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. 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. Numerical simulations demonstrate that optimal taxes and transfers are much less redistributive in unionized labor markets than in competitive labor markets.

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

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1 Introduction

Unions play a dominant 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.

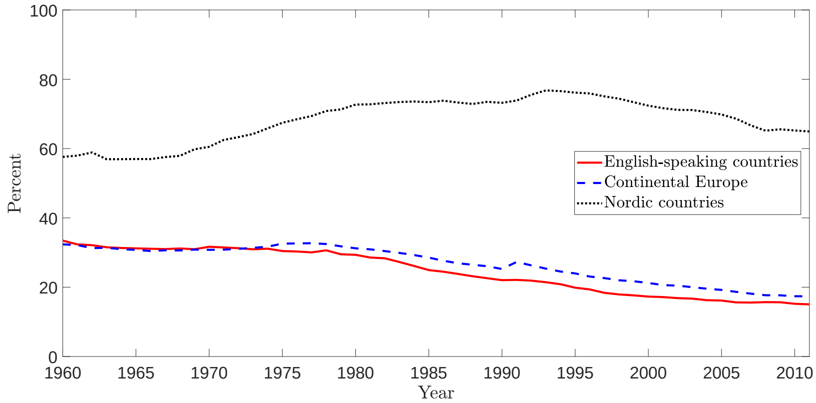
First, we answer the question how income taxes should be set in unionized labor markets. We show that optimal participation taxes (i.e., the sum of income taxes and unemployment benefits) are lower if unions are more powerful.[4] Intuitively, high income taxes and unemployment benefits worsen the inside 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, optimal

[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.

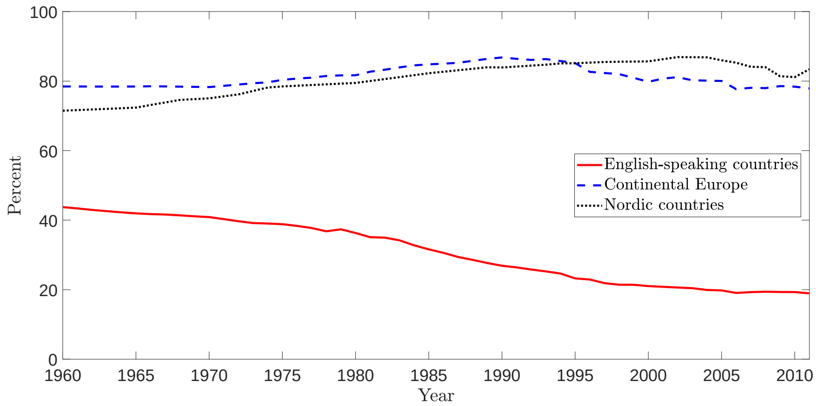
[2] See, for instance, Heckman (1993), Eissa and Liebman (1996), and Meyer (2002).

[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), 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, 2018a).

participation taxes are lowered. It may be optimal to subsidize participation even for workers whose welfare weight is below one, which never occurs if labor markets are competitive, cf. Diamond (1980), Saez (2002), and Choné and Laroque (2011). EITC programs 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 whose social welfare weight is above one.[5] Intuitively, in sectors where the workers' social welfare weight exceeds one, participation is subsidized on a net basis, see also Diamond (1980), Saez (2002), and Choné and Laroque (2011). Consequently, labor participation is distorted upwards. Unions alleviate the upward distortion in employment

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

by bidding up wages. Hence, involuntary unemployment acts as an implicit tax, which partially off-sets the explicit subsidy on labor participation.[6] Consequently, EITC policies 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 the social welfare weights of workers are below one, since labor participation is then taxed on a net basis.[7] In that case, implicit taxes from involuntary unemployment exacerbate explicit taxes on labor participation. Our results imply that it is socially optimal to let low-income workers organize themselves in a labor union, whereas labor markets for workers with higher incomes should remain competitive.

To explore the quantitative importance of unions for optimal tax policy and to study whether unions can be desirable, we simulate a structural version of our model for the Netherlands. We calibrate our model to match data on sectoral wages and employment, where in 2015 approximately 79.4% of all employees were covered by collective labor agreements (OECD, 2020). The degree of union power is used to match an involuntary unemployment rate of 6.9%. For plausible values of labor-demand and participation elasticities, optimal participation tax rates (i.e., the sum of income taxes and unemployment benefits as a fraction of the wage) are on average 7.4 percentage points lower in unionized labor markets than in perfectly competitive labor markets. Lower participation taxes induce unions to moderate their wage demands, which generates a welfare gain because some previously (involuntary) unemployed workers now find employment. The reduction in participation taxes is brought about by lower income taxes and lower unemployment benefits. Consequently, the optimal tax system with unions is less redistributive. Furthermore, in most of our simulations the social welfare weight of workers is below one (even in competitive labor markets), which implies that unions are never socially desirable. The government then prefers to increase the net incomes of low-skilled workers directly by reducing their income taxes rather than indirectly by increasing the bargaining power of the union representing them. However, this finding is sensitive to the redistributive preferences of the government. It can easily be overturned if the government attaches a larger welfare weight to low-income workers.

We also investigate the robustness of our findings by relaxing a number of important assumptions in this paper and in an online Appendix: i) if the government cannot (fully) tax profits, ii) if individuals can endogenously choose the sector in which they work ('intensive margin'), iii) if labor rationing is not fully efficient, iv) if a national union bargains over all sectoral wages with the aim to compress the wage distribution, and v) if unions and firms bargain over wages and employment, as in the efficient bargaining model of McDonald and Solow (1981). We show that expressions for optimal participation taxes remain the same if profits cannot be taxed, sectoral choice is endogenous, or a national union bargains over all wages, since we express our tax rules in terms of sufficient statistics. Optimal taxes are slightly 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 profits

[6] 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 welfare weight of the workers for whom the minimum wage binds exceeds one.

[7] 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 if the social welfare weight is below one. This is the case if the implicit tax is larger than the explicit subsidy on labor.

cannot be taxed, sectoral choice is endogenous, a national union bargains over all wages, and there is efficient bargaining. In contrast, the desirability condition for unions 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 accompanying online Appendix. Section 7 presents our simulations. Section 8 concludes. Finally, the Appendix 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.

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., 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). Since we focus on extensive labor-supply responses, we abstract from the wage-moderating effect of tax-rate progressivity. We contribute to this literature by studying optimal taxation rather than deriving comparative statics in models with unions.

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.[8] Instead, in our model labor supply responds only

[8]For instance, Aronsson and Sjögren (2004) show that the optimal labor income tax might be either progressive

on the extensive margin. 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 (EITCs) are optimal for low-income workers whose social welfare weight exceeds one. 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 whose social welfare weight is below one.

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 we consider a finite number of labor types which are imperfect substitutes in production. 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.[9]

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

or regressive depending on whether working hours are determined by the union or by workers themselves.

[9] 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).

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 working, every worker 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 denoted by $G(\varphi)$, which is assumed to be identical across sectors.[10] 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.[11] 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: $\varphi_i^* = w_i - T_i + T_u$. 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.

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.[12] 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 ($F_{Ki} \geq 0$). We do not make specific assumptions regarding the complementarity of different labor types. To derive some special cases, we sometimes assume 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

[10] It is straightforward to allow for a sector-specific distribution of participation costs $G_i(\varphi)$. None of our results would change.

[11] 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.

[12] 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.

market.[13]

Profits 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 $\varepsilon_i \equiv -F_i(\cdot)/(L_i F_{ii}(\cdot)) > 0$.[14]

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.

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.[15] 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.

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

[14] 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.

[15] 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.

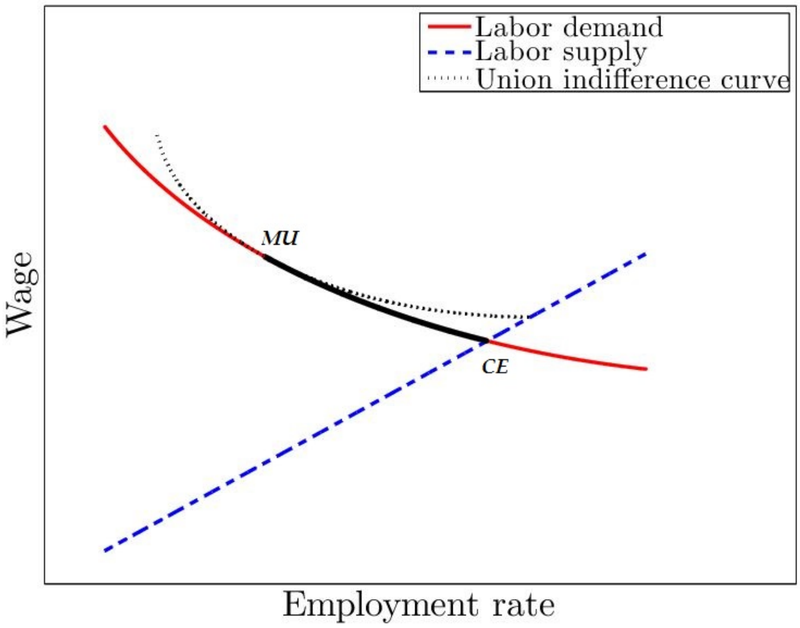


Figure 2: Labor market equilibria in the right-to-manage model

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 $\hat{\varphi}_i \equiv G^{-1}(E_i)$, 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: $E_i = G(\hat{\varphi}_i) \leq G(\varphi_i^*)$. If union i maximizes the expected utility of its members, and labor rationing is efficient, the union's objective function can be written as:

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

where $\overline{u(c_i)} \equiv \int_{\underline{\varphi}}^{\hat{\varphi}_i} u(c_{i,\varphi})\mathrm{d}G(\varphi)/E_i$ 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 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 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:

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

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. And, 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 Appendix A, we formally demonstrate that there exists a monotonic relationship between ρ_i and the union's Nash-bargaining parameter. Hence, using ρ_i as a measure for union power is without loss of generality, while it allows us to avoid technical complications that would arise if we instead assumed Nash bargaining.

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 the government attaches to firm-owners and ψ_i is the Pareto weight for 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.[16]

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).[17] 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. 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 Appendix C for details.

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.

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

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

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:*

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

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 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.[18] 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 B 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 will assume for analytical convenience that income effects are absent at the union level 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.[19] We show in Appendix D.2 that allowing for income effects at the union level does not yield any additional substantive insights. 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*

[18] 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.

[19] This is an assumption on the individual utility function $u(\cdot)$ that is always satisfied if $u(\cdot)$ is linear. Appendix B shows that income effects at the union level are also absent if $u(\cdot)$ is of the CARA-type.

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 $G_i' \equiv G'(E_i)$.

Proof. See Appendix B. □

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 (10), while taking into account the behavioral responses to tax policy. We characterize optimal tax policy in terms of elasticities and social welfare weights.[20] Social welfare weights of employed workers in sector i and the firm-owners are denoted by $b_i \equiv \psi_i \frac{\overline{u'(c_i)}}{\lambda}$ and $b_f \equiv \psi_f \frac{u'(c_f)}{\lambda}$, where λ is the multiplier on the government budget constraint. The welfare weight of the unemployed is given by the weighted average of the 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:*

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

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

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

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

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_{ij} 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 D.1. □

Equation (16) states that a weighted average of the welfare weights of the employed and unemployed workers equals one. 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).[21] 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 $b_i < 1$. Depending on the redistributive preferences of the government, there may also be employed workers whose 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 welfare weight. Given that the 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 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

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

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, for constant 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.

The change in the participation tax in one sector has implications for both employment and wages in all other sectors. 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. 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 welfare weight equals b_f) to workers in sector i (whose 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 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 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}).

Equation (18) gives an expression for optimal participation taxes in terms of welfare weights, elasticities and union wedges, which are generally endogenous. Under some functional-form assumptions, it is possible to derive an analytical solution for optimal participation taxes in terms of model primitives.

Corollary 1. *Let the utility function be linear, i.e., $u(c_{i,\varphi}) = c_{i,\varphi}$, sector-specific participation costs be uniformly distributed, i.e., $G_i(\varphi) = \xi_i + \sigma_i^{-1}\varphi$, $\xi_i, \sigma_i > 0$, Pareto weights be normalized such that $\sum_i N_i\psi_i / \sum_i N_i = \psi_f = 1$, and the production function be quadratic:*

$$F(K, N_1E_1, \cdots, N_IE_I) = f(K) + \sum_i \alpha_i N_i E_i \left(\beta_i - \frac{1}{2} N_i E_i\right), \quad f'(\cdot), \alpha_i, \beta_i > 0, \tag{22}$$

then the optimal tax structure has a solution in terms of model primitives with $b_i = \psi_i$ and

$$T_i - T_u = \frac{(\alpha_i\beta_i + \sigma_i\xi_i)(\alpha_i N_i \rho_i (2\psi_i - 1) + \sigma_i(\psi_i - 1))}{\alpha_i N_i (2(\psi_i - 1)\rho_i - 1) + \sigma_i(\psi_i - 2)}, \quad \forall i. \tag{23}$$

The optimal participation tax is affected by union power depending on:

$$\frac{\partial(T_i - T_u)}{\partial \rho_i} < 0 \quad \Leftrightarrow \quad \psi_i > \frac{1}{2 + \sigma_i/(\alpha_i N_i)} \quad \forall i. \tag{24}$$

Proof. See Appendix D.3. □

With the aid of Corollary 1, we are able to analytically determine the comparative statics of optimal participation taxes with respect to all model primitives. The most important insight is that the impact of union power ρ_i on optimal participation taxes is not unambiguous. On the one hand, an increase in union power ρ_i raises the union wedge, which lowers the optimal participation tax. On the other hand, an increase in union power ρ_i changes the behavioral elasticities η_{ii} and κ_{ii} with respect to participation taxes. This indirect effect can off-set the direct effect of larger union power. Optimal participation taxes are decreasing in union power only if the impact on elasticities is not large enough to off-set the direct impact of a larger union wedge τ_i. This is the case if the social welfare weight ψ_i is sufficiently high. In that case, union power has first-order welfare impacts on the labor market by increasing the labor wedge, while only second-order welfare impacts via changes in behavioral elasticities. These effects are driven by third-order derivatives of the production function. Hence, we expect that in general larger union power lowers optimal participation taxes (and we confirm this is the case in our simulations).

Three final remarks are in order. First, it might be optimal in unionized labor markets to subsidize participation even for workers whose welfare weight is below one. 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):

$$\left(\frac{t_i + \tau_i}{1 - t_i}\right) \eta_{ii} = (1 - b_i)(1 - \kappa_{ii}). \tag{25}$$

With independent labor markets, an increase in the participation tax in sector i increases distortions by lowering employment in sector i as indicated on the left-hand side. On the other hand, a higher participation tax features redistributional benefits, as indicated on the right-hand side. 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 whose welfare weight is above one, 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 whose welfare weight is below one ($b_i < 1$). 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 (such as an EITC) even for workers whose welfare weight is below one.

Second, the formula for the optimal participation tax simplifies considerably if labor markets are competitive – irrespective of whether wages are exogenous or endogenous. It is shown in Appendix D.4 that with competitive labor markets, the optimal tax formula (18) nests the one derived in Saez (2002) and simplifies to

$$\frac{t_i}{1 - t_i} = \frac{1 - b_i}{\pi_i}, \tag{26}$$

where $\pi_i \equiv \frac{g(\varphi_i^*)\varphi_i^*}{G(\varphi_i^*)}$ 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 (26) coincide. In this case, unions always refrain from demanding above market-clearing wages. The result from Saez (2002) also holds if labor types are imperfect substitutes in production and there are no unions (i.e., $\rho_i = 0$ for all i).[22] If labor markets are perfectly competitive, labor-demand considerations are irrelevant for the characterization of optimal participation tax rates.[23]

Third, 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

[22] The same result is derived as well in Christiansen (2015).

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

appropriation by unions.[24] In contrast to earlier literature, we find that the optimal participation tax given in equation (18) does *not* depend on the availability of a perfect profit tax. In particular, only if the profit tax is optimized, we have $b_f = 1$, otherwise $b_f \neq 1$. Our results demonstrate that a restriction on profit taxation only changes the level optimal participation tax rate, but not the tax formula. The reason is that profit taxes are a second source of non-distortionary public finance. The first one is (implicitly) a uniform transfer that can be provided to all workers.[25] Consequently, the government does not need taxes on profits to alleviate distortions of taxes on income, so that there are no interactions between setting participation and profit taxes. With a binding restriction on profit taxes, the social welfare weight of the firm-owners falls short of one, i.e., $b_f < 1$. Recall from Lemma 1 that a higher participation tax leads to higher wages. These wage increases redistribute income from firm-owners to workers. The welfare effect is proportional to $b_i - b_f$ and is stronger the higher are the wage elasticities with respect to the participation tax κ_{ji}. Although the formula for optimal participation tax is not affected by restrictions on the profit tax, the level of the participation tax is affected. In particular, the more binding is the restriction on profit taxation (i.e., the lower is b_f), the higher should the participation tax be set – *ceteris paribus*. Intuitively, the participation tax corrects for the absence of the profit tax and indirectly redistributes income from firm-owners to workers. The finding that income taxes are adjusted to indirectly redistribute income from firms 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 as in Proposition 1, then increasing union power ρ_i in sector i raises social welfare if and only if the welfare weight of the workers in sector i exceeds one: $b_i > 1$.*

Proof. See Appendix E.1. □

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 B. 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 reform offsets the change in the wage and

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

[25]The latter can be accomplished by a joint reduction in income taxes and an increase in non-employment benefits.

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 can be financed by raising the profit tax T_f. If the tax system is optimized, a marginal change in income and profit taxes does not change social welfare. The joint policy reform of raising union power, lowering the income tax, and raising the profit tax keeps all equilibrium wages and employment rates unaffected, and only brings about a transfer in income from firm-owners (whose welfare weight is one if the tax system is optimized) to workers in sector i (whose 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 welfare is that it might be optimal for the government to subsidize participation, which 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 (26), 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.[26]

Proposition 2 holds irrespective of whether there are income effects at the union level. Perhaps surprisingly, the result also generalizes to a setting where profits cannot be fully taxed (in which case $b_f < 1$), as formally demonstrated in Appendix E.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. The optimal tax system takes this form of indirect redistribution into account.[27] 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, 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 in each sector i.[28] This is done in the next Corollary.

Corollary 2. *Let $\hat{\rho}_i$ be the union power such that the social welfare weight of workers in sector i equals one: $\hat{\rho}_i \equiv \{\rho_i : b_i = 1\}$. If Assumption 2 (efficient rationing) is satisfied, and taxes and transfers are set according to Proposition 1, then the optimal degree of union power in sector i equals $\rho_i^* = \min[\hat{\rho}_i, 1]$ if $b_i \geq 1$, and $\rho_i^* = \max[\hat{\rho}_i, 0]$ if $b_i \leq 1$.*

According to Corollary 2, for workers whose social welfare weight exceeds one (i.e., $b_i \geq 1$), the power of the union representing them should optimally be increased until their social welfare weight equals one. However, if this is not feasible (which can happen if workers have low wages

[26] Lee and Saez (2012) and Gerritsen and Jacobs (2020) 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.

[27] This explains why *ceteris paribus* income taxes are higher when profit taxation is restricted (i.e., when b_f is low): see Proposition 1.

[28] Of course, it is not obvious how 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.

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 $\rho_i^* = 1$. For workers whose social welfare weight is smaller than one ($b_i < 1$), 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.[29] Moreover, assessing whether 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.[30] 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 as in Proposition 1, then a net-income neutral increase in union power ρ_i raises social welfare if and only if*

$$\sum_j N_j(t_j + \tau_j) w_j \mathrm{d}E_j^i > 0, \tag{27}$$

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

$$\mathrm{d}E_j^i = \frac{\partial E_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial E_j}{\partial T_k^i}\mathrm{d}T_k^i. \tag{28}$$

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

$$\frac{\partial w_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial w_j}{\partial T_k^i}\mathrm{d}T_k^i - \mathrm{d}T_j^i = 0. \tag{29}$$

Proof. See Appendix E.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 (29), which is obtained by setting $\mathrm{d}(w_j - T_j) = 0$ for each sector j. Provided the welfare weight of firm-owners equals one

[29] The only instance where welfare weights are exogenous is if the utility function is linear, see also Corollary 1. However, it is always possible to make the 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.

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

(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 (28). 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 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 (27) 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 E.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 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, participation is taxed for nearly all workers in OECD countries, see OECD (2018b). This implies that if the tax system in these countries is optimized and spillover effects between different sectors are small, an increase in union power unambiguously lowers welfare. We get back to this point in more detail in Section 7.

6 Summary of extensions

In the online Appendix accompanying this paper, we investigate the robustness of our results by relaxing some of the main assumptions in our model. i) We analyze the consequences of inefficient rationing. ii) We study endogenous occupational choice, or the 'intensive margin' as in Saez (2002). iii) We analyze a single, national union that bargains with firm-owners over the entire *distribution* of wages. iv) 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 Inefficient rationing

We have deliberately biased our findings in favor of unions by assuming that unemployment 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.

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 will be 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) still 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 that remain 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 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 one so as to compensate for the larger inefficiencies in labor rationing.

6.2 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. In this extension, we therefore 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 $p_i(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u)$. 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.[31]

We demonstrate that Proposition 1 carries over fully 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.

6.3 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.[32] 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, this extension analyzes a single union that 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

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

[32] 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).

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 the *weighted average welfare weight of* workers in sectors with involuntary unemployment exceeds one.

6.4 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.[33] 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.

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:

$$\frac{u(w_i - T_i - \hat{\varphi}_i) - u(-T_u)}{E_i \overline{u'(w_i - T_i - \varphi)}} = \frac{w_i - F_i(\cdot)}{E_i}. \tag{30}$$

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.[34] 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

[33] 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.

[34] 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.

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 Numerical analysis

We analyze how the presence of unions affect the optimal tax-benefit system in the Netherlands and study the desirability of unions. The reason for choosing the Netherlands rather than, for example, the United States, is that the Netherlands features highly unionized labor markets. In 2015, the year of our calibration, 79.4% of all employees are covered by collective labor agreements (OECD, 2020). Moreover, the RtM-model we use throughout this paper shares important features of the actual bargaining process between unions and employers in the Netherlands. In particular, unions and representatives of firms bargain over wages (mainly) at the sectoral level. Employment is subsequently determined unilaterally by firms.

7.1 Calibration

To calculate the optimal tax-benefit system and to study the desirability of unions, we calibrate a structural version of our model where income effects at the union level are absent and labor rationing is efficient (cf. Assumptions 2 and 3). Furthermore, we allow for spillover effects between different sectors as labor types are complements in aggregate production. 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.

7.1.1 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). We take the latter as the equivalent of a sector in our model. 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.[35] It

[35] 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.

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. To calculate taxes T_i, we multiply 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. For a detailed discussion of the data and which taxes are included, see Quist (2015). The average yearly non-employment benefit $-T_u$ 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).

7.1.2 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 tax, i.e., $R - T_f$, and not the composition over R and T_f.[36] 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.

7.1.3 Utility function

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

$$u(c - \varphi) = -\exp(-\theta(c - \varphi))/\theta. \tag{31}$$

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

[36] 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.

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.[37] In Section 7.3, we explore the sensitivity of our results with respect to θ.

7.1.4 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:

$$Y = F(K, L_1, ..., L_I) = AK^{1-\alpha} \left(\sum_i a_i L_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\alpha\sigma}{\sigma-1}}, \tag{32}$$

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 and employment in each sector i.

We calibrate σ to match the employment-weighted average labor-demand elasticity. The labor-demand elasticity in each sector i is given by (see Appendix F.1 for the derivation):

$$\varepsilon_i = \frac{\sigma}{1 + \phi_i(\sigma(1-\alpha) - 1)}, \tag{33}$$

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 7.3.

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:

$$w_i = F_i(\cdot) = \alpha a_i Y^{\frac{1-(1-\alpha)\sigma}{\alpha\sigma}} L_i^{-\frac{1}{\sigma}}, \tag{34}$$

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

[37] This figure may appear high, but includes both income taxes and unemployment benefits. The latter make up for a significant fraction of the wage, especially for individuals with low and middle incomes.

7.1.5 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:

$$G(\varphi) = \frac{\gamma\varphi^{\zeta}}{1+\gamma\varphi^{\zeta}}, \tag{35}$$

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 (35) generates participation elasticities that are declining in income, in line with emprical evidence, see Hansen (2019) for references. To see this, note that the participation elasticity can be written as

$$\pi_i \equiv \frac{G'(\varphi_i^*)\varphi_i^*}{G(\varphi_i^*)} = \frac{\zeta}{1+\gamma(\varphi_i^*)^{\zeta}}, \tag{36}$$

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.

