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Tax Policy in Imperfect Labor Markets

Erasmus University Rotterdam

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Tax Policy in Imperfect Labor Markets

Belastingbeleid met imperfecties in de arbeidsmarkt

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Contents

Chapter 1

Introduction

How to redistribute income at the lowest economic costs is one of the most important questions in public economics. This problem was first formally defined by William Vickrey in 1945 and solved by James Mirrlees in 1971, who would later share the Nobel Prize in Economics.[1] An important assumption in their original analysis and the vast majority of research building on their work is that labor markets are perfectly competitive. Each individual who wishes to work immediately finds a job at a wage equal to his or her productivity. While a very insightful benchmark and a natural starting point, real-world labor markets are far from this competitive ideal. This is immediately obvious when you look around. Wages depend on many other factors than productivity. People do not respond to the news of being hired or fired with the shrug of a shoulder.

The aim of this thesis is to understand the implications of labor market imperfections for tax policy and social welfare. This study is relevant both from an academic and a policy perspective. This is because tax policy has very different effects on wages and employment in competitive than in non-competitive labor markets. Moreover, if labor markets are imperfectly competitive, additional considerations become relevant when designing policy. Taxes might exacerbate or mitigate pre-existing distortions. Policies aimed at improving equity need not harm efficiency. Departures from perfect competition do not necessarily reduce welfare if distributional concerns play a role. Insights into these issues deepen our understanding of tax policy and can ultimately improve policy making.

[1]See Vickrey (1945) and Mirrlees (1971).

This thesis consists of three studies on tax policy in imperfect labor markets. Each study considers a specific departure from perfect competition. Chapter 2 focuses on the role of labor unions in determining wages and employment. Chapter 3 recognizes that finding a job or getting a vacancy filled is a costly process which takes time and effort. Chapter 4 deals with market power of firms, which pushes wages below productivity and prevents that profits are driven to zero. In each study, I analyze how taxes affect labor market outcomes and characterize optimal tax policy. Moreover, in Chapters 2 and 4 I ask how an increase in the bargaining power of workers and firms affects social welfare. To study these questions, I use formal models to describe the behavior of agents in the economy. Doing so encourages the researcher to be explicit about what assumptions underlie the analysis and to be precise when formulating the results.[2] An additional benefit is that these models can be used to investigate the quantitative importance of the effects that are being studied. Therefore, in each study I analyze the model both theoretically and quantitatively by calibrating it to match key moments in the data.

Labor unions play an important role in labor markets, especially in continental Europe and the Nordic countries. In Chapter 2, I analyze together with Bas Jacobs the implications of labor unions for tax policy and social welfare. In particular, we ask *'How should the government optimize income redistribution if labor markets are unionized?'* and *'Can labor unions be socially desirable if the government wants to redistribute income?'* To answer these questions, we analyze an economy with multiple sectors where individuals supply labor on the extensive (participation) margin. Workers within each sector are represented by a labor union and union power varies across sectors. Wages are determined through bargaining between unions and representatives of firm-owners, while individual firm-owners unilaterally determine how many workers to hire. Unions bid up wages above the market-clearing level, which generates involuntary unemployment. The government cares for redistribution and taxes labor income and profits to finance unemployment benefits and exogenous government spending. When doing so, it needs to take into account how unions respond to tax policy and how this affects labor market outcomes.

[2] As argued by Rodrik (2016): "The correct answer to almost any question in economics is: It depends. . . . They [models] are useful because they tell us precisely *what* the likely outcomes depend on."

We obtain two main results. First, optimal participation taxes (i.e., the sum of income taxes and unemployment benefits) are lower if unions are more powerful. Intuitively, lower participation taxes improve the inside option (employment) relative to the outside option (unemployment). This induces unions to lower their wage claims, which results in less involuntary unemployment. Policies aimed at encouraging participation are therefore more likely to be desirable if unions are more powerful. In fact, it might be optimal to subsidize participation even for workers whose welfare weight is less than one. This is never optimal if labor markets are competitive, cf. Diamond (1980) and Saez (2002). A calibration exercise to the Dutch economy suggests that the optimal tax-benefit system is much less redistributive if the impact of unions is taken into account. Second, we show that an increase in sectoral union power raises welfare if the union in that sector represents low-income workers whose participation is optimally subsidized. By bidding up wages, unions alleviate upward distortions in employment. The reverse is also true: unions are never desirable if labor participation is taxed, as is the case for almost all workers in OECD countries. In our calibration we find that an increase in union power typically lowers welfare, but this result is sensitive to the specification of the welfare function.

Unemployment leads to significant drops in consumption and reported life satisfaction. Moreover, the risk of becoming unemployed is not insurable and unequally distributed. Chapter 3 asks how unemployment risk affects the efficiency costs and consequently the optimal design of income taxes and unemployment benefits. To answer these questions, I analyze a model where individuals supply labor on the intensive (hours, effort) and extensive (participation) margin. Search frictions generate unemployment risk, which cannot be privately insured. When deciding where to apply, individuals face a trade-off between wages and probabilities: applying for a job which pays a higher wage reduces the likelihood of being matched. The tax-benefit system affects this decision and thereby unemployment in two opposing ways. On the one hand, a higher *marginal* tax rate lowers the value of applying for a job which pays a higher wage. This leads firms to post more vacancies, which reduces unemployment. On the other hand, a higher *average* tax rate or unemployment benefit lowers the value of finding a job. This puts upward pressure on wages, which raises unemployment. These changes in unemployment affect government finances because unemployed workers receive benefits and do not pay income taxes.

I derive intuitive formulas for the optimal tax-benefit system, which clearly illustrate how unemployment should be taken into account. These formulas can be used to obtain a number of insights. First, how unemployment affects the optimal tax-benefit system depends crucially on the elasticity of unemployment with respect to the marginal and average tax rate. Second, employment subsidies should phase in with income. This is because employment subsidies induce individuals to apply for jobs which pay inefficiently low wages. A phase-in region alleviates this distortion by making it more attractive to apply for jobs which pay a higher wage. This study therefore provides a rationale for the phase-in region of the EITC, one of the largest anti-poverty programs in the US. Third, marginal tax rates can be used to lower the moral hazard costs of unemployment insurance (UI). As a result, in contrast to what is commonly assumed in the literature, financing UI payments through either lump-sum or proportional taxes on labor income is sub-optimal even in the absence of a motive for redistribution. I calibrate the model to the US economy and find that unemployment is an important margin to consider when setting marginal tax rates at low levels of income. My calibration suggests that for every dollar the US government generates by raising tax rates at the bottom, it loses close to three cents due to unemployment responses.

A growing body of evidence documents that labor markets are highly concentrated and that firms exert significant monopsony (i.e., buyer) power.[3] Chapter 4 studies the implications of monopsony power for income taxation and welfare. To that end, I analyze a model where individuals derive income from providing labor effort and holding shares. The government observes labor earnings but not individuals' abilities or how pure economic profits are dissipated. Unlike the government, firms do observe ability. They offer combinations of earnings and labor effort to maximize profits subject to promising workers their reservation utility. In this framework, monopsony power does not generate efficiency losses but determines what share of the labor market surplus accrues to firms. An increase in monopsony power exacerbates inequality in capital income, but mitigates inequality in labor income. Moreover, monopsony power raises the share of the tax burden borne by firm-owners and reduces the share borne by workers.

[3]See, for instance, Azar et al. (2017, 2018, 2019), Benmelech et al. (2018), Lipsius (2018), Rinz (2018).

I show that if firms have monopsony power, income taxes are not only used to redistribute labor income, but also to redistribute capital income. This is because part of the incidence of income taxes falls on firms. Consequently, monopsony power makes income taxes less effective in redistributing labor income, but more effective in redistributing capital income. The latter is desirable if capital income is unequally distributed and if pure economic profits cannot be taxed at a confiscatory rate, e.g., due to the existence of tax havens. I derive a precise condition which can be used to assess if monopsony power raises or lowers the optimal marginal tax rate at each point in the income distribution. Moreover, I show that monopsony power has an ambiguous effect on social welfare. On the one hand, monopsony power generates a distributional conflict over profits. This lowers welfare provided capital income is more unequally distributed than labor income. On the other hand, monopsony power enables the governments to exploit the informational advantage of firms. This raises welfare as it alleviates the equity-efficiency trade-off that occurs because the government does not observe ability. I calibrate the model to the US economy and find that monopsony power raises optimal marginal tax rates at low levels of income and lowers optimal marginal tax rates for middle- and high-income earners. Moreover, the welfare effect of eliminating monopsony power (e.g., through competition policy) is sizable and ranges between −1.78% and +8.37% of GDP depending on the redistributive preferences of the government.

Chapter 2

Optimal income taxation in unionized labor markets[1]

joint with Bas Jacobs

2.1 Introduction

Unions play a dominant role in modern labor markets. Figure 2.1 plots union membership and coverage rates among three groups of OECD-countries over the period 1960-2011. While union membership has shown a steady downward trend since the early 1980s, the fraction of labor contracts covered by collective agreements has decreased by much less and remains high, especially in continental European and Nordic countries.

Despite their importance, surprisingly little is known about the impact of unions on the optimal design of redistributive policies. This paper aims to close this gap by studying optimal income redistribution in unionized labor markets. It asks two main questions: *'How should the government optimize income redistribution if labor markets are unionized?'* And: *'Can labor unions be socially desirable if the government wants to redistribute income?'* Although some papers have analyzed optimal taxation in unionized

[1]We would like to thank Thomas Gaube, Pieter Gautier, Aart Gerritsen, Egbert Jongen, Pim Kastelein, Rick van der Ploeg, Dominik Sachs, Kevin Spiritus and seminar and congress participants at Erasmus School of Economics, CPB Netherlands Bureau for Economic Policy Analysis, Max Planck Institute for Law and Public Finance, European University Institute, Taxation Theory Conference 2016 Toulouse, IIPF Congress 2016 Lake Tahoe, APET Meeting 2017 Paris, and Norwegian-German Seminar Public Economics 2017 Munich for useful comments and suggestions.

labor markets, no paper has, to the best of our knowledge, studied the desirability of unions for income redistribution.

To answer these questions, we extend the extensive-margin models of Diamond (1980), Saez (2002), and Choné and Laroque (2011) with unions.[2] Workers are heterogeneous with respect to their costs of participation and the sector (or occupation) in which they can work. Workers choose whether or not to participate, and supply labor on the extensive margin if they succeed in finding a job. In our model, we abstract from an intensive labor-supply margin. The extensive margin is often considered empirically more relevant compared to the intensive margin, especially at the lower part of the income distribution.[3] Workers within a sector are represented by a union, which maximizes the expected utility of its members. Firm-owners own a stock of capital and employ different labor types to produce a final consumption good. Our baseline is the canonical right-to-manage (RtM) model of Nickell and Andrews (1983). The wage in each sector is determined through bargaining between (representatives of) firm-owners and unions. Firm-owners, in turn, unilaterally determine how many workers to hire.[4] Finally, there is a government which sets income taxes, unemployment benefits and profit taxes to maximize a utilitarian social welfare function. Our main findings are the following.

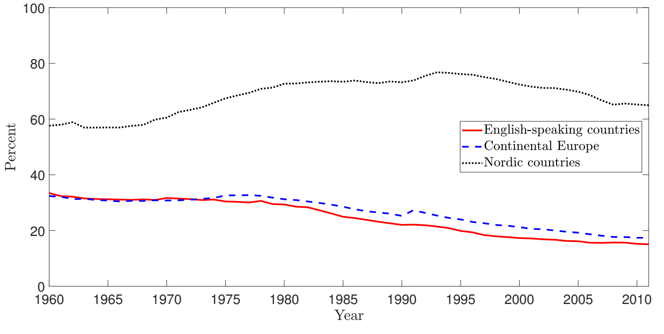
First, we answer the question how income taxes should be adjusted in unionized labor markets. We show that optimal participation tax rates (i.e., the sum of income taxes and unemployment benefits as a fraction of the wage) are lower if unions are more powerful.[5] Intuitively, high income taxes and unemployment benefits worsen the inside option of workers relative to their outside option. Hence, higher participation tax rates induce unions to bid up wages above market-clearing levels. This results in involuntary unemployment, which generates a welfare loss. Alternatively, involuntary unemployment creates an implicit tax, which exacerbates the explicit tax on labor participation. Con-

[2]Saez (2002) analyzes a model with both an extensive margin and an occupational-choice margin, which is referred to as the intensive margin.

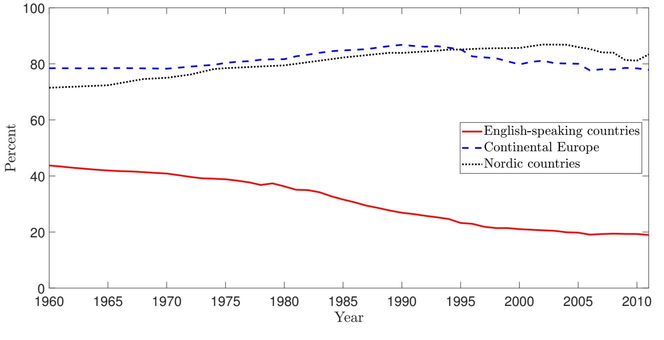
[3]See, for instance, Heckman (1993), Eissa and Liebman (1996), and Meyer (2002).

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

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



(a) Union membership



(b) Union coverage

Figure 2.1: Union membership (a) and union coverage (b). Data are obtained from the ICTWSS Database version 5.1 (ICTWSS, 2016). Membership is measured as the fraction of wage earners in employment who are member of a union, and coverage as the fraction of employees covered by collective bargaining agreements. Missing observations are linearly interpolated. The countries included are: Australia, Canada, the United Kingdom, the United States ('English-speaking countries'), Austria, Belgium, France, Germany, the Netherlands, Switzerland ('Continental Europe'), Denmark, Finland, Norway and Sweden ('Nordic countries'). Averages are computed using population weights, which are obtained from the OECD database (OECD, 2018b).

sequently, optimal participation tax rates are lowered. Moreover, it may be optimal to subsidize participation even for workers whose welfare weight is below one, which never occurs if labor markets are competitive, cf. Diamond (1980), Saez (2002), and Choné and Laroque (2011). EITC programs are therefore more likely to be desirable if unions are more powerful.

Second, we answer the question whether unions are desirable for income redistribution. We show that, if taxes are optimally set and labor rationing is efficient, then unions are desirable only if they represent workers whose social welfare weight is above one.[6] Intuitively, in sectors where the workers' welfare weight exceeds one, participation is subsidized on a net basis, see also Diamond (1980), Saez (2002), and Choné and Laroque (2011). Consequently, labor participation is distorted upwards. Unions alleviate the distortions on labor participation by reducing employment. Hence, involuntary unemployment acts as an implicit tax, which partially off-sets the explicit subsidy on labor participation.[7] Consequently, EITC policies and labor unions are complementary instruments to raise the net incomes of the low-skilled. The reverse is also true: unions are never desirable if the social welfare weights of workers are below one, since labor participation is then taxed on a net basis.[8] In that case, implicit taxes from involuntary unemployment exacerbate explicit taxes on labor participation. Therefore, our results imply that it is socially optimal to let low-income workers organize themselves in a labor union, whereas labor markets for workers with higher incomes should remain competitive.

In our numerical application, we calculate the optimal tax-benefit system for the Netherlands based on a sufficient-statistics approach recently introduced by Kroft et al. (2020). For plausible values of labor-demand and participation elasticities, the optimal tax-benefit system is much less redistributive if unions are more powerful. In particular, for workers with the lowest educational attainment optimal participation tax rates vary

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

[7]This finding echoes the results of Lee and Saez (2012) and Gerritsen and Jacobs (2020), who show that, if labor rationing is efficient, a binding minimum wage raises social welfare if the welfare weight of the workers for whom the minimum wage binds exceeds one. Intuitively, labor participation is then distorted upwards, and by reducing employment, the minimum wage alleviates this distortion.

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

from around 30% in the absence of unions to -4% if there are monopoly unions. The reduction in participation tax rates is brought about by lower income taxes, but mostly by a sharp decline in unemployment benefits. Furthermore, the welfare weight of the lowest-income workers is below one in most of our simulations, which implies that unions are generally not desirable. However, this finding is sensitive to changing the redistributive preferences of the government. It could easily be reversed if the government attaches a higher social welfare weight to the working poor, for example, because the low-income workers are considered to be 'more deserving' than the unemployed workers.

We also analyze the robustness of our findings by relaxing a number of important assumptions: i) if the government cannot (fully) tax profits, ii) if there are general-equibrium effects on the distribution of wages, iii) if labor rationing is not fully efficient, iv) if a national union bargains over all sectoral wages with the aim to compress the wage distribution, and v) if unions and firms bargain over wages and employment, as in the efficient bargaining model of McDonald and Solow (1981). First, we show that all our results continue to hold if profits cannot be fully taxed, if there are general-equilibrium effects on wages, and if there is a national union aiming to compress the wage distribution. Second, we find that if labor rationing is inefficient (so that the burden of unemployment is not necessarily borne by the workers with the highest participation costs), our results are slightly modified. Optimal participation tax rates are higher compared to case with efficient rationing, because participation taxes replace involuntary by voluntary unemployment. Further, we show that unions are desirable only if the social welfare weight of the low-income workers sufficiently exceeds one, since unions create more distortions if rationing is inefficient. Finally, in the efficient bargaining model, optimal participation tax rates are no longer necessarily lower in unionized labor markets, since employment is no longer unambiguously distorted downwards. However, we still find that unions are desirable only if they represent workers whose welfare weight exceeds one.

The remainder of this paper is organized as follows. Section 2.2 discusses the related literature. Section 2.3 outlines the basic structure of the model, characterizes general equilibrium, and discusses the comparative statics. Section 2.4 analyzes how participation tax rates, unemployment benefits, and profit taxes should optimally be set. Section 2.5 analyzes the desirability of labor unions. Section 2.6 investigates the robustness of the results by exploring the implications of inefficient rationing, efficient-bargaining, and national unions. Section 2.7 presents our simulations. Section 2.8 concludes. Finally, an Appendix contains the proofs and provides additional details on the simulations.

2.2 Related literature

Our paper relates to several branches in the literature. First, there is an extensive literature, which analyzes the impact of taxation on wages and employment in union models, but does not analyze optimal taxation as in our paper, see, e.g., Lockwood and Manning (1993), Bovenberg and van der Ploeg (1994), Koskela and Vilmunen (1996), Fuest and Huber (1997), Sørensen (1999), Fuest and Huber (2000), Lockwood et al. (2000), Bovenberg (2006), Aronsson and Sjögren (2004), Sinko (2004), van der Ploeg (2006), and Aronsson and Wikström (2011). In these papers, high unemployment benefits and high income taxes (i.e., high *average* tax rates) improve the position of the unemployed relative to the employed, which raises wage demands and lowers employment. Moreover, high marginal tax rates (for given average tax rates) moderate wage demands and boost employment, since wage increases are taxed at higher rates. If, however, individuals can also adjust their working hours, the impact of higher marginal tax rates on overall employment (i.e., total hours worked) becomes ambiguous (Sørensen, 1999, Fuest and Huber, 2000, Aronsson and Sjögren, 2004, and Koskela and Schöb, 2012). Since we focus on extensive labor-supply responses, we abstract from the wage-moderating effect of tax-rate progressivity.

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

Third, our paper is related to Diamond (1980), Saez (2002), and Choné and Laroque (2011), who analyze optimal redistributive income taxation with extensive labor-supply responses. Christiansen (2015) extends these analyses by allowing for imperfect substitutability between different labor types, so that wages are endogenous. These studies show that participation subsidies (EITCs) are optimal for low-income workers whose social welfare weight exceeds one. We extend these analyses to settings where wages are determined endogenously through bargaining between unions and firm-owners. Our model nests Diamond (1980), Saez (2002), and Choné and Laroque (2011) if labor types are perfect substitutes and it nests Christiansen (2015) if there are no unions. We find that optimal income taxes are less progressive, and benefits are lower if unions create involuntary unemployment. In addition, we show that participation subsidies may be optimal even for workers whose social welfare weight is below one.

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

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

2.3 Model

We consider an economy, which includes workers, unions, firm-owners and a government. The basic structure of the model follows Diamond (1980), except that we consider a finite number of labor types which are imperfect substitutes in production. Within each sector (or occupation), workers are represented by a single labor union that negotiates wages with firm-owners. The latter exogenously supply capital and produce a final consumption good using the labor input of workers in different sectors. The government aims to maximize social welfare by redistributing income between unemployed workers, employed workers, and firm-owners. We assume that each union takes tax policy as given and does not internalize the impact of its decisions on the government budget.

2.3.1 Workers

Workers differ in two dimensions: their participation costs and the sector in which they can work. There is a discrete number of I sectors. A worker of type $i \in \mathcal{I} \equiv \{1, \cdots, I\}$ can work only in 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, and has domain $[\underline{\varphi}, \overline{\varphi}]$, with $\underline{\varphi} < \overline{\varphi} \leq \infty$. The cumulative distribution function of participation costs of workers is denoted by $G(\varphi)$, which is assumed to be identical across sectors.[10]

Each worker is endowed with one indivisible unit of time and decides whether she wants to work or not. All workers derive utility from consumption net of participation costs.[11] Their utility function $u(\cdot)$ is strictly concave. The *net* consumption of an employed worker in sector i with participation costs φ equals labor income w_i, minus income taxes T_i and participation costs φ: $c_{i,\varphi} = w_i - T_i - \varphi$. Unemployed workers consume c_u, which equals an unemployment benefit of $-T_u$, hence $c_u = -T_u$. An individual in sector i with

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

[11] For analytical convenience, we model participation costs as a pecuniary cost rather than a utility cost, see also Choné and Laroque (2011). Utility is then a function of consumption net of participation costs.

participation costs φ is willing to work if

$$u(c_{i,\varphi}) = u(w_i - T_i - \varphi) \geq u(-T_u) = u(c_u). \tag{2.1}$$

For each sector i, equation (2.1) defines a cut-off φ_i^* at which individuals are indifferent between working and not working: $\varphi_i^* = w_i - T_i + T_u$. Higher wages w_i, lower income taxes T_i, and lower unemployment benefits $-T_u$ all raise the cut-off φ_i^*, and, thus, raise labor participation in sector i. Workers are said to be *involuntarily* unemployed if condition (2.1) is satisfied, but they are not employed.

2.3.2 Firms

There is a unit mass of firm-owners, who inelastically supply K units of capital, and employ all types of labor to produce a final consumption good.[12] We distinguish between individual firm-owners who take wages as given, and representatives of firm-owners who bargain with sectoral unions over the sectoral wage. The production technology is described by a constant-returns-to-scale production function:

$$F(K, L_1, \cdots, L_I), \quad F_K(\cdot), F_i(\cdot) > 0, \quad F_{KK}(\cdot), F_{ii}(\cdot), -F_{Ki}(\cdot) \leq 0. \tag{2.2}$$

Here, the subscripts refer to the partial derivatives with respect to capital and labor in sector i. We assume that capital and labor have positive, non-increasing marginal returns. Moreover, capital and labor in sector i are co-operant production factors ($F_{Ki} \geq 0$). In addition, in most of what follows we make the following assumption.

Assumption 2.1. (Independent labor markets) *Marginal 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 $i \neq j$.*

Under Assumption 2.1, a change in employment in one sector does not affect the marginal productivity of workers in other sectors. Hence, there are no spillover effects

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

between different sectors in the labor market. Section 2.6.1 shows that all our main results carry over to a setting in which labor markets are interdependent.

Profits equal output minus wage costs:

$$\pi = F(K, L_1, \cdots, L_I) - \sum_i w_i L_i. \tag{2.3}$$

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

$$w_i = F_i(K, L_1, \cdots, L_I). \tag{2.4}$$

Firms demand labor until its marginal product is equal to the wage. Under Assumption 2.1, the demand for labor in sector i is only a function of the wage in sector i: $L_i = L_i(w_i)$, where $L_i'(\cdot) = 1/F_{ii}(\cdot)$. The labor-demand elasticity ε_i in sector i is defined as $\varepsilon_i \equiv -F_i(\cdot)/(L_i F_{ii}(\cdot)) > 0$ and depends only L_i.

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

2.3.3 Unions and labor-market equilibrium

In each sector i, all workers are organized in a union, which aims to maximize the expected utility of its members.[13] We characterize labor-market equilibrium in sector i using a version of the Right-to-Manage (RtM) model due to Nickell and Andrews (1983). In this model, the wage w_i is determined through bargaining between the union in sector i and (representatives of) firm-owners. Individual firm-owners in each sector take the negotiated wage w_i as given and have the 'right to manage' how much labor to employ. The RtM-model nests both the competitive equilibrium (CE) as well as the monopoly-union (MU) model of Dunlop (1944) as special cases.

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

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

Assumption 2.2. (Efficient Rationing) *The incidence of involuntary unemployment is borne by the workers with the highest participation costs.*

If labor markets are competitive, there is no involuntary unemployment and Assumption 2.2 is trivially satisfied. However, if there is involuntary unemployment, there is no reason to believe that only individuals with the highest participation costs bear the burden of unemployment, see also Gerritsen (2017). The assumption of efficient rationing clearly biases our results in favor of unions and will be relaxed in Section 2.6.2.

Let $E_i \equiv L_i/N_i$ denote the employment rate for workers in sector i. Under Assumption 2.2, workers with participation costs $\varphi \in [\underline{\varphi}, \hat{\varphi}_i]$, where $\hat{\varphi}_i \equiv G^{-1}(E_i)$, are employed, whereas those with participation costs $\varphi \in (\hat{\varphi}_i, \overline{\varphi}]$ are not employed. Workers with participation costs $\varphi \in (\hat{\varphi}_i, \varphi_i^*]$ are involuntarily unemployed, since they participate in the labor market, but cannot find employment. Workers with participation costs $\varphi \in (\varphi_i^*, \bar{\varphi}]$ do not participate ('voluntary unemployment'). Because participation is voluntary, the fraction of workers willing to participate is weakly larger than the rate of employment: $E_i = G(\hat{\varphi}_i) \leq G(\varphi_i^*)$.

If union i maximizes the expected utility of its members, and labor rationing is efficient, then the union's objective function can be written as:

$$\Lambda_i = \int_{\underline{\varphi}}^{\hat{\varphi}_i} u(c_{i,\varphi})\mathrm{d}G(\varphi) + \int_{\hat{\varphi}_i}^{\overline{\varphi}} u(c_u)\mathrm{d}G(\varphi) = E_i\overline{u(c_i)} + (1 - E_i)u(c_u), \tag{2.5}$$

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

To characterize equilibrium, we employ a version of the RtM-model that allows for any intermediate degree of union power. This is graphically illustrated in Figure 2.2. The competitive equilibrium lies at the intersection of the labor-supply curve and the labor-demand curve. The MU-outcome, in turn, lies at the point where the union's indifference

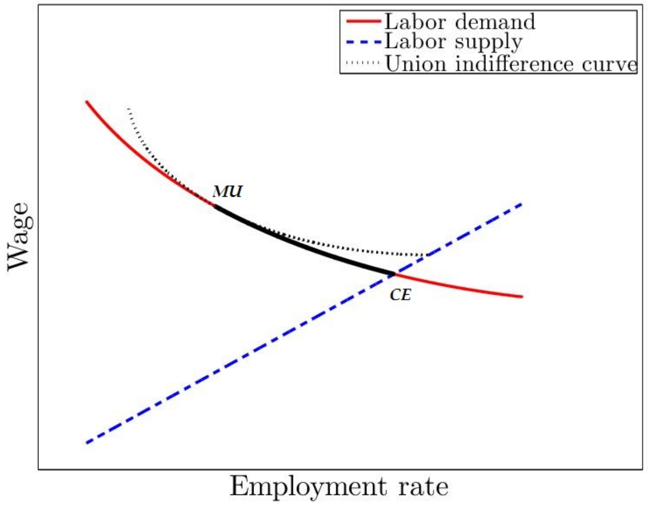


Figure 2.2: Labor market equilibria in the right-to-manage model

curve is tangent to the labor-demand curve. In our characterization of labor-market equilibrium, any point on the bold part of the labor-demand curve corresponds to an equilibrium in the RtM-model. The higher (lower) is union power, the closer is the outcome to the monopoly-union outcome (competitive outcome). Therefore, the monopoly-union outcome and the competitive outcome represent the two polar cases in our analysis.

We refer to the monopoly-union (MU) model if the union in sector i has full bargaining power. In this case, the union chooses the combination of the wage w_i and the rate of employment E_i, which maximizes its objective (2.5) subject to the labor-demand equation (2.4). This leads to the following (implicit) wage-demand equation:

$$1 = \varepsilon_i \frac{u(\hat{c}_i) - u(c_u)}{\overline{u'(c_i)} w_i}, \tag{2.6}$$

where $u(\hat{c}_i)$ denotes the utility of of the marginally employed worker (i.e., the worker with participation costs $\hat{\varphi}_i$), and $\overline{u'(c_i)}$ is the average marginal utility of employed workers in sector i. If the union has full bargaining power, it demands a wage w_i in sector i such that marginal benefit of raising the wage for the employed with one euro (left-hand side) equals the marginal cost 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 marginal worker's monetized utility gain of finding employment as a fraction of the wage: $\frac{u(\hat{c}_i)-u(c_u)}{\overline{u'(c_i)}w_i}$. Importantly, because rationing is efficient, the costs of setting a higher wage depend only on the utility loss of the marginally employed workers, since they lose their jobs following an increase in the wage. Furthermore, equation (2.6) implies that an increase in either the income tax T_i or the unemployment benefit $-T_u$ raises wage demands. Intuitively, higher income taxes T_i or unemployment benefits $-T_u$ make the outside option more attractive relative to the inside option of the worker.

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

$$E_i = G(\varphi_i^*). \tag{2.7}$$

Since there is no involuntary unemployment, we have $\hat{\varphi}_i = \varphi_i^* = w_i - T_i + T_u$. A reduction in either the income tax T_i or the unemployment benefit $-T_u$ leads to higher employment and, through the labor-demand equation (2.4), to a lower wage. The reduction in the wage comes about through an increase in labor participation, rather than through a reduction in the union's wage demand.

For an intermediate degree of union power in the RtM-model, a common approach to characterize the equilibrium is to solve the Nash bargaining problem between the union and the firm. Here, we choose a different approach. Rather than using bargaining weights, we introduce a *union power parameter* $\rho_i \in [0, 1]$, which determines directly which equilibrium is reached in the negotiations. In particular, we modify the wage-demand equation (2.6) and characterize labor-market equilibrium as:

$$\rho_i = \varepsilon_i \frac{u(\hat{c}_i) - u(c_u)}{\overline{u'(c_i)}w_i}. \tag{2.8}$$

Intuitively, the union power parameter ρ_i determines which point on the labor-demand curve between *MU* and *CE* is reached in the wage negotiations. If $\rho_i = 1$, the outcome corresponds to the equilibrium in the MU-model. And, if $\rho_i = 0$, the outcome corresponds to the CE. Consequently, $\rho_i \in (0,1)$ corresponds to any intermediate degree of union bargaining power in the RtM-model. The higher (lower) is ρ_i, the higher (lower) is the negotiated wage. In Appendix A, we formally demonstrate that there exists a monotonic relationship between ρ_i and the union's Nash bargaining parameter. Hence, using ρ_i as a measure for union power is without loss of generality, while it allows us to avoid technical complications, which would arise if we instead assumed Nash bargaining.

2.3.4 Government

The government is assumed to maximize a utilitarian social welfare function:[14]

$$\mathcal{W} \equiv \sum_i N_i(E_i\overline{u(c_i)} + (1-E_i)u(c_u)) + u(c_f). \tag{2.9}$$

The government observes the employment status of all workers, all sectoral wages, and the firms' profits. 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 with different participation costs. Furthermore, the government is unable to distinguish between workers who chose not to participate and those who are involuntarily unemployed. This results in a second-best problem, where the government needs to resort to distortionary taxes and transfers to redistribute income. In line with our informational assumptions, the government can set income taxes T_i, as well as a profit tax T_f to finance an unemployment benefit $-T_u$ and an exogenous revenue requirement R. The government's budget constraint is then given by:

$$\sum_i N_i(E_iT_i + (1-E_i)T_u) + T_f = R. \tag{2.10}$$

[14]The utilitarian specification is without loss of generality. One can easily allow for stronger redistributional desires by adopting a concave cardinalization of the utility function, or a concave transformation of individual utilities, or by introducing Pareto weights for each individual.

2.3.5 Elasticity concepts

Before characterizing optimal taxes, we first introduce the behavioral elasticities of wages and employment with respect to the tax instruments T_i and T_u. To simplify the exposition, we assume that income effects at the union level are absent in most of what follows.

Assumption 2.3. (No income effects at the union level) *Equilibrium wages and employment respond symmetrically to an increase in the income tax T_i or an increase in the unemployment benefit $-T_u$: $\frac{\partial w_i}{\partial T_i} = -\frac{\partial w_i}{\partial T_u}$ and $\frac{\partial E_i}{\partial T_i} = -\frac{\partial E_i}{\partial T_u}$.*

Under Assumption 2.3, giving both the employed and the unemployed an additional euro does not result in a change in union behavior. Hence, a simultaneous increase in the income tax and a reduction in the unemployment benefit such that the participation tax $T_i - T_u$ remains unaffected, does not affect equilibrium in the labor-market. We show in Appendix C that allowing for income effects at the union level does not yield any additional substantive insights.[15] By Assumption 2.3, the equilibrium wage and employment rate in sector i can be written solely as a function of the participation tax rate $t_i \equiv (T_i - T_u)/w_i$, i.e., $w_i = w_i(t_i)$ and $E_i = E_i(t_i)$. The behavioral elasticities are then given in the following Lemma.

Lemma 2.1. *If Assumptions 2.1 (independent labor markets), 2.2 (efficient rationing), and 2.3 (no income effects at the union level) are satisfied, then the wage and employment elasticities with respect to the participation tax rate t_i are given by:*

$$\kappa_i \equiv \frac{\partial w_i}{\partial t_i}\frac{1-t_i}{w_i} = \frac{u'_u w_i(1-t_i)}{\frac{\hat{u}'_i \varepsilon_i E_i}{g(\hat{\varphi}_i)} + u'_u w_i(1-t_i) - (\hat{u}_i - u_u)\left(1 + \varepsilon_i \varepsilon_{\varepsilon_i} + \varepsilon_i \frac{(\overline{u'_i} - \hat{u}'_i)}{\overline{u'_i}}\right)}, \tag{2.11}$$

$$\eta_i \equiv -\frac{\partial E_i}{\partial t_i}\frac{1-t_i}{E_i} = \frac{\varepsilon_i u'_u w_i(1-t_i)}{\frac{\hat{u}'_i \varepsilon_i E_i}{g(\hat{\varphi}_i)} + u'_u w_i(1-t_i) - (\hat{u}_i - u_u)\left(1 + \varepsilon_i \varepsilon_{\varepsilon_i} + \varepsilon_i \frac{(\overline{u'_i} - \hat{u}'_i)}{\overline{u'_i}}\right)}, \tag{2.12}$$

where $\varepsilon_{\varepsilon_i} \equiv \frac{\partial \varepsilon_i}{\partial E_i}\frac{E_i}{\varepsilon_i} = -\left(1 + \frac{1}{\varepsilon_i} + \frac{E_i F_{iii}}{F_{ii}}\right)$ is the elasticity of the labor-demand elasticity with respect to employment. The employment and wage elasticity are related via $\eta_i = \varepsilon_i \kappa_i$, and satisfy $\eta_i > 0$ and $0 < \kappa_i < 1$.

[15] This is an assumption on the shape of the individual utility function $u(\cdot)$. Appendix C shows that a sufficient condition for income effects to be absent is that $u(\cdot)$ is of the CARA-type.

Proof. See Appendix B. □

According to Lemma 2.1, an increase in the participation tax rate (resulting from either an increase in the income tax or the unemployment benefit) raises the union's wage demand, which reduces labor demand, and thus lowers employment.

2.4 Optimal taxation

The government optimally chooses participation tax rates t_i, the unemployment benefit $-T_u$, and profit taxes T_f in order to maximize its social welfare (2.9), subject to the budget constraint (2.10), and taking into account the behavioral responses summarized in Lemma 2.1. We characterize optimal tax policy in terms of elasticities and social welfare weights. Social welfare weights of workers in sector i, the unemployed, and the firm-owners are denoted by $b_i \equiv \frac{\overline{u'(c_i)}}{\lambda}$, $b_u \equiv \frac{u'(c_u)}{\lambda}$, and $b_f \equiv \frac{u'(c_f)}{\lambda}$, respectively, where λ is the multiplier on the government budget constraint. The social welfare weight of each group measures the monetized increase in social welfare resulting from a one unit increase in the income of that group. The following Proposition characterizes optimal tax policy.

Proposition 2.1. *Suppose Assumptions 2.1 (independent labor markets), 2.2 (efficient rationing), and 2.3 (no income effects at the union level) hold, then the optimal unemployment benefit $-T_u$, profit taxes T_f, and participation tax rates t_i are determined by:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{2.13}$$

$$b_f = 1, \tag{2.14}$$

$$\left(\frac{t_i + \tau_i}{1 - t_i}\right)\eta_i = (1 - b_i) + (b_i - 1)\kappa_i, \tag{2.15}$$

where $\omega_i \equiv \frac{N_i E_i}{\sum_j N_j}$ and $\omega_u \equiv \frac{\sum_i N_i(1-E_i)}{\sum_j N_j}$ are the employment shares of workers of type i and the unemployed, and $\tau_i \equiv \frac{u(\hat{c}_i)-u(c_u)}{\lambda w_i} = \frac{\rho_i b_i}{\varepsilon_i}$ is the union wedge.

Proof. See Appendix C. □

Equation (2.13) 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 a marginally higher transfer (left-hand side) are equal to the unit marginal costs (right-hand side).[16] Because the welfare weight of the unemployed always exceeds the welfare weights of the employed, it must be that $b_u > 1$. For condition (2.13) to be valid, there must be at least one sector i where $b_i < 1$. Depending on the redistributive preferences of the government, there may also be employed workers whose welfare weight is above one, see also Diamond (1980), Saez (2002), and Choné and Laroque (2011). In the remainder, we refer to workers for whom $b_i > 1$ as low-income, or low-skilled workers.

Condition (2.14) for optimal profit taxes 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 first-order condition for optimal participation tax rates is given by equation (2.15). The left-hand side of this expression captures the marginal distortions and the right-hand side captures the marginal redistributional gains (or losses) of raising the participation tax rate in sector i. The total wedge on labor participation is $\frac{t_i+\tau_i}{1-t_i}$ and consists of the explicit tax on participation t_i and the union wedge τ_i. The latter is the monetized loss in social welfare as a fraction of the wage if the marginal worker in sector i loses employment. Therefore, τ_i acts as an *implicit* tax on labor participation. The union wedge τ_i is proportional to union power ρ_i and inversely related to the labor-demand elasticity ε_i. Hence, $\tau_i = 0$ if either the union has no bargaining power ($\rho_i = 0$), or if labor demand is infinitely elastic ($\varepsilon_i \to \infty$). In the latter case, unions refrain from demanding a wage above the market-clearing level, since doing so would result in a complete breakdown of employment.

Equation (2.15) shows that – for given distributional benefits on the right-hand side – optimal participation tax rates t_i are lower in sectors where the welfare costs of involuntary unemployment are high, i.e., in sectors where τ_i is large. Hence, optimal participation tax rates are lower if unions are stronger. Low participation tax rates induce unions to moderate their wage demands, and thereby alleviate the welfare costs of unemployment.

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

The total wedge on labor participation $\frac{t_i+\tau_i}{1-t_i}$ is weighted by the employment elasticity with respect to the participation tax rate η_i. Therefore, if η_i is large, the optimal participation tax rate is lower. This is in line with the findings from Diamond (1980) and Saez (2002).

Turning to the marginal distributional benefits (or costs) on the right-hand side of equation (2.15), the first term captures the direct distributional effect of raising the participation tax rate. It equals the marginal value of raising one unit of revenue minus the utility loss if workers in sector i pay one unit more tax. Participation tax rates also indirectly redistribute resources from firm-owners to workers by affecting equilibrium wages, as captured by the second term. This redistribution of income is socially desirable if the workers in sector i have a higher social welfare weight than the firm-owners ($b_i > 1$). Moreover, this distributional effect is stronger, the higher is the elasticity of wages with respect to participation tax rates κ_i.

Like in Diamond (1980), Saez (2002), and Choné and Laroque (2011) we find that it is optimal to subsidize participation, i.e., setting $t_i < 0$, for low-income workers whose welfare weight is above one, i.e., if $b_i > 1$. However, and in contrast to these papers, in unionized labor markets subsidizing participation can also be optimal for workers whose welfare weight is below one ($b_i < 1$). This occurs if the welfare cost of involuntary unemployment is high, so that the implicit tax τ_i is large. Intuitively, explicit subsidies on participation can be desirable to offset the distortions from implicit taxes on participation even if $b_i < 1$.

Our optimal tax formula nests the one derived in Saez (2002) without an occupational-choice margin as a special case. In a model with exogenous wages, he shows that optimal participation tax rates satisfy:

$$\frac{t_i}{1-t_i} = \frac{1-b_i}{\gamma_i}, \quad \gamma_i \equiv \frac{\partial G(\varphi_i^*)}{\partial \varphi_i^*} \frac{\varphi_i^*}{G(\varphi_i^*)}, \tag{2.16}$$

where γ_i denotes the participation elasticity in sector i. If labor demand is infinitely elastic (i.e., if labor types are perfect substitutes in production), equations (2.15) and (2.16) coincide. In this case, unions always refrain from demanding above market-clearing wages. The result from Saez (2002) also holds if labor types are imperfect substitutes in production and there are no unions (i.e., $\rho_i = 0$ for all i). The same result is derived as well in Christiansen (2015). If labor markets are perfectly competitive, labor-demand considerations are therefore irrelevant for the characterization of optimal participation tax rates. See also Diamond and Mirrlees (1971a,b), who show that optimal taxes are the same in partial as in general equilibrium.[17]

Up to this point, we assumed that the government has access to a perfect profit tax. Earlier studies on (optimal) taxation in unionized labor markets have explicitly considered restrictions on profit taxation, either to prevent a first-best outcome or to analyze rent appropriation by unions.[18] How does a potential restriction on profit taxation affect the design of optimal participation tax rates? The following Corollary provides the answer.

Corollary 2.1. *If Assumptions 2.1 (independent labor markets), 2.2 (efficient rationing), and 2.3 (no income effects at the union level) are satisfied, and profit taxes T_f are exogenously determined, then optimal unemployment benefits $-T_u$ and participation tax rates t_i are determined by:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{2.17}$$

$$\left(\frac{t_i + \tau_i}{1 - t_i}\right) \eta_i = (1 - b_i) \left(1 + \frac{t_i}{1 - t_i} \kappa_i\right) + \left(\frac{b_i - b_f}{1 - t_i}\right) \kappa_i. \tag{2.18}$$

Proof. See Appendix C. □

Compared to Proposition 2.1, the expression for the optimal unemployment benefit is unaffected. The restriction on profit taxes modifies the optimal participation tax rate in two ways. First, if profits cannot be taxed, wage increases (resulting from an increase in the participation tax rate) are taxed. The welfare effect is proportional to $1 - b_i$ and is stronger the higher is the wage elasticity with respect to the participation tax κ_i. This is captured by the modification of the first term on the right-hand side of equation (2.18). Second, higher participation tax rates indirectly redistribute resources from firm-owners to workers by motivating unions to raise their wage demands. This is captured by the second term on the right-hand side of equation (2.18). The associated welfare effect is proportional to $b_i - b_f$ and is weighted by the elasticity of wages with respect to the participation tax rate κ_i. With a binding restriction on profit taxes, the welfare weight

[17] Saez (2004) refers to this finding as the 'tax-formula result'.

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

of the firm-owners falls short of one, i.e., $b_f < 1$. The more binding is the restriction on profit taxation (i.e., the lower is b_f), the higher should participation tax rates be set to correct for the absence of the profit tax and to indirectly redistribute income from firm-owners to workers. The finding that income taxes are adjusted to indirectly redistribute income from firms to workers has been established as well in Fuest and Huber (1997) and Aronsson and Sjögren (2004).

2.5 Desirability of unions

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

Proposition 2.2. *If Assumption 2.2 (efficient rationing) is satisfied, and taxes are set optimally as in Proposition 2.1, then increasing union power ρ_i in sector i raises social welfare if and only if the welfare weight of the workers in sector i exceeds one: $b_i > 1$.*

Proof. See Appendix D. □

According to Proposition 2.2, unions are desirable if they represent low-income workers for whom $b_i > 1$. To understand why, consider a marginal increase in union power ρ_i, starting from a competitive labor market (i.e., $\rho_i = 0$). If $b_i > 1$, participation is subsidized on a net basis in the policy optimum without unions, see Diamond (1980) and equation (2.16). Consequently, labor participation is distorted upwards: too many low-skilled workers decide to participate. Unions alleviate this distortion by offsetting the explicit subsidy on participation with an implicit tax τ_i on participation. The implicit tax τ_i lowers employment, and, hence, raises government revenue. Moreover, the rise in the equilibrium wage transfers income from firm-owners (whose welfare weight is one) to employed workers in sector i (whose welfare weight is above one), which again raises social welfare. Finally, starting from a competitive labor market, a marginal increase in unemployment does not lead to a utility loss of the workers who lose their job, since labor rationing is efficient. As a result, the introduction of a union unambiguously raises social welfare if the social welfare weight of the workers in this sector is larger than one ($b_i > 1$). This result bears resemblance to Lee and Saez (2012), who show that a minimum wage is desirable if the welfare weight of the workers subject to the minimum wage is larger than one. Intuitively, the minimum wage reduces upward participation distortions from participation subsidies by generating unemployment, see also Gerritsen and Jacobs (2020).

For the same reasons, there is no role for a union in sector i if workers have social welfare weights that are smaller than one, i.e., $b_i < 1$. In this case, labor participation is distorted downwards. Higher union power exacerbates these distortions. Moreover, higher union power results in redistributional losses, because the welfare weight of firm-owners is larger than the welfare weight of workers. Hence, unions cannot meaningfully complement an optimal tax system.[19]

Another way to understand the efficiency-enhancing role of unions is through the following thought experiment. Below we employ this policy experiment to analyze the desirability of unions in more complicated settings, including the case with inefficient rationing. Consider a marginal increase in union power ρ_i starting from an optimized tax-benefit system. Furthermore, suppose that jointly with the increase in union power ρ_i, the government off-sets the upward pressure on the wage w_i by lowering the participation tax rate t_i in sector i. To keep the budget balanced, the profit tax T_f can be increased.[20] This joint policy reform of raising union power, lowering the participation tax rate, and raising the profit tax thus keeps the equilibrium wage and employment fixed, and only brings about a transfer in income from firm-owners (whose welfare weight is one) to low-skilled workers (whose welfare weight exceeds one). Hence, raising union power ρ_i is welfare-enhancing if and only if $b_i > 1$.

Proposition 2.2 holds irrespective of whether there are income effects at the union level and whether labor markets are independent. Importantly, Proposition 2.2 also generalizes to a setting where profits cannot be fully taxed, as formally demonstrated in Appendix D. At first sight, this result appears counter-intuitive, because increasing union power

[19]In most OECD countries, participation is taxed on a net basis (OECD, 2018c). Hence, if the tax-benefit system is optimally set, an increase in union power reduces social welfare. We get back to this point in Section 2.7.

[20]Increasing the profit tax is only one way to finance the decrease in the participation tax rate for workers in sector i. As long as the marginal cost of public funds equals one, the argument carries over to other instruments as well.

may seem desirable if profits cannot be taxed directly. The reason why a restriction on profit taxes does not affect the desirability condition of unions is that the government can already achieve indirect redistribution from firms to workers via the tax-benefit system. As was demonstrated in Corollary 2.1, participation tax rates should be raised if profits cannot be fully taxed – *ceteris paribus*. Unions are not helpful to achieve more income redistribution over and above what can already be achieved via the tax-transfer system.

