Optimal Income Taxation in Unionized Labor Markets*

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Preliminary – Comments welcome

Abstract

We analyze optimal redistributive income taxes in unionized labor markets in the extensive labor-supply model of Diamond (1980) and Saez (2002). In a right-to-manage setting, unions bargain with firms over wages in each occupation/sector. Unions raise wages above market-clearing levels and create involuntary unemployment. Optimal income taxes and unemployment benefits are shown to be lower in unionized labor markets, because income redistribution from employed to unemployed workers raises wage demands and creates involuntary unemployment. Net participation subsidies (EITC programs) are always desirable for low-skilled workers whose social welfare weight exceeds one. However, in unionized labor markets net participation subsidies could be optimal as well for low-skilled workers whose social welfare weight is below one. Unions are socially desirable to reduce the distortions of overemployment when labor participation is subsidized on a net basis. Involuntary unemployment then acts as an implicit tax, which off-sets explicit subsidies on labor participation. However, unions are *never* desirable when labor participation is taxed on a net basis, since the implicit tax of involuntary unemployment only exacerbates distortions of explicit taxes on labor participation. Our simulations demonstrate that optimal taxes and transfers are much less redistributive in unionized labor markets.

Keywords: optimal taxation, unions, wage bargaining, participation
JEL classification: D63, H21, H23, J51, J58

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1 Introduction

Over the past decades, many Western economies have simultaneously experienced sharp increases in inequality and reductions in union membership rates. This pattern, recently documented by Jaumotte and Buitron (2015) and Kimball and Mishel (2015), is illustrated in Figure 1 for the case of the United States. While the negative relationship between unionization and (wage) inequality is well documented empirically, little is known about the consequences of unionization on the effectiveness or desirability of redistributive policies.[1] This is surprising, because unions play a dominant role in labor markets, most notably in continental Europe. In particular, between 63% (Germany) and 99% (Austria) of wage earners are covered or affected by collective labor agreements that are negotiated by unions (Visser, 2006). This paper therefore studies optimal income redistribution in unionized labor markets. It asks two main questions: *'How should the government optimize income redistribution when labor markets are unionized, and labor supply responses are concentrated on the extensive margin?'* And: *'Can labor unions be socially desirable when the government wants to redistribute income?'* Both questions have, to the best of our knowledge, not yet been addressed in the literature.

We analyze an economy that includes workers, unions, firm-owners, and a government. In doing so, we extend Diamond (1980) and Saez (2002) with unionized labor markets. Workers are heterogeneous with respect to their costs of participation and their sector- or occupation-specific wage rate. Workers choose whether or not they want to participate, and supply labor on the extensive margin in case they succeed in finding a job.[2] Within each sector, workers are represented by a labor union, whose goal it is to maximize the expected utility of its members. Firm-owners own a stock of capital and employ different labor types to produce a final consumption good. Wages are determined through bargaining between unions and (representatives of) firm-owners. Individual firm-owners, in turn, take wages as given and determine labor demand for each labor type.[3] Unions bid up wages above their market-clearing levels, and, thereby, generate involuntary unemployment. In our baseline model we assume efficient rationing in the labor market: the workers with the highest participation costs will become involuntarily unemployed. The government acts as the Stackelberg leader and maximizes social welfare by optimally setting a non-linear income tax, unemployment benefits, and profit taxes. Our model nests the canonical extensive-margin models of Diamond (1980) and Saez (2002) as special cases where unions are absent and wages are exogenously given.[4] Our main findings are the following.

First, we provide an answer to the question how the optimal tax-benefit system should be adjusted in unionized labor markets. We show that the tax-benefit system is not only geared

[1] The negative relationship between unionization and (wage) inequality is documented in, for instance, Freeman (1980, 1991), Machin (1997), Lemieux (1998), Card (2001), Fairris (2003), Card et al. (2004), Checchi and Pagani (2004), DiNardo and Lemieux (1997), Koeniger et al. (2007), Visser and Checchi (2011), Western and Rosenfeld (2011), and Mishel (2012).

[2] As argued by Lee and Saez (2012), the extensive (participation) margin is often considered the empirically more relevant than the intensive (or hours) margin at the lower part of the income distribution. Empirical evidence in favor of this claim is documented in, among others, Meyer (2002).

[3] This description of the labor market corresponds to what is known in the literature as the 'right-to-manage' model, due to Nickell and Andrews (1983).

[4] Christiansen (2015) extends the models of Diamond (1980) and Saez (2002) with competitively determined wages. This case is nested as well as a special case.

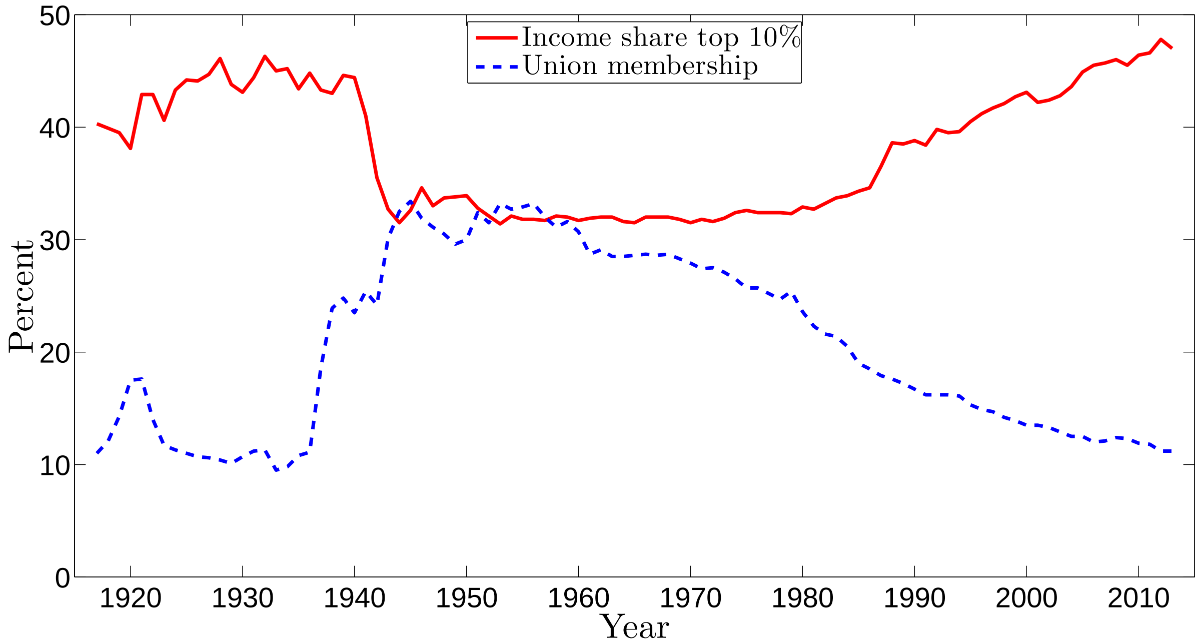

Figure 1: Union membership and inequality (Source: Kimball and Mishel, 2015)

towards redistributing income, but also to alleviate the distortions from involuntary unemployment. The government redistributes income by taxing workers and providing benefits to the non-employed. However, both taxes on workers and benefits for the unemployed induce unions to bid up wages above market-clearing levels, which results in involuntary unemployment. Therefore, the government optimally lowers income taxes and unemployment benefits to avoid higher involuntary unemployment. Intuitively, by lowering taxes or benefits, unions are motivated to moderate their wage demands, which reduces involuntary unemployment. Optimal participation taxes should be lower, the higher is the degree of unionization (i.e., the higher is the bargaining power of unions) – *ceteris paribus*.[5] Indeed, net participation subsidies may even be optimal for workers whose welfare weight is below one, which never occurs when labor markets are competitive, cf. Diamond (1980) and Saez (2002). The reason is that involuntary unemployment creates implicit taxes on labor participation which the government likes to offset by providing explicit subsidies on labor participation. EITC programs are thus more likely to be desirable when unions are strong.

Second, we provide an answer to the question whether unions are a useful institution when the government wants to redistribute income. Our main result is that increasing the bargaining power of unions that represent low-skilled workers (i.e., the workers whose social welfare weight exceeds one) raises social welfare, while the opposite holds true for the workers whose social welfare weight is below one. Intuitively, in sectors where the workers' welfare weight exceeds one, there is *excessive* labor participation because of positive participation subsidies, see also

[5]Because in an environment with involuntary unemployment participation no longer equals employment, Jacquet et al. (2012) and Kroft et al. (2015) prefer the term *employment tax* over the term *participation tax* to refer to the sum of the income tax and the unemployment benefit. However, because in our model the involuntarily unemployed do not engage in search activities or whatsoever, we will continue to use the term 'participation tax', keeping the above caveat in mind.

Diamond (1980) and Saez (2002). Unions reduce these labor-market distortions by demanding higher wages, which reduces employment. Involuntary unemployment acts as an implicit tax on labor participation, which partially off-sets the explicit subsidy on labor participation. By lowering the dead-weight losses of the tax-transfer system the government can thus redistribute more income, generate higher efficiency, or both.[6] Unions are never desirable when labor participation is taxed on a net basis. In that case, implicit taxes from involuntary unemployment only exacerbate explicit taxes on labor participation. Therefore, it is socially optimal to let low-skilled workers organize themselves in a union, whereas labor markets for more productive workers should remain competitive.

Finally, we simulate an empirically reasonable calibration of our model. We show that, for plausible values of labor-demand and participation elasticities, the optimal tax and benefit system looks quite different when the impact of unions is taken into account. In line with our theoretical predictions, optimal income taxes and unemployment benefits are (significantly) lower when labor markets are unionized. In particular, participation tax rates at the bottom of the income distribution may drop from well above 30 percent to -5 percent, depending on the degree of unionization. We thus confirm our theoretical prediction that the optimal tax-benefit system features a strong EITC-component when labor markets are unionized. Our simulations also suggest that the conditions under which unions are desirable are hard to meet empirically. In virtually all our simulations the welfare weight of even the lowest income groups falls short of one. For unions to become desirable, incomes of low-skilled workers would need to fall substantially below levels that are currently observed in the data.

The remainder of this paper is organized as follows. Section 2 discusses the related literature. Section 3 outlines the basic structure of the model and characterizes the general equilibrium for a given set of tax instruments. The question how these instruments should be optimally set is then addressed in Section 4. Section 5 subsequently examines how changing the bargaining power unions affects social welfare and characterizes the optimal degree of unionization in each sector. Section 6 investigates the robustness of the results. We present our simulations in Section 7. Finally, Section 8 concludes.

2 Related literature

Our paper relates to five branches in the literature. First, this paper adds to the literature on optimal taxation in unionized labor markets. In a model with multiple labor types and exogenous labor supply, Palokangas (1987) shows that the first-best can be achieved even when wage-setting is influenced by unions. Fuest and Huber (1997), Koskela and Schöb (2002), Aronsson and Sjögren (2004a,b) and Aronsson and Wikström (2011) analyze union models with only one labor type. Provided there are no informational frictions or restrictions on profit taxation, the first-best outcome is achieved as well. Aronsson and Sjögren (2003), Aronsson et al. (2005), Kessing and Konrad (2006), Aronsson et al. (2009) consider models with more

[6]This finding echoes the result of Lee and Saez (2012), who show that a binding minimum wage enhances social welfare if the welfare weight of the workers for whom the minimum wage binds exceeds one. For these workers, participation decisions are distorted upwards. Minimum wages can therefore alleviate the distortions induced by taxation, but only in sectors where participation is subsidized on a net basis.

than one labor type and allow for endogenous labor supply responses on the intensive margin. As in Mirrlees (1971), the government can neither observe wage rates nor working hours, which prevents a first-best outcome. Most of these studies find that (un)employment considerations are important to consider, though their impact on optimal tax policies is often ambiguous.[7] Our paper contributes to this literature by analyzing optimal income taxation in unionized labor markets with extensive rather than intensive labor-supply responses. We also avoid a first-best outcome, since participation costs are unobservable.

Second, there is an extensive literature that analyzes the impact of taxation on wages and employment in union models, see, e.g., Bovenberg and van der Ploeg (1994), Koskela and Vilmunen (1996), Fuest and Huber (1997), Sørensen (1999), Fuest and Huber (2000), Aronsson and Sjögren (2004b), Sinko (2004), Bovenberg (2006), van der Ploeg (2006), and Aronsson and Wikström (2011). In these models, higher unemployment benefits and high income taxes (i.e., high *average* tax rates), by improving the position of the unemployed relative to the employed, lead to higher wage demands and hence, lower employment. High *marginal* tax rates, on the other hand, moderate wage demands, since a larger fraction of marginal wage increases is taxed away by the government. In contrast to models with competitive labor markets, higher tax progression is thus associated with higher employment when wage-setting is influenced by unions, provided that working hours are fixed. If, however, individuals can also adjust their working hours, the impact of increased tax progressivity on overall employment (i.e., total hours worked) in models with unions becomes ambiguous (Sørensen, 1999, Fuest and Huber, 2000, Aronsson and Sjögren, 2004b, Koskela and Schöb, 2012). Since we focus on extensive labor supply responses, our model only features the impact of higher average taxes and benefits on wage demands. By using a discrete tax function, there is no direct wage-moderating effect of tax-rate progressivity. However, we do emulate the effects of higher marginal tax rates using employer taxes.

Third, we extend the analyses of Diamond (1980) and Saez (2002) of optimal taxation with extensive labor-supply responses to settings with finitely elastic labor demand and unions bargaining with firms over wages. Diamond (1980) and Saez (2002) show that the optimal tax-benefit system features participation subsidies for workers whose welfare weight exceeds one, much in the spirit of an Earned Income Tax Credit (EITC).[8] By allowing for varying degrees of union power and imperfect substitution between different types of labor, our result nests those obtained in Diamond (1980) and Saez (2002). The model analyzed by Christiansen (2015), who extends the analysis of Diamond (1980) and Saez (2002) with competitively determined wages, is also nested as a special case. Like the aforementioned studies, we also find that low-income workers should optimally be subsidized in an EITC-type program. In addition, we show that in unionized labor markets, participation subsidies may be optimal as well for workers whose welfare weight is below one.

Fourth, our analysis complements Christiansen (2016), who also studies optimal taxation in a unionized economy in which individuals differ in terms of their (unobservable) participa-

[7] An exception is Kessing and Konrad (2006), who focus on the impact of unions on (restrictions on) working hours and abstract from involuntary unemployment.

[8] This finding is confirmed in Choné and Laroque (2011), who consider a very general treatment of optimal taxation with extensive labor-supply responses.

tion costs. In his model, however, participation costs refer to the (utility) costs an individual experiences when switching between occupations, whereas in our model participation costs are incurred when moving from unemployment to employment. Furthermore, in Christiansen (2016) there is a single union concerned with wage compression, whereas our model features multiple unions and – for the purpose of tractability – abstracts from wage inequality within the group of workers represented by the same union. Finally, Christiansen (2016) abstracts from involuntary unemployment, which will prove an important consideration in our paper. Like Christiansen (2016), we show that union responses to taxation are important to consider when designing optimal tax policies.

Fifth, and finally, our study relates closely to recent literature on the optimality of minimum-wage policies in conjunction with optimal income taxation. Like unions, a binding minimum wage increases the income of certain groups of workers at the costs of creating involuntary unemployment. Lee and Saez (2012) show that introducing a minimum wage for low-skilled workers (whose welfare weight exceeds one) is welfare-enhancing provided that the rationing of unemployment is efficient. However, when the assumption of efficient rationing is relaxed, a minimum wage need no longer be optimal. Gerritsen and Jacobs (2014) study the optimality of minimum wage policies while allowing for general rationing schedules and endogenous human capital decisions. In their model, minimum wages could be desirable, since they alleviate the distortions in skill formation. Hungerbühler and Lehmann (2009) also analyze the optimality of a minimum wage, but do so in an economy with matching frictions. In their model, introducing a minimum wage is optimal if the bargaining power of the workers is too low for the Hosios condition to be satisfied. If, however, the government could directly increase the workers' bargaining power, a minimum wage ceases to be optimal. We also demonstrate that increasing the bargaining power of unions can improve social welfare. However, in contrast to Hungerbühler and Lehmann (2009), we allow the bargaining power of the unions to vary across sectors. We show that only an increase in the bargaining power of unions representing low-skilled workers may improve social welfare.