The average participation elasticity is given by

$$\bar{\pi} = \sum_i \left(\frac{N_i}{\sum_j N_j}\right)\pi_i = \zeta \sum_i \left(\frac{N_i}{\sum_j N_j}\right)\left[1 - \frac{\gamma(\varphi_i^*)^{\zeta}}{1+\gamma(\varphi_i^*)^{\zeta}}\right] = \zeta\left[1 - \frac{\sum_i N_i G(\varphi_i^*)}{\sum_j N_j}\right], \tag{37}$$

where the last term in brackets equals one minus the aggregate participation rate, as obtained from Statistics Netherlands (2020a). Fr 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.

7.1.6 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:

$$\rho \left(\frac{\int_0^{G^{-1}(E_i)} u'(w_i - T_i - \varphi) g(\varphi) \mathrm{d}\varphi}{E_i} \right) \frac{w_i}{\varepsilon_i} = u(w_i - T_i - G^{-1}(E_i)) - u(-T_u). \tag{38}$$

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.

7.1.7 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

$$R = \sum_i N_i(E_i T_i + (1 - E_i)T_u) + (1 - \alpha) \sum_i w_i L_i / \alpha. \tag{39}$$

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 (39). 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 1. Figure 5 in Appendix F.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 6 in Appendix F.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 (33), 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 1: 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

7.2 Optimal taxes and the desirability of unions

The numerical methods for solving the optimal tax system are explained in Appendix F. Figure 3 shows the optimal participation tax rates 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.[38] To facilitate comparison, all participation tax rates are plotted against *current* income.

Comparing the first two lines from Figure 3 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 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 the union wedge τ_i. The government optimally lowers participation taxes to moderate union wage demands and to reduce involuntary unemployment.

There is a substantial discrepancy between the current tax system and the optimal tax system, as can be seen from Figure 3. 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 pre-existing 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

[38] 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.

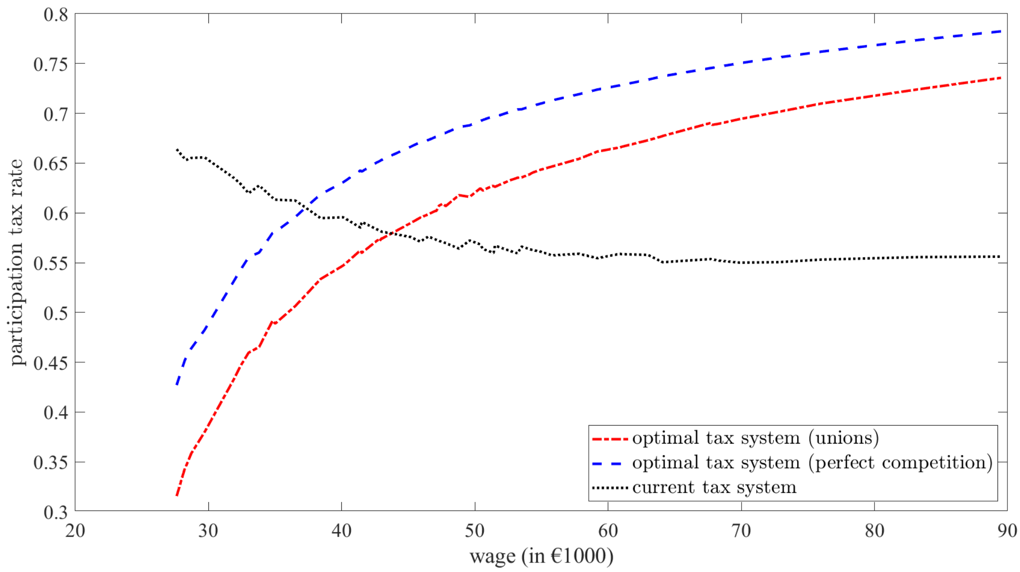


Figure 3: Optimal participation tax rates (baseline)

our model.[39]

Turning to the desirability of unions, Figure 4 plots the social welfare weights at the optimal tax system in unionized and in perfectly competitive labor markets. Given that the tax system is optimized, the average welfare weight in both cases equals one, cf. Proposition 2. Moreover, the concavity in the utility function ensures that the 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, workers in *all* sectors have a social welfare weight that is smaller than one. 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 do not improve social welfare should be interpreted with caution, for (at least) two reasons. First, Proposition 2 is derived under the assumption that income taxes are optimized. Hence, it cannot be used to asses the desirability of unions at the *current* tax system if the latter does not reflect the government's preferences for redistribution. Second, as will be demonstrated below, the result is sensitive to the specification of the social welfare function. In particular, the finding that unions for low-skilled workers do not raise social welfare can be overturned.

[39]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 unemployment 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.

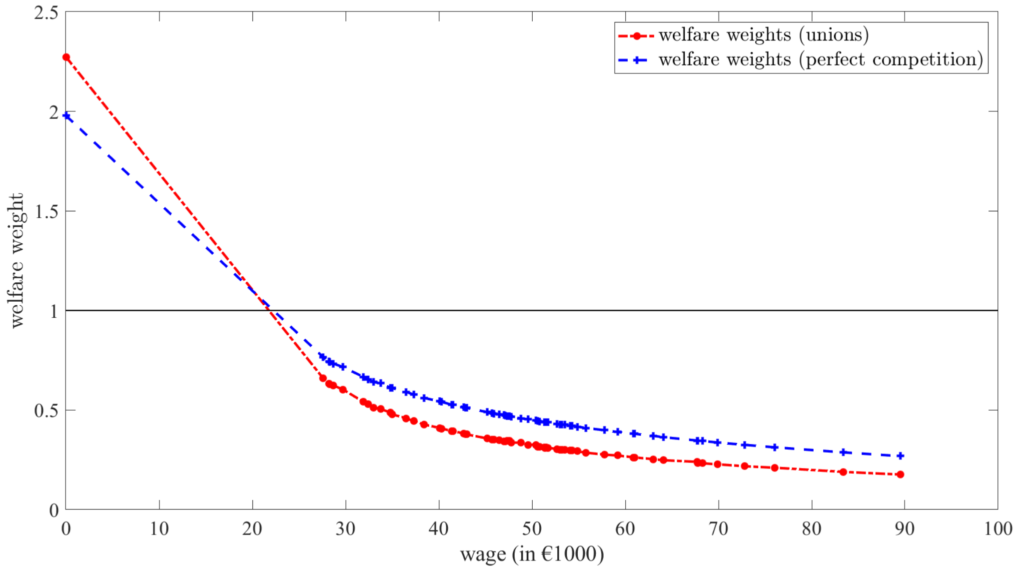


Figure 4: Social welfare weights (baseline)

7.3 Sensitivity analysis

We now analyze how our numerical results are affected if some of the key parameters of our model are changed. The corresponding figures can be found in Appendix F. For each of the robustness checks, we change one of the parameters and recalibrate the model to match the same empirical targets as in the baseline.[40]

7.3.1 Labor-demand elasticity

We first examine how our results are affected if we consider different values for the labor-demand elasticity. This elasticity ultimately determines the trade-off between wages and employment for the union. Figures 7 and 8 (9 and 10) show the optimal participation tax rates and social welfare weights if the average labor-demand elasticity is doubled to $\bar{\varepsilon} = 1.4$ or cut in half to $\bar{\varepsilon} = 0.35$. The implied elasticity of substitution in the production then equals $\sigma = 1.354$ and $\sigma = 0.355$, respectively. The average participation tax rate at the optimal tax system with unions is comparable to the baseline scenario as it ranges from 58.0% to 59.0%, depending on the elasticity of labor demand.

We confirm our finding that optimal participation tax rates are significantly lower in unionized labor markets: optimal participation tax rates in competitive labor markets are on average between 7.4 and 7.5 percentage points higher, depending on the elasticity of labor demand. Furthermore, we find that if the tax system is optimized, an increase in union power does not improve social welfare in both cases: the social welfare weight for all employed workers remains below one.

It might be surprising that the impact of unions on the average participation tax rate is so similar for different labor-demand elasticities. The explanation for this finding is that

[40] When we compare the optimal tax system with and without unions, we do *not* recalibrate the model, but instead conduct a comparative statics exercise by setting $\rho = 0$, see also footnote 38.

the degree of union power ρ is recalibrated to make sure that the unemployment rate in the calibrated economy corresponds to the actual unemployment rate of 6.9%. A higher labor-demand elasticity raises the costs of demanding higher wages, and, hence, requires higher union power to match the unemployment rate observed in the data. Hence, the impact of a larger labor-demand elasticity on the union wedge is countered by larger union power.

7.3.2 Union power

In this robustness check, we investigate how our results are affected if the degree of union power increases, see Figures 11 and 12. To that end, we calibrate the degree of union power at $\rho = 0.330$ to match an involuntary unemployment rate of 13.8%, which is twice as high as the rate of 6.9% in the baseline year 2015. Not surprisingly, the impact of unions on the optimal participation tax rates is larger. On average, the optimal participation tax rate with unions is approximately 10.5 percentage points below the optimal participation tax rate with perfectly competitive labor markets (compared to 7.4 percentage points in the baseline). Furthermore, we confirm our baseline finding that an increase in union power does not raise social welfare: all social welfare weights for employed workers are below one if the tax system is optimized.

Figures 13 and 14 plot the optimal participation tax rates and social welfare weights if the degree of union power is calibrated at $\rho = 0.125$, to match an unemployment rate of 3.45%, which is half the actual unemployment rate in the year 2015. This could capture, for instance, that only a fraction of involuntary unemployment is driven by unions demanding above market-clearing wages. We again find that an increase in union power reduces social welfare. Furthermore, unions lead to lower optimal participation tax rates compared to the competitive benchmark, but the difference is less pronounced (4.7 percentage points versus 7.4 percentage points in the baseline).

7.3.3 Participation elasticity

Next, we increase the average participation elasticity in the calibrated economy from its value of $\bar{\pi} = 0.25$ in the baseline to a value of $\bar{\pi} = 0.50$. Figures 15 and 16 plot the optimal participation tax rates and the social welfare weights at the optimal tax system with and without unions. In line with the theoretical findings from Diamond (1980), optimal participation tax rates are lower than before, as can be seen by comparing Figures 3 and 15. The difference is most pronounced for low- and middle-income groups. The reason is that the participation elasticity is declining in income, cf. equation (36). Targeting a higher average participation elasticity, in turn, leads to larger increases in the participation elasticity at lower levels of income. Consequently, compared to the baseline, optimal participation tax rates are lowered especially for these workers.

Interestingly, the impact of unions on the optimal tax system is less pronounced if the participation elasticity is increased. Optimal participation tax rates with unions are on average only 3.6 percentage points below the optimal participation tax rates with competitive labor markets (compared to a difference of 7.4 percentage points in the baseline). Intuitively, if the participation elasticity is large, an increase in the wage above the market-clearing level leads to a sharp increase in involuntary unemployment. Consequently, the degree of union power that is required to match the unemployment rate of 6.9% in the data is lower than in the baseline. The reduction in union power, in turn, lowers the union wedge. As a result, the impact of unions on the optimal tax-benefit system is smaller. Lastly, we again find that the social welfare weights for all employed workers are below one, which according to Proposition 2 implies that an increase in union power lowers welfare.

7.3.4 Inequality aversion

We significantly decrease inequality aversion by reducing the coefficient of absolute risk aversion to $\theta = 0.016$. At this value of θ, the coefficient of *relative* risk-aversion is 0.50 for an individual with zero participation costs who earns the average wage. The optimal participation tax rate with unions equals approximately 27.8% on average, which is less than half the current rate of 58.3%. With a lower degree of inequality aversion, the government redistributes less income towards the unemployed and more towards low-income workers. In particular, the optimal participation tax rate at the bottom of the income distribution is now *negative*, as can be seen from Figure 17. Hence, low-income workers receive a subsidy of approximately €8,228, which exceeds the non-employment benefit of €5,323 at the optimal tax system with unions (which is much lower than the value of €12,560 in the baseline).

The finding that participation is optimally subsidized for low-skilled workers has an important implication: the social welfare weight of low-skilled workers exceeds one, see Figure 18. Therefore, according to Proposition 2, an increase in union power for low-skilled workers *raises* social welfare – which does not occur in the baseline. This is true for individuals whose current earnings are below €28,300, where participation is subsidized. Hence, an increase in union power alleviates these upward distortions in labor participation.

8 Conclusions

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 the larger are the welfare gains from lowering involuntary unemployment. Therefore, it may be optimal to subsidize participation even for workers whose social welfare weight falls short of one, which cannot happen if labor markets are competitive (see, e.g., Diamond, 1980, Saez, 2002, and Choné and Laroque, 2011). Our simulations suggest that optimal participation tax rates are substantially lower if unions are more powerful. In our baseline simulation, optimal participation tax rates with unions are approximately 7.4 percentage points lower than would be the case if labor markets are perfectly competitive.

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 whose social welfare weight exceeds one is welfare-enhancing, while the opposite holds true for workers whose social welfare weight is below one. Since Diamond (1980), it is well known that participation is optimally subsidized for workers with a social welfare weight larger than one, i.e., they receive an income transfer which 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. In our simulations, we find that increasing union power typically lowers welfare, but this finding is sensitive to the government's preference for income redistribution. However, in nearly all OECD countries participation is taxed on a net basis, so that employment is distorted downwards. 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). For future research, it would be interesting to generalize our model to a setting where unions and the government interact strategically. Second, we have abstracted from labor supply on the intensive (hours, or effort) margin and from a wage-moderating effect of tax progressivity. It would be interesting to extend the model to include an intensive margin and to analyze how our results are affected if the union's decisions would also be influenced by marginal tax rates.

References

Aronsson, T. and T. Sjögren (2003). Income Taxation, Commodity Taxation and Provision of Public Goods under Labor Market Distortions. *FinanzArchiv 59*(3), 347–370.

Aronsson, T. and T. Sjögren (2004). Is the Optimal Labor Income Tax Progressive in a Unionized Economy? *Scandinavian Journal of Economics 106*(4), 661–675.

Aronsson, T. and M. Wikström (2011). Optimal Tax Progression: Does it Matter if Wage Bargaining is Centralized or Decentralized? mimeo, Umeå University.

Boeri, T. M. and J. C. Van Ours (2008). *The Economics of Imperfect Labor Markets*. Princeton: Princeton University Press.

Booth, A. L. (1995). *The Economics of the Trade Union*. Cambridge, UK: Cambridge University Press.

Bovenberg, A. L. (2006). Tax Policy and Labor Market Performance. In J. Agell and P. B. Sørensen (Eds.), *Tax Policy and Labor Market Performance*, Chapter 1, pp. 3–74. Cambridge, MA: MIT Press.

Bovenberg, A. L. and F. van der Ploeg (1994). Effects of the Tax and Benefit System on Wage Formation and Unemployment. mimeo, Tilburg University and University of Amsterdam.

Calmfors, L. and J. Driffill (1988). Bargaining Structure, Corporatism and Macroeconomic Performance. *Economic Policy 3*(6), 13–61.

Card, D. E. (2001). The Effect of Unions on Wage Inequality in the U.S. Labor Market. *Industrial and Labor Relations Review 54*(2), 296–315.

Card, D. E., T. Lemieux, and W. C. Riddell (2004). Unions and Wage Inequality. *Journal of Labor Research 25*(4), 519–559.

Choné, P. and G. Laroque (2011). Optimal Taxation in the Extensive Model. *Journal of Economic Theory 146*(2), 425 – 453.

Christiansen, V. (2015). Optimal Participation Taxes. *Economica 82*(328), 595–612.

Christiansen, V. and R. Rees (2018). Optimal Taxation in a Unionised Economy. CESifo Working Paper No. 6954, Munich: CESifo.

Diamond, P. A. (1980). Income Taxation with Fixed Hours of Work. *Journal of Public Economics 13*(1), 101–110.

Diamond, P. A. and J. A. Mirrlees (1971a). Optimal Taxation and Public Production I: Production Efficiency. *American Economic Review 61*(1), 8–27.

Diamond, P. A. and J. A. Mirrlees (1971b). Optimal Taxation and Public Production II: Tax Rules. *American Economic Review 61*(3), 261–278.

DiNardo, J. E. and T. Lemieux (1997). Diverging Male Wage Inequality in the United States and Canada, 1981–1988: Do Institutions Explain the Difference? *Industrial and Labor Relations Review 50*(4), 629–651.

Dunlop, J. T. (1944). *Wage Determination under Trade Unions*. London: Macmillan.

Eissa, N. and J. B. Liebman (1996). Labor Supply Response to the Earned Income Tax Credit. *Quarterly Journal of Economics 111*(2), 605–637.

Freeman, R. B. (1980). Unionism and the Dispersion of Wages. *Industrial and Labor Relations Review 34*(1), 3–23.

Freeman, R. B. (1993). How Much has De-Unionisation Contributed to the Rise in Male Earnings Inequality? In S. Danziger and P. Gottschalk (Eds.), *Uneven Tides: Rising Inequality in America*, Chapter 4, pp. 133–164. New York: Russel Sage.

Fuest, C. and B. Huber (1997). Wage Bargaining, Labor-Tax Progression, and Welfare. *Journal of Economics 66*(2), 127–150.

Fuest, C. and B. Huber (2000). Is Tax Progression Really Good for Employment? A Model with Endogenous Hours of Work. *Labour Economics 7*(1), 79–93.

Gercama, L., J. M. van Sonsbeek, and P. Koopmans (2020). Uitkeringselasticiteiten werkloosheid. CPB Achtergronddocument Mei 2020, The Hague: CPB Netherlands Bureau for Economic Policy Analysis.

Gerritsen, A. A. F. (2017). Equity and Efficiency in Rationed Labor Markets. *Journal of Public Economics 153*, 56–68.

Gerritsen, A. A. F. and B. Jacobs (2020). Is a Minimum Wage an Appropriate Instrument for Redistribution? *Economica 87*, 611–637.

Hansen, E. (2019). Optimal income taxation with labor supply responses at two margins: when is an Earned Income Tax Credit optimal? mimeo, University of Cologne.

Heckman, J. J. (1993). What Has Been Learned About Labor Supply in the Past Twenty Years? *American Economic Review 83*(2), 116–121.

Hungerbühler, M. and E. Lehmann (2009). On the Optimality of a Minimum Wage: New Insights from Optimal Tax Theory. *Journal of Public Economics 93*(3), 464–481.

ICTWSS (2016). ICTWSS: Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts in 51 countries between 1960 and 2014. http://www.uva-aias.net/en/ictwss.

Jacobs, B. (2018). The Marginal Cost of Public Funds is One at the Optimal Tax System. *International Tax and Public Finance 25*(4), 883–912.

Jacobs, B., E. L. W. Jongen, and F. T. Zoutman (2017). Revealed Social Preferences of Dutch Political Parties. *Journal of Public Economics 156*, 81–100.

Jacquet, L. M., E. Lehmann, and B. Van der Linden (2014). Optimal Income Taxation with Kalai Wage Bargaining and Endogenous Participation. *Social Choice and Welfare 42*(2), 381–402.

Kessing, S. G. and K. A. Konrad (2006). Union Strategy and Optimal Direct Taxation. *Journal of Public Economics 90*(1), 393–402.

Koskela, E. and R. Schöb (2002). Optimal Factor Income Taxation in the Presence of Unemployment. *Journal of Public Economic Theory 4*(3), 387–404.

Koskela, E. and R. Schöb (2012). Tax Progression under Collective Wage Bargaining and Individual Effort Determination. *Industrial Relations 51*(3), 749–771.

Koskela, E. and J. Vilmunen (1996). Tax Progression is Good for Employment in Popular Models of Trade Union Behaviour. *Labour Economics 3*(1), 65–80.

Kroft, K., K. J. Kucko, E. Lehmann, and J. F. Schmieder (2020). Optimal Income Taxation with Unemployment and Wage Responses: A Sufficient Statistics Approach. *American Economic Journal: Economic Policy 12*(1), 254–292.

Layard, P. R. G., S. J. Nickell, and R. Jackman (1991). *Unemployment: Macroeconomic Performance and the Labour Market*. Oxford: Oxford University Press.

Lee, D. S. and E. Saez (2012). Optimal Minimum Wage Policy in Competitive Labor Markets. *Journal of Public Economics 96*(9), 739–749.

Lemieux, T. (1993). Unions and Wage Inequality in Canada and the United States. In D. E. Card and R. B. Freeman (Eds.), *Small Differences that Matter: Labor Markets and Income Maintenance in Canada and the United States*, Chapter 3, pp. 69–108. Chicago: University of Chicago Press.

Lemieux, T. (1998). Estimating the Effects of Unions on Wage Inequality in a Panel Data Model with Comparative Advantage and Nonrandom Selection. *Journal of Labor Economics 16*(2), 261–291.

Lichter, A., A. Peichl, and S. Siegloch (2015). The Own-Wage Elasticity of Labor Demand: A Meta-Regression Analysis. *European Economic Review 80*, 94–119.

Lockwood, B. and A. Manning (1993). Wage Setting and the Tax System: Theory and Evidence for the United Kingdom. *Journal of Public Economics 52*(1), 1–29.

Lockwood, B., T. Sløk, and T. Tranæs (2000). Progressive Taxation and Wage Setting: Some Evidence for Denmark. *Scandinavian Journal of Economics 102*(4), 707–723.

Machin, S. (1997). The Decline of Labour Market Institutions and the Rise in Wage Inequality in Britain. *European Economic Review 41*(3), 647–657.

Mastrogiacomo, M., N. M. Bosch, M. D. A. C. Gielen, and E. L. W. Jongen (2013). A Structural Analysis of Labour Supply Elasticities in the Netherlands. CPB Discussion Paper No. 235, The Hague: CPB Netherlands Bureau for Economic Policy Analysis.

McDonald, I. M. and R. M. Solow (1981). Wage Bargaining and Employment. *American Economic Review 71*(5), 896–908.

Meyer, B. D. (2002). Labor Supply at the Extensive and Intensive Margins: The EITC, Welfare, and Hours Worked. *American Economic Review 92*(2), 373–379.

Mirrlees, J. A. (1971). An Exploration in the Theory of Optimum Income Taxation. *Review of Economic Studies 38*(114), 175–208.

Nickell, S. J. and M. J. Andrews (1983). Unions, Real Wages and Employment in Britain 1951-79. *Oxford Economic Papers 35*, 183–206.

OECD (2018a). OECD Statistics. http://stats.oecd.org/Index.aspx?DataSetCode=POP_FIVE_HIST.

OECD (2018b). Tax and Benefit Systems: OECD Indicators. http://www.oecd.org/els/soc/benefits-and-wages.htm.

OECD (2020). OECD Statistics. https://stats.oecd.org/.

Oswald, A. J. (1993). Efficient Contracts are on the Labour Demand Curve: Theory and Facts. *Labour Economics 1*(1), 85–113.

Palokangas, T. K. (1987). Optimal Taxation and Employment Policy with a Centralized Wage Setting. *Oxford Economic Papers 39*(4), 799–812.

Quist, A. (2015). Marginale druk en participatiebelasting per huishoudtype in 2015. CPB Achtergronddocument 26 April 2015, The Hague: CPB Netherlands Bureau for Economic Policy Analysis.

Rijksoverheid (2016). Uitkeringsbedragen per 1 januari 2016. https://www.rijksoverheid.nl/documenten/publicaties/2015/12/17/bedragen-uitkeringen-2016.

Saez, E. (2002). Optimal Income Transfer Programs: Intensive versus Extensive Labor Supply Responses. *Quarterly Journal of Economics 117*(3), 1039–1073.

Saez, E. (2004). Direct or Indirect Tax Instruments for Redistribution: Short-Run versus Long-Run. *Journal of Public Economics 88*(3), 503–518.

Sinko, P. (2004). Progressive Taxation under Centralised Wage Setting. VATT Discussion Papers No. 349, Helsinki: VATT.

Sørensen, P. B. (1999). Optimal Tax Progressivity in Imperfect Labour Markets. *Labour Economics 6*(3), 435–452.

Statistics Netherlands (2020a). Arbeidsdeelname; Kerncijfers. https://opendata.cbs.nl/#/CBS/nl/dataset/82309NED/table?dl=43F5D.

Statistics Netherlands (2020b). Arbeidsinkomensquote; Bedrijfstak. https://opendata.cbs.nl/#/CBS/nl/dataset/84178NED/table?dl=FA72.

Statistics Netherlands (2020c). Beloning en Arbeidsvolume van Werknemers; Bedrijfstak, Nationale Rekeningen. https://opendata.cbs.nl/#/CBS/nl/dataset/84165NED/table?dl=43F37.