Finally, we can use our model to characterize optimal union power in each sector in the next Corollary.[21]

Corollary 2.2. *Let $\hat{\rho}_i$ be the union power such that the social welfare weight of workers in sector i equals one: $\hat{\rho}_i \equiv \{\rho_i : b_i = 1\}$. If Assumption 2.2 (efficient rationing) is satisfied, and taxes and transfers are set according to Proposition 2.1, then the optimal degree of union power in sector i equals $\rho_i^* = \min[\hat{\rho}_i, 1]$ if $b_i \geq 1$, and $\rho_i^* = \max[\hat{\rho}_i, 0]$ if $b_i \leq 1$.*

According to Corollary 2.2, for workers whose social welfare weight exceeds one (i.e., $b_i \geq 1$), the power of the union representing these workers should optimally be increased until their social welfare weight equals one. However, if this is not feasible (which can happen if workers have low wages w_i), the next best thing to do is to make the labor union a monopoly union, i.e., to set $\rho_i^* = 1$. For workers whose social welfare weight is smaller than one ($b_i < 1$), the government would like to lower the power of the union representing them. However, the government cannot decrease union power below the competitive level.

2.6 Robustness analysis

In this Section, we investigate the robustness of our results by relaxing the assumptions of independent labor markets (Assumption 2.1) and efficient rationing (Assumption 2.2). In addition, we analyze two alternative bargaining structures: one in which a single, national union bargains with firm-owners over the entire *distribution* of wages, and one in which sectoral unions bargain with firms over wages *and* employment as in the efficient bargaining model of McDonald and Solow (1981).

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

2.6.1 Interdependent labor markets

If Assumption 2.1 is violated, and labor markets are interdependent (such that $F_{ij}(\cdot) \neq 0$ for all $i \neq j$), taxes levied in one sector also affect wages and employment in other sectors. Proposition 2.3 generalizes Proposition 2.1 and characterizes optimal tax policy if labor markets are interdependent.

Proposition 2.3. *If Assumptions 2.2 (efficient rationing) and 2.3 (no income effects at the union level) are satisfied, then optimal unemployment benefits $-T_u$, optimal profit taxes T_f, and optimal participation tax rates t_i are determined by:*

$$\sum_i \omega_i b_i + \omega_u b_u = 1, \tag{2.19}$$

$$b_f = 1, \tag{2.20}$$

$$\sum_j \omega_j \left(\frac{t_j + \tau_j}{1 - t_j} \right) \eta_{ji} = \omega_i (1 - b_i) + \sum_j \omega_j (b_j - 1) \kappa_{ji}, \tag{2.21}$$

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

$$\eta_{ji} \equiv -\frac{\partial E_j}{\partial t_i} \frac{1 - t_i}{E_j} \frac{w_j(1 - t_j)}{w_i(1 - t_i)}, \tag{2.22}$$

$$\kappa_{ji} \equiv \frac{\partial w_j}{\partial t_i} \frac{1 - t_i}{w_j} \frac{w_j(1 - t_j)}{w_i(1 - t_i)}. \tag{2.23}$$

Proof. See Appendix E. □

Equations (2.19)–(2.20) are identical to those stated in Proposition 2.1, and their explanation is not repeated here. Optimal participation tax rates t_i in equation (2.21) are modified compared to their counterparts in Proposition 2.1. The left-hand side gives the marginal costs in the form of larger labor-market distortions, whereas the right-hand side gives the marginal distributional benefits (or losses) of higher participation tax rates. In contrast to Proposition 2.1, both the labor-market distortions and the distributional benefits are now summed over all sectors due to the complementarities of labor in production. In particular, the overall distortion of the participation tax rate in sector i is given by the sum over all sectors of the total tax wedge in sector j multiplied by the weighted (cross) elasticity of employment in sector j with respect to the participation tax rate in sector i. If the participation tax rate in sector i is increased, then the union in sector i raises its wage demand. *Ceteris paribus,* this leads to a decrease in employment in sector i. If labor types are complementary (i.e., $F_{ij}(\cdot) > 0$ for $i \neq j$), then the decrease in employment in sector i lowers marginal productivity and thus labor demand in all other sectors $j \neq i$. Consequently, both employment and wages in all other sectors are reduced. The reduction in employment is larger if the (weighted) cross elasticity η_{ji} of employment in sector j with respect to the participation tax rate in sector i is larger. If the sum of the explicit and implicit tax on participation is positive (negative), i.e., $\frac{t_j+\tau_j}{1-t_j} > 0$ (< 0), a higher participation tax rate in sector i exacerbates (alleviates) labor-market distortions in sector j.

The right-hand side of equation (2.21) gives the sum of the marginal distributional benefits over all sectors of a higher participation tax rate in sector i. An increase in the participation tax rate t_i directly redistributes income from workers in sector i to the government. The associated welfare effect is proportional to $1 - b_i$. Furthermore, the increase in the participation tax rate in sector i redistributes income from firm-owners (whose welfare weight is one) to workers in sector i (whose welfare weight is b_i) via a change in the wage w_i. In addition, there are indirect redistributional consequences in all other sectors $j \neq i$, because wages in all other sectors are reduced if participation tax rates in sector i are raised. If the social welfare weight of workers in sector j is larger than one, i.e., $b_j > 1$, the reduction in the wage in sector j due to higher participation tax rates 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 sector j is smaller than one, i.e., $b_j < 1$, the reduction in the wage in sector j is welfare-enhancing. This indirect welfare effect is weighted by κ_{ji}, which measures the change in the wage in sector j with respect to the participation tax rate in sector i. If labor markets are independent, $\eta_{ji} = \kappa_{ji} = 0$ for all $j \neq i$, and Proposition 2.1 applies.

Turning to the question whether or not unions are desirable if labor markets are interdependent, we find that Proposition 2.2 generalizes completely (see Appendix E for the proof). As in the case with independent labor markets, an increase in union power ρ_i raises social welfare if and only if the social welfare weight of the workers in sector i

exceeds one, i.e., $b_i > 1$. While increasing union power in sector i puts upward pressure on the wage in sector i, this effect can be perfectly offset by lowering the participation tax rate t_i in sector i, such that no change in the wage and employment in sector i results. Therefore, if neither the wage nor employment in sector i is affected by the policy reform, then wages and employment in all other sectors j do not change, even if labor markets are interconnected. Hence, the logic of our earlier policy experiment to explore the desirability of unions fully extends to the case with interdependent labor markets.

2.6.2 Inefficient rationing

We have deliberately biased our findings in favor of unions by assuming that unemployment rationing is efficient: the burden of involuntary unemployment is borne by the workers with the highest participation costs. However, there are neither theoretical nor empirical reasons to expect that labor rationing is always efficient, see Gerritsen (2017) and Gerritsen and Jacobs (2020). In this Section, we analyze how the optimal tax formulas should be modified, and under which conditions unions are desirable if the assumption of efficient rationing is relaxed. We maintain the assumptions of independent labor markets and no income effects at the union level.

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

$$e_i(E_i, \varphi_i^*, \varphi), \quad e_{iE_i}(\cdot), -e_{i\varphi_i^*}(\cdot) > 0, \tag{2.24}$$

which specifies the probability $e_i \in [0,1]$ that workers with participation costs $\varphi \in [\underline{\varphi}, \varphi_i^*]$, find employment in sector i for given employment E_i and participation threshold φ_i^*. The probability $e_i(\cdot)$ of finding a job in sector i increases in employment E_i and decreases if labor participation rises, i.e., if φ_i^* is lower.[22] For all values of employment E_i and the participation cut-off φ_i^*, the following relationship must hold:

$$\int_{\underline{\varphi}}^{\varphi_i^*} e_i(E_i, \varphi_i^*, \varphi)\mathrm{d}G(\varphi) = E_i. \tag{2.25}$$

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

Integrating over all employment probabilities of the workers in sector i (who differ in terms of their participation costs) yields sectoral employment. The following Proposition characterizes the optimal tax formulas if labor rationing is inefficient.

Proposition 2.4. *If Assumptions 2.1 (independent labor markets), 2.3 (no income effects at the union level) are satisfied, and labor rationing is described by the rationing schedule (2.24), then optimal unemployment benefits $-T_u$, optimal profit taxes T_f, and optimal participation tax rates t_i are determined by:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{2.26}$$

$$b_f = 1, \tag{2.27}$$

$$\left(\frac{t_i + \hat{\tau}_i}{1 - t_i}\right)\eta_i - \left(\frac{\psi_i}{1 - t_i}\right)\gamma_i = (1 - b_i) + (b_i - 1)\kappa_i, \tag{2.28}$$

where the union wedge is redefined as

$$\hat{\tau}_i \equiv \int_{\underline{\varphi}}^{\varphi_i^*} e_{iE_i}(E_i, \varphi_i^*, \varphi)\left(\frac{u(w_i(1 - t_i) - T_u - \varphi) - u(-T_u)}{\lambda w_i}\right)\mathrm{d}G(\varphi), \tag{2.29}$$

and ψ_i denotes the rationing wedge, which is defined as

$$\psi_i \equiv \frac{e_i(E_i, \varphi_i^*, \varphi_i^*)}{E_i/G(\varphi_i^*)} \frac{\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i, \varphi_i^*, \varphi)(u(w_i(1 - t_i) - T_u - \varphi) - u(-T_u))dG(\varphi)}{\lambda w_i \int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i, \varphi_i^*, \varphi)dG(\varphi)}. \tag{2.30}$$

Proof. See Appendix F. □

The expressions for the optimal unemployment benefit and profit tax are again identical to those stated in Proposition 2.1 and their explanation is not repeated here. The expression for the optimal participation tax rate in equation (2.28) equates the marginal distortionary costs of a higher participation tax rate (left-hand side) to the marginal distributional gains of a higher participation tax rate (right-hand side). The expression for the optimal participation tax rate is modified in two ways compared to the one with efficient rationing in equation (2.15). First, with a general rationing scheme, the union wedge $\hat{\tau}_i$ no longer measures the monetized utility loss of a *marginal* worker losing her job, but the expected utility loss of *all rationed workers*, i.e., the workers who lose their job if the wage is marginally increased. Second, in addition to the union wedge $\hat{\tau}_i$, there is a distortion associated with the inefficiency of the rationing scheme, which is captured by the rationing wedge ψ_i.

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

According to equation (2.28), the higher is ψ_i, i.e., the more inefficient is the rationing scheme, the *higher* should be the optimal participation tax rate. The intuition is similar to Gerritsen (2017): by setting a higher participation tax rate, the workers who care least about finding a job opt out of the labor market. This, in turn, increases the employment prospects of the workers who experience a larger surplus from working. Consequently, the government replaces involuntary unemployment by voluntary unemployment, which reduces the inefficiency of labor market rationing.

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

Corollary 2.3. *If Assumptions 2.1 (independent labor markets), 2.3 (no income effects at the union level) are satisfied, labor rationing is described by rationing schedule (2.24), and taxes and transfers are set according to Proposition 2.4, then an increase in union power ρ_i in sector i raises social welfare if and only if*

$$b_i > 1 + \left(\frac{\psi_i}{1 - t_i}\right)\gamma_i. \tag{2.31}$$

Proof. See Appendix F. □

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

2.6.3 Bargaining over the wage distribution

In our baseline model, bargaining takes place at the sectoral level and wages vary only across (and not within) sectors. Each sectoral union faces a trade-off between employment and wages, but does not care about the overall *distribution* of wages. There is, however, ample empirical evidence that a higher degree of unionization is associated with lower wage inequality.[23] How do our results for optimal taxes and the desirability of unions change if unions care about the entire distribution of wages?

To answer this question, we now analyze a single union which bargains with firm-owners over *all* wages. To maintain tractability, we assume efficient rationing and we assume away income effects at the union level. The union has a utilitarian objective: it maximizes the sum of all workers' expected utilities. As in the RtM-model, wages

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

are determined through bargaining between the national union and firms, while firms (unilaterally) determine employment. Since the utility function $u(\cdot)$ is concave, the union has an incentive to compress the wage distribution. Doing so is only possible if labor markets are interdependent, since in that case marginal productivity (and hence, the wage) for any group of workers depends on employment in other sectors. If labor markets would be independent, a national union would simply set the same wages in each sector as a sectoral union would, and our previous results apply.

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

First, if the union has no bargaining power at all ($\beta = 0$), the labor-market equilibrium coincides with the competitive outcome. Second, if union power β is sufficiently high, there is at least one group of workers whose wage is raised above the market-clearing level. This follows from the assumptions that, first, the union has an incentive to compress the wage distribution and, second, labor rationing is efficient. Hence, starting from the competitive labor-market outcome, a marginal increase in the bargained wage in the sector with the lowest wage compresses the wage distribution, but entails negligible welfare losses due to involuntary unemployment. Third, it may not be in the union's best interest to raise *all* wages above the market-clearing level. This is because an increase in the wage for high-skilled workers depresses the wages for low-skilled workers. A national union may therefore refrain from demanding an above market-clearing wage for high-skilled workers. The next proposition shows how taxes should be optimized if there is a single union, which bargains with firm-owners over the entire distribution of wages.

Proposition 2.5. *If Assumptions 2.2 (efficient rationing), and 2.3 (no income effects at the union level) are satisfied, labor markets are interdependent, and a single union bargains over all wages* w_i *in all sectors* i*, then the expressions for the optimal unemployment benefits* $-T_u$*, optimal profit taxes* T_f*, and optimal participation tax rates* t_i *are the same as in Proposition 2.3.*

Proof. In the absence of income effects, the reduced-form wage and employment equations can be written as $w_i = w_i(t_1, ..., t_I)$ and $E_i = E_i(t_1, ..., t_I)$. Since the optimal tax formulas from Proposition 2.3 are derived for any relationship between tax instruments and labor-market outcomes, they remain the same. □

The reason why Proposition 2.3 generalizes to a national union bargaining over the entire wage distribution is that the optimal tax rules are expressed in terms of sufficient statistics and equilibrium wages and employment only depend on participation tax rates in both cases.[24]

How is the desirability condition for unions modified if the union negotiates the wages for all workers? Once more, we can answer this question by analyzing the welfare effects of a (marginal) increase in union power β combined with a tax reform that leaves wages and employment in all sectors unaffected. To analyze the impact of such a reform, we need to keep track of the sectors where the wage is set above the market-clearing level. Denote by $k(\beta) \equiv \{i : G(w_i(1-t_i)) > E_i\}$ the set of sectors where the wage is raised above the market-clearing level. This set $k(\cdot)$ depends – among other things – on the union power $\beta \in [0, 1]$. If the union has no power ($\beta = 0$), no wage is raised above the market-clearing level, and consequently $k(\cdot)$ is empty. On the other hand, $k(\beta)$ contains at least one element if $\beta = 1$, since a utilitarian monopoly union always has an incentive to increase the wage for the workers in the sector earning the lowest wage. We assume that the set of sectors where wages are above market-clearing levels $k(\beta)$ does not change in response to a marginal increase in union power.[25]

The rise in union power puts upward pressure on the wages of workers $i \in k(\beta)$ for whom the wage already exceeds the market-clearing level (the 'direct' effect). Through

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

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

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

$$\forall i \in k(\beta): \quad \sum_{j \in k(\beta)} \frac{\partial w_i(t_1, ..., t_I, \beta)}{\partial t_j} \mathrm{d}t_j^* + \frac{\partial w_i(t_1, ..., t_I, \beta)}{\partial \beta} \mathrm{d}\beta = 0. \tag{2.32}$$

Here, the functions $w_i = w_i(t_1, ..., t_I, \beta)$ are the reduced-form equations that solve the bargaining problem (see Appendix G for details). The next Proposition derives the desirability condition for the national union.

Proposition 2.6. *If Assumptions 2.2 (efficient rationing), and 2.3 (no income effects at the union level) are satisfied, there is a national utilitarian union bargaining with firm-owners over all wages, and the tax-benefit system is optimized according to Proposition 2.3, then an increase in union power β increases social welfare if and only if*

$$\sum_{i \in k(\beta)} \omega_i (b_i - 1)(-\mathrm{d}t_i^*) > 0, \tag{2.33}$$

where the changes in participation tax rates $\mathrm{d}t_i^*$ follow from equation (2.32) and $k(\beta) \equiv \{i : G(w_i(1 - t_i)) > E_i\}$.

Proof. See Appendix G. □

Proposition 2.6 is an intuitive counterpart of Proposition 2.2: an increase in union power raises social welfare if and only if doing so allows the government to increase the incomes of workers whose social welfare weight (on average) exceeds one. By the same logic as before, the joint increase in union power and the tax reform leaves all labor-market outcomes unaffected, while raising the *net* incomes for the low-skilled. Therefore, increasing union power raises social welfare if and only if the weighted average welfare weight of workers whose wage is above the market-clearing level exceeds one. The weight depends on the share ω_i of workers in sector i and on the change in the participation tax rate $-\mathrm{d}t_i^*$ in the policy reform.

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

2.6.4 Efficient bargaining

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

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

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

$$\frac{u(w_i - T_i - \hat{\varphi}_i) - u(-T_u)}{E_i \overline{u'(w_i - T_i - \varphi)}} = \frac{w_i - F_i(\cdot)}{E_i}. \tag{2.34}$$

Intuitively, if the equilibrium wage and employment level are on the contract curve, then it is impossible to raise either union i's utility while keeping firm profits constant, or vice versa.

The contract curve defines a set of potential labor-market equilibria (w_i, E_i) in sector i. Which contract is negotiated depends on the power of union i relative to that of the firm. We model union i's power as its ability to bargain for a wage that exceeds the marginal product of labor. In particular, let σ_i denote the power of union i. We select the equilibrium in labor market i using the following rent-sharing rule:

$$w_i = (1 - \sigma_i)F_i(\cdot) + \sigma_i \phi_i(E_i), \tag{2.35}$$

where $\phi_i(E_i) \equiv \frac{\Phi_i(N_i E_i)}{N_i E_i}$ is the average productivity of a worker in sector i and Φ_i is the contribution of sector i to total output:

$$\Phi_i(N_i E_i) \equiv F(K, N_1 E_1, \cdots, N_i E_i, \cdots, N_I E_I) - F(K, N_1 E_1, \cdots, 0, \cdots, N_I E_I). \tag{2.36}$$

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

The characterization of labor-market equilibrium is graphically illustrated in Figure 2.3. As in the RtM-model, the equilibrium coincides with the competitive outcome if the union has zero bargaining power. If union power increases, the equilibrium moves

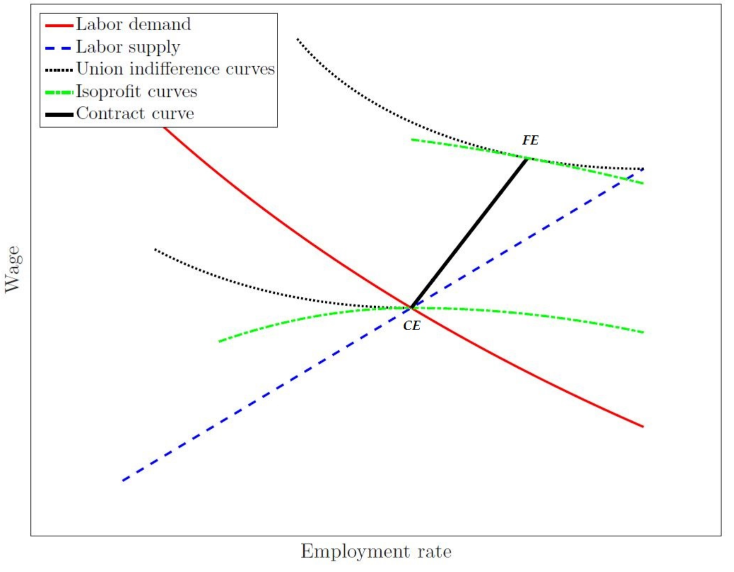


Figure 2.3: Labor market equilibria in the efficient bargaining model

along the contract curve towards the FE-equilibrium, where the union has full bargaining power. Which equilibrium is selected depends on union power σ_i.

Figure 2.3 provides three important insights. First, as in the RtM-model, there is involuntary unemployment if union power σ_i is positive. Without involuntary unemployment, unions are marginally indifferent to changes in employment, since labor rationing is efficient. Hence, unions are always willing to bargain for a slightly higher wage and accept some unemployment. Second, in contrast to the RtM-model, there is also a labor-demand distortion: the wage exceeds the marginal product of labor if $\sigma_i > 0$, see equation (2.35). Consequently, the labor-market equilibrium is no longer on the labor-demand curve. Intuitively, if the wage equals the marginal product of labor, firms are indifferent to changes in employment, whereas unions are generally not. Hence, it is possible to negotiate a labor contract with a lower wage and higher employment, which benefits both parties. As a result, efficient bargaining results in implicit subsidies on labor demand. Third, and in stark contrast to the RtM-model, an increase in union power will not only result in a higher wage, but also in *higher* employment. As illustrated in Figure 2.3, the contract curve is upward sloping. The higher is union power, the larger is the share of the bargaining surplus that accrues to union members. Due to the concavity of the utility function $u(\cdot)$, this surplus is translated partly into higher wages, and partly into higher employment.

In the absence of income effects at the union level, and assuming independent labor markets, the contract curve (2.34) and the rent-sharing rule (2.35) jointly determine the equilibrium wage w_i and employment E_i in sector i solely as a function of the participation tax rate t_i. If the participation tax rate increases, fewer workers want to participate. In terms of Figure 2.3, the labor-supply schedule shifts upward. As a result, the equilibrium wage (employment rate) will be higher (lower) following the increase in the participation tax rate. Therefore, the comparative statics are qualitatively the same as in the RtM-model. We replicate Lemma 2.1 for the EB-model in Appendix H. The following Proposition characterizes optimal taxes.

Proposition 2.7. *If Assumptions 2.1 (independent labor markets), 2.2 (efficient rationing), and 2.3 (no income effects at the union level) are satisfied, and the efficient-bargaining equilibrium in labor market i is determined by the contract curve (2.34) and the rent-sharing rule (2.35), then optimal unemployment benefits $-T_u$, profit taxes T_f, and participation tax rates t_i are determined by:*

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{2.37}$$

$$b_f = 1, \tag{2.38}$$

$$\left(\frac{t_i + \tau_i - m_i}{1 - t_i}\right)\eta_i = (1 - b_i) + (b_i - 1)\kappa_i, \tag{2.39}$$

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

$$\kappa_i = \frac{u_u' w_i(1-t_i)\left(\frac{(1-m_i)(1-\sigma_i)}{\varepsilon_i} + m_i\right)}{\frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)} + \frac{u_u' w_i(1-t_i)((1-m_i)(1-\sigma_i)+m_i\varepsilon_i)}{\varepsilon_i} + (\hat{u}_i - u_u)\left(\frac{(1-m_i)}{m_i}\frac{(1-\sigma_i)}{\varepsilon_i} - 1 + \frac{(\hat{u}_i' - \overline{u}_i')}{\overline{u}_i'}\right)}, \tag{2.40}$$

$$\eta_i = \frac{-u_u' w_i(1-t_i)}{\frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)} + \frac{u_u' w_i(1-t_i)((1-m_i)(1-\sigma_i)+m_i\varepsilon_i)}{\varepsilon_i} + (\hat{u}_i - u_u)\left(\frac{(1-m_i)}{m_i}\frac{(1-\sigma_i)}{\varepsilon_i} - 1 + \frac{(\hat{u}_i' - \overline{u}_i')}{\overline{u}_i'}\right)}. \tag{2.41}$$

Proof. See Appendix H. □

The optimality conditions in the EB-model are very similar to their counterparts in the RtM-model, see Proposition 2.1. Except from differences in the definitions of the elasticities, the main difference is the implicit subsidy on labor demand m_i in the expression for the optimal participation tax rate t_i in equation (2.39). Since the equilibrium wage exceeds the marginal product of labor, a decrease in employment in sector i positively affects the firm's profits, which the government can tax without generating distortions. The higher is the implicit subsidy on labor demand m_i, the higher should optimal participation tax rates be set – *ceteris paribus.*

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

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

Proposition 2.8. *If Assumption 2.2 (efficient rationing) is satisfied, the equilibrium in labor market i is determined by the contract curve (2.34) and the rent-sharing rule (2.35), and taxes and transfers are set according to Proposition 2.7, then increasing union power* σ_i *in sector i raises social welfare if and only if* $b_i > 1$.

Proof. See Appendix H. □

According to Proposition 2.8, the condition under which an increase union power in sector i is desirable is the same as in the RtM-model. Therefore, the question whether unions are desirable or not does not depend on the bargaining structure. This might seem surprising, given that – unlike in the RtM-model – employment increases in union power in the EB-model. However, also *unemployment* increases in union power, since the contract curve is steeper than the labor-supply curve. Intuitively, the union trades off employment and wages, which is not the case at the individual level. Only the effect on unemployment is critical to assess the desirability of unions. Stronger unions still generate more involuntary unemployment. Hence, an increase in union power is desirable only if there is too much employment as a result of net subsidies on participation. Therefore, the intuition for the desirability of unions in the RtM-model carries over to the EB-model: unions are only useful only if net participation subsidies lead to overemployment.

2.7 Numerical simulations

We illustrate numerically how the presence of unions affects the optimal tax-benefit system and we explore the desirability of unions. To do so, we employ the sufficient-statistics approach developed by Kroft et al. (2020) and apply it to the Netherlands, where 84.8% of all employees in 2013 were covered by collective labor agreements (OECD, 2017). Our theoretical model captures important featurs of the bargaining process in the Netherlands. In particular, unions and representatives of firms bargain over wages (mainly) at the sectoral level and employment is unilaterally determined by firms. To calculate the optimal tax-benefit system, we need to specify the structure of the labor market and preferences for redistribution. Moreover, we require measures of the wage distribution, the current tax-benefit system and unemployment rates by earnings level, and the current tax-benefit system.

2.7.1 Baseline calibration

Our baseline is the RtM-model with independent labor markets, efficient rationing, and no income effects at the union level. In our simulations, we assume the labor-market equilibrium relationships are described by the following reduced-form equations:

$$E_i = \xi_i w_i^{-\varepsilon_i}, \quad \xi_i, \varepsilon_i > 0, \tag{2.42}$$

$$E_i = \zeta_i (w_i(1-t_i))^{\gamma_i^e}, \quad \zeta_i, \gamma_i^e > 0. \tag{2.43}$$

Equation (2.42) gives the standard labor-demand schedule, where ε_i denotes the labor-demand elasticity. Equation (2.43) is the 'effective' labor-supply schedule. The effective labor-supply schedule differs from the standard 'notional' labor-supply schedule due to the unemployment created by unions. The union mark-up equation (2.8) implicitly defines the effective labor-supply schedule for a given labor-demand elasticity ε_i, union power ρ_i, and participation tax rate t_i. γ_i^e is the effective labor-supply elasticity, which in the absence of unions corresponds to the participation elasticity γ_i. Hence, in the absence of unions, effective and notional labor supply coincide.

Equilibrium employment and wages can be written as functions of the participation tax rates only, i.e., $E_i = E_i(t_i)$ and $w_i = w_i(t_i)$, with corresponding elasticities η_i and κ_i. The latter are related to the effective supply and demand elasticities through $\eta_i = \frac{\gamma_i^e \varepsilon_i}{\gamma_i^e + \varepsilon_i}$ and $\kappa_i = \frac{\gamma_i^e}{\gamma_i^e + \varepsilon_i}$. We assume a labor-demand elasticity of $\varepsilon_i = 0.3$, which is constant. This value is well within the range of common estimates, see, e.g., Lichter et al. (2015) for a recent overview. We proxy the effective labor-supply elasticity γ_i^e by an estimate for the participation elasticity γ_i. In particular, we set $\gamma_i^e = 0.16$ based on estimates for the Netherlands provided in Mastrogiacomo et al. (2013). We conduct sensitivity analyses for $\varepsilon_i = 0.6$ and $\gamma_i^e = 0.32$. We use three different degrees of union power: i) the competitive labor market ($\rho_i = 0$), ii) an intermediate degree of union power ($\rho_i = 0.5$), iii) monopoly unions ($\rho_i = 1$).

We assume a constant elasticity of inequality aversion $\nu \geq 0$ to write the social welfare weights as:

$$b_i \equiv \frac{1}{\lambda(w_i(1-t_i) - T_u)^{\nu}}, \quad b_u \equiv \frac{1}{\lambda(-T_u)^{\nu}}. \tag{2.44}$$

The government is non-redistributive if $\nu = 0$ and Rawlsian if $\nu \to \infty$. Our baseline value is $\nu = 1$. The social welfare weights only depend on consumption and do not account for participation costs, as in Saez (2002) and Kroft et al. (2020). The social welfare weights of the employed workers are therefore underestimated relative to the unemployed workers – *ceteris paribus*. In a robustness check, we analyze how our results are affected if the social welfare weight of the unemployed is scaled downwards.

Ideally, we like to use sectoral data on wage and unemployment rates to calibrate our model. However, this is empirically challenging, since we cannot observe sectoral unemployment rates. The latter requires assigning a specific sector to the unemployed workers. Therefore, we follow Kroft et al. (2020) and associate an earnings level with a particular level of education. This allows us to measure employment rates by earnings level. Data on wages, taxes, and unemployment rates for five education levels are obtained from CPB Netherlands Bureau for Economic Policy Analysis.[26] The value of the uemployment benefit is set equal to 12,000 euros.[27]

All simulation inputs are summarized in Table 2.1. Optimal participation tax rates and unemployment benefits are calculated by solving the optimal tax formulas in sufficient statistics, see Proposition 2.1. Since there is no clear-cut empirical counterpart of the pure profit tax T_f, we decided to ignore firm-owners in our simulations. This is without much loss of generality, since the revenue from the profit tax can be interpreted equivalently as a lower revenue requirement for the government. Hence, as the revenue requirement only affects the multiplier on the government budget constraint λ, the profit tax only implies a different cardinalization of the social preference for income redistribution. For further details on the simulations, see Appendix I.

Table 2.1: Labor-market statistics and tax-benefit system by education level

	(1) Primary education	(2) Lower secondary education	(3) Upper secondary education	(4) Bachelor degree	(5) Master degree
Wage	22,912	25,430	30,661	42,344	59,886
Employment rate	0.646	0.771	0.879	0.927	0.917
Income tax	5,471	6,771	9,120	14,587	22,423
Unemployment benefit	12,000	12,000	12,000	12,000	12,000
Labor force shares	0.081	0.230	0.432	0.174	0.083

Data are obtained from CPB Netherlands Bureau of Economic Policy Analysis and are calculated from the Labor Panel of Statistics Netherlands, see Jongen et al. (2014).

[26] CPB Netherlands Bureau for Economic Policy Analysis calculated the statistics reported in Table 2.1. These are based on the Labor Market Panel from Statistics Netherlands, which is a rich administrative household panel dataset covering the period 2006-2009. For more details, see Jongen et al. (2014).

[27] This corresponds to a monthly benefit of 1,000 euros, which lies between the social-assistance benefit for singles (approximately 600 euro), single parents (approximately 850 euro), and couples (approximately 1,200 euro) for the period 2006-2009 in the Netherlands.

2.7.2 Optimal taxes

Figure 2.4 shows our most important finding: optimal participation tax rates are substantially lower in unionized labor markets. In the baseline simulation, optimal participation tax rates at the bottom of the income distribution vary from around 30% without unions to approximately −4% if there are monopoly unions. The reduction in participation tax rates is brought about mostly by a sharp reduction in the optimal unemployment benefit, which is lowered from around 11,800 euros if unions are absent (close to the current value of 12,000 euros) to less than 3,000 euros with monopoly unions. The reason why participation tax rates are lowered by such a large amount is that the union wedge τ_i is high if unions are more powerful and the labor-demand elasticity ε_i is low, as in our simulations. Hence, the distortions generated by unions (in the form of higher unemployment) are large. The government then optimally lowers participation tax rates to moderate wage demands and to reduce involuntary unemployment.

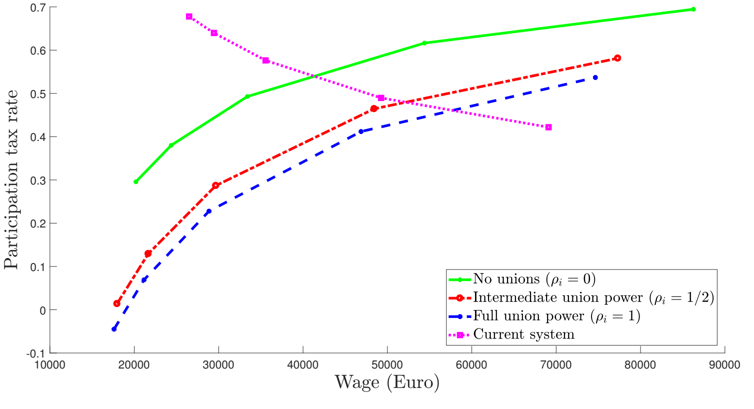


Figure 2.4: Optimal participation tax rates (baseline)

Figure 2.5 plots the social welfare weights by income. The social welfare weight for the unemployed is much higher if unions are strong, since the optimal unemployment benefit is much lower. Moreover, all workers have a social welfare weight that is smaller than one. Hence, participation is never subsidized on a net basis, which implies that the explicit subsidy on participation is never larger than the implicit tax on participation created by unions. However, it is still possible that participation is subsidized. In particular, Figure

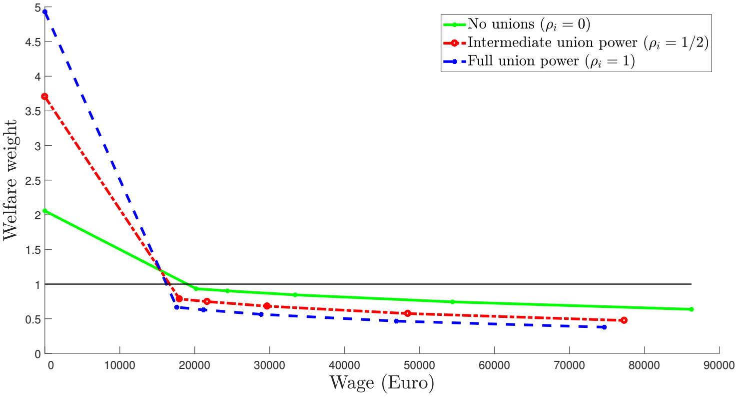


Figure 2.5: Social welfare weights (baseline)

2.4 shows that subsidizing participation (i.e., setting a negative participation tax rate) for low-income workers is optimal if union power is sufficiently close to one ($\rho_i \approx 1$), i.e., if the union is close to a monopoly union. Hence, if the costs of unemployment are sufficiently high, then the government may subsidize participation even if the welfare weight of the working poor falls short of one (see Proposition 2.1). This can never occur if labor markets are competitive, as in Diamond (1980) and Saez (2002).

Furthermore, since the social welfare weights of all working individuals are below one, Proposition 2.2 immediately implies that an increase in union power in any sector reduces social welfare, irrespective of the degree of initial union power. Therefore, even starting from a competitive labor market, introducing a union for low-income workers is not socially desirable. However, this result should be interpreted with caution, since it heavily relies on the specification for the social welfare weights, as we show below.

2.7.3 Sensitivity Analysis

In this Section, we analyze how our numerical results are affected if some of the key underlying parameters or assumptions are changed. The corresponding figures can be found in Appendix I. First, we double the labor-demand elasticity from to $\varepsilon_i = 0.3$ to to $\varepsilon_i = 0.6$. There is no empirical consensus on the value of the labor-demand elasticity. Based on an extensive meta-regression analysis, Lichter et al. (2015) give a preferred estimate of around 0.25, close to our baseline value of 0.3. However, they argue that there is substantial heterogeneity in the reported estimates, with higher estimates for lower-income workers, and over longer time horizons. Figure 2.6 shows optimal participation tax rates if the labor demand elasticity is doubled. Optimal participation tax rates are still lower if unions have more power. However, the reduction is less pronounced than with relatively inelastic labor demand, because the union wedge decreases in the labor-demand elasticity (see Proposition 2.1).

Turning to the participation elasticity, Figure 2.8 shows the optimal tax rates if the participation elasticity is doubled from a baseline value of $\gamma^e = 0.16$ to a value of $\gamma^e = 0.32$. As expected, a higher participation elasticity reduces optimal participation tax rates, in line with the theoretical findings from Diamond (1980), see Figures 2.4 and 2.8. The reduction in optimal participation tax rates due to unions is of a similar magnitude as before. Intuitively, the union wedge only depends on the labor-demand elasticity and not on the participation elasticity.

Next, we consider a reduction in the social welfare weight of the unemployed relative to the employed workers. Our baseline specification of the social welfare weights ignores participation costs, which generates an upward bias in the social welfare weight of the unemployed. Furthermore, there might be other (non-welfarist) motives why the government attaches a higher social welfare weight to the working poor, for instance because the government considers the working poor more deserving than the non-working poor. Figure 2.10 shows the optimal participation tax rates if the social welfare weight of the unemployed is scaled down with a factor 2.25. Not surprisingly, optimal participation tax rates are lower compared to the baseline. The reduction in optimal participation tax rates is brought about mostly by a reduction in the unemployment benefit. Therefore, equilibrium social welfare weights of the unemployed do not change much, despite the downward scaling of their weight, see Figures 2.5 and 2.11. Furthermore, Figure 2.11 shows that the social welfare weight of the working poor is now raised to a level slightly above one if there are monopoly unions. Hence, the conclusions on the desirability of unions are sensitive to the choice of the social welfare function. If sufficient weight is attached to the working poor relative to the non-working poor, an increase in union power for the low-income workers can be welfare-improving.

Finally, we analyze the case with interdependent labor markets. This case is theoretically analyzed in Section 2.6.1. In the presence of general-equilibrium spill-over effects on wages, the equilibrium in sector i depends on all tax instruments: $E_i = E_i(t_1, \cdots, t_I)$ and $w_i = w_i(t_1, \cdots, t_I)$. To calculate optimal taxes with the sufficient-statistics approach, we require knowledge on all the behavioral elasticities (i.e., on all η_{ij}'s and κ_{ij}'s). However, as argued by Kroft et al. (2020), there is hardly any direct evidence on these cross-elasticities. Hence, we impose structure on the production technology, which implies how the own- and cross-elasticities are related. In particular, we assume the production function is Cobb-Douglas:

$$F(K, L_1, \cdots, L_I) = AK^{1-\sum_i \alpha_i} \prod_i L_i^{\alpha_i}. \tag{2.45}$$

Labor demand in each sector i is then given by:

$$w_i = \alpha_i \frac{AK^{1-\sum_j \alpha_j} \prod_j L_j^{\alpha_j}}{L_i}, \tag{2.46}$$

which replaces the labor-demand equations (2.42) in our baseline simulation. The employment and wage elasticities with respect to the participation tax rates depend on the share parameters α_i. To obtain an estimate for α_i, we exploit the property that workers in sector i receive a fraction $\alpha_i / \sum_j \alpha_j$ of the total wage bill, which can be calculated from Table 2.1. Combined with an estimate of the aggregate labor income share $\sum_j \alpha_j$, this allows us to pin down the α_i for each sector i. We set $\sum_j \alpha_j = 0.75$, which is approximately an average of the aggregate labor share over the period 2006-2009 in the Netherlands.[28]

Figure 2.12 shows optimal participation tax rates in interdependent labor markets. The pattern of optimal participation tax rates is the same as before: they are increasing in income and lower if unions are stronger. The reduction of optimal participation tax rates in unionized labor markets is less pronounced than in the baseline, because the labor-demand elasticity is significantly higher. The own labor-demand elasticity equals $1/(1 - \alpha_i)$, which always exceeds one, cf. equation (2.46).[29] If labor demand is more elastic, unions refrain from demanding high wages and the welfare costs of involuntary

[28] See estimates of the labor income share ('arbeidsinkomensquote') from Statistics Netherlands (Statistics Netherlands, 2017).

[29] The labor-demand elasticity lies between 1.03 and 1.44 in the simulations, with an unweighted average of 1.19.

unemployment are lower. As a result, labor-market distortions are lower, and optimal participation tax rates are reduced less if the impact of unions is taken into account.

2.8 Conclusions

The aim of this paper has been to answer two questions concerning optimal income redistribution in unionized labor markets. Our first question was: *'How should the government optimize income redistribution if labor markets are unionized?'* Our most important finding is that the optimal tax-benefit system is much less redistributive than in competitive labor markets. Intuitively, the tax system is not only used to redistribute income, but also to alleviate the distortions induced by unions. Lower income taxes and lower benefits motivate unions to moderate their wage demands, which results in less involuntary unemployment. We show that participation tax rates should be lower the larger are the welfare gains from lowering involuntary unemployment. Therefore, it may be optimal to subsidize participation even for workers whose social welfare weight falls short of one, which cannot happen if labor markets are competitive (see, e.g., Diamond, 1980, Saez, 2002, and Choné and Laroque, 2011). Our simulations suggest that optimal participation tax rates are substantially lower if unions are more powerful. Hence, the optimal tax-benefit system may feature a strong EITC-component.

Our second question was: *'Can labor unions be socially desirable if the government wants to redistribute income?'* We show that increasing the power of the unions representing workers whose social welfare weight exceeds one is welfare-enhancing, while the opposite holds true for workers whose social welfare weight is below one. Since Diamond (1980), it is well known that participation is optimally subsidized for workers with a social welfare weight larger than one, i.e., they receive an income transfer which exceeds the unemployment benefit. Consequently, participation for these workers is distorted upwards, which results in *overemployment*. By bidding up wages, unions create implicit taxes on employment, which reduce the upward distortions from participation subsidies. However, in the typical case that participation is taxed on a net basis, employment is distorted downwards, and increasing union power only exacerbates labor-market distortions.

Whether unions are desirable thus depends critically on the preference for redistribution and, in particular, whether low-income workers are subsidized or taxed on a net basis.

We have made some assumptions that warrant further research. First, we assumed throughout that the government is the Stackelberg leader relative to firms and unions. However, unions may internalize some of the macro-economic and fiscal impacts of their decisions in wage negotiations, see also Calmfors and Driffill (1988). For future research, it would be interesting to generalize our model to a setting where unions and the government interact strategically. Second, we have abstracted from labor supply on the intensive margin and from a wage-moderating effect of tax progressivity. It would be interesting to extend the model to include an intensive margin and to analyze how our results are affected if the union's decisions would be influenced by marginal tax rates.

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

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

$$\begin{aligned}\max_{w_i,E_i}\ \Omega_i = \beta_i \log\left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi)\right)\\ + (1-\beta_i)\log\left(u(F(\cdot) - \sum_i w_i N_i E_i - T_f) - u(F(\cdot)|_{E_i=0} - \sum_{j\neq i} w_j N_j E_j - T_f)\right)\\ \text{s.t. } w_i = F_i(\cdot),\\ G(w_i - T_i + T_u) - E_i \geq 0, \qquad (2.47)\end{aligned}$$

where $\beta_i \in [0,1]$ is the weight attached to the union's payoff in the Nash product, and $F(\cdot)|_{E_i=0}$ is the firm's output if it does not reach an agreement with the union in sector i, and, hence, none of the workers in sector i find employment. The payoffs are taken in deviation from the payoff associated with the disagreement outcome. It is important to take the voluntary participation constraint in equation (2.47) explicitly into account, as it will bind for small values of β_i. If β_i is close to zero, labor-market equilibrium is characterized by the final two conditions, which jointly define the competitive equilibrium.

The Lagrangian reads as:

$$\begin{aligned}\mathcal{L} =& \beta_i \log\left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi)\right) \\ &+(1-\beta_i)\log\left(u(F(\cdot) - \sum_i w_i N_i E_i - T_f) - u(F(\cdot)|_{E_i=0} - \sum_{j\neq i} w_j N_j E_j - T_f)\right) \\ &+\vartheta_i(w_i - F_i(\cdot)) + \mu_i(G(w_i - T_i + T_u) - E_i). \end{aligned} \quad (2.48)$$

The first-order conditions are given by:

$$w_i: \ \frac{\beta_i}{(\overline{u_i} - u_u)}\overline{u_i'} - \frac{(1-\beta_i)}{(u_f - u_f^{-i})}u_f' N_i E_i + \vartheta_i + \mu_i G_i' = 0, \quad (2.49)$$

$$E_i: \ \frac{\beta_i}{(\overline{u_i} - u_u)}E_i(\hat{u}_i - u_u) - \vartheta_i F_{ii} - \mu_i = 0, \quad (2.50)$$

$$\vartheta_i: \ w_i - F_i = 0, \quad (2.51)$$

$$\mu_i: \ \mu_i(G_i - E_i) = 0, \quad (2.52)$$

where the bars indicate averages over all employed workers in sector i, and $\hat{u}_i$ is the utility of the marginal worker in sector i, $u_f^{-i} \equiv u(F(\cdot)|_{E_i=0} - \sum_{j\neq i} w_j N_j E_j - T_f)$ is the utility of firm-owners if they fail to reach an agreement with the union in sector i. If $\beta_i = 1$, equations (2.49)–(2.50) imply that $\mu_i = 0$, and we find the equilibrium of the monopoly-union model. For small values of β_i, the constraint $G_i = E_i$ becomes binding, and the labor-market equilibrium coincides with the competitive outcome. This can be verified by setting $\beta_i = 0$. Equations (2.49)–(2.50) then imply that $\mu_i > 0$. This is the case for all values of $\beta_i \in [0, \beta_i^*]$, where $\beta_i^* \in (0,1)$ solves:

$$\frac{\beta_i^*}{1-\beta_i^*} = \frac{E_i(\overline{u_i} - u_u)}{(u_f - u_f^{-i})}\frac{u_f' N_i}{\overline{u_i'}}. \quad (2.53)$$

This equation is obtained by setting $G_i = E_i$ and $\mu_i = 0$ in the system of first-order conditions in equations (2.49)–(2.52). The reason is that, at exactly this value of β_i, the constraint $G_i = E_i$ becomes binding. For values of $\beta_i \in [\beta_i^*, 1]$, we thus have $\mu_i = 0$. Combining equations (2.49)–(2.50) then leads to:

$$1 - \left(\frac{1-\beta_i}{\beta_i}\right) \frac{E_i(\overline{u_i} - u_u)}{(u_f - u_f^{-i})} \frac{u'_f N_i}{\overline{u'_i}} = \varepsilon_i \frac{(\hat{u}_i - u_u)}{\overline{u'_i} w_i}. \tag{2.54}$$

Defining the left-hand side of this equation as:

$$\rho_i \equiv 1 - \left(\frac{1-\beta_i}{\beta_i}\right) \frac{E_i(\overline{u_i} - u_u)}{(u_f - u_f^{-i})} \frac{u'_f N_i}{\overline{u'_i}}, \tag{2.55}$$

we arrive at our equilibrium condition in the RtM-model, as given by equation (2.8). Clearly, if $\beta_i = 1$, we have $\rho_i = 1$, so that the MU-model applies. If $\beta_i = \beta_i^*$, from equation (2.53) it follows that $\rho_i = 0$, and the equilibrium coincides with the competitive outcome. Hence, there exists a direct relationship between our measure of union power ρ_i and the Nash-bargaining parameter β_i:

$$\rho_i = \begin{cases} 0 & \text{if} \quad \beta_i \in [0, \beta_i^*), \\ 1 - \frac{(1-\beta_i)}{\beta_i} \frac{E_i(\overline{u_i} - u_u)}{(u_f - u_f^{-i})} \frac{u'_f N_i}{\overline{u'_i}} & \text{if} \quad \beta_i \in [\beta_i^*, 1]. \end{cases} \tag{2.56}$$

Appendix B: Derivation elasticities

This appendix derives the elasticities of wages and employment rates with respect to the tax instruments. If Assumption 2.1 is satisfied, and income effects at the union level are absent, we have $\partial E_i/\partial T_i = -\partial E_i/\partial T_u$ and $\partial w_i/\partial T_i = -\partial w_i/\partial T_u$. The equilibrium wage and employment rate in sector i can then be written solely as a function of the participation tax rate $t_i \equiv (T_i - T_u)/w_i$. Hence, we can write $E_i = E_i(t_i)$ and $w_i = w_i(t_i)$. The elasticities can then be derived using the labor-market equilibrium conditions:

$$w_i = F_i(E_i), \tag{2.57}$$

$$\rho_i \overline{u'(w_i(1-t_i) - T_u - \varphi)} w_i = \varepsilon_i(E_i)(u(w_i(1-t_i) - T_u - G^{-1}(E_i)) - u(-T_u)), \tag{2.58}$$

where

$$\overline{u'(w_i(1-t_i)-T_u-\varphi)} = E_i^{-1}\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i)-T_u-\varphi)\mathrm{d}G(\varphi), \tag{2.59}$$

denotes the average marginal utility of the employed workers.