3 Model

We consider an economy consisting of workers, unions, firms and a government. The basic structure of the model follows Diamond (1980), with the exception that we consider a finite number of labor types, and, hence, a finite number of unions. Workers supply labor on the extensive margin to different occupations. Within each occupation, workers are represented by a labor union which negotiates wages with firm-owners. The latter supply capital and produce the final consumption good. The government aims to maximize social welfare by redistributing income between unemployed workers, employed workers, and firm-owners. We assume that the government is the Stackelberg leader relative to all agents in the private sector, including the labor unions. Each union takes tax policy as given and does not internalize the impact of its decisions on the government's budget.[9]

[9]This assumption is not innocuous. We will come back to this point in Section 8.

3.1 Workers

Workers are heterogeneous in two dimensions: wages and participation costs. There is a discrete number of I occupations or sectors. A worker of type $i \in \mathcal{I} \equiv \{1, \cdots, I\}$ can work only in occupation/sector i where she earns wage w_i. We denote by N_i the mass of workers of type i. When working, every worker incurs a monetary participation cost φ, which is private information. φ has domain $[\underline{\varphi}, \overline{\varphi}]$, with $\underline{\varphi} < \overline{\varphi} \leq \infty$.[10] The cumulative distribution function of participation costs of workers is denoted by $G(\varphi)$.[11]

Each worker is endowed with one indivisible unit of time and decides whether she wants to work in occupation i or not. All workers derive utility from consumption $c_{i,\varphi}$. They have an identical utility function $u(c_{i,\varphi})$ with $u'(c_{i,\varphi}) > 0$, and $u''(c_{i,\varphi}) < 0$. Consumption of employed workers $c_{i,\varphi}$ 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/occupation i with participation costs φ is willing to work whenever

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

Because we assume that participation is voluntary, this condition is always satisfied whenever an individual is employed. The reverse, however, need not be true. If for some individuals condition (1) is satisfied, but they are not employed, this simply means that these workers are *involuntarily* unemployed.

For each sector i, equation (1) defines a cut-off $\bar{\varphi}_i$ at which individuals are indifferent between working and not working: $\bar{\varphi}_i \equiv w_i - T_i + T_u$. Higher wages w_i, lower taxes on work T_i, and higher unemployment benefits $-T_u$ all raise the cut-off $\bar{\varphi}_i$ and, thus, reduce labor participation in sector/occupation i.

3.2 Firms

There is a group of mass one (representative) firm-owners, who own K units of capital, and employ all types of labor to produce a final consumption good.[12] As will be discussed in the next section, we distinguish between individual firm-owners who take wages as given when making production decisions, and representatives of firm-owners who bargain with the unions over wages.

Production is described by a constant-returns-to-scale production function:

$$\begin{aligned} &F(K, L_1, \cdots, L_I), \quad F_K(\cdot), F_i(\cdot) > 0, \quad F_{KK}(\cdot), F_{ii}(\cdot), -F_{Ki}(\cdot) \leq 0, \\ &\lim_{K\to 0} F_K(\cdot) = \infty, \quad \lim_{K\to\infty} F_K(\cdot) = 0, \quad \lim_{L_i\to 0} F_i(\cdot) = \infty, \quad \lim_{L_i\to\infty} F_i(\cdot) = 0, \end{aligned} \tag{2}$$

where the subscripts refer to the partial derivatives with respect to capital and type i (j) labor. We assume that capital and labor have positive, but non-increasing returns in production. More-

[10] For analytical convenience, we model participation costs as a pecuniary cost rather than a utility cost, see also Choné and Laroque (2011).

[11] The distribution of participation costs is constant across sectors. We could allow for i-type specific (distributions of) participation costs $G_i(\varphi)$, but none of our results would change.

[12] Alternatively, we could assume there are sector-specific firms engaged in producing the final consumption good. As long as the government is able to observe (and tax) profits of all firms, none of our results would change.

over, capital and labor in sector i are co-operant production factors ($F_{Ki} \geq 0$). Furthermore, in deriving our main results, we make the following assumption:

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

Assumption 1 implies that a change in employment in one sector does not affect the productivity of workers in other sectors. This assumption is made for technical convenience, as it ensures that there are no spillover effects between different segments of the labor market. In Section 6.2 we show that all our main results carry over in a modified form to the setting where labor markets are not assumed to be independent.

An example of a production function that satisfies Assumption 1 is the following:

$$F(K, L_1, \cdots, L_I) = K^\alpha \left(\sum_i a_i L_i^{1-\alpha} \right), \quad 0 \leq \alpha < 1, \tag{3}$$

where differences in a_i govern differences in productivity between different types of labor, or, alternatively, the degree to which different types of workers are complementary to capital.

Profits are equal to output minus wage costs:

$$\pi = F(K, L_1, \cdots, L_I) - \sum_i w_i L_i. \tag{4}$$

The representative firm maximizes profits π taking sector-specific wage rates w_i as given. The first-order conditions for profit maximization are given by:

$$w_i = F_i(K, L_1, \cdots, L_I), \quad \forall i. \tag{5}$$

Firms increase labor demand until the marginal product of labor is equal to the wage rate. Under Assumption 1, the demand for labor in sector i is only a function of the wage rate in sector i:

$$L_i \equiv L_i(w_i), \quad L_i'(\cdot) = 1/F_{ii}(\cdot). \tag{6}$$

The labor demand elasticity ε_i in sector i is defined as:

$$\varepsilon_i \equiv -\frac{F_i(\cdot)}{L_i F_{ii}(\cdot)} > 0, \tag{7}$$

which depends only on the amount of type i labor employed, again due to Assumption 1. The indirect profit function is given by:

$$\begin{aligned} \pi(w_1, \cdots, w_I) &= F(K, L_1(w_1), \cdots, L_I(w_I)) - \sum_i w_i L_i(w_i), \\ \frac{\partial \pi}{\partial w_i} &= -L_i, \quad \forall i. \end{aligned} \tag{8}$$

where the second line follows from the Envelope theorem. The consumption of firm-owners is denoted by c_f, which equals their profits π minus profit taxes T_f. Their utility is given by:

$$u(c_f) = u(\pi(w_1, \cdots, w_I) - T_f). \tag{9}$$

The profit tax is fully non-distortionary, as it affects none of the economic decisions in our model. In Section 5.2.1, we also analyze the case where the government levies proportional employer taxes on wages. Contrary to a lump-sum profit tax, employer taxes are distortionary, since they affect the firms' hiring decisions.

3.3 Unions

All workers of type i are member of the union that is active in sector/occupation i.[13] Each union aims to maximize the expected utility of its members. We characterize the labor-market equilibrium in sector i using some version of the Right-to-Manage (RtM) union model, due to Nickell and Andrews (1983). In this model, the wage w_i in sector i is determined through bargaining between the union representing type-i workers and (representatives of) firm-owners. Unions in each sector bargain independently with firm-owners and do not coordinate their actions. Hence, there is no 'leapfrogging' of unions between sectors. Firm-owners in each sector take the agreed-upon wage w_i as given and have the 'right to manage' how much labor they wish to hire.[14] Hence, employment is determined via the labor demand equations (5). A well-known feature of the Right-to-Manage model is that it nests both the competitive equilibrium (CE) as well as the Monopoly-Union (MU) model (due to Dunlop, 1950) as a special case, each for a specific degree of the union's bargaining power relative to firm-owners. We will discuss these special cases in turn, and then show how our model can be parameterized for any intermediate degree of union bargaining power. Importantly, in the remainder of our analysis we will allow the latter to vary across sectors i.

Before doing so, however, we first need to specify how jobs are allocated among workers with different participation costs: who are the workers that become involuntarily unemployed if wages are set above their market-clearing levels? For now, we will make the assumption that labor-market *rationing* is efficient:

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

When labor markets are competitive, all unemployment is voluntary, and Assumption 2 is trivially satisfied. If, however, part of unemployment is involuntary, there is no reason to believe that only individuals with the highest participation costs will bear the burden of unemployment. Only if there would be a secondary market for jobs, would labor-market rationing be efficient (Gerritsen, 2016). The assumption of efficient rationing, which clearly biases our results in favor of unions, will be relaxed in Section 6.2.

[13] Equivalently, we can say that the fraction of type i workers who are union-members is representative for the population of type i workers. As long as the union cares about members who face a positive probability of becoming involuntarily unemployed, and as long as the wage negotiated by unions extends to non-union members, the qualitative predictions of the model remain robust to the details of the union's objective.

[14] Since the wage in sector i extends to all workers, our model abstracts from wage inequality between workers represented by the same union, as analyzed in Christiansen (2016).

Let $E_i \equiv L_i/N_i$ denote the employment rate in occupation i. Assumption 2 then implies that individuals 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 $\varphi \in (\hat{\varphi}_i, \overline{\varphi}]$ remain unemployed. Because participation is voluntary, the fraction of participation is always weakly larger than the rate of employment, i.e., $E_i \equiv \int_{\underline{\varphi}}^{\hat{\varphi}_i} \mathrm{d}G(\varphi) = G(\hat{\varphi}_i) \leq G(\bar{\varphi}_i)$. The expected utility of workers in sector i, and hence the union's payoff, then equals

$$\Lambda_i = \int_{\underline{\varphi}}^{\hat{\varphi}_i} u(c_{i,\varphi})\mathrm{d}G(\varphi) + \int_{\hat{\varphi}_i}^{\overline{\varphi}} u(c_u)\mathrm{d}G(\varphi) = E_i\overline{u(c_i)} + (1 - E_i)u(c_u), \tag{10}$$

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.

If a union in sector i has full bargaining power – which we will refer to as the Monopoly-Union (MU) – the union chooses the wage w_i, or, equivalently, the employment rate E_i, that maximizes its objective (10) subject to the firm's labor demand curve (5). The equilibrium in the MU-model can be found by solving:

$$\begin{aligned} \max_{E_i, w_i, \hat{\varphi}_i} \quad & \Lambda_i = \int_{\underline{\varphi}}^{\hat{\varphi}_i} u(w_i - T_i - \varphi)\mathrm{d}G(\varphi) + \int_{\hat{\varphi}_i}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \\ \text{s.t.} \quad & w_i = F_i(\cdot), \quad \hat{\varphi}_i \equiv G^{-1}(E_i). \end{aligned} \tag{11}$$

We can combine the first-order conditions to find the following optimality condition:

$$1 = \varepsilon_i \frac{u(\hat{c}_i) - u(c_u)}{\overline{u'(c_i)} w_i}, \tag{12}$$

where $\overline{u'(c_i)}$ is the average marginal utility of employed workers in sector i. In addition, the utility of the *marginally employed* worker in sector i with participation costs $\hat{\varphi}_i$ is defined as $u(\hat{c}_i) = u(w_i - T_i - \hat{\varphi}_i)$.

When the union has full bargaining power, it sets the wage w_i in sector i such that marginal benefit of raising the wage for the employed with one euro (left-hand side) equals the marginal costs of higher unemployment (right-hand side). The marginal cost of setting the wage above the market-clearing level equals the elasticity of labor demand multiplied with the utility differential between the marginally employed and unemployed worker, measured in money units (i.e., dividing by $\overline{u'(c_i)}$), as a fraction of the wage w_i in sector i. The wedge is determined solely by the utility loss of the marginally employed workers, since under Assumption 2 these workers are the first to lose their jobs when the wage is marginally increased. A decrease in either the unemployment benefit $-T_u$ or the income tax T_i reduces wage demands, since employment becomes more attractive than unemployment. Furthermore, note that, because the tax schedule is discrete, there is no wage-moderating effect of tax progression.[15]

If the union has no bargaining power at all, the equilibrium in the market for type-i labor coincides with the competitive outcome. In this case, the wage is driven to the point where the marginally employed worker is indifferent between participating and not participating, i.e.,

[15] See the literature review in Section 2. We emulate the tax progression channel in Section 5.2.1 where we introduce (sector-specific) employer taxes.

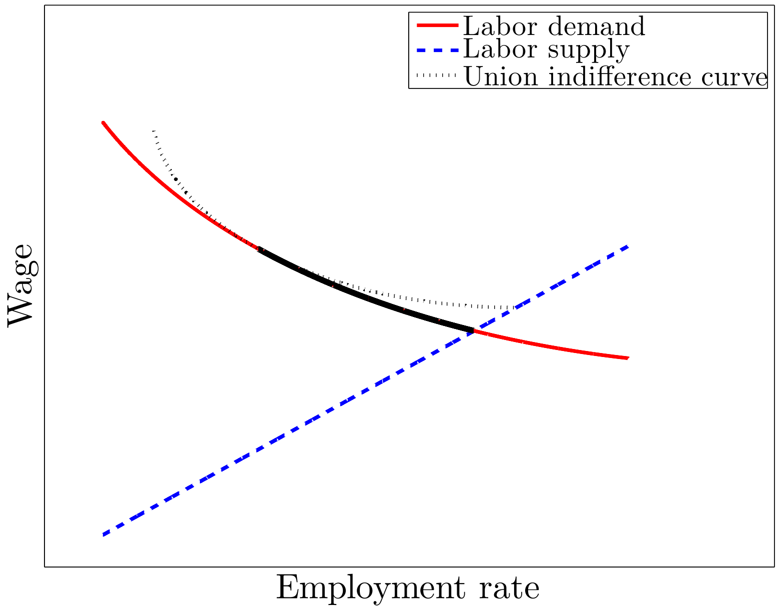

Figure 2: Labor market equilibria in the Right-to-Manage model

$u(\hat{c}_i) = u(c_u)$. Labor supply is then equal to:

$$E_i = G(w_i - T_i + T_u). \tag{13}$$

The competitive equilibrium is found by combining labor supply (13) and labor demand (5). Since there is no involuntary unemployment in this case, we have $\hat{\varphi}_i = \bar{\varphi}_i$. A reduction in either the income tax T_i or the unemployment benefit $-T_u$ boosts labor-force participation, which leads to a lower wage and a higher employment rate.

The competitive labor-market outcome and the Monopoly-Union outcome represent the two polar opposite cases in our analysis. We will employ some version of the RtM-model that allows for any intermediate degree of union power. This pattern is graphically illustrated in Figure 2. The competitive equilibrium lies at the intersection of the labor supply curve and the labor demand curve, which correspond to equations (13) and (5), respectively. The MU-outcome, in turn, lies at the point where the union's indifference curve is tangent to the labor demand curve. This point can be found by combining the union's first-order condition (12) with the labor demand schedule (5). In our specification of the labor market, any point on the bold part of the labor demand curve corresponds to an equilibrium in the RtM-model. The higher (lower) is the union's bargaining power, the closer will the outcome lie to the monopoly-union outcome (competitive outcome).

We characterize the equilibrium by some version of the RtM model. The union's bargaining power in sector i (or the degree of unionization in sector i) is denoted by $\rho_i \in [0, 1]$. This parameter determines which point of the labor demand curve between MU and CE is reached in the wage negotiations. In Appendix A we provide a microfoundation for ρ_i based on the standard RtM-model with Nash-bargaining between unions and firms. We demonstrate that there exists a monotonic relationship between ρ_i and the weight of the union in the Nash-product. Hence, our short-cut is without loss of generality and allows us to fully analytically trace down the implications of changing union power, while avoiding a number of unimportant analytical complications. Using ρ_i as our measure of the union's bargaining power, we characterize the equilibrium in the RtM-model as follows:

$$\rho_i = \varepsilon_i \frac{u(\hat{c}_i) - u(c_u)}{\overline{u'(c_i)}w_i}. \tag{14}$$

When $\rho_i = 1$, this outcome corresponds to the equilibrium of in the MU-model and when $\rho_i = 0$, the competitive outcome applies. Consequently, $0 < \rho_i < 1$ corresponds to any intermediate case of the RtM-model. The higher (lower) is ρ_i, the higher (lower) is the wage. As a result, the bargained wage is lower and employment is higher in the RtM-model than in the MU-model. The relationship between unions' bargaining power and unemployment (or, equivalently, real wages) is thus increasing in our model, rather than hump-shaped as in Calmfors and Driffill (1988). The interpretation of the expression is otherwise the same as in the case of the monopoly union.