Summers, L., J. Gruber, and R. Vergara (1993). Taxation and the Structure of Labor Markets: the Case of Corporatism. *Quarterly Journal of Economics 108*(2), 385–411.

van der Ploeg, F. (2006). Do Social Policies Harm Employment and Growth? Second-best Effects of Taxes and Benefits on Employment. In J. Agell and P. B. Sørensen (Eds.), *Tax Policy and Labor Market Performance*, Chapter 3, pp. 97–144. Cambridge, MA: MIT Press.

Visser, J. and D. Checchi (2011). Inequality and the Labor Market: Unions. In B. Nolan, W. Salverda, and T. Smeeding (Eds.), *The Oxford Handbook of Economic Inequality*, Chapter 10, pp. 230–256. Oxford: Oxford University Press.

Western, B. P. and J. Rosenfeld (2011). Unions, Norms and the Rise in U.S. Wage Inequality. *American Sociological Review 76*(4), 513–537.

Zoutman, F. T., B. Jacobs, and E. L. W. Jongen (2013). Optimal redistributive taxes and redistributive preferences in the netherlands. mimeo: Erasmus University Rotterdam / CPB Netherlands Bureau for Economic Policy Analysis.

A Derivation of ρ_i from the right-to-manage model

In this Appendix, we derive the relationship between our measure of union power ρ_i and the bargaining power in the Nash product that is more commonly used to characterize equilibrium in the RtM-model (see, for instance, Boeri and Van Ours, 2008). In particular, the Nash bargaining problem is given by:

$$\begin{aligned}
\max_{w_i,E_i} \; \Omega_i = \delta_i \log & \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u)) \mathrm{d}G(\varphi) \right) \\
& + (1-\delta_i) \log \left(u(F(\cdot) - \sum_i w_i N_i E_i - T_f) - u(F(\cdot)|_{E_i=0} - \sum_{j \neq i} w_j N_j E_j - T_f) \right) \\
\text{s.t. } & w_i = F_i(\cdot), \\
& G(w_i - T_i + T_u) - E_i \geq 0,
\end{aligned} \tag{40}$$

where $\delta_i \in [0,1]$ is the weight attached to the union's payoff in the Nash product, and $F(\cdot)|_{E_i=0}$ is the firm's output if it does not reach an agreement with the union in sector i, and, hence, none of the workers in sector i find employment. The payoffs are taken in deviation from the payoff associated with the disagreement outcome. It is important to take the voluntary participation constraint in equation (40) explicitly into account, as it will bind for small values of δ_i. If δ_i is close to zero, labor-market equilibrium is characterized by the final two conditions, which jointly determine the competitive equilibrium.

The Lagrangian reads as:

$$\begin{aligned}
\mathcal{L} = & \delta_i \log \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u)) \mathrm{d}G(\varphi) \right) \\
& + (1-\delta_i) \log \left(u(F(\cdot) - \sum_i w_i N_i E_i - T_f) - u(F(\cdot)|_{E_i=0} - \sum_{j \neq i} w_j N_j E_j - T_f) \right) \\
& + \vartheta_i (w_i - F_i(\cdot)) + \mu_i (G(w_i - T_i + T_u) - E_i).
\end{aligned} \tag{41}$$

The first-order conditions are given by:

$$w_i: \; \frac{\delta_i}{(\overline{u_i} - u_u)} \overline{u_i'} - \frac{(1-\delta_i)}{(u_f - u_f^{-i})} u_f' N_i E_i + \vartheta_i + \mu_i G_i' = 0, \tag{42}$$

$$E_i: \; \frac{\delta_i}{E_i(\overline{u_i} - u_u)} (\hat{u}_i - u_u) - \vartheta_i F_{ii} N_i - \mu_i = 0, \tag{43}$$

$$\vartheta_i: \; w_i - F_i = 0, \tag{44}$$

$$\mu_i: \; \mu_i (G_i - E_i) = 0, \tag{45}$$

where the bars indicate averages over all employed workers in sector i, $\hat{u}_i$ is the utility of the marginal worker in sector i and $u_f^{-i} \equiv u(F(\cdot)|_{E_i=0} - \sum_{j \neq i} w_j N_j E_j - T_f)$ is the utility of firm-owners if they fail to reach an agreement with the union in sector i. If $\delta_i = 1$, equations (42)–(43) imply that $\mu_i = 0$, and we find the equilibrium of the monopoly-union model. For small values of δ_i, the constraint $G_i = E_i$ becomes binding, and the labor-market equilibrium coincides with the competitive outcome. This can be verified by setting $\delta_i = 0$. Equations (42)–(43) then imply that $\mu_i > 0$. This is the case for all values of $\delta_i \in [0, \delta_i^*]$, where $\delta_i^* \in (0, 1)$ solves:

$$\frac{\delta_i^*}{1-\delta_i^*} = \frac{E_i(\overline{u_i} - u_u)}{(u_f - u_f^{-i})} \frac{u_f' N_i}{\overline{u_i'}}. \tag{46}$$

This equation is obtained by setting $G_i = E_i$ and $\mu_i = 0$ in the system of first-order conditions in equations (42)–(45). The reason is that, at exactly this value of δ_i, the constraint $G_i = E_i$ becomes binding. For values of $\delta_i \in [\delta_i^*, 1]$, we thus have $\mu_i = 0$. Combining equations (42)–(43) then leads to:

$$1 - \left(\frac{1-\delta_i}{\delta_i}\right) \frac{E_i(\overline{u_i} - u_u)}{(u_f - u_f^{-i})} \frac{u_f' N_i}{\overline{u_i'}} = \varepsilon_i \frac{(\hat{u}_i - u_u)}{\overline{u_i'} w_i}. \tag{47}$$

Defining the left-hand side of this equation as:

$$\rho_i \equiv 1 - \left(\frac{1-\delta_i}{\delta_i}\right) \frac{E_i(\overline{u_i} - u_u)}{(u_f - u_f^{-i})} \frac{u_f' N_i}{\overline{u_i'}}, \tag{48}$$

we arrive at our equilibrium condition (8). Clearly, if $\delta_i = 1$, we have $\rho_i = 1$, so that the MU-model applies. If $\delta_i = \delta_i^*$, from equation (46) it follows that $\rho_i = 0$, and the equilibrium coincides with the competitive outcome. Hence, there exists a direct relationship between our measure of union power ρ_i and the Nash-bargaining parameter δ_i:

$$\rho_i = \begin{cases} 0 & \text{if} \quad \delta_i \in [0, \delta_i^*), \\ 1 - \frac{(1-\delta_i)}{\delta_i} \frac{E_i(\overline{u_i} - u_u)}{(u_f - u_f^{-i})} \frac{u_f' N_i}{\overline{u_i'}} & \text{if} \quad \delta_i \in [\delta_i^*, 1]. \end{cases} \tag{49}$$

B 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:

$$\Gamma(E_i, T_i, T_u, \rho_i) \equiv$$
$$\rho_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(F_i(\cdot) - T_i - \varphi) \mathrm{d}G(\varphi) F_{ii}(\cdot) N_i + \big(u(F_i(\cdot) - T_i - G^{-1}(E_i)) - u(-T_u)\big) = 0. \tag{50}$$

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 $\hat{\varphi}_i = G^{-1}(E_i)$ and $w_i = F_i(\cdot)$, it follows that $\Gamma(\cdot)$ is decreasing in E_i. The comparative statics can be determined through the implicit function theorem:

$$\frac{\partial E_i}{\partial T_i} = -\frac{\Gamma_{T_i}}{\Gamma_{E_i}} = \frac{\rho_i E_i \overline{u_i''} F_{ii} N_i + \hat{u}_i'}{\rho_i E_i \overline{u_i''}(F_{ii}N_i)^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} < 0, \tag{51}$$

$$\frac{\partial E_i}{\partial T_u} = -\frac{\Gamma_{T_u}}{\Gamma_{E_i}} = \frac{-u_u'}{\rho_i E_i \overline{u_i''}(F_{ii}N_i)^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} > 0, \tag{52}$$

$$\frac{\partial E_i}{\partial \rho_i} = -\frac{\Gamma_{\rho_i}}{\Gamma_{E_i}} = \frac{-E_i \overline{u_i'} F_{ii} N_i}{\rho_i E_i \overline{u_i''}(F_{ii}N_i)^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} < 0. \tag{53}$$

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

$$\frac{\partial w_i}{\partial x} = \frac{\partial w_i}{\partial E_i}\frac{\partial E_i}{\partial x} = F_{ii}N_i \frac{\partial E_i}{\partial x}, \quad x = T_i, T_u, \rho_i \tag{54}$$

$$\frac{\partial w_i}{\partial T_i} = \frac{(\rho_i E_i \overline{u_i''} N_i F_{ii} + \hat{u}_i')F_{ii}N_i}{\rho_i E_i \overline{u_i''}(N_i F_{ii})^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} > 0, \tag{55}$$

$$\frac{\partial w_i}{\partial T_u} = \frac{-u_u' F_{ii} N_i}{\rho_i E_i \overline{u_i''}(N_i F_{ii})^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} < 0, \tag{56}$$

$$\frac{\partial w_i}{\partial \rho_i} = \frac{-E_i \overline{u_i'} (F_{ii} N_i)^2}{\rho_i E_i \overline{u_i''}(N_i F_{ii})^2 + \rho_i E_i \overline{u_i'} F_{iii} N_i^2 + \hat{u}_i'((1+\rho_i)F_{ii}N_i - 1/G_i')} > 0. \tag{57}$$

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 (50) and multiply the expression by $\exp(-\theta T_u)$. The equation then depends on the tax instruments only through the participation tax level $T_i - T_u$.

C First-best allocation

We assume throughout the paper that the government cannot observe participation costs φ. Hence, taxes cannot be conditioned on φ. However, if taxes can be conditioned on participation costs, it is possible to decentralize the first-best allocation as a competitive equilibrium.[41] In this case, the wage in each sector is equated to the marginal productivity of labor, i.e., $w_i = F_i(\cdot)$. Moreover, individuals in sector i with participation costs $\varphi \leq G^{-1}(E_i)$ will all be employed. The first-best allocation is characterized by choosing taxes $T_{i,\varphi}$, T_f and employment rates E_i that maximize social welfare subject only to the government budget constraint. The Lagrangian

[41] Because the first-best allocation can be decentralized as a competitive equilibrium, it follows immediately that unions cannot improve on the allocation.

for this maximization problem is given by:

$$\mathcal{L} = \sum_i \psi_i N_i \Big[\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(F_i(\cdot) - T_{i,\varphi} - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_{i,\varphi})\mathrm{d}G(\varphi)\Big]$$
$$+ \psi_f u(F(\cdot) - \sum_i F_i(\cdot)N_i E_i - T_f) + \lambda\Big[\sum_i N_i \int_{\underline{\varphi}}^{\overline{\varphi}} T_{i,\varphi}\mathrm{d}G(\varphi) + T_f - R\Big]. \quad (58)$$

The first-order conditions are:

$$T_{i,\varphi}: \quad N_i(\lambda - \psi_i u'(F_i(\cdot) - T_{i,\varphi} - \varphi))g(\varphi) = 0 \quad \text{if} \quad \varphi \leq G^{-1}(E_i), \quad (59)$$
$$N_i(\lambda - \psi_i u'(-T_{i,\varphi}))g(\varphi) = 0 \quad \text{if} \quad \varphi > G^{-1}(E_i), \quad (60)$$
$$T_f: \quad \lambda - \psi_f u'(c_f) = 0, \quad (61)$$
$$E_i: \quad \psi_i N_i (u(F_i(\cdot) - T_{i,\varphi} - G^{-1}(E_i)) - u(-T_{i,\varphi}))$$
$$+ N_i \sum_j F_{ji}(\cdot) N_j \Big[\int_{\underline{\varphi}}^{G^{-1}(E_i)} \psi_j u'(F_j(\cdot) - T_{j,\varphi} - \varphi)\mathrm{d}G(\varphi) - \psi_f u'(c_f)\Big] = 0, \quad (62)$$
$$\lambda: \quad \sum_i N_i \int_{\underline{\varphi}}^{\overline{\varphi}} T_{i,\varphi}\mathrm{d}G(\varphi) + T_f - R = 0. \quad (63)$$

$c_f = F(\cdot) - \sum_i F_i(\cdot)N_i E_i - T_f$ is the consumption of firm-owners. At the first-best allocation, all welfare weights are equalized: $\psi_f u'(c_f) = \psi_i u'(c_{i,\varphi}) = \lambda$, where $c_{i,\varphi}$ is the consumption of an individual in sector i with participation costs φ. Because all welfare weights are equalized, the terms in the second line of equation (62) cancel. Equation (62) then implies employment is efficient: $F_i(\cdot) = G^{-1}(E_i)$.

D Optimal taxation

D.1 Proof Proposition 1

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

$$\mathcal{L} = \sum_i \psi_i N_i \Big(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i - (T_i - T_u) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi)\Big) \quad (64)$$
$$+ \psi_f u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_i(T_i - T_u)) + T_f - R\right).$$

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:

$$T_u: \quad -\sum_i \psi_i N_i(E_i\overline{u_i'} + (1-E_i)u_u') + \lambda \sum_i N_i = 0, \tag{65}$$

$$T_f: \quad -\psi_f u_f' + \lambda = 0, \tag{66}$$

$$T_i - T_u: \quad -N_iE_i(\psi_i\overline{u_i'} - \lambda) + \sum_j N_jE_j\left[\psi_j\overline{u_j'} - \psi_f u_f'\right]\frac{\partial w_j}{\partial(T_i - T_u)}$$
$$+ \sum_j N_j\left[\psi_j(\hat{u}_j - u_u) + \lambda(T_j - T_u)\right]\frac{\partial E_j}{\partial(T_i - T_u)} = 0. \tag{67}$$

To obtain equation (16), divide equation (65) by $\lambda\sum_j N_j$ to find

$$1 = \sum_i \underbrace{\left(\frac{N_iE_i}{\sum_j N_j}\right)}_{\equiv\omega_i}\underbrace{\left(\frac{\psi\overline{u_i'}}{\lambda}\right)}_{\equiv b_i} + \underbrace{\left(\frac{\sum_i N_i(1-E_i)}{\sum_j N_j}\right)}_{\equiv\omega_u}\underbrace{\left(\frac{\sum_i N_i(1-E_i)\psi_i u_u'}{\sum_i N_i(1-E_i)\lambda}\right)}_{\equiv b_u}. \tag{68}$$

Next, divide equation (66) by λ to find equation (17).

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

$$\eta_{ji} \equiv -\left(\frac{\partial E_j}{\partial(T_i - T_u)}\frac{(w_i - (T_i - T_u))}{E_j}\right)\frac{w_j(1-t_j)}{w_i(1-t_i)}, \tag{69}$$

$$\kappa_{ji} \equiv \left(\frac{\partial w_j}{\partial(T_i - T_u)}\frac{(w_i - (T_i - T_u))}{w_j}\right)\frac{w_j}{w_i(1-t_i)} \tag{70}$$

Then, divide equation (67) 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:

$$\sum_j \omega_j\frac{(t_j + \tau_j)}{(1-t_j)}\eta_{ji} = \omega_i(1-b_i) + \sum_j \omega_j(b_j - b_f)\kappa_{ji}. \tag{71}$$

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

D.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 $E_i = E_i(T_1 - T_u, ..., T_I - T_u, T_u)$ and $w_i = w_i(T_1 - T_u, ..., T_I - T_u, T_u)$. In this case, only the first-order condition for the optimal unemployment benefit (i.e., the counterpart of equation (65)) has to be modified:

$$T_u: -\sum_i \psi_i N_i(E_i\overline{u_i'} + (1-E_i)u_u') + \lambda\sum_i N_i$$
$$+ \sum_i N_iE_i\left[\psi_i\overline{u_i'} - \psi_f u_f'\right]\frac{\partial w_i}{\partial T_u} + \sum_i N_i\left[\lambda(T_i - T_u) + \psi_i(\hat{u}_i - u_u)\right]\frac{\partial E_i}{\partial T_u} = 0 \tag{72}$$

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

$$-\sum_i \frac{N_i E_i}{\sum_i N_i}(b_i + \frac{(1-E_i)}{E_i}\psi_i u_u'/\lambda) + 1$$
$$+\sum_i \frac{N_i E_i}{\sum_i N_i}\left[b_i - b_f\right]\frac{\partial w_i}{\partial T_u} + \sum_i \frac{N_i E_i}{\sum_i N_i}\left[(T_i - T_u) + \psi_i(\hat{u}_i/\lambda - u_u/\lambda)\right]\frac{\partial E_i}{\partial T_u}\frac{1}{E_i} = 0 \qquad (73)$$

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:

$$-\sum_i \omega_i b_i - \omega_u b_u + 1$$
$$+\sum_i \omega_i\left[b_i - b_f\right]\frac{\partial w_i}{\partial T_u} + \sum_i \omega_i\left[(T_i - T_u) + \psi_i(\hat{u}_i/\lambda - u_u/\lambda)\right]\frac{\partial E_i}{\partial T_u}\frac{1}{E_i} = 0 \qquad (74)$$

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

$$\sum_i \omega_i b_i + \omega_u b_u = 1 + \sum_i \omega_i\left[b_i - 1\right]\frac{\partial w_i}{\partial T_u} + \sum_i \omega_i\left[(T_i - T_u) + \tau_i w_i\right]\frac{\partial E_i}{\partial T_u}\frac{1}{E_i} \qquad (75)$$

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 (75). A change in the equilibrium wage in sector i indirectly redistributes income between workers in that sector (whose welfare weight is b_i) and firm-owners (whose welfare weight is one). In addition, a change in the employment rate in sector i affects 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 (75) 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 (75) can then be written as

$$\sum_i \omega_i b_i + \omega_u b_u = 1 + \sum_i \omega_i\left[b_i - 1\right]\frac{\partial w_i}{\partial T_u} + \sum_i \omega_i\left[(T_i - T_u) + \tau_i w_i\right]\frac{\partial E_i}{\partial w_i}\frac{\partial w_i}{\partial T_u}\frac{1}{E_i} \qquad (76)$$

$$\sum_i \omega_i b_i + \omega_u b_u = 1 + \sum_i \left(\omega_i\left[b_i - 1\right] + \omega_i\left[(T_i - T_u) + \tau_i w_i\right]\frac{\partial E_i}{\partial w_i}\frac{1}{E_i}\right)\frac{\partial w_i}{\partial T_u} \qquad (77)$$

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 $T_i - T_u$:

$$\omega_i(1-b_i) + \omega_i\left[(T_i - T_u) + \tau_i w_i\right]\frac{1}{E_i}\frac{\partial E_i}{\partial(T_i - T_u)} + \omega_i(b_i - 1)\frac{\partial w_i}{\partial(T_j - T_u)} = 0 \qquad (78)$$

$$\left(\omega_i\left[b_i - 1\right] + \omega_i\left[(T_i - T_u) + \tau_i w_i\right]\frac{1}{E_i}\frac{\partial E_i}{\partial w_i}\right)\frac{\partial w_i}{\partial(T_i - T_u)} = -\omega_i(1-b_i), \qquad (79)$$

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:

$$\sum_i \omega_i b_i + \omega_u b_u = 1 - \sum_i \omega_i (1-b_i) \frac{\partial w_i/\partial T_u}{\partial w_i/\partial (T_i - T_u)} \tag{80}$$

$$\sum_i \omega_i b_i + \omega_u b_u = 1 - \sum_i \omega_i (1-b_i)\iota_i, \tag{81}$$

where $\iota_i \equiv \frac{\partial w_i}{\partial T_u} / \frac{\partial w_i}{\partial (T_i - T_u)}$. Appendix B 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., $u(c) \equiv -\frac{1}{\theta}\exp[-\theta c]$.

D.3 A closed-form solution for the optimal participation tax

Assume the utility function is linear: $u(c) = c$. Moreover, normalize the weights such that $\sum_i N_i \psi_i / \sum_i N_i = \psi_f = 1$. The first-order conditions for T_u in (16) or T_f in (17) then imply $\sum_i N_i b_i / \sum_i N_i = b_f = 1$. Moreover, assume participation costs are uniformly distributed: $G_i(\varphi) = \xi_i + \sigma_i^{-1}\varphi$, with ξ_i, $\sigma_i > 0$.[42] Finally, suppose the production function is quadratic:

$$F(K, N_1E_1, \cdots, N_IE_I) = f(K) + \sum_i \alpha_i N_i E_i \left(\beta_i - \frac{1}{2}N_iE_i\right), \quad f'(\cdot), \alpha_i, \beta_i > 0, \tag{82}$$

Labor markets are thus independent, since $F_{ij}(\cdot) = 0$ for all $i \neq j$. The elasticity of labor demand is not constant and can be written as

$$\varepsilon_i = -\frac{F_i}{F_{ii}L_i} = \frac{\alpha_i(\beta_i - E_iN_i)}{\alpha_i E_i N_i} = \frac{\beta_i}{E_iN_i} - 1. \tag{83}$$

Equilibrium wages are given by:

$$w_i = F_i(\cdot) = \alpha_i(\beta_i - N_iE_i). \tag{84}$$

Use $E_iN_i = \beta_i - w_i/\alpha_i$ to write the labor-demand elasticity in terms of w_i:

$$\varepsilon_i = \frac{\beta_i}{\beta_i - w_i/\alpha_i} - 1 = \frac{w_i}{\alpha_i\beta_i - w_i}. \tag{85}$$

The wage mark-up equation can then be written as:

$$\rho_i = \varepsilon_i \frac{w_i - (T_i - T_u) - \hat{\varphi}_i}{w_i}. \tag{86}$$

Subsituting the elasticity ε_i from (85) and rewriting yields:

$$\hat{\varphi}_i = (1+\rho_i)w_i - (T_i - T_u) - \rho_i\alpha_i\beta_i, \tag{87}$$

$$\hat{\varphi}_i = (1+\rho_i)\alpha_i(\beta_i - N_iE_i) - (T_i - T_u) - \rho_i\alpha_i\beta_i. \tag{88}$$

[42] Here, we allow the distribution of participation costs to vary across sectors.

