G_i^{-1}(E_i)}^{\overline{\varphi}} u(-T_u) \mathrm{d}G_i(\varphi) \right) \\
& + \psi_f u(F(\cdot) - \sum_i F_i(\cdot) N_i E_i - T_f) + \lambda \left(\sum_i N_i (T_u + E_i(T_i - T_u)) + T_f - R \right)
\end{aligned}$$

$$+\sum_i \mu_i\bigg(\rho_i \int_{\underline{\varphi}}^{G_i^{-1}(E_i)} u'(F_i(\cdot)-(T_i-T_u)-T_u-\varphi)\mathrm{d}G_i(\varphi)F_{ii}(\cdot)N_i$$

$$+u(F_i(\cdot)-(T_i-T_u)-T_u-G_i^{-1}(E_i))-u(-T_u)\bigg). \tag{69}$$

To save on notation, in the remainder we ignore function arguments and use bars to denote averages. The first-order conditions are then given by:

$$T_i-T_u:\ -N_iE_i(\psi_i\overline{u_i'}-\lambda)-\mu_i\Big(\rho_i\overline{u_i''}F_{ii}N_iE_i+\hat{u}_i'\Big)=0, \tag{70}$$

$$T_u:\ -\sum_i N_iE_i\psi_i\overline{u_i'}-\sum_i N_i(1-E_i)\psi_iu_u'+\lambda\sum_i N_i$$
$$-\sum_i\mu_i\left(\rho_i\overline{u_i''}F_{ii}N_iE_i+\hat{u}_i'-u_u'\right)=0, \tag{71}$$

$$T_f:\ -\psi_fu_f'+\lambda=0 \tag{72}$$

$$E_i:\ N_i\psi_i(\hat{u}_i-u_u)+\lambda N_i(T_i-T_u)+N_i\sum_j N_jE_j(\psi_j\overline{u_j'}-\psi_fu_f')F_{ji}+\mu_i\Big(\rho_i\hat{u}_i'F_{ii}N_i-\hat{u}_i'/G_i'\Big)$$
$$+N_i\sum_j\mu_j\left[\Big(\rho_jE_j\overline{u_j''}F_{jj}N_j+\hat{u}_j'\Big)F_{ji}+\rho_jE_j\overline{u_j'}N_jF_{jji}\right]=0, \tag{73}$$

$$\lambda:\ \sum_i N_i(T_u+E_i(T_i-T_u))+T_f-R=0 \tag{74}$$

$$\mu_i:\ \rho_iE_i\overline{u_i'}F_{ii}+(\hat{u}_i-u_u)=0 \tag{75}$$

This system of first-order conditions implicitly characterizes optimal tax policy in terms of the primitives of the model (in particular, union power, Pareto weights, the revenue requirement and properties of the utility and production function). Unfortunately, these equations are rather difficult to interpret or to simplify. This explains why, in the main text, we focus on the characterization of optimal tax policy in terms of sufficient statistics.

To examine how an increase in union power ρ_i in sector i affects social welfare, differentiate the Lagrangian (69) with respect to ρ_i, and apply the envelope theorem:

$$\frac{\partial\mathcal{W}}{\partial\rho_i}=\frac{\partial\mathcal{L}}{\partial\rho_i}=\mu_iE_i\overline{u_i'}F_{ii}N_i. \tag{76}$$

Since $E_i\overline{u_i'}F_{ii}N_i<0$ (provided that labor demand is not perfectly elastic), the expression in equation (76) is positive if and only if $\mu_i<0$. To determine the sign of μ_i, rearrange the first-order condition (70) with respect to the participation tax T_i-T_u:

$$\lambda N_iE_i\left(1-\frac{\psi_i\overline{u_i'}}{\lambda}\right)=\mu_i\Big(\rho_i\overline{u_i''}F_{ii}N_iE_i+\hat{u}_i'\Big). \tag{77}$$

By concavity of the utility function $u(\cdot)$ and the production function $F(\cdot)$, $\rho_i\overline{u_i''}F_{ii}N_iE_i+\hat{u}_i'>0$. Denoting by $b_i=\psi_i\overline{u_i'}/\lambda$, it follows that

$$\mu_i<0\quad\Leftrightarrow\quad b_i>1. \tag{78}$$

Hence, an increase in ρ_i leads to an increase in social welfare if and only if $b_i > 1$. Importantly, nowhere in the proof is it necessary to assume that income effects are absent or that profit taxation is unrestricted (i.e., $b_f = 1$). Proposition 2 thus generalizes to settings with income effects and a binding restriction on profit taxation.