3.4 Government

The government's is assumed to have the following utilitarian objective:[16]

$$\mathcal{W} \equiv \sum_i N_i(E_i\overline{u(c_i)} + (1 - E_i)u(c_u)) + u(c_f). \tag{15}$$

The government aims to maximize this objective by transferring resources between firm-owners, employed workers (in various occupations), and unemployed workers. The government observes the employment status of all workers, as well as wages (assumed to vary across occupations) and profits.[17] Tax policy cannot be conditioned on participation costs φ, which are private information. Consequently, the government cannot redistribute income between workers in the same sector who face different participation costs, and is furthermore unable to distinguish between workers who chose not to participate and those who did not manage to find a job. This results in a second-best problem where the government needs to resort to distortionary taxes and transfers to redistribute income.

In line with the informational assumptions, the government can set (sector-specific) income taxes T_i, as well as a profit tax T_f to finance an unemployment benefit $-T_u$ and an exogenous revenue requirement. Allowing the government to choose sector-specific income taxes T_i is – within our discrete-sector model – equivalent to letting the government choose a fully non-linear

[16]The utilitarian specification is without loss of generality, since one can allow for stronger redistributional desires by adopting a more concave cardinalization of the utility function or adopt a concave transformation of individual utilities.

[17]We ignore the possibility that workers of different occupations may earn the same gross wage. There is little reason to believe that gross wages will be the same, since workers in different occupations generally vary in terms of their marginal productivities, participation costs, and the bargaining power of the union representing them.

income tax.[18] The government's budget constraint reads:

$$\sum_i N_i(E_iT_i + (1-E_i)T_u) + T_f = R. \tag{16}$$

3.5 General equilibrium

Wages w_i and employment rates E_i in each sector i follow from simultaneously solving the wage mark-ups (14) and labor demand equations (5). Goods market equilibrium, in turn, requires that all consumption demands and the revenue requirement from the government equal production:

$$F(K, N_1E_1, \cdots, N_IE_I) = \sum_i \int_{\underline{\varphi}}^{\hat{\varphi}_i} N_i(c_{i,\varphi} + \varphi)\mathrm{d}G(\varphi) + \sum_i N_i(1-E_i)c_u + c_f + R. \tag{17}$$

Note that if the budget constraints of workers and firm-owners and the governments budget constraint hold, the economy's resource constraint is satisfied automatically by Walras' law.

3.6 Comparative statics

We will express the optimal tax and benefit system in terms of the elasticities of employment and wages with respect to the policy parameters T_i and T_u. For analytical convenience, we will focus on the case where there are no income effects at the union level.[19] In the absence of income effects, union's wage demands respond symmetrically to changes in either the income tax or the unemployment benefit. This allows us to express employment and wages exclusively in terms of the participation tax rate $t_i \equiv (T_i - T_u)/w_i$. Hence we can write $w_i = w_i(t_i)$ and $E_i = E_i(t_i)$. The following Lemma derives the elasticities of wages and employment with respect to the participation tax rate.

Lemma 1. *Under Assumption 1 and Assumption 2, and assuming away income effects at the union level, the wage and employment elasticities with respect to the participation tax rate t_i are given by*

$$\kappa_i \equiv \frac{\partial w_i}{\partial t_i}\frac{1-t_i}{w_i} = \frac{u_u' w_i(1-t_i)}{\hat{u}_i'\varepsilon_i E_i/g(\hat{\varphi}_i) + u_u' w_i(1-t_i) - (\hat{u}_i - u_u)\left(1 + \varepsilon_i\varepsilon_{\varepsilon_i} + \varepsilon_i\frac{(\overline{u_i'} - \hat{u}_i')}{\overline{u_i'}}\right)} > 0, \tag{18}$$

$$\eta_i \equiv -\frac{\partial E_i}{\partial t_i}\frac{1-t_i}{E_i} = \frac{\varepsilon_i u_u' w_i(1-t_i)}{\hat{u}_i'\varepsilon_i E_i/g(\hat{\varphi}_i) + u_u' w_i(1-t_i) - (\hat{u}_i - u_u)\left(1 + \varepsilon_i\varepsilon_{\varepsilon_i} + \varepsilon_i\frac{(\overline{u_i'} - \hat{u}_i')}{\overline{u_i'}}\right)} > 0, \tag{19}$$

where $\varepsilon_{\varepsilon_i} \equiv \frac{\partial \varepsilon_i}{\partial E_i}\frac{E_i}{\varepsilon_i} = -\left(1 + \frac{1}{\varepsilon_i} + \frac{E_iF_{iii}}{F_{ii}}\right)$ is the elasticity of the labor-demand elasticity with respect to the employment rate, and the elasticities are related via $\eta_i = \varepsilon_i\kappa_i$.

Proof. See Appendix B. □

[18] As argued before, however, by letting the government choose income tax *levels*, we ignore the impact of tax *progressivity* on union behavior. We emulate this channel when we introduce employer taxes in Section 5.2.1.

[19] In Appendix C.3 we derive the optimal tax structure with income effects, and demonstrate that allowing for income effects brings no substantive economic insights.

The signs of the elasticities follow from the observation that both an increase in the income tax and an increase in the unemployment benefit motivate unions to increase their wage demands. Consequently, an increase in the participation tax rate t_i – brought about by either an increase in the income tax T_i or the unemployment benefit $-T_u$ – unambiguously raises the union's wage demands. The latter, in turn, reduces employment through the impact on labor demand.

4 Optimal taxation

The government optimally chooses unemployment benefits $-T_u$, profit taxes T_f and participation tax rates t_i in order to maximize its objective (15), subject to the budget constraint (16), the firm's labor demand equations (5), and wage mark-ups (14).[20]

To characterize the optimal tax policy, let us first define the social welfare weights of different groups of individuals:

$$b_i = \frac{\overline{u'(c_i)}}{\lambda}, \quad b_u = \frac{u'(c_u)}{\lambda}, \quad b_f = \frac{u'(c_f)}{\lambda}. \tag{20}$$

The welfare weight b_j measures the monetized increase in social welfare resulting from a one-unit increase in the incomes of individuals belonging to group j. We furthermore define the labor shares of workers ω_i and the unemployed ω_u as:

$$\omega_i = \frac{N_i E_i}{\sum_j N_j}, \quad \omega_u = \frac{\sum_i N_i(1-E_i)}{\sum_j N_j}. \tag{21}$$

The following Proposition describes the optimal tax policy:

Proposition 1. *When unemployment benefits $-T_u$, profit taxes T_f and participation tax rates t_i are optimally set, the following conditions must hold:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{22}$$

$$b_f = 1, \tag{23}$$

$$\left(\frac{t_i + \tau_i}{1-t_i}\right)\eta_i = (1-b_i) + (b_i - 1)\kappa_i, \tag{24}$$

where $\tau_i \equiv \frac{u(\hat{c}_i)-u(c_u)}{\lambda w_i} = \frac{\rho_i b_i}{\varepsilon_i}$ is the implicit tax on employment due to unions.

Proof. See Appendix C □

Equation (22) states that a weighted average of the welfare weights of the employed and unemployed workers should sum to one. Intuitively, the government uniformly raises transfers to all individuals until the marginal utility benefits of doing so – expressed in money units – of a higher transfer (left-hand side) equal the unit marginal costs of providing everyone with

[20]It is more convenient to optimize over participation tax rates t_i rather than income taxes T_i. In the absence of income effects, equilibrium employment rate and wage in sector i are a function only of the participation tax rate t_i. Since income and participation taxes are related via $t_i = (T_i - T_u)/w_i$, the outcomes under both procedures are equivalent. An additional benefit is that we can relate our results more easily to earlier studies who derive optimal participation taxes (e.g., Diamond, 1980, Saez, 2002 and Christiansen, 2015).

a marginally higher transfer (right-hand side). This confirms the intuition from Jacobs (2013) that the marginal cost of public funds equals one in the policy optimum even under distortionary taxation.[21] A direct implication of this result is that the social welfare weight of some groups of workers will exceed one, while for others their welfare weight is below one. Because the welfare weight of the non-employed always exceeds the welfare weights of the different groups of employed workers, it must be that $b_u > 1$. For condition (22) to remain valid, there must be at least one group of workers i for whom $b_i < 1$. This, however, does not imply that the welfare weight of *all* employed workers are below one. Depending on the redistributive preferences of the government, there may also be employed workers whose welfare weight is above one. In the remainder, we will refer to workers for whom $b_i > 1$ as the low-income, or low-skilled workers.

Equation (23), in turn, states that the government taxes firm-owners until their welfare weight equals one. Since the profit tax is a non-distortionary tax, the government raises profit taxes until it is indifferent between raising firm-owners' consumption with one unit and receiving a unit of public funds.

The optimal participation tax rate t_i is determined by equation (24). The left-hand side of this expression captures the total distortions of participation taxes in sector i. The right-hand side gives the distributional gains of participation taxes in sector i.

The total wedge on labor is $\frac{t_i+\tau_i}{1-t_i}$ and consists of the explicit tax on participation t_i, and the union wedge, which acts as an *implicit* tax on labor. $\tau_i \equiv (u(\hat{c}_i) - u(c_u))/(\lambda w_i) = \rho_i b_i/\varepsilon_i$ measures the loss in social welfare when the marginal worker in sector i loses employment – expressed in money units as a fraction of gross earnings in sector i. The implicit tax is proportional to the union's bargaining power and measures distortions of unions bidding up wages above the market-clearing level. The implicit tax on labor τ_i is zero either when the union has zero bargaining power ($\rho_i = 0$), or when labor demand becomes infinitely elastic ($\varepsilon_i = \infty$). In the latter case, unions refrain from demanding a wage that is above the market-clearing level, since this would result in a complete breakdown of employment.

Naturally, optimal participation taxes are lower when employment reacts strongly to taxation (i.e., when η_i is large). However, an increase in t_i not only lowers the number of people willing to participate, but also affects involuntary unemployment. Intuitively, an increase in either the income tax or the unemployment benefit makes employed workers worse off relative to unemployed workers. The union in sector i responds by demanding higher wages, thereby creating more involuntary unemployment. The social loss of more involuntary unemployment is measured by the implicit tax on work τ_i. The larger is the implicit tax, the more distortionary are participation taxes, and the lower should they be set.

Alternatively, equation (24) shows that the government should set lower participation taxes in sectors where the welfare gains from lowering involuntary unemployment are high, i.e., in sectors where τ_i is large. By inducing unions to moderate their wage claims, low participation taxes alleviate the welfare costs of involuntary unemployment. Hence, when the welfare costs of unemployment are very high, participation tax rates should optimally be lowered.

The right-hand side gives the (24) distributional benefits (or costs) of increasing the participation tax rate by raising income taxes T_i. First, if workers in sector i have a welfare weight

[21]We show in Appendix C.3 that a very similar result holds in the presence of income effects.

below 1 ($b_i < 1$), the government wishes to tax the workers in this sector in order to redistribute income to other individuals (who have an average welfare weight of one). Second, higher participation taxes raise wage demands, which reduce the income of firm-owners. Participation taxes thus indirectly redistribute resources from the firm-owners towards the workers via higher wage demands. This is socially desirable if the workers in sector i have a higher welfare weight than the firm owners ($b_i > 1$). In that case, participation taxes should be higher the more responsive are wages increase to increases in the participation tax (higher κ_i).

Like in Diamond (1980) and Saez (2002) we find that it is optimal to subsidize participation on a net basis (i.e., setting $t_i < 0$) for low-income workers whose welfare weight is above one, i.e., when $b_i > 1$. However, unlike in these studies, subsidizing participation can also be optimal for workers whose welfare weight is below unity ($b_i < 1$). This happens whenever the welfare costs of involuntary unemployment resulting from unions is very high, so that the implicit tax rate τ_i is large. This finding demonstrates that income taxes (or subsidies) are not only used to redistribute income, but also serve to alleviate the labor-market distortions induced by unions. With unions, it may therefore be optimal to subsidize participation even for workers whose welfare weight falls short of one, which never occurs in Diamond (1980) and Saez (2002).

Our optimal tax formula nest the one derived in Saez (2002) (for the case with no intensive margin) as a special case. When wages are exogenous, optimal participation taxes are determined via:

$$\frac{t_i}{1-t_i} = \frac{1-b_i}{\pi_i}, \tag{25}$$

where

$$\pi_i \equiv \frac{\partial G(\overline{\varphi}_i)}{\partial \overline{\varphi}_i} \frac{\overline{\varphi}_i}{G(\overline{\varphi}_i)} \tag{26}$$

denotes the participation elasticity in sector i. When labor demand is infinitely elastic, equations (24) and (25) coincide. In this case, unions will always refrain from demanding above market-clearing wages. Consequently, wages are essentially exogenous and the result from Saez (2002) applies.

The result from Saez (2002) also holds in a perfectly competitive labor market with endogenous wages, which in our model corresponds to the case with $\rho_i = 0$. Hence, when labor markets are competitive, labor-demand considerations are irrelevant for the characterization of optimal participation taxes. This result is derived as well in Christiansen (2015), and is a version of what is labeled by Saez (2004) the 'Tax-Formula result' due to Diamond and Mirrlees (1971a,b). When $\rho_i > 0$ and labor demand is not perfectly elastic, labor-demand considerations are no longer irrelevant in the optimal tax formulae, since they interfere with the union behavior. By affecting the unions' behavior, the labor-demand elasticity enters the general-equilibrium employment elasticity η_i, the wage elasticity κ_i, and the union wedge τ_i. This finding is consistent with Jacquet et al. (2012), who derive an expression for the optimal participation tax in a model with matching frictions on the labor market. They also identify a crucial role for the labor-demand elasticity.

4.1 Restricted profit taxation

Some studies analyze the role of unions to redistribute profits to workers, see, e.g., Fuest and Huber (1997), Koskela and Schöb (2002), Aronsson and Sjögren (2004b), Aronsson and Wikström (2011), Christiansen (2015). To investigate how these concerns affect the design of the optimal tax and benefit system, consider the case where there is a binding restriction on profit taxation. The following Corollary presents the restricted optimum when the government cannot freely choose the profit tax T_f.

Corollary 1. *When unemployment benefits $-T_u$ and participation tax rates t_i are optimally set for given levels of profit taxation T_f, the following conditions must hold:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{27}$$

$$\left(\frac{t_i + \tau_i}{1 - t_i}\right) \eta_i = (1 - b_i) + \left(\frac{b_i - b_f + (1 - b_i) t_i}{1 - t_i}\right) \kappa_i. \tag{28}$$

where $\tau_i \equiv \frac{u(\hat{c}_i) - u(c_u)}{\lambda w_i} = \frac{\rho_i b_i}{\varepsilon_i}$ is the implicit tax on employment due to unions.

Proof. See Appendix C $\square$

The expression for the optimal participation tax rates is slightly more involved than the corresponding expression without a restriction on profit taxation (see Proposition 1). When there are limits to the extent profits can be taxed, the welfare weight of firm-owners falls short of one, i.e., $b_f < 1$. Intuitively, firm-owners have higher income than before, so their social welfare weight is lower than in the case without a binding restriction on profit taxation. This provides an additional rationale for levying participation taxes. Participation taxes, by motivating unions to increase their wage demands, indirectly redistribute resources from firm-owners to workers. The welfare effect proportional to $b_i - b_f$ and weighed by the elasticity of wages with respect to the participation tax rate. Equation (28) thus states that the more binding is the restriction on profit taxation (i.e. the lower is b_f), the higher should participation taxes be set, as this indirectly brings about redistribution from firm-owners to workers. Furthermore, because we characterize the optimum by letting the government choose optimal participation tax *rates* t_i rather than income taxes T_i, higher wages also redistribute resources from workers in sector i to the government. This is reflected by the second term in the numerator on the right-hand side.[22] When profit taxation is unrestricted, $b_f = 1$ and the result from Proposition 1 applies.

[22]This term, however, merely appears only for mechanical reasons, not because the government actually levies proportional taxes on income gains. If this were the case, also the union's mark-up equation would have to be modified. The decision variables of the government consist of income taxes T_i rather than participation tax rates t_i, in addition to the unemployment benefit $-T_u$. The reason to characterize the optimum in terms of the participation tax rates is because this allows us to relate the results more easily to earlier literature.

5 Desirability of unions and the optimal degree of unionization

5.1 Desirability of unions

The previous section analyzed the optimal tax-benefit system when labor markets are unionized. 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 addresses both these points.