From the relationship $E_i = G_i(\hat{\varphi}_i)$ and the distribution of participation costs follows that:

$$\sigma_i(E_i - \xi_i) = \hat{\varphi}_i. \tag{89}$$

Solving for employment E_i, the cut-off $\hat{\varphi}_i$, and wages w_i from equations (84), (88) and (89) then yields:

$$\sigma_i(E_i - \xi_i) = (1+\rho_i)\alpha_i(\beta_i - N_i E_i) - (T_i - T_u) - \rho_i\alpha_i\beta_i, \tag{90}$$

$$E_i = \frac{\sigma_i\xi_i + \alpha_i\beta_i - (T_i - T_u)}{\sigma_i + (1+\rho_i)\alpha_i N_i}, \tag{91}$$

$$\hat{\varphi}_i = \sigma_i E_i - \sigma_i\xi_i = \sigma_i\left(\frac{\sigma_i\xi_i + (1+\rho_i)\alpha_i\beta_i - (T_i - T_u)}{\sigma_i + (1+\rho_i)\alpha_i N_i}\right) - \sigma_i\xi_i, \tag{92}$$

$$w_i = \alpha_i\beta_i - \alpha_i N_i\left(\frac{\sigma_i\xi_i + \alpha_i\beta_i - (T_i - T_u)}{\sigma_i + (1+\rho_i)\alpha_i N_i}\right). \tag{93}$$

For later reference, we can derive the following results:

$$\frac{\partial w_i}{\partial(T_i - T_u)} - 1 = \frac{\alpha_i N_i}{\sigma_i + (1+\rho_i)\alpha_i N_i} - 1 = -\frac{\sigma_i + \rho_i\alpha_i N_i}{\sigma_i + (1+\rho_i)\alpha_i N_i}, \tag{94}$$

$$-\frac{\partial E_i}{\partial(T_i - T_u)} = \frac{1}{\sigma_i + (1+\rho_i)\alpha_i N_i}, \tag{95}$$

$$\sigma_i + (1+\rho_i)\alpha_i N_i = \frac{\sigma_i\xi_i + \alpha_i\beta_i - (T_i - T_u)}{E_i}, \tag{96}$$

$$\frac{\psi_i(\hat{u}_i - u_u)}{\lambda} = \frac{\rho_i b_i w_i}{\varepsilon_i} = \rho_i b_i\alpha_i N_i E_i = \rho_i b_i\alpha_i\beta_i - \rho_i b_i\alpha_i(\beta_i - N_i E_i). \tag{97}$$

Next, take the optimal participation tax from equation (18) and substitute the optimal profit tax from (17) to derive:

$$\omega_i(T_i - T_u + \psi_i(\hat{u}_i - u_u)/\lambda)\frac{-\partial E_i}{\partial(T_i - T_u)}\frac{1}{E_i} = \omega_i(1 - b_i)\left(1 - \frac{\partial w_j}{\partial(T_i - T_u)}\right). \tag{98}$$

Substitute the partial derivatives from equations (95) and (94), equation (96), and the union wedge from equation (97) in equation (98) and simplify:

$$(T_i - T_u) - \rho_i b_i\alpha_i(\beta_i - N_i E_i) - E_i(1 - b_i)(\sigma_i + \rho_i\alpha_i N_i) + \rho_i b_i\alpha_i\beta_i = 0. \tag{99}$$

Rewrite the labor-market clearing condition in equation (90) to derive:

$$(T_i - T_u) - (1+\rho_i)\alpha_i(\beta_i - N_i E_i) + \sigma_i(E_i - \xi_i) + \rho_i\alpha_i\beta_i = 0. \tag{100}$$

Finally, solve equations (99) and (100) for $(T_i - T_u)$. First, solve for $(\beta_i - N_i E_i)$ from equations (99):

$$(\beta_i - N_i E_i) = \frac{(T_i - T_u)}{\rho_i b_i\alpha_i} - \frac{E_i(1 - b_i)}{\rho_i b_i\alpha_i}(\sigma_i + \rho_i\alpha_i N_i) + \beta_i. \tag{101}$$

Substitute (101) in equation (100) and rewrite:

$$-\left(\frac{1+\rho_i(1-b_i)}{\rho_i b_i}\right)(T_i - T_u) + \left(\sigma_i + (1+\rho_i)\frac{(1-b_i)}{\rho_i b_i}(\sigma_i + \rho_i\alpha_i N_i)\right)E_i = \alpha_i\beta_i + \sigma_i\xi_i. \quad (102)$$

Substitute for E_i from equation (91) and solve for $T_i - T_u$:

$$T_i - T_u = -\frac{(\alpha_i\beta_i + \sigma_i\xi_i)((1+\rho_i)\alpha_i N_i\rho_i b_i - (1+\rho_i)(1-b_i)(\sigma_i + \rho_i\alpha_i N_i))}{(1+\rho_i(1-b_i))(\sigma_i + (1+\rho_i)\alpha_i N_i) + \rho_i b_i\sigma_i + (1+\rho_i)(1-b_i)(\sigma_i + \rho_i\alpha_i N_i)}. \quad (103)$$

Expand the numerator of equation (103) to find:

$$(1+\rho_i)\alpha_i N_i\rho_i b_i - (1+\rho_i)(1-b_i)(\sigma_i + \rho_i\alpha_i N_i) = \alpha_i N_i\rho_i(2b_i - 1) + (b_i - 1)\sigma_i. \quad (104)$$

Expand the denominator of equation (103) to find:

$$\begin{aligned} & (1+\rho_i(1-b_i))\alpha_i N_i + (1+\rho_i(1-b_i) + (1+\rho_i)(1-b_i))(\sigma_i + \rho_i\alpha_i N_i) + \rho_i b_i\sigma_i \quad (105) \\ = \; & (1+\rho_i)(\alpha_i N_i(1 + 2(1-b_i)\rho_i) + (2-b_i)\sigma_i). \end{aligned}$$

Substituting equations (104) and (105) into equation (103), and using $b_i = \psi_i$ gives:

$$T_i - T_u = \frac{(\alpha_i\beta_i + \sigma_i\xi_i)(\alpha_i N_i\rho_i(2\psi_i - 1) + \sigma_i(\psi_i - 1))}{\alpha_i N_i(2(\psi_i - 1)\rho_i - 1) + \sigma_i(\psi_i - 2)}. \quad (106)$$

The comparative statics of the optimal participation tax with respect to union power follow from taking the derivative of $T_i - T_u$ with respect to ρ_i:

$$\begin{aligned} \frac{\partial(T_i - T_u)}{\partial\rho_i} = & \frac{1}{(\alpha_i N_i(2(\psi_i - 1)\rho_i - 1) + \sigma_i(\psi_i - 2))^2}\times \\ & \Big[(\alpha_i N_i(2(\psi_i - 1)\rho_i - 1) + \sigma_i(\psi_i - 2))(\alpha_i\beta_i + \sigma_i\xi_i)\alpha_i N_i(2\psi_i - 1) \\ & - (\alpha_i\beta_i + \sigma_i\xi_i)(\alpha_i N_i\rho_i(2\psi_i - 1) + \sigma_i(\psi_i - 1))\alpha_i N_i 2(\psi_i - 1)\Big]. \quad (107) \end{aligned}$$

The derivative is negative if and only if the term in brackets is negative. After canceling terms, this is the case if and only if:

$$\begin{aligned} & \alpha_i N_i 2(\psi_i - 1)(\alpha_i\beta_i + \sigma_i\xi_i)\sigma_i(\psi_i - 1) \quad (108) \\ > \; & (\alpha_i\beta_i + \sigma_i\xi_i)\alpha_i N_i(2\psi_i - 1)\left(-\alpha_i N_i + \sigma_i(\psi_i - 2)\right). \end{aligned}$$

Divide by $(\alpha_i\beta_i + \sigma_i\xi_i)\alpha_i N_i\sigma_i$ and rewrite:

$$\psi_i + (2\psi_i - 1)\alpha_i N_i/\sigma_i > 0. \quad (109)$$

Hence, we find that

$$\frac{\partial(T_i - T_u)}{\partial\rho_i} < 0 \quad \Leftrightarrow \quad \psi_i > \frac{1}{2 + \sigma_i/(\alpha_i N_i)}. \quad (110)$$

D.4 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 $G(F_i(\cdot) - (T_i - T_u)) = E_i$ 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:

$$\begin{aligned}\mathcal{L} = &\sum_i \psi_i N_i \bigg(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(F_i(\cdot) - (T_i - T_u) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \bigg) \\ &+ \psi_f u(F(\cdot) - \sum_i F_i(\cdot) N_i E_i - T_f) + \lambda \left(\sum_i N_i (T_u + E_i(T_i - T_u)) + T_f - R \right) \\ &\sum_i \mu_i \Big[G(F_i(\cdot) - (T_i - T_u)) - E_i \Big]. \end{aligned} \tag{111}$$

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

$$T_i - T_u : \quad N_i E_i(\lambda - \psi_i \overline{u_i'}) - \mu_i G_i' = 0, \tag{112}$$

$$E_i : \quad \lambda N_i (T_i - T_u) - \mu_i + N_i \sum_j F_{ji} \Big[N_j E_j (\psi_j \overline{u_j'} - \psi_f u_f') + \mu_j G_j' \Big] = 0. \tag{113}$$

If the profit tax is optimally set, $\psi_f u_f' = \lambda$, and hence, $b_f = 1$. The first-order condition (112) then implies that the term in brackets in equation (113) that is summed over j equals zero. Next, use equation (112) to substitute for μ_i in equation (113), divide the equation by λN_i, and use the property $E_i = G(\cdot)$. Rearranging gives the result stated in the main text:

$$\frac{t_i}{1 - t_i} = \frac{1 - b_i}{\pi_i}, \quad \pi_i \equiv \frac{g(\varphi_i^*)\varphi_i^*}{G(\varphi_i^*)}, \tag{114}$$

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

E Desirability of unions

E.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:

$$\max_{T_u, T_f, \{T_i - T_u, w_i, E_i\}_{i=1}^I} \mathcal{W} = \sum_i \psi_i N_i \bigg(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i - (T_i - T_u) - T_u - \varphi)\mathrm{d}G(\varphi)$$

$$
\begin{aligned}
&+\int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi)\Bigg) + \psi_f u(F(\cdot) - \sum_i w_i N_i E_i - T_f), \\
\text{s.t.} \qquad &\sum_i N_i(T_u + E_i(T_i - T_u)) + T_f = R, \\
&w_i = F_i(\cdot), \quad \forall i, \\
&\rho_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(w_i - (T_i - T_u) - T_u - \varphi)\mathrm{d}G(\varphi) F_{ii}(\cdot) N_i \\
&+ u(w_i - (T_i - T_u) - T_u - G^{-1}(E_i)) - u(-T_u) = 0, \quad \forall i. \qquad (115)
\end{aligned}
$$

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

$$
\begin{aligned}
\mathcal{L} =& \sum_i \psi_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(F_i(\cdot) - (T_i - T_u) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \right) \\
&+ \psi_f u(F(\cdot) - \sum_i F_i(\cdot) N_i E_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_i(T_i - T_u)) + T_f - R \right) \\
&+ \sum_i \mu_i \Bigg(\rho_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(F_i(\cdot) - (T_i - T_u) - T_u - \varphi)\mathrm{d}G(\varphi) F_{ii}(\cdot) N_i \\
&+ u(F_i(\cdot) - (T_i - T_u) - T_u - G^{-1}(E_i)) - u(-T_u) \Bigg). \qquad (116)
\end{aligned}
$$

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:

$$
T_i - T_u: \ -N_i E_i(\psi_i \overline{u_i'} - \lambda) - \mu_i \left(\rho_i \overline{u_i''} F_{ii} N_i E_i + \hat{u}_i' \right) = 0, \qquad (117)
$$

$$
\begin{aligned}
T_u: \ &-\sum_i N_i E_i \psi_i \overline{u_i'} - \sum_i N_i(1 - E_i)\psi_i u_u' + \lambda \sum_i N_i \\
&- \sum_i \mu_i \left(\rho_i \overline{u_i''} F_{ii} N_i E_i + \hat{u}_i' - u_u' \right) = 0, \qquad (118)
\end{aligned}
$$

$$
T_f: \ -\psi_f u_f' + \lambda = 0 \qquad (119)
$$

$$
\begin{aligned}
E_i: \ &N_i \psi_i(\hat{u}_i - u_u) + \lambda N_i(T_i - T_u) + N_i \sum_j N_j E_j(\psi_j \overline{u_j'} - \psi_f u_f')F_{ji} + \mu_i \left(\rho_i \hat{u}_i' F_{ii} N_i - \hat{u}_i'/G_i' \right) \\
&+ N_i \sum_j \mu_j \left[\left(\rho_j E_j \overline{u_j''} F_{jj} N_j + \hat{u}_j' \right) F_{ji} + \rho_j E_j \overline{u_j'} N_j F_{jji} \right] = 0, \qquad (120)
\end{aligned}
$$

$$
\lambda: \ \sum_i N_i(T_u + E_i(T_i - T_u)) + T_f - R = 0 \qquad (121)
$$

$$
\mu_i: \ \rho_i E_i \overline{u_i'} F_{ii} + (\hat{u}_i - u_u) = 0 \qquad (122)
$$

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, unless one imposes strong functional-form assumptions as in

Appendix D.3. 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 (116) with respect to ρ_i, and apply the envelope theorem:

$$\frac{\partial \mathcal{W}}{\partial \rho_i} = \frac{\partial \mathcal{L}}{\partial \rho_i} = \mu_i E_i \overline{u_i'} F_{ii} N_i. \tag{123}$$

Since $E_i \overline{u_i'} F_{ii} N_i < 0$ (provided that labor demand is not perfectly elastic), the expression in equation (123) is positive if and only if $\mu_i < 0$. To determine the sign of μ_i, rearrange the first-order condition (117) with respect to the participation tax $T_i - T_u$:

$$\lambda N_i E_i \left(1 - \frac{\psi_i \overline{u_i'}}{\lambda}\right) = \mu_i \left(\rho_i \overline{u_i''} F_{ii} N_i E_i + \hat{u}_i'\right). \tag{124}$$

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

$$\mu_i < 0 \quad \Leftrightarrow \quad b_i > 1. \tag{125}$$

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.

E.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 (116) augmented with the additional inequality constraints) is given by

$$\mu_i E_i \psi_i \overline{u_i'} F_{ii} N_i + \underline{\chi}_i - \overline{\chi}_i = 0. \tag{126}$$

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 (126) and (124) 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 (126) 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 $b_i = 1$.

E.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:

$$
\begin{aligned}
E_i &= E_i(\rho_1, ..., \rho_I, T_1, ..., T_I, T_u), &(127)\\
w_i &= w_i(\rho_1, ..., \rho_I, T_1, ..., T_I, T_u). &(128)
\end{aligned}
$$

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

$$
\mathrm{d}w_j^i = \frac{\partial w_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial w_j}{\partial T_k^i}\mathrm{d}T_k^i \tag{129}
$$

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 (29):

$$
\frac{\partial w_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial w_j}{\partial T_k^i}\mathrm{d}T_k^i - \mathrm{d}T_j^i = 0. \tag{130}
$$

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:

$$
\mathrm{d}E_j^i = \frac{\partial E_j}{\partial \rho_i}\mathrm{d}\rho_i + \sum_k \frac{\partial E_j}{\partial T_k^i}\mathrm{d}T_k^i. \tag{131}
$$

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

$$
\begin{aligned}
\mathcal{L} = &\sum_i \psi_i N_i \Big(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i - T_i - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \Big) &(132)\\
&+ \psi_f u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_i(T_i - T_u)) + T_f - R \right),
\end{aligned}
$$

where equilibrium employment rates and wages are given by equations (127)–(128). 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:

$$
\begin{aligned}
\mathrm{d}\mathcal{W} = &\sum_j \psi_j N_j \int_{\underline{\varphi}}^{G^{-1}(E_j)} u_j' \mathrm{d}G(\varphi)(\mathrm{d}w_j^i - \mathrm{d}T_j^i) &(133)\\
&- \psi_f u_f' \sum_j N_j E_j \mathrm{d}w_j^i + \lambda \sum_j N_j E_j \mathrm{d}T_j^i + \sum_j \psi_j N_j \left(\hat{u}_j - u_u\right) g(\hat{\varphi}_j) \frac{\partial G^{-1}(E_j)}{\partial E_j}\mathrm{d}E_j^i
\end{aligned}
$$

$$+\psi_f u_f' \sum_j (F_j - w_j) N_j \mathrm{d}E_j^i + \lambda \sum_j N_j (T_j - T_u) \mathrm{d}E_j^i.$$

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 $E_j = G(\hat{\varphi}_j)$ follows that $g(\hat{\varphi}_j)\frac{\partial G^{-1}(E_j)}{\partial E_j} = 1$. Divide the expression by λ and substitute the 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:

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = \sum_j N_j \left(T_j - T_u + \frac{\psi_j \left(\hat{u}_j - u_u\right)}{\lambda} \right) \mathrm{d}E_j^i, \tag{134}$$

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 welfare if

$$\sum_j N_j (t_j + \tau_j) w_j \mathrm{d}E_j^i > 0. \tag{135}$$

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 welfare if and only if inequality (135) 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:

$$\rho_j \int_{\underline{\varphi}}^{G^{-1}(E_j)} u'(F_j(\cdot) - T_j - \varphi) \mathrm{d}G(\varphi) F_{jj}(\cdot) N_j + \big(u(F_j(\cdot) - T_j - G^{-1}(E_j)) - u(-T_u)\big) = 0. \tag{136}$$

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 (136), 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.

F Simulations

F.1 Derivation labor-demand elasticity

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

$$Y = \left(\sum_i a_i L_i^{1/\delta}\right)^{\alpha\delta}, \quad \delta \equiv \frac{\sigma}{\sigma - 1}. \tag{137}$$

The derivatives are given by:

$$w_i = F_i = \alpha \left(\sum_j a_j L_j^{1/\delta}\right)^{\alpha\delta - 1} a_i L_i^{1/\delta - 1}, \tag{138}$$

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

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

$$\phi_i \equiv \frac{w_i L_i}{\sum_j w_j L_j} = \frac{a_i L_i^{1/\delta}}{\sum_j a_j L_j^{1/\delta}}. \tag{139}$$

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

$$\begin{aligned}\varepsilon_i \equiv -\frac{F_i}{F_{ii} L_i} &= -\frac{\alpha \left(\sum_j a_j L_j^{1/\delta}\right)^{\alpha\delta - 1} a_i L_i^{1/\delta - 1}}{\alpha \left(\sum_j a_j L_j^{1/\delta}\right)^{\alpha\delta - 1} a_i L_i^{1/\delta - 1} \left[(1/\delta - 1) + \phi_i(\alpha - 1/\delta)\right]} \\ &= \frac{\sigma}{1 + \phi_i(\sigma(1-\alpha) - 1)}.\end{aligned} \tag{140}$$

F.2 Numerically calculating optimal taxes

The optimal tax problem is given by

$$\begin{aligned}\max_{T_u, \{T_i, E_i\}_{i=1}^I} \mathcal{W} &= \sum_i N_i \left[\int_0^{G^{-1}(E_i)} u(F_i(\cdot) - T_i - \varphi) g(\varphi) \mathrm{d}\varphi + (1 - E_i) u(-T_u)\right] \\ \text{s.t.} \ &\sum_i N_i(E_i T_i + (1 - E_i) T_u) + F(\cdot) - \sum_i F_i(\cdot) N_i E_i = R, \\ &\rho F_{ii}(\cdot) N_i \int_0^{G^{-1}(E_i)} u'(F_i(\cdot) - T_i - \varphi) g(\varphi) \mathrm{d}\varphi + u(F_i(\cdot) - T_i - G^{-1}(E_i)) - u(-T_u) = 0, \ \forall i,\end{aligned} \tag{141}$$

where we substituted the labor-demand equations $w_i = F_i(\cdot)$, imposed $\underline{\varphi} = 0$, $\rho_i = \rho$ 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.[43]

F.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:

$$T_i - T_u = -\frac{1}{\theta}\ln\left[\frac{\theta\rho w_i}{\varepsilon_i E_i}\int_0^{G^{-1}(E_i)} \exp(-\theta(w_i-\varphi)g(\varphi)\mathrm{d}\varphi + \exp(-\theta(w_i - G^{-1}(E_i)))\right]. \quad (142)$$

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:

$$T_u = \frac{1}{\sum_i N_i}\left[R + \sum_i F_i(\cdot)N_iE_i - F(\cdot) - \sum N_iE_i(T_i - T_u)\right]. \quad (143)$$

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 (141), 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.

F.2.2 Solving first-order conditions

Another approach is to solve for the first-order conditions associated with maximization problem (141). 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, 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 again 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.

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

F.3 Additional graphs

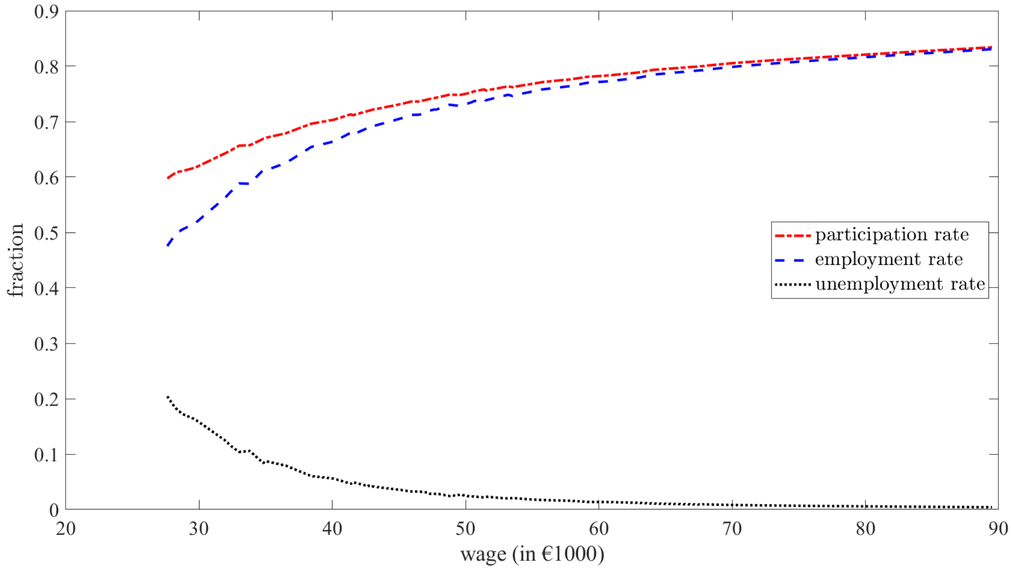


Figure 5: Participation, employment and unemployment rates by income

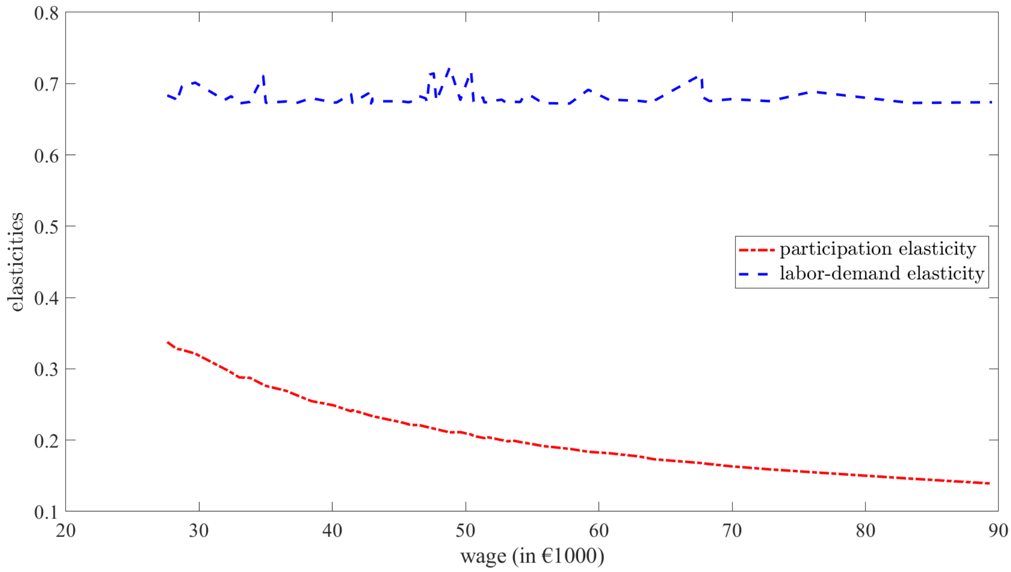


Figure 6: Participation elasticity and labor-demand elasticity by income

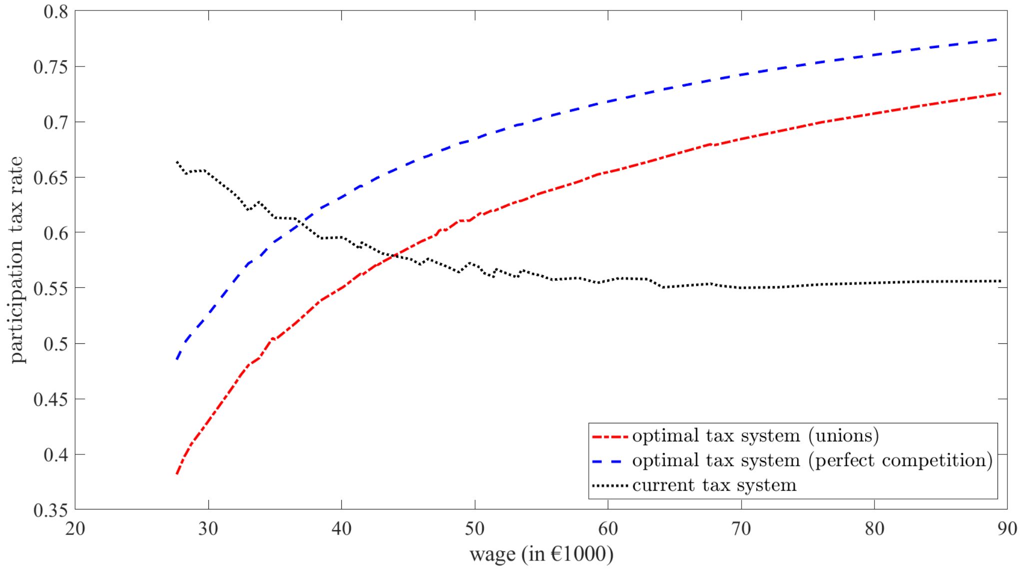


Figure 7: Optimal participation tax rates (high labor-demand elasticity)