Without income effects, T_u affects E_i and w_i only through its impact on t_i. Formally, this implies that the derivative of equation (2.58) with respect T_u, while keeping t_i constant, is zero:

$$-\rho_i\overline{u''(w_i(1-t_i)-T_u-\varphi)}w_i = -\varepsilon_i(E_i)(u'(w_i(1-t_i)-T_u-G^{-1}(E_i))-u'(-T_u)). \tag{2.60}$$

See also the derivation for the case with income effects in Appendix C.

To obtain an expression for the elasticities, we log-linearize the labor-market equilibrium conditions around an initial equilibrium:

$$\frac{\mathrm{d}E_i}{E_i} = -\varepsilon_i\frac{\mathrm{d}w_i}{w_i}, \tag{2.61}$$

$$\frac{\mathrm{d}\overline{u_i'}}{\overline{u_i'}} + \frac{\mathrm{d}w_i}{w_i} = \frac{\mathrm{d}\varepsilon_i}{\varepsilon_i} + \frac{\mathrm{d}(\hat{u}_i-u_u)}{\hat{u}_i-u_u}. \tag{2.62}$$

Using equation (2.60), we can linearize the parts of the last equation:

$$\frac{\mathrm{d}\overline{u_i'}}{\overline{u_i'}} = \frac{\overline{u_i''}w_i(1-t_i)}{\overline{u_i'}}\left(\frac{\mathrm{d}w_i}{w_i}-\frac{\mathrm{d}t_i}{1-t_i}\right) + \frac{(\hat{u}_i'-\overline{u_i'})}{\overline{u_i'}}\frac{\mathrm{d}E_i}{E_i}, \tag{2.63}$$

$$\frac{\mathrm{d}\varepsilon_i}{\varepsilon_i} = \varepsilon_{\varepsilon_i}\frac{\mathrm{d}E_i}{E_i}, \tag{2.64}$$

$$\frac{\mathrm{d}(\hat{u}_i-u_u)}{\hat{u}_i-u_u} = \frac{\hat{u}_i'w_i(1-t_i)}{\hat{u}_i-u_u}\left(\frac{\mathrm{d}w_i}{w_i}-\frac{\mathrm{d}t_i}{1-t_i}\right) - \frac{\hat{u}_i'E_i}{g(\hat{\varphi}_i)(\hat{u}_i-u_u)}\frac{\mathrm{d}E_i}{E_i}, \tag{2.65}$$

where $\varepsilon_{\varepsilon_i}$ is the elasticity of the labor-demand elasticity with respect to the rate of employment:

$$\varepsilon_{\varepsilon_i} \equiv \frac{\partial\varepsilon_i}{\partial E_i}\frac{E_i}{\varepsilon_i} = -\left(1+\frac{1}{\varepsilon_i}+\frac{E_iF_{iii}}{F_{ii}}\right). \tag{2.66}$$

We find the relative changes in wages and employment in sector i as functions of the changes in the participation tax rates by solving equations (2.61) and (2.62) and substituting equations (2.63)–(2.65):

$$\frac{\mathrm{d}w_i}{w_i} = \frac{u'_u w_i(1-t_i)}{\hat{u}'_i \varepsilon_i E_i / g(\hat{\varphi}_i) + u'_u w_i(1-t_i) - (\hat{u}_i - u_u)\left(1 + \varepsilon_i \varepsilon_{\varepsilon_i} + \varepsilon_i \frac{(\overline{u'_i} - \hat{u}'_i)}{\overline{u'_i}}\right)} \frac{\mathrm{d}t_i}{1-t_i}, \quad (2.67)$$

$$\frac{\mathrm{d}E_i}{E_i} = -\frac{\varepsilon_i u'_u w_i(1-t_i)}{\hat{u}'_i \varepsilon_i E_i / g(\hat{\varphi}_i) + u'_u w_i(1-t_i) - (\hat{u}_i - u_u)\left(1 + \varepsilon_i \varepsilon_{\varepsilon_i} + \varepsilon_i \frac{(\overline{u'_i} - \hat{u}'_i)}{\overline{u'_i}}\right)} \frac{\mathrm{d}t_i}{1-t_i}. \quad (2.68)$$

Appendix C: Optimal taxation

Full optimum

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

$$\mathcal{L} = \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \right) \quad (2.69)$$
$$+ u(F(K, E_1 N_1, \cdots, E_I N_I) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i (T_u + E_i t_i w_i) + T_f - R \right).$$

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 are given by:

$$T_u : -\sum_i N_i E_i \overline{u'_i} - \sum_i N_i (1-E_i) u'_u + \lambda \sum_i N_i = 0, \quad (2.70)$$

$$T_f : -u'_f + \lambda = 0, \quad (2.71)$$

$$t_i : -N_i E_i w_i (\overline{u'_i} - \lambda) + \frac{\partial E_i}{\partial t_i} \left(N_i(\hat{u}_i - u_u) + \lambda N_i t_i w_i \right) \quad (2.72)$$
$$+ \frac{\partial w_i}{\partial t_i} \left(N_i E_i \overline{u'_i}(1-t_i) - N_i E_i u'_f + \lambda N_i E_i t_i \right) = 0,$$

where it should be noted that $\frac{\partial G^{-1}(E_i)}{\partial E_i} g(\hat{\varphi}_i) = 1$, since $\frac{\partial G^{-1}(E_i)}{\partial E_i} = \frac{\partial \hat{\varphi}_i}{\partial E_i} = \frac{1}{g(\hat{\varphi}_i)}$. To obtain the first result of Proposition 1, divide equation (2.70) by $\lambda \sum_i N_i$ and use the definitions $b_i \equiv \overline{u'(c_i)}/\lambda$, $b_u \equiv u'(c_u)/\lambda$, $\omega_i \equiv N_i E_i / \sum_j N_j$ and $\omega_u \equiv \sum_i N_i (1-E_i)/\sum_j N_j$. The second result can be found by dividing equation (2.71) by λ and using $b_f \equiv u'(c_f)/\lambda$. The final result can be found as follows. First, substitute $u'_f = \lambda$ in equation (2.72) and divide by $\lambda N_i w_i$. Next, use the definition $b_i \equiv \overline{u'(c_i)}/\lambda$, the union wedge $\tau_i \equiv \frac{u(\hat{c}_i) - u(c_u)}{\lambda w_i}$, as well as the wage elasticity κ_i and the employment elasticity η_i from equations (2.11)–(2.12), and rearrange.

Restricted profit taxation

To derive the optimal participation tax rate in the presence of a restriction on profit taxation (i.e., if $b_f < 1$), divide equation (2.72) by $\lambda N_i w_i$ and use the definitions of the welfare weights $b_i \equiv \overline{u'(c_i)}/\lambda$ and $b_f \equiv u'(c_f)/\lambda$, the union wedge $\tau_i \equiv \frac{u(\hat{c}_i)-u(c_u)}{\lambda w_i}$, as well as the wage elasticity κ_i and the employment elasticity η_i from equations (2.11)–(2.12):

$$\left(\frac{t_i + \tau_i}{1 - t_i}\right)\eta_i = (1 - b_i) + \left(\frac{b_i - b_f + (1 - b_i)t_i}{1 - t_i}\right)\kappa_i. \tag{2.73}$$

If profit taxation is unrestricted, i.e., $b_f = 1$, the result from Proposition 2.1 applies.

Income effects

If there are income effects, changes in the unemployment benefit $-T_u$ affect equilibrium employment E_i and wages w_i not only through their impact on participation tax rates t_i, but also via income effects at the union level. Therefore, we write $E_i = E_i(t_i, T_u)$ and $w_i = w_i(t_i, T_u)$. In this case, only the expression for the optimal unemployment benefit has to be modified. The first-order condition – the counterpart of equation (2.70) – reads as:

$$\begin{aligned} T_u : &- \sum_i N_i E_i \overline{u_i'} - \sum_i N_i(1 - E_i)u_u' + \lambda \sum_i N_i \\ &+ \sum_i \left(N_i(\hat{u}_i - u_u) + \lambda N_i t_i w_i\right) \frac{\partial E_i}{\partial T_u} \\ &+ \sum_i \left(N_i E_i \overline{u_i'}(1 - t_i) - N_i E_i u_f' + \lambda N_i E_i t_i\right) \frac{\partial w_i}{\partial T_u} = 0. \end{aligned} \tag{2.74}$$

To simplify this expression, divide by $\lambda \sum_i N_i$, and impose $b_f = 1$. Furthermore, note that in equilibrium employment is on the labor-demand curve. Therefore, we can use the property

$$\frac{\partial E_i}{\partial x_i} = \frac{\partial E_i}{\partial w_i}\frac{\partial w_i}{\partial x_i}, \tag{2.75}$$

for $x_i \in \{T_u, t_i\}$. Here, $\partial E_i/\partial w_i = 1/F_{ii}(\cdot)$ is the slope of the labor-demand curve. Then, combine equations (2.72), (2.74) and (2.75) to obtain:

$$\sum_i \omega_i b_i + \omega_u b_u = 1 - \sum_i \omega_i (1 - b_i)\iota_i, \tag{2.76}$$

where $\iota_i \equiv w_i \frac{\partial E_i}{\partial T_u} / \frac{\partial E_i}{\partial t_i}$. This expression generalizes equation (2.13) to the case with income effects. To obtain an expression for ι_i, combine the union mark-up in equation (2.8), and the labor-demand equation (2.4) to find:

$$\begin{aligned} &\rho_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(F_i(\cdot)(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi)F_{ii}(\cdot) \\ &+ u(F_i(\cdot)(1-t_i) - T_u - G^{-1}(E_i)) - u(-T_u) = 0. \end{aligned} \tag{2.77}$$

We can then use implicit differentiation of equation (2.77) to obtain an expression for ι_i:

$$\iota_i = 1 - \frac{u'_u}{\hat{u}'_i - (\hat{u}_i - u_u)\frac{\overline{u''_i}}{\overline{u'_i}}}. \tag{2.78}$$

Equation (2.76) is the analogue of the first result stated in Proposition 2.1. If income effects are absent, we have $\iota_i = 0$, and equation (2.60) results. This is the case if the utility function $u(\cdot)$ is of the CARA-type, i.e., $u(c) \equiv -\frac{1}{\beta}\exp[-\beta c]$.

Appendix D: Desirability of unions

In this appendix, we explicitly take the labor-market equilibrium conditions into account as constraints in the government's optimization problem, rather than deriving our results in terms of sufficient statistics. The reason for doing so is that this approach allows us to directly derive the welfare effect of an increase in union power. The maximization problem for the government then reads as:

$$\begin{aligned} \max_{T_u, T_f, \{t_i, w_i, E_i\}_{i=1}^I} \mathcal{W} = \sum_i N_i \Bigg(&\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) \\ &+ \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \Bigg) \end{aligned}$$

$$
\begin{aligned}
&+ u(F(K, E_1N_1, \cdots, E_IN_I) - \sum_i w_iN_iE_i - T_f),\\
\text{s.t.} &\sum_i N_i(T_u + E_it_iw_i) + T_f = R,\\
&w_i = F_i(K, E_1N_1, \cdots, E_IN_I), \quad \forall i,\\
&\rho_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi)F_{ii}(\cdot)\\
&+ u(w_i(1-t_i) - T_u - G^{-1}(E_i)) - u(-T_u) = 0, \quad \forall i. \qquad (2.79)
\end{aligned}
$$

The corresponding Lagrangian is given by:

$$
\begin{aligned}
\mathcal{L} = &\sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \right)\\
&+ u(F(K, E_1N_1, \cdots, E_IN_I) - \sum_i w_iN_iE_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_it_iw_i) + T_f - R \right)\\
&+ \sum_i \vartheta_i(w_i - F_i(K, E_1N_1, \cdots, E_IN_I))\\
&+ \sum_i \mu_i \Bigg(\rho_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi)F_{ii}(K, E_1N_1, \cdots, E_IN_I)\\
&+ u(w_i(1-t_i) - T_u - G^{-1}(E_i)) - u(-T_u) \Bigg). \qquad (2.80)
\end{aligned}
$$

To examine how an increase in union power ρ_i in sector i affects social welfare, differentiate the Lagrangian (2.80) with respect to ρ_i, and apply the envelope theorem:

$$
\frac{\partial \mathcal{W}}{\partial \rho_i} = \frac{\partial \mathcal{L}}{\partial \rho_i} = \mu_i E_i \overline{u_i'} F_{ii}. \qquad (2.81)
$$

Since $E_i\overline{u_i'}F_{ii} < 0$ (provided that labor demand is not perfectly elastic), the expression in equation (2.81) is positive if and only if $\mu_i < 0$. To determine the sign of μ_i, consider the first-order condition of equation (2.80) with respect to t_i:

$$
N_iE_i(\overline{u_i'} - \lambda) = -\mu_i \left(\rho_i E_i \overline{u_i''} F_{ii} + \hat{u}_i' \right). \qquad (2.82)
$$

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

$$\mu_i < 0 \quad \Leftrightarrow \quad b_i > 1. \tag{2.83}$$

Hence, an increase in ρ_i leads to an increase in social welfare if and only if $b_i > 1$. Importantly, nowhere in the proof is it necessary to assume that income effects are absent, that labor markets are independent, or that profit taxation is unrestricted (i.e., $b_f = 1$). Proposition 2.2 thus generalizes to settings with income effects, interdependent labor markets, and a binding restriction on profit taxation.

Optimal union power

Suppose that the government could optimally determine union power ρ_i. If we denote by $\underline{\chi}_i \geq 0$ the Kuhn-Tucker multiplier on the restriction $\rho_i \geq 0$, and by $\overline{\chi}_i \geq 0$ the multiplier on the restriction $1 - \rho_i \geq 0$, the first-order condition for optimal union power ρ_i in sector i (obtained from differentiating the Lagrangian (2.80) augmented with the additional inequality constraints) is given by

$$\mu_i E_i \overline{u_i'} F_{ii} + \underline{\chi}_i - \overline{\chi}_i = 0. \tag{2.84}$$

This expression should be considered alongside the other first-order conditions of the optimization program. In an interior optimum (i.e., where the optimal $\rho_i \in (0,1)$), the Kuhn-Tucker conditions require that $\underline{\chi}_i = \overline{\chi}_i = 0$. Equations (2.84) and (2.82) then imply that in these sectors $b_i = 1$. If the solution is at the boundary, then by the Kuhn-Tucker conditions it must be that either $\overline{\chi}_i = 0$ and $\underline{\chi}_i > 0$ or $\underline{\chi}_i = 0$ and $\overline{\chi}_i > 0$. If labor demand is not perfectly elastic, equation (2.84) implies that $\mu_i > 0$ in the first case (in which case $b_i < 1$) and $\mu_i < 0$ in the second case (in which case $b_i > 1$). Optimal union power thus equals $\rho_i = \min[\rho_i^*, 1]$ if $b_i \geq 1$, and $\rho_i = \max[\rho_i^*, 0]$ if $b_i \leq 1$, where ρ_i^* is the bargaining power of the union for which $b_i = 1$.

Appendix E: Interdependent labor markets

The Lagrangian is the same as in the proof of Proposition 2.1 in Appendix C:

$$\mathcal{L} = \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi) \right) \tag{2.85}$$
$$+ u(F(K, E_1N_1, \cdots, E_IN_I) - \sum_i w_iN_iE_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_it_iw_i) + T_f - R \right).$$

If labor markets are interdependent, 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 $E_i = E_i(t_1, t_2, \cdots, t_I)$. The case with income effects can be analyzed in analogous fashion as is done is Appendix C The first-order conditions read as:

$$T_u : -\sum_i N_iE_i\overline{u_i'} - \sum_i N_i(1-E_i)u_u' + \lambda \sum_i N_i = 0, \tag{2.86}$$

$$T_f : -u_f' + \lambda = 0, \tag{2.87}$$

$$t_i : -N_iE_iw_i(\overline{u_i'} - \lambda) + \sum_j \left(N_j(\hat{u}_j - u_u) + \lambda N_jt_jw_j\right) \frac{\partial E_j}{\partial t_i}$$
$$+ \sum_j \left(N_jE_j\overline{u_j'}(1-t_j) - N_jE_ju_f' + \lambda N_jE_jt_j\right) \frac{\partial w_j}{\partial t_i} = 0. \tag{2.88}$$

The first two results from Proposition 2.3 follow directly from equations (2.86)–(2.87). To arrive at the final result, divide equation (2.88) by $\lambda w_i \sum_j N_j$ and impose $b_f = 1$ to find:

$$\omega_i(1-b_i) + \sum_j \omega_j(t_j + \tau_j)\frac{w_j}{w_i}\frac{1}{E_j}\frac{\partial E_j}{\partial t_i} + \sum_j \omega_j(b_j - 1)\frac{1-t_j}{w_i}\frac{\partial w_j}{\partial t_i}. \tag{2.89}$$

The latter can be rewritten as:

$$\sum_j \omega_j \left(\frac{t_j + \tau_j}{1-t_j}\right)\eta_{ji} = \omega_i(1-b_i) + \sum_j \omega_j(b_j - 1)\kappa_{ji}, \tag{2.90}$$

where the elasticities are given by

$$\eta_{ji} \equiv -\frac{\partial E_j}{\partial t_i}\frac{1-t_i}{E_j}\frac{w_j(1-t_j)}{w_i(1-t_i)}, \tag{2.91}$$

$$\kappa_{ji} \equiv \frac{\partial w_j}{\partial t_i}\frac{1-t_i}{w_j}\frac{w_j(1-t_j)}{w_i(1-t_i)}. \tag{2.92}$$

Finally, as shown in Appendix D, the proof regarding the desirability of unions requires no assumption on the cross-derivatives $F_{ij}(\cdot)$ and hence, generalizes to a setting with interdependent labor markets.

Appendix F: Inefficient rationing

Optimal taxation

To prove Proposition 2.4, we start by characterizing some properties of the general rationing schedule, which satisfies, for all values of E_i and φ_i^*

$$\int_{\underline{\varphi}}^{\varphi_i^*} e_i(E_i, \varphi_i^*, \varphi)\mathrm{d}G(\varphi) = E_i. \tag{2.93}$$

We can differentiate equation (2.93) with respect to E_i and φ_i^* to obtain:

$$\int_{\underline{\varphi}}^{\varphi_i^*} e_{iE_i}(E_i, \varphi_i^*, \varphi)\mathrm{d}G(\varphi) = 1, \tag{2.94}$$

$$\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i, \varphi_i^*, \varphi)\mathrm{d}G(\varphi) + e_i(E_i, \varphi_i^*, \varphi_i^*)G'(\varphi_i^*) = 0. \tag{2.95}$$

Rather than deriving labor-market equilibrium explicitly for a general rationing scheme, we instead assume that income effects at the union level are absent and labor markets are independent. In this case, the equilibrium wage and employment rate only depend on the participation tax rate: $E_i = E_i(t_i)$ and $w_i = w_i(t_i)$. To derive the social welfare function, first use equation (2.93) to derive an expression for the expected utility of the unemployed:

$$(1-E_i)u(-T_u) = u(-T_u) - \int_{\underline{\varphi}}^{\varphi_i^*} e_i(E_i, \varphi_i^*, \varphi)u(-T_u). \tag{2.96}$$

Consequently, the Lagrangian for maximizing social welfare is given by:

$$\begin{aligned}\mathcal{L} = & \quad (2.97) \\ & \sum_i N_i \left(u(-T_u) + \int_{\underline{\varphi}}^{\varphi_i^*} e_i(E_i, \varphi_i^*, \varphi)(u(w_i(1-t_i) - T_u - \varphi) - u(-T_u))\mathrm{d}G(\varphi) \right) \\ & + u(F(K, E_1N_1, \cdots, E_IN_I) - \sum_i w_iN_iE_i - T_f) + \lambda \left(\sum_i N_i(T_u + E_it_iw_i) + T_f - R \right).\end{aligned}$$

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

$$T_u : -\sum_i N_iE_i\overline{u_i'} - \sum_i N_i(1-E_i)u_u' + \lambda \sum_i N_i = 0, \tag{2.98}$$

$$T_f : -u_f' + \lambda = 0. \tag{2.99}$$

$$\begin{aligned} t_i : & -N_iE_iw_i(\overline{u_i'} - \lambda) - w_iN_i \int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(u_i(\varphi) - u_u)\mathrm{d}G(\varphi) \\ & + \frac{\partial w_i}{\partial t_i} \left(\lambda N_iE_it_i + (1-t_i)N_iE_i\overline{u_i'} + (1-t_i)N_i \int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(u_i(\varphi) - u_u)\mathrm{d}G(\varphi) - N_iE_iu_f' \right) \\ & + \frac{\partial E_i}{\partial t_i} \left(\lambda N_it_iw_i + N_i \int_{\underline{\varphi}}^{\varphi_i^*} e_{iE_i}(u_i(\varphi) - u_u)\mathrm{d}G(\varphi) \right) = 0, \end{aligned} \tag{2.100}$$

where expected utility of the employed workers is given by:

$$\overline{u_i'} \equiv \int_{\underline{\varphi}}^{\varphi_i^*} \frac{e_i(E_i, \varphi_i^*, \varphi)}{E_i} u'(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi), \tag{2.101}$$

and $u_i(\varphi) \equiv u(w_i(1-t_i) - T_u - \varphi)$ is the utility of the worker with participation costs $\varphi \in [\underline{\varphi}, \varphi_i^*]$ who is employed in sector i.

Equations (2.98) and (2.99) lead to the first two results in Proposition 2.4. Next, divide equation (2.100) by $N_iE_iw_i\lambda$ and impose $b_f = 1$. In addition, define the expected utility loss of labor rationing in sector i for those workers who lose their job if the employment rate E_i is marginally reduced as:

$$\hat{\tau}_i \equiv \int_{\underline{\varphi}}^{\varphi_i^*} e_{iE_i}(E_i, \varphi_i^*, \varphi) \left(\frac{u(w_i(1-t_i) - T_u - \varphi) - u(-T_u)}{\lambda w_i} \right) \mathrm{d}G(\varphi). \tag{2.102}$$

Substitute equation (2.102) into equation (2.100) and rearrange to obtain:

$$\left(\frac{t_i+\hat{\tau}_i}{1-t_i}\right)\eta_i = (1-b_i)+(b_i-1)\kappa_i+\frac{\kappa_i-1}{E_i}\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)\frac{(u_i(\varphi)-u_u)}{\lambda}\mathrm{d}G(\varphi). \quad (2.103)$$

Next, observe that $\kappa_i - 1 = \frac{\partial\varphi_i^*}{\partial t_i}\frac{(1-t_i)}{\varphi_i^*}$. In addition, use equation (2.95) to rewrite the last part of equation (2.103) as:

$$\frac{\kappa_i-1}{E_i}\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)\frac{(u_i(\varphi)-u_u)}{\lambda}\mathrm{d}G(\varphi) = \quad (2.104)$$
$$-\frac{\partial\varphi_i^*}{\partial t_i}\frac{(1-t_i)}{\varphi_i^*}\frac{e_i(E_i,\varphi_i^*,\varphi_i^*)G'(\varphi_i^*)}{E_i}\int_{\underline{\varphi}}^{\varphi_i^*}\frac{e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)}{\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)\mathrm{d}G(\varphi)}\frac{(u_i(\varphi)-u_u)}{\lambda}\mathrm{d}G(\varphi).$$

Finally, define

$$\psi_i \equiv \frac{e_i(E_i,\varphi_i^*,\varphi_i^*)}{E_i/G(\varphi_i^*)}\frac{\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)(u(w_i(1-t_i)-T_u-\varphi)-u(-T_u))dG(\varphi)}{\lambda w_i\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)dG(\varphi)} \quad (2.105)$$

and

$$\gamma_i \equiv -\frac{\partial G(\varphi_i^*)}{\partial t_i}\frac{1-t_i}{G(\varphi_i^*)}. \quad (2.106)$$

After substituting these definitions in equation (2.103), we arrive at:

$$\left(\frac{t_i+\hat{\tau}_i}{1-t_i}\right)\eta_i - \left(\frac{\psi_i}{1-t_i}\right)\gamma_i = (1-b_i)+(b_i-1)\kappa_i. \quad (2.107)$$

Desirability of unions

To study the welfare effects of the reform described in Section 2.6.2, one can differentiate the Lagrangian in equation (2.97) with respect to t_i and T_f under the assumptions that the reform is budget neutral, and leaves wages and employment in sector i (i.e., w_i and E_i) unaffected. The welfare effect is then:

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = -N_iE_ib_iw_i\mathrm{d}t_i - b_f\mathrm{d}T_f$$
$$-N_iw_iw_i\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i,\varphi_i^*,\varphi)\frac{u(w_i-T_i-\varphi)-u(-T_u)}{w_i\lambda}\mathrm{d}G(\varphi)\mathrm{d}t_i. \quad (2.108)$$

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

Under the balanced-budget assumption, we have $N_i E_i w_i \mathrm{d}t_i + \mathrm{d}T_f = 0$. In addition, if the government can levy a non-distortionary profit tax, then $b_f = 1$. Substituting these results and equation (2.95) in equation (2.108), the change in social welfare can be written as:

$$\begin{aligned}\frac{\mathrm{d}\mathcal{W}}{\lambda} =& -N_i E_i \Bigg(b_i - 1 - e_i(E_i, \varphi_i^*, \varphi_i^*) \frac{G'(\varphi_i^*)}{E_i} \\ &\times \int_{\underline{\varphi}}^{\varphi_i^*} \frac{e_{i\varphi_i^*}(E_i, \varphi_i^*, \varphi)}{\int_{\underline{\varphi}}^{\varphi_i^*} e_{i\varphi_i^*}(E_i, \varphi_i^*, \varphi) \mathrm{d}G(\varphi)} \frac{u(w_i - T_i - \varphi) - u(-T_u)}{\lambda} \mathrm{d}G(\varphi) \Bigg) w_i \mathrm{d}t_i. \qquad (2.109)\end{aligned}$$

Given that t_i is lowered in the policy experiment (i.e., $\mathrm{d}t_i < 0$), the welfare effect is positive provided that the term in between brackets is positive. Using the definitions for ψ_i and γ_i from equations (2.105) and (2.106), this is the case if:

$$b_i > 1 + \left(\frac{\psi_i}{1 - t_i} \right) \gamma_i. \qquad (2.110)$$

Appendix G: Bargaining over multiple wages

Labor-market equilibrium

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

$$\max_{\{w_i,E_i\}_{i\in\mathcal{I}}} \Omega \;=\; \beta \log\left(\sum_i N_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi)\right)$$
$$+ (1-\beta)\log\left(u(F(K, E_1N_1, \cdots, E_IN_I) - \sum_i w_iN_iE_i - T_f) - u(F(K, 0, \cdots, 0) - T_f)\right)$$
$$\text{s.t.} \quad \forall i: \quad w_i - F_i(K, E_1N_1, \cdots, E_IN_I) = 0, \quad G(w_i - T_i + T_u) - E_i \geq 0. \tag{2.111}$$

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

$$\mathcal{L} = \beta \log\left(\sum_i N_i \int_{\underline{\varphi}}^{G^{-1}(E_i)} (u(w_i - T_i - \varphi) - u(-T_u))\mathrm{d}G(\varphi)\right)$$
$$+ (1-\beta)\log\left(u(F(K, E_1N_1, \cdots, E_IN_I) - \sum_i w_iN_iE_i - T_f) - u(F(K, 0, \cdots, 0) - T_f)\right)$$
$$+ \sum_i \vartheta_i(w_i - F_i(K, E_1N_1, \cdots, E_IN_I)) + \sum_i \mu_i(G(w_i - T_i + T_u) - E_i). \tag{2.112}$$

The first-order conditions are:

$$w_i: \frac{\beta}{\sum_j N_jE_j(\overline{u_j} - u_u)} N_iE_i\overline{u_i'} - \frac{1-\beta}{u_f - \underline{u}_f} N_iE_i\overline{u_f'} + \vartheta_i + \mu_iG_i' = 0, \tag{2.113}$$
$$E_i: \frac{\beta}{\sum_j N_jE_j(\overline{u_j} - u_u)} N_i(\hat{u}_i - u_u) - N_i\sum_j \vartheta_jF_{ji} - \mu_i = 0, \tag{2.114}$$
$$\vartheta_i: w_i - F_i = 0, \tag{2.115}$$
$$\mu_i: G_i - E_i = 0. \tag{2.116}$$

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

First, if the union has zero bargaining power ($\beta = 0$), the equilibrium coincides with the competitive outcome (i.e., $G_i = E_i$ and $w_i = F_i$ for all i). To see why, substitute $\beta = 0$ in the first-order conditions for w_i and E_i in equations (2.113) and (2.114). Next, use (2.113) to substitute for ϑ_i in equation (2.114) and rearrange:

$$\mu_i\underbrace{(N_iG_i'F_{ii}-1)}_{<0}+\ N_i\sum_{j\neq i}\mu_j\underbrace{G_j'F_{ji}}_{\geq 0}=N_i\underbrace{\frac{u_f'}{u_f-\underline{u}_f}}_{>0}\underbrace{\sum_j N_jE_jF_{ji}}_{=-F_{Ki}K<0}. \tag{2.117}$$

The inequalities follow from the assumptions of co-operant factors of production and constant returns to scale. Non-increasing marginal productivity and co-operant factors of production imply $F_{ii}\leq 0\leq F_{ji}$, whereas constant returns to scale implies $\sum_j N_jE_jF_{ji}=-F_{Ki}K\leq 0$.[30] Suppose that there is a sector in which $G_i>E_i$, i.e., the wage is above the market-clearing level. Then, from the Kuhn-Tucker conditions, it must be that $\mu_i=0$. Because of the non-negativity of all multipliers, however, equation (2.117) cannot be satisfied unless all labor types would be perfect substitutes, i.e., $F_{ii}=F_{ij}=F_{Ki}=0$ for all i,j. This is a contradiction. Therefore, $G_i=E_i$ for all i.

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

$$\Lambda=\sum_i N_i\int_{\underline{\varphi}}^{G^{-1}(E_i)}(u(F_i(K,E_1N_1,\cdots,E_IN_I)-T_i-\varphi)-u(-T_u))\mathrm{d}G(\varphi). \tag{2.118}$$

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

$$\mathrm{d}\Lambda=N_\ell\sum_j N_jE_j\overline{u_j'}F_{j\ell}\times\mathrm{d}E_\ell=N_\ell\left(N_\ell E_\ell F_{\ell\ell}\overline{u_\ell'}+\sum_{j\neq\ell}N_jE_jF_{j\ell}\overline{u_j'}\right)\mathrm{d}E_\ell. \tag{2.119}$$

[30] This follows from differentiating $F(\cdot)=F_K(\cdot)K+\sum_j N_jE_jF_j(\cdot)$ with respect to E_ℓ.

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

Optimal taxation

In the absence of income effects and under the assumption that firm-owners are risk-neutral, the first-order conditions in equations (2.113) and (2.116) characterize equilibrium wages and employment rates as a function the participation tax rates: $w_i = w_i(t_1, .., t_I)$ and $E_i = E_i(t_1, .., t_I)$.[31] These reduced-form equations can be used to derive the optimal tax formulas. This case is identical to the one with multiple unions and interdependent labor markets, which is analyzed in Appendix E. The optimal tax formulas (written in terms of elasticities) therefore remain unaffected.

Desirability of unions

To study the desirability of a national union, we analyze the welfare effects of a joint marginal increase in union power β and a marginal change in participation tax rates, which leaves all labor-market outcomes unaffected. If the tax system is optimized, any change in welfare must then necessarily be the result of the change in union power.

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

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

labor-market equilibrium condition in a sector i where the wage is at the market-clearing level:

$$G_i(F_i(\cdot)(1-t_i)) = E_i. \tag{2.120}$$

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

$$\forall i \in k(\beta): \quad \sum_{j\in k(\beta)} \frac{\partial w_i(t_1,..,t_I,\beta)}{\partial t_j}\mathrm{d}t_j^* + \frac{\partial w_i(t_1,..,t_I,\beta)}{\partial \beta}\mathrm{d}\beta = 0. \tag{2.121}$$

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

$$\frac{\mathrm{d}\mathcal{W}}{\lambda} = \sum_{i\in k(\beta)} N_i E_i (1-b_i)\mathrm{d}t_i^*, \tag{2.122}$$

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

$$\sum_{i\in k\beta} \omega_i(1-b_i)\mathrm{d}t_i^* > 0. \tag{2.123}$$

Appendix H: Efficient bargaining

Derivation elasticities

Partial equilibrium in labor market i is obtained by combining the contract curve from equation (2.34) and the rent-sharing rule from equation (2.35):

$$\overline{u'(w_i(1-t_i)-T_u-\varphi)}(w_i-F_i(E_i)) = u(w_i(1-t_i)-T_u-G^{-1}(E_i))-u(-T_u), \quad (2.124)$$

$$w_i = (1-\sigma_i)F_i(E_i)+\sigma_i\phi_i(E_i). \quad (2.125)$$

In the absence of income effects, these equations define $E_i = E_i(t_i)$ and $w_i = w_i(t_i)$. As before, the absence of income effects implies a change in T_u does not affect equilibrium wages and employment if the participation tax rate t_i remains constant. Hence, the derivative of equation (2.124) with respect T_u, while keeping t_i constant, is zero:

$$-\overline{u''(w_i(1-t_i)-T_u-\varphi)}(w_i-F_i(E_i)) = -u'(w_i(1-t_i)-T_u-G^{-1}(E_i))+u'(-T_u). \quad (2.126)$$

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

$$\frac{\mathrm{d}w_i}{w_i} = -\left((1-m_i)\frac{(1-\sigma_i)}{\varepsilon_i}+m_i\right)\frac{\mathrm{d}E_i}{E_i}, \quad (2.127)$$

where $m_i \equiv (w_i - F_i)/w_i = 1 - F_i/w_i$ is the implicit subsidy on labor demand, as a fraction of the wage. If union power is zero, $\sigma_i = 0$, $m_i = 0$, and equation (2.127) reduces to the linearized labor-demand equation.

Second, linearizing the contract curve yields:

$$\frac{\mathrm{d}\overline{u_i'}}{\overline{u_i'}} + \frac{\mathrm{d}(w_i-F_i)}{w_i-F_i} = \frac{\mathrm{d}(\hat{u}_i-u_u)}{\hat{u}_i-u_u}. \quad (2.128)$$

Using equation (2.126), the linearized sub-parts are given by:

$$\frac{\mathrm{d}\overline{u_i'}}{\overline{u_i'}} = \frac{\overline{u_i''}w_i(1-t_i)}{\overline{u_i'}}\left(\frac{\mathrm{d}w_i}{w_i}-\frac{\mathrm{d}t_i}{1-t_i}\right)+\frac{(\hat{u}_i'-\overline{u_i'})}{\overline{u_i'}}\frac{\mathrm{d}E_i}{E_i}, \quad (2.129)$$

$$\frac{\mathrm{d}(w_i - F_i)}{w_i - F_i} = \frac{1}{m_i}\left(\frac{\mathrm{d}w_i}{w_i} + \frac{(1-m_i)}{\varepsilon_i}\frac{\mathrm{d}E_i}{E_i}\right), \tag{2.130}$$
$$\frac{\mathrm{d}(\hat{u}_i - u_u)}{\hat{u}_i - u_u} = \frac{\hat{u}_i' w_i(1-t_i)}{(\hat{u}_i - u_u)}\left(\frac{\mathrm{d}w_i}{w_i} - \frac{\mathrm{d}t_i}{1-t_i}\right) - \frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)(\hat{u}_i - u_u)}\frac{\mathrm{d}E_i}{E_i}. \tag{2.131}$$

Using the definitions $\kappa_i \equiv \frac{\partial w_i}{\partial t_i}\frac{1-t_i}{w_i}$ and $\kappa_i \equiv -\frac{\partial E_i}{\partial t_i}\frac{1-t_i}{E_i}$ and solving for the relative changes in employment and wages gives the elasticities as given in Proposition 2.7:

$$\kappa_i = \frac{u_u' w_i(1-t_i)\left(\frac{(1-m_i)(1-\sigma_i)}{\varepsilon_i} + m_i\right)}{\frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)} + \frac{u_u' w_i(1-t_i)((1-m_i)(1-\sigma_i)+m_i\varepsilon_i)}{\varepsilon_i} + (\hat{u}_i - u_u)\left(\frac{(1-m_i)}{m_i}\frac{(1-\sigma_i)}{\varepsilon_i} - 1 + \frac{(\hat{u}_i' - \overline{u_i'})}{\overline{u_i'}}\right)}, \tag{2.132}$$
$$\eta_i = \frac{-u_u' w_i(1-t_i)}{\frac{\hat{u}_i' E_i}{g(\hat{\varphi}_i)} + \frac{u_u' w_i(1-t_i)((1-m_i)(1-\sigma_i)+m_i\varepsilon_i)}{\varepsilon_i} + (\hat{u}_i - u_u)\left(\frac{(1-m_i)}{m_i}\frac{(1-\sigma_i)}{\varepsilon_i} - 1 + \frac{(\hat{u}_i' - \overline{u_i'})}{\overline{u_i'}}\right)}. \tag{2.133}$$

Optimal taxation

The derivation is similar as in Appendix C. Start with the Lagrangian for the maximization of social welfare:

$$\mathcal{L} = \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi)\mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u)\mathrm{d}G(\varphi)\right)$$
$$+ u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda\left(\sum_i N_i(T_u + E_i t_i w_i) + T_f - R\right). \tag{2.134}$$

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

$$T_u : -\sum_i N_i E_i \overline{u_i'} - \sum_i N_i(1-E_i)u_u' + \lambda\sum_i N_i = 0, \tag{2.135}$$
$$T_f : -u_f' + \lambda = 0, \tag{2.136}$$
$$t_i : -N_i E_i w_i(\overline{u_i'} - \lambda) + \frac{\partial E_i}{\partial t_i}\left(N_i(\hat{u}_i - u_u) + u_f' N_i(F_i - w_i) + \lambda N_i t_i w_i\right)$$
$$+ \frac{\partial w_i}{\partial t_i}\left(N_i E_i \overline{u_i'}(1-t_i) - N_i E_i u_f' + \lambda N_i E_i t_i\right) = 0. \tag{2.137}$$

The first two expressions from Proposition 2.8 are obtained by dividing equation (2.135) by $\lambda\sum_i N_i$ and equation (2.136) by λ, and imposing the definitions of the welfare weights $b_i \equiv \overline{u'(c_i)}/\lambda$, $b_u \equiv u'(c_u)/\lambda$ and the employment shares $\omega_i \equiv N_i E_i/\sum_j N_j$ and $\omega_u \equiv \sum_i N_i(1-E_i)/\sum_j N_j$. The second result can be found by dividing equation (2.136) by λ and using $b_f \equiv u'(c_f)/\lambda$. The expression for the optimal participation tax rate t_i is obtained by substituting $u'_f = \lambda$ in equation (2.137) and dividing the expression by $N_i E_i \lambda w_i$. After imposing the definitions of the union wedge $\tau_i \equiv \frac{u(\hat{c}_i)-u(c_u)}{\lambda w_i}$, the mark-up $m_i = \frac{w_i - F_i}{w_i}$ and the elasticities κ_i and η_i as defined in equations (2.40)–(2.41), we arrive at the final expression stated in Proposition 2.8.

Desirability of unions

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

$$
\begin{aligned}
\mathcal{L} = & \sum_i N_i \left(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u(w_i(1-t_i) - T_u - \varphi) \mathrm{d}G(\varphi) + \int_{G^{-1}(E_i)}^{\overline{\varphi}} u(-T_u) \mathrm{d}G(\varphi) \right) \\
& + u(F(\cdot) - \sum_i w_i N_i E_i - T_f) + \lambda \left(\sum_i N_i (T_u + E_i t_i w_i) + T_f - R \right) \\
& + \sum_i \vartheta_i N_i (w_i - (1-\sigma_i) F_i(\cdot) - \sigma_i \phi_i(\cdot)) \\
& + \sum_i \mu_i N_i \Bigg(\int_{\underline{\varphi}}^{G^{-1}(E_i)} u'(w_i(1-t_i) - T_u - \varphi) \mathrm{d}G(\varphi)(F_i(\cdot) - w_i) \\
& + E_i(u(w_i(1-t_i) - T_u - G^{-1}(E_i)) - u(-T_u)) \Bigg). \qquad (2.138)
\end{aligned}
$$

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

$$
\frac{\partial \mathcal{W}}{\partial \sigma_i} = \frac{\partial \mathcal{L}}{\partial \sigma_i} = N_i \vartheta_i (F_i - \phi_i). \qquad (2.139)
$$

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

$$
\begin{aligned}
t_i : & - w_i N_i E_i (\overline{u'_i} - \lambda) - \mu_i w_i N_i E_i \left(\overline{u''_i} (F_i - w_i) + \hat{u}'_i \right) = 0, \qquad (2.140) \\
w_i : & (1-t_i) N_i E_i \overline{u'_i} - N_i E_i u'_f + \lambda t_i N_i E_i + \vartheta_i N_i
\end{aligned}
$$

$$+ \mu_i(1-t_i)N_i\left(E_i\overline{u_i''}(F_i-w_i)+E_i\hat{u}_i'\right)-\mu_iN_iE_i\overline{u_i'}=0, \tag{2.141}$$

$$T_f : -u_f' + \lambda = 0. \tag{2.142}$$

Combining equations (2.140) and (2.141) and substituting equation (2.142) yields:

$$\vartheta_i = \mu_i E_i \overline{u_i'}. \tag{2.143}$$

Substituting for μ_i using equation (2.140) and simplifying gives:

$$\vartheta_i = E_i\left(\frac{\lambda\overline{u_i'}(1-b_i)}{\overline{u_i''}(F_i-w_i)+\hat{u}_i'}\right). \tag{2.144}$$

From equations (2.139) and (2.144), it follows that an increase in σ_i increases social welfare if and only if the term on the right-hand side of expression (2.144) is negative:

$$b_i > 1. \tag{2.145}$$

Appendix I: Simulations

Calculating optimal taxes

This appendix provides additional information regarding the simulations. we calculate the optimal tax-benefit system for varying degrees of union power ρ_i. In order to do so, we numerically solve the optimal tax expressions for the unemployment benefit and the participation tax rates. As explained in the main text, we ignore firm-owners and do not calculate the optimal profit tax. This only implies a slightly different cardinalization of the social preference for income redistribution via the revenue requirement of the government. Under Assumptions 2.1 and 2.2, the policy optimum is characterized by (see Proposition 2.1):

$$\omega_u b_u + \sum_i \omega_i b_i = 1, \tag{2.146}$$

$$\left(\frac{t_i+\frac{\rho_i b_i}{\varepsilon_i}}{1-t_i}\right)\eta_i = (1-b_i)+(b_i-1)\kappa_i, \tag{2.147}$$

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

$$\sum_i N_i \left(T_u + E_i t_i w_i \right) = R. \tag{2.148}$$

The labor-market equilibrium conditions and the welfare weights are:

$$E_i = \zeta_i (w_i(1 - t_i))^{\gamma_i^e}, \tag{2.149}$$

$$E_i = \xi_i w_i^{-\varepsilon_i}, \tag{2.150}$$

$$b_i = \frac{1}{\lambda(w_i(1 - t_i) - T_u)^{\nu}}, \tag{2.151}$$

$$b_u = \frac{1}{\lambda(-T_u)^{\nu}}. \tag{2.152}$$

We numerically solve the system (2.146)– (2.152) for the tax instruments t_i and T_u, equilibrium wages w_i and employment E_i, welfare weights b_i and b_u, and the multiplier on the government budget constraint λ. Values for R, ζ_i, and ξ_i are calibrated using the Dutch statistics on observed wages, employment rates, and the tax-transfer system, see Table 2.1. Following Saez (2002) and Kroft et al. (2020), we set $\nu = 1$ in our baseline simulations. We set the effective participation elasticity at $\gamma_i^e = 0.16$ and the labor-demand elasticity $\varepsilon_i = 0.3$. We then solve these equations for competitive labor markets without unions ($\rho_i = 0$ for all i), intermediate union power ($\rho_i = 1/2$ for all i), and monopoly unions ($\rho_i = 1$ for all i).

To solve for the optimal taxes with interdependent labor markets, we replace equation (2.147) with (2.21) and the labor-demand equations (2.150) with equation (2.46).