Proposition 2. *If taxes and transfers are set according to Proposition 1, increasing the bargaining power ρ_i of the union 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 D. □

Proposition 2 implies that, despite the fact that unions distort an efficient functioning of the labor market, it is socially desirable to let low-income workers organize themselves in a union. To understand why, consider the introduction of a union in a low-income sector where wages were initially determined competitively. That is, consider a marginal increase in ρ_i above zero in a sector where $b_i > 1$.

The introduction of a union will lead to an increase in the wage and an accompanying decrease in the rate of employment, as illustrated in Figure 2. When $b_i > 1$ and labor markets are competitive, participation is subsidized on a net basis in the policy optimum (see equation (25)). As a result, labor participation is distorted *upwards*: too many low-skilled workers decide to participate. Unions alleviate this distortion by putting upward pressure on the wage, which leads to lower employment and hence, higher government revenue. Moreover, the rise in the equilibrium wage is an implicit transfer from firm-owners (whose welfare weight is one) to employed workers in sector i (whose welfare weight is above one), which raises social welfare. Furthermore, starting from the competitive labor-market outcome without unemployment, a marginal increase in unemployment does not lead to a utility loss of the workers who lose their job, since rationing is assumed to be efficient. Indeed, the employed workers who enter unemployment first following the introduction of the labor union are indifferent between employment and non-employment. Summing up, it is immediately implied that the introduction of a union unambiguously raises social welfare when the welfare weight of the workers in this sector is larger than one ($b_i > 1$).

The reverse is also true: there is no role for a union in a sector where the social welfare weights of the workers in sector i is smaller than one, i.e., $b_i < 1$. When $b_i < 1$ and labor markets are competitive, participation is taxed on a net basis. Compared to the efficient level, there is now too little employment. Raising union power ρ_i will reduce employment even further, which is accompanied by a loss in tax revenues. Moreover, the increase in the wage brings about an implicit transfer from firm-owners (whose welfare weight is one) to employed workers in sector i (whose welfare weight is now below above one), which lowers social welfare. Thus, when $b_i > 1$, unions exacerbate pre-existing labor-market distortions even further by creating involuntary unemployment.

Another way to understand the efficiency-enhancing role of unions is the following. Consider an exogenous, marginal increase in union power ρ_i starting from an arbitrary degree of ρ_i in an initially optimized tax system. High union power puts upward pressure on the wage – *ceteris paribus*. Suppose, however, that the government offsets this wage increase by lowering the income tax T_i, such that the wage and, hence, the employment rate, remain unaffected. The loss in tax revenue, in turn, can be financed by raising the profit tax.[23] This policy intervention brings about a transfer in resources from firm-owners (whose welfare weight is one) to low-skilled workers (whose welfare weight exceeds one). There is, however, another effect: *voluntary* unemployed is substituted for *involuntary* unemployment. Due to the rise in the net income for the low-skilled, more workers want to participate.[24] From a welfarist perspective, however, the distinction between voluntary and involuntary unemployment is immaterial, since utilities – and thereby social welfare levels – in both states are the same. Hence, the total welfare effect of the policy reform is proportional to $b_i - 1$.

It is worthwhile to point out that the result stated in Proposition 2 also applies when there is a binding restriction on profit taxation. Hence, also when the welfare weight of firm-owners falls short of one will an increase in union bargaining power only lead to higher social welfare if the union represents workers whose welfare weight exceeds one. As illustrated above, unions allow the government to redistribute income in a lump-sum way to the workers represented by a union. The latter is desirable if and only if the workers' welfare weight exceeds one, irrespective of whether there is a restriction on profit taxation.

5.2 Optimal degree of unionization

We also take a first pass at addressing the question: what is the socially optimal degree of unionization? Suppose that the government could impose the bargaining power of unions ρ_i at no costs, how would it choose to set the bargaining power of each union relative to that of the firm-owners?[25] The results are summarized in the next Corollary.

Corollary 2. *If taxes and transfers are set according to Proposition 1, then the optimal degree of unionization in each sector i equals $\rho_i = \min[\rho_i^*, 1]$ whenever $b_i \geq 1$, and $\rho_i = \max[\rho_i^*, 0]$ whenever $b_i \leq 1$, where ρ_i^* is the bargaining power of the union required to make the social welfare weight of workers in sector i equal to one: i.e., $\rho_i = \rho_i^*$ whenever $b_i = 1$.*

Proof. See Appendix D. □

Corollary 2 states that for workers whose social welfare weight exceeds one (i.e., $b_i \geq 1$), the bargaining power of the union representing these workers should optimally be increased until their welfare weight equals one. If this is not feasible, which can happen if workers have low wage

[23] Increasing the profit tax is only one way to finance the decrease in the income tax for workers in sector i. As long as the welfare costs of raising one unit of revenue with other instruments are equal to one, the argument carries over to other instruments as well.

[24] Under the assumption of efficient rationing, however, none of these workers would be able to find a job (recall that the rate of employment is kept constant).

[25] Obviously, a thorough analysis requires careful examination of whether, and at what costs, the government is able to affect unions' bargaining 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 in which unions are financed and regulated can affect the workers' bargaining power.

rates w_i, then the next best thing to do is to make the labor union a monopoly-union, i.e., to set $\rho_i = 1$. As explained above, increasing the bargaining power of workers allows the government to redistribute income towards the workers represented by this union. The opposite holds true for workers with a social welfare weight smaller than one ($b_i < 1$). The government will then lower the union's bargaining power, but it can never decrease the degree of unionization below the competitive level, i.e., where $\rho_i = 0$. Since unions only exacerbate the distortions from the tax-transfer system in sectors where $b_i < 1$, the government wishes to completely eliminate union distortions by lowering union power, and possibly even eliminate unions altogether in those sectors.

Corollary 2 bears clear similarity with the findings obtained in Lee and Saez (2008, 2012).[26] They show that, whenever rationing is efficient and labor demand is not perfectly elastic (the same conditions that unerlie Corollary 2), it is optimal to increase the minimum wage up to the point where the welfare weight of the low-income workers is equal to one. The reasoning is very similar: whenever rationing is efficient and participation decisions are distorted upwards, both a minimum wage and the introduction of a union allow the government to redistribute resources in a non-distortionary way towards low-income workers, and such income redistribution should be carried out until their welfare weight equals one.

5.2.1 Implementation

At this point, the natural question arises if and how the government can influence the unions' bargaining power to implement the allocation described by Corollary 2. Workers' bargaining power ρ_i is not a direct policy instrument, as also noted by Hungerbühler and Lehmann (2009) in a context with matching frictions. Here, we highlight one possibility to control the bargaining power of unions. We show in Appendix D that the government could use sector-specific, proportional employer taxes (i.e., payroll taxes) to indirectly control union power and implement the allocation described in Corollary 2. In particular, suppose that the government levies a proportional, sector-specific employer tax on wages denoted by θ_i. Then, the demand for type i labor reads:

$$w_i(1+\theta_i) = F_i(K, L_1, \cdots, L_I). \tag{29}$$

The wage mark-up equation, in turn, is modified to:[27]

$$\frac{\rho_i}{1+\theta_i} = \varepsilon_i \frac{u(\hat{c}_i) - u(c_u)}{\overline{u'(c_i)}w_i}. \tag{30}$$

This expression illustrates that employer taxes θ_i can serve as an instrument to control 'effective' union power $\rho_i/(1+\theta_i)$. From the union's perspective, higher wage demands are less attractive when employer taxes are high, because firms need to pay more payroll taxes when wage demands are higher. Employer taxes thus indirectly determine how much labor demand will be reduced if the unions demand a higher (pretax) wage w_i. Accordingly, the government can use employer taxes ($\theta_i > 0$) to discipline the union's wage demands. This is socially desirable whenever

[26] See Proposition 3 in Lee and Saez (2008) or Proposition 2 in Lee and Saez (2012).

[27] This equation can be derived in completely analogous fashion as in Section 3.3, with the labor demand schedule (5) replaced by equation (29).

$b_i < 1$. Equivalently, the government can use employment subsidies ($\theta_i < 0$) whenever higher wage demands are socially desirable, which is the case when $b_i > 1$. This way, employer taxes play a very similar role as tax rate progressivity, from which we have abstracted in our model.[28] Like employer taxes, a high degree of tax progression moderates wage demands and boosts employment. Optimal employer taxes ensure that effective union power $\rho_i/(1+\theta_i)$ equals the optimal degree of union power, as characterized in Corollary 2.[29]

As a final remark, it should be noted that our result regarding the desirability of unions does not disappear if we expand the set of instruments to include employer taxes. If, in our model, unions would be absent (i.e., $\rho_i = 0$ for all i), employer taxes – unlike, potentially, unions – cannot improve on the allocation that can already be achieved with the set of instruments considered (in particular, income taxes T_i, a profit tax T_f and an unemployment benefit $-T_u$). Hence, there is only a role for employer taxes *because* of wage bargaining between unions and firm-owners. In particular and as illustrated above, employer taxes can be used to bring the unions' 'effective' bargaining power at their socially optimal level, which would not be possible if unions are absent.

6 Robustness analysis

In this section, we investigate the robustness of our results by relaxing the assumption of independent labor markets (Assumption 1) and the assumption of efficient rationing (Assumption 2).

6.1 Interdependent labor markets

When Assumption 1 is violated and labor markets are interdependent (such that $F_{ij} \neq 0$ for all $i \neq j$), taxes levied in one sector will also affect labor market outcomes in other sectors. These effects have to be taken into account when designing the optimal tax-benefit system. We maintain the assumption that income effects are absent and rationing is efficient. The next Proposition generalizes Proposition 1, and characterizes the policy optimum when labor markets are interdependent.

Proposition 3. *Optimal unemployment benefits $-T_u$, profit taxes T_f, and participation tax rates t_i when labor markets are interdependent are determined by:*

$$\sum_i \omega_i b_i + \omega_u b_u = 1, \tag{31}$$

$$b_f = 1, \tag{32}$$

$$\sum_j \omega_j \left(\frac{t_j + \tau_j}{1 - t_j}\right) \eta_{ji} = \omega_i (1 - b_i) + \sum_j \omega_j (b_j - 1) \kappa_{ji}, \tag{33}$$

[28] See also the literature discussed in section 2.

[29] In fact, since the effective union power $\rho_i/(1+\theta_i)$ is not restricted to lie below one, the allocation with optimally chosen employer taxes may actually even improve on the allocation described in Corollary 2. This happens if there is a sector i for which $\rho_i^* > 1$.

where the cross elasticities of employment and wages in sector j with respect to participation taxes in sector i are defined as:

$$\eta_{ji} \equiv -\frac{\partial E_j}{\partial t_i}\frac{1-t_i}{E_j}\frac{w_j(1-t_j)}{w_i(1-t_i)}, \tag{34}$$

$$\kappa_{ji} \equiv \frac{\partial w_j}{\partial t_i}\frac{1-t_i}{w_j}\frac{w_j(1-t_j)}{w_i(1-t_i)}. \tag{35}$$

Proof. See Appendix E □

Equations (31)-(32) are identical to those stated in Proposition 1, and their discussion is not repeated here. The equation for optimal participation tax rates t_i in equation (33) is modified compared to the optimal participation tax in Proposition 1. When labor markets are interdependent, an increase in the participation tax rate in sector i affects labor market outcomes in potentially all sectors of the economy. This explains the summation in equation (33) over all sectors. As in Proposition 1, the left-hand side of equation (33) gives the marginal cost of higher participation taxes in the form of larger labor-market distortions, whereas the right-hand side gives the distributional benefits (or losses) of higher participation taxes. When the participation tax rate in sector i is increased through an increase in the income tax T_i, the union in sector i responds by increasing its wage claim. *Ceteris paribus,* this leads to a decrease in the rate of employment in sector i. When labor types are complementary, the decrease in the rate of employment in sector i brings about a decrease in the productivity of workers, and thus in labor demand, in all other sectors j. Consequently, both employment and the bargained wages in all sectors j are reduced. The reduction of employment is larger when the (scaled) cross elasticity η_{ji} of employment in sector j with respect to the participation tax rate in sector i is larger.

The right-hand side of (33) captures the distributional benefits of a higher participation tax in sector i. An increase in the participation tax rate t_i due to an increase in the income tax T_i redistributes income from workers in sector i to the government, and hence to everyone else in the economy. The associated welfare effect is proportional to $b_i - 1$. Furthermore, the change in the participation tax in sector i brings about redistribution from firm-owners (whose welfare weight is one in the optimum) to workers in sector i (whose welfare weight is b_i) via a change in w_i. In addition, there are indirect redistributional consequences in all other sectors $j \neq i$, because wages in all other sectors are reduced when participation taxes in sector i are raised. Hence, if the social welfare weights of workers in sectors j are larger than one, i.e., $b_j > 1$, the reduction in wages in sector j due to higher participation taxes in sector i is socially costly, because the social welfare weight of the firm-owners is lower. However, if the social welfare weight of workers in sectors j is smaller than one, i.e., $b_j < 1$, the reduction in wages in sector j is socially beneficial, because the social welfare weight of the firm-owners is higher. The strength of these cross-sectoral redistributions of income between firm-owners and workers is determined by the wage elasticity κ_{ji} in sector j with respect to the participation tax rate in sector i. When labor markets are independent, $\eta_{ji} = \kappa_{ji} = 0$ for all $j \neq i$ and the result from Proposition 1 applies.

When labor markets are competitive, such that $\tau_i = 0$ for all i, the result of Saez (2002) (restated in equation (25)) still applies. Hence, when wages are competitively determined, the optimal tax formulae do not correct for spillover effects between different segments of the labor market. This result, also obtained in Christiansen (2015), follows from the more general Tax-Formula Result due to Diamond and Mirrlees (1971a,b). When prices are endogenously determined, the optimal tax formulae do not account for the impact of taxation on (producer) prices, provided that profit taxation is unrestricted. Therefore, the expression for optimal participation tax rates are the same when labor markets are interdependent or not.

Turning to the question whether or not unions are desirable when labor markets are interdependent, we find that Proposition 2 generalizes completely. In particular, an increase in union bargaining power ρ_i raises social welfare if and only if the social welfare weight of the workers exceeds one, i.e., $b_i > 1$. The reason is that, as explained before, increasing the bargaining power of a union in a particular sector allows the government to *de facto* redistribute income in a lump-sum way towards those working in this sector (provided that rationing is efficient), irrespective of whether labor markets are interdependent or not. While increasing the union's bargaining power in sector i puts upward pressure on the wage in sector i, this effect can be perfectly offset by changing the income taxes T_i in sector i, such that no change in wages and employment in sector i results. Because there are no changes in employment or the wage in sector i, there are also no changes in employment and wages in sector j either, irrespective of whether labor markets are independent or not. Hence, our earlier argument extends to the case with interdependent labor markets. In particular, to finance the tax cut in sector i, the government needs to increase taxes elsewhere. This can done by increasing profit taxes T_f or lowering benefits T_u. Since the average social welfare weight for firm-owners or the average weight of all workers equals one in the policy optimum, the policy raises (lowers) social welfare if and only if the social welfare weight of workers in sector i exceeds (falls short of) one.

6.2 Inefficient rationing

We have deliberately biased our findings in favor of unions by assuming that unemployment rationing is efficient: whenever involuntary unemployment occurs, the burden of unemployment is always borne by the workers who have the lowest surplus from working. However, there are neither theoretical nor empirical reasons to expect that labor market rationining is always efficient (Gerritsen and Jacobs, 2014). Therefore, in this section we analyze how the optimal tax formulae should be modified, and under which condition unions are still desirable when this assumption is relaxed.