C.2 Optimal union power

Suppose that the government could optimally determine union power ρ_i. If we denote by $\underline{\chi}_i \geq 0$ the Kuhn-Tucker multiplier on the restriction $\rho_i \geq 0$, and by $\overline{\chi}_i \geq 0$ the multiplier on the restriction $1 - \rho_i \geq 0$, the first-order condition for optimal union power ρ_i in sector i (obtained from differentiating the Lagrangian (69) augmented with the additional inequality constraints) is given by

$$\mu_i E_i \psi_i \overline{u_i'} F_{ii} N_i + \underline{\chi}_i - \overline{\chi}_i = 0. \tag{79}$$

This expression should be considered alongside the other first-order conditions of the optimization program. In an interior optimum (i.e., where the optimal $\rho_i \in (0,1)$), the Kuhn-Tucker conditions require that $\underline{\chi}_i = \overline{\chi}_i = 0$. Equations (79) and (77) then imply that in these sectors $b_i = 1$. If the solution is at the boundary, then by the Kuhn-Tucker conditions it must be that either $\overline{\chi}_i = 0$ and $\underline{\chi}_i > 0$ or $\underline{\chi}_i = 0$ and $\overline{\chi}_i > 0$. If labor demand is not perfectly elastic, equation (79) implies that $\mu_i > 0$ in the first case (in which case $b_i < 1$) and $\mu_i < 0$ in the second case (in which case $b_i > 1$). Optimal union power thus equals $\rho_i = \min[\rho_i^*, 1]$ if $b_i \geq 1$, and $\rho_i = \max[\rho_i^*, 0]$ if $b_i \leq 1$, where ρ_i^* is the bargaining power of the union for which $b_i = 1$.

C.3 Proof Proposition 3

As in the proof of Proposition 1, in this Appendix we work with the reduced-form equations describing labor-market equilibrium:

$$E_i = E_i(\rho_1, \cdots, \rho_I, T_1, \cdots, T_I, T_u), \tag{80}$$

$$w_i = w_i(\rho_1, \cdots, \rho_I, T_1, \cdots, T_I, T_u). \tag{81}$$

These relationships can be found by solving the labor-demand and the wage-demand equations (11)–(12) for all i. Importantly, we neither impose that labor markets are independent, nor that income effects at the union level are absent.

Consider a marginal increase in union power in sector i, $\mathrm{d}\rho_i > 0$, and a tax reform $\{\mathrm{d}T_k^i\}_k$ that keeps after-tax wages $w_j - T_j$ in all sectors constant following the increase in ρ_i. This tax reform can be found by equating $\mathrm{d}w_j^i = \mathrm{d}T_j^i$, where

$$\mathrm{d}w_j^i = \frac{\partial w_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial w_j}{\partial T_k^i}\mathrm{d}T_k^i \tag{82}$$

is the change in the wage in sector j following an increase in ρ_i and the tax reform $\{\mathrm{d}T_k^i\}_k$.

Setting $\mathrm{d}w_j = \mathrm{d}T_j^i$ and rearranging gives equation (26):

$$\frac{\partial w_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial w_j}{\partial T_k^i}\mathrm{d}T_k^i - \mathrm{d}T_j^i = 0. \tag{83}$$

The impact of the joint increase in union power ρ_i and the tax reform $\{\mathrm{d}T_k^i\}_k$ on employment is given by:

$$\mathrm{d}E_j^i = \frac{\partial E_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial E_j}{\partial T_k^i}\mathrm{d}T_k^i. \tag{84}$$