Sensitivity Analysis

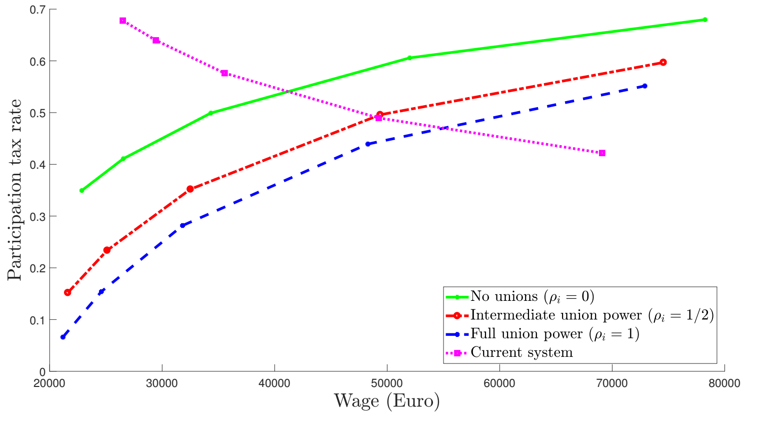


Figure 2.6: Optimal participation tax rates with higher labor-demand elasticity ($\varepsilon_i = 0.6$)

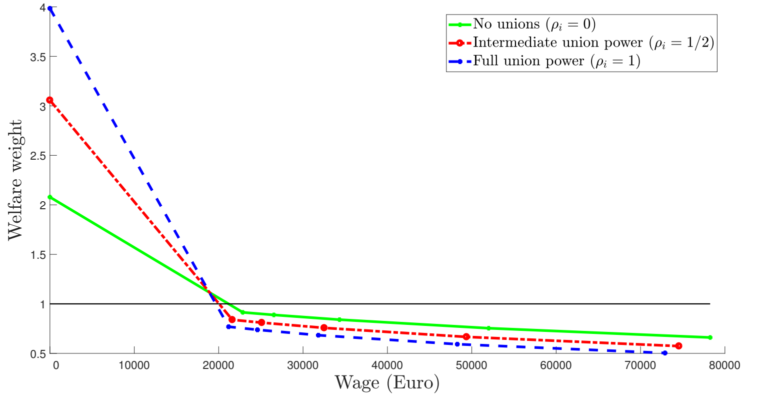


Figure 2.7: Social welfare weights with higher labor-demand elasticity ($\varepsilon_i = 0.6$)

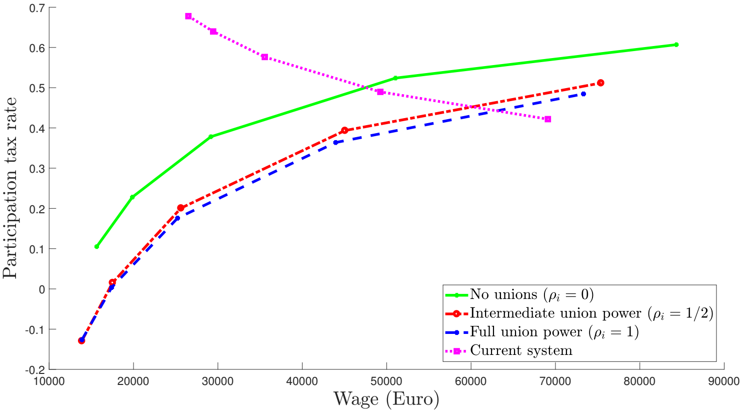


Figure 2.8: Optimal participation tax rates with higher participation elasticity ($\gamma_i^e = 0.32$)

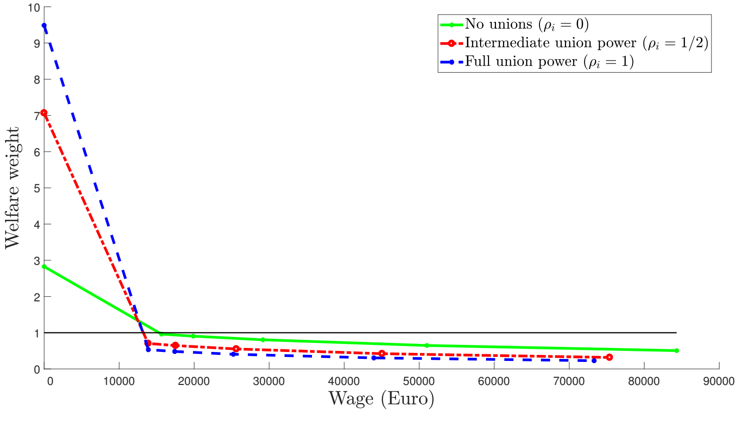


Figure 2.9: Social welfare weights with higher participation elasticity ($\gamma_i^e = 0.32$)

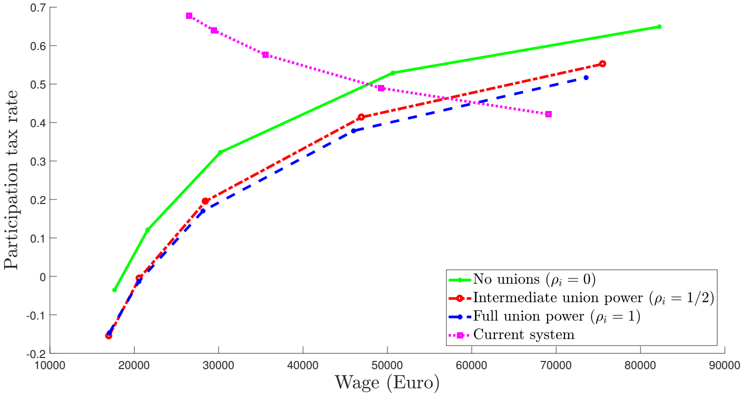


Figure 2.10: Optimal participation tax rates with lower social welfare weight of the unemployed ($b_u = 1/(2.25\lambda(-T_u)^\nu)$)

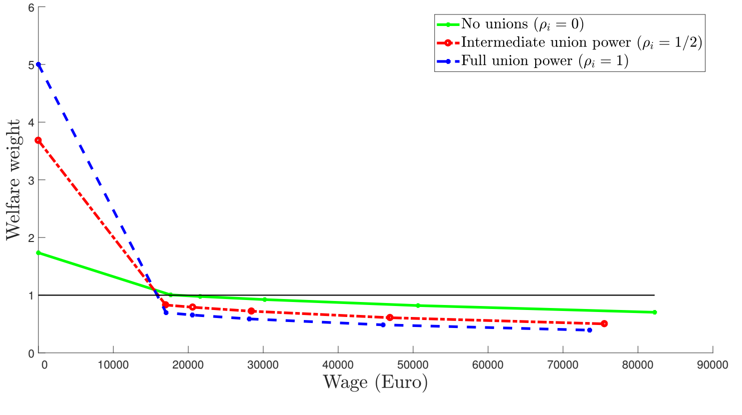


Figure 2.11: Social welfare weights with lower social welfare weight of the unemployed ($b_u = 1/(2.25\lambda(-T_u)^\nu)$)

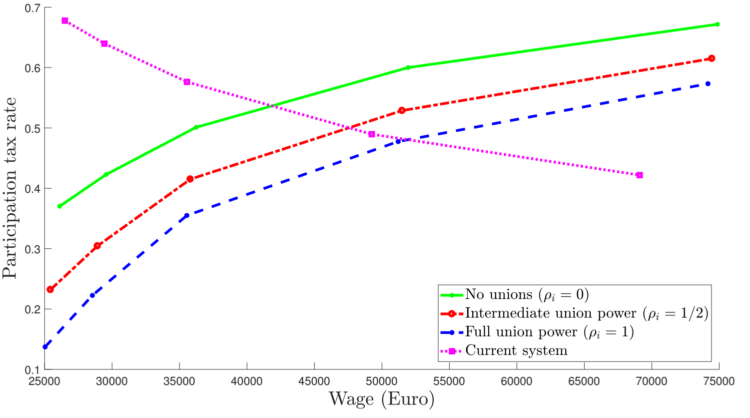


Figure 2.12: Optimal participation tax rates with interdependent labor markets

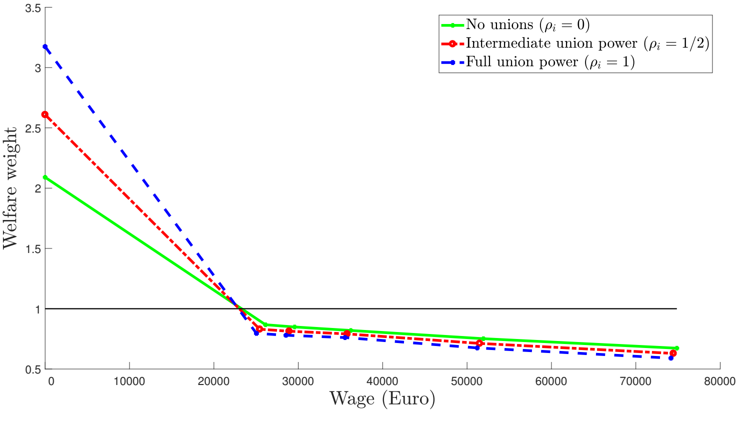


Figure 2.13: Social welfare weights with interdependent labor markets

Chapter 3

Unemployment and tax design[1]

3.1 Introduction

Unemployment is a major policy concern. It leads to significant drops in consumption and life satisfaction and is an important source of inequality (Winkelmann and Winkelmann (1998), Kassenboehmer and Haisken-DeNew (2009)). Governments around the world use complicated systems of taxes and benefits to redistribute income and provide insurance against unemployment risk. When doing so, they face a complex trade-off. On the one hand, unemployment motivates the use of the tax-benefit system because unemployment risk is not insurable and unequally distributed.[2] On the other hand, unemployment limits how much insurance and redistribution the government can provide. This is because the tax-benefit system affects individuals' incentives to search and supply labor and thereby unemployment. This two-way interaction calls for a joint analysis of unemployment and the tax-benefit system. Yet, despite the apparent policy relevance the literature offers little guidance as to how unemployment should be taken into account when designing the tax-benefit system.

[1] I am grateful to Aart Gerritsen, Bas Jacobs and Dominik Sachs for continuous guidance and support at various stages of the project. Also I would like to thank Björn Brügemann, Peter Diamond, Emmanuel Farhi, Pieter Gautier, Nathan Hendren, Philipp Kircher, Etienne Lehmann, Marcelo Pedroni, Florian Scheuer, Stefanie Stantcheva, Uwe Thümmel and Matthew Weinzierl for many helpful comments and suggestions. Finally, this paper has benefited greatly from discussions at IIPF 2018 Tampere, SaM 2018 Cambridge, ZEW 2018 Mannheim, Erasmus School of Economics, Paris Center for Law and Economics, Tinbergen Institute and VU University Amsterdam.

[2] For example, in the US individuals who completed primary education are approximately three times more likely to be unemployed than those who completed tertiary education. Figures for other OECD countries are comparable (OECD (2018a)).

This paper characterizes the optimal joint design of unemployment insurance and income redistribution. To do so, I develop a directed search model where individuals differ in terms of their skills and participation costs. They supply labor on the extensive (participation) and intensive (hours, effort) margin and optimally choose whether and where to apply. Matching frictions generate unemployment risk, which is not insurable. The government cannot observe individuals' labor supply and search behavior but only their earnings and employment status. It provides partial insurance and redistributes income by setting an unemployment benefit and a non-linear income tax. I use the model to (i) study how the tax-benefit system affects labor-market outcomes and (ii) derive optimal policy rules. Finally, I do a quantitative analysis by calibrating the model to the US economy. My main findings are the following.

First, the government faces a trade-off between lowering the unemployment rate among low-skilled workers and among individuals with higher skills. This trade-off for the government directly originates from a trade-off individuals face between *wages* and *probabilities*. In particular, individuals are less likely to be matched if they apply for a job which pays a higher wage. The tax-benefit system affects this trade-off and hence unemployment, in two opposing ways. On the one hand, an increase in the *marginal* tax rate makes individuals care less about higher wages. This leads firms to post lower wages and hire more workers. As a result, unemployment declines. I label this the employment-enhancing effect (EEE) of taxation. On the other hand, an increase in the *average* tax rate or unemployment benefit makes individuals care less about finding a job. This puts upward pressure on wages, which leads firms to hire fewer workers and unemployment to increase. I label this the employment-reducing effect (ERE) of taxation. Hence, for a given average tax rate, an increase in the marginal tax rate reduces unemployment and *vice versa*. Both effects are consistent with empirical evidence – as will be made clear below. Moreover, because an increase in the marginal tax rate at some income level mechanically raises average tax rates at higher levels of income, lowering the unemployment rate at some point in the skill distribution comes at the costs of increasing it at higher skill levels.

Second, I characterize the optimal tax-benefit system in terms of the income distribution, social welfare weights and behavioral responses. These sufficient-statistics formulas clearly demonstrate how unemployment should be taken into account when designing the tax-benefit system. Changes in unemployment generate fiscal externalities because an unemployed worker receives benefits and does not pay income taxes. These externalities, in turn, call for intuitive adjustments of standard optimal tax formulas. How unemployment affects optimal tax policy depends on two types of statistics: (i) the elasticity of unemployment with respect to the marginal and average tax rate and (ii) the hazard rate of the income distribution. Intuitively, an increase in the marginal tax rate at some income level mechanically raises average tax rates further up in the income distribution. Provided the employment tax (i.e., the sum of the income tax and the unemployment benefit) is non-zero, the associated changes in employment due to the EEE and ERE affect government finances.[3] The revenue effect of the former is proportional to the elasticity of unemployment with respect to the marginal tax rate and the fraction of people whose marginal tax rate is increased (i.e., the density of the income distribution). The latter generates a revenue effect which is proportional to the elasticity of unemployment with respect to the average tax rate and the fraction of individuals whose average tax rate is increased (i.e., one minus the cumulative distribution of income). In the typical case that the employment tax is positive, the EEE (ERE) raises (lowers) the optimal marginal tax rate.

Third, employment subsidies should phase in with income. Put differently, if the *level* of the employment tax for low-income workers is negative, these workers should also face a negative *marginal* tax rate. My model thus provides a rationale for the phase-in region of the EITC. This result complements those from Diamond (1980) and Saez (2002). They show that it is optimal to subsidize employment if the government cares sufficiently about the working poor and labor-supply responses are mostly concentrated on the extensive margin. If unemployment is taken into account, the case for lowering *marginal* tax rates for these workers is then a particularly strong one. Intuitively, doing so induces them to apply for jobs which pay a higher wage, whereas the implied reduction in average tax rates lowers wages for individuals with higher skills. If employment is subsidized at the bottom and taxed at higher levels of income, both the reduction in employment

[3] The literature typically uses the term participation tax to refer to the sum of the income tax and the unemployment benefit. However, as pointed out by Kroft et al. (2020), the term employment tax is more appropriate in case there are individuals who participate (i.e., who look for a job), but nevertheless remain unemployed.

among low-skilled workers and the increase in employment among higher-skilled workers positively affect government finances. As a result, the optimal marginal tax rates for low-income workers are lower if unemployment is taken into account and negative at the very bottom if employment is subsidized.

Fourth, the optimal provision of unemployment insurance (UI) is closely linked to the shape of the tax schedule. My results are close in spirit to those derived in Baily (1978) and Chetty (2006). Importantly, however, I do not restrict UI payments to be financed through lump-sum or proportional taxes on labor income. In fact I show that doing so is sub-optimal. To see why, suppose there is no *ex ante* heterogeneity. The tax-benefit system is then merely used for insurance (and not redistributive) purposes. If individuals are risk-averse, the government optimally provides an unemployment benefit, which is financed through a positive *average* tax rate on earnings. As in the Baily-Chetty framework, this form of insurance leads to an upward distortion in unemployment (through the ERE) and optimal policy balances the insurance benefits against the distortionary costs. I complement this result by showing that the optimal *marginal* tax rate is positive as well. Intuitively, raising the marginal tax rate reduces wage pressure. The associated increase in employment (through the EEE) partially off-sets the upward distortion in unemployment generated by UI. The optimal marginal tax rate satisfies a simple inverse-elasticity rule and increases in the size of the employment tax and the elasticity of unemployment with respect to the marginal tax rate.

Finally, I calibrate the model to the US economy and find that unemployment is an important margin to consider when setting tax rates at low levels of income. In my preferred calibration, the government loses close to 3 cents on the dollar due to unemployment responses if – starting from the *current* tax-benefit system – marginal tax rates for low-income workers are increased. This is because (i) unemployment is more responsive to changes in the average than to changes in the marginal tax rate and (ii) the hazard rate of the income distribution is low at low levels of income. Consequently, raising the marginal tax rates for low-skilled workers improves the employment prospects of only a few individuals, whereas the implied increase in average tax rate reduces employment at virtually all other skill levels. Despite this, the quantitative implications of unemployment for the *optimal* tax-benefit system appear to be modest.

3.1.1 Related literature

Taxation in imperfect labor markets

Theory There is an extensive literature which analyzes the impact of the tax-benefit system on labor-market outcomes in imperfectly competitive labor markets (see, e.g., Bovenberg and van der Ploeg (1994) and Picard and Toulemonde (2003) for overviews). A robust finding is that – for a given average tax rate – an increase in the marginal tax rate reduces unemployment. Conversely, for a given marginal tax rate, an increase in the average tax rate or unemployment benefit raises unemployment. I label the first of these the employment-enhancing effect (EEE) of taxation and the second the employment-reducing effect (ERE). These results are obtained in union bargaining models (Hersoug (1984), Lockwood and Manning (1993), Koskela and Vilmunen (1996)), in matching models with individual bargaining (Pissarides (1985, 1998)) and in models where firms pay efficiency wages (Pisauro (1991)). I contribute to this literature by showing the results also hold if firms post vacancies to attract workers and matching frictions generate unemployment. Moreover, because in the framework I analyze workers differ in their skills, the EEE and ERE imply that lowering the unemployment rate at some skill level by raising the marginal tax rate comes at the costs of raising unemployment among individuals with higher skills.

Evidence There exists ample evidence that benefit generosity positively affects unemployment and unemployment duration, in line with the ERE (see, e.g., Meyer (1990), Chetty (2008) and Card et al. (2015)). Moreover, many macro-empirical studies document a positive effect of income taxes on unemployment (see, e.g., Nickell and Layard (1999), Blanchard and Wolfers (2000), Daveri and Tabellini (2000), Griffith et al. (2007), Bassanini and Duval (2009)). However, because these studies do not distinguish between marginal and average tax rates, the results are not very informative about the EEE and ERE. The only study I know which empirically separates these channels is a recent paper by Lehmann et al. (2016). Using data on a panel of OECD countries, they find that average tax rates positively affect unemployment, whereas marginal tax rates have the opposite effect. Similarly, Manning (1993) shows that a single index of tax progressivity (which increases in the marginal tax rate and decreases in the average tax rate) is negatively associated with unemployment in the UK.

More indirect evidence comes from studies which analyze the impact of income taxes on wages. A typical finding in the macro-empirical literature is that an increase in the average tax rate is associated with an increase in the hourly wage, whereas an increase in the marginal tax rate has the opposite effect (see, e.g., Malcomson and Sartor (1987), Lockwood and Manning (1993), Holmlund and Kolm (1995)). Using micro-level data, Blomquist and Selin (2010) exploit a series of Swedish tax reforms and find a strong negative effect of marginal tax rates on wages, in line with the EEE. Schneider (2005) and Rattenhuber (2017) obtain similar results using data on German workers. The results from these studies are consistent with the predictions from my model.

Optimal taxation with intensive and extensive labor-supply responses

This paper builds on a literature which studies optimal income taxation when individuals supply labor both on the extensive (participation) and intensive (hours, effort) margin. In an influential paper, Saez (2002) shows that if labor supply is most responsive on the intensive margin the optimal policy features a Negative Income Tax (NIT), i.e., a substantial guaranteed income which is quickly phased out. If labor-supply responses are mostly concentrated along the extensive margin, the optimal tax schedule more closely resembles an Earned Income Tax Credit (EITC) with a low guaranteed income and substantial in-work benefits. Jacquet et al. (2013) generalize this framework and derive conditions under which marginal tax rates and employment taxes are positive. Hansen (2017) analyzes under which conditions marginal tax rates and employment taxes are negative at low levels of income. Jacobs et al. (2017) use a similar framework to derive optimal tax formulas in terms of sufficient statistics. I contribute to this literature by analyzing the implications of unemployment for optimal tax design. My optimal tax formulas generalize those of

Jacobs et al. (2017).[4] Moreover, I show that if unemployment is taken into account it is optimal to let employment subsidies (such as the EITC) phase in with income.

Optimal taxation and search

This paper is closely related to a literature which studies optimal taxation with search frictions. Boone and Bovenberg (2004, 2006) analyze a model where workers engage in costly search effort. Recently, Sleet and Yazici (2017) study optimal income taxation in a framework with on and off the job search. In these papers unemployment is not affected by policy choices. By contrast, the interaction between unemployment and the design of the tax-benefit system lies at the heart of the current paper.

Hungerbühler et al. (2006) study optimal income taxation in a framework where wages are determined through Nash bargaining, but labor supply is exogenous. As in my model, an increase (decrease) in the marginal (average) tax rate leads to wage moderation, which reduces unemployment. Hungerbühler and Lehmann (2009), Lehmann et al. (2011) and Jacquet et al. (2014) extend the framework to study minimum wages, endogenous participation and alternative bargaining structures. Golosov et al. (2013) use a similar matching model to analyze the optimal redistribution of residual wage inequality (i.e., wage inequality among equally skilled workers). I contribute to this literature in three ways. First, I study a model where individuals supply labor both on the extensive and intensive margin. Second, I characterize optimal policy in terms of the income distribution and behavioral responses ("sufficient statistics" in the terminology of Chetty (2009)). This clearly illustrates how unemployment affects the optimal design of the tax-benefit system. Third, I study the optimal provision of unemployment insurance and show that it is closely linked to the shape of the tax schedule even in the absence of wage heterogeneity.

[4] Kroft et al. (2020) and Hummel and Jacobs (2018) also derive optimal tax formulas in a model where wages and unemployment respond to taxation. In their models there is a discrete set of occupations and the government sets the tax liability in each occupation separately. By contrast, in my model there is a single labor market and the government levies a non-linear income tax. This implies marginal and average tax rates cannot be set independently, which gives rise to the trade-off between the EEE and ERE.

Optimal unemployment insurance

Finally, this paper relates to a literature on the optimal provision of unemployment insurance (UI). In a seminal paper, Baily (1978) shows that optimal UI policy balances insurance gains against the adverse effects of UI on job search. Chetty (2006) generalizes this framework and derives a sufficient-statistic formula for the optimal UI benefit which holds in a wide class of models. The framework I present differs in a number of ways from these and most other models used in the literature. I abstract from dynamic considerations but allow UI to not only affect unemployment but also wages (as in Acemoglu and Shimer (1999) and Fredriksson and Holmlund (2001)) and labor supply. Moreover, I do not restrict UI payments to be financed through lump-sum or proportional taxes on labor income. This has two important implications. First, UI does not only affect government finances through unemployment but also through earnings responses. This calls for an intuitive adjustment of the Baily-Chetty formula for the optimal benefit level. Second, the optimal provision of UI is closely linked to the shape of the tax schedule. In particular, I show that financing UI payments through lump-sum or proportional taxes on labor income is sub-optimal.

The remainder of this paper is organized as follows. Section 3.2 presents a directed search model of the labor market. Section 3.3 discusses the efficiency properties and analyzes how the tax-benefit system affects labor-market outcomes. Section 3.4 characterizes the optimal tax-benefit system. Section 3.5 presents the quantitative analysis. Section 3.6 concludes and discusses directions for future research. All proofs and additional details on the numerical analysis can be found in the appendices.

3.2 A directed search model of the labor market

This section presents the model which is used in the remainder of the analysis. The main ingredients are the following. There is a continuum of individuals who are heterogeneous in terms of their ability and costs of participating in the labor market, both of which are private information. They supply labor on the extensive (participation) and on the intensive (hours, effort) margin to homogeneous firms. Firms post vacancies in order to attract applicants, and continue to do so until expected profits are zero. Matching frictions generate unemployment, and the risk of becoming unemployed is not privately insurable. The government cares for redistribution but faces asymmetric information regarding individuals' types and their labor supply and search decisions. It only observes an individual's labor earnings and whether or not he is employed. Consequently it can levy a non-linear income tax and provide a uniform unemployment benefit. The latter is paid both to non-participants and to individuals who decided to search but nevertheless remained unemployed. I first characterize the equilibrium for a given tax-benefit system and analyze the government's optimization problem separately in Section 3.4.

Individuals

The economy is populated by a unit mass of individuals, who are also referred to as workers. They differ both in terms of their ability (or skill), and in their costs of participating in the labor market. Ability is denoted by $n \in [n_0, n_1]$, and participation costs by $\varphi \in [\varphi_0, \varphi_1]$. $F(\varphi, n)$ describes the joint distribution and $f(\varphi, n)$ the corresponding density.

Individuals derive utility from consumption c and disutility from producing output y. To produce y units of output, an individual with ability n must exert y/n units of effort. Each individual can be in three states: employment, unemployment or non-participation. If employed, an individual consumes his earnings z net of taxes $T(z)$. If not, he consumes an unemployment benefit b. Hence, the government does not distinguish between individuals who chose not to participate and those who are (involuntarily) unemployed. Moreover, unemployment risk is not privately insurable.[5] I denote by e the employment rate conditional on participation, which can also be interpreted as the matching probability or the job-finding rate. The unemployment rate is then given by $1 - e$.

[5] Both the assumption that unemployment risk is not privately insurable and that the government cannot distinguish between non-participants and unemployed workers can be micro-founded by assuming an individual's application strategies are private information and hence, not contractible. See Boadway and Cuff (1999) and Boadway et al. (2003) for an analysis of optimal income taxation if the government can distinguish between non-participants and the involuntary unemployed (e.g., through costly monitoring).

The expected utility of an individual (n, φ) who applies for a job where he earns income z, produces output y and becomes employed with probability e, equals:

$$U(n, \varphi) = e\left[u(z - T(z)) - v\left(\frac{y}{n}\right)\right] + (1 - e)u(b) - \varphi. \tag{3.1}$$

Here, sub-utility over consumption $u(\cdot)$ is assumed to be strictly increasing and weakly concave, and disutility of labor effort $v(\cdot)$ is strictly increasing and strictly convex. The value of $v(0)$ is normalized to zero. Note that participation costs are incurred irrespective of whether or not an individual finds a job. They can therefore be equivalently interpreted as the costs of searching.

Firms

Firms are homogeneous and post vacancies at unit cost $k > 0$. A vacancy (y, z) specifies (i) how much output y a potential employee is expected to produce, and (ii) the income z he receives as compensation. Because a vacancy specifies output (and not effort), the only source of uncertainty which matters for the firm is *whether* the vacancy is filled, not *by whom*.[6] The firm is therefore indifferent as to whether the vacancy is filled by a high-skilled worker who exerts little effort or by a low-skilled worker who has to work harder to produce the same output.

Government

There is a government that cares for redistribution. Its objective is formally defined in Section 3.4. The government cannot observe individuals' types nor their labor supply or search behavior. Instead, it can only observe an individuals' labor earnings and whether or not he is employed. As a result, the government can levy a non-linear tax $T(z)$ on labor income to finance a (uniform) unemployment benefit b and some exogenous spending G.

[6] This is different from Stantcheva (2014), who analyzes the implications of adverse selection for optimal income taxation. In her model, firms do not know the productivity of workers and screen them through contracts which specify income and working hours (i.e., effort).

Matching

Workers and firms interact through frictional labor markets. Frictions are captured in a reduced-form way through a matching function. The latter relates the number of matches to the number of job-seekers and the number of vacancies. If the matching function features constant returns to scale, the job-finding (or employment) rate depends only on labor market tightness, i.e., the ratio of vacancies to job-seekers. I denote the inverse of this relationship by $\theta = \theta(e)$. Hence, $\theta(e)$ measures how many vacancies relative to job-seekers must be posted for a fraction e of job-seekers to find employment. The probability that a firm is matched is then given by $e/\theta(e)$. The function $\theta(e)$ fully captures the presence and severity of matching frictions. I assume it is strictly increasing, strictly convex, and satisfies $\theta(0) = 0$. For technical convenience, I furthermore assume that the elasticity $\theta'(e)e/\theta(e)$ is non-decreasing.[7]

3.2.1 Equilibrium

Firms continue to post vacancies until profits are zero in expectation. If a vacancy (y, z) is posted in equilibrium, the following must hold:

$$k = \frac{e}{\theta(e)}(y - z). \tag{3.2}$$

In words, free entry ensures that the cost of opening a vacancy equals the probability that a vacancy is filled, multiplied by the profit margin. Hence, if a posted vacancy implies a high profit margin, free entry ensures it is filled with low probability. The conditions on the matching function then imply that workers are matched with a high probability if they apply for such a vacancy. Intuitively, the matching probability of workers is high if there are many vacancies relative to job-seekers, and *vice versa* for firms. However, a vacancy which specifies a high profit margin (and hence a high matching probability for workers) implies a low wage per unit of effort.[8] This trade-off between ‘prices and

[7]This condition holds for virtually all commonly employed matching functions (including the micro-founded ones) and guarantees that $\theta(\cdot)$ is “sufficiently” convex.

[8]To see why, let $w = z/(y/n)$ denote the wage per unit of effort (say, hours). For given ability and output, a high profit margin $y - z = y(1 - w/n)$ then corresponds to a low wage.

probabilities' is typical in models where search is directed (see, e.g., Wright et al. (2017)). It plays a crucial role in what follows.

Individuals maximize their expected utility (3.1) by optimally choosing (i) whether to apply and – conditional on participation – (ii) where to apply. Working backward, suppose an individual of type (n, φ) decides to participate. When considering where to apply, the zero-profit condition (3.2) implies he faces a trade-off not only between income and leisure, but also between a high wage and a low probability of becoming unemployed (i.e., between prices and probabilities). After incurring participation costs φ, he solves:

$$\mathcal{U}(n) \equiv \max_{y,z,e} \left\{ e\left[u(z - T(z)) - v\left(\frac{y}{n}\right)\right] + (1-e)u(b) \text{ s.t. } k = \frac{e}{\theta(e)}(y - z) \right\}. \quad (3.3)$$

Because participation costs are sunk, individuals with the same ability n make the same choices conditional on participation. Hence, their expected utility net of participation costs only depends on n. The decision whether or not to participate is then a very simple one: an individual of type (n, φ) participates if and only if his participation costs φ are below the threshold

$$\varphi(n) \equiv \mathcal{U}(n) - u(b). \quad (3.4)$$

I denote by $\pi(n)$ the participation rate of individuals with ability n. The latter is given by:

$$\pi(n) = \frac{\int_{\varphi_0}^{\varphi(n)} f(\varphi, n) d\varphi}{\int_{\varphi_0}^{\varphi_1} f(\varphi, n) d\varphi}. \quad (3.5)$$

As mentioned before, the decision where to apply revolves around two trade-offs. The first is between income (i.e., consumption) and leisure. The relevant first-order condition is:[9]

$$u'(z - T(z))n(1 - T'(z)) = v'\left(\frac{y}{n}\right). \quad (3.6)$$

[9]This condition is obtained by combining the first-order conditions of maximization problem (3.3) with respect to z and y. I assume the second-order conditions are satisfied. In the absence of taxes and benefits, the conditions on the utility and matching function guarantee this is the case.

Equation (3.6) equates the marginal utility costs of exerting more effort (on the right-hand side) to the marginal benefits in the form of higher income (on the left-hand side). This condition coincides with the standard labor-supply equation in a competitive equilibrium where individuals optimally choose their working hours and the costs of opening a vacancy are zero (in which case free entry implies $z = y$).

In addition, individuals face a trade-off between the wage and the probability of finding employment. The relevant first-order condition is:

$$eu'(z - T(z))(1 - T'(z)) = \frac{e}{(\theta'(e) - \theta(e)/e)k} \left[u(z - T(z)) - v\left(\frac{y}{n}\right) - u(b) \right]. \tag{3.7}$$

The left-hand side multiplies the employment rate by the marginal utility of income. Hence, it equals the marginal benefits of applying for a job which pays a higher wage. The right-hand side captures the marginal costs of doing so. It equals the product of two terms. The first term measures by how much the job-finding probability decreases if an individual applies for a job which specifies higher earnings (i.e., a higher wage). This reduction is multiplied by the (opportunity) costs of not finding employment, as given by the utility difference between employment and unemployment.

It is worth pointing out that both terms on the right-hand side reflect an externality associated with the decision to post a vacancy. If a firm posts a vacancy, it does not take into account that it becomes more difficult for other firms to fill theirs. This business-stealing externality is captured by the difference between the social and private costs of getting a vacancy filled.[10] It shows up in the denominator of the first term on the right-hand side, which – as mentioned before – measures by how much the job finding (i.e., employment) rate changes if an individual applies for a job which pays a higher wage. Intuitively, if firms impose a larger business-stealing externality on each other vacancy posting (and hence employment) becomes less responsive to changes in the wage. Second, firms also do not internalize the utility gain a potential employee experiences if he finds a job, as captured by the second term. From a social perspective, the first (second) effect causes excessive (too little) vacancy creation. I discuss the implications for efficiency in the next section.

[10]The social costs is given by $\theta'(e)k$ and the private costs by $\theta(e)k/e$.

Combined, the two first-order conditions (3.6)-(3.7) and the zero-profit condition (3.2) constitute a system of three equations in three unknowns. Because individuals with the same ability but different participation costs make the same choices (conditional on participation), I denote the solution by $z(n)$, $y(n)$ and $e(n)$, respectively. The next section discusses in detail how these outcomes are affected by the tax-benefit system. For now, I complete the characterization of the equilibrium by requiring the government budget constraint is satisfied:

$$\int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n)} e(n)(T(z(n)) + b) dF(\varphi, n) = b + G. \tag{3.8}$$

Total spending (on the right-hand side) equals total tax revenue collected from all employed individuals (on the left-hand side). The latter consists of both the tax bill and the foregone payments in unemployment benefits. The term $T(z(n)) + b$ measures the increase in government revenue if an individual with ability n moves from unemployment to employment. In the remainder I refer to this term as the 'employment tax'.

3.3 Efficiency and comparative statics

This section discusses the efficiency properties of the equilibrium and analyzes how the labor-market outcomes (including unemployment) are affected by the tax-benefit system. Both turn out to be crucial for understanding how unemployment should be taken into account when the government optimally designs the tax-benefit system.

3.3.1 Efficiency

In a directed search equilibrium the allocation of resources is typically efficient in the absence of government intervention (see, for instance, Moen (1997)). Intuitively, this is because vacancies are posted in advance and hence play an allocative role similar to that of prices in a competitive equilibrium. In Appendix A I show that this result also holds in my model where workers are heterogeneous in two dimensions and supply labor on the intensive and extensive margin, *provided* they are risk-neutral (i.e., $u(c) = c$). In that case, condition (3.7) simplifies to:

$$\left(\theta'(e(n)) - \frac{\theta(e(n))}{e(n)}\right) k = z(n) - v\left(\frac{y(n)}{n}\right). \tag{3.9}$$

In words, the business-stealing externality (on the left-hand side) exactly off-sets the utility gain of finding a job (on the right-hand side). In models with random search, this property only holds if the bargaining power of workers and firms equals the elasticity of the matching function with respect to their input (see Hosios (1990)). By contrast, if search is directed the condition for efficiency is endogenously satisfied. Equation (3.9) can be simplified further by combining it with the zero-profit condition (3.2):

$$\theta'(e(n))k = y(n) - v\left(\frac{y(n)}{n}\right). \tag{3.10}$$

This is another way to interpret the efficiency result. In equilibrium employment is raised to the point where the additional vacancy creation costs (on the left-hand side) equals the increase in output net of the utility costs to produce it (on the right-hand side).

In Appendix A I also show that the allocation is Pareto inefficient if individuals are risk-averse. This is because unemployment risk is not privately insurable. Consequently, if individuals are risk-averse it is possible to increase all individuals' *expected* utilities by transferring income from the state of employment to the state of unemployment. However, it is not possible to increase an individual's *realized* utility without lowering that of someone else. The allocation without government intervention is therefore said to be constrained efficient, meaning there is no scope for an *ex post* Pareto improvement. As will be made clear in Section 3.4, the missing insurance market has important implications for the optimal design of the tax-benefit system.

3.3.2 Comparative statics

I now turn to study how changes in the tax-benefit system affect labor-market outcomes. Unlike the unemployment benefit b, tracing out the effects of income taxes requires changing a function $T(z)$ as opposed to a parameter. In a recent paper, Golosov et al. (2014)

propose a method for doing so. I follow their approach and define a function

$$T^*(z,\kappa) = T(z) + \kappa R(z). \tag{3.11}$$

Here, $T^*(z,\kappa)$ is the tax function individuals face if the tax function $T(z)$ is perturbed "in the direction" $R(z)$ by a magnitude κ. Hence, $R(z)$ can be interpreted as a reform to the current system. The impact of a tax reform $R(z)$ on the labor-market outcomes can then be derived in two steps. The first is to characterize the equilibrium for a given tax system $T^*(z,\kappa)$. This simply requires replacing $T(z)$ by $T^*(z,\kappa)$ in the individual optimization problem (3.3). The second step is to determine the impact of the reform parameter κ on the equilibrium outcomes (e.g., through implicit differentiation) and evaluate the result at the reform of interest (see also Gerritsen (2016) and Jacquet and Lehmann (2017)).

As can be seen from equations (3.5)-(3.7), earnings, participation and unemployment are affected by changes in the marginal tax rate $T'(z)$, the tax liability $T(z)$ and the benefit b. I therefore consider a local increase in each of these (i.e., holding the other fixed). This can be done by setting $R(z) = z - z(n)$ and $R(z) = 1$. The first reform raises the marginal tax rate while leaving the tax liability (and hence the average tax rate) at income level $z(n)$ unaffected. The second reform increases the tax liability (and hence, the average tax rate) while holding the marginal tax rate fixed. The next Proposition summarizes how these reforms and an increase in the unemployment affect the labor-market outcomes.

Proposition 3.1. *Starting from the laissez-faire equilibrium, Table 3.1 shows how changes in the tax-benefit system affect labor-market outcomes (for fixed ability n). How the outcomes vary with abillity n is discussed separately in Appendix B.*

Table 3.1: Comparative statics

	Participation	Earnings	Unemployment
Marginal tax rate	=	–	–
Tax liability	–	+	+
Unemployment benefit	–	+	+

Note: A +/=/– indicates that the row variable has a positive/zero/negative impact on the column variable.

The first row in Table 3.1 shows the impact of locally increasing the marginal tax rate on participation, earnings and unemployment of individuals with ability n. Because the reform only increases the marginal tax rate (and not the tax liability), the participation rate remains unaffected. Earnings decline in response to the reform, for two reasons. First, a higher marginal tax rate reduces effort – the classic distortion which gives rise to the trade-off between equity and efficiency in Mirrlees (1971). Second, a higher marginal tax rate also reduces the wage. As a result, unemployment decreases as well. Intuitively, this is because individuals face a trade-off not only between consumption and leisure but also between high wages and low unemployment risk. An increase in the marginal tax rate makes individuals care less about a higher wage. In response, they optimally apply for a job which specifies a lower wage. Free entry then ensures that firms post more vacancies, which raises employment and hence, reduces unemployment. I label this the employment-enhancing (EEE) effect of taxation:[11]

Definition 3.1. ***Employment-enhancing effect (EEE)*** *For a given average tax rate, an increase in the marginal tax rate raises employment (and hence reduces unemployment).*

At this point, it is worthwhile to point out that the EEE has important implications for the elasticity of taxable income (ETI) – a statistic of central interest in the public economics literature. See Gruber and Saez (2002) and Saez et al. (2012) for extensive reviews. The ETI measures the percentage increase in earnings following a one-percent increase in the net-of-tax rate. It serves as a sufficient statistic for calculating the the efficiency costs of taxation in a wide class of models. As already pointed out by Hungerbühler et al. (2006), both the canonical labor-supply model and models with matching frictions are consistent with a positive ETI. However, the mechanisms which drive the ETI are very different. In the labor-supply model earnings decline because a higher marginal tax rate lowers the incentives to exert effort. By contrast, in models with matching frictions and wage bargaining a higher marginal tax rate lowers the wage. The model presented here captures both these mechanisms: a higher marginal tax rate reduces both effort as well as the wages posted by firms. While the focus of the optimal tax literature has been almost exclusively on the first of these, Blomquist and Selin (2010) find that a substantial share

[11] An alternative way to understand the EEE is to reason from the firms' perspective. Firms post vacancies in order to attract applicants. An increase in the marginal tax rate, in turn, makes wages a less effective tool to attract applicants. Wages go down, which induces firms to post more vacancies. As a result, employment increases.

of the ETI can be attributed to wage (as opposed to hours) responses – at least in the short run.[12] As will be made clear below, if both these forces are present the ETI is no longer a sufficient statistic to calculate the efficiency costs of taxation.

Turning to the second row of Table 3.1, consider an increase in the tax liability which leaves the marginal tax rate unaffected (i.e., $R(z) = 1$). Such a tax reform reduces the benefits of working and hence, lowers participation. Earnings increase in response to the reform, again for two reasons. First, if there are income effects in labor supply a higher tax bill makes individuals work harder.[13] Second, the reform reduces the utility gain of finding a job. In response individuals apply for a job which pays a higher wage, thereby accepting an increase in the probability of remaining unemployed. I label this effect the employment-reducing effect (ERE) of taxation:[14]

Definition 3.2. ***Employment-reducing effect (ERE)*** *For a given marginal tax rate, an increase in the average tax rate reduces employment (and hence raises unemployment).*

The last row of Table 3.1 shows the impact of increasing the unemployment benefit. By raising the value of non-employment, this reform lowers participation. In addition, conditional on participation a higher unemployment benefit reduces the utility gain of finding employment. Following an increase in the unemployment benefit, individuals apply for higher-wage jobs which reduces their matching probability. Hence, both earnings and unemployment increase. This second effect is very similar to the ERE discussed above.

3.4 Optimal taxation

I now turn to study how unemployment affects the optimal design of the tax-benefit system. To do so, I assume the government maximizes a standard (utilitarian) social

[12]The figures are around 70% for males and 40% for females, although the latter is estimated with less precision.

[13]This effect is only present if the marginal utility of consumption is decreasing. For details, see Appendix B.

[14]Again, the ERE can be understood through the lens of firms as well. A higher tax liability makes individuals care less about finding a job. Consequently, wages become a more effective tool to attract applicants. This leads to fewer vacancies being posted, and hence a higher unemployment rate.

welfare function:

$$\mathcal{W} = \int_{n_0}^{n_1} \int_{\varphi(n)}^{\varphi_1} \Psi(u(b)) dF(\varphi, n) + \int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n)} \Psi(\mathcal{U}(n) - \varphi) dF(\varphi, n). \tag{3.12}$$

Here, $\Psi(\cdot)$ is strictly increasing and weakly concave, and $\mathcal{U}(n)$ and $\varphi(n)$ are as defined in (3.3) and (3.4). Note that the government maximizes a concave transformation of expected – as opposed to realized – utilities. As such, it respects individual preferences. Strict concavity in either $\Psi(\cdot)$ or $u(\cdot)$ generates a motive for redistribution, which is absent only if the marginal utility of consumption is constant (i.e., $u''(\cdot) = 0$) and if the government attaches equal weight to each individual's expected utility (i.e., $\Psi''(\cdot) = 0$).

Variational approach

The government chooses the tax function $T(\cdot)$ and the unemployment benefit b to maximize social welfare (3.12) subject to the budget constraint (3.8), taking into account the behavioral responses as summarized in Proposition 3.1. I solve this problem using the variational approach (see, e.g., Saez (2001), Golosov et al. (2014) and Gerritsen (2016)). This approach differs from the classic mechanism-design approach introduced in Mirrlees (1971) by relying directly on perturbations (i.e., reforms) of the tax system.[15] These reforms generate welfare-relevant effects. Optimal policy rules are then derived from the notion that if the tax-benefit system is optimal, these welfare-relevant effects must sum to zero. The reforms I consider are exactly the ones analyzed in Proposition 3.1: a (local) increase in (i) the marginal tax rate, (ii) the tax liability and (iii) the unemployment benefit.

Figure 3.1 graphically illustrates how the variational approach can be used to derive optimal policy rules. It shows the welfare-relevant effects associated with an increase in the marginal tax rate in the (small) interval $[Z, Z + \omega]$. The dashed and red line show the tax schedule before and after the reform. The increase in the marginal tax rate generates behavioral responses. According to Proposition 3.1, it reduces earnings and – through

[15] Instead, the classic approach proceeds by first deriving the allocation which maximizes welfare subject to resource and incentive constraints, and then deriving the tax system which implements the allocation. See Jacquet and Lehmann (2017) for a rigorous proof that both methods yield the same outcomes.

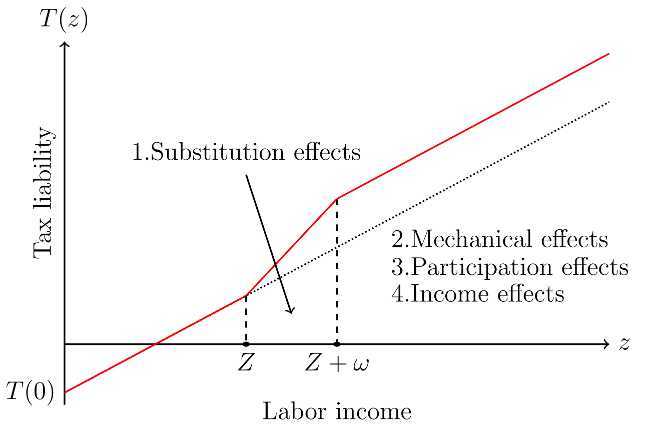


Figure 3.1: Variational approach

the EEE – unemployment for individuals with earnings potential between Z and $Z+\omega$.[16] Because a local change in the marginal tax rate does not affect the expected utility of individuals who are affected, I label these substitution (or compensated) effects. By the Envelope theorem, these behavioral responses have no first-order effect on individuals' expected utility. However, changes in earnings and employment do affect government finances. These so-called fiscal externalities are relevant for welfare and should be taken when considering such a reform.

The reform increases the tax liability for individuals with earnings above $Z+\omega$. This generates three types of welfare-relevant effects. First, there is a mechanical welfare effect as the reform transfers income from these individuals to the government budget. Second, a higher tax liability reduces participation among individuals with earnings potential above $Z+\omega$. Because only individuals who are indifferent between participation and non-participation change their participation decisions following an increase in the tax liability, these responses have no direct utility effect. However, they do affect government revenue. Third, a higher tax liability also generates income effects in earnings and unemployment (see Proposition 3.1). In particular, individuals with earnings potential above $Z+\omega$ decide to search for higher-wage jobs which – through the ERE – raises unemployment. Again,

[16]The individuals who are affected by the marginal tax rate are those who apply for jobs which pay an income in the interval $[Z, Z+\omega]$. Since not all applicants are successful, I refer to these workers as those with earnings potential (rather than those with earnings) between Z and $Z+\omega$.

by the Envelope theorem these behavioral responses do not affect individuals' expected utilities. However, because earnings and employment are taxed they do generate (welfare-relevant) fiscal externalities.

Income distribution

In Section 3.4.1 I use the variational approach to derive optimal tax formulas. These formulas are expressed in terms of the (observable) income distribution rather than the (unobservable) distribution of types (i.e., skills and participation costs). I denote the income distribution by $H(z)$, and the corresponding density by $h(z)$. Moreover, let $z_0 = z(n_0)$ and $z_1 = z(n_1)$ denote the lowest and highest level of positive earnings. The income and type distribution are related via:

$$H(z(n)) = \int_{n_0}^{n_1} \int_{\varphi(m)}^{\varphi_1} f(\varphi, m) d\varphi dm + \int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(m)} (1 - e(m)) f(\varphi, m) d\varphi dm + \int_{n_0}^{n} \int_{\varphi_0}^{\varphi(m)} e(m) f(\varphi, m) d\varphi dm. \tag{3.13}$$

Here, $f(\cdot)$ denotes the density of the type distribution, $e(m)$ the employment rate for individuals with ability m and the participation thresholds $\varphi(m)$ are as defined in (3.4). The fraction of individuals with income below $z(n)$ equals the sum of the non-participants (first term), the unemployed (second term) and the employed individuals with ability below n (third term). Because there is non-participation and unemployment, the income distribution has a mass point at zero. The fraction of individuals with zero income equals $H(z_0)$.

Elasticity concepts

In addition to the income distribution, a second main ingredient in the optimal tax formulas are the behavioral responses with respect to changes in the tax-benefit system. With some abuse of notation, I denote by $x_{T'} = \mathrm{d}x/\mathrm{d}T'$ and $x_T = \mathrm{d}x/\mathrm{d}T$ the equilibrium changes in $x \in \{\pi, z, e\}$ following a (local) increase in the marginal tax rate and the tax liability, respectively.[17] For instance, $\mathrm{d}z/\mathrm{d}T'$ measures the impact of a change in the marginal tax rate on income, holding the tax liability (i.e., the average tax rate) fixed. Conversely, $\mathrm{d}z/\mathrm{d}T$ refers to the change in earnings following an increase in the tax liability, holding the marginal tax rate fixed.

For future references I introduce the following elasticities:

$$\varepsilon_{zT'} = -\frac{\mathrm{d}z}{\mathrm{d}T'}\frac{1-T'}{z}, \quad \varepsilon_{eT'} = \frac{\mathrm{d}e}{\mathrm{d}T'}\frac{1-T'}{e}. \tag{3.14}$$

Both elasticities are positive according to Proposition 3.1. The first is the elasticity of taxable income (ETI). As discussed before, the ETI captures both labor-supply and wage responses. The second measures the percentage decrease in the employment rate following a one-percent increase in the net-of-tax rate. This elasticity therefore quantifies the employment-enhancing effect (EEE) of taxation.

3.4.1 Optimal tax formulas

The next Proposition characterizes the optimal tax-benefit system.

Proposition 3.2. *If the tax-benefit system is optimal, the following condition must hold for all $z \in [z_0, z_1]$:*

$$\frac{T'(z)}{1-T'(z)} = \frac{1}{\varepsilon_{zT'}}\int_z^{z_1}\left[1-g(z')+\frac{\pi_T}{\pi}(T(z')+b)+z_T T'(z')\right]\frac{dH(z')}{zh(z)}$$
$$+\frac{\varepsilon_{eT'}}{\varepsilon_{zT'}}\frac{(T(z)+b)/z}{1-T'(z)}+\frac{1}{\varepsilon_{zT'}}\int_z^{z_1}\frac{e_T}{e}(T(z')+b)\frac{dH(z')}{zh(z)}. \tag{3.15}$$

In addition, the optimum satisfies the following conditions:

$$\int_{z_0}^{z_1}\left[1-g(z)+\frac{\pi_T}{\pi}(T(z)+b)+z_T T'(z)\right]dH(z)+\int_{z_0}^{z_1}\frac{e_T}{e}(T(z)+b)dH(z)=0 \tag{3.16}$$

[17]These behavioral responses capture the (total) equilibrium changes along the actual budget curve, and not along a linearized budget curve (as in Saez, 2001). Hence, they account for the non-linearity of the tax schedule. See Jacquet et al. (2013) for a discussion of this issue.

$$(1 - g(0))H(z_0) = \tag{3.17}$$

$$\int_{z_0}^{z_1} \frac{\pi_b}{\pi}(T(z) + b)dH(z) + \int_{z_0}^{z_1} \left[z_b T'(z) + \frac{e_b}{e}(T(z) + b) \right] dH(z).$$

Here, $g(z')$ denotes the average social welfare weight of individuals with earnings z' and $g(0)$ the average social welfare weight of the non-participants and involuntarily unemployed. Both are formally defined in Appendix C.

Proposition 3.2 characterizes the optimal tax-benefit system in terms of three sufficient statistics (Chetty (2009)): the income distribution, behavioral responses, and social welfare weights. The welfare weight $g(z)$ measures by how much social welfare increases if individuals with income z (possibly zero) receive an additional unit of consumption. These weights fully summarize the redistributive preferences of the government (see also Saez and Stantcheva (2016)).