We follow Gerritsen and Jacobs (2014) and citetgerritsen2016 by modelling the rationing scheme using conditional employment probabilities. In particular, the rationing schedule is a function $e_i(E_i, \bar{\varphi}_i, \varphi)$ which specifies the employment rate $e_i \in [0,1]$ of workers in sector i with participation costs $\varphi \in [\underline{\varphi}, \bar{\varphi}_i]$ for a given level of aggregate employment E_i and a given participation threshold $\overline{\varphi}_i$. Using this definition, the following relationship must hold identically for all values of the employment rate E_i and the participation cut-off $\bar{\varphi}_i$:

$$\int_{\underline{\varphi}}^{\bar{\varphi}_i} e_i(E_i, \bar{\varphi}_i, \varphi)\mathrm{d}G(\varphi) \equiv E_i, \quad \forall i. \tag{36}$$

The function $e_i(\cdot)$ is assumed to be differentiable, increasing in its first and decreasing in its second argument, i.e., $e_{iE_i}(\cdot), -e_{i\overline{\varphi}_i}(\cdot) > 0$. An example of a rationing scheme that satisfies the above criteria is a uniform rationing scheme, a case considered in Lee and Saez (2008). When rationing is uniform, all workers willing to participate face the same probability of (not) finding a job. This case corresponds to setting $e_i(E_i, \bar{\varphi}_i, \varphi) = E_i/G(\bar{\varphi}_i)$ for all values of $\varphi \in [\underline{\varphi}, \bar{\varphi}_i]$. The following Proposition generalizes the optimal tax formulae to account for inefficient rationing.

Proposition 4. *Assume that the employment probability of worker $\varphi \in [\underline{\varphi}, \bar{\varphi}_i]$ in sector i is $e_i(E_i, \bar{\varphi}_i, \varphi)$. Under Assumption 1 and in the absence of income effects, the optimal tax formulae are given by*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{37}$$

$$b_f = 1, \tag{38}$$

$$\left(\frac{t_i + \hat{\tau}_i}{1 - t_i}\right)\eta_i - \left(\frac{\psi_i}{1 - t_i}\right)\gamma_i = (1 - b_i) + (b_i - 1)\kappa_i, \tag{39}$$

where the definition of the union wedge τ_i is modified to

$$\hat{\tau}_i \equiv \int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{iE_i}(E_i, \overline{\varphi}_i, \varphi)\left(\frac{u(w_i(1 - t_i) - T_u - \varphi) - u(-T_u)}{\lambda w_i}\right)\mathrm{d}G(\varphi), \tag{40}$$

and ψ_i denotes the 'rationing wedge', defined as

$$\psi_i \equiv \frac{e_i(E_i, \overline{\varphi}_i, \overline{\varphi}_i)}{E_i/G(\overline{\varphi}_i)} \int_{\underline{\varphi}}^{\bar{\varphi}_i} \frac{e_{i\bar{\varphi}_i}(E_i, \bar{\varphi}_i, \varphi)}{\int_{\underline{\varphi}}^{\bar{\varphi}_i} e_{i\bar{\varphi}_i}(E_i, \bar{\varphi}_i, \varphi)\mathrm{d}G(\varphi)}\left(\frac{u(w_i(1 - t_i) - T_u - \varphi) - u(-T_u)}{\lambda w_i}\right)\mathrm{d}G(\varphi). \tag{41}$$

Finally, $\gamma_i \equiv -\frac{\partial G(\overline{\varphi}_i)}{\partial t_i}\frac{1-t_i}{G(\overline{\varphi}_i)} > 0$ denotes the participation elasticity with respect to the participation tax rate in sector i.

Proof. See Appendix F. □

Equations (37) and (38) are identical to those stated in Proposition 1 and their explanation is not repeated here. The expression for the optimal participation tax rate (39) again equates the distortionary costs (left-hand side) of a higher participation tax rate to the distributional gains of a higher participation tax rate (right-hand side). Compared to equation (24), the expression for the optimal participation tax is modified in two ways. First, with a general rationing scheme, the union wedge $\hat{\tau}_i$ no longer measures the monetized utility loss of the *marginal* worker, but instead the expected utility loss of the *rationed* workers. Second, in addition to the union wedge $\hat{\tau}_i$, there is a distortion associated to the inefficiency of the rationing scheme. The latter is captured by the 'rationing wedge' ψ_i.

To understand this term, consider the case where the participation tax rate t_i is lowered, but the union refrains from demanding a higher wage, so that also the employment rate remains unaffected. Following the reduction in the participation tax rate, more people want to participate. When rationing is efficient, none of the new participants would be able to find a job. However, when rationing is inefficient, this is no longer the case. In particular, a fraction $e_i(E_i, \overline{\varphi}_i, \overline{\varphi}_i)$ of the workers who are at the participation margin (i.e., those who are indifferent between employment and non-employment) will succeed in finding a job. With a constant employment rate, this comes at the cost of other workers losing their job. The term ψ_i captures the welfare costs that results from the inefficient allocation of jobs over the participants. The welfare losses of inefficient rationing increase in the participation elasticity with respect to the participation tax rate, as captured by γ_i. When rationing is efficient, the employment probability for the marginal participant is zero, i.e., $e_i(E_i, \overline{\varphi}_i, \overline{\varphi}_i) = 0$. Hence, in that case we have $\psi_i = 0$. The higher is ψ_i, i.e., the more inefficient the rationing scheme, and the *higher* should be the optimal participation tax rate. The intuition is similar to Gerritsen (2016). By setting a higher participation tax, the government replaces involuntary unemployment by voluntary unemployment, and thereby reduces the inefficiency of labor market rationing. In particular, a higher participation tax discourages participation. This induces the workers who care least about finding a job to opt out of the labor market and increases the employment prospects of the workers who experience a higher surplus from working.

To answer the question whether it is still optimal to increse the union's bargaining power, we consider the following policy reform (starting from a situation where taxes are optimally set):

1. Starting from an arbitrary degree of union power $\rho_i \in [0, 1)$, the union's power in sector i is marginally increased.

2. There is a simultaneous reduction in the income tax T_i in sector i such that the gross wage w_i, and hence the rate of employment E_i, are kept constant.[30]

3. The reduction in the income tax is financed by an increase in the profit tax T_f to ensure that the government budget remains balanced.

The next Corollary gives the condition under which an increase in the union's bargaining power improves social welfare when rationing is no longer efficient:

Corollary 3. *Consider the case where taxes are set in accordance with Proposition 4. Then, an increase in the union i's bargaining power ρ_i raises social welfare if*

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

Proof. See Appendix F. □

The proposition can be understood as follows. By construction of the policy reform, there are no welfare effects associated with changes in equilibrium wages and employment rates. The reduction in the income tax raises the welfare of type-i workers with $-N_i E_i b_i \mathrm{d}T_i$. The increase in the profit tax lowers the welfare of the firm-owners with $-b_f \mathrm{d}T_f = b_f N_i E_i \mathrm{d}T_i = N_i E_i \mathrm{d}T_i$, where the first equality follows from the balanced-budget assumption and the second from the notion that the welfare weight of the firm-owners equals one when the profit tax is optimally set. When labor-market rationing is efficient, these are all the relevant effects. Hence, the total

[30]This implies that also the wages and employment rates in other sectors remain unaffected, even when labor markets are interdependent (see Section 6.1). Hence, our analysis does not require labor markets to be independent.

welfare effect from the reform is proportional to $b_i - 1$, which confirms the result from Proposition 2. This is no longer true when rationing is inefficient. The increase in net earnings $w_i - T_i$ in sector i increases participation in sector i. Now, if some of the (previously voluntarily) non-employed workers find a job, a welfare loss occurs because – with a constant rate of employment – this has to come at the costs of workers with lower participation costs not finding a job.

The welfare loss of inefficient rationing is captured by the second term on the right-hand side of equation (42) and is proportional to the rationing wedge ψ_i, and the participation elasticity γ_i. Corollary 3 states that the more inefficient the rationing scheme is, or the higher is the participation elasticity (i.e., the higher are ψ_i and γ_i), the less likely it is that an increase in the bargaining power of the union in this sector is socially desirable. By increasing net incomes, unions raise the participation rate, while rationing the number of jobs. The welfare costs of inefficient rationing could be so large that they completely off-set the potential welfare gains of unions. Consequently, when rationing is inefficient, it is no longer guaranteed that increasing the union power in a sector where $b_i > 1$ raises social welfare.

7 Numerical illustration

This section intends to illustrate numerically how the presence of unions affects the optimal tax and benefit system. To do so, we implement a sufficient-statistics approach developed by Kroft et al. (2015). They show that the optimal tax-benefit system in the presence of wage and (un)employment responses can be derived using only a limited number of sufficient statistics, and subsequently calibrate the optimal tax and transfer schedule using estimates of these statistics.[31] In this section, we will first identify which statistics are required to calculate the optimal tax and benefit system derived in the current paper. Next, using estimates of these elasticities and descriptive statistics provided by Kroft et al. (2015), we calculate the optimal tax-benefit system for varying degrees of unionization. In our calibration we focus on the model with independent labor markets, efficient rationing and no income effects at the union level.

In the optimal tax formulae derived in Proposition 1, two types of behavioral responses show up: the wage elasticity (κ_i) and the employment elasticity (η_i) with respect to the participation tax rate t_i. In addition, the union wedge is (inversely) related to the labor demand elasticity ε_i. These elasticities, in turn, are related via $\eta_i = \varepsilon_i \kappa_i$. Consequently, we only require estimates for two out of these three effects to calculate the optimal tax and benefit system. Of these, the labor demand elasticity is the one most frequently estimated in the empirical literature (see Lichter et al. (2014) for a recent overview). To obtain an estimate for either κ_i or η_i, we rely on the large empirical literature which estimates the impact of participation taxes on *participation rates*. Assuming the latter can be used to approximate the impact of the participation tax rate on the rate of employment, and assuming that elasticities are constant, we write the labor-

[31] In particular, they show these statistics consist of (i) the micro participation elasticity; (ii) the macro participation elasticity, which differs from the micro-elasticity through general-equilibrium effects on wages and employment probabilities; and (iii) the macro employment elasticity to taxation.

market equilibrium conditions as:

$$E_i = \zeta_i (w_i(1-t_i))^{\hat{\pi}_i}, \tag{43}$$
$$E_i = \xi_i w_i^{-\varepsilon_i}. \tag{44}$$

Equation (43) represents the combination of wages and employment rates which – for a given labor-demand elasticity and union power – solves the markup-equation (14). Hence, it is best thought of as a modified labor-supply schedule, and consequently $\hat{\pi}_i$ as a modified labor-supply elasticity (which we proxy using estimates of the participation elasticity).[32] Equation (44) gives the labor demand schedule, and ε_i the corresponding labor-demand elasticity. Combined, these relationships implicitly define the equilibrium wage and employment rate in each sector i as a function of the participation tax rate t_i, i.e., $E_i = E_i(t_i)$ and $w_i = w_i(t_i)$. The corresponding elasticities are given by:

$$\eta_i = \frac{\hat{\pi}_i \varepsilon_i}{\hat{\pi}_i + \varepsilon_i}, \quad \kappa_i = \frac{\hat{\pi}_i}{\hat{\pi}_i + \varepsilon_i}, \tag{45}$$

which measure the impact of the participation tax rate on the rate of employment and the wage, respectively.

Following Saez (2002) and Kroft et al. (2015), we parameterize the social welfare weights using the conventional CRRA-specification:

$$b_i = \frac{1}{\lambda (w_i(1-t_i) - T_u)^{\nu}}, \tag{46}$$
$$b_u = \frac{1}{\lambda (-T_u)^{\nu}}. \tag{47}$$

Here, λ refers to the multiplier on the government's budget constraint and ν measures the concavity of the social welfare function (or, equivalently, of the individual utility function).

To calculate the optimal tax and benefit system, we combine estimates of the labor-demand and participation elasticities with descriptive statistics provided by Kroft et al. (2015) on labor-market outcomes and taxes. Regarding the first, we use a labor-demand elasticity of 0.6 in our baseline simulations, which is assumed constant across sectors. This value is well within the range of estimates reported in Lichter et al. (2014). For the participation elasticity, we assume a value of 0.4 in our baseline simulations, again assumed not to vary across sectors. This value lies somewhat in between the estimates obtained for primary earners, which are typically lower, and the estimates that are obtained from exploiting EITC variation, which tend to be somewhat higher.[33] Regarding the descriptive statistics provided by Kroft et al. (2015), here we only restate the information that is directly relevant for our purposes.[34] Using U.S. data on single women, their study divides the labor market into four categories (or occupations), based on educational attainment.[35] For each of these categories, information is provided regarding (i)

[32]These elasticities would coincide when unions are absent, i.e., when $\rho_i = 0$.

[33]This is also the type of variation exploited by Kroft et al. (2015), the study from which we use the information regarding labor-market outcomes and the current tax system.

[34]For a detailed description of the data set and the type of variation that is exploited, we refer to their paper and the accompanying Online Appendix.

[35]The groups that are considered are the high school dropouts, the high school graduates, those women tho attended some college and those who obtained a bachelors degree or more.

the sample size, (ii) the rate of employment, (iii) the average wage, and (iv) the average tax bill. Also, the (average) transfer received by the unemployed is observed. Hence, for each segment of the labor market, we observe our empirical counterparts of the population sizes, as well as the labor market outcomes under the current tax system. Table 1 provides a summary of all the inputs we use in our simulations.

Table 1: Simulation Inputs

	(1) High-school dropout	(2) High-school graduate	(3) Some college	(4) Bachelors degree plus
Average wage (w_i)	10021	16925	21503	36547
Employment rate (E_i)	0.459	0.714	0.802	0.892
Average income tax (T_i)	312	3079	4733	10430
Unemployment benefit ($-T_u$)	2070	2070	2070	2070
Number of observations (N_i)	138766	334359	300242	234456
Labor-demand elasticity (ε_i)	0.6	0.6	0.6	0.6
Participation elasticity ($\hat{\pi}_i$)	0.4	0.4	0.4	0.4

Descriptive statistics are obtained from Kroft et al. (2015) and an earlier version of their paper. The values for T_i and T_u are calculated for single women without children.[36]

For details regarding the simulations, we refer to Appendix G. The main results are presented in Figures 3–5. Figure 3 plots the current and optimal second-best allocations. They are characterized by the bundles of consumption (or net incomes) and gross incomes. Figure 4 displays the current and optimal participation tax rates against the gross earnings. In both graphs, the current tax system is compared to the optimal tax-benefit system under under (i) competitive labor markets without unions (i.e., $\rho_i = 0$ for all i), (ii) a scenario with an intermediate degree of unionization (i.e., $\rho_i = 1/2$ for all i), (iii) a scenario with monopoly unions (i.e., $\rho_i = 1$ for all i). Finally, Figure 5 plots the social welfare weights of the different income groups.

Figure 4 gives our most striking finding. Participation taxes should be substantially lower in more unionized labor markets. This is in line with the theoretical prediction from Proposition 1, which stated that participation taxes should be lower the larger are the distortionary costs of unionization. The latter, in turn, are higher, the higher is the degree of unionization. When unions are strong, the optimal tax-benefit system thus combines low guaranteed incomes with substantial in-work benefits for low-skilled workers, much in the spirit of an EITC. These lower participation taxes are brought about both by lower income taxes, but most notably by lower unemployment benefits (as can be seen from Figure 3). By generating involuntary unemployment, unions raise the cost of redistributing income towards the unemployed. Consequently, both income taxes and benefits are optimally lower.

Figure 4 furthermore highlights that participation subsidies for low-income workers (i.e. negative participation taxes) are optimal only when the degree of unionization is very close to one, that is, when unions are close to monopoly unions. Optimal participation taxes at

[36] The N_i observations (which we use to calculate the population shares) also include women with children. Unfortunately, we could not correct for differences in the number of children between the different groups based on the descriptive statistics.