To analyze the impact of the tax reform and the increase in union power on social welfare, recall that the Lagrangian associated with the government's optimization problem is given by:

$$\begin{aligned}\mathcal{L} = &\sum_i \psi_i N_i \Big(\int_{\underline{\varphi}}^{G_i^{-1}(E_i)} u(w_i - T_i - \varphi)\mathrm{d}G_i(\varphi) + \int_{G_i^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G_i(\varphi)\Big) \\ &+ \psi_f u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_i(T_i - T_u)) + T_f - R \right),\end{aligned} \tag{85}$$

where equilibrium employment rates and wages are given by equations (80)–(81). The joint increase in union power and the tax reform affects wages, employment rates and government finances. The impact on social welfare can be found by taking the total differential of the Lagrangian with respect to changes in taxes, wages and employment rates:

$$\begin{aligned}\mathrm{d}\mathcal{W} = &\sum_j \psi_j N_j \int_{\underline{\varphi}}^{G_i^{-1}(E_j)} u_j' \mathrm{d}G_i(\varphi)(\mathrm{d}w_j^i - \mathrm{d}T_j^i) \\ &- \psi_f u_f' \sum_j N_j E_j \mathrm{d}w_j^i + \lambda \sum_j N_j E_j \mathrm{d}T_j^i + \sum_j \psi_j N_j \left(\hat{u}_j - u_u\right) G_i'(\hat{\varphi}_j) \frac{\partial G_i^{-1}(E_j)}{\partial E_j}\mathrm{d}E_j^i \\ &+ \psi_f u_f' \sum_j (F_j - w_j) N_j \mathrm{d}E_j^i + \lambda \sum_j N_j (T_j - T_u)\mathrm{d}E_j^i.\end{aligned} \tag{86}$$

This equation can be simplified in a number of steps. First, the tax reform is such that $\mathrm{d}w_j^i = \mathrm{d}T_j^i$, so the first line drops. Moreover, profit maximization implies that $F_j = w_j$, so that the first term in the last line drops out as well. Moreover, from the definition of $E_j = G_j(\hat{\varphi}_j)$ follows that $G_i'(\hat{\varphi}_j)\frac{\partial G_i^{-1}(E_j)}{\partial E_j} = 1$. Divide the expression by λ and substitute the social welfare weights. If the tax system is optimized we have $b_f = 1$, so the first two terms on the second line drop as well. Rewriting then yields:

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = \sum_j N_j \left(T_j - T_u + \frac{\psi_j\left(\hat{u}_j - u_u\right)}{\lambda}\right)\mathrm{d}E_j^i, \tag{87}$$

Setting the final expression larger than zero, and using the definition of t_j and τ_j, we find that the joint increase in union power and the tax reform that keeps net incomes constant raises social welfare if

$$\sum_j N_j (t_j + \tau_j) w_j \mathrm{d}E_j^i > 0. \tag{88}$$

The welfare impact of the tax reform $\{\mathrm{d}T_k^i\}_k$ equals zero if the tax system is optimized. Therefore, any welfare impact of the joint increase in ρ_i and the tax reform $\{\mathrm{d}T_k^i\}_k$ is driven only by the increase in union power. An increase in union power thus raises social welfare if and only if inequality (88) holds.

The impact of the joint increase in union power ρ_i and the tax reform $\{\mathrm{d}T_k^i\}_k$ on employment in other sectors is generally ambiguous (i.e., $\mathrm{d}E_j^i$ can be negative or positive for $j \neq i$). To analyze how employment in other sectors is affected, combine equations (11) and (12) for all j and write:

$$\rho_j \int_{\underline{\varphi}}^{G_i^{-1}(E_j)} u'(F_j(\cdot) - T_j - \varphi)\mathrm{d}G_i(\varphi) F_{jj}(\cdot) N_j + \left(u(F_j(\cdot) - T_j - G_i^{-1}(E_j)) - u(-T_u)\right) = 0. \quad (89)$$

These equations pin down equilibrium employment rates in all sectors given union power and the tax-benefit system that is in place. Hence, they can be used to determine how employment rates are affected by the joint increase in ρ_i and the tax reform that keeps after-tax wages constant. From equation (89), it can immediately be seen that if the wage in sector $j \neq i$ is determined competitively (i.e., $\rho_j = 0$), there will be no change in employment: $\mathrm{d}E_j^i = 0$. This is because the first term cancels and the reform keeps $w_j - T_j = F_j(\cdot) - T_j$ constant. In that case, employment E_j is not affected either. In sectors where wages are not determined competitively, the impact of the joint increase in union power ρ_i and the tax reform $\{\mathrm{d}T_k^i\}_k$ on employment is generally ambiguous. Because the reform leaves ρ_j and $F_j(\cdot) - T_j$ unchanged, any impact on equilibrium employment must come from general-equilibrium effects in $F_{jj}(\cdot)$. If this term only depends on E_j (i.e., if labor markets are independent), then again $\mathrm{d}E_j^i = 0$. Generally, the term $F_{jj}(\cdot)$ depends on employment in all sectors. If F_{jjk} is small for $j \neq k$ (i.e., if the production function can be approximated well by a second-order Taylor expansion), then $\mathrm{d}E_j^i \approx 0$ for $j \neq i$, and there will be approximately no changes in employment in sector $j \neq i$ following the joint increase in ρ_i and the tax reform $\{\mathrm{d}T_k^i\}_k$ that keeps net incomes fixed.