Optimal marginal tax rate

Equation (3.15) gives the optimality condition from considering a local increase in the marginal tax rate around income level $z \in [z_0, z_1]$, as graphically illustrated in Figure 3.1. The formula clearly demonstrates how unemployment affects the optimal marginal tax rate. Without unemployment responses (i.e., $\varepsilon_{eT'} = e_T = 0$), both terms in the second line would cancel. The resulting optimal tax formula is then closely related to those derived in Saez (2002), Jacquet et al. (2013) and Jacobs et al. (2017), who analyze a model with labor-supply responses on the intensive and extensive margin but abstract from unemployment. For a detailed explanation of this formula, see their papers. It should be pointed out that although my optimal tax formula without unemployment responses is similar to theirs when written in sufficient statistics, the mechanisms which drive these statistics are quite different. In particular, the elasticity of taxable income (ETI) $\varepsilon_{zT'}$ captures both labor-supply and wage responses. The same is true for the effect of the tax liability on earnings (as captured by z_T). By contrast, in the aforementioned studies these statistics only capture labor-supply responses.

When matching frictions generate unemployment, the expression for the optimal marginal tax rate is modified in two ways: see the second line of equation (3.15). The first modification results from the employment-enhancing effect (EEE) of taxation. Intuitively, an increase in the marginal tax rate at income level z reduces wage pressure around this income level, as the reform makes individuals care less about higher wages. This leads firms to hire more workers, which increases the employment rate of individuals with earnings potential z. By how much depends on the elasticity of employment with respect to the net-of-tax rate, as captured by $\varepsilon_{eT'}$. This term is multiplied by the fiscal externality of reducing unemployment, as given by the employment tax $T(z) + b$. In the typical case that the employment tax is positive, the EEE calls for a *higher* optimal marginal tax rate.

The second modification occurs because an increase in the marginal tax rate at income level z mechanically raises tax liabilities further up in the income distribution (see Figure 3.1). In response, individuals with higher earnings potential choose to apply for higher-wage jobs and accept a decrease in the probability of finding employment. The magnitude of this employment-reducing effect (ERE) of taxation is captured by the responsiveness of the employment rate with respect to the tax liability, as given by e_T. As before, the behavioral response is multiplied by the employment tax. If the product of these terms averaged over all individuals with earnings above z is negative (which is to be expected, as $e_T < 0$ and typically $T(z') + b > 0$), the ERE calls for a *lower* the optimal marginal tax rate.

Which of these forces dominates depends critically on two types of statistics: (i) the responsiveness of the employment (or unemployment) rate with respect to the marginal and average tax rate (holding the other fixed) and (ii) the (relative) hazard rate of the income distribution.[18] To see this, multiply the expression for the optimal marginal tax rate (3.15) by $\varepsilon_{zT'}$. The last two terms on the right-hand side can then be written as:

$$\frac{e_{T'}}{e}\left(\frac{T(z)+b}{z}\right) + \mathrm{E}\left[\frac{e_t}{e}\left(\frac{T(z')+b}{z'}\right)\middle| z' > z\right]\frac{1-H(z)}{zh(z)}. \tag{3.18}$$

Here, e_t measures the impact of a change in the average tax rate $t = T(z)/z$ on the employment rate, holding the marginal tax rate fixed. In addition to the fiscal externalities associated with changes in unemployment (as captured by $(T(z) + b)/z$), equation (3.18) depends on the semi-elasticity of the employment rate with respect to the marginal and

[18] Note that the employment elasticities can easily be transformed into *un*employment elasticities by multiplying it with $e/(1 - e)$.

average tax rate (as captured by $e_{T'}/e$ and e_t/e) and the relative hazard rate $zh(z)/(1-H(z))$ of the income distribution. The latter is critical for quantifying the EEE and ERE as it captures how many people are affected by an increase in the marginal tax rate at income level z compared to those who see their tax liability increase, i.e., those with earnings above z. If employment taxes are positive, unemployment is therefore more likely to reduce optimal marginal tax rates if the hazard rate of the income distribution is low – as is the case at low levels of income.

Many studies find that at high levels of income, the relative hazard rate is approximately constant (see, e.g., Saez (2001)). This implies the top of the income distribution is well approximated by a Pareto distribution. Equation (3.15) can then readily be manipulated to obtain an expression for the optimal top rate (see Appendix D for details).

Corollary 3.1. *If incomes at the top are Pareto distributed with tail parameter a and if the elasticities of earnings, employment and participation with respect to (one minus) the marginal and average tax rate converge, the optimal top rate is given by:*

$$T'(z) = \frac{1-g(z)}{1-g(z)+a(\varepsilon_{zT'}-\varepsilon_{eT'})+\varepsilon_{\pi t}+\varepsilon_{zt}+\varepsilon_{et}}, \tag{3.19}$$

where ε_{xt} denotes the elasticity of $x \in \{\pi, z, e\}$ with respect to one minus the average tax rate.

Equation (3.19) generalizes the results of Jacquet et al. (2013) and Jacobs et al. (2017), who abstract from unemployment responses and who assume away income effects for high-income earners (in which case $\varepsilon_{zt}=0$). Whether the optimal top rate is higher or lower if unemployment is taken into account depends on a very simple condition. In particular, for a given welfare weight, earnings and participation elasticities for top-income earners, the optimal top rate is higher compared to a setting without unemployment if and only if the following condition holds:

$$a\varepsilon_{eT'} > \varepsilon_{et}. \tag{3.20}$$

This condition is intuitive. If the employment tax is positive (as is always the case at the top), the employment-enhancing effect raises the optimal top rate, whereas the employment-reducing effect does the opposite. The optimal top rate with unemployment is therefore higher if the responsiveness of employment with respect to the marginal tax rate is high relative to the average tax rate (i.e., if $\varepsilon_{eT'}$ is high relative to ε_{et}) and if the tail of the income distribution is thin (i.e., if a is high). A high Pareto parameter a implies that an increase in the marginal tax rate reduces the employment prospects of only only a few people further up in the income distribution. While the presence of unemployment leads to an intuitive adjustment of the expression for the optimal top rate, it should be noted that the quantitative implications are likely to be small if unemployment is not an important margin for individuals with high ability (as one might expect). This will be confirmed in Section 3.5.

Employment taxes and the optimality of an EITC

Equation (3.16) gives the optimality condition from considering a uniform increase in the tax liability. Compared to a setting without unemployment, the only modification of this condition is due to the employment-reducing effect (ERE), as captured by the second term. For a given distribution of income, welfare weights, and behavioral responses, the optimal tax liability (and hence the employment tax) is therefore lower if unemployment is taken into account. Intuitively, a lower tax liability reduces the incentives for individuals who participate to look for higher-wage jobs. In response, firms post more vacancies and employment increases. Provided the employment tax is positive on average, the reduction in the tax liability generates a positive fiscal externality which would be absent if there are no unemployment responses.

Combined, equations (3.15) and (3.16) have an important implication for the optimal design of employment subsidies (such as the EITC).

Proposition 3.3. *If employment is subsidized for low-income workers, the optimal marginal tax rate at the bottom is negative. Hence, it is optimal to let employment subsidies (such as the EITC) phase in with income.*

In two influential papers, Diamond (1980) and Saez (2002) show that employment for low-income workers is optimally subsidized if labor-supply responses are concentrated (mostly) along the extensive margin and if the government cares sufficiently about the working poor. These papers thus explain why the *level* of the employment tax can be negative for low-income workers. Proposition 3.3 complements this result by showing that if employment is optimally subsidized, the optimal *marginal* tax rate for low-income workers is negative as well.[19] Intuitively, a negative marginal tax rate off-sets the upward distortion in employment generated by employment subsidies. This distortion occurs because employment subsidies (i.e., high in-work benefits) induce workers to apply for low-wage jobs. The associated increase in employment generates a negative fiscal externality if employment is subsidized. A negative marginal tax rate is then optimal as it makes applying for high-wage jobs more attractive. The associated reduction in employment positively affect government finances.

To see how Proposition 3.3 and the results from Diamond (1980) and Saez (2002) are linked, consider a reform which decreases the marginal tax rate at a low income level z combined with an increase in the intercept of the tax function which ensures the net income of individuals with earnings above z is unaffected. The optimality condition associated with this reform (which is obtained by combining equations (3.15) and (3.16)) is:

$$\begin{aligned}\varepsilon_{zT'}\frac{T'(z)}{1-T'(z)}zh(z) = &\int_{z_0}^{z}\left[g(z')-1-\frac{\pi_T}{\pi}(T(z')+b)+z_T T'(z')\right]dH(z')\\ &+\varepsilon_{eT'}\frac{T(z)+b}{1-T'(z)}h(z)-\int_{z_0}^{z}\frac{e_T}{e}(T(z')+b)dH(z'). \qquad (3.21)\end{aligned}$$

From equation (3.21), it is clear that it is optimal to subsidize employment (i.e., to set $T(z')+b<0$) if the government cares a lot about the working poor (i.e., if $g(z')>1$ at low levels of income) and if earnings and unemployment responses are absent (i.e., if $\varepsilon_{zT'}=z_T=\varepsilon_{eT'}=e_T=0$). This finding goes back to Diamond (1980), who was the first to provide a rationale for employment subsidies (such as the EITC) in an optimal-tax framework. The terms in the second line of equation (3.21) highlight why it might be optimal to let the EITC phase in with income if unemployment is taken into account. First, a negative marginal tax rate raises wages and reduces employment around income

[19] In a model without unemployment, Hansen (2017) shows that the optimal EITC may also feature a phase-in region if participation elasticities are decreasing in the skill dimension.

level z through the EEE. If employment is subsidized, this generates a positive fiscal externality. Second, the reduction in the marginal tax rate allows the government to increase the tax liability. Through the ERE, this lowers employment among individuals with earnings potential below z.[20] Again, this generates a positive fiscal externality. Hence, if employment is subsidized, the fiscal externalities of the EEE and ERE go hand in hand and the optimal marginal tax rate for low-income workers is unambiguously lower if unemployment is taken into account. When evaluated at $z = z_0$, equation (3.21) immediately implies that the optimal marginal tax rate is negative at the bottom if employment is subsidized (confirming the result from Proposition 3.3).

Optimal unemployment insurance

The results from Proposition 3.2 are related to those obtained in Baily (1978) and Chetty (2006). They study the optimal provision of unemployment insurance in a model where (identical) risk-averse individuals face an uninsurable risk of becoming unemployed. The government optimally provides UI payments, which are financed through a lump-sum or proportional tax on labor income. The optimal benefit trades off the insurance gains against the distortionary costs of UI on job search. To see how my results are related to theirs, assume all individuals are identical and participate (i.e., $n_0 = n_1$ and $\varphi_0 = \varphi_1$ sufficiently low). Equations (3.16) and (3.17) then simplify to:[21]

$$e(1 - g(z)) + e\left[z_T T'(z) + \frac{e_T}{e}(T(z) + b)\right] = 0, \tag{3.22}$$

$$(1 - e)(g(0) - 1) + e\left[z_b T'(z) + \frac{e_b}{e}(T(z) + b)\right] = 0. \tag{3.23}$$

If individuals are risk-averse, consumption in the state of unemployment is valued more than in the state of unemployment. As a result, $g(z) > g(0)$ and the government optimally provides unemployment insurance. As in the Baily-Chetty framework, the government balances the insurance gains against the distortionary costs of UI on employment (as captured by e_b and e_T). I show in Appendix F how the Baily-Chetty formula (see Propo-

[20]Recall: the joint reduction in the marginal tax rate around income z and the reduction in the tax liability leaves individuals with earnings potential above z unaffected.

[21]The income distribution has a mass point at zero. Consequently, $H(z_0) = 1 - e$ and the income distribution between z_0 and z_1 integrates to e: $H(z_1) - H(z_0) = e$.

sition 1 in Chetty (2006)) is recovered if UI payments are financed by lump-sum taxes (i.e., $T'(z) = 0$). If this is not the case and if UI also affects wages (as is the case in my model), the Baily-Chetty formula is modified to take into account the fiscal externalities associated with earnings responses.

The fact that I do not restrict UI payments to be financed by lump-sum or proportional taxes on labor income has another important implication.

Proposition 3.4. *Suppose all individuals are identical and decide to participate (i.e., $n_0 = n_1$ and $\varphi_0 = \varphi_1$ sufficiently low). The optimal marginal tax rate then satisfies the following inverse-elasticity rule:*

$$\frac{T'(z)}{(T(z)+b)/z} = \frac{\varepsilon_{eT'}}{\varepsilon_{zT'}}. \tag{3.24}$$

Moreover, financing UI payments through lump-sum or proportional taxes on labor income is generally sub-optimal.

Proposition 3.4 shows there exists a close link between the optimal provision of unemployment insurance and the shape of the tax schedule – even without income heterogeneity. I am not aware of any other paper which highlights this link.[22] Instead the vast majority of the literature on the optimal provision of UI assumes benefit payments are either financed by lump-sum or proportional taxes on labor income (see, e.g., Baily (1978), Flemming (1978), Shavell and Weiss (1979), Hopenhayn and Nicolini (1997), Acemoglu and Shimer (1999), Chetty (2006, 2008)). Proposition 3.4 states that doing so is generally sub-optimal. Intuitively, the government wants to use the marginal tax rate to partially off-set the upward distortion in unemployment generated by UI. If the government provides such insurance (which is optimal if individuals are risk-averse), the employment tax is positive. This reduces the utility difference between employment and unemployment and thereby induces individuals to apply for high-wage jobs. Through the ERE, employment decreases which generates a negative fiscal externality. It is then optimal for the government to set a positive *marginal* tax rate as well. Doing so reduces the

[22] Golosov et al. (2013) also study the link between unemployment insurance and the shape of the tax schedule. However, they do so in a framework where search frictions generate heterogeneity in wages among equally skilled workers. By contrast, in my model there is no heterogeneity in wages if individuals are identical.

attractiveness of applying for a job which specifies a high wage. Consequently wages drop and – through the EEE – employment increases. The optimal marginal tax rate satisfies a simple inverse-elasticity rule (see equation (3.24)). Naturally, it increases in the fiscal externality of raising employment and the responsiveness of employment with respect to the marginal tax rate and decreases in the elasticity of taxable income (ETI). This result immediately implies that lump-sum taxes are sub-optimal. The same is generally true for proportional taxes, except in special cases.[23]

3.5 Quantitative analysis

This section explores the quantitative implications of unemployment for the (optimal) design of the tax-benefit system. The purpose is twofold. The first is to get a sense of the importance of unemployment considerations (i.e., the EEE and ERE) in the *current* tax-benefit system. The second is to analyze the *optimal* tax-benefit system if unemployment is taken into account.

3.5.1 Calibration

The model is calibrated to the US economy. The data source I use is the March release of the 2016 Current Population Survey (CPS). This data set provides detailed information on earnings, taxes and benefits for a large sample of individuals. Importantly, it also provides information on individuals' employment status (i.e., employment, unemployment, or not in the labor force). The participation rate is 86.2% and the unemployment rate (conditional on participation) equals 5.1%. For the individuals with positive earnings, I focus on full-time employees who earn at least the federal hourly minimum wage of $7.25. A detailed description of the sample selection procedure can be found in Appendix H.

In the model, earnings, participation and unemployment all vary with ability. Naturally, in the data I only observe individual earnings and their employment status, but not their ability or probability of having found employment. To get an estimate of these, I

[23] Intuitively, this is because the *level* of the tax function serves to finance UI payments whereas the *slope* is used to partially off-set the distortions of UI on unemployment. However, if the tax function is proportional (i.e., $T(z) = tz$) the level and the slope cannot be set separately.

invert the first-order conditions (3.6) and (3.7) for each individual with positive earnings. This gives a distribution of abilities which is consistent with the empirical income distribution. Doing so requires specifying the current tax-benefit system, functional forms for the utility and matching function, and a value for the costs of opening a vacancy k. Moreover, to get an estimate of the participation rate at different ability levels (as given by equation (3.5)), I require an empirical counterpart of the distribution of participation costs. I discuss each of these inputs in turn.

Tax-benefit system

As in Saez (2001) and Sleet and Yazici (2017), I approximate the current US tax schedule by regressing total taxes paid on taxable income. This gives an estimate of a (constant) marginal tax rate of 34.3% and a negative intercept of \$3,663. These numbers imply that individuals start paying taxes if their annual income exceeds $\$10,679$. The value for the benefit is set at \$4,605, which equals the average income from unemployment compensation for individuals who received such income and whose reported labor force status is unemployment.

Functional forms and the costs of opening a vacancy

The utility function takes a simple quasi-linear and iso-elastic form:

$$u(c) - v\left(\frac{y}{n}\right) = c - \frac{\left(\frac{y}{n}\right)^{1+\frac{1}{\varepsilon}}}{1+\frac{1}{\varepsilon}}. \tag{3.25}$$

The value for the labor-supply elasticity is set at $\varepsilon = 0.33$ (Chetty, 2012).[24] For the matching technology, I use the following specification:

$$e(\theta) = (\theta^{\gamma} + 1)^{\frac{1}{\gamma}}, \tag{3.26}$$

which can be inverted to get $\theta(e)$. Equation (3.26) can be derived from an aggregate matching function where the elasticity of substitution between vacancies and unemploy-

[24]Without frictions, the absence of income effects ensures ε corresponds to both the compensated and uncompensated elasticity of labor supply.

ment is constant, see also Den Haan et al. (2000) and Hagedorn and Manovskii (2008).[25] The main advantage of this functional form over the often-used Cobb-Douglas specification is that the employment rate is bounded between 0 and 1, provided $\gamma < 0$. This is important in the current application, because in my model the employment rates vary along the income distribution (i.e., vary with ability) and because I consider potentially large policy changes (in particular from the current tax-benefit system to the optimal one). The value of γ is used to target a matching elasticity of 0.3 at the current aggregate rate of unemployment (Petrongolo and Pissarides (2001)).

The costs of opening a vacancy k is calibrated to match the unemployment rate of 5.1% in the data. The corresponding value is \$10,250. While I refer to these as the costs of opening a vacancy, in the model they can also be thought to include more indirect costs associated with hiring a new worker, such as those related to recruitment and training. The reason why these costs are fairly substantial, is because the calibrated value of $\gamma = -6.81$ implies a low degree of substitutability between vacancies and unemployment.[26] If this is the case, vacancies are very efficient in generating matches. The costs of opening one must therefore be high in order to match the unemployment rate of 5.1%. I analyze an example with a higher elasticity of substitution and lower vacancy creation costs in Section 3.5.4.

Distribution of ability and participation costs

Ability and participation costs are assumed to be independently distributed. The joint distribution $F(\varphi, n)$ is then obtained in two steps. First, I assume ability follows a log-normal distribution up to the level associated with \$250,000 in annual earnings, above which I append a Pareto tail. The parameters μ and σ are estimated using maximum likelihood on the (censored) ability distribution. The latter is obtained jointly with the employment rates from the empirical income distribution by inverting the first-order conditions (3.6) and (3.7). The value of the Pareto coefficient a^* of the *ability* distribution is

[25] To see this, let $m(b, s) = (b^\gamma + s^\gamma)^{1/\gamma}$ denote the number of matches for a given number of buyers b (i.e., vacancies) and sellers s (i.e., job-seekers). The elasticity of substitution between buyers and sellers is constant and equal to $1/(1-\gamma)$. The probability that a seller is matched (i.e., the employment rate) is then given by $m(b, s)/s = ((b/s)^\gamma + 1)^{1/\gamma}$ or $e = (\theta^\gamma + 1)^{1/\gamma}$, where θ equals the buyer-seller ratio (i.e., the ratio of vacancies to job-seekers).

[26] The constant elasticity of substitution equals approximately 0.13.

set in such a way that the Pareto coefficient of the *income* distribution is $a = 1.5$ in the absence of frictions (Piketty et al. (2014), Saez and Stantcheva (2016)).[27] This implies a value of $a^* = 2$. The scale parameter of the Pareto distribution ensures the density is continuous at the point where the Pareto tail is pasted.

Second, I assume the distribution of participation costs is such that the participation rate is iso-elastic with respect to the *utility* difference $\varphi(n) = \mathcal{U}(n) - u(b)$:[28]

$$\pi(n) = A\varphi(n)^{\eta}. \tag{3.27}$$

The latter is capped at a maximum value of one. Besides its simplicity, an additional benefit of using this functional form is that, in line with the empirical evidence, it generates a decreasing pattern of participation elasticities (i.e., the percentage increase in the participation rate if the *consumption* difference increases by 1%). See, for instance, Meyer and Rosenbaum (2001) and Meghir and Phillips (2006). I calculate A to target an aggregate participation rate of 86.2% in the data, and η to target a participation elasticity of 0.15 at the median of the income distribution (corresponding to $50,000 in annual earnings). This value is below the one reported in Chetty et al. (2011), who base their estimate of 0.25 on an extensive meta analysis. However, in the analysis I focus on full-time employees, who are typically found to be less responsive. Moreover, the value of 0.15 masks substantial heterogeneity: the implied participation elasticity is around 0.21 at the bottom of the income distribution, and 0 at income levels above $192,000.

Participation and employment rates by income

Figure 3.2 plots the employment rates for different income levels up to $100,000. As mentioned before the employment rates are obtained from inverting the first-order conditions (3.6) and (3.7) for each level of positive earnings observed in the data. Because the model predicts that individuals with higher ability earn more and are less likely to be unemployed, the relationship is increasing. In particular, the current calibration suggests

[27] If there are no frictions, no income effects (i.e., quasi-linear utility) and if the tax system is proportional, the tail parameter of the income distribution is $a = a^*/(1 + \varepsilon)$.

[28] This expression for the participation rate is obtained if the lowest participation costs is $\varphi_0 = 0$ and the (conditional) density is $\eta A\varphi^{\eta-1}$.

that around 15% of the participants with the lowest earnings ability are unemployed, whereas the unemployment rate of individuals with an earnings potential of \$100,000 is only 2.5%, and drops further to 1.4% for individuals with earnings potential \$200,000 (not plotted). Figure 3.2 also shows the (non-targeted) distribution of average earnings and employment rates for individuals with different educational attainments. The categories are the following: less than high school, high school, some college, college, advanced. In line with the model, the data shows an increasing relationship.

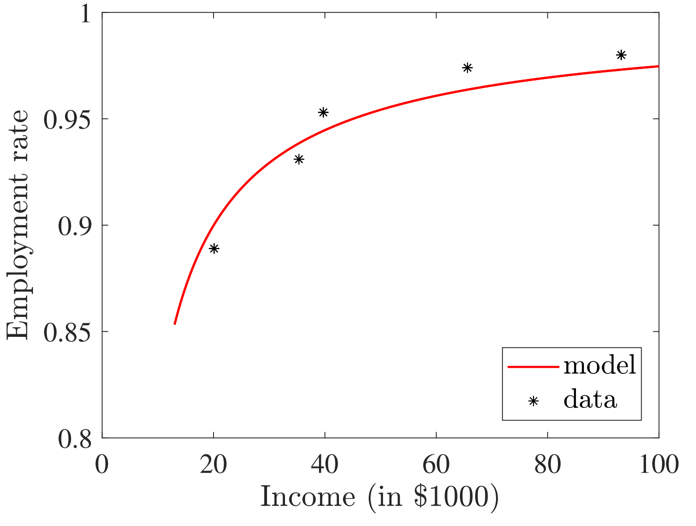


Figure 3.2: Employment rates by income

Figure 3.3 plots the participation rates at different levels of income, which are obtained from equation (3.27). As before, the model predicts an increasing relationship: individuals with higher ability earn more and are more likely to participate. In the current calibration, the participation rate among individuals with the lowest skill level is around 70% and it increases monotonically to 100% for individuals with earnings potential above \$192,000 (not plotted). The predictions from the model are contrasted with the (non-targeted) profile of earnings and participation rates of individuals with different educational backgrounds. Again, in line with the model, the data shows an increasing relationship.

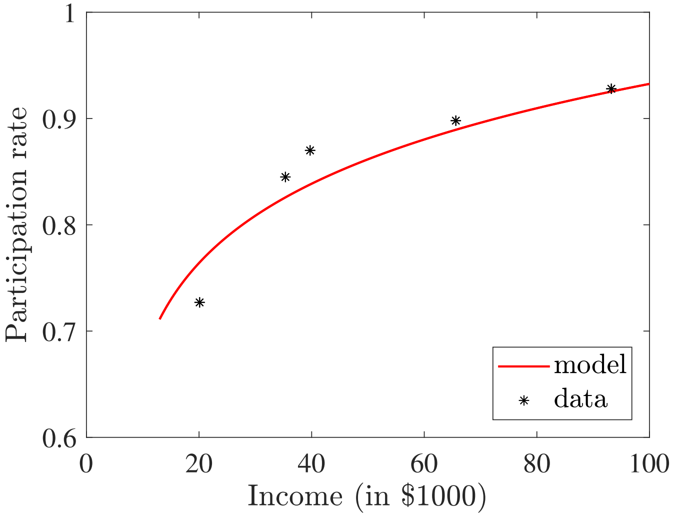


Figure 3.3: Participation rates by income

3.5.2 Unemployment responses in the current tax-benefit system

To get a sense of the quantitative importance of the employment-enhancing effect (EEE) and the employment-reducing effect (ERE), Figure 3.4 plots the employment responses to taxation at the current tax-benefit system. To facilitate the comparison, I plot the elasticity of employment with respect to one minus the marginal and one minus the average tax rate, both in absolute value (i.e., $\varepsilon_{eT'}$ and ε_{et} as defined in equation (3.14) and Corollary 3.1). Two points are worth mentioning. First, in the calibrated model employment (or unemployment) is more responsive to changes in the average tax rate than to changes in the marginal tax rate. Second, the elasticities are decreasing in income. In particular, the numbers suggest that a one percentage point increase in the marginal tax rate (holding the average tax rate fixed) reduces the unemployment rate by 0.11 percentage points for the lowest skill type and by 0.05 percentage points around the median of the income distribution.[29] The corresponding figures for a one percentage point increase in

[29]Note: these numbers are obtained from, but not equal to, the ones shown in Figure 3.4. The latter plots the percentage decrease (increase) in the employment rate for a one percent increase in one minus the marginal (average) tax rate.

the average tax rate (holding the marginal tax rate fixed) are a 0.25 and 0.07 percentage points increase in the unemployment rate.

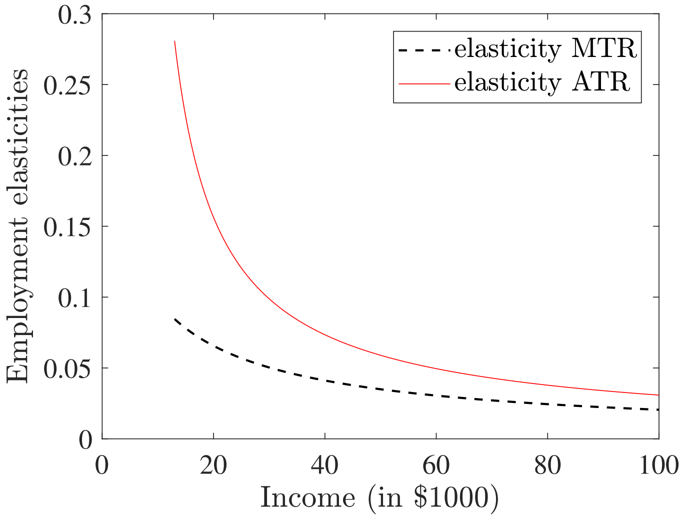


Figure 3.4: Employment elasticities

How the government should take into account unemployment responses ultimately depends on the fiscal externalities associated with the EEE and the ERE: see equation (3.15). Figure 3.5 plots these, as well as the total effect. In particular, it shows – for different levels of income z – the budgetary effects due to the unemployment responses following a one percentage point increase in the marginal tax rate in the interval $[z, z+\Delta]$. For ease of interpretation, I set $\Delta = \$100$, so that the tax reform raises the tax liability of individuals with earnings above $z + \Delta$ by exactly \$1. On the one hand, the reform raises tax revenue because it reduces wage pressure and hence raises employment in the interval $[z, z + \Delta]$ (through the EEE). The top line shows the budgetary effect. Since the effect is proportional to the density, the shape is similar to that of the income distribution (which is approximately log-normal). On the other hand, the implied rise in the average tax rates for incomes above $z + \Delta$ raises wage pressure and hence unemployment for individuals with higher earnings potential (through the ERE). The bottom line shows by how much government revenue is affected. As can be seen from the figure, the revenue effect is larger at low levels of income. This happens for two reasons. First, an increase in the marginal tax rate at some income level raises only the average tax rates of individuals with higher income. This also explains why the shape is more similar to that of the cumulative income distribution. Second, employment responses to the average tax rates are declining in income: see Figure 3.4.

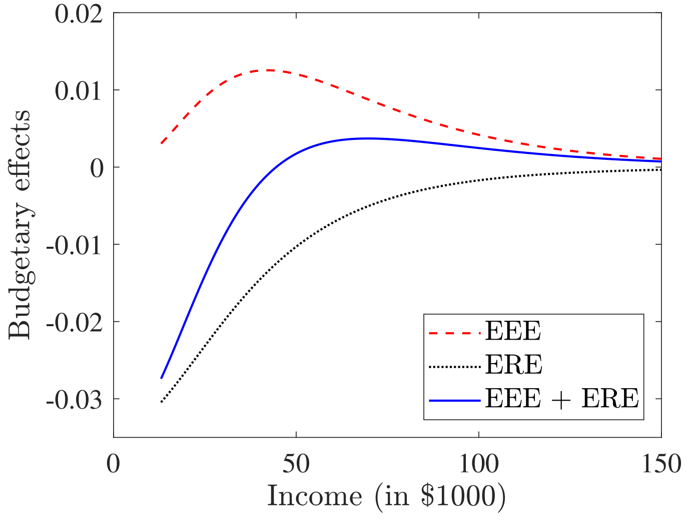


Figure 3.5: Budgetary effects

Figure 3.5 also plots the sum of both effects. Two points are noteworthy. First, the net revenue effect is virtually zero for reforms which (locally) increase the marginal tax rate at income levels above the median (i.e., $50,000). Unemployment responses to taxation therefore only appear important to consider when changing tax rates for low-income workers. Second, the negative revenue effect of the ERE is much stronger than the positive effect of the EEE at the bottom of the income distribution. In particular, the government loses close to $0.03 due to unemployment responses if it aims to collect $1 more from (almost) all employed individuals by raising the marginal tax rate at the bottom. The reason why the ERE dominates the EEE is threefold. First, unemployment is more responsive to changes in the average tax rate than to changes in the marginal tax rate (see Figure 3.4). Second, the hazard rate is low at low levels of income. Consequently, an increase in the marginal tax rate improves the employment prospects of only a few individuals, whereas the implied increase in the average tax rate raises the unemployment rate at virtually all other income levels. Third, the fiscal externality due to unemployment responses increases in income. As a result, the increase in unemployment at higher income levels generates a larger revenue effect than the reduction in unemployment at low levels of income.

Figure 3.6 compares the net revenue effects due to unemployment responses (i.e., the sum of EEE and ERE) to those associated with earnings responses (the typical focus in the optimal tax literature). On the one hand, an increase in the marginal tax rate at some income level reduces both effort and wages around that income level. This leads to a reduction in revenue. On the other hand, the associated increase in the average tax rate raises wages further up in the income distribution, which increases tax revenue. As can be seen from Figure 3.6, the net revenue effect is negative and follows the shape of the income distribution. This suggests the first of these effects dominates. Moreover, the revenue effects due to earnings responses are significantly larger (in absolute value) than those associated with unemployment responses, *except* at low levels of income. For instance, raising the marginal tax rate around the median income level (so as to generate \$1 dollar of revenue from individuals with higher income) costs the government close to \$0.14. At the bottom, however, the revenue effect due to earnings responses is negligible, whereas the revenue effect due to the EEE and ERE is close to \$0.03 (see also Figure 3.5). Until roughly \$18,000 in annual earnings, the net revenue effect due to unemployment responses is larger (in absolute value) than the effect due to earnings responses.

3.5.3 A quantitative analysis of optimal taxes

How does the optimal tax-benefit system look like and how does it compare to a setting where unemployment is not taken into account? Answering these questions requires a specification of the government's objective function as well as the revenue requirement G. The latter is calibrated to ensure the budget constraint (3.8) holds at the current tax-benefit system. The implied value equals $G = \$15,157$, which corresponds to roughly 21.2% of average annual earnings. For the welfare function (3.12), I use the following:

$$\Psi(U) = \frac{U^{1-\sigma} - 1}{1 - \sigma}, \tag{3.28}$$

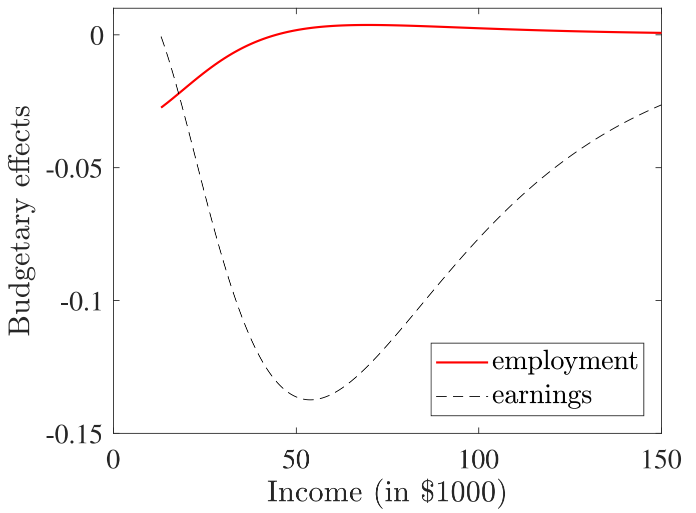


Figure 3.6: Budgetary effects

where $\sigma > 0$ reflects the degree of inequality aversion. In the baseline calibration, I set $\sigma = 0.5$.[30] I solve the government's optimization problem by maximizing social welfare (3.12) subject to the budget constraint (3.8), taking into account the behavioral responses as summarized in Table 3.1. Further details on the numerical optimization procedures can be found in Appendix H.

Figure 3.7 plots the optimal marginal tax rates $T'(z)$ up to $300,000 in annual earnings. The tax rates clearly follow the conventional U-shape pattern (Diamond (1998), Saez (2001)). They are quickly decreasing until modal income, stay roughly constant up to $150,000, and start increasing afterwards. The optimal top rate is around 58% in the current calibration. The latter applies at income levels above $215,000, which is the point where the Pareto tail starts at the optimal allocation.[31] The reason why optimal tax rates follow a U-shape pattern is largely due to the behavior of the hazard rate of the income distribution: see Saez (2001).

[30]This value implies the government is indifferent between giving $1 to an individual whose net income is x and giving $0.71 to an individual whose net income is $x/2$.

[31]Note that the Pareto tail starts at $250,000 in annual earnings at the *current* tax-benefit system. At the *optimal* tax-benefit system, the earnings for individuals with that ability are approximately $35.000 lower.

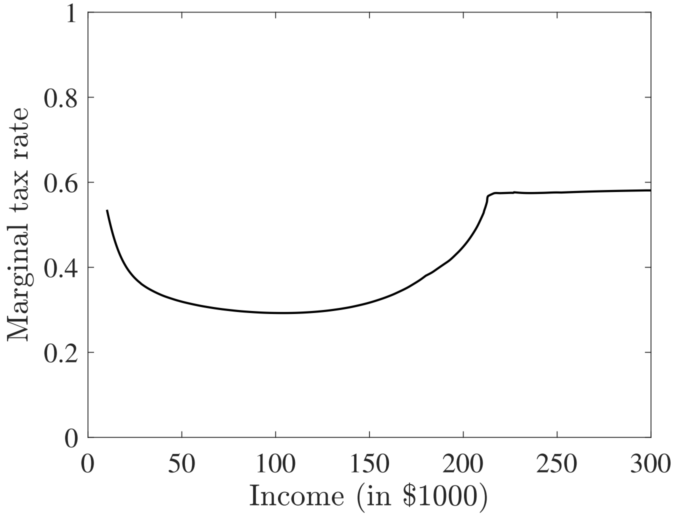


Figure 3.7: Optimal marginal tax rates

Figure 3.8 plots the optimal average tax rates $T(z)/z$, again for income levels up to $300,000. The average tax rates are negative at low income levels, remain more or less flat between $50,000 and $215,000 (i.e., the region where the marginal tax rates are approximately constant) and start increasing again at the point where the Pareto tail starts. Given the degree of inequality aversion (i.e., given $\sigma = 0.5$), the optimal tax-benefit system is more redistributive than the current one. In particular, average tax rates are lower than in the current system up to roughly $222,000 in annual earnings (not plotted). Moreover, the average tax rate remains negative up to approximately $15,000 in annual earnings at the optimal tax-benefit system, whereas the corresponding figure in the current tax-benefit system is $10,679. Also the optimal unemployment benefit is higher than in the current system (i.e., $6,086 compared to $4,605). As a result, the optimal employment tax (as given by the sum of $T(z)+b$) is always positive in the current calibration. Hence, subsidizing employment for low-income workers (through an EITC type of policy) is not optimal given the current specification of social welfare.

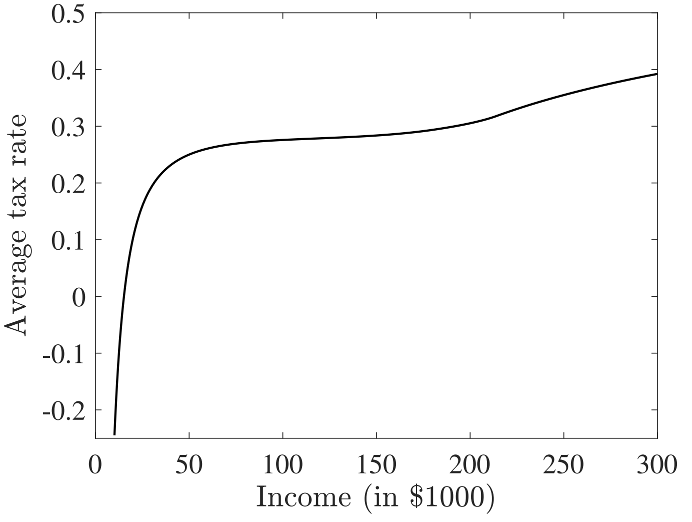


Figure 3.8: Optimal average tax rates

Comparison to the tax schedule without unemployment

How does the optimal tax-benefit system compare to the one that would be obtained if unemployment is not taken into account? To answer that question, I also calculate the optimal tax-benefit system assuming there are no frictions. In this case, the costs of opening a vacancy are zero and all individuals who participate find employment (i.e., $k = 0$ and $e(n) = 1$ for all n). I recalibrate the ability distribution to make it consistent with the empirical income distribution. The current tax-benefit system, utility function and procedures to calibrate the distribution of participation costs and the revenue requirement are the same as before.

Figure 3.9 compares the optimal marginal tax rates with and without unemployment. In both cases, the optimal tax rates follow a very similar U-shape pattern and converge to virtually the same top rate. This suggests unemployment responses at the top are quantitatively unimportant. For incomes up to $200,000, the optimal tax rates are somewhat lower if unemployment is taken into account. The largest discrepancies are found at very low levels of income (where the optimal tax rate is considerably higher if there are matching frictions), and at income levels between $100,000 and $200,000. These results should be interpreted with caution, for at least two reasons. First, the differences in optimal tax rates cannot simply be attributed to the fiscal externalities associated with unemployment responses. The reason is that the condition for the optimal tax rate (3.15) is expressed in terms of endogenous objects. The income distribution, fiscal externalities, welfare weights, and elasticities all vary with the tax-benefit system. In addition, the ability distribution and revenue requirement are recalibrated to match the empirical income distribution and ensure the government's budget constraint holds. Second, as will be shown below the difference between the optimal marginal tax rates with and without unemployment are much smaller under an alternative calibration of the matching function.

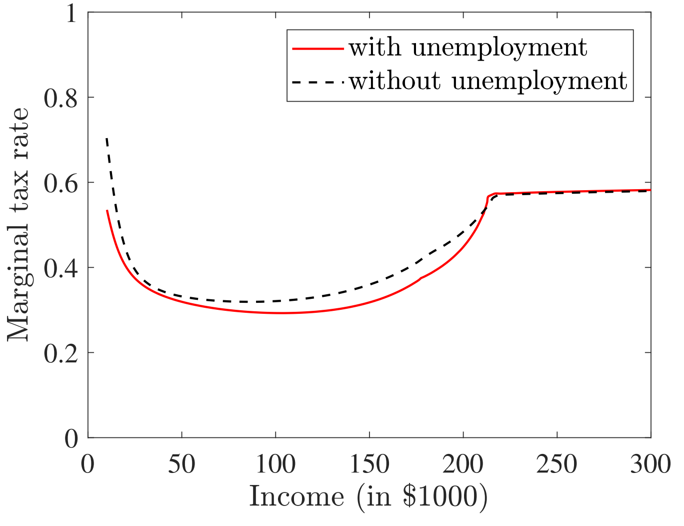


Figure 3.9: Comparison optimal marginal tax rates

3.5.4 An example with low vacancy costs

In the current calibration firms incur significant costs to get their vacancies filled. For the median worker, they amount to roughly 20% of output, leaving around 80% to be paid in wages (recall: firms make zero profits).[32] As mentioned before, this is because the low degree of substitutability between vacancies and unemployment implies vacancies are very efficient in generating matches. The vacancy costs must then be substantial

[32]This number differs from $k = \$10,250$ as a fraction of median earnings $50,000, because the expected costs of getting a vacancy filled equal $\theta(e)k/e$ and not k.

to match the unemployment rate in the data. This is not the case if the elasticity of substitution between vacancies and unemployment is larger. Suppose, for instance, the latter is increased from around 0.13 to 0.44 (as in Den Haan et al., 2000).[33] In order to get an unemployment rate of 5.1%, the costs of opening a vacancy equals $k = \$255$. For the median worker, the costs of getting a vacancy filled then amount to approximately 4.4% (compared to 20% in the baseline calibration). I now repeat part of the analysis using these values. As before, the ability distribution is recalibrated and I use the same tax-benefit system, utility function and procedure to calibrate the distribution of participation costs and the revenue requirement.

Figure 3.10 shows the relationship between employment rates and earnings when vacancy costs are lower. For comparison, I also plot the relationship in the baseline calibration and the profile of employment rates and earnings for different education levels (see Figure 3.2). Employment rates are increasing less quickly in earnings if vacancy costs are low. Moreover, the baseline calibration appears to do a better job in capturing the profile of earnings and employment for different education levels. In particular, the unemployment rate at the average earnings level of individuals with a low educational attainment is understated relative to their actual unemployment rate, and *vice versa* for high income levels.

A direct implication is that unemployment is less responsive to changes in the tax-benefit system if vacancy costs are low. Consequently, the revenue effects associated with employment responses are smaller as well. This is graphically illustrated in Figure 3.11, which compares the sum of the EEE and ERE in the calibration with low vacancy costs and in the baseline calibration. If vacancy costs are low, raising the marginal tax rate at the bottom of the income distribution (so as to generate \$1 from almost all working individuals) implies a reduction of \$0.02 in revenue due to unemployment responses. The corresponding figure in the baseline calibration is close to \$0.03. As before the net revenue effect is close to zero at higher income levels, suggesting again that unemployment responses to taxation are most relevant to consider when setting taxes at low income levels.

[33] They use a dynamic model and calibrate a value of $\gamma = -1.27$ to match statistics job separation and firm and worker match probabilities. The implied CES between vacancies and unemployment is approximately 0.44.

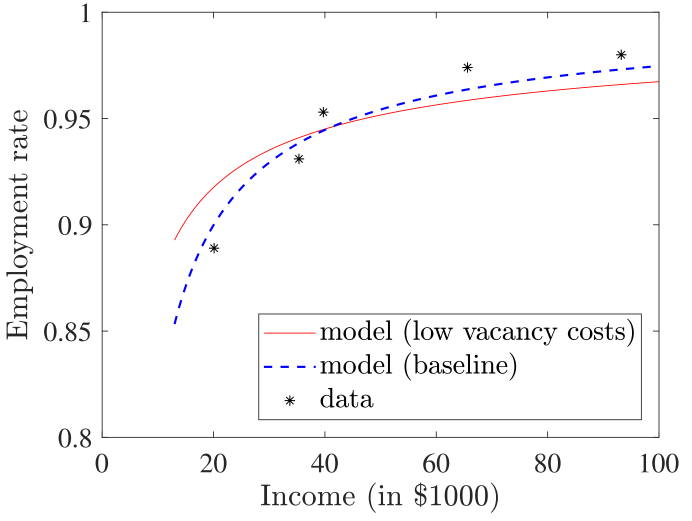


Figure 3.10: Employment rates by income

Finally, Figure 3.12 compares the optimal marginal tax rates with those obtained in the baseline calibration and assuming away frictions (i.e., abstracting from unemployment). The final two are also shown in Figure 3.9. If vacancy costs are low, the optimal tax rates are very similar to the ones that would be obtained if unemployment is not taken into account (except possibly at the very bottom). Hence, the finding that *optimal* tax rates are lower if unemployment is taken into account (as is suggested by Figure 3.9) is not particularly robust. However, this does not imply that unemployment responses should not be taken into account when considering reforms to the *current* tax-benefit system. In fact, the findings presented in Figures 3.5, 3.6 and 3.11 suggest unemployment responses to taxation are important to consider when setting tax rates at low levels of income. The negative revenue effects due to unemployment considerations lower the revenue gain of raising tax rates at low income levels by $0.03 in the baseline calibration and $0.02 in the calibration with lower vacancy costs.

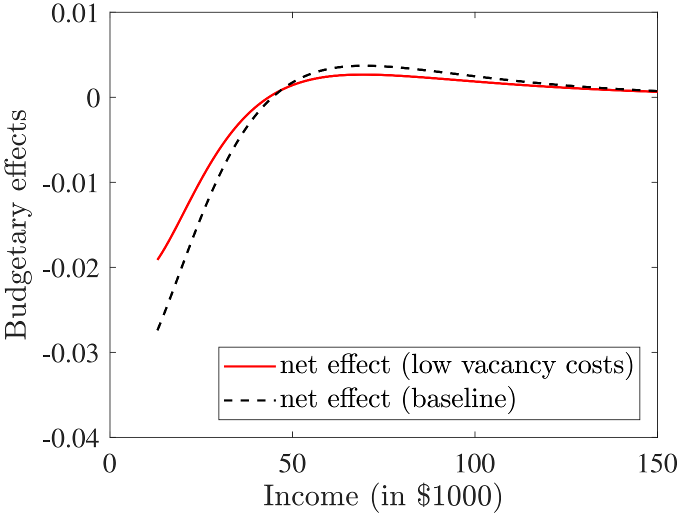


Figure 3.11: Budgetary effects

3.6 Conclusion

This paper characterizes optimal unemployment insurance and income redistribution in a directed search model where matching frictions generate uninsurable and heterogeneous unemployment risk. Individuals differ in terms of their ability and participation costs and supply labor on the intensive and extensive margin. In addition to the standard trade-off between consumption and leisure they face a trade-off between high wages and low unemployment risk. The government affects this trade-off and hence unemployment by altering the costs and benefits of searching. On the one hand, an increase in the marginal tax rate raises employment as it lowers the benefits of looking for higher-wage jobs. On the other hand, an increase in the tax burden or unemployment benefit reduces employment as it lowers the benefits of finding a job. I label the first of these the employment-enhancing effect (EEE) and the second the employment-reducing (ERE) effect of taxation.