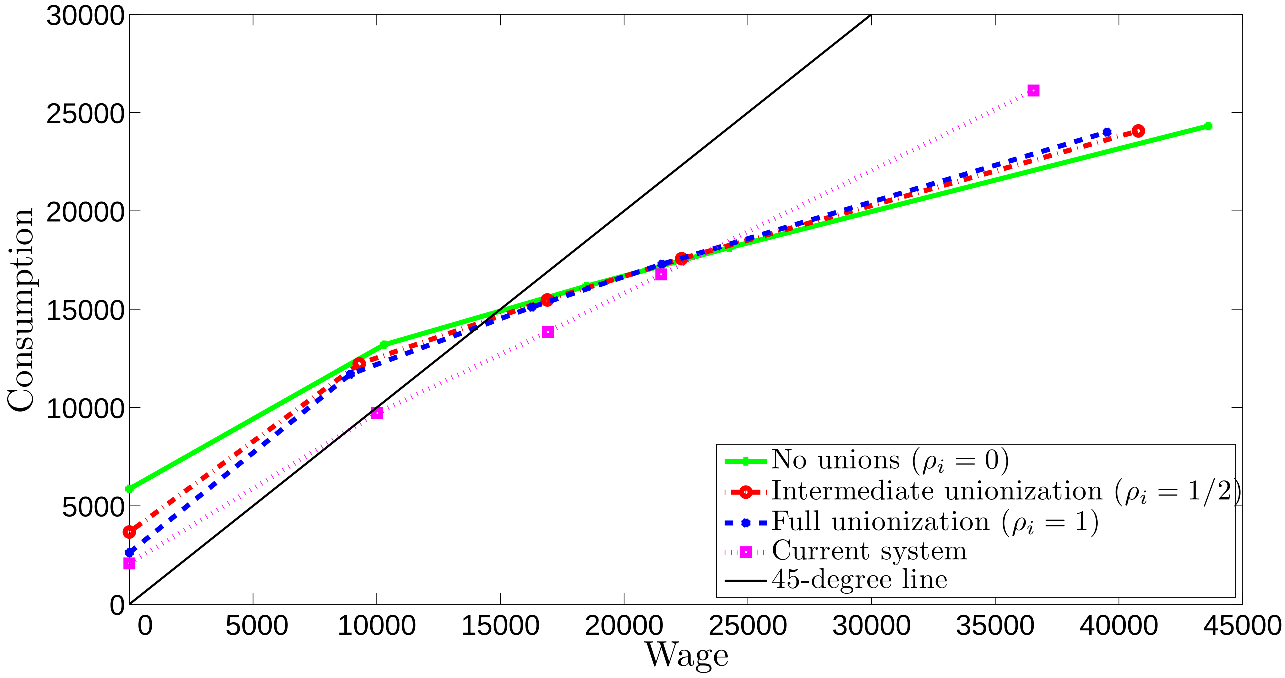

Figure 3: Optimal allocation

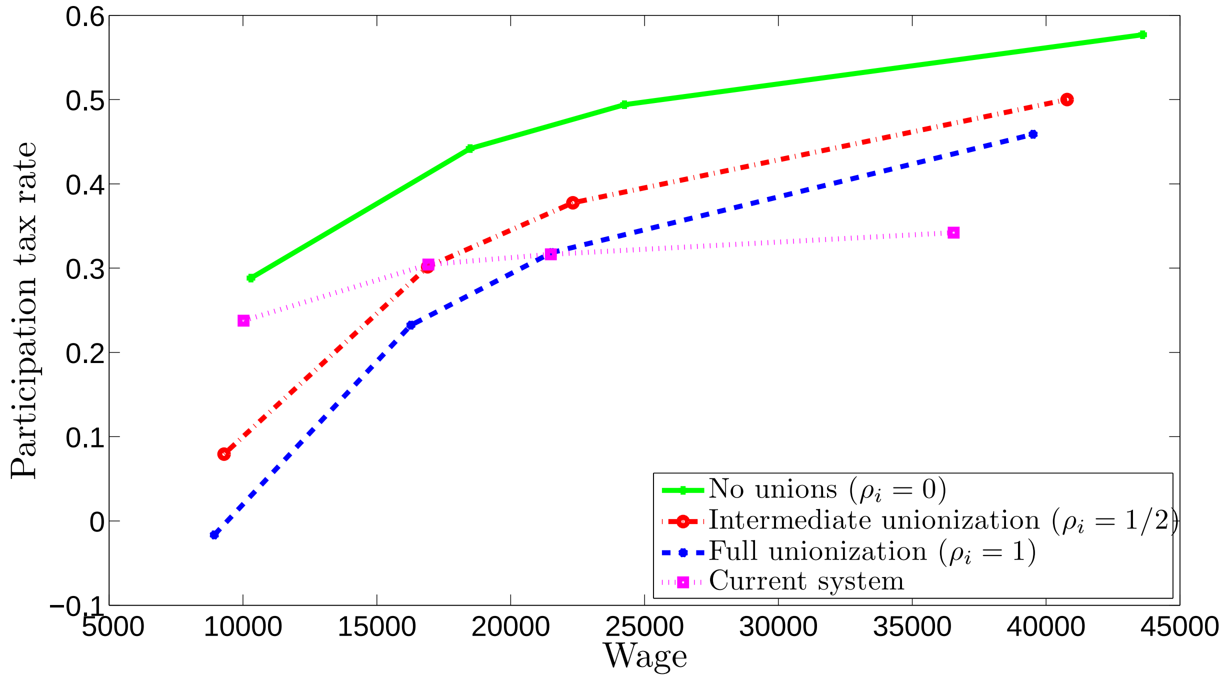

Figure 4: Participation tax rates

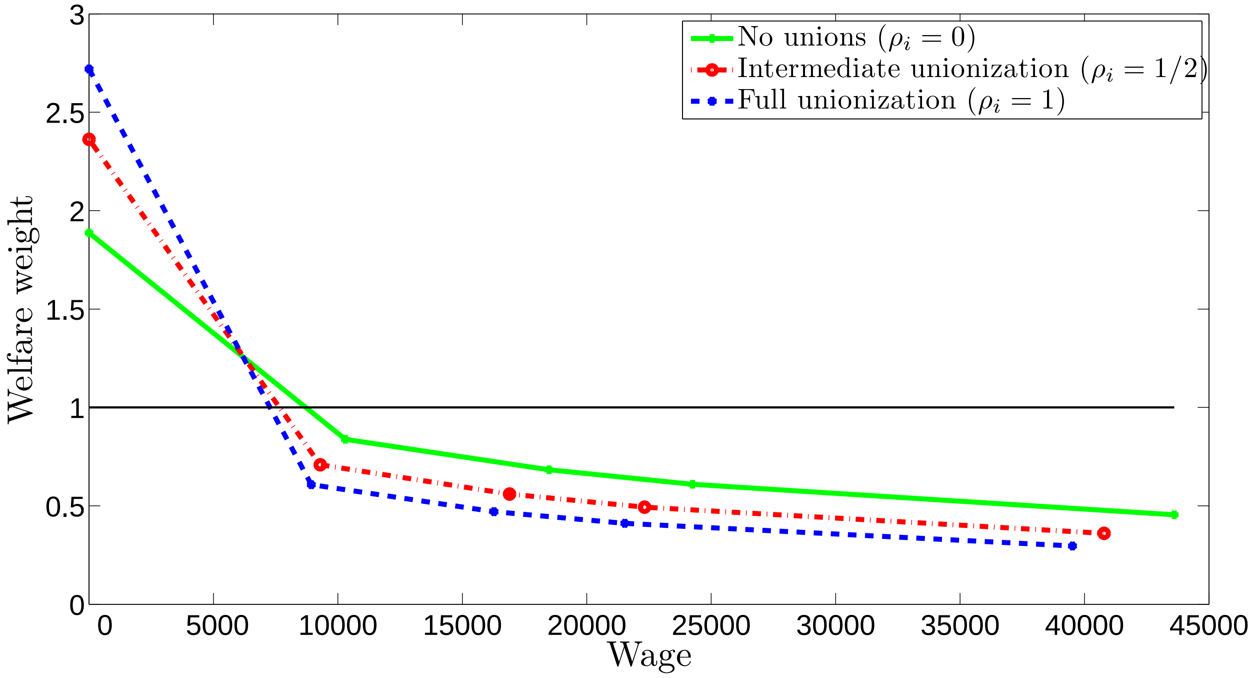

Figure 5: Welfare weights

the bottom are always positive when labor markets are (close to) competitive. Indeed, the only group whose welfare weight consistently exceeds one is the group of unemployed workers. Therefore, the only reason why a negative participation tax rate is optimal is that the tax-benefit system also aims to alleviate the distortions induced by unions. In our simulations, we thus never find the 'classical' case of an EITC based on a welfare weight larger than one. We find that an EITC may be desirable when labor markets are unionized, even though the welfare weight of low-income workers falls short of one.

The welfare weights of the different groups of workers are plotted in Figure 5. In our baseline simulations, the welfare weight for all groups of workers is below one. According to Proposition 2, an increase in the degree of unionization (irrespective for which type of workers) would therefore always lead to lower social welfare. This finding, however, should be interpreted with caution, since it relies heavily on the specification of the social welfare weights. Furthermore, we ignored participation costs in the definition of the welfare weights (see Appendix G), which biases our results against unions, while the assumption of efficient rationing biases the results in favor of unions. Therefore, it remains rather unclear whether in our models unions could be a desirable institution for redistribution. The robust finding from our simulations is that unions strongly reduce optimal participation tax rates.

8 Conclusions

The aim of this paper has been to answer two questions concerning optimal income redistribution in unionized labor markets. With respect to the question, *'How should the government optimize income redistribution when labor markets are unionized and labor supply responses are* *concentrated on the extensive margin?'*, our most important finding is that the optimal tax and benefit system is not only used to redistribute income, but also serves to alleviate the distortions induced by unions. In particular, we show that participation taxes should be lower the larger are the welfare gains from lowering involuntary unemployment. Intuitively, low income taxes and low benefits motivate the unions to moderate wage demands, which results in less involuntary unemployment. It may therefore be optimal to subsidize participation on a net basis (i.e., setting an income subsidy that exceeds the unemployment benefit) even for workers whose welfare weight falls short of one, something that can never be optimal when labor markets are competitive (see, e.g., Diamond, 1980, Saez, 2002, and Christiansen, 2015). Our simulations, based on a sufficient-statistics approach introduced by Kroft et al. (2015), suggest that optimal participation taxes can be substantially lower when labor markets are strongly unionized. Indeed, in strongly unionized labor markets, the optimal tax-benefit system features a strong EITC-component.

Concerning the question *'Can labor unions be socially desirable when the government wants to redistribute income?'*, we show that increasing the bargaining power of the unions representing workers whose welfare weight exceeds one is welfare-enhancing, while the opposite holds true for workers whose welfare weight is below one. Since Diamond (1980), it is well known that workers whose welfare weight exceeds one should optimally receive a participation subsidy. Consequently, participation decisions for these workers are distorted upwards, which results in *overemployment*. By bidding up wages, unions can reduce the distortions from taxation. However, in the typical case where participation is taxed on a net basis, employment is already too low and increasing the bargaining power of unions representing these workers lowers social welfare. Our simulations indicate that, at least in our model, the case in favor of unions – even if they would only represent the interest of the lowest-income groups – does not appear to be a particularly strong one.

In deriving our results, we have made several simplifying assumptions that warrant further research. First, we have made a crucial assumption throughout that the government is the Stackelberg leader relative to all agents in the private sector, including the unions. This assumption has not gone uncontested in the literature. Since Calmfors and Driffill (1988) it is well understood that unions may internalize some of the macro-economic and fiscal impacts of their decisions in wage negotiations.[37] Since our model features multiple unions, all of whom vary in terms of their bargaining power, it appears most most natural to assume that the government is the Stackelberg leader. However, it remains to be seen whether our results generalize to a setting where unions and the government interact strategically.

Secondly, we have abstracted from intensive margin considerations (neither the union, nor the individual could influence working hours) and, consequently, from the wage-moderating effect of tax progression (see, e.g., Aronsson and Sjögren, 2004b). By following the convention in extensive labor-supply models to let the government choose tax levels (see, e.g., Diamond, 1980, Saez, 2002, Choné and Laroque, 2011, Christiansen, 2015), marginal tax rates are zero by construction and do not affect the wage-employment trade-off faced by unions. We emulated

[37] In particular, Boeters and Schneider (1999) and Aronsson and Wikström (2011), among others, consider the case where the union is the Stackelberg leader. In both these studies, and in contrast to our paper, there is only one type of labor and consequently only one union, which is assumed to have full bargaining power.

this channel in our model by introducing employer taxes. Nevertheless, it remains interesting to see how our results would be affected when the union's decisions would be influenced by marginal tax rates, especially if the model would be extended to include an intensive margin. These provide interesting avenues for future research.

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A Derivation of ρ_i from the Right-to-Manage model

In this Appendix, we derive the relationship between our measure of the union's bargaining power ρ_i and the bargaining power in the Nash product that is more commonly used to characterize the equilibrium in the Right-to-Manage model (see, for instance, Heijdra, 2009). Using

Nash bargaining, we can characterize the equilibrium in sector i by solving:[38]

$$\begin{aligned}
\max_{w_i,E_i} \Omega_i = \ & \beta_i \log\left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi)\right) \\
& + (1-\beta_i)\log\left(u(F(\cdot) - \sum_i w_i N_i E_i - T_f) - u(-T_f)\right) \\
\text{s.t.} \quad & w_i = F_i(\cdot) \\
& G(w_i - T_i + T_u) - E_i \geq 0,
\end{aligned}$$

where $\beta_i \in [0,1]$ is the weight attached to the union's payoff in the Nash product. It is important to take the final constraint (the voluntary participation constraint) into account, as it will bind for small values of β_i. If this is the case (i.e., when β_i is close to zero), the labor-market equilibrium is given by the final two conditions, which characterize the competitive equilibrium.

The corresponding Lagrangian is given by:

$$\begin{aligned}
\mathcal{L} = \ & \beta_i \log\left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi)\right) \\
& + (1-\beta_i)\log\left(u(F(\cdot) - \sum_i w_i N_i E_i - T_f) - u(-T_f)\right) \\
& + \lambda_i(w_i - F_i(\cdot)) + \mu_i(G(w_i - T_i + T_u) - E_i).
\end{aligned} \tag{48}$$

By using the following definitions:

$$\Lambda_i \equiv \int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi), \tag{49}$$

$$\Delta_i \equiv u(F(\cdot) - \sum_i w_i N_i E_i - T_f) - u(-T_f), \tag{50}$$

we can write the first-order conditions as

$$w_i : \quad \frac{\beta_i}{\Lambda_i} E_i \overline{u'_i} - \frac{1-\beta_i}{\Delta_i} u'_f N_i E_i + \lambda_i + \mu_i G'_i = 0 \tag{51}$$

$$E_i : \quad \frac{\beta_i}{\Lambda_i}(\hat{u}_i - u_u) - \lambda_i F_{ii} - \mu_i = 0 \tag{52}$$

$$\lambda_i : \quad w_i - F_i = 0 \tag{53}$$

$$\mu_i : \quad \mu_i(G_i - E_i) = 0. \tag{54}$$

When $\beta_i = 1$, equations (51)-(52) imply that $\mu_i = 0$ and the equilibrium coincides with the one derived in the Monopoly-Union model. For small values of β_i, on the other hand, the constraint $G_i = E_i$ becomes binding, so that the labor market equilibrium coincides with the competitive

[38] Note that for both the union and the firm-owners, the value of the outside option (given by $u(-T_u)$ and $u(-T_f)$ respectively) is subtracted from the payoff. This may give rise to some technical issues when $T_f > 0$. Here we suffice by stating that the subtraction of the outside options is inconsequential in the remainder of the argument and could also be ignored.

outcome.[39] This happens for all values of $\beta_i \in [0, \beta_i^*]$, where $\beta_i^* \in (0,1)$ is implicitly defined by:[40]

$$\frac{\beta_i^*}{1-\beta_i^*} = \frac{\Lambda_i}{\Delta_i} \frac{u'_f N_i}{\overline{u'_i}}. \tag{55}$$

For values of $\beta_i \in [\beta_i^*, 1]$, we thus have $\mu_i = 0$. Combining equations (51)-(52) then leads to

$$\frac{\beta_i}{\Lambda_i}\left(E_i \overline{u'_i} + \frac{\hat{u}_i - u_u}{F_{ii}}\right) - \frac{1-\beta_i}{\Delta_i} u'_f N_i E_i = 0, \tag{56}$$

or, alternatively,

$$1 - \left(\frac{1-\beta_i}{\beta_i}\right) \frac{\Lambda_i}{\Delta_i} \frac{u'_f N_i}{\overline{u'_i}} = \varepsilon_i \frac{\hat{u}_i - u_u}{\overline{u'_i} w_i}. \tag{57}$$

Defining the left-hand side of this equation as

$$\rho_i \equiv 1 - \left(\frac{1-\beta_i}{\beta_i}\right) \frac{\Lambda_i}{\Delta_i} \frac{u'_f N_i}{\overline{u'_i}}, \tag{58}$$

we arrive at our equilibrium condition in the Right-to-Manage model, as given by equation (14). Clearly, whenever $\beta_i = 1$, $\rho_i = 1$ as well and the Monopoly-Union model applies. When $\beta_i = \beta_i^*$, from equation (55) if follows that $\rho_i = 0$ and the equilibrium coincides with the competitive outcome. Hence, there exists a direct relationship between our measure of the union's bargaining power ρ_i and the Nash-bargaining parameter β_i. In particular,

$$\rho_i = \begin{cases} 0 & \text{if} \quad \beta_i \in [0, \beta_i^*), \\ 1 - \frac{1-\beta_i}{\beta_i} \frac{\Lambda_i}{\Delta_i} \frac{u'_f N_i}{\overline{u'_i}} & \text{if} \quad \beta_i \in [\beta_i^*, 1]. \end{cases} \tag{59}$$

B Proof Lemma 1

This appendix derives the elasticities of wages and employment rates to the tax instruments when income effects at the union level are absent. When Assumption 1 is satisfied and income effects are absent (in which case $\partial E_i/\partial T_i = -\partial E_i/\partial T_u$ and $\partial w_i/\partial T_i = -\partial w_i/\partial T_u$), the equilibrium wage and employment rate can be written solely as a function of the participation tax $T_i - T_u$ or, equivalently, the participation tax rate $t_i = (T_i - T_u)/w_i$. Hence, we can write $E_i = E_i(t_i)$ and $w_i = w_i(t_i)$. The relevant elasticities can be derived using the labor-market equilibrium conditions:

$$w_i = F_i(E_i), \tag{60}$$

$$\rho_i \overline{u'(w_i(1-t_i) - T_u - \varphi)} w_i = \varepsilon_i(E_i)(u(w_i(1-t_i) - T_u - G^{-1}(E_i)) - u(-T_u)), \tag{61}$$

where

$$\overline{u'(w_i(1-t_i) - T_u - \varphi)} \equiv \frac{\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi) \mathrm{d}G(\varphi)}{E_i}, \tag{62}$$

[39] This can be verified by setting $\beta_i = 0$. Equations (51)-(52) then imply that $\mu_i > 0$.