D Descriptive statistics

Table 4: Union densities and participation tax rates by country

	No.	Union density				Participation tax rate			
Country	sectors	Mean	Std. dev.	Min.	Max	Mean	Std. dev.	Min.	Max.
Sample	294	27.09	22.42	0.00	96.87	36.67	13.52	9.49	100.0
Australia	13	16.09	10.36	2.40	32.50	47.05	4.54	39.89	54.48
Austria	5	24.57	9.04	11.83	33.10	46.19	30.09	31.96	100.0
Canada	18	29.58	21.76	3.80	69.00	45.10	9.21	34.88	65.05
Denmark	14	67.62	10.91	41.65	82.00	64.39	11.84	44.55	86.52
Finland	12	62.99	10.09	46.86	83.00	32.71	15.73	22.52	81.53
France	15	10.98	5.69	4.10	24.10	43.44	4.23	36.92	51.74
Germany	7	19.76	10.07	6.46	34.00	49.38	3.91	41.29	53.00
Hungary	18	10.61	7.56	1.00	25.20	27.76	7.34	14.76	34.50
Ireland	16	28.02	17.12	6.00	60.84	40.60	8.13	33.60	60.00
Italy	9	48.17	21.16	23.50	96.87	29.24	12.59	9.49	41.63
Japan	11	18.64	12.75	5.40	48.70	50.27	9.34	34.60	66.12
Korea	12	16.37	16.55	2.10	54.30	25.42	10.63	14.01	48.38
Latvia	10	12.88	11.88	0.00	38.13	28.45	2.14	22.47	29.69
Netherlands	17	19.73	8.25	7.00	34.00	40.67	9.21	35.55	71.64
Norway	13	51.77	22.38	16.00	82.00	28.10	1.80	25.53	32.88
New Zealand	13	13.79	13.81	1.90	40.00	35.60	3.04	30.19	39.99
Slovakia	10	19.47	14.94	9.07	58.00	26.24	3.75	18.93	29.85
Spain	17	18.51	9.66	2.04	40.00	25.25	12.67	16.59	72.24
Sweden	15	62.92	13.92	32.00	82.00	24.90	3.06	19.17	34.08
Switzerland	7	24.83	15.64	7.42	47.83	28.21	1.55	26.93	30.93
Turkey	6	12.72	14.74	2.98	41.45	21.07	4.11	15.76	27.38
United Kingdom	18	22.12	13.99	3.30	47.60	40.89	8.85	28.71	55.63
United States	18	11.28	9.36	2.10	30.20	35.37	7.64	29.92	49.84

Table 5: Union densities and participation tax rates by sector

	No.	Union density				Participation tax rate			
Sector	countries	Mean	St. dev.	Min.	Max	Mean	St. dev.	Min.	Max.
Sample	294	27.09	22.42	0.00	96.87	36.67	13.52	9.49	100.0
Agriculture	19	16.39	23.83	0.00	96.87	45.52	26.72	9.49	100.0
Commercial services	17	21.89	18.7	5.40	61.30	34.45	10.95	20.66	62.51
Construction	21	24.26	22.1	2.00	70.89	34.35	15.09	9.74	68.41
Education	17	40.24	22.19	9.60	82.00	33.85	7.89	20.02	49.82
Finance	17	27.38	24.02	2.10	70.00	34.34	6.79	14.01	44.56
Health care	10	32.98	22.31	8.70	81.00	34.52	6.37	25.79	45.19
Hotels and restaurants	15	13.21	16.68	1.00	56.00	38.39	15.18	15.32	60.36
Industry	15	29.47	23.69	4.45	75.81	36.0	9.74	23.49	60.24
Manufacturing	22	27.21	22.55	5.25	77.00	34.63	9.18	19.05	55.12
Mining	8	22.38	10.84	4.70	41.45	33.94	9.96	21.78	54.11
Other services	15	20.30	22.21	3.92	72.00	45.22	18.24	16.59	86.51
Public administration	19	42.43	26.20	4.25	83.00	35.46	8.79	25.12	60.42
Real estate and business services	14	17.25	19.75	1.90	62.00	36.48	10.88	19.36	59.45
Services	16	27.28	20.00	10.02	66.87	35.60	11.34	21.23	65.53
Social services	23	33.18	21.35	6.04	76.00	37.86	16.83	14.40	86.52
Trade	17	18.12	18.73	3.00	59.00	36.79	11.52	17.09	63.79
Transport and communication	18	33.82	19.41	2.10	67.00	36.57	12.82	14.53	66.12
Utilities	11	36.95	21.16	7.00	81.70	33.50	9.91	14.47	54.49