Because an unemployed worker receives unemployment benefits and does not pay income taxes, changes in unemployment affect government finances. These fiscal externalities call for intuitive adjustments of standard optimal tax formulas. The latter are used to obtain the following insights. First, how unemployment affects optimal tax policy

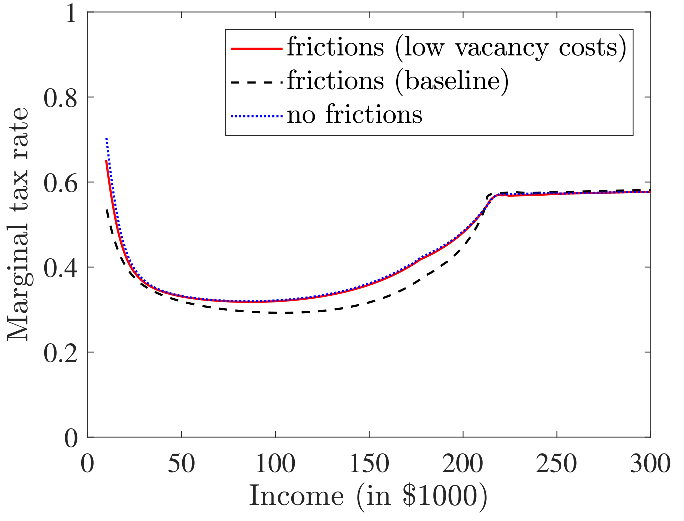


Figure 3.12: Comparison marginal tax rates

depends on two types of statistics: (i) the elasticity of unemployment with respect to the marginal and average tax rate and (ii) the hazard rate of the income distribution. Second, if it is optimal to subsidize employment, the optimal marginal tax rates are negative at the bottom of the income distribution. My model can therefore explain why it is optimal to let employment subsidies (such as the EITC) phase in with income. Third, the optimal provision of unemployment insurance is closely linked to the shape of the tax schedule. In particular, financing UI payments through lump-sum or proportional taxes on labor income – as is commonly assumed in the literature – is sub-optimal even in the absence of a motive for redistribution. Finally, a calibration of the model to the US economy reveals that unemployment is an important margin to consider when setting tax rates at low levels of income. I find that the government loses three cents on the dollar due to unemployment responses if – starting from the current tax-benefit system – it raises the marginal tax rate for low-income workers. Despite this, the quantitative impact of unemployment on the pattern of *optimal* taxes appears to be modest.

The analysis from this paper can be extended in a number of directions. First, in my model the missing insurance market is the only source of inefficiency and unemployment affects optimal tax policy only through fiscal externalities. It would be interesting to allow for further departures from efficiency. Second, I have assumed wages can freely adjust in response to changes in the tax-benefit system. This may not be the case if there is a binding minimum wage. How the tax-benefit system and minimum wages should jointly be optimized is an interesting and policy-relevant question. Third, I have abstracted from dynamic considerations. As a result, individuals cannot insure their unemployment risk through precautionary savings and UI payments cannot be conditioned on past earnings. Extending the model to include these features would both make it more realistic and significantly enrich the set of policy questions it can address. Finally, this paper can serve as a motivation for future empirical work. There is little evidence about the separate effects of marginal and average tax rates on unemployment. My analysis indicates that both responses are key for analyzing the welfare effects of tax reforms.

Appendix A: Constrained efficiency

This appendix formally demonstrates that the allocation of resources in the absence of government intervention is Pareto efficient (from an *ex ante* perspective) if and only if individuals are risk-neutral. To do so, I first show that if individuals are risk-neutral the *laissez-faire* allocation maximizes the sum of expected utilities subject to the aggregate resource constraint. Then, I show that if individuals are risk-averse there exists a Pareto-improving and resource-feasible perturbation of the equilibrium allocation.

If individuals are risk-neutral (i.e., $u(c) = c$) and if there are no taxes and benefits (i.e., $T(z) = b = 0$), the equilibrium satisfies the following conditions:[34]

$$\theta(e(n))k = e(n)(y(n) - z(n)), \tag{3.29}$$

$$\varphi(n) = e(n)\left(z(n) - v\left(y(n)/n\right)\right), \tag{3.30}$$

$$n = v'\left(y(n)/n\right), \tag{3.31}$$

$$\left(\theta'(e(n)) - \theta(e(n))/e(n)\right)k = z(n) - v\left(y(n)/n\right). \tag{3.32}$$

These correspond to the zero-profit condition (3.2), the participation decision (3.4) and the first-order conditions (3.6) and (3.7). To see why the implied allocation is Pareto

[34] The government budget constraint (3.8) then requires $G = 0$.

efficient, suppose the government chooses the allocation which maximizes the sum of all individuals' expected utilities subject to the resource constraint. The Lagrangian is given by:

$$\begin{aligned}\mathcal{L} = & \int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n)} \left[e(n) \left(z(n) - v \left(\frac{y(n)}{n} \right) \right) - \varphi \right] f(\varphi, n) d\varphi dn \\ & + \lambda \left(\int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n)} \Big[e(n)(y(n) - z(n)) - \theta(e(n))k \Big] f(\varphi, n) d\varphi dn \right). \end{aligned} \quad (3.33)$$

Here, $\mathcal{U}(n) - \varphi = e(n)(z(n) - v(y(n)/n)) - \varphi$ denotes the expected utility of an individual of type (n, φ) who participates. Utility of the non-participants equals $u(0) = 0$. Moreover, λ denotes the multiplier on the aggregate resource constraint. The resource constraint is obtained by integrating the zero-profit condition over all participants. The first-order conditions associated with the optimization problem (3.33) are:

$$z(n) : (1 - \lambda) \int_{\varphi_0}^{\varphi(n)} e(n) f(\varphi, n) d\varphi = 0, \quad (3.34)$$

$$y(n) : \int_{\varphi_0}^{\varphi(n)} e(n) \left(-\frac{v'(y(n)/n)}{n} + \lambda \right) f(\varphi, n) d\varphi = 0, \quad (3.35)$$

$$e(n) : \int_{\varphi_0}^{\varphi(n)} \Big[z(n) - v(y(n)/n) + \lambda(y(n) - z(n) - \theta'(e(n))k) \Big] f(\varphi, n) d\varphi = 0, \quad (3.36)$$

$$\varphi(n) : e(n) \left(z(n) - v \left(\frac{y(n)}{n} \right) \right) - \varphi(n) + \lambda \Big(e(n)(y(n) - z(n)) - \theta(e(n))k \Big) = 0. \quad (3.37)$$

To verify that the equilibrium allocation (as implicitly defined by (3.29)-(3.32)) satisfies these conditions, first observe that (3.34) implies $\lambda = 1$. Then, equations (3.31) and (3.35) coincide. Similarly, setting $\lambda = 1$ and using (3.29) to substitute out for $z(n)$ in (3.32) implies (3.36) holds as well. Finally, (3.37) is equivalent to (3.29) because the zero-profit condition (3.30) implies the second term in (3.37) is zero. The *laissez-faire* allocation thus maximizes the sum of expected utilities subject to the aggregate resource constraint. This implies there exists no resource-feasible Pareto improvement if individuals are risk-neutral.

Conversely, if individuals are risk-averse there exists a Pareto-improving and resource-feasible perturbation of the equilibrium allocation. To see why, note that – in the absence of taxes and benefits – an individual with ability n who decides to participate, solves:

$$\mathcal{U}(n) \equiv \max_{y,z,e} \left\{ e\left[u(z) - v\left(\frac{y}{n}\right)\right] + (1-e)u(0) \;\text{ s.t. }\; k = \frac{e}{\theta(e)}(y-z) \right\}. \tag{3.38}$$

Denote the solution of the above maximization problem by $(y(n), z(n), e(n))$. Hence, a fraction $e(n)$ of the participants with ability n becomes employed, produces $y(n)$ and consumes $z(n)$, whereas a fraction $1-e(n)$ remains unemployed and does not consume at all. Now, consider a perturbation where the consumption of individuals with ability n in the state of unemployment is marginally raised by $\mathrm{d}c_u > 0$ and consumption in the state of employment is reduced by $\mathrm{d}c_u(1-e(n))/e(n)$. Such a perturbation is resource feasible as it does not affect aggregate consumption of individuals with ability n. The impact on expected utility is:

$$d\mathcal{U}(n) = (1-e(n))(u'(0) - u'(z(n)))dc_u. \tag{3.39}$$

The latter is strictly positive whenever $u(\cdot)$ is strictly concave. Since the perturbation raises the expected utility of type n individuals without decreasing the expected utility of any other type, the laissez-faire equilibrium is not Pareto efficient if individuals are risk-averse.[35]

Appendix B: Comparative statics

This appendix derives how the labor-market equilibrium outcomes are affected by the tax-benefit system and how they vary with ability (see Proposition 3.1). To do so, I use the variational approach introduced in Golosov et al. (2014). As a first step, I characterize the equilibrium outcomes for an individual with ability n who is confronted with the tax schedule $T^*(z,\kappa)$. The equilibrium earnings, output and employment rate are determined by:

$$e(y-z) - \theta(e)k = 0, \tag{3.40}$$

[35] Note however that the reform only raises the *expected* (i.e., *ex ante*) utility of individuals. It does not generate an increase in *realized* (i.e., *ex post*) utilities, because the reform lowers the utility in the state of employment.

$$u'(z - T(z) - \kappa R(z))n(1 - T'(z) - \kappa R'(z)) - v'(y/n) = 0, \tag{3.41}$$

$$(u(z - T(z) - \kappa R(z)) - v(y/n) - u(b))n - v'(y/n)(\theta'(e) - \theta(e)/e)k = 0. \tag{3.42}$$

These correspond with the equilibrium conditions (3.2), (3.6) and (3.7) under the assumption that the tax schedule is given by $T^*(z, \kappa) = T(z) + \kappa R(z)$. Denote the above system by $\Lambda(\mathbf{x}; \mathbf{t}) = 0$, which implicitly defines the equilibrium outcomes $\mathbf{x} = (z, y, e)'$ as a function of parameters $\mathbf{t} = (\kappa, b, n)'$. The comparative statics can be determined via the implicit function theorem:

$$\frac{\mathrm{d}\mathbf{x}}{\mathrm{d}\mathbf{t}} = -\left(\frac{\partial \Lambda(\mathbf{x}; \mathbf{t})}{\partial \mathbf{x}}\right)^{-1} \frac{\partial \Lambda(\mathbf{x}; \mathbf{t})}{\partial \mathbf{t}} = -\Lambda_{\mathbf{x}}^{-1} \Lambda_{\mathbf{t}}. \tag{3.43}$$

Working out (3.43) using co-factor expansion yields:

$$\frac{\mathrm{d}\mathbf{x}}{\mathrm{d}\mathbf{t}} = \frac{-1}{|\Lambda_{\mathbf{x}}|} \begin{pmatrix} \Lambda_y^2\Lambda_p^3 - \Lambda_p^2\Lambda_y^3 & \Lambda_p^1\Lambda_y^3 - \Lambda_y^1\Lambda_p^3 & \Lambda_y^1\Lambda_p^2 - \Lambda_p^1\Lambda_y^2 \\ \Lambda_p^2\Lambda_z^3 - \Lambda_z^2\Lambda_p^3 & \Lambda_z^1\Lambda_p^3 - \Lambda_p^1\Lambda_z^3 & \Lambda_p^1\Lambda_z^2 - \Lambda_z^1\Lambda_p^2 \\ \Lambda_z^2\Lambda_y^3 - \Lambda_y^2\Lambda_z^3 & \Lambda_y^1\Lambda_z^3 - \Lambda_z^1\Lambda_y^3 & \Lambda_z^1\Lambda_y^2 - \Lambda_y^1\Lambda_z^2 \end{pmatrix} \begin{pmatrix} \Lambda_\kappa^1 & \Lambda_b^1 & \Lambda_n^1 \\ \Lambda_\kappa^2 & \Lambda_b^2 & \Lambda_n^2 \\ \Lambda_\kappa^3 & \Lambda_b^3 & \Lambda_n^3 \end{pmatrix}. \tag{3.44}$$

The superscripts correspond to the rows in $\Lambda(\mathbf{x}; \mathbf{t})$. The elements of $\Lambda_{\mathbf{x}}$ are (ignoring function arguments for notational convenience):

$$\begin{aligned} &\Lambda_z^1 = -e, \quad \Lambda_y^1 = e, \quad \Lambda_e^1 = -\chi, \\ &\Lambda_z^2 = u''n(1 - T' - \kappa R')^2 - u'n(T'' + \kappa R''), \quad \Lambda_y^2 = -v''/n, \quad \Lambda_e^2 = 0, \\ &\Lambda_z^3 = v', \quad \Lambda_y^3 = -v' - \chi v''/n, \quad \Lambda_e^3 = -v'(\theta''k - \chi/e). \end{aligned} \tag{3.45}$$

The elements in $\Lambda_{\mathbf{t}}$ are:

$$\begin{aligned} &\Lambda_\kappa^1 = 0, \quad \Lambda_b^1 = 0, \quad \Lambda_n^1 = 0, \\ &\Lambda_\kappa^2 = -u''n(1 - T' - \kappa R')R - u'nR', \quad \Lambda_b^2 = 0, \quad \Lambda_n^2 = v'/n + v''y/n^2, \\ &\Lambda_\kappa^3 = -u'nR, \quad \Lambda_b^3 = -u_0'n, \quad \Lambda_n^3 = v'\chi/n + v'y/n + \chi v''y/n^2. \end{aligned} \tag{3.46}$$

Equations (3.45)-(3.46) are simplified somewhat using the conditions (3.40)-(3.42). In addition, I denote by $\chi = (\theta'(e) - \theta(e)/e)k > 0$ the difference between the marginal and average costs of getting a vacancy filled and by $u'_0 \equiv u'(b)$ the marginal utility of consumption of the unemployed.

The impact of income taxes on labor-market outcomes can be determined by calculating the partial effect of the reform parameter κ, evaluated at the reform of interest (see, e.g., Gerritsen (2016), Jacquet and Lehmann (2017)). The reforms I consider are the following:

$$R(z) = z - z(n) \tag{3.47}$$

$$R(z) = 1 \tag{3.48}$$

The first of these increases the marginal tax rate while leaving the average tax rate at income level $z(n)$ unaffected. The second generates an increase in the tax liability but does not affect the marginal tax rate. In order to simplify the exposition and to sign the partial effects, I perturb the tax functions starting from the *laissez-faire* equilibrium: $T(\cdot) = b = \kappa = 0$. The impact of the first reform is obtained by working out the first column of (3.44) evaluated at the reform (3.47). With a slight abuse of notation, I denote the results by:

$$\frac{\mathrm{d}z}{\mathrm{d}T'} = \frac{u'n(\chi^2 v''/n + pkv'\theta'')}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} < 0 \tag{3.49}$$

$$\frac{\mathrm{d}y}{\mathrm{d}T'} = \frac{u'npkv'\theta''}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} < 0 \tag{3.50}$$

$$\frac{\mathrm{d}e}{\mathrm{d}T'} = \frac{-\chi u'npv''/n}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} > 0 \tag{3.51}$$

Similarly, for the reform (3.48):

$$\frac{\mathrm{d}z}{\mathrm{d}T} = \frac{u''n(\chi^2 v''/n + pkv'\theta'') - \chi u'v''}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} > 0 \tag{3.52}$$

$$\frac{\mathrm{d}y}{\mathrm{d}T} = \frac{u''n(pkv'\theta'' - \chi u'n)}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} \geq 0 \tag{3.53}$$

$$\frac{\mathrm{d}e}{\mathrm{d}T} = \frac{p(u'v'' - u''n(\chi v''/n + u'n))}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} < 0 \tag{3.54}$$

The effects of changing the unemployment benefit b are given by:

$$\frac{\mathrm{d}z}{\mathrm{d}b} = \frac{-\chi v'' u_0'}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} > 0 \tag{3.55}$$

$$\frac{\mathrm{d}y}{\mathrm{d}b} = \frac{-\chi u'' n^2 u_0'}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} \leq 0 \tag{3.56}$$

$$\frac{\mathrm{d}e}{\mathrm{d}b} = \frac{pnu_0'(v''/n - u''n)}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} < 0 \tag{3.57}$$

Finally, how labor-market outcomes vary with ability n is determined by:

$$\frac{\mathrm{d}z}{\mathrm{d}n} = \frac{-v'(p(\theta''k - \chi/p)v''y/n^2 + pv'\theta''k/n)}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} > 0 \tag{3.58}$$

$$\frac{\mathrm{d}y}{\mathrm{d}n} = \frac{-((v'/n + v''y/n^2)(pv'\theta''k - \chi^2 u''n) - \chi v' y u'')}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} > 0 \tag{3.59}$$

$$\frac{\mathrm{d}e}{\mathrm{d}n} = \frac{p((v'/n + v''y/n^2)\chi u''n - v'y(v''/n - u''n)/n)}{u''n(\chi^2 v''/n + pkv'\theta'') - pkv'\theta''v''/n} > 0 \tag{3.60}$$

The signs of all these effects follow from the assumptions on $u(\cdot)$, $v(\cdot)$ and $\theta(\cdot)$ combined with the observation that $u'(\cdot)n = v'(\cdot)$ in the absence of taxes.[36] Since unemployment is given by $1 - e(n)$, unemployment is decreasing in ability n and the marginal tax rate T' and increasing in the tax liability T and the unemployment benefit b.

Finally, to analyze the impact of the tax-benefit system on the participation rate, note that the participation threshold $\varphi(n) = \mathcal{U}(n) - u(b)$ satisfies:

$$\varphi(n) = \max_{z,e} \left\{ e \left[u(z - T(z) - \kappa R(z)) - v\left(\frac{1}{n}\left(z + \frac{\theta(e)}{e}k\right)\right) - u(b)\right] \right\}, \tag{3.61}$$

where the last step follows from using the zero-profit condition (3.2) to substitute out for z in (3.3). Differentiating (3.61) with respect to the parameters κ and b, evaluated at the reform of interest, gives:

$$\frac{\mathrm{d}\varphi}{\mathrm{d}T'} = 0, \qquad \frac{\mathrm{d}\varphi}{\mathrm{d}T} = -eu' < 0, \qquad \frac{\mathrm{d}\varphi}{\mathrm{d}b} = -eu_0' < 0. \tag{3.62}$$

[36]The assumption that the elasticity of $\theta(\cdot)$ is non-decreasing implies $\theta''k - \chi/p > 0$, which is the only term of which the sign might appear ambiguous.

Since the participation rate (3.5) increases in the threshold (3.61), the participation rate is decreasing in the tax liability and the unemployment benefit and unaffected by a local change in the marginal tax rate.

Appendix C: Optimal tax-benefit system

To derive the optimal policy rules from Proposition 3.2, write the Lagrangian associated with the government's optimization problem as follows:

$$\begin{aligned}\mathcal{L} = & \int_{n_0}^{n_1}\int_{\varphi_0}^{\varphi(n,\kappa,b)} \Psi\left(\mathcal{U}(n,\kappa,b)-\varphi\right) f(\varphi,n)d\varphi dn \\ & + \int_{n_0}^{n_1}\int_{\varphi(n,\kappa,b)}^{\varphi_1} \Psi(u(b))f(\varphi,n)d\varphi dn \\ & + \lambda\left[\int_{n_0}^{n_1}\int_{\varphi_0}^{\varphi(n,\kappa,b)} e(n,\kappa,b)\left(T(z(n,\kappa,b))+\kappa R(z(n,\kappa,b))+b\right) f(\varphi,n)d\varphi dn - b - G\right].\end{aligned} \tag{3.63}$$

Here, λ is the multiplier on the government's budget constraint and the tax function is given by $T(z)+\kappa R(z)$. The notation (n,κ,b) is used to denote which variables depend on ability n, the tax reform parameter κ and the benefit b. The expected utility of an individual with ability n who participates is given by:

$$\mathcal{U}(n,\kappa,b) = \max_{z,e}\left\{(1-e)u(b) + e\left[u(z-T(z)-\kappa R(z)) - v\left(\frac{y(z,e)}{n}\right)\right]\right\}, \tag{3.64}$$

where $y(z,e)$ is obtained from the zero-profit condition (3.2): $y(z,e) = z+\theta(e)k/e$. Moreover, the participation threshold satisfies:

$$\varphi(n,\kappa,b) = \mathcal{U}(n,\kappa,b) - u(b) \tag{3.65}$$

To derive equation (3.17), differentiate the Lagrangian with respect to b, taking into account the impact on $\mathcal{U}(n,\kappa,b)$ and $\varphi(n,\kappa,b)$. The first-order condition is given by:

$$\begin{aligned}\frac{\mathrm{d}\mathcal{L}}{\mathrm{d}b} = & \int_{n_0}^{n_1}\int_{\varphi_0}^{\varphi(n,\kappa,b)}(1-e(n,\kappa,b))\left[\Psi'(\mathcal{U}(n,\kappa,b)-\varphi)u'(b)-\lambda\right]f(\varphi,n)d\varphi dn \\ & + \int_{n_0}^{n_1}\int_{\varphi(n,\kappa,b)}^{\varphi_1}\left[\Psi'(u(b))u'(b)-\lambda\right]f(\varphi,n)d\varphi dn\end{aligned} \tag{3.66}$$

$$+ \ \lambda \int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n,\kappa,b)} \frac{\mathrm{d}z}{\mathrm{d}b} \left[e(n,\kappa,b)(T'(z(n,\kappa,b)) + \kappa R'(z(n,\kappa,b))) \right] f(\varphi,n) d\varphi dn$$
$$+ \ \lambda \int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n,\kappa,b)} \frac{\mathrm{d}e}{\mathrm{d}b} \left[T(z(n,\kappa,b)) + \kappa R(z(n,\kappa,b)) + b \right] f(\varphi,n) d\varphi dn$$
$$+ \ \lambda \int_{n_0}^{n_1} \frac{\mathrm{d}\varphi}{\mathrm{d}b} \left[e(n,\kappa,b)(T(z(n,\kappa,b)) + \kappa R(z(n,\kappa,b)) + b) \right] f(\varphi(n),n) dn = 0.$$

The first two lines give the mechanical welfare effects of transferring income to the unemployed (first line) and the non-participants (second line). The mass of these individuals equals the share of the population with zero income:

$$H(z_0) = \int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n,\kappa,b)} (1 - e(n,\kappa,b)) f(\varphi,n) d\varphi dn + \int_{n_0}^{n_1} \int_{\varphi(n,\kappa,b)}^{\varphi_1} f(\varphi,n) d\varphi dn. \quad (3.67)$$

Denote their average welfare weight by:

$$g(0) = \frac{1}{\lambda H(z_0)} \left[\int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n,\kappa,b)} (1 - e(n,\kappa,b)) \Psi'(\mathcal{U}(n,\kappa,b) - \varphi) u'(b) f(\varphi,n) d\varphi dn \right.$$
$$\left. + \int_{n_0}^{n_1} \int_{\varphi(n,\kappa,b)}^{\varphi_1} \Psi'(u(b)) u'(b) f(\varphi,n) d\varphi dn \right], \quad (3.68)$$

which measures the monetized increase in social welfare if individuals with zero income receive an additional unit of consumption. Using this notation, the first two terms of (3.66) can be written as:

$$\lambda(g(0) - 1) H(z_0). \quad (3.69)$$

To write the remaining terms of (3.66) also in terms of the income distribution, note that the relationship between the income and type distribution implies:

$$h(z(n)) z'(n) = \int_{\varphi_0}^{\varphi(n)} e(n) f(\varphi,n) d\varphi, \quad (3.70)$$

which is obtained by differentiating (3.13) with respect to n. Upon changing variables and evaluating the reform at $\kappa = 0$, the second and third line from (3.66) can be written as:

$$\lambda \int_{z_0}^{z_1} \left[z_b T'(z) + \frac{e_b}{e}(T(z) + b) \right] h(z) dz. \tag{3.71}$$

The final term can be simplified as follows. First, note that (3.5) implies:

$$\frac{\mathrm{d}\varphi}{\mathrm{d}b} f(\varphi(n), n) = \frac{\mathrm{d}\pi/\pi}{\mathrm{d}b} \int_{\varphi_0}^{\varphi(n)} f(\varphi, n) d\varphi. \tag{3.72}$$

The last line of (3.66) then simplifies to (using the same change of variables):

$$\int_{z_0}^{z_1} \frac{\pi_b}{\pi}(T(z) + b) h(z) dz. \tag{3.73}$$

Equation (3.17) is obtained by setting the sum of (3.69), (3.71) and (3.73) equal to zero, divide the resulting expression by λ and rearrange.

The procedure for deriving equation (3.16) is very similar. As a first step, maximize the Lagrangian with respect to κ, evaluated at the reform $R(z) = 1$. The first-order condition is:

$$\begin{aligned} \frac{\mathrm{d}\mathcal{L}}{\mathrm{d}T} &= \int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n,\kappa,b)} e(n,\kappa,b) \qquad (3.74) \\ \times & \left[\lambda - \Psi'(\mathcal{U}(n,\kappa,b) - \varphi) u'(z(n,\kappa,b) - T(z(n,\kappa,b)) - \kappa R(z(n,\kappa,b))) \right] f(\varphi,n) d\varphi dn \\ + \ \lambda & \int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n,\kappa,b)} \frac{\mathrm{d}z}{\mathrm{d}T} \left[e(n,\kappa,b)(T'(z(n,\kappa,b)) + \kappa R'(z(n,\kappa,b))) \right] f(\varphi,n) d\varphi dn \\ + \ \lambda & \int_{n_0}^{n_1} \int_{\varphi_0}^{\varphi(n,\kappa,b)} \frac{\mathrm{d}e}{\mathrm{d}T} \left[T(z(n,\kappa,b)) + \kappa R(z(n,\kappa,b)) + b \right] f(\varphi,n) d\varphi dn \\ + \ \lambda & \int_{n_0}^{n_1} \frac{\mathrm{d}\varphi}{\mathrm{d}T} \left[e(n,\kappa,b)(T(z(n,\kappa,b)) + \kappa R(z(n,\kappa,b)) + b) \right] f(\varphi(n),n) dn = 0. \end{aligned}$$

The first two lines capture the mechanical welfare effect of transferring income from all employed individuals to the government budget. To write this in terms of the income distribution and welfare weights, denote the average welfare weight of all individuals with earnings $z(n)$ as:

$$g(z(n)) = \frac{\int_{\varphi_0}^{\varphi(n)} e(n)\Psi'(\mathcal{U}(n) - \varphi)u'(z(n) - T(z(n)))f(\varphi, n)d\varphi}{\int_{\varphi_0}^{\varphi(n)} e(n)f(\varphi, n)d\varphi}. \tag{3.75}$$

Here, the welfare weight is evaluated at $\kappa = 0$ and I suppress the dependency on the policy parameters (κ, b). The first two lines of (3.74) can now be written as:

$$\lambda \int_{z_0}^{z_1} (1 - g(z))h(z)dz. \tag{3.76}$$

The last three lines of (3.74) can be simplified in exactly the same way as was done with the first-order condition with respect to the benefit b (3.66). The welfare effect associated with the participation, earnings and unemployment responses is:

$$\lambda \int_{z_0}^{z_1} \left[\frac{\pi_T}{\pi}(T(z') + b) + z_T T'(z') + \frac{e_T}{e}(T(z') + b)\right] dH(z'). \tag{3.77}$$

Equation (3.16) from Proposition 3.2 is then obtained by setting the sum of (3.76) and (3.77) equal to zero, and divide by λ.

Finally, to derive equation (3.15) consider the following reform:

$$R(z) = \begin{cases} 0 & \text{if } z \leq z(m), \\ z - z(m) & \text{if } z \in (z(m), z(m) + \omega], \\ \omega & \text{if } z > z(m) + \omega. \end{cases} \tag{3.78}$$

For ω small, this reform corresponds to a local increase in the *marginal* tax rate around income level $z(m)$ (see Figure 3.1). Clearly, the reform does not affect individuals with ability below m. For individuals with earnings potential above $z(m) + \omega$, the reform increases their (expected) tax liability. The welfare effects are therefore the same as before (see (3.76) and (3.77)), and given by:

$$\omega \times \lambda \int_{z(m)+\omega}^{z_1} \left[1 - g(z') + \frac{\pi_T}{\pi}(T(z') + b) + z_T T'(z') + \frac{e_T}{e}(T(z') + b)\right] h(z')dz' \tag{3.79}$$

This equation is obtained by summing (3.76) and (3.77) and replacing the lower bound of the integral by $z(m)+\omega$. The multiplication with ω is because the increase in the tax liability for individuals with earnings above $z(m)+\omega$ is proportional to ω.

The reform also affects individuals with earnings potential in the interval $[z(m), z(m)+\omega]$. The corresponding interval of the ability distribution is $[m, m+\omega/z'(m)]$. The welfare effect is obtained by differentiating the Lagrangian (3.63) with respect to κ, evaluated at the reform $R(z) = z - z(m)$:

$$
\begin{aligned}
\frac{\mathrm{d}\mathcal{L}}{\mathrm{d}T'} &= \int_m^{m+\frac{\omega}{z'(m)}} \int_{\varphi_0}^{\varphi(n,\kappa,b)} e(n,\kappa,b)(z(n)-z(m)) \times \\
&\Big[\lambda - \Psi'(\mathcal{U}(n,\kappa,b)-\varphi)u'(z(n,\kappa,b)-T(z(n,\kappa,b))-\kappa R(z(n,\kappa,b)))\Big] f(\varphi,n)d\varphi dn \\
&+ \lambda \int_m^{m+\frac{\omega}{z'(m)}} \int_{\varphi_0}^{\varphi(n,\kappa,b)} \frac{\mathrm{d}z}{\mathrm{d}T'}\Big[e(n,\kappa,b)(T'(z(n,\kappa,b))+\kappa R'(z(n,\kappa,b)))\Big] f(\varphi,n)d\varphi dn \\
&+ \lambda \int_m^{m+\frac{\omega}{z'(m)}} \int_{\varphi_0}^{\varphi(n,\kappa,b)} \frac{\mathrm{d}e}{\mathrm{d}T'}\Big[T(z(n,\kappa,b))+\kappa R(z(n,\kappa,b))+b\Big] f(\varphi,n)d\varphi dn \\
&+ \lambda \int_m^{m+\frac{\omega}{z'(m)}} \frac{\mathrm{d}\varphi}{\mathrm{d}T'}\Big[e(n,\kappa,b)(T(z(n,\kappa,b))+\kappa R(z(n,\kappa,b))+b)\Big] f(\varphi(n),n)dn \qquad (3.80)
\end{aligned}
$$

To proceed, divide the resulting expression by ω and take the limit as $\omega \to 0$. The mechanical welfare effect then cancels (see the first line).[37] Moreover, by Proposition 3.1, $\mathrm{d}\varphi/\mathrm{d}T' = 0$ and hence the final term cancels as well. Finally, using the property (3.70) we can simplify equation (3.80) to:

$$
\lambda\Big[z_{T'}T'(z(m)) + \frac{e_{T'}}{e}(T(z(m)+b)\Big]h(z(m)). \qquad (3.81)
$$

To obtain equation (3.15), also divide equation (3.79) by ω and take the limit as $\omega \to 0$. Add the resulting expression to (3.81) and set the sum equal to zero. Finally, use the definitions of the elasticities (3.14) and replace the point where the marginal tax rate is increased $z(m)$ by z. Rearranging gives (3.15).

[37] To see why, note that ω shows up in the upper bound of the integral and $z(n) - z(m) \leq \omega$.

Appendix D: Optimal top rate

The expression for the optimal top rate (3.19) is obtained in a number of steps. First, define by

$$\varepsilon_{\pi t} = -\frac{\mathrm{d}\pi}{\mathrm{d}t}\frac{1-t}{\pi}, \quad \varepsilon_{zt} = -\frac{\mathrm{d}z}{\mathrm{d}t}\frac{1-t}{z}, \quad \varepsilon_{et} = -\frac{\mathrm{d}e}{\mathrm{d}t}\frac{1-t}{e} \tag{3.82}$$

the elasticity of participation, earnings, and employment with respect to one minus the *average* tax rate (i.e., holding the marginal tax rate fixed). The term $\frac{\mathrm{d}x}{\mathrm{d}t}$ is related to $\frac{\mathrm{d}x}{\mathrm{d}T}$ through $\frac{\mathrm{d}x}{\mathrm{d}t} = \frac{\mathrm{d}x}{\mathrm{d}(T/z)} = \frac{\mathrm{d}x}{\mathrm{d}T}z$ for $x \in \{\pi, z, e\}$.

Next, consider equation (3.15). If the marginal tax rate converges, $\lim_{z\to\infty}(T(z)+b)/z = T'(z)$. For high levels of income, equation (3.15) can then be rewritten as:

$$\begin{aligned}&\frac{T'(z)}{1-T'(z)}(\varepsilon_{zT'} - \varepsilon_{eT'}) = \\ &\mathrm{E}\left[1 - g(z') + \frac{T'(z')}{1-T'(z')}\left(\varepsilon_{\pi t} + \varepsilon_{zt} + \varepsilon_{et}\right)\middle| z' > z\right]\frac{1-H(z)}{zh(z)}.\end{aligned} \tag{3.83}$$

If incomes at the top are Pareto distributed (with tail parameter a), $zh(z)/(1-H(z)) = a$. Moreover, if the welfare weight and elasticities for top-income earners converge, condition (3.83) simplifies to:

$$\frac{T'(z)}{1-T'(z)}a(\varepsilon_{zT'} - \varepsilon_{eT'}) = 1 - g(z) + \frac{T'(z)}{1-T'(z)}\left(\varepsilon_{\pi t} + \varepsilon_{zt} + \varepsilon_{et}\right), \tag{3.84}$$

Equation (3.19) is then obtained by collecting terms and solving the above expression for $T'(z)$.

Appendix E: Proof Proposition 3.3

The result from Proposition 3.3 follows immediately from Propositions 3.1 and 3.2. To see this, evaluate equation (3.15) in Proposition 3.2 at $z = z_0$ and combine the result with equation (3.16) to find:

$$\frac{T'(z_0)}{(T(z_0)+b)/z_0} = \frac{\varepsilon_{eT'}}{\varepsilon_{zT'}}. \tag{3.85}$$

Since $\varepsilon_{eT'}, \varepsilon_{zT'} > 0$ (see Proposition 3.1), the marginal tax rate is negative at the bottom (i.e., $T'(z_0) < 0$) if and only if the employment tax for individuals with the lowest skills is negative (i.e., $T(z_0) + b < 0$). Hence, it is optimal to let employment subsidies (such as the EITC) phase in with income.

Appendix F: Relation to Baily-Chetty formula

This appendix demonstrates the link between my results for the optimal provision of unemployment insurance and those from Baily (1978) and Chetty (2006). To do so, suppose all individuals are identical and participate (i.e., $n_0 = n_1$ and $\varphi_0 = \varphi_1$ sufficiently low). Moreover, assume unemployment benefits are financed by lump-sum taxes on labor and set the revenue requirement $G = 0$. The government's budget constraint then reads $eT = (1 - e)b$.

For a given tax-benefit system (T, b), individuals solve:

$$V(T, b) = \max_{z,e} \left\{ u(b) + e \left(u(z - T) - v \left(\frac{1}{n} \left(z + \frac{\theta(e)}{e} k \right) \right) - u(b) \right) \right\}. \tag{3.86}$$

The government then optimally chooses T and b to maximize $V(T, b)$ subject to the budget constraint. Upon substituting $T = (1 - e)b/e$, the first-order condition is:

$$\frac{\partial V}{\partial b} = (1 - e)(u'(b) - u'(z - T)) - \varepsilon_{eb} u'(z - T) = 0, \tag{3.87}$$

where ε_{eb} is the elasticity of the employment rate with respect to a budget-neutral increase in the unemployment benefit.[38] Next, divide the above equation by $u'(z - T)$ and use a first-order Taylor approximation to write:

$$\frac{u'(b) - u'(z - T)}{u'(z - T)} = - \left(\frac{u''(z - T)(z - T)}{u'(z - T)} \right) \left(\frac{z - T - b}{z - T} \right). \tag{3.88}$$

The first term on the right-hand side is the coefficient of relative risk aversion and the second measures the percentage drop in consumption due to unemployment. Substituting

[38] The employment rate corresponds to one minus the unemployment duration in the Baily-Chetty framework.

in (3.87) gives the same result as in Chetty (2006), Proposition 1. The main difference between this result and equations (3.22)-(3.23) is that the latter are obtained from considering a separate perturbation of the tax liability $T(z)$ and the benefit b. By contrast, Baily (1978) and Chetty (2006) consider a joint (budget-neutral) increase in the benefit and the tax liability. Moreover, I do not assume UI payments are financed by lump-sum taxes on labor. As a result, also the fiscal externalities due to the wage responses show up in (3.22) and (3.23) (which are absent in Baily (1978) and Chetty (2006)).

Appendix G: Derivation inverse-elasticity rule (3.24)

This appendix derives the inverse-elasticity rule from Proposition 3.4. To do so, assume there is no heterogeneity and all individuals decide to participate (i.e., $n_0 = n_1$ and $\varphi_0 = \varphi_1$ sufficiently low). The government chooses the tax function $T(z)$ and b to maximize social welfare. The Lagrangian is given by:

$$\mathcal{L} = \mathcal{U}(\kappa, b) + \lambda \Big[e(\kappa, b)(T(z(\kappa, b)) + \kappa R(z(\kappa, b)) + b) - b - G \Big]. \tag{3.89}$$

Here, the expected utility solves:

$$\mathcal{U}(\kappa, b) = \max_{z,e} \left\{ (1-e)u(b) + e \left(u(z - T(z) - \kappa R(z)) - v\left(\frac{y(z,e)}{n} \right) \right) \right\}, \tag{3.90}$$

where $y(z,e) = z + \theta(e)k/e$: see the zero-profit condition (3.2). Now, consider a local increase in the marginal tax rate. This can be done by setting $R(z) = z - z(\kappa, b)$, where $z(\kappa, b)$ denotes equilibrium income. A local increase in the marginal tax rate does not affect individual's expected utility (see Appendix C). Hence, an increase in the marginal tax rate only affects welfare through fiscal externalities. The first-order condition is:

$$\frac{\partial \mathcal{L}}{\partial T'} = \tag{3.91}$$
$$\lambda \left[\frac{\mathrm{d}e}{\mathrm{d}T'} (T(z(\kappa, b) + \kappa R(z(\kappa, b)) + b) + \frac{\mathrm{d}z}{\mathrm{d}T'} e(\kappa, b)(T'(z(\kappa, b)) + \kappa R'(z(\kappa, b))) \right] = 0.$$

To obtain the inverse-elasticity rule (3.24), divide the resulting expression by λ. Next, evaluate (3.91) at $\kappa = 0$ and use the definitions of $\varepsilon_{zT'}$ and $\varepsilon_{eT'}$. Rearranging gives (3.24).

The above result immediately implies that financing UI payments through lump-sum taxes is sub-optimal. Moreover, financing them through proportional taxes (i.e., $T(z) = tz$) is also generally sub-optimal, as it requires marginal and average tax rates to be the same. The reason is that the *marginal* tax rate is set to maximize $e(T(z) + b)$ in (3.89). The *average* tax rate, on the other hand, is set to balance the insurance gains of higher UI payments against the distortionary effects of income taxes on unemployment. The optimal marginal and average tax rate therefore coincide only in special cases.

Appendix H: Quantitative analysis

Sample selection

The data source I use in the quantitative analysis is the 2016 March release of the Current Population Survey (CPS). These can be freely downloaded in Stata-format.[39] The unemployment rate is calculated as the number of individuals whose reported labor-force status is unemployed as a fraction of all individuals whose reported labor-force status is either employed or unemployed. This gives an (aggregate) unemployment rate of 5.1%. The unemployment rates are also calculated separately for five different educational attainments: less than high school, high school, some college, college, advanced (see Figure 3.2). To obtain the participation rates, I keep individuals who listed inability to find work or taking care of home and family as reasons for not working and drop those who listed disability, going to school, retirement or other reasons.[40] The aggregate participation rate equals 86.2% and the participation rates by educational attainment are shown in Figure 3.3.

I measure labor earnings as the income from wage and salary payments. The averages by education level are shown in Figures 3.2 and 3.3 for individuals who received such income. To align the model with the data, in the final sample I focus on individuals between 25 and 65 years who worked full-time (i.e., who were working at least 45 weeks in 2015 for on average 35 hours per week or more). Moreover, I drop all individuals who

[39] http://ceprdata.org/cps-uniform-data-extracts/march-cps-supplement/march-cps-data/

[40] The reason for doing so is that in my model ability is fixed and individuals can always choose to participate.

received an hourly wage below the Federal minimum wage of $7.25. Finally, I multiply the incomes of individuals who are top-coded by a factor of 3, which is consistent with a Pareto parameter of $a = 1.5$.[41] The number of observations I use in the final analysis is 55,425. For each individual, I calculate the tax liability as the sum of state and federal taxes after credits. The latter is regressed linearly on taxable income to approximate the current US tax schedule (see also Saez (2001) and Sleet and Yazici (2017)). The unemployment benefit is calculated as the average income from unemployment compensation for individuals who received such income and whose reported labor force status is unemployment.

Numerical optimization

To numerically solve the government's optimization problem, I formulate it as an optimal control problem where the government directly optimizes over the allocation variables $\mathcal{U}(n)$, $y(n)$, $e(n)$ and the benefit b. The objective function is given by (3.12). The differential equation which serves as a constraint in the optimization problem is obtained by differentiating expected utility (3.3) with respect to n:

$$\mathcal{U}'(n) = e(n)v'\left(\frac{y(n)}{n}\right)\frac{y(n)}{n^2}. \tag{3.92}$$

Moreover, combining the household's first-order conditions (3.6) and (3.7) leads to the following implementability constraint:

$$n\left(\mathcal{U}(n) - u(b)\right) = v'\left(\frac{y(n)}{n}\right)\left(\theta'(e(n))e(n) - \theta(e(n))\right)k, \tag{3.93}$$

which must hold for all n. Finally, the aggregate resource constraint is obtained by using the definition of expected utility (3.3) and the zero-profit condition (3.2) to substitute out for the tax liability in the government budget constraint.

For the numerical optimization I use the GPOPS-II software package. The parameterization of the utility function, matching function, social welfare function and the joint distribution of ability and participation costs are as described in the main text. The values for n_0 and n_1 are set at the ability level of the individual with the lowest and highest

[41] In particular, if incomes at the top are Pareto distributed the average income for individuals above some threshold z^* equals $\mathrm{E}[z|z \geq z^*] = \frac{a}{a-1}z^*$.

earnings, respectively. Finally, I assume there is a 5% share of non-participants whose utility is bounded from above by the expected utility of the individuals with the lowest ability.

Chapter 4

Monopsony power, income taxation and welfare[1]

4.1 Introduction

There is growing concern among economists and policymakers that firms exercise monopsony power (or buyer power) in labor markets. Recently, the Council of Economic Advisers published an issue brief on labor market monopsony (CEA (2016)) and the topic was extensively discussed during hearings held by the Federal Trade Commission (FTC (2018a,b)) and the House of Representatives.[2] The report and hearings cite a growing body of evidence documenting that (i) labor markets are highly concentrated and (ii) labor market concentration is associated with significantly lower wages (see, e.g., Azar et al. (2017, 2018, 2019), Benmelech et al. (2018), Lipsius (2018), Rinz (2018)). In addition to the potentially adverse effects on employment, output and economic efficiency, many people have voiced concerns about the *distributional* implications of monopsony power.[3]

[1]I would like to thank Aart Gerritsen, Bas Jacobs, Marcelo Pedroni, Sander Renes, Dominik Sachs, Dirk Schindler, Kevin Spiritus and Christian Stoltenberg for helpful comments and suggestions. This paper has benefited greatly from discussions at the University of Amsterdam and Erasmus University Rotterdam.

[2]The hearing on "Antitrust and Economic Opportunity: Competition in Labor Markets" was held on October 29, 2019. See `https://docs.house.gov/Committee/Calendar/ByEvent.aspx?EventId=110152`.

[3]For example, Alan Krueger noted in his address at the 2018 Fed conference in Jackson Hole:

This paper studies how monopsony power affects optimal income taxation and welfare if monopsony power changes the distribution of income without generating efficiency losses. To do so, I extend the non-linear tax framework from Mirrlees (1971) with monopsony power. Monopsony power determines what share of the labor market surplus is translated into pure economic profits. These profits are taxed at an exogenous rate and after-tax profits flow back as capital income to individuals according to their heterogeneous shareholdings. The model features inequality in labor income driven by differences in ability and inequality in capital income driven by differences in shareholdings. The government has a preference for redistribution and optimizes a non-linear tax on labor earnings.

The model generates two predictions that are of particular relevance to policymakers. First, monopsony power raises the incidence of labor income taxes that falls on firms and reduces the incidence that falls on workers. Intuitively, income taxes lower the labor market surplus and monopsony power determines what share of the surplus accrues to firms. As a result, income taxes reduce profits if firms have monopsony power. Second, monopsony power reduces inequality in labor income but increases inequality in capital income. This is because monopsony power raises aggregate profits and lowers the aggregate wage bill. As a result, any dispersion in labor (capital) income generated by differences in ability (shareholdings) is mitigated (exacerbated) if firms capture a larger share of the surplus.

Turning to the optimal tax problem, I derive an intuitive expression for the marginal tax rate on labor income at each point in the income distribution and how it is affected by monopsony power. Income taxes are not only used to redistribute labor income, but also to redistribute capital income. The reason is that part of the tax burden is borne by firms if they have monopsony power. As a result, monopsony power makes labor income taxes less effective in redistributing labor income, but more effective in redistributing capital income. Whether monopsony power raises or lowers optimal tax rates is *a priori* ambiguous and depends on the covariance between welfare weights and shareholdings,

"... I would argue that the main effects of the increase in monopsony power and decline in worker bargaining power over the last few decades have been to shrink the slice of the pie going to workers and increase the slice going to employers, not to reduce the size of the pie overall." (Krueger (2018)) which reflects the government's preference for redistributing capital income. Monopsony power raises optimal tax rates if the government cares strongly about redistributing capital income.

Monopsony power has an ambiguous effect on welfare. On the one hand, it increases inequality in capital income driven by differences in shareholdings. The associated impact on welfare is negative and proportional to the covariance between welfare weights and capital income. On the other hand, monopsony power decreases inequality in labor income driven by differences in ability. The associated impact on welfare is positive and proportional to the covariance between welfare weights and labor market payoffs (i.e., after-tax labor income minus the disutility of working). The reason why monopsony power might raise welfare is that firms observe ability, while the government does not. If firms have monopsony power, they reduce inequality in labor market payoffs generated by differences in ability. This reduction in inequality comes at zero efficiency costs, which can never be achieved with distortionary taxes on labor income. Monopsony power thus alleviates the equity-efficiency trade-off that occurs because the government does not observe ability, but at the expense of exacerbating inequality in capital income.

In the baseline version of the model, I assume all workers suffer to the same extent from monopsony power in the sense that with linear taxes on labor income, firms capture a constant (i.e., non ability-specific) share of the labor market surplus. I analyze an extension where this share is declining in ability, which may reflect that individuals with higher ability also have more bargaining power. Compared to the case where monopsony power does not vary with ability, optimal marginal tax rates are higher and the welfare effect of raising monopsony power is lower. Intuitively, inequality driven by differences in ability is exacerbated if individuals with higher ability suffer less from monopsony.

To illustrate the implications of monopsony power for optimal income taxation and welfare, I calibrate the baseline version of the model to the US economy. The degree of monopsony power is used to target an estimate of the pure profit share from Barkai and Benzell (2018). I find that monopsony power raises (lowers) optimal marginal tax rates at low (high) earnings levels. Moreover, taking monopsony power into account when designing tax policy leads to modest welfare gains that range between 0.07% and 1.04% of GDP in the calibrated economy depending on the covariance between welfare weights and shareholdings. By contrast, changing the degree of monopsony power to zero can have a large negative or positive impact on welfare (ranging between between –1.78% and +8.37% of GDP), again depending on the covariance between welfare weights and shareholdings. Finally, if the current tax system is optimal, an increase in monopsony power raises welfare only if the negative covariance between welfare weights and after-tax labor income is at least 2.85 times as large as the negative covariance between welfare weights and after-tax capital income.

Related literature. A few papers study optimal income taxation in an environment where firms have monopsony power. As I do, Hariton and Piaser (2007) and da Costa and Maestri (2019) analyze a model where labor supply responds on the intensive (hours, effort) margin, whereas Cahuc and Laroque (2014) focus on the extensive (participation) margin. These studies assume that firms – like the government – do *not* observe workers' abilities (Hariton and Piaser (2007) and da Costa and Maestri (2019)) or their reservation wages (Cahuc and Laroque (2014)). Monopsony power then leads to a downward distortion in employment, either in hours worked or the number of individuals employed. To partly off-set this distortion, the government finds it optimal to subsidize employment. This requires *negative* marginal (participation) tax rates if labor supply responds on the intensive (extensive) margin. By contrast, in my model firms observe ability and there is no distortion in employment. Optimal marginal tax rates only serve to redistribute income and are generally *positive*. Moreover, in my model monopsony power might raise welfare. This is not possible in Hariton and Piaser (2007), Cahuc and Laroque (2014) and da Costa and Maestri (2019), since firms do not have an informational advantage compared to the government.