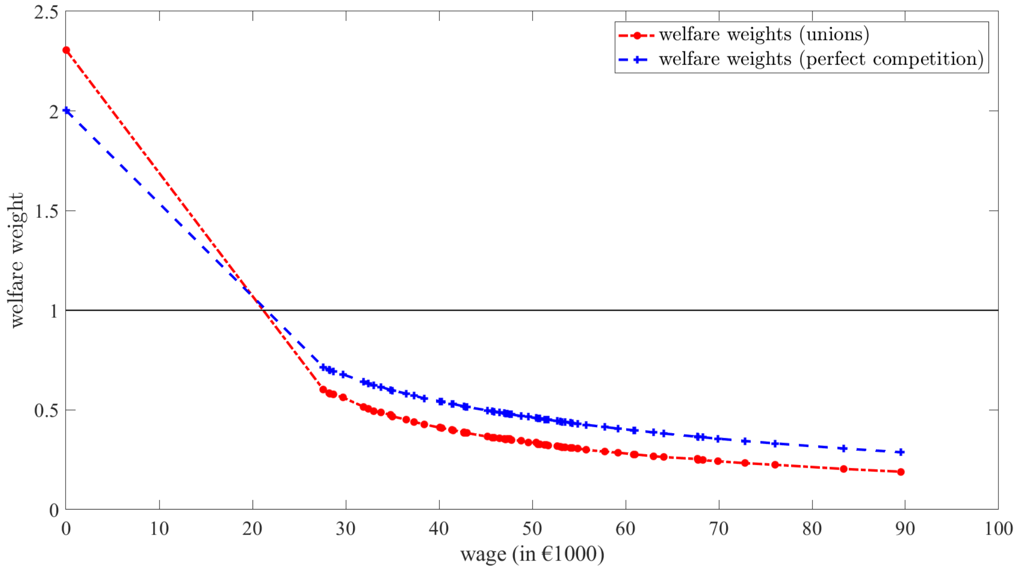


Figure 8: Social welfare weights (high labor-demand elasticity)

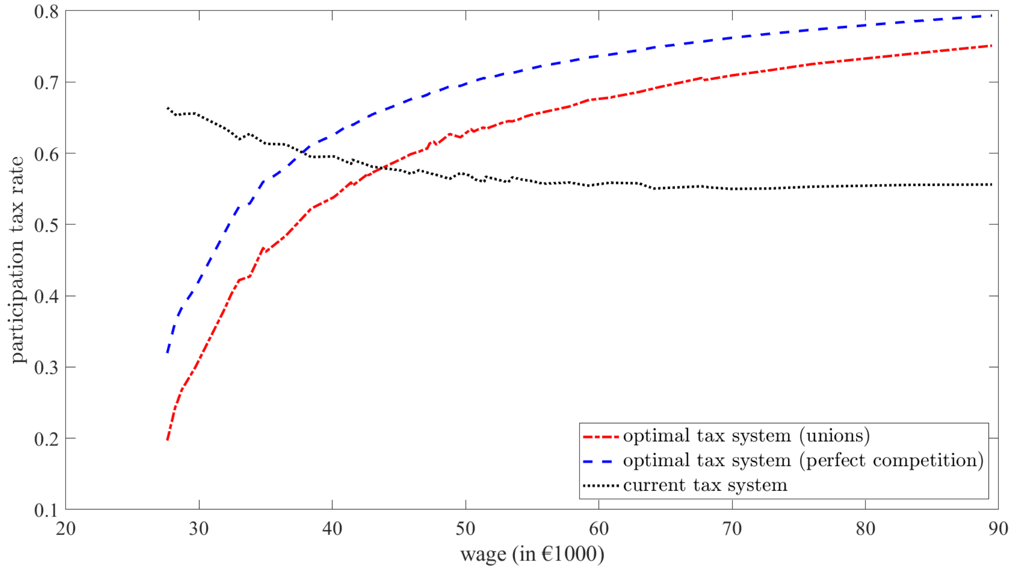


Figure 9: Optimal participation tax rates (low labor-demand elasticity)

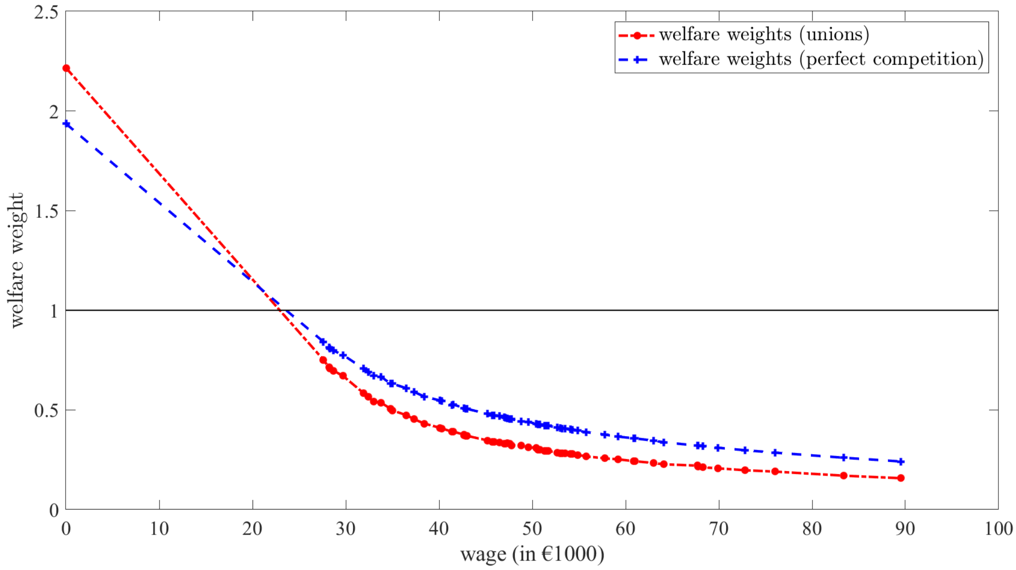


Figure 10: Social welfare weights (low labor-demand elasticity)

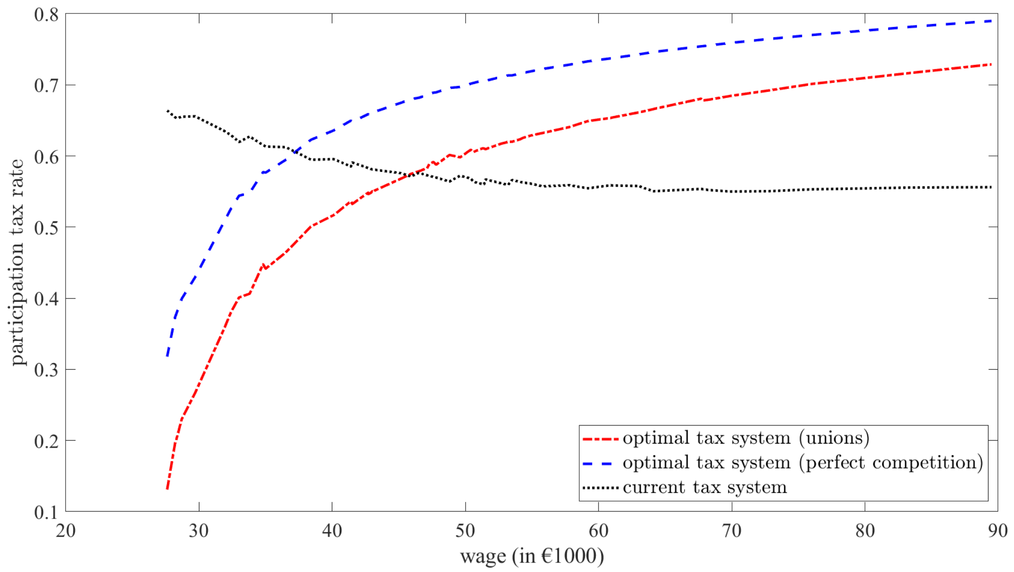


Figure 11: Optimal participation tax rates (strong unions)

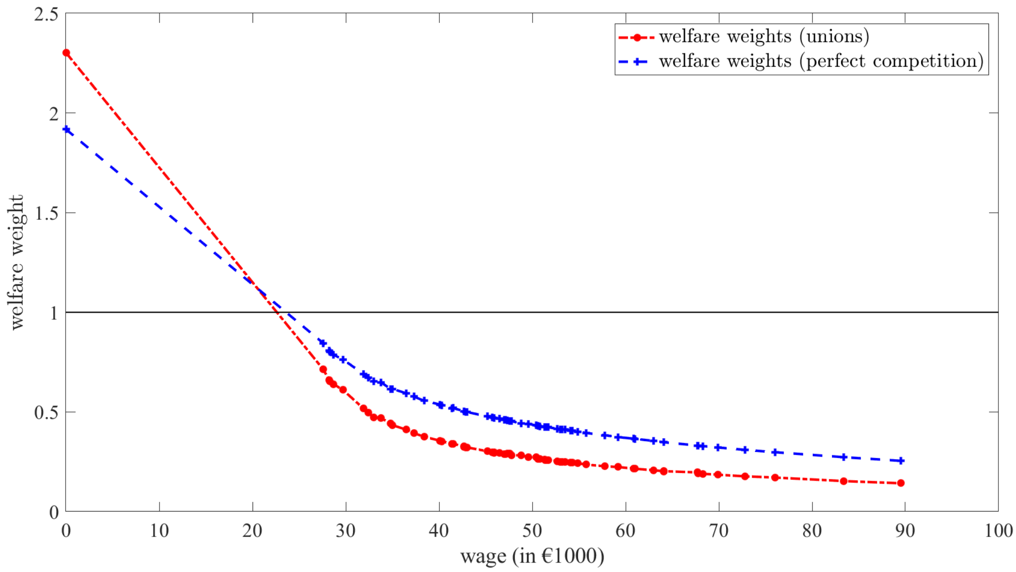


Figure 12: Social welfare weights (strong unions)

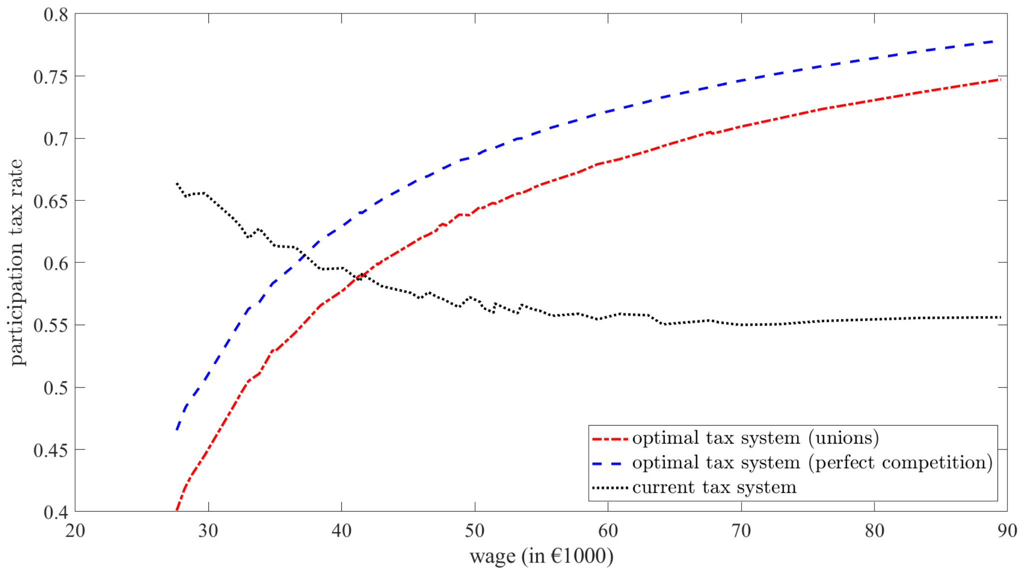


Figure 13: Optimal participation tax rates (weak unions)

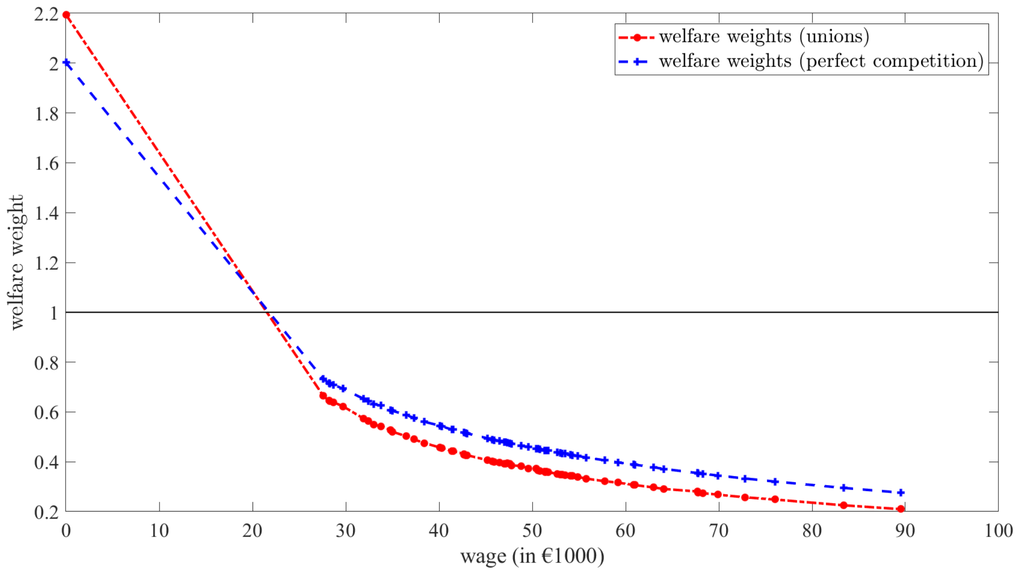


Figure 14: Social welfare weights (weak unions)

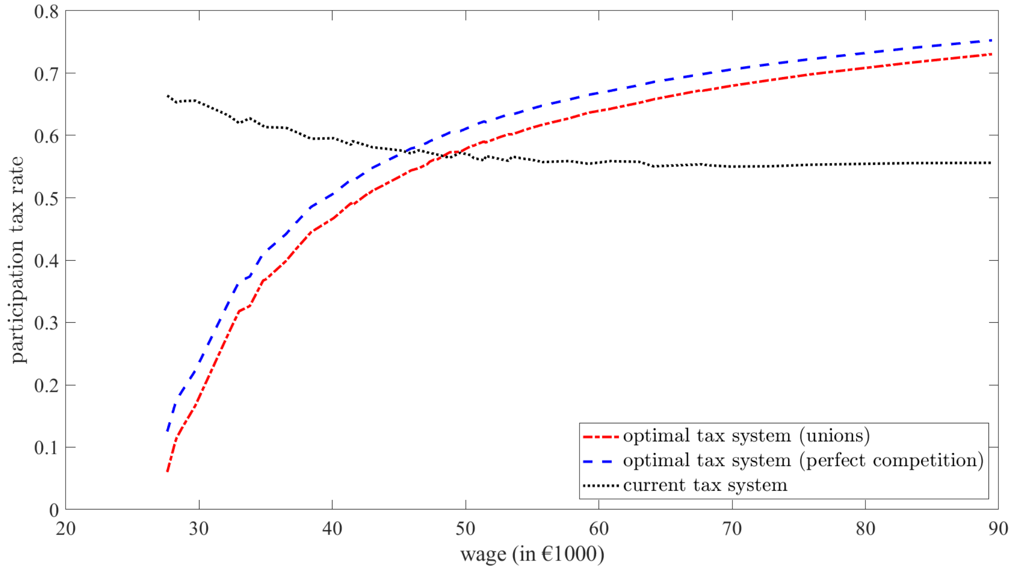


Figure 15: Optimal participation tax rates (high participation elasticity)

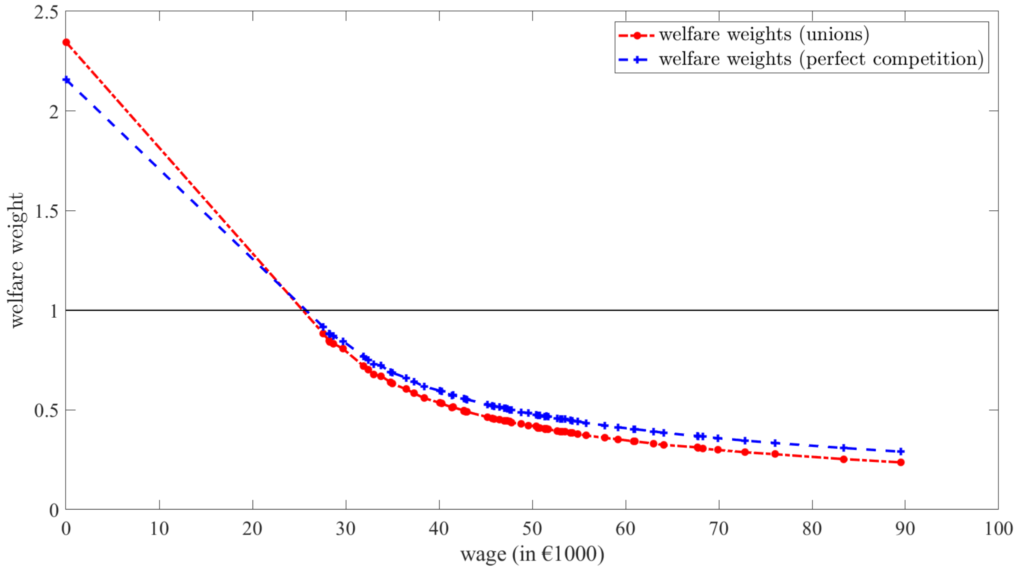


Figure 16: Social welfare weights (high participation elasticity)

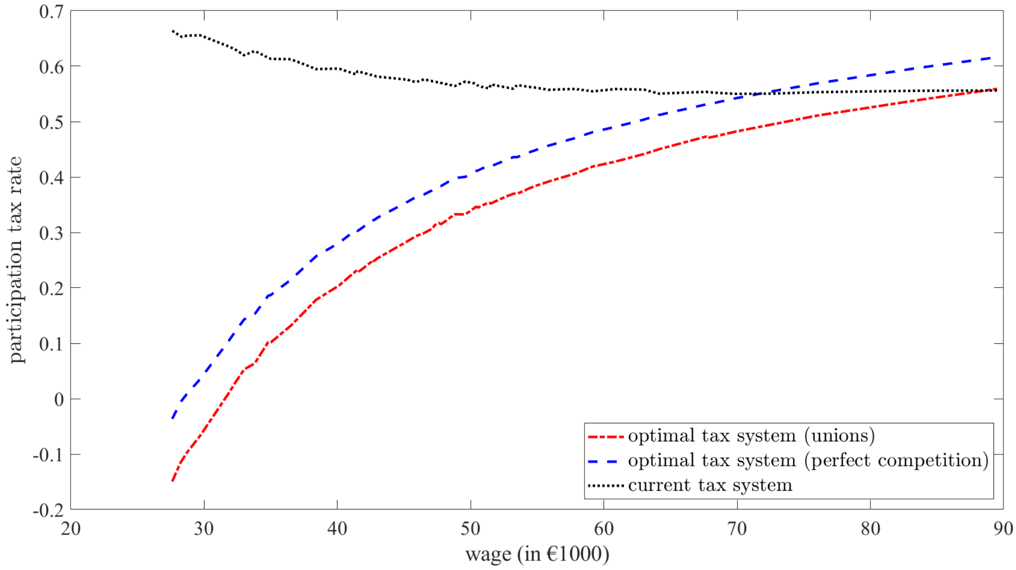


Figure 17: Optimal participation tax rates (low inequality aversion)

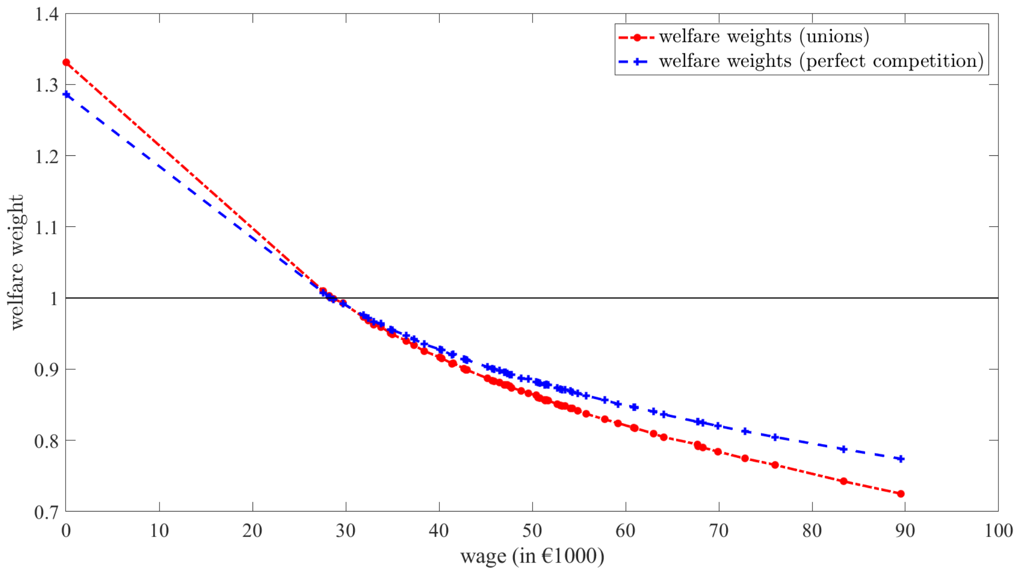


Figure 18: Social welfare weights (low inequality aversion)

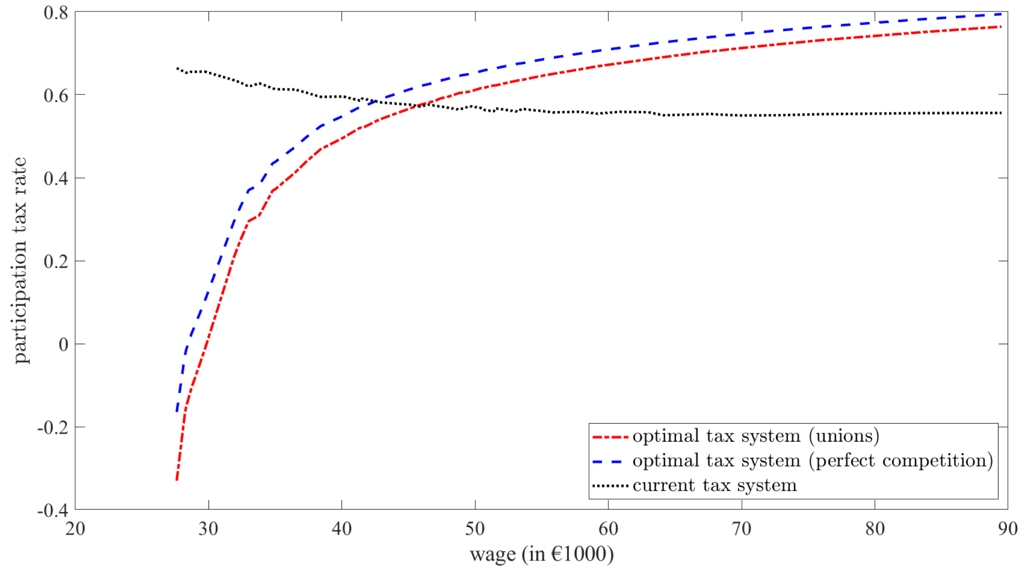


Figure 19: Optimal participation tax rates (high participation rate)

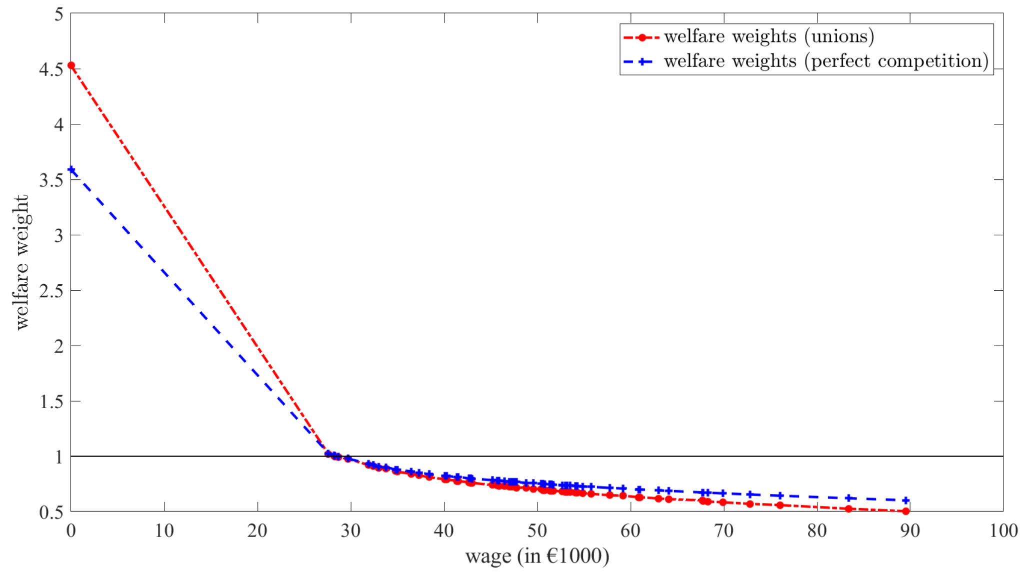


Figure 20: Social welfare weights (high participation rate)

Online Appendix: Optimal Income Taxation in Unionized Labor Markets

Albert Jan Hummel* Bas Jacobs†

May 14, 2021

In this Appendix, we investigate the robustness of our results by relaxing the assumption of efficient rationing (Assumption 2 in the main text). Moreover, we study endogenous occupational choice, or the 'intensive margin' as in Saez (2002). In addition, we analyze two alternative bargaining structures: one in which a single, national union bargains with firm-owners over the entire *distribution* of wages, and one in which sectoral unions bargain with firms over wages *and* employment as in the efficient bargaining model of McDonald and Solow (1981).