Figure 9: Union densities and participation tax rates by country

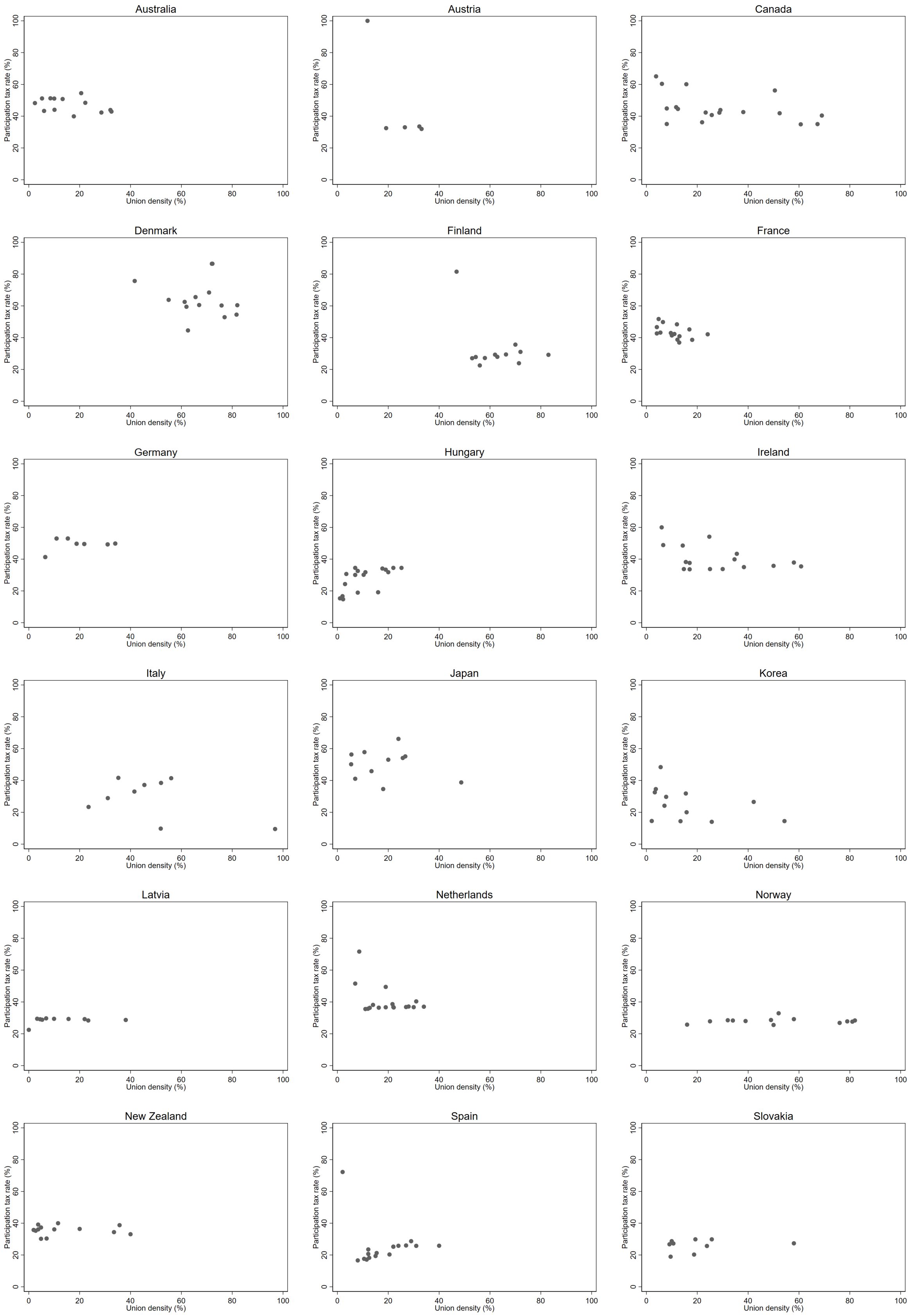
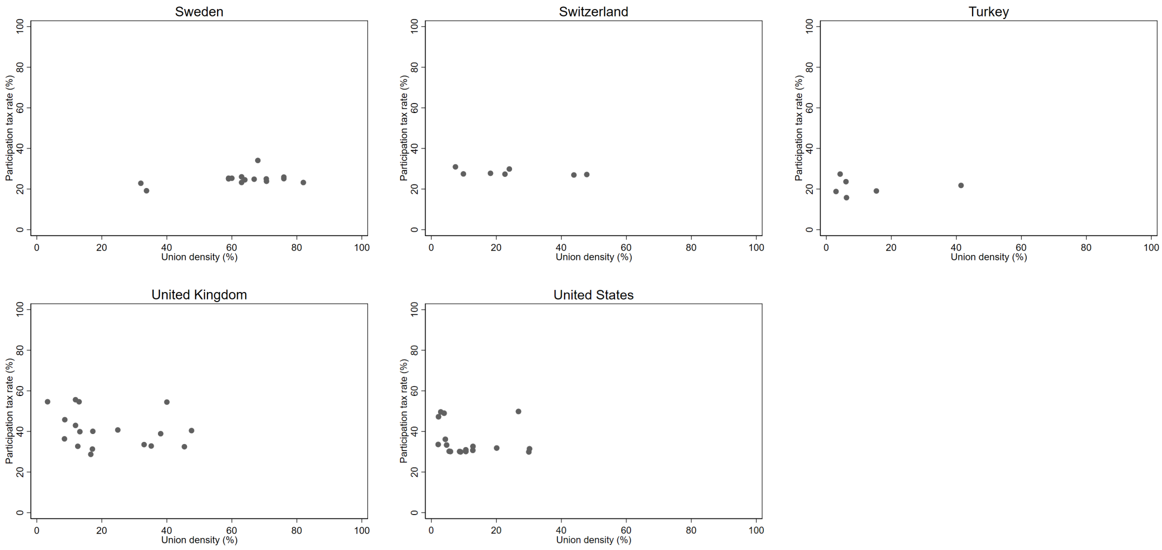