[40] This equation is obtained by setting $G_i = E_i$ and $\mu_i = 0$ in the system of first-order conditions. The reason is that, at exactly this value of β_i, the constraint $G_i = E_i$ starts to bind.

denotes the average marginal utility of the employed workers. Log-linearizing these equations around the solution, we obtain:

$$\frac{\mathrm{d}E_i}{E_i} = -\varepsilon_i \frac{\mathrm{d}w_i}{w_i}, \tag{63}$$

$$\frac{\mathrm{d}\overline{u_i'}}{\overline{u_i'}} + \frac{\mathrm{d}w_i}{w_i} = \frac{\mathrm{d}\varepsilon_i}{\varepsilon_i} + \frac{\mathrm{d}(\hat{u}_i - u_u)}{\hat{u}_i - u_u}. \tag{64}$$

Without income effects, T_u affects E_i and w_i only through its impact on t_i. Using this insight, we can linearize the relevant sub-parts of the last equation:

$$\frac{\mathrm{d}\overline{u_i'}}{\overline{u_i'}} = \frac{\overline{u_i''}w_i(1-t_i)}{\overline{u_i'}}\left(\frac{\mathrm{d}w_i}{w_i} - \frac{\mathrm{d}t_i}{1-t_i}\right) + \frac{\hat{u}_i' - \overline{u_i'}}{\overline{u_i'}}\frac{\mathrm{d}E_i}{E_i} \tag{65}$$

$$\frac{\mathrm{d}\varepsilon_i}{\varepsilon_i} = \varepsilon_{\varepsilon_i}\frac{\mathrm{d}E_i}{E_i} \tag{66}$$

$$\frac{\mathrm{d}(\hat{u}_i - u_u)}{\hat{u}_i - u_u} = \frac{\hat{u}_i' w_i(1-t_i)}{\hat{u}_i - u_u}\left(\frac{\mathrm{d}w_i}{w_i} - \frac{\mathrm{d}t_i}{1-t_i}\right) - \frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)(\hat{u}_i - u_u)}\frac{\mathrm{d}E_i}{E_i}, \tag{67}$$

where $\varepsilon_{\varepsilon_i}$ is the elasticity of the labor demand elasticity w.r.t. the rate of employment, as given by

$$\varepsilon_{\varepsilon_i} \equiv \frac{\partial \varepsilon_i}{\partial E_i}\frac{E_i}{\varepsilon_i} = -\left(1 + \frac{1}{\varepsilon_i} + \frac{E_i F_{iii}}{F_{ii}}\right). \tag{68}$$

Substituting the subparts, as well as the log-linearized labor-demand equation in the log-linearized mark-up equation allows us to solve for the relative changes in the wage and employment rate in sector i:

$$\frac{\mathrm{d}w_i}{w_i} = \frac{u_u' w_i(1-t_i)}{\hat{u}_i'\varepsilon_i E_i/g(\hat{\varphi}_i) + u_u' w_i(1-t_i) - (\hat{u}_i - u_u)\left(1 + \varepsilon_i\varepsilon_{\varepsilon_i} + \varepsilon_i\frac{\overline{u_i'} - \hat{u}_i'}{\overline{u_i'}}\right)}\frac{\mathrm{d}t_i}{1-t_i} \tag{69}$$

$$\frac{\mathrm{d}E_i}{E_i} = -\frac{\varepsilon_i u_u' w_i(1-t_i)}{\hat{u}_i'\varepsilon_i E_i/g(\hat{\varphi}_i) + u_u' w_i(1-t_i) - (\hat{u}_i - u_u)\left(1 + \varepsilon_i\varepsilon_{\varepsilon_i} + \varepsilon_i\frac{\overline{u_i'} - \hat{u}_i'}{\overline{u_i'}}\right)}\frac{\mathrm{d}t_i}{1-t_i} \tag{70}$$

The elasticities are now as given in Lemma 1.

C Proof Proposition 1

C.1 Case without income effects

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

$$\max_{T_u, \{t_i\}_{i=1}^I, T_f} \quad \mathcal{L} \equiv \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi)\right)$$
$$+ u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda\left(\sum_i N_i(T_u + E_i t_i w_i) + T_f - R\right). \tag{71}$$

When differentiating with respect to the policy instruments, we have to take into account the dependency of w_i and E_i on t_i. The first-order conditions (assumed to be necessary and sufficient) are given by:

$$\frac{\partial \mathcal{L}}{\partial T_u} = -\sum_i N_i E_i \overline{u_i'} - \sum_i N_i(1-E_i)u_u' + \lambda \sum_i N_i = 0 \tag{72}$$

$$\frac{\partial \mathcal{L}}{\partial T_f} = -u_f' + \lambda = 0 \tag{73}$$

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial t_i} &= -N_i E_i w_i(\overline{u_i'} - \lambda) + \frac{\partial E_i}{\partial t_i}\left(N_i(\hat{u}_i - u_u) + \lambda N_i t_i w_i\right) \\ &\quad + \frac{\partial w_i}{\partial t_i}\left(N_i E_i \overline{u_i'}(1-t_i) - N_i E_i u_f' + \lambda N_i E_i t_i\right) = 0.\end{aligned} \tag{74}$$

To obtain the first result from the proposition, divide the first expression by $\lambda \sum_i N_i$ and use our definitions of the welfare weights and the labor force shares. The second result can be found by dividing the first-order condition with respect to T_f by λ and imposing the definition of b_f. The final result can be found as follows. First, substitute $u_f' = \lambda$ in the first-order condition with respect to t_i, and divide by $\lambda N_i(1-t_i)$. Next, use the definitions of the welfare weight b_i, the union wedge τ_i, as well as the employment elasticity η_i and the wage elasticity κ_i. After rearranging, one obtains the final result stated in Proposition 1.

C.2 Restricted profit taxation

To derive an expression for the optimal participation tax rate in the presence of a restriction on profit taxation (in which case $b_f < 1$), divide equation (72) by $\lambda N_i(1-t_i)$ and use the definitions of the welfare weights b_i and b_f, the union wedge τ_i, as well as the employment elasticity η_i and the wage elasticity κ_i to obtain:

$$\left(\frac{t_i + \tau_i}{1-t_i}\right)\eta_i = (1-b_i) + \left(\frac{b_i - b_f + (1-b_i)t_i}{1-t_i}\right)\kappa_i. \tag{75}$$

When $b_f = 1$ (unrestricted profit taxation), one obtains the result stated in Proposition 1.

C.3 Case with income effects

When there are income effects, changes in the unemployment benefit $-T_u$ do not affect E_i and w_i only through the impact on participation tax rates t_i. Therefore, we write $E_i = E_i(t_i, T_u)$ and $w_i = w_i(t_i, T_u)$. The first-order condition with respect to T_u (the counterpart of equation (72)) then reads:

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial T_u} &= -\sum_i N_i E_i \overline{u_i'} - \sum_i N_i(1-E_i)u_u' + \lambda \sum_i N_i \\ &\quad + \sum_i \frac{\partial E_i}{\partial T_u}\left(N_i(\hat{u}_i - u_u) + \lambda N_i t_i w_i\right) \\ &\quad + \sum_i \frac{\partial w_i}{\partial T_u}\left(N_i E_i \overline{u_i'}(1-t_i) - N_i E_i u_f' + \lambda N_i E_i t_i\right) = 0.\end{aligned} \tag{76}$$

To proceed, divide the entire expression by $\lambda \sum_i N_i$, and impose $b_f = 1$. Furthermore, use the property

$$\frac{\partial E_i}{\partial t_i} = \frac{\partial w_i}{\partial t_i}\frac{\partial E_i}{\partial w_i}, \quad \frac{\partial E_i}{\partial T_u} = \frac{\partial w_i}{\partial T_u}\frac{\partial E_i}{\partial w_i}. \tag{77}$$

Then, combine this result with equations (74)–(76) to find:

$$\sum_i \omega_i b_i + \omega_u b_u = 1 - \sum_i \omega_i (1 - b_i)\iota_i,$$

where $\iota_i \equiv \frac{\partial E_i}{\partial t_i} w_i / \frac{\partial E_i}{\partial T_u}$. To obtain an expression for ι_i, combine the mark-up and the labor-demand equation to arrive at:

$$\rho_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(F_i(\cdot)(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi)F_{ii}(\cdot) + u(F_i(\cdot)(1-t_i) - T_u - G^{-1}(E_i)) - u(-T_u) = 0, \tag{78}$$

which implicitly defines $E_i = E_i(t_i, T_u)$. By using the implicit function theorem, we can derive

$$\iota_i = 1 - \frac{u'_u}{\hat{u}'_i - (\hat{u}_i - u_u)\frac{\overline{u''_i}}{\overline{u'_i}}}. \tag{79}$$

In words, ι_i measures how the union responds differently to changes in either the income tax or the unemployment benefit. When income effects are absent (or when there are no unions), $\iota_i = 0$, and the standard result highlighted in Proposition 1 prevails.[41] When there are income effects, only the expression for the average welfare weights has to be modified. Similar results can be derived for the cases analyzed in Section 6.

D Proof Proposition 2 and Corollary 1

D.1 Proof Proposition 2

To determine how a change in ρ_i affects social welfare, we consider a slightly rewritten version of the Lagrangian for the government's optimization problem. Here, we do not derive the results in terms of sufficient statistics, but we derive the results using the labor-market equilibrium conditions (i.e. the mark-up equations and the labor-demand equations) as constraints in the government's optimization problem. After substituting out $w_i = F_i(\cdot)$, we can write the

[41] One can actually show that a sufficient condition for this to be the case, is when the individual utility function $u(\cdot)$ is of the CARA-type.

Lagrangean corresponding to the government's optimization problem as:

$$\begin{aligned}\mathcal{L} =& \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(F_i(\cdot)(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \right) \\ &+ u(F(\cdot) - \sum_i F_i(\cdot)N_iE_i - T_f) + \lambda \left(\sum_i N_i \left(T_u + E_iF_i(\cdot)t_i\right) + T_f - R \right) \\ &+ \sum_i \mu_i N_i \left(\rho_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(F_i(\cdot)(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi)F_{ii}(\cdot) \right. \\ &\left. + u(F_i(\cdot)(1-t_i) - T_u - G^{-1}(E_i)) - u(-T_u) \right). \end{aligned} \tag{80}$$

Here, the final constraints reflect the union's mark-up equations (with $w_i = F_i(\cdot)$ substituted out for).

In order to investigate how an increase in the degree of unionization ρ_i in sector i affects social welfare, differentiate the Lagrangian (81) with respect to ρ_i and apply the Envelope theorem:

$$\frac{\partial \mathcal{W}}{\partial \rho_i} = \frac{\partial \mathcal{L}}{\partial \rho_i} = \mu_i N_i E_i \overline{u_i'} F_{ii}. \tag{81}$$

Since $N_iE_i\overline{u_i'}F_{ii} < 0$ (provided that labor demand is not perfectly elastic), the expression in equation (82) is positive if and only if $\mu_i < 0$. To determine the sign of μ_i, set the derivative of the Lagrangian with respect to t_i equal to zero (as this variable is chosen optimally):

$$\frac{\partial \mathcal{L}}{\partial t_i} = -N_iE_i(\overline{u_i'} - \lambda)F_i - \mu_i N_i \left(\rho_i E_i \overline{u_i''} F_{ii} + \hat{u}_i{}' \right) F_i = 0. \tag{82}$$

After some rearranging, we find

$$1 - b_i = \frac{\mu_i}{\lambda E_i} \left(\rho_i E_i \overline{u_i''} F_{ii} + \hat{u}_i{}' \right). \tag{83}$$

Since $\lambda E_i > 0$ and $\rho_i E_i \overline{u_i''} F_{ii} + \hat{u}_i' > 0$, it must be that:

$$\mu_i < 0 \quad \Leftrightarrow \quad b_i > 1. \tag{84}$$

Hence, an increase in ρ_i leads to an increase in social welfare if and only if $b_i > 1$. Note that nowhere in the above derivations did we require labor markets to be independent, or that the government has access to a perfect profit tax (in which case $b_f = 1$). The result stated in Proposition 2 thus generalizes to a setting with interdependent labor markets or a binding restriction on profit taxation.

D.2 Proof Corollary 1

Suppose that the government could also optimally set the bargaining power of each union ρ_i in addition to the tax instruments, and reconsider the Lagrangian from the previous Appendix. If we denote by $\underline{\kappa}_i \geq 0$ the Kuhn-Tucker multiplier on the restriction that $\rho_i \geq 0$ and by $\overline{\kappa}_i \geq 0$ the multiplier on the restriction that $1 - \rho_i \geq 0$. Then, the first-order condition with respect to ρ_i

(obtained from differentiating the Lagrangian (81)) augmented with the additional restrictions is given by

$$\mu_i N_i E_i \overline{u_i'} F_{ii} + \underline{\kappa}_i - \overline{\kappa}_i = 0. \tag{85}$$

In an interior optimum (i.e. where the optimal $\rho_i^* \in (0,1)$), the Kuhn-Tucker conditions require that $\underline{\kappa}_i = \overline{\kappa}_i = 0$, which by (86) requires that $\mu_i = 0$ (again provided that labor demand is not perfectly elastic). Then, from condition (84), it follows that $b_i = 1$ in any interior optimum. If the solution is at the boundary, then by the Kuhn-Tucker conditions it must be that either $\overline{\kappa}_i = 0$ and $\underline{\kappa}_i > 0$ or $\underline{\kappa}_i = 0$ and $\overline{\kappa}_i > 0$. Whenever labor demand is not perfectly elastic, equation (86) implies that $\mu_i > 0$ in the first case (which by equation (84) requires that $b_i < 1$) and $\mu_i < 0$ in the second case (which requires by equation (84) that $b_i > 1$).