1 Inefficient rationing

We have deliberately biased our findings in favor of unions by assuming that unemployment 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 Section, we analyze how the optimal tax formulas should be modified, and under which conditions unions are desirable, if the assumption of efficient rationing is relaxed. For analytical convenience, we assume that labor markets are independent and there are no income effects at the union level.

We follow Gerritsen (2017) and Gerritsen and Jacobs (2020) by defining the rationing schedule as a continuously differentiable function

$$e_i(E_i, \varphi_i^*, \varphi), \quad e_{iE_i}(\cdot), -e_{i\varphi_i^*}(\cdot) > 0, \tag{1}$$

which specifies the probability $e_i \in [0,1]$ that workers with participation costs $\varphi \in [\underline{\varphi}, \varphi_i^*]$, find employment in sector i for a given sectoral employment rate E_i and a given participation threshold φ_i^*. The probability $e_i(\cdot)$ 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.[1] For all values of employment E_i and

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[1] An example of a rationing schedule that satisfies these criteria is a uniform rationing scheme. All participating workers then face the same probability of finding a job, i.e., $e_i(E_i, \varphi_i^*, \varphi) = E_i/G(\varphi_i^*)$ for all values of $\varphi \in [\underline{\varphi}, \varphi_i^*]$.

the participation cut-off φ_i^*, the following relationship must hold:

$$\int_{\underline{\varphi}}^{\varphi_i^*} e_i(E_i, \varphi_i^*, \varphi)\mathrm{d}G(\varphi) = E_i. \tag{2}$$

Hence, integrating over all employment probabilities of the workers in sector i (who differ in terms of their participation costs) yields sectoral employment.

Under independent labor markets and no income effects, we can describe the equilibrium using reduced-form equations $w_i = w_i(\rho_i, T_i - T_u)$ and $E_i(\rho_i, T_i - T_u)$, which pin down the equilibrium wage and employment rate in sector i as a function of union power ρ_i and the participation tax $T_i - T_u$. The following Proposition characterizes the optimal tax formulas if labor rationing is inefficient.

Proposition 1. *If Assumptions 1 (independent labor markets), 3 (no income effects at the union level) are satisfied, and labor rationing is described by the rationing schedule (1), then optimal unemployment benefits $-T_u$, optimal profit taxes T_f, and optimal participation taxes $T_i - T_u$ are determined by:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{3}$$

$$b_f = 1, \tag{4}$$

$$\left(\frac{t_i + \hat{\tau}_i}{1 - t_i}\right)\eta_{ii} - \left(\frac{\varrho_i}{1 - t_i}\right)\gamma_i = (1 - b_i) + (b_i - b_f)\kappa_{ii}, \tag{5}$$

where the union wedge is redefined as

$$\hat{\tau}_i \equiv \psi_i \int_{\underline{\varphi}}^{\varphi_i^*} e_{iE_i}(E_i, \varphi_i^*, \varphi)\left(\frac{u(w_i - T_i - \varphi) - u(-T_u)}{\lambda w_i}\right)\mathrm{d}G(\varphi), \tag{6}$$

and ϱ_i denotes the rationing wedge, which is defined as

$$\varrho_i \equiv \frac{\psi_i e_i(E_i, \varphi_i^*, \varphi_i^*)}{E_i/G(\varphi_i^*)} \int_{\underline{\varphi}}^{\varphi_i^*} \frac{e_{i\varphi_i^*}(E_i, \varphi_i^*, \varphi)}{\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i, \varphi_i^*, \varphi)\mathrm{d}G(\varphi)}\left(\frac{u(w_i - T_i - \varphi) - u(-T_u)}{\lambda w_i}\right)\mathrm{d}G(\varphi) \tag{7}$$

and $\gamma_i \equiv -\frac{\partial G(\varphi_i^*)}{\partial(T_i - T_u)}\frac{\varphi_i^*}{G(\varphi_i^*)}$ captures the participation response.

Proof. See Appendix A.1. $\square$

The expressions for the optimal unemployment benefit and profit tax are identical to those stated in Proposition 1 in the main text and their explanation is not repeated here. The expression for the optimal participation tax in equation (5) equates the marginal distortionary costs of a higher participation tax (left-hand side) to the marginal distributional gains of a higher participation tax (right-hand side). The expression for the optimal participation tax is modified in two ways compared to the one with efficient rationing. First, with a general rationing scheme, the union wedge $\hat{\tau}_i$ 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 $\hat{\tau}_i$, there is a distortion associated with the inefficiency of the rationing scheme, which is captured by the rationing wedge ϱ_i.

To understand the rationing wedge ϱ_i, consider a decrease in the participation tax $T_i - T_u$. Moreover, suppose the reduction in the participation tax is combined with an increase in union power ρ_i so that the equilibrium wage (and hence, the equilibrium employment rate) remains unaffected. More people want to participate if the participation tax is lowered. A fraction $e_i(E_i, \varphi_i^*, \varphi_i^*)$ of the workers who are at the participation margin (i.e., those who are indifferent between employment and unemployment) will succeed in finding a job. However, if employment remains constant, other workers become unemployed. Since these workers are not indifferent between work and unemployment, a welfare loss occurs. The latter is captured by the term ϱ_i, which measures the marginal welfare costs associated with an inefficient allocation of jobs over those who are willing to work. These costs are weighted by the participation response γ_i.

According to equation (5), the higher is ϱ_i, i.e., the more inefficient is the rationing scheme, the *higher* should be the optimal participation tax. The intuition is similar to Gerritsen (2017): by setting a higher participation tax, the workers who care least about finding a job opt out of the labor market. This, in turn, increases the employment prospects of the workers who experience a larger surplus from finding a job. Consequently, the government replaces involuntary unemployment by voluntary unemployment, which reduces the inefficiency of labor-market rationing.

The next Corollary gives the condition under which an increase in union power raises social welfare if rationing is no longer efficient.

Corollary 1. *If labor rationing is described by the rationing schedule (1), and taxes and transfers are set according to Proposition 1, then an increase in union power ρ_i in sector i raises social welfare if and only if*

$$b_i > 1 + \left(\frac{\varrho_i}{1-t_i}\right)\gamma_i. \tag{8}$$

Proof. See Appendix A.2. □

To understand whether it is optimal to increase union power, consider again a policy reform starting from a situation where taxes are optimally set. We marginally raise union power ρ_i in sector i, while simultaneously reducing the participation tax $T_i - T_u$ in sector i such that the wage w_i, and hence employment E_i, is kept constant. The reduction in the participation tax is financed by an increase in the profit tax T_f to ensure that the government budget remains balanced. If the tax system is optimized, the tax reform has no impact on social welfare. Therefore, any impact on social welfare must come from the increase in union power. The reform transfers income from firm-owners to workers in sector i. As before, the associated welfare effect is proportional to $b_i - 1$. By construction, there are no welfare effects associated with changes in equilibrium wages and employment. However, the increase in net earnings raises participation of workers in sector i. If some of the (previously voluntarily) unemployed workers find a job, a welfare loss occurs because – with constant employment – some participants who experience a surplus from working will not be able to find a job. The more inefficient is the rationing scheme, or the higher is the participation response (i.e., the higher ϱ_i or γ_i), the higher should be the social welfare weight of workers b_i for unions in sector i to be desirable – *ceteris* *paribus*. The welfare costs of inefficient rationing could be so large that they completely off-set the potential welfare gains of unions. Consequently, if rationing is inefficient, increasing union power in a sector where $b_i > 1$ does not necessarily raise social welfare.

2 Occupational choice

So far we have abstracted from an intensive margin of labor supply: each individual can only work a fixed number of hours in one particular sector. The main reason for doing so is that an intensive margin raises a number of very complicated issues that we cannot yet address. For example, which party (i.e., unions or individuals) decides on the number of hours worked? Does the incidence of unemployment fall on the intensive (hours) or extensive (participation) margin? How do unions aggregate worker preferences if they can switch between sectors? In this Section, we do not attempt to answers these difficult questions. Instead, we will demonstrate that our main insights carry over to a setting where workers can switch between occupations. This is what Saez (2002) refers to as the 'intensive margin' in discrete labor-supply models.

To model occupational choice, we assume that each of the N workers draws a vector $\boldsymbol{\varphi} \equiv (\varphi_0, \varphi_1, \cdots, \varphi_I) \in \Phi$ of participation costs according to some cumulative distribution function $G(\boldsymbol{\varphi})$. The i-th element of vector $\boldsymbol{\varphi}$ indicates how costly it is for an individual to work in sector i. Based on their participation costs, individuals choose in which sector (or: occupation) to look for a job. Without labor unions, this choice simply boils down to finding the occupation j where the net payoff from working $w_j - T_j - \varphi_j$ is maximized, provided the latter exceeds the payoff from not working $-T_u$. With labor unions, however, this problem is more complicated, because individuals may not be able to find a job if wages are set above the market-clearing level. An additional difficulty is that it is no longer clear how the union objective should be specified if individuals can switch between sectors. To overcome these issues, we adopt a similar approach as with inefficient rationing (see Section 1). In particular, we assume that there exist reduced-form equations $p_i(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u)$ that are differentiable functions of all participation taxes, which specify a probability $p_i \in [0, 1]$ that an individual becomes employed if he or she looks for a job in sector i. If the individual is unsuccessful, he or she cannot move to another sector but instead becomes unemployed. Each individual then solves:

$$\max_{j \in \{0,1,...,I\}} \quad u(-T_u) + p_j(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u)(u(w_j - T_j - \varphi_j) - u(-T_u)), \tag{9}$$

where occupation 0 refers to non-employment, with $w_0 = \varphi_0 = 0$, $T_0 = T_u$, and $p_0 = 1$.

As before, we assume that there are no income effects at the union level and we denote by $w_i(T_1 - T_u, ..., T_I - T_u)$ and $E_i(T_1 - T_u, ..., T_I - T_u)$ the equilibrium wage and *total* employment (as opposed to the employment rate) in sector i as a function of the participation taxes. Furthermore, let Φ_i denote the set of all individuals who look for a job in sector i (including non-employment):

$$\Phi_i \equiv \{\boldsymbol{\varphi} \in \Phi | \text{ arg max}_j \; p_j(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u)(u(w_j - T_j - \varphi_j) - u(-T_u)) = i\}. \tag{10}$$

In equilibrium, the following relationship holds for all i and for all participation taxes:

$$N \int_{\Phi_i} p_i(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u) \mathrm{d}G(\varphi) = E_i(T_1 - T_u, ..., T_I - T_u). \tag{11}$$

We make the following assumption regarding the functions $p_i(\cdot)$, which ensures that rationing is efficient.

Assumption 1. (Efficient rationing with occupational choice) *$p_i = 0$ on the boundary of the set Φ_i for all sectors i.*

Assumption 1 extends 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. This form of rationing is efficient in the sense that individuals with the lowest surplus from working in a particular sector (compared to their second-best alternative) do not find a job if wages are set above the market-clearing level. This notion of efficient rationing is similar to Lee and Saez (2012).

The following Proposition characterizes the optimal tax system with an intensive, occupational-choice margin.

Proposition 2. *If Assumptions 3 (no income effects at the union level) and 1 (efficient rationing with occupational choice) are satisfied, and individuals optimally choose their occupation according to eq. (9), then the optimal unemployment benefit $-T_u$, profit taxes T_f, and participation taxes $T_i - T_u$ are determined by:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{12}$$

$$b_f = 1, \tag{13}$$

$$\sum_j \omega_j \left(\frac{t_j + \tau_j^o}{1 - t_j} \right) \eta_{ji} = \omega_i (1 - b_i) + \sum_j \omega_j (b_j - b_f) \kappa_{ji}, \quad \forall i, \tag{14}$$

where the union wedge with endogenous occupational choice is

$$\tau_j^o \equiv \psi_j N \int_{\Phi_j} \frac{\partial p_j / \partial (T_i - T_u)}{\partial E_j / \partial (T_i - T_u)} \left(\frac{u(w_j - T_j - \varphi_j) - u(-T_u)}{\lambda w_j} \right) \mathrm{d}G(\varphi).$$

Proof. See Appendix B.1. □

The optimal tax formulas are almost identical to the ones in the model without an occupational choice and the interpretation is similar. There are a few, subtle differences between equation (14) and the expression for the optimal participation tax without an occupational choice. First, the union wedge 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.[2] This term is similar to the union wedge $\hat{\tau}_j$ with inefficient rationing.

[2]To see why τ_j^o captures an average welfare loss, differentiate equation (11) for $i = j$ with respect to $T_i - T_u$

$$N \int_{\Phi_j} \frac{\partial p_j(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u)}{\partial (T_i - T_u)} \mathrm{d}G(\varphi) = \frac{\partial E_j(T_1 - T_u, ..., T_I - T_u)}{\partial (T_i - T_u)}.$$

A second difference is that the employment and wage responses η_{ji} and κ_{ji} not only capture 'demand interactions' (through complementarities in production), but also 'supply interactions' (through occupational choice). To illustrate this, suppose that the participation tax in sector i is increased. *Ceteris paribus* this leads to a higher wage and a lower employment rate in sector i. Without an occupational choice, employment and wages in other sectors go down if labor types are complementary factors in production. With an occupational choice, a higher participation tax in sector i might lead some individuals to switch to sector $j \neq i$. This puts further downward pressure on wages in other sectors, but mitigates (and possibly overturns) the negative impact on employment in other sectors. An occupational choice thus affects the magnitude, and possibly the sign, of wage and employment responses. However, *given* these responses, i.e., given η_{ji} and κ_{ji}, the optimal tax formulas are the same as we had before.

Our second main result on the desirability of unions also generalizes to an environment with an occupational choice.

Corollary 2. *If Assumptions 3 (no income effects at the union level) and 1 (efficient rationing with occupational choice) are satisfied, individuals optimally choose their occupation according to eq. (9), and taxes and transfers are set according to Proposition 2, then an increase in union power ρ_i in sector i raises social welfare if and only if $b_i > 1$.*

Proof. See Appendix B.2. □

The key to understanding why the desirability condition from Proposition 2 from the main text also holds in the current setting with occupational choice is that labor rationing is efficient. To see this, consider again a marginal increase in union power in sector i: $\mathrm{d}\rho_i > 0$. This reform puts upward pressure on the wage in sector i, which can be off-set by lowering the income tax in sector i: $\mathrm{d}T_i < 0$. The reduction in the income tax, in turn, can be financed by raising the profit tax: $\mathrm{d}T_f > 0$. As before, the tax reform has no impact on social welfare if the tax system is optimized. Furthermore, as in the model without an occupational choice, this combined reform transfers resources from firm-owners (whose social welfare weight equals one) to workers in sector i (whose social welfare weight equals b_i). However, unlike before, the higher net income of workers in sector i could attract workers from other sectors (possibly non-employment) to look for a job in sector i. These individuals experience the smallest surplus from working in sector i compared to their second-best alternative. Under our assumption of efficient rationing, they will not find a job. Anticipating this, workers on the boundary of Φ_i will not switch between sectors following an increase in union power ρ_i. The impact on social welfare is therefore the same as without an occupational-choice margin, which explains why the desirability condition is unaffected.[3]

3 Bargaining over the wage distribution

In our baseline model, bargaining takes place at the sectoral level and wages vary only across (and not within) sectors. Each sectoral union faces a trade-off between employment and wages,

[3]This result is similar to Lee and Saez (2012) who find that a minimum wage is desirable if and only if $b_i > 1$.

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.[4] 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, we now analyze a single union which bargains with firm-owners over *all* wages. To maintain tractability, we assume efficient rationing and we assume away income effects at the union level. The union has a utilitarian objective: it maximizes the sum of all workers' expected utilities. As in the RtM-model, wages are determined through bargaining between the national union and firms, while firms (unilaterally) determine employment. Since the utility function $u(\cdot)$ is concave, the union has an incentive to compress the wage distribution. Doing so is only possible if labor markets are interdependent, since in that case marginal productivity (and hence, the wage) for any group of workers depends on employment in other sectors. If labor markets would be independent, a national union would simply set the same wages in each sector as a sectoral union would, and our previous results apply.

We explicitly solve the Nash-bargaining problem to characterize labor-market equilibrium, where the national union's bargaining power is denoted by $\delta \in [0, 1]$. Since there is only one union, we can no longer use a sector-specific measure of union power ρ_i to analyze the union's desirability. However, under Nash-bargaining, equilibrium wages and employment also depend on profit taxes, which is not the case if we use ρ_i to parameterize union power. To maintain comparability with our previous findings, we therefore assume that firm-owners are risk neutral. This ensures that equilibrium wages and employment can be written only in terms of participation taxes, like before. In Appendix C.1, we set up the bargaining problem, characterize labor-market equilibrium, and extensively discuss its properties. Here, we only highlight the most important features.

First, if the union has no bargaining power at all ($\delta = 0$), the labor-market equilibrium coincides with the competitive outcome. Second, if union power δ is sufficiently high, there is at least one group of workers whose wage is raised above the market-clearing level. This follows from the assumptions that, first, the union has an incentive to compress the wage distribution and, second, labor rationing is efficient. Hence, starting from the competitive labor-market outcome, a marginal increase in the bargained wage in the sector with the lowest wage compresses the wage distribution, but entails negligible welfare losses due to involuntary unemployment. Third, it may not be in the union's best interest to raise *all* wages 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.

The next proposition shows how taxes should be optimized if there is a single union, which bargains with firm-owners over the entire distribution of wages. To abstain from conflicting union and government objectives, we assume that both the government and the union maximize a utilitarian objective.

Proposition 3. *If Assumptions 2 (efficient rationing), and 3 (no income effects at the union*

[4] 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).

level) are satisfied, labor markets are interdependent, and a single union bargains over all wages w_i in all sectors i, then the expressions for the optimal unemployment benefits $-T_u$, optimal profit taxes T_f, and optimal participation taxes $T_i - T_u$ are the same as in Proposition 1 from the main text.

Proof. In the absence of income effects, the reduced-form wage and employment equations can be written as $w_i = w_i(T_1 - T_u, ..., T_I - T_u)$ and $E_i = E_i(T_1 - T_u, ..., T_I - T_u)$. Since the optimal tax formulas from Proposition 1 in the main text are derived for any relationship between tax instruments and labor-market outcomes, they remain the same. □

The reason why Proposition one generalizes to a national union bargaining over the entire wage distribution is that the optimal tax rules are expressed in terms of sufficient statistics and equilibrium wages and employment only depend on participation taxes in both cases.[5]

How is the desirability condition for unions modified if the union negotiates the wages for all workers? Once more, we can answer this question by analyzing the welfare effects of a (marginal) increase in union power δ combined with a tax reform that leaves wages and employment in all sectors unaffected. If the tax system is optimized, the tax reform has no impact on social welfare. Any effect on social welfare must then necessarily come from the increase in union power. To analyze the effects of such a reform, we need to keep track of the sectors where the wage is set above the market-clearing level. Denote by $k(\delta) \equiv \{i : G(w_i - (T_i - T_u)) > E_i\}$ the set of sectors where the wage is raised above the market-clearing level. This set $k(\cdot)$ depends – among other things – on union power $\delta \in [0, 1]$. If the union has no power ($\delta = 0$), no wage is raised above the market-clearing level, and consequently $k(\cdot)$ is empty. On the other hand, $k(\delta)$ contains at least one element if $\delta = 1$, since a utilitarian monopoly union always has an incentive to increase the wage for the workers in the sector with the lowest wage. We assume that the set of sectors where wages are above market-clearing levels $k(\delta)$ does not change in response to a marginal increase in union power.[6]

The rise in union power puts upward pressure on the wages of workers $i \in k(\delta)$ for whom the wage already exceeds the market-clearing level (the 'direct' effect). Through spillovers in production, the wages for workers in other sectors $j \notin k(\delta)$ will be affected as well (the 'indirect' effect). Now, consider a tax reform that leaves all wages and employment levels unaffected. Such a tax reform *only* requires an adjustment in the income taxes T_i for those workers whose wage exceeds the market-clearing level, i.e., for sectors $i \in k(\delta)$. Intuitively, if the adjustment in the tax system offsets the 'direct' effects, there will also be no 'indirect' effects. As before, the marginal changes in the participation taxes can be financed by a marginal increase in the profit tax such that the government budget remains balanced. The tax reform that leaves equilibrium wages and employment constant is characterized by the solution to the following system of equations:

$$\forall i \in k(\delta) : \quad \sum_{j \in k(\delta)} \frac{\partial w_i(T_1 - T_u, ..., T_I - T_u, \delta)}{\partial T_j} \mathrm{d}T_j^* + \frac{\partial w_i(T_1 - T_u, ..., T_I - T_u, \delta)}{\partial \delta} \mathrm{d}\delta = 0. \quad (15)$$

[5] The optimal tax levels are not necessarily the same because the elasticities and wedges generally differ between the different bargaining structures.

[6] Assuming $k(\delta)$ does not change following a marginal change in δ is without loss of generality, since there is a discrete number of sectors.

Here, the functions $w_i = w_i(T_1 - T_u, ..., T_I - T_u, \delta)$ are the reduced-form equations that solve the bargaining problem (see Appendix C.1 for details). The next Proposition derives the desirability condition for the national union.

Proposition 4. *If Assumptions 2 (efficient rationing), and 3 (no income effects at the union level) are satisfied, there is a national utilitarian union bargaining with firm-owners over all wages, and the tax-benefit system is optimized according to Proposition 3, then an increase in union power δ increases social welfare if and only if*

$$\sum_{i \in k(\delta)} \omega_i (b_i - 1)(-\mathrm{d}T_i^*) > 0, \tag{16}$$

where the changes in income taxes $\mathrm{d}T_i^*$ follow from equation (15) and $k(\delta) \equiv \{i : G(w_i - (T_i - T_u)) > E_i\}$.

Proof. See Appendix C.3 □

Proposition 4 is an intuitive counterpart of Proposition 2 from the main text: an increase in union power raises social welfare if and only if doing so allows the government to increase the incomes of workers whose social welfare weight (on average) exceeds one. By the same logic as before, the joint increase in union power and the tax reform leaves all labor-market outcomes unaffected, while raising the *net* incomes for the low-skilled. Therefore, increasing union power raises social welfare if and only if the weighted average social welfare weight of workers whose wage is above the market-clearing level exceeds one. The weight depends on the share ω_i of workers in sector i and on the change in the income taxes $-\mathrm{d}T_i^*$ in the policy reform.

Since the desirability condition remains unaltered, the union's desire to compress the wage distribution does not provide an *additional* reason why a welfarist government would like to raise union power. As was the case with a restriction on profit taxes, the government can achieve the same wage compression as the labor union through the tax-transfer system, without creating involuntary unemployment. Hence, unions cannot redistribute income via wage compression any better than the government can.

4 Efficient bargaining

Up to this point, we have assumed that bargaining takes place in a right-to-manage setting. This bargaining structure generally leads to outcomes that are not Pareto efficient, because firm-owners – who take wages as given – do not take into account the impact of their hiring decisions on the union's objective (McDonald and Solow, 1981). This inefficiency can be overcome if unions and firm-owners bargain over both wages *and* employment. This Section explores whether our results generalize to a setting with efficient bargaining (EB), as in McDonald and Solow (1981). For analytical convenience we do impose the assumptions of independent labor markets, efficient rationing, and no income effects at the union level.

We would like to emphasize from the outset that we consider the EB-model less appealing for two main 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. Therefore, we maintain the RtM-model as our baseline.

The key feature of the EB-model is that any potential 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:

$$\frac{u(w_i - T_i - \hat{\varphi}_i) - u(-T_u)}{E_i \overline{u'(w_i - T_i - \varphi)}} = \frac{w_i - F_i(\cdot)}{E_i}. \tag{17}$$

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.