Figure 9: Union densities and participation tax rates by country – continued



E Simulations

E.1 Derivation labor-demand elasticity

Imposing the normalization $AK^{1-\alpha} = 1$, the production function is given by

$$Y = \left(\sum_i a_i L_i^{1/\delta} \right)^{\alpha\delta}, \quad \delta \equiv \frac{\sigma}{\sigma - 1}. \tag{90}$$

The derivatives are given by:

$$w_i = F_i = \alpha \left(\sum_j a_j L_j^{1/\delta} \right)^{\alpha\delta - 1} a_i L_i^{1/\delta - 1}, \tag{91}$$

$$F_{ii} = \alpha \left(\sum_j a_j L_j^{1/\delta} \right)^{\alpha\delta - 1} a_i L_i^{1/\delta - 2} \left[(1/\delta - 1) + (\alpha - 1/\delta)\phi_i \right],$$

where ϕ_i denotes the share of aggregate labor income that goes to workers in sector i:

$$\phi_i \equiv \frac{w_i L_i}{\sum_j w_j L_j} = \frac{a_i L_i^{1/\delta}}{\sum_j a_j L_j^{1/\delta}}. \tag{92}$$

Hence, using $\delta \equiv \frac{\sigma}{\sigma - 1}$ the elasticity of labor demand in sector i is thus equal to:

$$\begin{aligned} \varepsilon_i \equiv -\frac{F_i}{F_{ii} L_i} &= -\frac{\alpha \left(\sum_j a_j L_j^{1/\delta} \right)^{\alpha\delta - 1} a_i L_i^{1/\delta - 1}}{\alpha \left(\sum_j a_j L_j^{1/\delta} \right)^{\alpha\delta - 1} a_i L_i^{1/\delta - 1} \left[(1/\delta - 1) + \phi_i(\alpha - 1/\delta) \right]} \\ &= \frac{\sigma}{1 + \phi_i(\sigma(1 - \alpha) - 1)}. \end{aligned} \tag{93}$$