This paper is also related to Kaplow (2019), who studies optimal income taxation in a model with multiple goods where firms sell their products at an exogenous, good-specific mark-up over labor costs. As in the classic model of monopoly, employment and output are inefficiently low. This calls for a downward adjustment in optimal tax rates on labor income. Without variation in mark-ups, such an adjustment would "undo the wrongs" of monopoly and market power has no impact on welfare.[4] The most important difference compared to Kaplow (2019) is that I assume firms offer employees a combination of earnings and labor effort instead of charging consumers a constant mark-up over labor costs. As a result, the outcome in the absence of taxation is efficient. Hence, tax policy is exclusively aimed at redistribution – not to restore efficiency. Moreover, tax policy cannot be used to off-set the impact of monopsony power. Therefore, monopsony power affects welfare even if there is only one good and hence, no variation in mark-ups.

The model of labor market monopsony I analyze features important similarities and differences with the classic monopsony model from Robinson (1969) and the new monopsony models introduced in Manning (2003). The first similarity is that firms can exercise monopsony power because they face an upward-sloping labor supply curve. In Robinson (1969) and Manning (2003), this is because firms attract more workers if they pay higher wages. In my model, the number of workers available to each firm is fixed, but a firm can increase their labor effort by offering contracts that imply a higher wage per hour. Second, the mark-up of productivity over wages, the measure of "exploitation" due to Pigou (1920), is decreasing in the elasticity of labor supply. Third and in line with empirical evidence, the pass-through of productivity gains into wages is less than one-for-one.[5] The most important difference is that in Robinson (1969) and Manning (2003), monopsony power generates distortions. By contrast, in my model the equilibrium in the absence of taxation is efficient. The same is true in Sandmo (1994), who analyzes a setting where a monopsonist chooses a payment schedule that consists of a fixed income and a wage proportional to output. Sandmo (1994) discusses the distortionary effects and incidence of income taxes, but he does not analyze how monopsony power affects optimal tax policy or welfare, which is the main goal of this paper.

Outline. The remainder of this paper is organized as follows. Section 4.2 presents the model. Section 4.3 analyzes how monopsony power affects optimal income taxation and welfare. Section 4.4 explores quantitatively the policy and welfare implications of

[4] If mark-ups vary across goods, market power does affect welfare. Kaplow (2019) shows that optimal policy is aimed at reducing the *spread* in mark-ups.

[5] See, e.g., Kline et al. (2019) for recent evidence on the pass-through from productivity gains into wages.

monopsony power by calibrating the model to the US economy. Section 4.5 concludes. An appendix contains all proofs and additional details of the analysis.

4.2 A Mirrleesian model with monopsony power

The basic structure of the model follows Mirrlees (1971). There is a continuum of individuals who differ in their ability. They supply labor on the intensive margin to identical firms, which produce output using a linear technology with labor as the only input. The government has a preference for redistribution but – unlike firms – does not observe individuals' abilities. Instead it can only observe and hence, tax labor earnings. The main departure from the standard model is that I allow for the possibility that firms have monopsony power. Whenever this is the case, firms earn pure economic profits. These profits are taxed at an exogenous rate and after-tax profits flow back to individuals according to their heterogeneous shareholdings. Consequently, the model features inequality in labor income generated by differences in ability and inequality in capital income generated by differences in shareholdings. Both types of inequality play an important role in the remainder of the analysis.

4.2.1 Individuals

There is a unit mass of individuals who differ in their ability $n \in [n_0, n_1]$ and shareholdings $\sigma \in [\sigma_0, \sigma_1]$ with $n_0 > 0$ and $\sigma_0 \geq 0$. Ability measures how much output an individual produces per unit of effort and shareholdings determine how aggregate profits are dissipated. Let $H(n, \sigma)$ denote the joint distribution over ability and shareholdings and $h(n, \sigma)$ the corresponding density. The latter is assumed to be positive on its entire support. Moreover, denote by $F(n)$ the marginal distribution of ability with density $f(n)$.

Individuals derive utility from consumption c and disutility from providing labor effort l. Their preferences are described by a quasi-linear utility function $u(c, l) = c - \phi(l)$, where $\phi(\cdot)$ is strictly increasing, strictly convex and satisfies $\phi(0) = \phi'(0) = 0$. The assumption of quasi-linearity is made for analytical convenience and ensures that all variables except capital income vary only with ability (and not with shareholdings).[6] I denote by $l(n) \geq 0$ the labor effort exerted by an individual with ability n. In exchange for her services, she receives labor income $z(n) \geq 0$, which is subject to a labor income tax $T(\cdot)$. Individuals also generate income from holding shares in a diversified portfolio. Each individual's capital income is therefore proportional to the economy's aggregate profits. Denote by $\pi(n) = nl(n) - z(n) \geq 0$ the profits firms generate from hiring a worker with ability n. Aggregate profits are given by

$$\bar{\pi} = \int_{n_0}^{n_1} \pi(n) f(n) dn. \tag{4.1}$$

Profits are taxed linearly at an exogenous rate $\tau \in [0, 1]$ and after-tax profits flow back to individuals according to how many shares they own. Normalizing aggregate shareholdings to one, the utility of an individual with ability n and shareholdings σ is

$$\mathcal{U}(n, \sigma) = \upsilon(n) + \sigma(1 - \tau)\bar{\pi}. \tag{4.2}$$

Here, $\sigma(1 - \tau)\bar{\pi}$ is after-tax capital income and $\upsilon(n) = z(n) - T(z(n)) - \phi(l(n))$ is the payoff from working, or labor market payoff.

4.2.2 Firms

Firms produce output using an identical, linear technology with labor as the only input. Each firm is matched exogenously with a number of workers. I make the important assumption that each firm observes the ability of the workers with whom it is matched. To a (potential) employee, a firm offers a bundle (l, z) which consists of an effort (or hours) requirement $l \geq 0$ and labor earnings $z \geq 0$. Firms choose the bundle to maximize profits, subject to the requirement that the employee's labor market payoff exceeds some threshold, or outside option $\underline{\upsilon}(n)$. The latter is takes as given by firms and allowed to vary with ability. As will be made clear below, in equilibrium the outside option is related

[6] This would also be the case with Greenwood-Hercowitz-Huffman (GHH) preferences, so that the utility function is of the form $u(c, l) = V(c - \phi(l))$, where $V(\cdot)$ is increasing. I briefly comment on this alternative specification when describing the welfare function below.

to firms' monopsony power. If a firm is matched to a worker with ability n, it solves

$$\max_{l\geq 0, z\geq 0} \quad \pi(n) = nl - z, \tag{4.3}$$
$$\text{s.t.} \qquad z - T(z) - \phi(l) \geq \underline{v}(n).$$

I assume the tax function $T(\cdot)$ is such that the first-order conditions are both necessary and sufficient and denote the solution to the maximization problem (4.3) by $l(n)$ and $z(n)$. At an interior solution, labor effort and earnings are related through

$$n = \frac{\phi'(l(n))}{1 - T'(z(n))}. \tag{4.4}$$

In the optimum, firms offer bundles which equate an individual's productivity (on the left-hand side) to her willingness to substitute between labor effort and earnings (on the right-hand side). Without taxes on labor income, there is no distortion in labor supply as the marginal rate of substitution between consumption and labor effort equals the marginal rate of transformation. The reason why the equilibrium without taxation is efficient is that firms take into account how labor earnings and effort affect the utility of its workers. As a result, there are no unexploited gains from trade and workers and firms divide the full labor market surplus. How this is done depends on the degree of monopsony power.

4.2.3 Monopsony power

Monopsony power determines what share of the labor market surplus is translated into pure economic profits. If labor markets are competitive as in Mirrlees (1971), the full labor market surplus accrues to workers as profits are driven to zero: $\pi(n) = 0$ and labor earnings satisfy $z(n) = nl(n)$.[7] Conversely, if firms have full monopsony power, the labor market surplus is translated into profits as workers are put on their participation

[7] This equilibrium occurs if individuals can always find a job where they work their preferred number of hours at an hourly wage equal to their productivity. The outside option $\underline{v}(n)$ is then given by

$$\underline{v}(n) = \max_{l} \quad \{nl - T(nl) - \phi(l)\}.$$

constraint. The outside option then equals $\underline{v}(n) = -T(0)$ and the Lagrangian associated with the firm's maximization problem (4.3) is

$$\mathcal{L}(n) = nl - z + \kappa_1 \Big[z - T(z) - \phi(l) + T(0) \Big] + \kappa_2 l + \kappa_3 z, \tag{4.5}$$

where the κ's are Lagrange multipliers. I assume the non-employment benefit $-T(0)$ is such that firms do not make profits from hiring the least productive workers: $\pi(n_0) = 0$.[8] To derive an expression for the profits from hiring *any* worker, differentiate the objective (4.5) with respect to ability n and apply the Envelope theorem to find $\mathcal{L}'(n) = \pi'(n) = l(n)$, where $l(n)$ is the optimal choice of labor effort offered to an individual with ability n. Integrating this relationship and imposing the boundary condition $\pi(n_0) = 0$ gives an expression for profits if firms have full monopsony power:

$$\pi(n) = \int_{n_0}^{n} l(m)dm. \tag{4.6}$$

For any intermediate degree of monopsony power, firms capture part of the labor market surplus. To study the welfare effects of monopsony power and to keep the optimal tax problem tractable, I choose a specific way to operationalize monopsony power. It is formally defined as follows.

Definition 4.1. ***Monopsony power*** $\mu(n) \in [0,1]$ *and the profits* $\pi(n) = nl(n) - z(n)$ *firms generate from hiring a worker with ability* n *are related through*

$$\pi(n) = \mu(n) \int_{n_0}^{n} l(m)dm. \tag{4.7}$$

Clearly, profits are zero if labor markets are competitive (i.e., if $\mu(n) = 0$). Conversely, if firms have full monopsony power (i.e., if $\mu(n) = 1$), equations (4.6) and (4.7) coincide. In this case, the full labor market surplus is translated into profits as workers are put on their participation constraint. The degree of monopsony power $\mu(n)$ might vary with ability, which captures that individuals with different abilities might suffer more or less from monopsony.

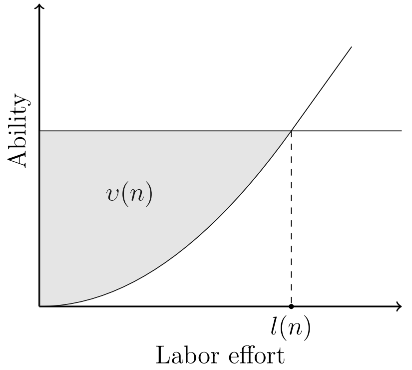
[8] As is formally demonstrated in Appendix 4.5, from an optimal tax perspective the assumption that firms do not earn profits from hiring the least productive workers is without loss of generality.

If taxes on labor income are linear, monopsony power $\mu(n) \in [0,1]$ equals the share of the labor market surplus that is translated into pure economic profits if firms hire a worker with ability n. The payoffs for workers and firms then coincide with those obtained under the weighted Kalai-Smorodinsky bargaining solution introduced in Thomson (1994), where the payoff of each party is proportional to her ideal ('utopia') pay-off.[9] The weights $\mu(n)$ and $1-\mu(n)$ can therefore be interpreted as the bargaining power of firms and workers, respectively. To make sure high-ability workers are not worse off, I assume individuals with higher ability do not have a lower bargaining power (i.e., do not suffer more from monopsony): $\mu'(n) \leq 0$.

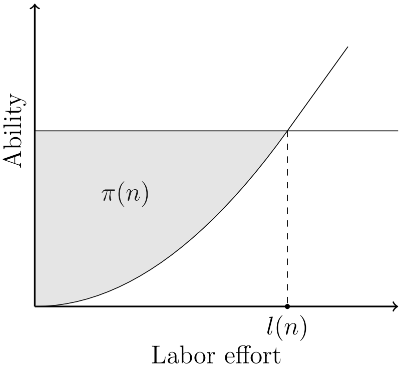
Figure 4.1 graphically illustrates how monopsony power affects the payoffs of workers and firms. Here, I assume income taxes are absent: $T(\cdot) = 0$. The horizontal line plots an individual's ability and corresponds to the labor demand schedule if labor markets are competitive. The upward-sloping line plots the relationship $\phi'(l) = n$, which – under perfect competition – corresponds to the labor supply schedule. The shaded area shows the labor market surplus. Monopsony power does not affect the size of the surplus (i.e., does not generate efficiency losses), but determines how it is split between workers and firms. If labor markets are competitive, firms earn zero profits and the full surplus accrues to workers. The shaded area then corresponds to the individual's labor market payoff $v(n)$: see Figure 4.1a. Conversely, if labor markets are fully monopsonistic, all surplus accrues to firms. The shaded area then corresponds to profits $\pi(n)$: see Figure 4.1b.[10]

[9]Strictly speaking, the payoffs no longer necessarily coincide with those from the weighted Kalai-Smorodinsky solution if taxes on labor income are non-linear. The reason is that with non-linear taxes, labor effort generally depends on the degree of monopsony power as it is no longer pinned down only by the first-order condition (4.4) (as would be the case with linear income taxes). As stated above, the reason for choosing to operationalize monopsony power in this specific way is to guarantee the optimal tax problem remains tractable and to make it possible to study the welfare effects of monopsony power.

[10]The equilibrium with full monopsony power also occurs if firms engage in first-degree price discrimination. In that case, firms pay workers their reservation wage *for every hour worked* and demand labor effort up to the point where the worker's productivity is high enough to compensate for the marginal disutility of working.



(a) Perfect competition: $\mu(n) = 0$



(b) Full monopsony power: $\mu(n) = 1$

Figure 4.1: Labor market equilibrium

4.2.4 Government

The government's preferences are described by the following welfare function:

$$\mathcal{W} = \int_{\sigma_0}^{\sigma_1} \int_{n_0}^{n_1} \gamma(n,\sigma)\mathcal{U}(n,\sigma)h(n,\sigma)dnd\sigma. \tag{4.8}$$

Here, $\gamma(n,\sigma) \geq 0$ is the welfare weight (or Pareto weight) the government attaches to an individual with ability n and shareholdings σ. The average welfare weight is normalized to one. To make sure the government wishes to redistribute from individuals with high to individuals with low capital income, I assume the average welfare weight of individuals with the same shareholdings $\mathbb{E}[\gamma(n,\sigma)|\sigma]$ is weakly decreasing in σ. Similarly, to generate a motive to redistribute from individuals with high to individuals with low labor income, I assume the average welfare weight of individuals with the same ability $g(n) = \mathbb{E}[\gamma(n,\sigma)|n]$ is weakly decreasing in n.[11] Using the welfare weights $g(n)$, it is instructive to write the welfare function as follows.

[11] An alternative way to generate a motive for redistribution (without the need to specify exogenous Pareto weights) is to assume the individual utility function is of the GHH-form $u(c,l) = V(c-\phi(l))$, where $V(\cdot)$ is strictly increasing and strictly concave: see footnote 6. Doing so is slightly more complicated and does not generate additional, substantive insights. Another advantage of using exogenous welfare weights is that in some cases it is possible to derive a closed-form solution for the optimal marginal tax rate, as will be made clear below.

Lemma 4.1. *The welfare function (4.8) can be written as*

$$\mathcal{W} = \int_{n_0}^{n_1} \left[g(n)v(n) + (1-\Sigma)(1-\tau)\pi(n) \right] f(n)dn, \tag{4.9}$$

where $\Sigma = -\text{Cov}[\boldsymbol{\sigma}, \boldsymbol{\gamma}] \in [0,1]$ *is the negative covariance between shareholdings and welfare weights, which is bounded between zero and one.*

Proof. See Appendix 4.5. □

Individuals derive utility from earning labor income and capital income. Welfare is therefore increasing in the labor market payoff and after-tax profits. Importantly, the extent to which after-tax profits contribute to welfare depends on the covariance between shareholdings and welfare weights. This is because the government wishes to redistribute from individuals with high to individuals with low capital income. A higher concentration of firm-ownership (captured by a higher Σ) therefore *ceteris paribus* lowers welfare. It is worth pointing out that the covariance term Σ is exogenous and bounded between zero and one. It depends only on welfare weights and the distribution of ability and shareholdings. As such, it reflects properties of the joint distribution of capital and labor income and the government's desire to redistribute capital income. An increase in the government's desire to redistribute capital income raises Σ and thereby lowers the contribution of profits to welfare.

Turning to the instrument set, as in Mirrlees (1971) I assume the government does not observe individuals' abilities but only their labor earnings, which are subject to a non-linear tax $T(\cdot)$. In addition, the government observes aggregate profits, which are taxed linearly (either at the firm or the individual level) at an exogenous rate $\tau \in [0,1]$. The government's budget constraint reads

$$\int_{n_0}^{n_1} \left[T(z(n)) + \tau\pi(n) \right] f(n)dn = G, \tag{4.10}$$

where $G \geq 0$ denotes some exogenous government spending. Because the government wishes to redistribute from individuals with high to individuals with low shareholdings, levying a non-distortionary tax on pure economic profits is a very efficient way to redistribute capital income. One can therefore interpret the exogenous rate τ as the *maximum* share of pure economic profits that can be taxed. Without a restriction on profit taxation, $\tau = 1$. Conversely, if profit taxation is restricted, $\tau < 1$. Such a restriction may reflect the existence of tax havens and profit-shifting opportunities or the government's inability to distinguish between normal and above-normal returns.[12] The restriction could also reflect that levying a confiscatory tax on pure economic profits is not optimal, for example due to adverse effects on investment and firm entry.

4.2.5 Equilibrium

An equilibrium is formally defined as follows.

Definition 4.2. *An **equilibrium** consists of levels of labor effort $l(n) \geq 0$, earnings $z(n) \geq 0$ and profits $\pi(n) = nl(n) - z(n) \geq 0$ such that, for given monopsony power $\mu(n)$ and given labor income taxes $T(\cdot)$, profit taxes τ and government spending G,*

1. *for all n, labor effort and earnings are related through (4.4) or $l(n) = z(n) = 0$,*
2. *for all n, profits satisfy (4.7),*
3. *the government runs a balanced budget: (4.10).*

Definition 4.2 describes the equilibrium for a given profile of monopsony power and a given set of tax instruments. Because of the specific way of modeling monopsony power, finding the equilibrium outcomes requires solving an integral equation if labor income taxes $T(\cdot)$ are non-linear.[13] As stated before, the main advantage of this modeling choice is that it keeps the optimal tax problem tractable and makes it possible to study the welfare effects of monopsony power. A disadvantage is that it is generally not possible to obtain sharp results when studying the impact of tax reforms or monopsony power on equilibrium outcomes. Keeping this caveat in mind, it is useful to highlight two implications of monopsony power. First, monopsony power increases the incidence of labor income taxes that falls on firms and decreases the incidence that falls on workers. To see this, compare the equilibria with $\mu(n) = 0$ (perfect competition) and $\mu(n) = 1$ (full monopsony power)

[12] In the model there is no productive capital. As a result, all income generated from firm-ownership is above-normal. In reality, distinguishing between normal and above-normal returns is very cumbersome.

[13] The integral equation is $\pi(n) = \mu(n) \int_{n_0}^{n} l(m)dm$, where $l(m)$ solves the first-order condition for profit maximization $m(1 - T'(ml(m) - \pi(m))) = \phi'(l(m))$ at an interior solution. See also footnote 9.

for all n. If labor markets are competitive, firms earn zero profits – irrespective of the level of taxation. The full incidence of labor income taxes then falls on workers. Conversely, if firms have full monopsony power, all workers are put on their participation constraint. An increase in the tax burden must then be compensated one-for-one by higher labor earnings as otherwise workers prefer non-employment. In this case, the full incidence of labor income taxes falls on firms.

Second, monopsony power decreases inequality in labor income generated by differences in ability but increases inequality in capital income generated by differences in shareholdings. Intuitively, monopsony power determines what share of the labor market surplus is translated into labor income and what share is translated into capital income. An increase in monopsony power raises aggregate profits and lowers the aggregate wage bill. As a result, monopsony power mitigates inequality in labor income driven by differences in ability but exacerbates inequality in capital income driven by differences in shareholdings.

I am not aware of any direct evidence either in favor or against these hypotheses. A key challenge is that one needs variation in monopsony power, which should then be linked to measures of tax incidence and inequality. Webber (2015) and Rinz (2018) attempt to do the latter. They find that a lower elasticity of labor supply at the firm level and a higher labor market concentration (the two most commonly used measures of monopsony power: see Azar et al. (2019)) are associated with higher inequality in labor earnings. At first sight, these findings appear inconsistent with the hypothesis that monopsony power reduces inequality in labor income. However, Section 4.4 illustrates that the model presented here does not make clear-cut predictions on the impact of monopsony power on the measures of inequality used in these papers, i.e., the variance in log earnings and the P90/P10 earnings ratio. Moreover, the model can accommodate these findings if individuals with higher ability suffer less from monopsony (i.e., if $\mu'(n) < 0$). Regarding the impact of monopsony power on tax incidence, Saez et al. (2019) find that a payroll tax cut in Sweden raised profits without affecting net-of-tax wages. This result suggests firms have substantial monopsony power, but cannot be used to test if monopsony power increases the tax incidence borne by firms. By contrast, Benmelech et al. (2018) find support for the closely related hypothesis that the pass-through from productivity gains into wages is lower when labor markets are more concentrated.

4.3 Optimal tax policy and the welfare effects of monopsony power

This Section analyzes how monopsony power affects optimal income taxation and welfare. For analytical convenience, I start by considering the case where monopsony power does not vary with ability: $\mu'(n) = 0$. Section 4.3.1 derives results for optimal income taxation and Section 4.3.2 analyzes the welfare impact of increasing monopsony power. Section 4.3.3 generalizes the main findings to the case where monopsony power varies with ability.

4.3.1 Optimal income taxation

The government's problem consists of choosing the tax function $T(\cdot)$ that maximizes welfare. To solve this problem, I follow the approach pioneered by Mirrlees (1971) and characterize the allocation that maximizes welfare subject to resource and incentive constraints. The details can be found in Appendix 4.5. Here, I directly state the first main result of this paper.

Proposition 4.1. *Consider the case where monopsony power does not vary with ability: $\mu(n) = \mu$ for all n. At the optimal allocation, the marginal tax rate at earnings level $z(n)$ satisfies*

$$T'(z(n)) = \left[\mu(1-\tau)\Sigma + (1-\mu)(1 - T'(z(n)))(1 + 1/\varepsilon(n))(1 - \bar{g}(n))\right] \frac{1 - F(n)}{nf(n)}, \quad (4.11)$$

provided the local Pareto parameter of the ability distribution $a(n) = nf(n)/(1 - F(n)) \geq \mu(1-\tau)\Sigma$. Here, $\bar{g}(n) \in [0,1]$ is the average welfare weight for individuals with ability at least equal to n and $\varepsilon(n) = \frac{\phi'(l(n))}{\phi''(l(n))l(n)} > 0$ is the elasticity of labor supply. The marginal tax rate is generally positive and zero at the top: $T'(z(n_1)) = 0$. Individuals with ability levels where $a(n) < \mu(1-\tau)\Sigma$ do not work at the optimal allocation: $l(n) = z(n) = 0$.

Proof. See Appendix 4.5. □

Proposition 4.1 gives an expression for the optimal marginal tax rate at each point in the income distribution, which is generally positive and zero only at the top.[14] At the optimum, the marginal tax rate equals a weighted average between two components, where the weights depend on the degree of monopsony power. To understand this result, consider the case where firms have full monopsony power: $\mu = 1$. The optimal marginal tax rate is then given by

$$T'(z(n)) = \frac{(1-\tau)\Sigma(1-F(n))}{nf(n)}. \tag{4.12}$$

If labor markets are fully monopsonistic, taxes on labor earnings are used exclusively to redistribute capital income and not to redistribute labor income. This is because the full incidence of the tax burden falls on firms as all workers are put on their participation constraint. An increase in taxes on labor earnings must then be compensated one-for-one by higher earnings as otherwise workers prefer non-employment. The purpose of the *marginal* tax rate at earnings level $z(n)$ is to raise the *tax burden* of all individuals with earnings at least equal to $z(n)$.[15] The mass of individuals for whom this is the case equals $1 - F(n)$, which shows up in the numerator of equation (4.12). Because labor earnings for these workers are increased one-for-one with an increase in the tax burden, the government indirectly taxes profits. This is valuable provided profit taxation is restricted and the negative covariance between welfare weights and shareholdings is positive: $\tau < 1$ and $\Sigma > 0$. The benefits of indirectly taxing profits by raising the marginal tax rate $T'(z(n))$ should be weighed against the distortions in labor effort: see equation (4.4). The efficiency costs are proportional to ability n and the density $f(n)$, which determines for how many individuals labor effort is distorted. Both terms show up in the denominator of equation (4.12).

The second component in the optimal tax formula (4.11) is as in the benchmark model without monopsony power. To see this, suppose labor markets are perfectly competitive:

[14] Hence, the famous result from Seade (1977) that the optimal marginal tax rate equals zero at *both* end-points does not apply. As will be explained below, the reason is that the marginal tax rate at the bottom can be used to redistribute capital income by indirectly taxing profits.

[15] Note that individuals with different abilities do not earn the same labor income if firms have full monopsony power. This is because firms demand more labor effort from individuals with higher ability. To compensate them (i.e., to ensure the participation constraint holds), firms must pay higher labor earnings to these individuals.

$\mu = 0$. The optimal marginal tax rate then satisfies

$$\frac{T'(z(n))}{1-T'(z(n))} = \left(1 + \frac{1}{\varepsilon(n)}\right)(1-\bar{g}(n))\left(\frac{1-F(n)}{nf(n)}\right). \tag{4.13}$$

This is the well-known *ABC*-formula from Diamond (1998). Because profits are zero if labor markets are competitive, the sole purpose of income taxes is to redistribute labor income and not to redistribute capital income.

According to equation (4.11), the higher the degree of monopsony power, the more taxes on labor earnings are geared toward redistributing capital income and the less they are geared toward redistributing labor income. Intuitively, monopsony power increases the incidence of income taxes that falls on firms and decreases the incidence that falls on workers. Monopsony power therefore makes labor income taxes less (more) effective in redistributing labor (capital) income. Whether monopsony power raises or lowers optimal marginal tax rates is *a priori* ambiguous and depends crucially on the government's preferences for redistribution. This insight is formalized in the next Corollary.

Corollary 4.1. *Suppose the utility function is iso-elastic: $\phi(l) = l^{1+1/\varepsilon}/(1+1/\varepsilon)$, so that $\varepsilon(n) = \varepsilon$ for all n. At ability levels where the local Pareto parameter $a(n) \geq \mu(1-\tau)\Sigma$, the closed-form solution for the optimal marginal tax rate is*

$$T'(z(n)) = \frac{\mu(1-\tau)\Sigma + (1-\mu)(1+1/\varepsilon)(1-\bar{g}(n))}{a(n) + (1-\mu)(1+1/\varepsilon)(1-\bar{g}(n))}. \tag{4.14}$$

If $(1-\tau)\Sigma > 0$, an increase in monopsony power unambiguously raises the marginal tax rate $T'(z(n_0))$ at the bottom of the income distribution if $a(n_0) \geq \mu(1-\tau)\Sigma$. Moreover, at ability levels where $\bar{g}(n) < 1$ an increase in monopsony power raises $T'(z(n))$ if and only if

$$((1-\tau)\Sigma))^{-1} < ((1+1/\varepsilon)(1-\bar{g}(n)))^{-1} + a(n)^{-1}. \tag{4.15}$$

Proof. See Appendix 4.5. □

Equation (4.14) gives a closed-form solution for the optimal marginal tax rate. It follows directly from rearranging equation (4.11) and plays an important role when exploring the quantitative implications of monopsony power for tax policy in Section 4.4. Equation (4.15), in turn, gives a precise condition which can be used to determine if an increase in monopsony power raises the optimal marginal tax rate at each point in the income distribution. Because monopsony power makes income taxes more (less) effective in redistributing capital (labor) income, the impact of monopsony power on optimal tax rates is generally ambiguous. According to equation (4.15), the first (positive) effect dominates if profit taxation is severely restricted (i.e., if τ is low) and if the government has a strong preference for redistributing capital income (i.e., if Σ is high). Conversely, the second (negative) effect dominates if redistributing from individuals with high to individuals with low ability is very important (i.e., if $\bar{g}(n)$ is low).[16]

The impact of monopsony power on optimal tax rates varies along the income distribution depending on the behavior of $\bar{g}(n)$ and the local Pareto parameter $a(n)$. Because the average welfare weight of all individuals equals one (i.e., $\bar{g}(n_0) = 1$), condition (4.15) is always satisfied at the bottom of the income distribution. Hence, monopsony power unambiguously raises $T'(z(n_0))$ if $a(n_0) \geq \mu(1-\tau)\Sigma$. Intuitively, the marginal tax rate at the bottom only serves to indirectly tax profits as it does not help to redistribute labor income from individuals with high to individuals with low ability. This becomes more important if monopsony power increases. At higher levels of income, redistributing labor income from individuals above to individuals below that level becomes on average more valuable: $\bar{g}(n)$ is decreasing. Monopsony power makes income taxes less effective in redistributing labor income as part of the tax incidence falls on firms. *Ceteris paribus*, monopsony power therefore has a smaller positive or a larger negative impact on optimal tax rates at higher income levels.

Finally, it is worth pointing out that the marginal tax rate according to equation (4.14) exceeds 100% if the local Pareto parameter $a(n) < \mu(1-\tau)\Sigma$. Clearly, this violates the first-order condition for profit maximization (4.4). In this case, the non-negativity constraint on labor effort $l(n) \geq 0$ in the government's optimization problem is binding:

[16] Monopsony power also lowers the optimal marginal tax rate if the local Pareto parameter $a(n)$ is high. The reason is quite mechanical. In the second component of equation (4.11), monopsony power affects optimal marginal tax rates through the term $T'(z(n))/(1-T'(z(n)))$. The latter changes faster (and hence, implies a smaller change in the marginal tax rate), the higher is $T'(z(n))$. This is the case if the local Pareto parameter is low. Therefore, a lower Pareto parameter makes it easier for condition (4.15) to be satisfied.

see Appendix 4.5 for details. Hence, at the optimal tax system some individuals may not work if firms have monopsony power. Empirically, this is only a relevant issue at the bottom of the ability distribution, where the local Pareto parameter $a(n)$ is low. The reason why the government may find it optimal to have some individuals not work is that stimulating participation by lowering the tax liability raises aggregate profits if $\mu > 0$, which has a negative impact on welfare if $(1-\tau)\Sigma > 0$.

4.3.2 Welfare impact of raising monopsony power

I now turn to analyze how an increase in monopsony power affects welfare. The following Proposition states the second main result of this paper.

Proposition 4.2. *Suppose monopsony power does not vary with ability and the tax function $T(\cdot)$ is optimized. An increase in monopsony power raises welfare if and only if*

$$\mu\Sigma^{\upsilon} > (1-\mu)\Sigma^{k}, \tag{4.16}$$

where $\Sigma^{\upsilon} = -\text{Cov}[\boldsymbol{\upsilon}, \boldsymbol{\gamma}] \geq 0$ is the negative covariance between labor market payoffs and welfare weights and $\Sigma^{k} = -\text{Cov}[\boldsymbol{\sigma}(1-\tau)\bar{\pi}, \boldsymbol{\gamma}] = \Sigma(1-\tau)\bar{\pi} \geq 0$ is the negative covariance between capital income and welfare weights.

Proof. See Appendix 4.5. □

Monopsony power raises aggregate profits and lowers the aggregate wage bill. The associated impact on welfare is ambiguous. On the one hand, monopsony power reduces inequality in labor income generated by differences in ability. The positive welfare effect is captured by the left-hand side of equation (4.16). On the other hand, it increases inequality in capital income generated by differences in shareholdings. The negative welfare effect is captured by the right-hand side of equation (4.16).

To gain further intuition why monopsony power might raise welfare, recall that firms observe ability while the government does not. If labor markets are competitive, firms do not benefit from this information as profits are driven to zero. By contrast, profits are positive if firms have monopsony power. Moreover, the profits firms generate from hiring a worker are increasing in ability. An increase in monopsony power thus reduces inequality in labor market payoffs generated by differences in ability. Importantly, unlike with distortionary taxes on labor income, the reduction in inequality comes at zero efficiency costs. An increase in monopsony power thus alleviates the equity-efficiency trade-off that occurs because the government does not observe ability, cf. Mirrlees (1971).

The negative welfare effect of monopsony power that occurs because it exacerbates inequality in capital income depends critically on the extent to which pure economic profits are taxed. Without a restriction on profit taxation (i.e., if $\tau = 1$), an increase in monopsony power unambiguously raises welfare as there is no inequality in capital income that is exacerbated by monopsony power. Welfare is therefore highest if firms have full monopsony power (i.e., if $\mu = 1$ as well). In this case, there is no inequality in labor market payoffs either, as all individuals are put on their identical participation constraint.[17] The government optimally uses the proceeds from the confiscatory tax on profits to finance a universal basic income $-T(0)$ that should not be taxed away if individuals earn labor income.[18] If profit taxation is unrestricted, monopsony power reduces inequality generated by differences in ability without exacerbating inequality generated by differences in shareholdings, which is welfare-enhancing. However, if profits cannot be taxed at a confiscatory rate, the welfare effect of monopsony power is generally ambiguous.

A few remarks are in order. First, equation (4.16) depends on capital income and labor market payoffs, which are both endogenous. I show in Appendix 4.5 that the welfare effect of raising monopsony power can be written as a function of exogenous variables if the labor supply elasticity is constant. Second, the result from Proposition 4.2 is derived assuming income taxes are optimized. Hence, the result can only be used to assess the welfare effect of raising monopsony power at the *current* tax system under the additional assumption that the latter reflects the government's preferences for redistribution.[19] Third, labor market payoffs depend on the disutility of working, which is difficult to measure. It is

[17]Despite that all individuals are put on their identical participation constraint, there is still inequality in labor income. This is because firms demand more labor effort from individuals with higher ability: see footnote 15.

[18]Put differently, optimal marginal tax rates are zero. To see this, substitute $\tau = \mu = 1$ in equation (4.11).

[19]The welfare weights that make the current tax system optimal can be calculated using the inverse optimal tax method: see Bourguignon and Spadaro (2012).

also possible to derive a necessary condition that depends on the covariance between welfare weights and after-tax labor income.

Corollary 4.2. *Suppose monopsony power does not vary with ability and the tax function $T(\cdot)$ is optimized. If labor effort is weakly increasing in ability at the optimal allocation, i.e., $l'(n) \geq 0$, an increase in monopsony power raises welfare only if*

$$\mu\Sigma^{\ell} > (1-\mu)\Sigma^{k}, \tag{4.17}$$

where $\Sigma^{\ell} = -\text{Cov}[\boldsymbol{z} - T(\boldsymbol{z}), \boldsymbol{\gamma}] > \Sigma^{v} \geq 0$ is the negative covariance between welfare weights and after-tax labor income.

Proof. See Appendix 4.5. □

If individuals with higher ability exert more effort, the negative covariance between welfare weights and after-tax labor income exceeds the negative covariance between welfare weights and labor market payoffs. Therefore, equation (4.17) gives a necessary condition which can be used to determine if an increase in monopsony power could raise welfare. The advantage compared to the necessary and sufficient condition from Proposition (4.2) is that condition (4.17) is arguably easier to assess for policymakers, as it depends on after-tax labor income and not on the disutility of working.

4.3.3 Ability-specific monopsony power

The results from Propositions 4.1 and 4.2 are derived assuming all individuals suffer to the same extent from monopsony power. Hence, if labor income taxes are linear, firms capture a share of the labor market surplus that does not vary with ability: $\mu(n) = \mu$ for all n. I now generalize these results by allowing for the possibility that individuals with higher ability also have more bargaining power (i.e., suffer less from monopsony): $\mu'(n) \leq 0$.[20]

[20] In line with this assumption, the findings from Webber (2015) and Rinz (2018) suggest that individuals at lower parts of the earnings distribution suffer more from firms' ability to exercise monopsony power.

Proposition 4.3. *Suppose monosony power is weakly decreasing in ability:* $\mu'(n) \leq 0$. *The optimal marginal tax rate satisfies*

$$T'(z(n)) = \Bigg[\bar{\mu}(n)(1-\tau)\Sigma + (1-\mu(n))(1-T'(z(n)))(1+1/\varepsilon(n))(1-\bar{g}(n)) \tag{4.18}$$

$$- \frac{\int_n^{n_1} \mu'(m)(1-T'(z(m)))\left(\int_m^{n_1}(1-g(s))f(s)ds\right)dm}{1-F(n)}$$

$$- \frac{\mu'(n)\pi(n)(1-T'(z(n)))(1-\bar{g}(n))}{\mu(n)\varepsilon(n)l(n)}\Bigg]\frac{1-F(n)}{nf(n)}$$

provided $a(n) \geq \bar{\mu}(n)(1-\tau)\Sigma - \int_n^{n_1}\mu'(m)\frac{\phi'(l(m))}{m}\int_m^{n_1}(1-g(s))f(s)dsdm/(1-F(n))$, *where* $\bar{\mu}(n)$ *denotes the average monopsony power for individuals with ability at least equal to* n. *Individuals with ability levels where this condition is not satisfied do not work:* $l(n) = z(n) = 0$. *The optimal marginal tax rate is generally positive and zero at the top:* $T'(z(n_1)) = 0$. *To assess the welfare effect of monopsony power, consider a proportional increase in monopsony power from* $\mu(n)$ *to* $\mu(n)(1+\alpha)$. *The associated impact on welfare is determined by*

$$\frac{\partial \mathcal{W}(\alpha)}{\partial \alpha} = \int_{n_0}^{n_1}\Bigg[\frac{\phi'(l(n))}{n}\int_n^{n_1}(1-g(m))f(m)dm - (1-\tau)\Sigma\int_n^{n_1}\frac{\mu(m)}{\mu(n)}f(m)dm$$

$$+ \int_n^{n_1}\frac{\mu'(m)}{\mu(n)}\frac{\phi'(l(m))}{m}\left(\int_m^{n_1}(1-g(s))f(s)ds\right)dm\Bigg]\mu(n)l(n)dn. \tag{4.19}$$

Proof. See Appendix 4.5 and 4.5. □

Compared to the case where monopsony power is constant, inequality generated by differences in ability is higher if individuals with higher ability suffer less from monopsony. This explains why *ceteris paribus* optimal marginal tax rates are higher. Compared to the result from Proposition 4.1, two additional effects show up in equation (4.18). First, a reduction in monopsony power *at a particular ability level* implies the labor market payoff increases more quickly in ability. Second, a reduction in monopsony power *at higher ability levels* lowers the profits firms generate from hiring more productive workers. Hence, individuals with higher ability manage to capture a larger share of the labor market surplus. Both effects raise the distributional benefits of income taxes and hence, raise the optimal marginal tax rate.

Equation (4.19) gives an expression for the welfare effect of raising monopsony power. If monopsony power does not vary with ability, the first (positive) term is proportional to Σ^v and the second (negative) term is proportional to Σ^k. Hence, one additional effect shows up in equation (4.19) compared to the result from Proposition 4.2. As stated before, individuals with higher ability capture a larger share of the labor market surplus if they suffer less from monopsony. This lowers the positive welfare effect of raising monopsony power that occurs because monopsony power mitigates inequality driven by differences in ability. Hence, an increase in monopsony power has a smaller positive or a larger negative impact on welfare compared to the case where monopsony power does not vary with ability.

4.4 Numerical illustration

This Section quantitatively explores the implications of monopsony power in the baseline version of the model where monopsony power does not vary with ability. After presenting the calibration (Section 4.4.1) and the welfare function (Section 4.4.2), I analyze how monopsony power affects optimal income taxation (Section 4.4.3) and welfare (Section 4.4.4).

4.4.1 Calibration

Data

I calibrate the model on the basis of US data. The primary data source is the March release of the 2018 Current Population Survey (CPS), which provides detailed information on income and taxes for a large sample of individuals. For each individual I observe taxable income, the tax liability (computed as the sum of federal and state taxes) and income from wage and salary payments. In the remainder the latter is referred to as labor income, or labor earnings. In the analysis I include individuals between 25 and 65 years who derive strictly positive labor income and whose hourly wage is at least half the federal minimum wage of \$7.25. For individuals whose labor income is top-coded I multiply the reported income with a factor 2.67, consistent with an estimate of the Pareto parameter of 1.6 for the distribution of labor income at the top obtained by Saez and Stantcheva (2018).[21]

Functional forms

To calibrate the model I require a specification of the utility function and the current tax schedule. The utility function is assumed to be of the iso-elastic form

$$u(c,l) = c - \frac{l^{1+1/\varepsilon}}{1+1/\varepsilon}, \tag{4.20}$$

where ε is the constant elasticity of labor supply. The latter is set at a value $\varepsilon = 0.33$, as suggested by Chetty (2012). I approximate the current tax schedule using a linear specification

$$T(z(n)) = -g + tz(n). \tag{4.21}$$

Values for the lump-sum transfer g and the constant marginal tax rate t are obtained by regressing the tax liability on taxable income, see, e.g., Saez (2001). This gives $g = \$4,590$ and $t = 33.1\%$ with an R^2 of approximately 0.94. Figure 4.4 in Appendix 4.5 plots the actual and fitted values for incomes up to \$500,000.

Equilibrium

If the utility function is iso-elastic and the tax function is linear, it is straightforward to derive the equilibrium (cf. Definition 4.2). Labor effort follows from equation (4.4):

$$l(n) = (1-t)^{\varepsilon} n^{\varepsilon}. \tag{4.22}$$

[21] If labor income at the top follows a Pareto distribution with tail parameter $\tilde{a}$, the expected value of income above a certain amount z' equals $\mathbb{E}[z|z \geq z'] = \left(\frac{\tilde{a}}{\tilde{a}-1}\right) z'$.

Labor earnings, in turn, are obtained by substituting labor effort in equation (4.7) and using the definition $\pi(n) = nl(n) - z(n)$. This gives

$$z(n) = \left(1 - \frac{\mu}{1+\varepsilon}\right)(1-t)^{\varepsilon} n^{1+\varepsilon} + \left(\frac{\mu}{1+\varepsilon}\right) z(n_0). \quad (4.23)$$

An individual's labor income equals a weighted average of the output she produces (first term) and the labor income of the individuals with the lowest ability (second term).[22] The profits $\pi(n) = nl(n) - z(n)$ firms generate from hiring a worker with ability n are given by

$$\pi(n) = \left(\frac{\mu}{1+\varepsilon-\mu}\right)(z(n) - z(n_0)). \quad (4.24)$$

Equations (4.23) and (4.24) give a mapping from (observable) labor income to (unobservable) ability and pure economic profits, respectively.

With this closed-form characterization of the equilibrium, a few remarks are in place. First, as in the classic and new monopsony models introduced in Robinson (1969) and Manning (2003), the mark-up of productivity over wages (or output over earnings) is decreasing in the elasticity of labor supply. To see this, denote by $w(n) = z(n)/l(n)$ the hourly wage of an individual with ability n and assume $z(n_0)$ is very small, as in the data. Using equation (4.23), the mark-up, i.e., the measure of "exploitation" introduced by Pigou (1920), is

$$\frac{n - w(n)}{w(n)} = \frac{\mu}{1+\varepsilon-\mu}. \quad (4.25)$$

Clearly, the latter is increasing in monopsony power μ and decreasing in the elasticity of labor supply ε. Second, equation (4.23) implies that if firms have monposony power, productivity gains (captured by an increase in ability n) are not translated one-for-one

[22] The reason why the lowest income shows up in equation (4.23) is that, by assumption, firms make no profits from hiring individuals with the lowest ability: $\pi(n_0) = 0$. This can only be the case for *any* degree of monposony power if individuals with ability n_0 are indifferent between working and not working. Therefore, the lowest income level is informative about the outside option of non-employment. Note that the value of non-employment generally differs from the lump-sum transfer g, for example because non-employed individuals are entitled to an additional benefit or because of (non-modeled) utility costs or benefits of having a job.

into higher wages. This is a standard prediction from models where firms have monopsony power that is supported by empirical evidence (see Kline et al. (2019) for a recent example). Third, from equation (4.23) it is clear that monopsony power mitigates inequality in labor earnings driven by differences in ability. Despite this, monposony power has no impact on typical measures of inequality in labor earnings, such as the Gini coefficient, the variance in log earnings or the P90/P10 earnings ratio. The reason is that monopsony power simply scales down labor earnings for this particular choice of the utility and tax function. In the more general case where monopsony power, the marginal tax rate or the elasticity of labor supply vary with ability, the model does not make a clear-cut prediction on the impact of monopsony power on these measures of inequality.[23]

Monopsony power

Monopsony power μ determines how much pure economic, or above-normal profits firms make. In recent work, Barkai and Benzell (2018) and Barkai (2020) decompose US output into a labor share, a capital share and a profit share. The labor share is calculated as total compensation to employees as a fraction of gross value added. The capital share, in turn, is calculated as the product of the capital stock and the required (or normal) rate of return, again as a fraction of gross value added. The remainder, i.e., the profit share, is a measure of pure economic profits. Because my model abstracts from productive capital, I calibrate monopsony power μ to target the ratio of aggregate profits to aggregate labor income, or the ratio of the *profit share* to the *labor share*. For the most recent year 2015, Barkai and Benzell (2018) calculate that the ratio of aggregate profits to aggregate wages is approximately 24.2%. Using their estimate, the value for monopsony power μ can be calculated by integrating equation (4.24) over the ability distribution and dividing by aggregate labor income $\bar{z} = \int_{n_0}^{n_1} z(n)f(n)dn$. This gives

$$\left(\frac{\bar{\pi}}{\bar{z}}\right) = \left(\frac{\mu}{1+\varepsilon-\mu}\right)\left(1-\left(\frac{z(n_0)}{\bar{z}}\right)\right), \tag{4.26}$$

[23]This could also explain why Webber (2015) and Rinz (2018) find a positive association between measures of monopsony power and the variance in log earnings or the P90/P10 earnings ratio, respectively.

which can be solved for the degree of monopsony power:

$$\mu = (1+\varepsilon)\left[\frac{(\bar{\pi}/\bar{z})}{1+(\bar{\pi}/\bar{z})-(z(n_0)/\bar{z})}\right]. \tag{4.27}$$

Substituting out for the elasticity of labor supply and the ratio of profits to wages gives a value for monopsony power of approximately $\mu = 0.26$.[24]

Ability distribution

As in Saez (2001), I calibrate the ability distribution to match the empirical income distribution. To do so, I use equation (4.23) and calculate the ability n for each individual with positive labor earnings. This gives an empirical counterpart of the ability distribution $F(n)$. I subsequently smooth this distribution by estimating a kernel density. The empirical distribution and the kernel density are plotted in the top panel of Figure 4.5 in Appendix 4.5. The bottom panel plots the distribution of labor earnings and the implied kernel density.

I make one adjustment to the density as plotted in the top panel of Figure 4.5. In particular, I append a right Pareto tail starting at an ability level associated with \$350,000 in annual earnings. The reason for doing so is that individuals with very high labor earnings are significantly under-represented in the CPS data. I choose the tail parameter of the *ability* distribution to be consistent with a tail parameter of 1.6 of the *labor income* distribution at the top.[25] This is the estimate obtained by Saez and Stantcheva (2018) using tax returns data. The scale parameter of the Pareto distribution is set to ensure there is no jump in the density at the point where the Pareto tail is pasted.

[24] In the CPS data, the lowest earnings level is very small compared to average earnings. Hence, the choice of $z(n_0)/\bar{z}$ only has a small effect on the calibrated value of μ.