The contract curve defines a set of potential labor-market equilibria (w_i, E_i) in sector i. Which contract 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. In particular, let υ_i denote the power of union i. We select the equilibrium in labor market i using the following rent-sharing rule:

$$w_i = (1 - \upsilon_i)F_i(\cdot) + \upsilon_i \phi_i(E_i), \tag{18}$$

where $\phi_i(E_i) \equiv \frac{\hat{\phi}_i(N_i E_i)}{N_i E_i}$ is the average productivity of a worker in sector i and $\hat{\phi}_i$ is the contribution of sector i to total output:[7]

$$\hat{\phi}_i(N_i E_i) \equiv F(K, N_1 E_1, \cdots, N_i E_i, \cdots, N_I E_I) - F(K, N_1 E_1, \cdots, 0, \cdots, N_I E_I). \tag{19}$$

If unions have zero bargaining power, i.e., $\upsilon_i = 0$, the outcome in the EB-model coincides with the competitive equilibrium: $w_i = F_i(\cdot)$. Efficiency then requires $\hat{\varphi}_i = w_i - (T_i - T_u) = \varphi_i^*$. If, on the other hand, union i has full bargaining power, i.e., $\upsilon_i = 1$, it can offer a contract which leaves no surplus to firm-owners. In the latter case, the wage equals average labor productivity and the firm makes zero profits from hiring workers in sector i: $w_i N_i E_i = \hat{\phi}_i(\cdot)$. We refer to this outcome as the full expropriation (FE) outcome.

The characterization of labor-market equilibrium is graphically illustrated in Figure 1. As in the RtM-model, the equilibrium coincides with the competitive outcome if the union has zero bargaining power. If union power increases, the equilibrium moves along the contract curve towards the FE-equilibrium, where the union has full bargaining power. Which equilibrium is selected depends on union power υ_i.

Figure 1 provides three important insights. First, as in the RtM-model, there is involuntary unemployment if union power υ_i is positive. Without involuntary unemployment, unions are marginally indifferent to changes in employment, since labor rationing is efficient. Hence, unions are always willing to bargain for a slightly higher wage and accept some unemployment. Sec-

[7]It should be noted that ϕ_i is different from the one used in Section 7 of the main text, where it denotes the wage share of sector i in aggregate labor income.

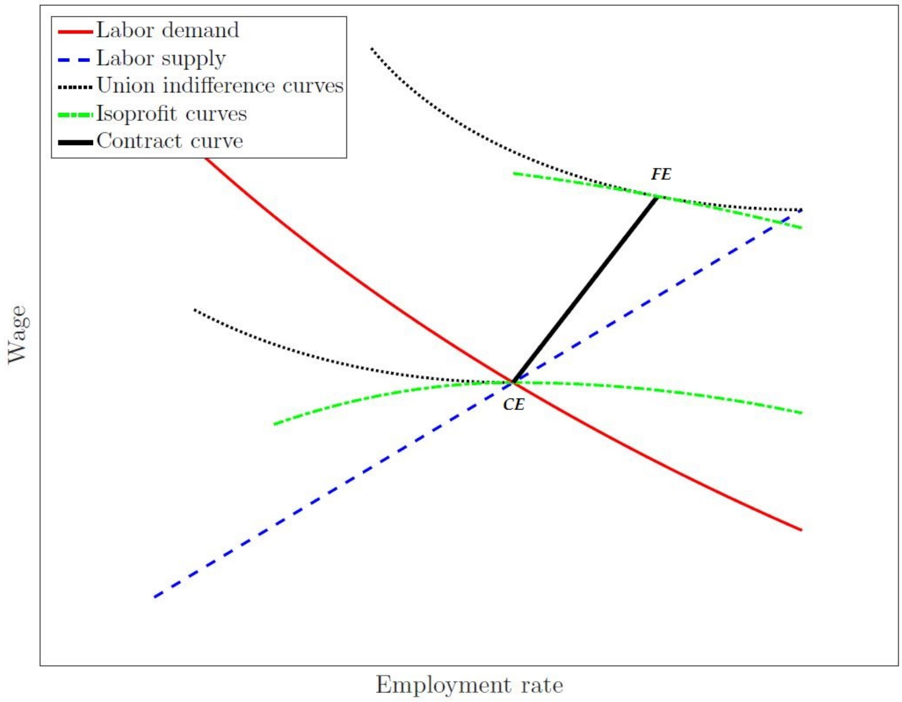

Figure 1: Labor market equilibria in the efficient bargaining model

ond, in contrast to the RtM-model, there is also a labor-demand distortion: the wage exceeds the marginal product of labor if $\upsilon_i > 0$, see equation (18). Consequently, the labor-market equilibrium is no longer on the labor-demand curve. Intuitively, if the wage equals the marginal product of labor, firms are indifferent to changes in employment, whereas unions are generally not. Hence, it is possible to negotiate a labor contract with a lower wage and higher employment, which benefits both parties. As a result, efficient bargaining results in implicit subsidies on labor demand. Third, and 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. As illustrated in Figure 1, the contract curve is upward sloping. The higher is union power, the larger is the share of the bargaining surplus that accrues to union members. Due to the concavity of the utility function $u(\cdot)$, this surplus is translated partly into higher wages, and partly into higher employment.

In the absence of income effects at the union level, and assuming independent labor markets, the contract curve (17) and the rent-sharing rule (18) jointly determine the equilibrium wage w_i and employment E_i in sector i solely as a function of the participation taxes $T_i - T_u$. If the participation tax increases, fewer workers want to participate. In terms of Figure 1, the labor-supply schedule shifts upward. As a result, the equilibrium wage (employment rate) will be higher (lower) following the increase in the participation tax. Therefore, the comparative statics are qualitatively the same as in the RtM-model. We replicate Lemma 1 from the main text for the EB-model in Appendix D.1. The following Proposition characterizes optimal taxes.

Proposition 5. *If Assumptions 1 (independent labor markets), 2 (efficient rationing), and 3 (no income effects at the union level) are satisfied, and the efficient-bargaining equilibrium in labor market i is determined by the contract curve (17) and the rent-sharing rule (18), then optimal unemployment benefits $-T_u$, profit taxes T_f, and participation tax rates t_i are* *determined by:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{20}$$

$$b_f = 1, \tag{21}$$

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

where $m_i \equiv \frac{w_i - F_i}{w_i} = \upsilon_i \left(\frac{\phi_i - F_i}{w_i}\right)$ *is the implicit subsidy on labor demand. The wage and employment elasticities with respect to the participation tax rate* t_i *are given by:*

$$\kappa_{ii} = \frac{u_u' w_i (1 - t_i)\left(\frac{(1-m_i)(1-\upsilon_i)}{\varepsilon_i} + m_i\right)}{\frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)} + u_u' w_i (1 - t_i)\left(\frac{(1-m_i)(1-\upsilon_i)}{\varepsilon_i} + m_i\right) + (\hat{u}_i - u_u)\left(\frac{(1-m_i)}{m_i}\frac{(1-\upsilon_i)}{\varepsilon_i} - 1 + \frac{(\hat{u}_i' - \overline{u_i'})}{\overline{u_i'}}\right)} > 0, \tag{23}$$

$$\eta_{ii} = \frac{-u_u' w_i (1 - t_i)}{\frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)} + u_u' w_i (1 - t_i)\left(\frac{(1-m_i)(1-\upsilon_i)}{\varepsilon_i} + m_i\right) + (\hat{u}_i - u_u)\left(\frac{(1-m_i)}{m_i}\frac{(1-\upsilon_i)}{\varepsilon_i} - 1 + \frac{(\hat{u}_i' - \overline{u_i'})}{\overline{u_i'}}\right)} > 0. \tag{24}$$

Proof. See Appendix D.2. □

The optimality conditions in the EB-model are very similar to their counterparts in the RtM-model. Except from differences in the definitions of the elasticities, the main difference is the implicit subsidy on labor demand m_i in the expression for the optimal participation tax rate t_i in equation (22). Since the equilibrium wage exceeds the marginal product of labor, a decrease in employment in sector i positively affects the firm's profits, which the government can tax without generating distortions. The higher is the implicit subsidy on labor demand m_i, the higher should optimal participation tax rates be set – *ceteris paribus*.

The optimal participation tax aims to redistribute income and to counter the implicit taxes on labor participation τ_i and the implicit subsidies on labor demand m_i. The equilibrium is neither on the labor-supply nor on the labor-demand curve if the union has some bargaining power. 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 tax rates. On the other hand, employment is too high, because unions generate implicit subsidies on labor demand (as captured by m_i), which calls for higher participation tax rates. Hence, it is no longer unambiguously true that participation taxes should optimally be lower in unionized labor markets. This result contrasts with our finding from the RtM-model.

How is the desirability condition for unions affected if we assume efficient bargaining? The next Proposition answers this question.

Proposition 6. *If Assumption 2 (efficient rationing) is satisfied, the equilibrium in labor market* i *is determined by the contract curve (17) and the rent-sharing rule (18), and taxes and transfers are set according to Proposition 5, then increasing union power* υ_i *in sector* i *raises social welfare if and only if* $b_i > 1$.

Proof. See Appendix D.3. □

According to Proposition 6, the condition under which an increase union power in sector i is desirable is the same as in the RtM-model. Therefore, the question whether unions are desirable or not does not depend on the bargaining structure. This might seem surprising, given that – unlike in the RtM-model – employment increases in union power in the EB-model. However, also *unemployment* increases in union power, since the contract curve is steeper than the labor-supply curve. Intuitively, the union trades off employment and wages, which is not the case at the individual level. Only the effect on unemployment is critical to assess the desirability of unions. Stronger unions still generate more involuntary unemployment. Hence, an increase in union power is desirable only if there is too much employment as a result of net subsidies on participation. Therefore, the intuition for the desirability of unions in the RtM-model carries over to the EB-model: unions are only useful only if net participation subsidies lead to overemployment.

References

Boeri, T. M. and J. C. Van Ours (2008). *The Economics of Imperfect Labor Markets*. Princeton: Princeton University Press.

Card, D. E. (2001). The Effect of Unions on Wage Inequality in the U.S. Labor Market. *Industrial and Labor Relations Review 54*(2), 296–315.

Card, D. E., T. Lemieux, and W. C. Riddell (2004). Unions and Wage Inequality. *Journal of Labor Research 25*(4), 519–559.

DiNardo, J. E. and T. Lemieux (1997). Diverging Male Wage Inequality in the United States and Canada, 1981–1988: Do Institutions Explain the Difference? *Industrial and Labor Relations Review 50*(4), 629–651.

Freeman, R. B. (1980). Unionism and the Dispersion of Wages. *Industrial and Labor Relations Review 34*(1), 3–23.

Freeman, R. B. (1993). How Much has De-Unionisation Contributed to the Rise in Male Earnings Inequality? In S. Danziger and P. Gottschalk (Eds.), *Uneven Tides: Rising Inequality in America*, Chapter 4, pp. 133–164. New York: Russel Sage.

Gerritsen, A. A. F. (2017). Equity and Efficiency in Rationed Labor Markets. *Journal of Public Economics 153*, 56–68.

Gerritsen, A. A. F. and B. Jacobs (2020). Is a Minimum Wage an Appropriate Instrument for Redistribution? *Economica 87*, 611–637.

Lee, D. S. and E. Saez (2012). Optimal Minimum Wage Policy in Competitive Labor Markets. *Journal of Public Economics 96*(9), 739–749.

Lemieux, T. (1993). Unions and Wage Inequality in Canada and the United States. In D. E. Card and R. B. Freeman (Eds.), *Small Differences that Matter: Labor Markets and Income*

Maintenance in Canada and the United States, Chapter 3, pp. 69–108. Chicago: University of Chicago Press.

Lemieux, T. (1998). Estimating the Effects of Unions on Wage Inequality in a Panel Data Model with Comparative Advantage and Nonrandom Selection. *Journal of Labor Economics 16*(2), 261–291.

Machin, S. (1997). The Decline of Labour Market Institutions and the Rise in Wage Inequality in Britain. *European Economic Review 41*(3), 647–657.

McDonald, I. M. and R. M. Solow (1981). Wage Bargaining and Employment. *American Economic Review 71*(5), 896–908.

Oswald, A. J. (1993). Efficient Contracts are on the Labour Demand Curve: Theory and Facts. *Labour Economics 1*(1), 85–113.

Saez, E. (2002). Optimal Income Transfer Programs: Intensive versus Extensive Labor Supply Responses. *Quarterly Journal of Economics 117*(3), 1039–1073.

Visser, J. and D. Checchi (2011). Inequality and the Labor Market: Unions. In B. Nolan, W. Salverda, and T. Smeeding (Eds.), *The Oxford Handbook of Economic Inequality*, Chapter 10, pp. 230–256. Oxford: Oxford University Press.

Western, B. P. and J. Rosenfeld (2011). Unions, Norms and the Rise in U.S. Wage Inequality. *American Sociological Review 76*(4), 513–537.

A Inefficient rationing

A.1 Optimal taxation

To prove Proposition 1, we start by characterizing some properties of the general rationing schedule, which satisfies, for all values of E_i and φ_i^*

$$\int_{\underline{\varphi}}^{\varphi_i^*} e_i(E_i, \varphi_i^*, \varphi)\mathrm{d}G(\varphi) = E_i. \tag{25}$$

Differentiate equation (25) with respect to E_i and φ_i^* to obtain:

$$\int_{\underline{\varphi}}^{\varphi_i^*} e_{iE_i}(E_i, \varphi_i^*, \varphi)\mathrm{d}G(\varphi) = 1, \tag{26}$$

$$\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i, \varphi_i^*, \varphi)\mathrm{d}G(\varphi) + e_i(E_i, \varphi_i^*, \varphi_i^*)G'(\varphi_i^*) = 0. \tag{27}$$

As stated in the main text, rather than deriving labor-market equilibrium explicitly for a general rationing scheme, we instead assume that income effects at the union level are absent and labor markets are independent. In this case, the equilibrium wage and employment rate in sector i depend only on union power ρ_i and the participation tax: $E_i = E_i(\rho_i, T_i - T_u)$ and $w_i = w_i(\rho_i, T_i - T_u)$. To derive the social welfare function, first use equation (25) to write

$$(1 - E_i)u(-T_u) = u(-T_u) - \int_{\underline{\varphi}}^{\varphi_i^*} e_i(E_i, \varphi_i^*, \varphi)u(-T_u)dG(\varphi). \tag{28}$$

Consequently, the Lagrangian for maximizing social welfare is:

$$\begin{aligned}\mathcal{L} = &\sum_i \psi_i N_i \left(u(-T_u) + \int_{\underline{\varphi}}^{\varphi_i^*} e_i(E_i, \varphi_i^*, \varphi)(u(w_i - (T_i - T_u) - T_u - \varphi) - u(-T_u))\mathrm{d}G(\varphi) \right) \\ &+ \psi_f u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_i(T_i - T_u)) + T_f - R \right).\end{aligned} \tag{29}$$

The first-order conditions for T_u, T_f, and $T_i - T_u$ are given by:

$$T_u: \quad -\sum_i \psi_i N_i (E_i \overline{u_i'} + (1 - E_i)u_u') + \lambda \sum_i N_i = 0, \tag{30}$$

$$T_f: \quad -\psi_f u_f' + \lambda = 0, \tag{31}$$

$$\begin{aligned}T_i - T_u: \quad & -N_i E_i(\psi_i \overline{u_i'} - \lambda) + N_i E_i \left[\psi_i \overline{u_i'} - \psi_f u_f' \right] \frac{\partial w_i}{\partial (T_i - T_u)} \\ & + N_i E_i \left[\psi_i \int_{\underline{\varphi}}^{\varphi_i^*} e_{iE_i}(u_i(\varphi) - u_u)\mathrm{d}G(\varphi) + \lambda(T_i - T_u) \right] \frac{\partial E_i}{\partial (T_i - T_u)} \\ & + N_i \left[\psi_i \int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(u_i(\varphi) - u_u)\mathrm{d}G(\varphi) \right] \frac{\partial \varphi_i^*}{\partial (T_i - T_u)} = 0.\end{aligned} \tag{32}$$

Here, we used the assumption that labor markets are independent. The expected utility of the employed workers in sector i is given by:

$$\overline{u_i'} \equiv \int_{\underline{\varphi}}^{\varphi_i^*} \frac{e_i(E_i, \varphi_i^*, \varphi)}{E_i} u'(w_i - T_i - \varphi)\mathrm{d}G(\varphi), \tag{33}$$

and $u_i(\varphi) \equiv u(w_i - T_i - \varphi)$ is the utility of the worker with participation costs $\varphi \in [\underline{\varphi}, \varphi_i^*]$ who is employed in sector i.

Equations (30) and (31) lead to the first two results in Proposition 1. Next, divide equation (32) by $N_i E_i \lambda$. Define the expected utility loss of labor rationing in sector i for those workers who lose their job if the employment rate E_i is marginally reduced as:

$$\hat{\tau}_i \equiv \psi_i \int_{\underline{\varphi}}^{\varphi_i^*} e_{iE_i}(E_i, \varphi_i^*, \varphi) \left(\frac{u(w_i - T_i - \varphi) - u(-T_u)}{\lambda w_i} \right) \mathrm{d}G(\varphi). \tag{34}$$

Substitute equation (34) into equation (32) and use the definition of the elasticities η_{ii} and κ_{ii}

to find

$$\left(\frac{t_i+\hat{\tau}_i}{1-t_i}\right)\eta_{ii} = (1-b_i)+(b_i-b_f)\kappa_{ii} \\ + \frac{\partial\varphi_i^*}{\partial(T_i-T_u)}\frac{1}{E_i}\left[\psi_i\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)\frac{(u_i(\varphi)-u_u)}{\lambda}\mathrm{d}G(\varphi)\right]. \tag{35}$$

Next, use equation (27) to rewrite the last part of equation (35) as:

$$\frac{\partial\varphi_i^*}{\partial(T_i-T_u)}\frac{1}{E_i}\left[\psi_i\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)\frac{(u_i(\varphi)-u_u)}{\lambda}\mathrm{d}G(\varphi)\right] \\ = -\frac{\partial\varphi_i^*}{\partial(T_i-T_u)}\frac{G'(\varphi_i^*)}{G(\varphi_i^*)}\frac{\varphi_i^*}{1-t_i}\frac{e_i(E_i,\varphi_i^*,\varphi_i^*)}{E_i/G(\varphi_i^*)} \\ \times\left[\psi_i\int_{\underline{\varphi}}^{\varphi_i^*}\frac{e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)}{\int_{\underline{\varphi}}^{\varphi_i^*}e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)\mathrm{d}G(\varphi)}\left(\frac{u_i(\varphi)-u_u}{\lambda w_i}\right)\mathrm{d}G(\varphi)\right]. \tag{36}$$

As a final step, define the rationing wedge as

$$\varrho_i \equiv \frac{\psi_i e_i(E_i,\varphi_i^*,\varphi_i^*)}{E_i/G(\varphi_i^*)}\int_{\underline{\varphi}}^{\varphi_i^*}\frac{e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)}{\int_{\underline{\varphi}}^{\varphi_i^*}e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)\mathrm{d}G(\varphi)}\left(\frac{u(w_i-T_i-\varphi)-u(-T_u)}{\lambda w_i}\right)\mathrm{d}G(\varphi) \tag{37}$$

and the participation response by

$$\gamma_i \equiv -\frac{\partial G(\varphi_i^*)}{\partial(T_i-T_u)}\frac{\varphi_i^*}{G(\varphi_i^*)}, \tag{38}$$

where the threshold depends on the participation tax through $\varphi_i^* = w_i(\rho_i, T_i-T_u)-(T_i-T_u)$. After substituting these definitions in equation (35), we arrive at:

$$\left(\frac{t_i+\hat{\tau}_i}{1-t_i}\right)\eta_{ii} - \left(\frac{\varrho_i}{1-t_i}\right)\gamma_i = (1-b_i)+(b_i-b_f)\kappa_{ii}. \tag{39}$$

A.2 Desirability of unions

To study the welfare effects of the reform described in Section 1, one can differentiate the Lagrangian in equation (29) with respect to T_i and T_f under the assumptions that the reform is budget neutral, and leaves wages and employment in sector i (i.e., w_i and E_i) unaffected. The welfare effect is then:

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = N_iE_i(1-b_i)\mathrm{d}T_i + (1-b_f)\mathrm{d}T_f \\ + N_iE_i\left[\psi_i\frac{1}{E_i}\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)\left(\frac{u_i(\varphi)-u_u}{\lambda}\right)\mathrm{d}G(\varphi)\right]\frac{\partial\varphi_i^*}{\partial(T_i-T_u)}\mathrm{d}T_i. \tag{40}$$

The first term reflects the (direct) change in workers' utility in sector i following the change in the participation tax, whereas the second term reflects the change in firm-owners' utility induced by a change in the profit tax. The third term reflects the utility loss due to a change in labor participation: if T_i is lowered, more workers want to participate. If some of these workers find a job and employment remains constant, then it must be that some other workers lose their jobs and thus experience a utility loss, since rationing is not fully efficient.

Under the balanced-budget assumption, we have $N_i E_i \mathrm{d}T_i + \mathrm{d}T_f = 0$. In addition, if the government can levy a non-distortionary profit tax, then $b_f = 1$. Substituting these results in equation (40), the change in social welfare can be written as:

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = N_i E_i \left(1 - b_i + \left[\psi_i \frac{1}{E_i} \int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i, \varphi_i^*, \varphi) \left(\frac{u_i(\varphi) - u_u}{\lambda} \right) \mathrm{d}G(\varphi) \right] \frac{\partial \varphi_i^*}{\partial (T_i - T_u)} \right) \mathrm{d}T_i. \quad (41)$$

Given that T_i is lowered in the policy experiment (i.e., $\mathrm{d}T_i < 0$), the welfare effect is positive provided that the term in between brackets is negative. Using the definitions for ϱ_i and γ_i from equations (37) and (38), this is the case if:

$$b_i > 1 + \left(\frac{\varrho_i}{1 - t_i} \right) \gamma_i. \quad (42)$$

The proof is completed by the observation that if the tax system is optimized, the welfare impact of the joint reform (increasing union power ρ_i, lowering T_i and raising T_f) is driven only by the increase in union power, as changes in the tax system have no impact on social welfare.

B Occupational choice

B.1 Optimal taxation

The total labor force consists of N workers who draw a vector $\boldsymbol{\varphi} \equiv (\varphi_0, \varphi_1, \cdots, \varphi_I) \in \Phi$ of participation costs according to some distribution function $G(\boldsymbol{\varphi})$. Based on this draw, each individual chooses the occupation $j \in \{0, 1, .., I\}$ according to equation (9), where occupation 0 refers to non-employment with $w_0 = \varphi_0 = 0$ and $T_0 = T_u$. Aggregate employment in sector i is denoted by E_i and total (voluntary and involuntary) unemployment is given by E_0, so that $\sum_{i=0}^{I} E_i = N$. This notation differs from what is used in the rest of the paper, where E_i is the employment *rate*. Another difference is that, unless stated otherwise, summation over i in this Appendix means summing over $i \in \{0, 1, ..., I\}$ instead of summing over $i \in \{1, ..., I\}$.