E.2 Numerically calculating optimal taxes

The optimal tax problem is given by

$$\max_{T_u,\{T_i,E_i\}_{i=1}^I} \mathcal{W} = \sum_i N_i \left[\int_0^{G^{-1}(E_i)} u(F_i(\cdot) - T_i - \varphi) g(\varphi) \mathrm{d}\varphi + (1 - E_i) u(-T_u) \right] \tag{94}$$

$$\text{s.t.} \quad \sum_i N_i(E_i T_i + (1 - E_i) T_u) + F(\cdot) - \sum_i F_i(\cdot) N_i E_i = R,$$

$$\rho F_{ii}(\cdot) N_i \int_0^{G^{-1}(E_i)} u'(F_i(\cdot) - T_i - \varphi) g(\varphi) \mathrm{d}\varphi + u(F_i(\cdot) - T_i - G^{-1}(E_i)) - u(-T_u) = 0, \ \forall i,$$

where we substituted the labor-demand equations $w_i = F_i(\cdot)$, imposed $G_i(\varphi) = G(\varphi)$, $\underline{\varphi} = 0$, $\rho_i = \rho$ for all i, and set the Pareto weights equal to one (utilitarian government), i.e., $\psi_i = 1$ for all i. Furthermore, we assume that all profits flow back to the government. We impose functional forms on $u(\cdot)$, $F(\cdot)$ and $G(\varphi)$, their derivatives or inverses. The primitives are the calibrated parameters of these functions (θ, α, σ, $\{a_i\}_i$, γ and ζ), union power ρ, the labor force sizes $\{N_i\}_i$ and the revenue requirement R. Our simulations exploit two possible algorithms to find optimal taxes, depending on which algorithm is faster or more stable.[76]

E.2.1 Solving unconstrained optimum

The most straightforward solution is to exploit the CARA utility function and analytically solve for the optimal participation tax level $T_i - T_u$ from the union wage-demand equation:

$$T_i - T_u = -\frac{1}{\theta} \ln \left[\frac{\theta \rho w_i}{\varepsilon_i E_i} \int_0^{G^{-1}(E_i)} \exp(-\theta(w_i - \varphi) g(\varphi) \mathrm{d}\varphi + \exp(-\theta(w_i - G^{-1}(E_i))) \right]. \tag{95}$$

Here, $w_i = F_i(\cdot)$ and $\varepsilon_i = \sigma/(1+\phi_i(\sigma(1-\alpha)-1))$. Hence, this is a solution for the participation tax as a function of all employment levels $\{E_i\}_i$. Next, we can use the government budget constraint to calculate:

$$T_u = \frac{1}{\sum_i N_i} \left[R + \sum_i F_i(\cdot) N_i E_i - F(\cdot) - \sum N_i E_i (T_i - T_u) \right]. \tag{96}$$

Hence, we have all taxes $\{T_i\}_i$ and T_u as a function of all employment rates $\{E_i\}_i$. After substituting these equations in the objective and constraints of problem (94), we obtain an *unconstrained* maximization problem in the employment rates $\{E_i\}_i$. Starting from the current employment rates in the calibrated economy, we numerically search for the vector of employment rates that maximizes social welfare.

E.2.2 Solving first-order conditions

Another approach is to solve for the first-order conditions associated with maximization problem (94). We specify all first-order conditions of the optimal tax problem: one for T_u, one for each T_i and E_i, the government budget constraint, and the union wage-demand equation for every sector i. This is a system of $3 \times I + 2$ equations in an equal number of unknowns: T_i, E_i,

[76] All programs are written in Matlab and are available on request from the authors.

T_u, μ_i (multiplier on union wage-demand equation), and λ (multiplier on government budget constraint). We can simplify this system as follows. The union wage-demand equation and the government budget constraint can be used to solve for T_i and T_u, as shown in the first method. Moreover, the system is linear in the multipliers μ_i, hence this multiplier can be eliminated as well. Finally, we use the first-order condition for T_u to solve for the multiplier on the resource constraint λ. We then obtain a system of I equations in I unknowns: all first-order conditions with respect to the employment rates $\{E_i\}_i$. Starting from the employment rates in the calibrated economy, we numerically solve for the vector of employment rates. We verify our solution to the first-order conditions indeed maximizes social welfare by using the candidate solution as a guess in the unconstrained maximization problem.