D.2.1 Employer Taxes

Here, we briefly analyze the welfare effects associated with introducing employer taxes. Modifying equation (81) to take into account employer taxes as well as the modified labor-market equilibrium constraints (30), we obtain:

$$\begin{aligned}
\mathcal{L} =& \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u\left(F_i(\cdot)\frac{1-t_i}{1+\theta_i} - T_u - \varphi \right) \mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \right) \\
&+ u(F(\cdot) - \sum_i F_i(\cdot)N_i E_i - T_f) + \lambda \left(\sum_i N_i \left(T_u + E_i F_i(\cdot) \left(1 - \frac{1-t_i}{1+\theta_i} \right) \right) + T_f - R \right) \\
&+ \sum_i \mu_i N_i \left(\frac{\rho_i}{1+\theta_i} \int_{\underline{\varphi}}^{G^{-1}(E_i)} u' \left(F_i(\cdot)\frac{1-t_i}{1+\theta_i} - T_u - \varphi \right) \mathrm{d}G(\varphi) F_{ii}(\cdot) \right. \\
&\left. + u\left(F_i(\cdot)\frac{1-t_i}{1+\theta_i} - T_u - G^{-1}(E_i) \right) - u(-T_u) \right),
\end{aligned} \tag{86}$$

where we used $w_i = F_i/(1+\theta_i)$ and modified the government's budget constraint to account for employer taxes. In addition, the labor-market equilibrium condition is modified in accordance with equation (29). Now, observe that θ_i only shows up through the term $\frac{1-t_i}{1+\theta_i}$ almost everywhere, except in the first term of mark-up equation. When t_i is chosen optimally, the welfare effects from introducing an employer tax (i.e., setting $\theta_i > 0$) or employer subsidy (i.e., setting $\theta_i < 0$) on this term can be ignored by the Envelope theorem. The welfare impact of a change in the employer taxes in sector i is then given by:

$$\frac{\partial \mathcal{W}}{\partial \theta_i} = -\frac{\mu_i N_i \rho_i E_i \overline{u_i'} F_{ii}}{(1+\theta_i)^2} > 0 \quad \Leftrightarrow \quad \mu_i > 0 \quad \Leftrightarrow \quad b_i < 1, \tag{87}$$

provided that labor markets are not perfectly competitive (in which case $\rho_i = 0$) and labor demand not perfectly elastic (in which case $F_{ii} = 0$).[42] Hence, when labor markets are to some extent unionized, introducing an employer tax in a particular sector (which prevents unions from demanding high wages) is welfare-enhancing if and only if the welfare weight of the workers in

[42] In fact, it can readily be shown that when labor markets are perfectly competitive (such that $\rho_i = 0$), an introduction of an employer tax or subsidy does not affect social welfare, provided that profit taxation is unrestricted.

that particular sector is below one.

E Proof Proposition 3

The Lagrangian is the same as in Proposition 1:

$$\max_{T_u,\{t_i\}_{i=1}^I,T_f} \quad \mathcal{L} \equiv \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \right)$$
$$+ u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i (T_u + E_i t_i w_i) + T_f - R \right). \quad (88)$$

When labor markets are interconnected, however, we have to take into account that the wage and employment rate in sector i are also affected by taxes levied in sector $j \neq i$. Ignoring income effects, these relationships can be written as $w_i = w_i(t_1, t_2, \cdots, t_I)$ and $E_i = E_i(t_1, t_2, \cdots, t_I)$.[43] The first-order conditions read

$$\frac{\partial \mathcal{L}}{\partial T_u} = -\sum_i N_i E_i \overline{u_i'} - \sum_i N_i (1-E_i) u_u' + \lambda \sum_i N_i = 0 \quad (89)$$
$$\frac{\partial \mathcal{L}}{\partial T_f} = -u_f' + \lambda = 0 \quad (90)$$
$$\frac{\partial \mathcal{L}}{\partial t_i} = -N_i E_i w_i (\overline{u_i'} - \lambda) + \sum_j \frac{\partial E_j}{\partial t_i} (N_j(\hat{u}_j - u_u) + \lambda N_j t_j w_j)$$
$$+ \sum_j \frac{\partial w_j}{\partial t_i} \left(N_j E_j \overline{u_j'}(1-t_j) - N_j E_j u_f' + \lambda N_j E_j t_j \right) = 0. \quad (91)$$

The first two results from Proposition 3 follow directly from equations (90)-(91). To arrive at the final result, divide the final expression by $\lambda w_i \sum_j N_j$ and impose $b_f = 1$. One then obtains

$$\omega_i(1-b_i) + \sum_j \omega_j \frac{\partial E_j}{\partial t_i} \frac{1}{E_j} (t_j + \tau_j) \frac{w_j}{w_i} + \sum_j \omega_j \frac{\partial w_j}{\partial t_i} (b_j - 1) \frac{1-t_j}{w_i}. \quad (92)$$

The latter can be rewritten as

$$\sum_j \omega_j \left(\frac{t_j + \tau_j}{1-t_j} \right) \eta_{ji} = \omega_i(1-b_i) + \sum_j \omega_j (b_j - 1) \kappa_{ji}, \quad (93)$$

where the elasticities are given by

$$\eta_{ji} \equiv -\frac{\partial E_j}{\partial t_i} \frac{1-t_i}{E_j} \frac{w_j(1-t_j)}{w_i(1-t_i)}, \quad (94)$$
$$\kappa_{ji} \equiv \frac{\partial w_j}{\partial t_i} \frac{1-t_i}{w_j} \frac{w_j(1-t_j)}{w_i(1-t_i)}. \quad (95)$$

[43] The case with income effects can be analyzed in analogous fashion as is done is Appendix C.

F Proof Proposition 4 and Corollary 2

F.1 Proof Proposition 4

To prove the result stated in Proposition 4, we start by characterizing some properties of the rationing scheme. The general rationing scheme is given by

$$\int_{\underline{\varphi}}^{\overline{\varphi}_i} e_i(E_i, \overline{\varphi}_i, \varphi)\mathrm{d}G(\varphi) \equiv E_i. \tag{96}$$

Under the assumption that the function $e_i(\cdot)$ is differentiable with respect to its first and second argument, the following relationships must hold:[44]

$$\int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{iE_i}(E_i, \overline{\varphi}_i, \varphi)\mathrm{d}G(\varphi) = 1, \tag{97}$$

$$\int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{i\bar{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi)\mathrm{d}G(\varphi) + e_i(E_i, \overline{\varphi}_i, \bar{\varphi}_i)G'(\overline{\varphi}_i) = 0. \tag{98}$$

Instead of deriving the labor-market equilibrium conditions for a general rationing schedule, we assume that the rationing schedule implicitly defines relationships $E_i = E_i(t_i)$ and $w_i = w_i(t_i)$, between the participation tax rate in sector i to an equilibrium wage and employment rate in sector i. Hence, we ignore income effects and labor market spillovers. Using $E_i = E_i(t_i)$ and $w_i = w_i(t_i)$, we can write the government's problem as:

$$\begin{aligned}\max_{T_u, \{t_i\}_{i=1}^I, T_f} \quad \mathcal{L} \equiv & \sum_i N_i \left(u(-T_u) + \int_{\underline{\varphi}}^{\overline{\varphi}_i} e_i(E_i, \overline{\varphi}_i, \varphi)(u(w_i(1-t_i) - T_u - \varphi) - u(-T_u))\mathrm{d}G(\varphi) \right) \\ & + u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i (T_u + E_i t_i w_i) + T_f - R \right). \end{aligned} \tag{99}$$

In the absence of income effects, and with a perfect profit tax, we can derive

$$\frac{\partial \mathcal{L}}{\partial T_u} = -\sum_i N_i E_i \overline{u_i'} - \sum_i N_i (1 - E_i) u_u' + \lambda \sum_i N_i = 0, \tag{100}$$

$$\frac{\partial \mathcal{L}}{\partial T_f} = -u_f' + \lambda = 0, \tag{101}$$

which leads to the first two results from the proposition. To derive the final result, differentiate the Lagrangian with respect to t_i, and set the resulting expression to zero:

$$\begin{aligned} & - N_i E_i w_i (\overline{u_i'} - \lambda) - w_i N_i \int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{i\bar{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi)(u_i(\varphi) - u_u)\mathrm{d}G(\varphi) \\ & \frac{\partial w_i}{\partial t_i} \left((1-t_i) N_i E_i \overline{u_i'} + (1-t_i) N_i \int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{i\bar{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi)(u_i(\varphi) - u_u)\mathrm{d}G(\varphi) - N_i E_i u_f' + \lambda N_i E_i t_i \right) \\ & \frac{\partial E_i}{\partial t_i} \left(\lambda N_i t_i w_i + N_i \int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{iE_i}(E_i, \overline{\varphi}_i, \varphi)(u_i(\varphi) - u_u)\mathrm{d}G(\varphi) \right) = 0, \end{aligned} \tag{102}$$

[44] This follows from differentiating (97) with respect to E_i and $\overline{\varphi}_i$.

where

$$\overline{u_i'} \equiv \int_{\underline{\varphi}}^{\overline{\varphi}_i} \frac{e_i(E_i, \overline{\varphi}_i, \varphi)}{E_i} u'(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi). \tag{103}$$

denotes the expected utility of the employed workers, and $u_i(\varphi) \equiv u(w_i(1-t_i)-T_u-\varphi)$ measures the utility of the worker with participation costs $\varphi \in [\underline{\varphi}, \overline{\varphi}_i]$ who is employed in sector i. To proceed, divide the entire expression by $N_i E_i w_i \lambda$, impose $b_f = 1$. In addition, define

$$\hat{\tau}_i \equiv \int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{iE_i}(E_i, \overline{\varphi}_i, \varphi) \left(\frac{u(w_i(1-t_i) - T_u - \varphi) - u(-T_u)}{\lambda w_i} \right) \mathrm{d}G(\varphi), \tag{104}$$

as the expected utility loss of the rationed workers, i.e., the workers who lose their job when the employment rate E_i is marginally reduced.[45] After some rearranging, we obtain

$$\left(\frac{t_i + \hat{\tau}_i}{1 - t_i} \right) \eta_i = (1 - b_i) + (b_i - 1)\kappa_i + \frac{\kappa_i - 1}{E_i} \int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{i\overline{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi) \frac{u_i(\varphi) - u_u}{\lambda} \mathrm{d}G(\varphi). \tag{105}$$

Next, observe that $\kappa_i - 1 = \frac{\partial \overline{\varphi}_i}{\partial t_i} \frac{(1-t_i)}{\overline{\varphi}_i}$. In addition, using equation (99), we can rewrite the last part of the previous expression as:

$$\begin{aligned} &\frac{\kappa_i - 1}{E_i} \int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{i\overline{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi) \frac{u_i(\varphi) - u_u}{\lambda} \mathrm{d}G(\varphi) = \\ &- \frac{\partial \overline{\varphi}_i}{\partial t_i} \frac{1 - t_i}{\overline{\varphi}_i} \frac{e_i(E_i, \overline{\varphi}_i, \overline{\varphi}_i) G'(\overline{\varphi}_i)}{E_i} \int_{\underline{\varphi}}^{\overline{\varphi}_i} \frac{e_{i\overline{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi)}{\int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{i\overline{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi) \mathrm{d}G(\varphi)} \frac{u_i(\varphi) - u_u}{\lambda} \mathrm{d}G(\varphi). \end{aligned} \tag{106}$$

Then, define

$$\psi_i \equiv \frac{e_i(E_i, \overline{\varphi}_i, \overline{\varphi}_i)}{E_i / G(\overline{\varphi}_i)} \int_{\underline{\varphi}}^{\bar{\varphi}_i} \frac{e_{i\bar{\varphi}_i}(E_i, \bar{\varphi}_i, \varphi)}{\int_{\underline{\varphi}}^{\bar{\varphi}_i} e_{i\bar{\varphi}_i}(E_i, \bar{\varphi}_i, \varphi) \mathrm{d}G(\varphi)} \left(\frac{u(w_i(1-t_i) - T_u - \varphi) - u(-T_u)}{\lambda w_i} \right) \mathrm{d}G(\varphi),$$

and

$$\gamma_i \equiv -\frac{\partial G(\overline{\varphi}_i)}{\partial t_i} \frac{1 - t_i}{G(\overline{\varphi}_i)}. \tag{107}$$

After substituting all these definitions in equation (106), we arrive at

$$\left(\frac{t_i + \hat{\tau}_i}{1 - t_i} \right) \eta_i - \left(\frac{\psi_i}{1 - t_i} \right) \gamma_i = (1 - b_i) + (b_i - 1)\kappa_i. \tag{108}$$

[45] Note that, by equation (98), the terms $e_{iE_i}(\cdot)$ integrate to one, so that the term defined as $\hat{\tau}_i$ is indeed an expected value.

F.2 Proof Corollary 2

The policy reform keeps wages and employment rates constant. The change in social welfare is then given by:[46]

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = - N_i E_i b_i \mathrm{d}T_i - b_f \mathrm{d}T_f \\ - N_i \int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{i\bar{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi) \frac{u(w_i - T_i - \varphi) - u(-T_u)}{\lambda} \mathrm{d}G(\varphi) \mathrm{d}T_i. \tag{109}$$

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

Under the balanced-budget assumption we have $N_i E_i \mathrm{d}T_i + \mathrm{d}T_f = 0$. In addition, the government can levy a non-distortionary profit tax ($b_f = 1$). Using these results, and equation (99), we can rewrite the change in social welfare as:

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = -N_i E_i \mathrm{d}T_i \Bigg(b_i - 1 - e_i(E_i, \overline{\varphi}_i, \overline{\varphi}_i) \frac{G'(\overline{\varphi}_i)}{E_i} \\ \times \int_{\underline{\varphi}}^{\overline{\varphi}_i} \frac{e_{i\bar{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi)}{\int_{\underline{\varphi}}^{\overline{\varphi}_i} e_{i\bar{\varphi}_i}(E_i, \overline{\varphi}_i, \varphi) \mathrm{d}G(\varphi)} \frac{u(w_i - T_i - \varphi) - u(-T_u)}{\lambda} \mathrm{d}G(\varphi) \Bigg). \tag{110}$$

Given that T_i is lowered in the policy experiment (such that $\mathrm{d}T_i < 0$), the welfare effect is positive provided that the term in between brackets is positive. Using the definitions for ψ_i and γ_i, this is the case if:

$$b_i > 1 + \left(\frac{\psi_i}{1 - t_i} \right) \gamma_i. \tag{111}$$

G Simulations

This Appendix provides additional information regarding the simulations. The objective is to calculate the optimal tax and benefit system for varying degrees of union power ρ_i. In order to do so, we numerically solve equations which characterize the policy optimum. Since we focus on calculating the optimal tax and benefit system, we ignore the presence of firm-owners in our simulations. Under Assumption 1 and Assumption 2, the policy optimum is characterized by (see Proposition 1):

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{112}$$

[46]Note that, in order to induce a change in the participation tax rate in sector i while keeping the participation tax rates in sectors $j \neq i$ constant, we can only adjust the income tax in sector i. Hence, all changes are phrased in terms of a change in the income tax T_i, rather than a change in the participation tax rate t_i.

$$\left(\frac{t_i + \frac{\rho_i b_i}{\varepsilon_i}}{1 - t_i}\right)\eta_i = (1 - b_i) + (b_i - 1)\kappa_i, \tag{113}$$

where we substituted out for the union wedge using $\tau_i = \frac{\rho_i b_i}{\varepsilon_i}$. The government's budget constraint reads:

$$\sum_i N_i \left(T_u + E_i t_i w_i\right) - R = 0. \tag{114}$$

The labor-market equilibrium conditions and the welfare weights are assumed to take the following form:

$$E_i = \zeta_i (w_i(1 - t_i))^{\hat{\pi}_i} \tag{115}$$

$$E_i = \xi_i w_i^{-\varepsilon_i} \tag{116}$$

$$b_i = \frac{1}{\lambda(w_i(1 - t_i) - T_u)^{\nu}} \tag{117}$$

$$b_u = \frac{1}{\lambda(-T_u)^{\nu}}. \tag{118}$$

We numerically solve the system (113)-(119) for the tax instruments t_i and T_u, the labor-market outcomes w_i and E_i, the welfare weights b_i and b_u, and the multiplier on the government's budget constraint. Values for R, ζ_i, and ξ_i are calibrated using the current values of wages, employment rates and the tax system that is in place (see Table 1). Following Saez (2002) and Kroft et al. (2015), we choose $\nu = 1$ in our baseline simulations. Finally, we set the (modified) participation elasticity $\hat{\pi}_i = 0.4$ and the labor-demand elasticity $\varepsilon_i = 0.6$. We solve these equations for the following three scenarios:

1. Competitive labor markets without unions: $\rho_i = 0$ for all i,

2. Intermediate union power: $\rho_i = 1/2$ for all i,

3. Monopoly unions: $\rho_i = 1$ for all i.

The results are displayed in Figures 3-5.