The Lagrangian for the maximization of social welfare is:

$$\mathcal{L} = N \sum_i \psi_i \int_{\Phi_i} \Big[u(-T_u) + p_i(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u)(u(w_i - (T_i - T_u) - T_u) - u(-T_u)) \mathrm{d}G(\varphi) \Big]$$
$$+ \psi_f u(F(\cdot) - \sum_i w_i E_i - T_f) + \lambda \Big[\sum_i E_i T_i + T_f - R \Big]. \quad (43)$$

As in the previous cases, the first-order conditions with respect to T_u and T_f imply that the average social welfare weight of all workers and firm-owners equals one. The first-order condition with respect to the participation tax $T_i - T_u$ in sector i is:

$$E_i(\lambda - \psi_i \overline{u_i'}) + \lambda \sum_{j=1}^{I} E_j(\psi_j \overline{u_j'} - \psi_f u_f') \frac{\partial w_j}{\partial (T_i - T_u)} + \lambda \sum_{j=0}^{I} T_j \frac{\partial E_j}{\partial (T_i - T_u)} \tag{44}$$
$$+ \lambda N \sum_{j=1}^{I} \psi_j \int_{\Phi_j} \frac{\partial p_j(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u)}{\partial (T_i - T_u)} (u(w_j - T_j - \varphi_j) - u(-T_u)) \mathrm{d}G(\varphi) = 0.$$

Here, we used the property that $w_0 = 0$ and $p_0 = 1$, so they are not affected by taxation. The average marginal utility of employed workers in sector i is:

$$\overline{u_i'} = \frac{N}{E_i} \int_{\Phi_i} p_i(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u) u'(w_j - T_j - \varphi_j) \mathrm{d}G(\varphi). \tag{45}$$

The first-order condition (44) can be simplified in a number of steps. First, because $\sum_{j=0}^{I} E_j(T_1 - T_u, .., T_I - T_u) = 1$ for all tax instruments, we can differentiate both sides with respect to $T_i - T_u$:

$$\sum_{j=0}^{I} \frac{\partial E_j}{\partial (T_i - T_u)} = 0 \quad \Leftrightarrow \quad \sum_{j=1}^{I} \frac{\partial E_j}{\partial (T_i - T_u)} = -\frac{\partial E_0}{\partial (T_i - T_u)}. \tag{46}$$

Therefore, the the third term on the first line of eq. (44) can be simplified to:

$$\sum_{j=0}^{I} \frac{\partial E_j}{\partial (T_i - T_u)} T_j = \sum_{j=1}^{I} \frac{\partial E_j}{\partial (T_i - T_u)} T_j + \frac{\partial E_0}{\partial (T_i - T_u)} T_u = \sum_{j=1}^{I} \frac{\partial E_j}{\partial (T_i - T_u)} (T_j - T_u). \tag{47}$$

Second, for all tax instruments, aggregate employment and the employment probabilities are related through

$$N \int_{\Phi_j} p_j(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u) \mathrm{d}G(\varphi) \equiv E_j(T_1 - T_u, ..., T_I - T_u). \tag{48}$$

Differentiating both sides with respect to $T_i - T_u$ and imposing that employment probabilities are zero on the boundary of Φ_j allows us to rewrite the second line of equation (44):

$$N \int_{\Phi_j} \frac{\partial p_j(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u)}{\partial (T_i - T_u)} \mathrm{d}G(\varphi) = \frac{\partial E_j(T_1 - T_u, ..., T_I - T_u)}{\partial (T_i - T_u)}. \tag{49}$$

Next, multiply and divide the final term in equation (44) by $\partial E_j / \partial (T_i - T_u)$ for each j and divide the entire expression by λ to find:

$$E_i(1 - b_i) + \sum_j E_j(b_j - b_f) \frac{\partial w_j}{\partial (T_i - T_u)} \tag{50}$$
$$\sum_{j=1}^{I} \frac{\partial E_j}{\partial (T_i - T_u)} \left[(T_j - T_u) + \psi_j N \int_{\Phi_j} \frac{\partial p_j / \partial (T_i - T_u)}{\partial E_j / \partial (T_i - T_u)} \left(\frac{u(w_j - T_j - \varphi_j) - u(-T_u)}{\lambda} \right) \mathrm{d}G(\varphi) \right] = 0.$$

The union wedge with an occupational choice is defined as follows:

$$\tau_j^o = \psi_j N \int_{\Phi_j} \frac{\partial p_j / \partial (T_i - T_u)}{\partial E_j / \partial (T_i - T_u)} \left(\frac{u(w_j - T_j - \varphi_j) - u(-T_u)}{\lambda w_j} \right) \mathrm{d}G(\varphi). \tag{51}$$

Using this notation, and the the definitions of the labor shares (ω_i and ω_i) and wage and employment elasticities (κ_{ji} and η_{ji}), we obtain the final result from Proposition 2.

B.2 Desirability of unions

To study the desirability of labor unions, start from the Lagrangian

$$\begin{aligned} \mathcal{L} = N \sum_i \psi_i \int_{\Phi_i} \Big[u(-T_u) + p_i(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u)(u(w_i - (T_i - T_u) - T_u) - u(-T_u)) \mathrm{d}G(\varphi) \Big] \\ + \psi_f u(F(\cdot) - \sum_i w_i E_i - T_f) + \lambda \Big[\sum_i E_i T_i + T_f - R \Big]. \end{aligned} \tag{52}$$

Equilibrium wages and employment rates depend on the participation taxes $T_i - T_u$ and union power ρ_i in all sectors. As before, we analyze a reform where union power in sector i is increased: $\mathrm{d}\rho_i > 0$. This reform puts upward pressure on the wage w_i sector i and downward pressure on employment E_i. To off-set the impact on the equilibrium wage, the reform is combined by reduction in the income tax in sector i: $\mathrm{d}T_i < 0$. This reduction, in turn, is financed by an increase in the profit tax: $\mathrm{d}T_f > 0$. The combined welfare effect is

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = E_i(1 - b_i)\mathrm{d}T_i + (1 - b_f)\mathrm{d}T_f, \tag{53}$$

which is very similar to the equation (40) except there is no welfare loss due to an inefficient allocation of jobs over workers (i.e., there is no rationing wedge). Because the reform is budget-neutral, we have $E_i \mathrm{d}T_i = -\mathrm{d}T_f$. Moreover, the social welfare weight of firm-owners equals one if the tax system is optimized: $b_f = 1$. The increase in union power ρ_i combined with a reduction in the income tax T_i financed by a higher profit tax T_f increases the net incomes of workers in sector i. The prospects of a higher net wage could induce some individuals to switch from other sectors j (possibly non-employment) to sector i. However, this is only the case for workers who are *ex ante* indifferent between choosing occupation i and their second-best alternative. Under our assumption of efficient rationing, the employment probability of these individuals is zero: $p_i(\boldsymbol{\varphi}, T_1 - T_u, ..., T_I - T_u) = 0$ on the boundary of Φ_i. Hence, there is no welfare effect associated with such changes. According to equation (53), a higher union power then raises welfare if and only if $b_i > 1$.

C Bargaining over multiple wages

C.1 Labor-market equilibrium

We assume that there is one union with a utilitarian objective and denote union power by $\delta \in [0, 1]$. The union bargains with the firm-owners over the wages all sectors i. Hence, the union affects the entire wage distribution. Under Nash-bargaining, the solution for wages and employment in all sectors i follow from solving the following maximization problem:

$$
\begin{aligned}
\max_{\{w_i,E_i\}_{i\in\mathcal{I}}} \Omega \;=\; & \delta \log\left(\sum_i N_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi)\right) \\
& + (1-\delta)\log\left(u(F(K, E_1N_1, \cdots, E_IN_I) - \sum_i w_iN_iE_i - T_f) - u(F(K,0,\cdots,0) - T_f)\right) \\
\text{s.t. } & w_i - F_i(K, E_1N_1, \cdots, E_IN_I) = 0, \quad \forall i, \\
& G(w_i - T_i + T_u) - E_i \geq 0, \quad \forall i.
\end{aligned} \tag{54}
$$

The payoffs of both parties are taken in deviation from the payoff associated with the disagreement outcome. The Lagrangian is:

$$
\begin{aligned}
\mathcal{L} =& \delta \log\left(\sum_i N_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi)\right) \\
&+ (1-\delta)\log\left(u(F(K, E_1N_1, \cdots, E_IN_I) - \sum_i w_iN_iE_i - T_f) - u(F(K,0,\cdots,0) - T_f)\right) \\
&+ \sum_i \vartheta_i(w_i - F_i(K, E_1N_1, \cdots, E_IN_I)) + \sum_i \mu_i(G(w_i - T_i + T_u) - E_i).
\end{aligned} \tag{55}
$$

The first-order conditions are:

$$
w_i : \frac{\delta}{\sum_j N_jE_j(\overline{u_j} - u_u)} N_iE_i\overline{u_i'} - \frac{1-\delta}{u_f - \underline{u}_f} N_iE_i\overline{u_f'} + \vartheta_i + \mu_iG_i' = 0, \tag{56}
$$

$$
E_i : \frac{\delta}{\sum_j N_jE_j(\overline{u_j} - u_u)} N_i(\hat{u}_i - u_u) - N_i \sum_j \vartheta_jF_{ji} - \mu_i = 0, \tag{57}
$$

$$
\vartheta_i : w_i - F_i = 0, \tag{58}
$$

$$
\mu_i : G_i - E_i = 0. \tag{59}
$$

where $\underline{u}_f \equiv u(F(K,0,\cdots,0) - T_f)$. These conditions characterize labor-market equilibrium, which has the following properties.

First, if the union has zero bargaining power ($\delta = 0$), the equilibrium coincides with the competitive outcome (i.e., $G_i = E_i$ and $w_i = F_i$ for all i). To see why, substitute $\delta = 0$ in the first-order conditions for w_i and E_i in equations (56) and (57). Next, use (56) to substitute for ϑ_i in equation (57) and rearrange:

$$
\mu_i\underbrace{(N_iG_i'F_{ii} - 1)}_{<0} + N_i \sum_{j\neq i} \mu_j \underbrace{G_j'F_{ji}}_{\geq 0} = N_i \underbrace{\frac{u_f'}{u_f - \underline{u}_f}}_{>0} \underbrace{\sum_j N_jE_jF_{ji}}_{=-F_{Ki}K<0}. \tag{60}
$$

The inequalities follow from the assumptions of co-operant factors of production and constant returns to scale. Non-increasing marginal productivity and co-operant factors of production imply $F_{ii} \leq 0 \leq F_{ji}$, whereas constant returns to scale implies $\sum_j N_j E_j F_{ji} = -F_{Ki}K \leq 0$.[8] Suppose that there is a sector in which $G_i > E_i$, i.e., the wage is above the market-clearing level. Then, from the Kuhn-Tucker conditions, it must be that $\mu_i = 0$. Because of the non-negativity of all multipliers, however, equation (60) cannot be satisfied unless all labor types would be perfect substitutes, i.e., $F_{ii} = F_{ij} = F_{Ki} = 0$ for all i, j. This is a contradiction. Therefore, $G_i = E_i$ for all i if $\delta = 0$.

Second, if the union has sufficiently high bargaining power δ, there is at least one sector i for which the wage exceeds the market-clearing level, i.e., there exists a sector i such that $G_i > E_i$. To see why, suppose $\delta = 1$. In this case, the union is a monopoly union, and sets wages in order to maximize the expected utility of all workers, subject to the labor-demand equations $w_i = F_i(K, E_1N_1, \cdots, E_IN_I)$. Consequently, the union objective can be written as:

$$\Lambda = \sum_i N_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(F_i(K, E_1N_1, \cdots, E_IN_I) - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi). \tag{61}$$

Now, suppose that, starting from the competitive equilibrium where $G(F_i - T_i - T_u) = E_i$ for all i, the union considers reducing the employment rate in the sector ℓ where the marginal utility of workers' consumption is highest (i.e., $\overline{u'_\ell} > \overline{u'_j}$ for all $j \neq \ell$). This reduction in employment increases the wage of the workers with the highest marginal utility of consumption and reduce the wages for all other workers. The impact of a reduction in employment in sector ℓ on the union's objective is:

$$\mathrm{d}\Lambda = N_\ell \sum_j N_j E_j \overline{u'_j} F_{j\ell} \times \mathrm{d}E_\ell = N_\ell \left(N_\ell E_\ell F_{\ell\ell} \overline{u'_\ell} + \sum_{j \neq \ell} N_j E_j F_{j\ell} \overline{u'_j} \right) \mathrm{d}E_\ell. \tag{62}$$

This expression can be thought of as summing a weighted average of marginal utilities, with weights $N_j E_j F_{j\ell}$. The first term in brackets is negative (because $F_{\ell\ell} < 0$), whereas the second term in brackets is positive (because $F_{j\ell} \geq 0$ for all $j \neq \ell$). The first term unambiguously dominates the second term. This is because the weights sum to less than zero (constant returns to scale implies $\sum_j N_j E_j F_{j\ell} = -F_{Ki}K \leq 0$) and the only negative component (i.e., $N_\ell E_\ell F_{\ell\ell}$) is multiplied by the largest marginal utility (i.e., $\overline{u'_\ell} > \overline{u'_j}$ for all $j \neq \ell$). Consequently, the union objective unambiguously increases if – starting from the competitive equilibrium – the rate of employment for workers in the sector with the lowest wage is reduced (i.e., $\mathrm{d}E_\ell < 0$). Hence, a monopoly union ($\delta = 1$) always demands a wage above the market-clearing level in at least one sector.

C.2 Optimal taxation

In the absence of income effects and under the assumption that firm-owners are risk-neutral, the first-order conditions in equations (56) and (59) characterize equilibrium wages and employment rates as a function the participation tax rates: $w_i = w_i(T_1 - T_u, .., T_1 - T_u)$ and $E_i = E_i(T_1 -$

[8] This follows from differentiating $F(\cdot) = F_K(\cdot)K + \sum_j N_j E_j F_j(\cdot)$ with respect to E_ℓ.

$T_u, .., T_1 - T_u)$.[9] These reduced-form equations can be used to derive the optimal tax formulas. This case is identical to the one with multiple unions, which is analyzed in the main text. The optimal tax formulas (written in terms of elasticities) therefore remain unaffected.

C.3 Desirability of unions

To study the desirability of a national union, we analyze the welfare effects of a joint marginal increase in union power δ combined with a tax reform, such that all labor-market outcomes are unaffected. If the tax system is optimized, any change in welfare must then necessarily be the result of the change in union power.

Which tax reform offsets any impact of the increase in union power on equilibrium wages and employment? First, the tax reform cannot include a change in the participation tax for workers whose wage is at the market-clearing level. To see why, consider the labor-market equilibrium condition in a sector i where the wage is at the market-clearing level:

$$G_i(F_i(\cdot) - (T_i - T_u)) = E_i. \tag{63}$$

A change in the participation tax in this sector needs to be accompanied by a change in either $F_i(\cdot)$ or E_i. For this to be the case, employment in at least one sector i needs to adjust. However, the tax change is intended keep employment in all sectors unaffected. Hence, in sectors where $G_i = E_i$ it must be the case that $\mathrm{d}(T_i - T_u) = 0$. The tax reform thus changes income taxes in all sectors j where the wage is set above above the martket-clearing level, i.e., where $G_i > E_i$. The marginal tax reform should then satisfy:

$$\forall i \in k(\delta): \quad \sum_{j \in k(\delta)} \frac{\partial w_i(T_1 - T_u, ..., T_I - T_u, \delta)}{\partial T_j} \mathrm{d}T_j^* + \frac{\partial w_i(T_1 - T_u, ..., T_I - T_u, \delta)}{\partial \delta} \mathrm{d}\delta = 0. \tag{64}$$

Here, $k(\delta) \equiv \{i : G_i > E_i\}$ is the set of sectors where the wage is raised above the market-clearing level. As before, assume that the government adjusts the profit tax to keep the budget balanced. Since the combined increase in union power δ and the tax reform $\mathrm{d}T_j^*$ for all j leaves all labor-market outcomes unaffected, there is only a transfer of resources from firm-owners to the workers whose wage is higher than the market-clearing level (i.e., for whom $G_i > E_i$). The welfare effect is thus equal to:

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = \sum_{i \in k(\delta)} N_i E_i (1 - b_i) \mathrm{d}T_i^*, \tag{65}$$

where λ is the multiplier on the government budget constraint. Divide the latter by $\sum_i N_i > 0$. The remaining term is positive if and only if

$$\sum_{i \in k\delta} \omega_i (1 - b_i) \mathrm{d}T_i^* > 0. \tag{66}$$

[9] Risk-neutrality of firm-owners ensures that equilibrium wages and employment rates do not depend on the profit tax.

D Efficient bargaining

D.1 Derivation elasticities

Partial equilibrium in labor market i is obtained by combining the contract curve from equation (17) and the rent-sharing rule from equation (18):

$$\overline{u'(w_i(1-t_i)-T_u-\varphi)}(w_i-F_i(E_i)) = u(w_i(1-t_i)-T_u-G^{-1}(E_i))-u(-T_u), \tag{67}$$
$$w_i = (1-\upsilon_i)F_i(E_i)+\upsilon_i\phi_i(E_i). \tag{68}$$

Unlike before, here we directly express our results in terms of participation tax rates t_i, as opposed to levels $T_i - T_u$. This has no implications for the main insights. In the absence of income effects, these equations define $E_i = E_i(t_i)$ and $w_i = w_i(t_i)$. As before, the absence of income effects implies a change in T_u does not affect equilibrium wages and employment if the participation tax rate t_i remains constant. Hence, the derivative of equation (67) with respect T_u, while keeping t_i constant, is zero:

$$-\overline{u''(w_i(1-t_i)-T_u-\varphi)}(w_i-F_i(E_i)) = -u'(w_i(1-t_i)-T_u-G^{-1}(E_i))+u'(-T_u). \tag{69}$$

To derive the elasticities of employment and wages with respect to the participation tax rate, we first linearize the rent-sharing rule:

$$\frac{\mathrm{d}w_i}{w_i} = -\left((1-m_i)\frac{(1-\upsilon_i)}{\varepsilon_i}+m_i\right)\frac{\mathrm{d}E_i}{E_i}, \tag{70}$$

where $m_i \equiv (w_i - F_i)/w_i = 1 - F_i/w_i$ is the implicit subsidy on labor demand, as a fraction of the wage. If union power is zero, $\upsilon_i = 0$, $m_i = 0$, and equation (70) reduces to the linearized labor-demand equation.

Second, linearizing the contract curve yields:

$$\frac{\mathrm{d}\overline{u'_i}}{\overline{u'_i}} + \frac{\mathrm{d}(w_i-F_i)}{w_i-F_i} = \frac{\mathrm{d}(\hat{u}_i-u_u)}{\hat{u}_i-u_u}. \tag{71}$$

Using equation (69), the linearized sub-parts are given by:

$$\frac{\mathrm{d}\overline{u'_i}}{\overline{u'_i}} = \frac{\overline{u''_i}w_i(1-t_i)}{\overline{u'_i}}\left(\frac{\mathrm{d}w_i}{w_i}-\frac{\mathrm{d}t_i}{1-t_i}\right)+\frac{(\hat{u}'_i-\overline{u'_i})}{\overline{u'_i}}\frac{\mathrm{d}E_i}{E_i}, \tag{72}$$
$$\frac{\mathrm{d}(w_i-F_i)}{w_i-F_i} = \frac{1}{m_i}\left(\frac{\mathrm{d}w_i}{w_i}+\frac{(1-m_i)}{\varepsilon_i}\frac{\mathrm{d}E_i}{E_i}\right), \tag{73}$$
$$\frac{\mathrm{d}(\hat{u}_i-u_u)}{\hat{u}_i-u_u} = \frac{\hat{u}'_iw_i(1-t_i)}{(\hat{u}_i-u_u)}\left(\frac{\mathrm{d}w_i}{w_i}-\frac{\mathrm{d}t_i}{1-t_i}\right)-\frac{\hat{u}'_iE_i}{g(\hat{\varphi}_i)(\hat{u}_i-u_u)}\frac{\mathrm{d}E_i}{E_i}. \tag{74}$$

Solving for the relative changes in employment and wages yields:

$$\frac{\mathrm{d}E_i}{E_i} = \frac{-u_u' w_i(1-t_i)}{\frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)} + u_u' w_i(1-t_i)\left(\frac{(1-m_i)(1-\upsilon_i)}{\varepsilon_i} + m_i\right) + (\hat{u}_i - u_u)\left(\frac{(1-m_i)}{m_i}\frac{(1-\upsilon_i)}{\varepsilon_i} - 1 + \frac{(\hat{u}_i' - \overline{u_i'})}{\overline{u_i'}}\right)} \frac{\mathrm{d}t_i}{1-t_i}, \tag{75}$$

$$\frac{\mathrm{d}w_i}{w_i} = \frac{u_u' w_i(1-t_i)\left(\frac{(1-m_i)(1-\upsilon_i)}{\varepsilon_i} + m_i\right)}{\frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)} + u_u' w_i(1-t_i)\left(\frac{(1-m_i)(1-\upsilon_i)}{\varepsilon_i} + m_i\right) + (\hat{u}_i - u_u)\left(\frac{(1-m_i)}{m_i}\frac{(1-\upsilon_i)}{\varepsilon_i} - 1 + \frac{(\hat{u}_i' - \overline{u_i'})}{\overline{u_i'}}\right)} \frac{\mathrm{d}t_i}{1-t_i}. \tag{76}$$

The elasticities are now as given in Proposition 5.

D.2 Optimal taxation

Start with the Lagrangian for the maximization of social welfare if the government has utilitarian preferences:[10]

$$\begin{aligned} \mathcal{L} =& \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \right) \\ &+ u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_i t_i w_i) + T_f - R \right). \end{aligned} \tag{77}$$

Differentiating with respect to T_u, T_f, and t_i yields:

$$T_u : -\sum_i N_i E_i \overline{u_i'} - \sum_i N_i(1-E_i)u_u' + \lambda \sum_i N_i = 0, \tag{78}$$

$$T_f : -u_f' + \lambda = 0, \tag{79}$$

$$\begin{aligned} &t_i : -N_i E_i w_i(\overline{u_i'} - \lambda) + \frac{\partial E_i}{\partial t_i}\left(N_i(\hat{u}_i - u_u) + u_f' N_i(F_i - w_i) + \lambda N_i t_i w_i\right) \\ &+ \frac{\partial w_i}{\partial t_i}\left(N_i E_i \overline{u_i'}(1-t_i) - N_i E_i u_f' + \lambda N_i E_i t_i\right) = 0. \end{aligned} \tag{80}$$

The first two expressions from Proposition 5 are obtained by dividing equation (78) by $\lambda \sum_i N_i$ and equation (79) by λ, and imposing the definitions of the welfare weights $b_i \equiv \overline{u'(c_i)}/\lambda$, $b_u \equiv u'(c_u)/\lambda$ and the employment shares $\omega_i \equiv N_i E_i / \sum_j N_j$ and $\omega_u \equiv \sum_i N_i(1-E_i)/\sum_j N_j$. The second result can be found by dividing equation (79) by λ and using $b_f \equiv u'(c_f)/\lambda$. The expression for the optimal participation tax rate t_i is obtained by substituting $u_f' = \lambda$ in equation (80) and dividing the expression by $N_i E_i \lambda w_i$. After imposing the definitions of the union wedge $\tau_i \equiv \frac{u(\hat{c}_i) - u(c_u)}{\lambda w_i}$, the mark-up $m_i = \frac{w_i - F_i}{w_i}$ and the elasticities κ_{ii} and η_{ii} as defined in equations (23)–(24), we arrive at the final expression stated in Proposition 5.

[10] It is straightforward to add Pareto weights ψ_i and adjust the definitions of the welfare weights accordingly. This has no implications for our results.

D.3 Desirability of unions

To determine how a change in union power υ_i affects social welfare, we formulate the Lagrangian by taking the labor-market equilibrium conditions explicitly into account:

$$\begin{aligned}\mathcal{L} = & \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \right) \\ & + u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_i t_i w_i) + T_f - R \right) \\ & + \sum_i \vartheta_i N_i (w_i - (1-\upsilon_i)F_i(\cdot) - \upsilon_i \phi_i(\cdot)) \\ & + \sum_i \mu_i N_i \Bigg(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi)(F_i(\cdot) - w_i) \\ & + E_i(u(w_i(1-t_i) - T_u - G^{-1}(E_i)) - u(-T_u)) \Bigg). \end{aligned} \tag{81}$$

To determine how a change in the union power affects social welfare, differentiate the Lagrangian with respect to υ_i, and apply the envelope theorem:

$$\frac{\partial \mathcal{W}}{\partial \upsilon_i} = \frac{\partial \mathcal{L}}{\partial \upsilon_i} = N_i \vartheta_i (F_i - \phi_i). \tag{82}$$

Because the production function $F(\cdot)$ is concave in E_i, $w_i - F_i = \upsilon_i(\phi_i(\cdot) - F_i(\cdot)) > 0$ if $\upsilon_i > 0$. Hence, $\frac{\partial \mathcal{L}}{\partial \upsilon_i}$ is positive if and only if $\vartheta_i < 0$. To determine the sign of ϑ_i ,use the first-order conditions of the Lagrangian with respect to t_i, w_i and T_f:

$$t_i : - w_i N_i E_i(\overline{u_i'} - \lambda) - \mu_i w_i N_i E_i \left(\overline{u_i''}(F_i - w_i) + \hat{u}_i' \right) = 0, \tag{83}$$

$$\begin{aligned} w_i : & (1-t_i)N_i E_i \overline{u_i'} - N_i E_i u_f' + \lambda t_i N_i E_i + \vartheta_i N_i \\ & + \mu_i (1-t_i) N_i \left(E_i \overline{u_i''}(F_i - w_i) + E_i \hat{u}_i' \right) - \mu_i N_i E_i \overline{u_i'} = 0, \end{aligned} \tag{84}$$

$$T_f : - u_f' + \lambda = 0. \tag{85}$$

Combining equations (83) and (84) and substituting equation (85) yields:

$$\vartheta_i = \mu_i E_i \overline{u_i'}. \tag{86}$$

Substituting for μ_i using equation (83) and simplifying gives:

$$\vartheta_i = E_i \left(\frac{\lambda \overline{u_i'}(1-b_i)}{\overline{u_i''}(F_i - w_i) + \hat{u}_i'} \right). \tag{87}$$

From equations (82) and (87), it follows that an increase in υ_i increases social welfare if and only if the term on the right-hand side of expression (87) is negative:

$$b_i > 1. \tag{88}$$