E.3 Additional graphs

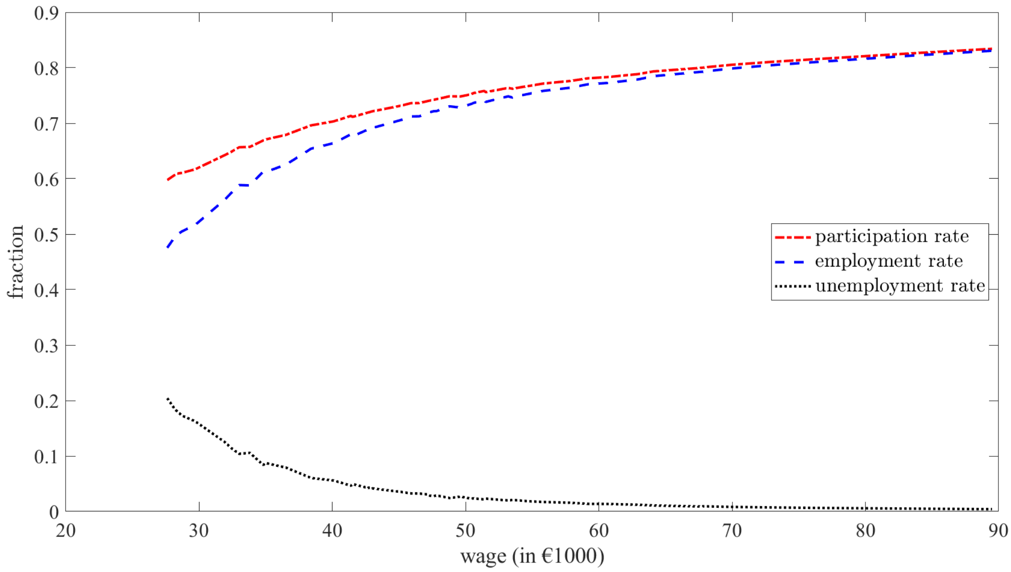


Figure 10: Participation, employment and unemployment rates by income

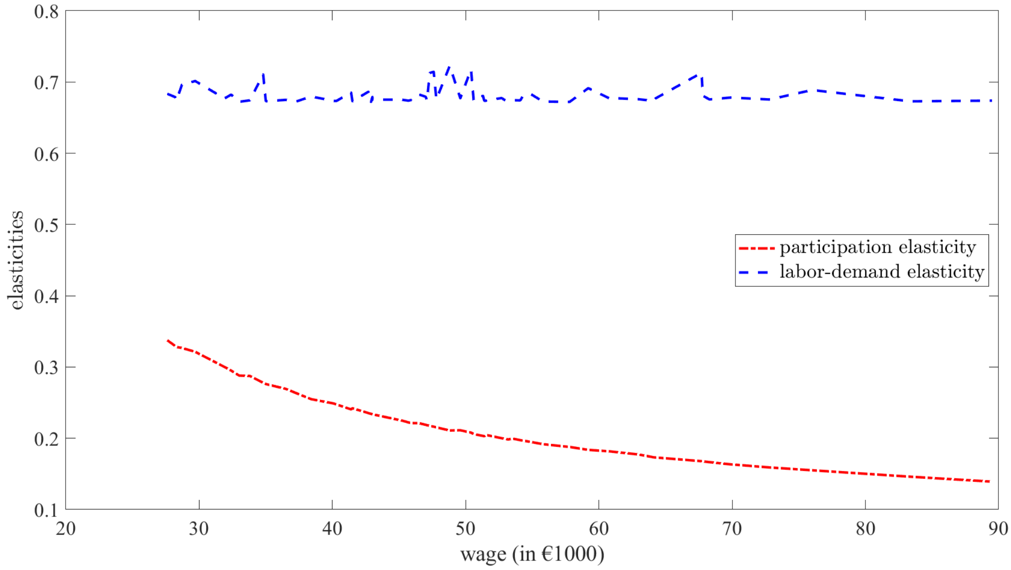


Figure 11: Participation elasticity and labor-demand elasticity by income