[25] Let $\tilde{F}(z(n))$ denote the labor income distribution with density $\tilde{f}(z(n))$. Monotonicity of labor earnings implies $F(n) = \tilde{F}(z(n))$ for all n where $z(n) > 0$ and hence, $f(n) = \tilde{f}(z(n))z'(n)$. The local Pareto parameter of the ability distribution $a(n) = nf(n)/(1-F(n))$ and income distribution $\tilde{a}(z(n)) = z(n)\tilde{f}(z(n))/(1-\tilde{F}(z(n)))$ are related through $a(n) = \tilde{a}(z(n))e_{zn}$, where $e_{zn} = z'(n)n/z(n)$ is the elasticity of labor earnings with respect to ability. The latter equals approximately $1+\varepsilon$ at high levels of labor earnings: see equation (4.23).

Profit taxation and revenue requirement

In the model, there is no productive capital and τ is the rate at which pure economic, or above-normal profits are taxed. The current tax system does not distinguish between normal and above-normal returns. I therefore assume all capital income is taxed at a rate $\tau = 36\%$, taken from Trabandt and Uhlig (2011). This figure is very similar to the one that is obtained if the government levies a corporate tax rate of 21% at the firm level and a capital gains tax rate of 20% at the individual level. For a given value of τ, the government's budget constraint (4.10) can be used to calculate the revenue requirement. This gives $G = \$22,049$, which in the calibrated economy corresponds to approximately 28.6% of aggregate output. Table 4.1 summarizes the calibration strategy.

Variable	Target	Source	Value
μ	Aggregate profits over wages	Barkai and Benzell (2018)	0.26
ε	Elasticity of labor supply	Chetty (2012)	0.33
τ	Tax rate on capital income	Trabandt and Uhlig (2011)	0.36
G	Government budget constraint	Equilibrium condition	\$22,049
$T(z)$	Tax liability	CPS 2018	Figure 4.4
$F(n)$	Income distribution	CPS 2018	Figure 4.5

Table 4.1: Calibration

4.4.2 Welfare function

The welfare function (4.9) depends on the average welfare weights $g(n)$ of individuals with the same ability and the negative covariance $\Sigma \in [0, 1]$ between welfare weights and shareholdings. The first (second) determines how much the government values reducing inequality generated by differences in ability (shareholdings). In the remainder, I let Σ vary between zero and one. If $\Sigma = 0$, the government does not value redistributing capital income. Conversely, if $\Sigma = 1$, the government cares a lot about redistributing capital income as all shares are held by individuals with a welfare weight of zero. Regarding the average welfare weights of individuals with the same ability, I use the following specification:

$$g(n) = \rho n^{-\beta}. \tag{4.28}$$

Here, $\rho > 0$ is a scaling parameter and $\beta \geq 0$ governs how much the government wishes to redistribute from individuals with high to individuals with low ability. If $\beta = 0$, the government attaches the same average weight to individuals of all ability levels. Conversely, if $\beta \to \infty$, the government only cares about individuals with the lowest ability.

Before selecting a value for ρ and β, I make one adjustment to the welfare function (4.9). In particular, I assume there is a mass of $\nu = 0.05$ non-participants, who earn zero labor and capital income and whose welfare weight equals twice the average welfare weight of all other individuals. The government optimizes a benefit for the non-participants, subject to the requirement that their utility does not exceed the labor market payoff of individuals with the lowest ability. Under these assumptions, the optimal marginal tax rate at the bottom of the income distribution is positive even if labor markets are competitive or there is no (desire to reduce) capital income inequality: $(1 - \tau)\Sigma = 0$. This avoids technical difficulties associated with steeply increasing marginal tax rates at very low earnings.[26] The parameter ρ is set to make sure the average welfare weight of all individuals (including the non-participants) equals one. Moreover, I choose the value of β such that the average marginal tax rate at the optimal tax system with competitive labor markets equals the current rate $t = 33.1\%$.

4.4.3 Optimal marginal tax rates

Figure 4.2 plots optimal marginal tax rates for different assumptions on the degree of monopsony power μ and the negative covariance between welfare weights and shareholdings Σ. To facilitate the comparison, the horizontal axis shows *current* labor earnings. The red, solid line plots the marginal tax rates a "naive" government would set that acts *as if* labor markets are competitive. The tax rates are calculated by substituting $\mu = 0$ in equation (4.14). Consistent with the calibrated value of β, the average marginal tax rate equals 33.1%. The conventional U-shape pattern (see, e.g., Diamond (1998) and Saez (2001)) follows from the behavior of the local Pareto parameter $a(n)$: see Figure 4.6 in Appendix 4.5.

[26] These difficulties arise because a low value of the local Pareto parameter $a(n)$ at the bottom implies the optimal marginal tax rate jumps from $T'(z(n_0)) = 0$ immediately to a high value. Such a jump often leads to a violation of the monotonicity condition: see Appendix 4.5.

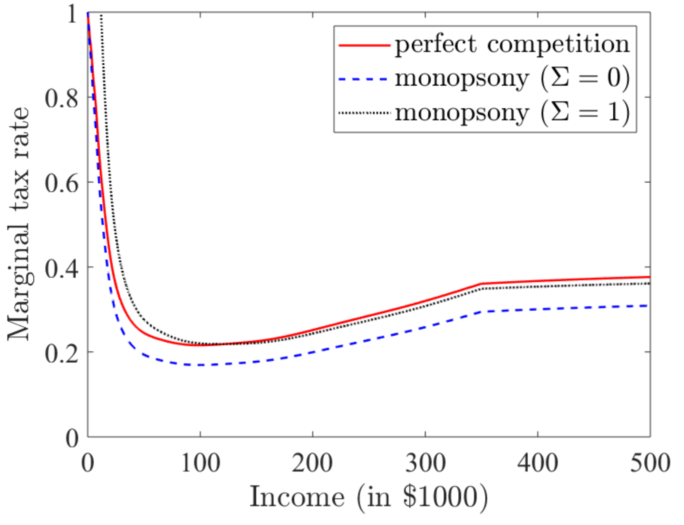


Figure 4.2: Optimal marginal tax rates

The blue, dashed line in Figure 4.2 plots the optimal marginal tax rates if the degree of monopsony power is as in the calibrated economy and the government does not value redistributing capital income: $\mu = 0.26$ and $\Sigma = 0$. Compared to the case with competitive labor markets, optimal marginal tax rates are lower, cf. Corollary 4.1. This is because monopsony power makes labor income taxes less effective in redistributing labor income as part of the incidence falls on firms. The average reduction in optimal marginal tax rates brought about by monopsony power is 5.6 percentage points.

The black, dotted line plots the optimal marginal tax rates if the government has a very strong preference for redistributing capital income: $\Sigma = 1$. Naturally, tax rates are higher compared to the case with $\Sigma = 0$. The average increase brought about by a change in the covariance between welfare weights and shareholdings is 13.2 percentage points. Compared to the case with competitive labor markets, optimal marginal tax rates are higher (lower) for individuals whose current labor earnings are below (above) approximately $122,000. On average, the optimal marginal tax rate with monopsony power is 7.7 percentage points higher. The increase is driven mostly by substantially higher marginal tax rates at low earnings levels, where the local Pareto parameter $a(n)$ is low: see Corollary 4.1 and Figure 4.6. The low Pareto parameter at the bottom also implies that some individuals do not work at the optimal allocation, as the constraint $l(n) \geq 0$ is binding. This is the case for individuals whose current labor earnings are below approximately \$12,000.

According to Corollary 4.1, the impact of monopsony power on optimal tax rates is generally ambiguous. The analysis here suggests that if the government wishes to reduce inequality generated by differences in *both* ability and shareholdings, monopsony power tends to increase optimal marginal tax rates at lower earnings levels and to decrease optimal marginal tax rates at higher earnings levels. At what earnings level the impact changes from positive to negative depends critically on the covariance between welfare weights and shareholdings.

4.4.4 Implications for welfare

To assess the quantitative implications of monopsony power for welfare in the calibrated economy, I conduct two exercises. First, I calculate the welfare costs of ignoring monopsony power when designing tax policy. To do so, I compare the allocation that is obtained if the government sets income taxes optimally (cf. the dashed and dotted lines in Figure 4.2) with the one that is obtained if a "naive" government wrongfully sets tax policy *as if* labor markets are competitive (cf. the solid line in Figure 4.2). Second, I calculate how much the government is willing to pay for changing the degree of monopsony power to zero. The first exercise gives an indication of the welfare benefits of taking a *given* degree of monopsony power into account when designing tax policy, whereas the second exercise is informative about the costs or benefits of *changing* the degree of monopsony power.

Figure 4.3 shows the results of both exercises for different values of the covariance between welfare weights and shareholdings. The left axis plots the welfare costs of ignoring monopsony power when designing tax policy (i.e., the costs of "misoptimization"). The right axis plots the welfare effect of changing the degree of monopsony power from its value in the calibrated economy to zero. In both cases, the welfare impact is expressed in consumption equivalents as a percentage of current GDP in the calibrated economy. Regarding the first exercise, the welfare costs of ignoring monopsony power when designing tax policy range between \$57 and \$802 in consumption equivalents, or between 0.07% and

1.04% of GDP. These costs are small for low values of the negative covariance between welfare weights and shareholdings and largest if the government has a strong preference for redistributing capital income. To illustrate, moving from the solid to the dashed tax code plotted in Figure 4.2 generates a welfare gain equivalent to increasing all individuals' net income by \$70, or 0.09% of GDP. By contrast, moving from the solid to the dotted tax code plotted in Figure 4.2 generates a welfare gain equivalent to increasing all individuals' net income by \$802, or 1.04% of GDP.

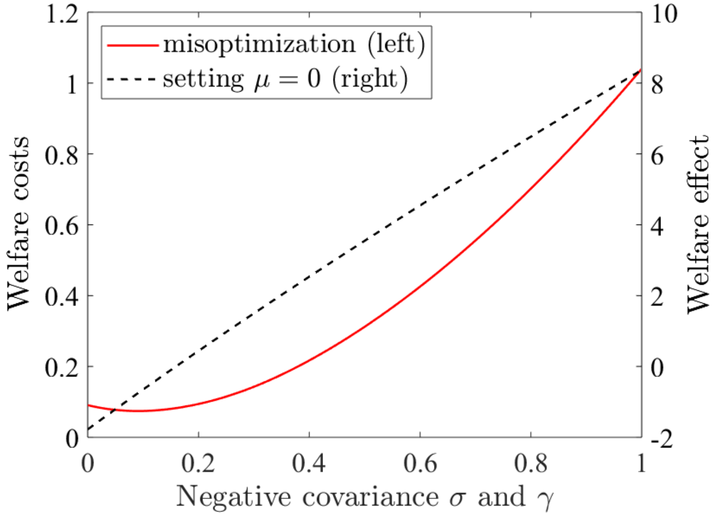


Figure 4.3: Welfare impact in consumption equivalents (% of GDP)

Regarding the second exercise, changing the degree of monopsony power from its value in the calibrated economy to zero can have a negative or positive impact on welfare depending on the covariance between shareholdings and welfare weights. If $\Sigma = 0$, getting rid of monopsony power leads to a welfare loss of \$1,370 in consumption equivalents, or 1.78% of GDP. This loss occurs because a reduction in monopsony power exacerbates labor income inequality and the government does not value the associated reduction in capital income inequality. By contrast, the welfare impact is positive if the government cares about redistributing capital income. In the calibrated economy, this happens whenever $\Sigma \geq 0.17$. If $\Sigma = 1$, the welfare gain of firms losing monopsony power is large and equals \$6,453 in consumption equivalents, or 8.37% of GDP.

The previous exercise illustrates that changing the degree of monopsony power from its value in the calibrated economy to zero and simultaneously re-optimizing the tax code can have a large negative or positive impact on welfare. It is also possible to analyze the welfare effect of a marginal increase in monopsony power at the current tax system provided the latter reflects the government's preferences for redistribution. Because labor effort is increasing in ability (see equation (4.22)), the result from Corollary 4.2 applies. Hence, an increase in monopsony power raises welfare only if

$$\left(\frac{\Sigma^{\ell}}{\Sigma^{k}}\right) > \left(\frac{1-\mu}{\mu}\right). \tag{4.29}$$

In the calibrated economy, the right-hand side equals approximately 2.85. Hence, if the current tax system is optimal, an increase in monopsony power raises welfare only if the negative covariance between welfare weights and after-tax labor income exceeds the negative covariance between welfare weights and after-tax capital income by a factor of at least this amount. If the preferences for redistribution are such that this condition is not satisfied at the current tax system, an increase in monopsony power lowers welfare.

To summarize, correcting the sub-optimal tax code by taking monopsony power into account leads to welfare gains that vary between 0.07% and 1.04% of current GDP in the calibrated economy. Moreover, changing the degree of monopsony power to zero has a welfare impact that ranges between −1.78% to +8.37% of GDP depending on the covariance between welfare weights and shareholdings. Finally, if the current tax system is optimal, an increase in monopsony power raises welfare only if the negative covariance between welfare weights and labor income exceeds the negative covariance between welfare weights and capital income by a factor of at least 2.85.

4.5 Conclusion

This paper extends the non-linear tax framework of Mirrlees (1971) with monopsony power and studies the implications for optimal income taxation and welfare. In my model, monopsony power does not reduce the size of the labor market surplus but determines what share is translated into pure economic profits. These profits flow back as capital income to individuals who differ in their ability and shareholdings.

Monopsony power makes labor income taxes less effective in redistributing labor income, but more effective in redistributing capital income. This is because monopsony power raises the tax incidence that falls on firms and lowers the tax incidence that falls on workers. The impact of monopsony power on optimal marginal tax rates is ambiguous and depends on the covariance between welfare weights and shareholdings, which captures the government's preference for redistributing capital income. Monopsony power raises optimal tax rates if the government cares strongly about redistributing capital income. A calibration of the model to the US economy suggests that monopsony power raises (lowers) optimal marginal tax rates at low (high) earnings levels if the government wishes to reduce inequality generated by differences in both ability and shareholdings. The welfare costs of ignoring monopsony power when designing tax policy range between 0.07% and 1.04% of GDP in the calibrated economy depending on the covariance between welfare weights and shareholdings.

An increase in monopsony power might increase or decrease welfare, as it mitigates (exacerbates) inequality in labor (capital) income. The reason why monopsony power might raise welfare is that firms observe ability, while the government does not. Monopsony power reduces inequality generated by differences in ability. This alleviates the trade-off between equity and efficiency that occurs if the government does not observe ability, but at the expense of increasing capital income inequality. In the calibrated economy, eliminating monopsony power has a welfare effect that ranges between −1.78% and +8.37% of GDP depending on the covariance between welfare weights and shareholdings. Moreover, if the current tax system is optimal, an increase in monopsony power raises welfare only if the negative covariance between welfare weights and after-tax labor income is at least 2.85 times as high as the negative covariance between welfare weights and after-tax capital income.

The analysis from this paper can be extended in at least two directions. First, in order to focus sharply on distributional issues I have abstracted from efficiency costs associated with monopsony power. Recent evidence by Berger et al. (2019) suggests these costs are significant. A natural way to introduce distortions from monopsony power in my model is to assume firms do not perfectly observe ability (as in Hariton and Piaser (2007) and da Costa and Maestri (2019)) or cannot offer contracts that specify both earnings and labor effort (as in Robinson (1969)). Second, I have treated monopsony power as exogenously determined. In reality monopsony power is unlikely to be policy-invariant. Extending the analysis with distortions from monopsony power and a potential role for the government to affect monopsony power (e.g., through competition policy) seems highly policy-relevant.

Appendix A: Rewriting the welfare function

The result from Lemma 4.1 can be obtained as follows. Substitute the utility function (4.2) in the welfare function (4.8) and rewrite the resulting expression in a number of steps:

$$\begin{aligned}
\mathcal{W} &= \int_{\sigma_0}^{\sigma_1}\int_{n_0}^{n_1} \gamma(n,\sigma)\mathcal{U}(n,\sigma)h(n,\sigma)dnd\sigma \\
&= \int_{\sigma_0}^{\sigma_1}\int_{n_0}^{n_1} \gamma(n,\sigma)\Big[\upsilon(n)+\sigma(1-\tau)\bar{\pi}\Big]h(n,\sigma)dnd\sigma \\
&= \int_{n_0}^{n_1} \upsilon(n)\underbrace{\left(\int_{\sigma_0}^{\sigma_1}\gamma(n,\sigma)h(n,\sigma)d\sigma\right)}_{=\ g(n)f(n)}dn + (1-\tau)\bar{\pi}\int_{\sigma_0}^{\sigma_1}\int_{n_0}^{n_1}\sigma\gamma(n,\sigma)h(n,\sigma)dnd\sigma \\
&= \int_{n_0}^{n_1} g(n)\upsilon(n)f(n)dn + (1-\tau)\bar{\pi}\Bigg(1+\underbrace{\int_{\sigma_0}^{\sigma_1}\int_{n_0}^{n_1}(\sigma-1)(\gamma(n,\sigma)-1)h(n,\sigma)dnd\sigma}_{=\ \mathrm{Cov}[\boldsymbol{\sigma},\boldsymbol{\gamma}]\ =\ -\Sigma}\Bigg) \\
&= \int_{n_0}^{n_1} g(n)\upsilon(n)f(n)dn + (1-\tau)(1-\Sigma)\int_{n_0}^{n_1}\pi(n)f(n)dn, \qquad (4.30)
\end{aligned}$$

which corresponds to equation (4.9). To show that $\Sigma \in [0,1]$, write

$$\begin{aligned}
\Sigma &= -\int_{\sigma_0}^{\sigma_1}\int_{n_0}^{n_1}(\sigma-1)(\gamma(n,\sigma)-1)h(n,\sigma)dnd\sigma \\
&= 1-\int_{\sigma_0}^{\sigma_1}\int_{n_0}^{n_1}\sigma\gamma(n,\sigma)h(n,\sigma)dnd\sigma. \qquad (4.31)
\end{aligned}$$

Given that $\sigma \geq 0$ and $\gamma(n,\sigma) \geq 0$, it follows that $\Sigma \leq 1$. Next, write the covariance as

$$\Sigma = \int_{\sigma_0}^{\sigma_1} \int_{n_0}^{n_1} (1-\sigma)\gamma(n,\sigma)h(n,\sigma)dnd\sigma = \int_{\sigma_0}^{\sigma_1} (1-\sigma) \int_{n_0}^{n_1} \gamma(n,\sigma)h(n,\sigma)dnd\sigma$$
$$= \int_{\sigma_0}^{\sigma_1} (1-\sigma) \underbrace{\left(\frac{\int_{n_0}^{n_1} \gamma(n,\sigma)h(n,\sigma)dn}{\int_{n_0}^{n_1} h(n,\sigma)dn} \right)}_{=\ \mathbb{E}[\gamma(n,\sigma)|\sigma]} \underbrace{\left(\int_{n_0}^{n_1} h(n,\sigma)dn \right)}_{=\ k(\sigma)} d\sigma. \tag{4.32}$$

By assumption, $\mathbb{E}[\gamma(n,\sigma)|\sigma]$ is non-increasing and σ averages to one. Therefore,

$$\Sigma = \int_{\sigma_0}^{\sigma_1} (1-\sigma)\mathbb{E}[\gamma(n,\sigma)|\sigma]k(\sigma)d\sigma \geq \int_{\sigma_0}^{\sigma_1} (1-\sigma)k(\sigma)d\sigma = 0. \tag{4.33}$$

Appendix B: Optimal tax problem

To solve the optimal tax problem, I follow the approach from Mirrlees (1971) and let the government choose the allocation variables to maximize welfare (4.9) subject to resource and incentive constraints. The allocation variables are labor effort $l(n)$, the labor market payoff $\upsilon(n)$ and the profits $\pi(n)$ firms make from hiring a worker with ability n. To derive the resource constraint in terms of the allocation variables, substitute $T(z(n)) = z(n) - \upsilon(n) - \phi(l(n)) = nl(n) - \pi(n) - \upsilon(n) - \phi(l(n))$ in the government's budget constraint (4.10) and rearrange to find

$$\int_{n_0}^{n_1} nl(n)f(n)dn = \int_{n_0}^{n_1} \Big[\upsilon(n) + \phi(l(n)) + (1-\tau)\pi(n) \Big] f(n)dn + G. \tag{4.34}$$

In words, aggregate output equals the sum of private consumption (first term) and public consumption (second term).

In addition to the resource constraint, the allocation must also satisfy incentive constraints. To derive the first of these, differentiate the labor market payoff $\upsilon(n) = z(n) - T(z(n)) - \phi(l(n))$ with respect to ability to find

$$\upsilon'(n) = (1 - T'(z(n)))z'(n) - \phi'(l(n))l'(n). \tag{4.35}$$

Next, use the first-order condition from the profit maximization problem (4.4) and the relationship $\pi(n) = nl(n) - z(n)$. Condition (4.35) can then be written as

$$\upsilon'(n) = \frac{\phi'(l(n))}{n}\left[l(n) - \pi'(n)\right]. \tag{4.36}$$

This condition differs from the incentive constraint in the Mirrlees (1971) problem through the occurrence of the term $\pi'(n)$, which is zero if labor markets are competitive. The labor market payoff increases less quickly in ability if firms generate more profits from hiring individuals with higher ability.

To derive the second incentive constraint, differentiate the condition for profits (4.7) with respect to ability to find

$$\pi'(n) = \mu(n)l(n) + \frac{\mu'(n)}{\mu(n)}\pi(n). \tag{4.37}$$

Intuitively, profits increase more rapidly in ability the higher is monopsony power and labor effort. Profits increase less quickly in ability if individuals with higher ability suffer less from monopsony (i.e., if $\mu'(n) < 0$). Combining equations (4.36) and (4.37) gives

$$\upsilon'(n) = \frac{\phi'(l(n))}{n}\left[(1 - \mu(n))l(n) - \frac{\mu'(n)}{\mu(n)}\pi(n)\right]. \tag{4.38}$$

By assumption, more productive workers do not suffer more from monopsony: $\mu'(n) \leq 0$. Equation (4.38) then implies that the labor market payoff is weakly increasing in ability: $\upsilon'(n) \geq 0$. The labor market payoff does not vary with ability if firms have full monopsony power (i.e., if $\mu(n) = 1$ for all n). In that case, all individuals are put on their identical participation constraint and hence, $\upsilon'(n) = 0$.

The government's problem consists of choosing the allocation variables $\upsilon(n)$, $\pi(n)$ and $l(n)$ at each ability level n to maximize welfare (4.9), subject to the resource constraint (4.34) and the incentive constraints (4.37) – (4.38). As it turns out, it is important to take the non-negativity constraint $l(n) \geq 0$ explicitly into account.[27] The final restriction we need to impose is that the profits from hiring the least productive workers are non-

[27] To ensure consumption is non-negative, one could also include the constraint $\upsilon(n) + \phi(l(n)) \geq 0$ for all n. I assume the revenue requirement G and preferences for redistribution are such that this constraint never binds.

negative: $\pi(n_0) \geq 0$. This condition guarantees that firms are willing to hire individuals of all ability levels.[28] It is shown in Appendix 4.5 that this constraint is always binding, which *ex post* validates the assumption that $\pi(n_0) = 0$ in the description of the equilibrium: see Definition 4.2 and equation (4.7). The optimal tax problem can now be formulated as a standard optimal control problem where $\upsilon(n)$ and $\pi(n)$ are the state variables and $l(n)$ is the control variable. The corresponding Lagrangian and first-order conditions can be found in Appendix 4.5.

To make sure that the optimal allocation (as implicitly characterized in Appendix 4.5) can be decentralized using a tax on profits τ and a non-linear tax on labor income $T(z(n))$, I assume that earnings $z(n) = nl(n) - \pi(n)$ are increasing in ability whenever the non-negativity constraint on labor effort is not binding: $z'(n) > 0$ if $l(n) > 0$. This condition serves two purposes. First, it guarantees that individuals with different abilities do not earn the same income and hence, are not required to face the same marginal tax rate. Second, the monotonicity condition also ensures that the second-order condition for profit maximization is satisfied – see Appendix 4.5 for details.

Appendix C: Monotonicity condition

This Appendix demonstrates the equivalence between the monotonicity condition $z'(n) > 0$ and the requirement that the second order-condition for the profit maximization problem (4.3) is satisfied. To do so, note that the constraint in the firm's maximization problem (4.3) is always binding. If not, firms can raise profits by increasing labor effort. Invert the constraint with respect to labor effort to write $l = \hat{l}(z, \upsilon(n))$, where $\upsilon(n) = \underline{\upsilon}(n)$ for all n. The profit maximization problem is

$$\max_{z \geq 0} \quad n\hat{l}(z, \upsilon(n)) - z. \tag{4.40}$$

[28] To see why, note that the general solution to the differential equation (4.37) is

$$\pi(n) = \mu(n) \left[\frac{\pi(n_0)}{\mu(n_0)} + \int_{n_0}^{n} l(m) dm \right], \tag{4.39}$$

which simplifies to equation (4.7) if $\pi(n_0) = 0$. Because labor effort is non-negative, it follows that $\pi(n_0) \geq 0$ implies $\pi(n) \geq 0$ for all n.

By the implicit function theorem, $\hat{l}_z = (1 - T')/\phi'$, where I ignore function arguments to save on notation. At an interior solution, the first-order condition is given by

$$\frac{n(1 - T'(z))}{\phi'(\hat{l}(z, \upsilon(n)))} - 1 = 0. \tag{4.41}$$

The second-order condition is strictly satisfied if the left-hand side of equation (4.41) is strictly decreasing in earnings z. The latter is true if and only if

$$-\phi''(l) - n^2 T''(z) < 0, \tag{4.42}$$

where I used the first-order condition (4.41) and substituted out for $\hat{l}(z, \upsilon(n)) = l$. Because $\phi(\cdot)$ is strictly convex, condition (4.42) is satisfied as long as the tax function is not too concave.

To determine how earnings z vary with ability, rewrite equation (4.41) and define

$$L(z, n) \equiv n(1 - T'(z)) - \phi'(\hat{l}(z, \upsilon(n))) = 0. \tag{4.43}$$

Next, apply the implicit function theorem and use the first-order condition (4.41) and the property $\hat{l}_\upsilon = -1/\phi'$ to find

$$z'(n) = -\frac{L_n(z, n)}{L_z(z, n)} = \frac{\phi'(l) + \frac{\phi''(l)}{\phi'(l)} n \upsilon'(n)}{\phi''(l) + n^2 T''(z)}. \tag{4.44}$$

From the incentive constraint (4.38), $\upsilon'(n) \geq 0$ as long as monopsony power is non-increasing in ability. The numerator in (4.44) is therefore unambiguously positive. Hence, $z'(n) > 0$ if and only if the denominator is positive as well. This is the case if and only if the second-order condition (4.42) is satisfied. Therefore, if the allocation satisfies the monotonicity condition $z'(n) > 0$, it follows that the first-order condition for profit maximization (4.41) is both necessary and sufficient.

Appendix D: Lagrangian and first-order conditions

Written in terms of the allocation variables, the optimal tax problem is

$$\max_{[\upsilon(n),\pi(n),l(n)]_{n_0}^{n_1}} \quad \mathcal{W} = \int_{n_0}^{n_1} \Big[g(n)\upsilon(n) + (1-\Sigma)(1-\tau)\pi(n)\Big] f(n)dn, \tag{4.45}$$

$$\begin{aligned}
\text{s.t.} \quad & \int_{n_0}^{n_1} \Big[nl(n) - \upsilon(n) - \phi(l(n)) - (1-\tau)\pi(n)\Big] f(n)dn = G,\\
\forall n: \quad & \upsilon'(n) = \frac{\phi'(l(n))}{n}\left[(1-\mu(n))l(n) - \frac{\mu'(n)}{\mu(n)}\pi(n)\right],\\
\forall n: \quad & \pi'(n) = \mu(n)l(n) + \frac{\mu'(n)}{\mu(n)}\pi(n),\\
\forall n: \quad & l(n) \geq 0,\\
& \pi(n_0) \geq 0.
\end{aligned}$$

The corresponding Lagrangian is given by

$$\begin{aligned}
\mathscr{L} = \int_{n_0}^{n_1} \Bigg[& \Bigg(g(n)\upsilon(n) + (1-\Sigma)(1-\tau)\pi(n) + \eta\Big(nl(n) - \upsilon(n) - \phi(l(n))\\
& - (1-\tau)\pi(n) - G\Big)\Bigg) f(n) + \chi(n)\frac{\phi'(l(n))}{n}\left((1-\mu(n))l(n) - \frac{\mu'(n)}{\mu(n)}\pi(n)\right)\\
& + \chi'(n)\upsilon(n) + \lambda(n)\left(\mu(n)l(n) + \frac{\mu'(n)}{\mu(n)}\pi(n)\right) + \lambda'(n)\pi(n) + \psi(n)l(n)\Bigg] dn\\
& + \chi(n_0)\upsilon(n_0) - \chi(n_1)\upsilon(n_1) + \lambda(n_0)\pi(n_0) - \lambda(n_1)\pi(n_1) + \xi\pi(n_0).
\end{aligned} \tag{4.46}$$

Suppressing the function argument of $\phi'(\cdot)$ and $\phi''(\cdot)$ to save on notation, the first-order conditions are given by

$$\upsilon(n): \quad (g(n) - \eta) f(n) + \chi'(n) = 0, \tag{4.47}$$

$$\pi(n): \quad (1-\tau)(1-\Sigma-\eta)f(n) - \frac{\mu'(n)}{\mu(n)}\left(\chi(n)\frac{\phi'}{n} - \lambda(n)\right) + \lambda'(n) = 0, \tag{4.48}$$

$$l(n): \quad \eta(n-\phi') f(n) + \frac{\chi(n)}{n}\left((1-\mu(n))(\phi' + \phi'' l(n)) - \phi''\frac{\mu'(n)}{\mu(n)}\pi(n)\right) \tag{4.49}$$

$$+ \lambda(n)\mu(n) + \psi(n) = 0,$$

$$\chi(n): \quad \frac{\phi'}{n}\left((1-\mu(n))l(n) - \frac{\mu'(n)}{\mu(n)}\pi(n)\right) - \upsilon'(n) = 0, \tag{4.50}$$

$$\lambda(n): \quad \mu(n)l(n) + \frac{\mu'(n)}{\mu(n)}\pi(n) - \pi'(n) = 0, \tag{4.51}$$

$$\eta: \quad \int_{n_0}^{n_1} (nl(n) - \upsilon(n) - \phi(l(n)) - (1-\tau)\pi(n) - G)f(n)dn = 0, \tag{4.52}$$

$$\upsilon(n_0): \quad \chi(n_0) = 0, \tag{4.53}$$

$$\upsilon(n_1): \quad -\chi(n_1) = 0, \tag{4.54}$$

$$\pi(n_0): \quad \lambda(n_0) + \xi = 0, \tag{4.55}$$

$$\pi(n_1): \quad -\lambda(n_1) = 0, \tag{4.56}$$

$$\psi(n): \quad \psi(n)l(n) = 0, \qquad \psi(n) \geq 0 \quad \text{and} \quad l(n) \geq 0, \tag{4.57}$$

$$\xi: \quad \xi\pi(n_0) = 0, \qquad \xi \geq 0 \quad \text{and} \quad \pi(n_0) \geq 0. \tag{4.58}$$

I assume the second-order conditions for the welfare maximization problem are satisfied and that earnings $z(n) = nl(n) - \pi(n)$ satisfy the monotonicity condition $z'(n) > 0$ if $l(n) > 0$.

Appendix E: Derivation of the optimal marginal tax rate

This Appendix derives the optimal marginal tax rate in the general case where monopsony power $\mu(n)$ varies with ability. To that end, it is useful to first derive an expression for the multipliers $\chi(n)$ and $\lambda(n)$. Combining equations (4.47) and (4.54) gives

$$\chi(n) = \chi(n_1) - \int_n^{n_1} \chi'(m)dm = -\int_n^{n_1} (\eta - g(n)) f(m)dm. \tag{4.59}$$

Evaluate equation (4.59) at $n = n_0$ and use the transversality condition (4.53) and the normalization $\int_{n_0}^{n_1} g(n)f(n)dn = 1$ to find

$$\int_{n_0}^{n_1} (\eta - g(n)) f(n)dn = \eta - 1 = 0. \tag{4.60}$$

This is a standard result in optimal tax theory. When the tax system is optimized, the marginal cost of public funds equals one: see Jacobs (2018). Next, define by

$$\bar{g}(n) = \frac{\int_n^{n_1} g(m)f(m)dm}{1-F(n)} \tag{4.61}$$

the average welfare weight of individuals with ability at least equal to n, so that $\chi(n) = -(1-\bar{g}(n))(1-F(n))$. Because $\bar{g}(n_0) = 1$ and $g(n)$ is non-increasing in ability it follows that $\bar{g}(n) \leq 1$ and hence, $\chi(n) \leq 0$. To derive an expression for $\lambda(n)$, rewrite equation (4.48):

$$\lambda'(n) + \frac{\mu'(n)}{\mu(n)}\lambda(n) = (1-\tau)\Sigma f(n) - \frac{\mu'(n)}{\mu(n)}\frac{\phi'(l(n))}{n}\int_n^{n_1}(1-g(m))f(m)dm, \tag{4.62}$$

where I used equation (4.59) to substitute out for $\chi(n)$. Equation (4.62) is a linear differential equation in $\lambda(n)$. Using the transversality condition (4.56), the solution is

$$\lambda(n) = \tag{4.63}$$
$$-\frac{\bar{\mu}(n)}{\mu(n)}(1-\tau)\Sigma(1-F(n)) + \int_n^{n_1}\frac{\mu'(m)}{\mu(n)}\frac{\phi'(l(m))}{m}\int_m^{n_1}(1-g(s))f(s)dsdm,$$

where $\bar{\mu}(n)$ is the average monopsony power (i.e., one minus the bargaining power) of individuals with ability at least equal to n. To sign $\lambda(n)$, note that $\phi' \geq 0$ and monopsony power is non-increasing in ability. Consequently, $\lambda(n) \leq 0$. Equations (4.55) and (4.58) then imply $\xi \geq 0$. The assumption that firms do not earn profits from hiring the least productive workers (i.e., $\pi(n_0) = 0$) is therefore without loss of generality.

To derive an expression for the marginal tax rate, consider the first-order condition for labor effort (4.49). Because $\phi' = 0$ and $\pi(n) = 0$ if $l(n) = 0$, the non-negativity constraint on labor effort is binding (i.e., $\psi(n) > 0$) if

$$nf(n) - \bar{\mu}(n)(1-\tau)\Sigma(1-F(n))$$
$$+\int_n^{n_1}\mu'(m)\frac{\phi'(l(m))}{m}\int_m^{n_1}(1-g(s))f(s)dsdm < 0, \tag{4.64}$$

where I imposed $\eta = 1$ and substituted out for $\lambda(n)$ using equation (4.63). The latter is true if the local Pareto parameter

$$a(n) = \frac{nf(n)}{1-F(n)} < \bar{\mu}(n)(1-\tau)\Sigma - \frac{\int_n^{n_1} \mu'(m)\frac{\phi'(l(m))}{m}\int_m^{n_1}(1-g(s))f(s)dsdm}{1-F(n)}. \quad (4.65)$$

Hence, at ability levels where condition (4.65) holds, optimal labor effort and earnings are zero: $l(n) = 0$ and $z(n) = nl(n) - \pi(n) = 0$. If monopsony power does not vary with ability (i.e., if $\mu(n) = \mu$), the right-hand side simplifies to $\mu(1-\tau)\Sigma$. At ability levels where condition (4.65) does not hold, labor effort and earnings are positive. Substituting $\psi(n) = 0$, $\eta = 1$ and the first-order condition for profit maximization $n(1-T') = \phi'$ in equation (4.49) gives

$$T'(z(n))nf(n) = -\frac{\chi(n)}{n}\left((1-\mu(n))(\phi' + \phi'' l(n)) - \phi''\frac{\mu'(n)}{\mu(n)}\pi(n)\right) - \mu(n)\lambda(n). \quad (4.66)$$

Substituting $\chi(n)$ and $\lambda(n)$ from equations (4.59) and (4.63), equation (4.66) can be written as

$$T'(z(n))nf(n) = (1-\bar{g}(n))(1-F(n))\frac{\phi'}{n}\left[(1-\mu(n))\left(1+\frac{\phi'' l(n)}{\phi'}\right) - \pi(n)\frac{\phi''}{\phi'}\frac{\mu'(n)}{\mu(n)}\right]$$

$$+\bar{\mu}(n)(1-\tau)\Sigma(1-F(n)) - \int_n^{n_1}\mu'(m)\frac{\phi'(l(m))}{m}\left(\int_m^{n_1}(1-g(s))f(s)ds\right)dm. \quad (4.67)$$

Next, use the condition $n(1-T') = \phi'$ and denote by $\varepsilon(n) = \frac{\phi'}{\phi'' l(n)}$ the elasticity of labor supply. Upon dividing equation (4.67) by $nf(n)$ and rearranging, we obtain equation (4.18) from Proposition 4.3:

$$T'(z(n)) = \Bigg[\bar{\mu}(n)(1-\tau)\Sigma + (1-\mu(n))(1-T'(z(n)))(1+1/\varepsilon(n))(1-\bar{g}(n)) \quad (4.68)$$

$$-\frac{\int_n^{n_1}\mu'(m)(1-T'(z(m)))\left(\int_m^{n_1}(1-g(s))f(s)ds\right)dm}{1-F(n)}$$

$$-\frac{\mu'(n)\pi(n)(1-T'(z(n)))(1-\bar{g}(n))}{\mu(n)\varepsilon(n)l(n)}\Bigg]\frac{1-F(n)}{nf(n)}$$

If monopsony power does not vary with ability (i.e., $\mu'(n) = 0$), the last two terms cancel. Substituting $\mu(n) = \bar{\mu}(n) = \mu$ gives equation (4.11) from Proposition 4.1.

From equation (4.68) it follows immediately that the optimal marginal tax rate is zero at the top: $T'(z(n_1)) = 0$. To show that the optimal marginal tax rate is generally positive, note that monopsony power is non-increasing: $\mu'(n) \leq 0$. Moreover, $\bar{g}(n) \leq 1$ and from the profit-maximization condition (4.4) it follows that the marginal tax rate cannot exceed one at an interior solution. Hence, all terms on the right-hand side of equation (4.68) are non-negative.

Appendix F: Impact of monopsony power on optimal marginal tax rates

To derive an expression for the optimal marginal tax rate if the utility function is iso-elastic (i.e., $\phi(l) = l^{1+1/\varepsilon}/(1 + 1/\varepsilon)$), substitute $\varepsilon(n) = \varepsilon$ in equation (4.11) and use the definition of $a(n)$. Rearranging gives the result from Corollary 4.1:

$$T'(z(n)) = \frac{\mu(1-\tau)\Sigma + (1-\mu)(1+1/\varepsilon)(1-\bar{g}(n))}{a(n) + (1-\mu)(1+1/\varepsilon)(1-\bar{g}(n))}. \tag{4.69}$$

This is a closed-form solution for the optimal marginal tax rate. To determine how the latter varies with monopsony power, differentiate equation (4.69) with respect to μ to find

$$\frac{\partial T'(z(n))}{\partial \mu} = \frac{a(n)((1-\tau)\Sigma - \left(1+\frac{1}{\varepsilon}\right)(1-\bar{g}(n))) + (1-\tau)\Sigma\left(1+\frac{1}{\varepsilon}\right)(1-\bar{g}(n))}{(a(n) + (1-\mu)\left(1+\frac{1}{\varepsilon}\right)(1-\bar{g}(n)))^2}. \tag{4.70}$$

Equation (4.70) is positive if and only if the numerator is positive. Because $\bar{g}(n_0) = 1$, this is always the case at the bottom of the income distribution if $(1-\tau)\Sigma > 0$. At higher ability levels, the impact of monposony power on optimal tax rates is generally ambiguous. To see why, note that $\bar{g}(n) < 1$ for all $n > n_0$ if the government wishes to reduce inequality generated by differences in ability. To derive the result from the corollary, divide the numerator in equation (4.70) by $a(n)(1-\tau)\Sigma(1-\bar{g}(n)) > 0$. The resulting expression is positive if and only if

$$((1-\tau)\Sigma))^{-1} < ((1+1/\varepsilon)(1-\bar{g}(n)))^{-1} + a(n)^{-1}. \tag{4.71}$$

Appendix G: Welfare effect of raising monopsony power

This Appendix analyzes the welfare effect of a proportional increase in monopsony power by α percent, starting from a situation where monopsony power might vary with ability. Hence, after the increase monopsony power is $\hat{\mu}(n) = \mu(n)(1+\alpha)$. Welfare is then given by

$$\begin{aligned}\mathscr{L}(\alpha) = \int_{n_0}^{n_1} \Bigg[\Bigg(& g(n)\upsilon(n) + (1-\Sigma)(1-\tau)\pi(n) + \eta\Bigg(nl(n) - \upsilon(n) - \phi(l(n)) \\ &- (1-\tau)\pi(n) - G\Bigg)\Bigg) f(n) + \chi(n)\frac{\phi'(l(n))}{n}\left((1-\mu(n)(1+\alpha))l(n) - \frac{\mu'(n)}{\mu(n)}\pi(n)\right) \\ &+ \chi'(n)\upsilon(n) + \lambda(n)\left(\mu(n)(1+\alpha)l(n) + \frac{\mu'(n)}{\mu(n)}\pi(n)\right) + \lambda'(n)\pi(n) + \psi(n)l(n)\Bigg]dn \\ &+ \chi(n_0)\upsilon(n_0) - \chi(n_1)\upsilon(n_1) + \lambda(n_0)\pi(n_0) - \lambda(n_1)\pi(n_1) + \xi\pi(n_0). \end{aligned} \tag{4.72}$$

which is the optimized Lagrangian (4.46) evaluated at $\hat{\mu}(n) = \mu(n)(1+\alpha)$. Here I used the fact that the increase in monopsony power is proportional, which implies

$$\frac{\hat{\mu}'(n)}{\hat{\mu}(n)} = \frac{\mu'(n)(1+\alpha)}{\mu(n)(1+\alpha)} = \frac{\mu'(n)}{\mu(n)}. \tag{4.73}$$

By the Envelope theorem, the welfare effect is

$$\frac{\partial \mathcal{W}(\alpha)}{\partial \alpha} = \frac{\partial \mathscr{L}(\alpha)}{\partial \alpha} = \int_{n_0}^{n_1} \left(-\chi(n)\frac{\phi'}{n} + \lambda(n)\right)\mu(n)l(n)dn. \tag{4.74}$$

Next, use equations (4.59) and (4.63) to substitute out for $\chi(n)$ and $\lambda(n)$. This leads to equation (4.19) as stated in Proposition 4.3:

$$\frac{\partial \mathcal{W}(\alpha)}{\partial \alpha} = \int_{n_0}^{n_1} \left[\frac{\phi'(l(n))}{n}\int_{n}^{n_1}(1-g(m))f(m)dm - (1-\tau)\Sigma\int_{n}^{n_1}\frac{\mu(m)}{\mu(n)}f(m)dm\right.$$

$$+\int_{n}^{n_1}\frac{\mu'(m)}{\mu(n)}\frac{\phi'(l(m))}{m}\left(\int_{m}^{n_1}(1-g(s))f(s)ds\right)dm\Bigg]\mu(n)l(n)dn. \quad (4.75)$$

This expression simplifies considerably if monopsony power does not vary with ability. The term in the second line of equation (4.75) cancels. Substituting $\mu(n)=\mu$ gives

$$\frac{\partial\mathcal{W}(\alpha)}{\partial\alpha}= \quad (4.76)$$
$$\int_{n_0}^{n_1}\Bigg[\mu\underbrace{\frac{\phi'(l(n))l(n)}{n}}_{=\,\upsilon'(n)/(1-\mu)}\int_{n}^{n_1}(1-g(m))f(m)dm-(1-\tau)\Sigma\underbrace{\mu l(n)}_{=\,\pi'(n)}\int_{n}^{n_1}f(m)dm\Bigg]dn.$$

Apply integration by parts with boundary conditions $\bar{g}(n_0)=1$ and $\pi(n_0)=0$:

$$\frac{\partial\mathcal{W}(\alpha)}{\partial\alpha}=\int_{n_0}^{n_1}\left[\frac{\mu}{1-\mu}(1-g(n))\upsilon(n)-(1-\tau)\Sigma\pi(n)\right]f(n)dn. \quad (4.77)$$

The latter can be simplified further after defining

$$\Sigma^{\upsilon}=-\mathrm{Cov}[\boldsymbol{\upsilon},\boldsymbol{\gamma}]\geq 0, \quad (4.78)$$
$$\Sigma^{k}=-\mathrm{Cov}[\boldsymbol{\sigma}(1-\tau)\bar{\pi},\boldsymbol{\gamma}]=\Sigma(1-\tau)\bar{\pi}\geq 0. \quad (4.79)$$

The first measures the negative covariance between labor market payoffs $\upsilon(n)$ and welfare weights $\gamma(n,\sigma)$. The second measures the negative covariance between capital income $\sigma(1-\tau)\bar{\pi}$ and welfare weights. It is proportional to the covariance between shareholdings and welfare weights introduced before. Substituting these terms in (4.77) gives

$$\frac{\partial\mathcal{W}(\alpha)}{\partial\alpha}=\frac{\mu}{1-\mu}\Sigma^{\upsilon}-\Sigma^{k}. \quad (4.80)$$

From this relationship, it immediately follows that if the tax system is optimized, an increase in monopsony power raises welfare if and only if (cf. Proposition 4.2)

$$\mu\Sigma^{\upsilon}>(1-\mu)\Sigma^{k}. \quad (4.81)$$

As stated in the main text, it is possible to derive an expression for the welfare effect of raising monopsony power in terms of exogenous variables if the utility function is iso-elastic: $\phi(l) = l^{1+1/\varepsilon}/(1+1/\varepsilon)$. To see this, recall that Corollary 4.1 gives a closed-form expression for the marginal tax rate:

$$T'(z(n)) = \frac{\mu(1-\tau)\Sigma + (1-\mu)(1+1/\varepsilon)(1-\bar{g}(n))}{a(n) + (1-\mu)(1+1/\varepsilon)(1-\bar{g}(n))}, \tag{4.82}$$

provided $a(n) \geq \mu(1-\tau)\Sigma$. Labor effort can then be determined from equation (4.4):

$$l(n) = n^{\varepsilon} \left(\frac{a(n) - \mu(1-\tau)\Sigma}{a(n) + (1-\mu)(1+1/\varepsilon)(1-\bar{g}(n))} \right)^{\varepsilon} \tag{4.83}$$

and $l(n) = 0$ if $a(n) < \mu(1-\tau)\Sigma$. Denote by $n' \geq n_0$ the participation threshold, which is the highest ability level where the non-negativity constraint on labor effort $l(n) \geq 0$ binds. Substituting the above in equation (4.75) and setting $\mu(n) = \mu$ and hence, $\mu'(n) = 0$ gives

$$\begin{aligned} \frac{\partial \mathcal{W}(\alpha)}{\partial \alpha} = \int_{n'}^{n_1} \mu \Bigg[\left(\frac{a(n) - \mu(1-\tau)\Sigma}{a(n) + (1-\mu)(1+1/\varepsilon)(1-\bar{g}(n))} \right) (1-\bar{g}(n)) - (1-\tau)\Sigma \Bigg] \\ \times (1-F(n)) n^{\varepsilon} \left(\frac{a(n) - \mu(1-\tau)\Sigma}{a(n) + (1-\mu)(1+1/\varepsilon)(1-\bar{g}(n))} \right)^{\varepsilon} dn, \end{aligned} \tag{4.84}$$

which is expressed solely in terms of exogenous variables.

To derive the result from Corollary 4.2, note that equation (4.81) gives a necessary and sufficient condition to determine if an increase in monopsony power raises welfare. Next, write

$$\begin{aligned} \Sigma^{\upsilon} &= \int_{n_0}^{n_1} (1-g(n))\upsilon(n) f(n) dn = \int_{n_0}^{n_1} (1-g(n))(z(n) - T(z(n)) - \phi(l(n))) f(n) dn \\ &= \int_{n_0}^{n_1} (1-g(n))(z(n) - T(z(n))) f(n) dn - \int_{n_0}^{n_1} (1-g(n))\phi(l(n)) f(n) dn \\ &= -\mathrm{Cov}[\boldsymbol{z} - T(\boldsymbol{z}), \boldsymbol{\gamma}] - \int_{n_0}^{n_1} (1-g(n))\phi(l(n)) f(n) dn \\ &= \Sigma^{\ell} - \int_{n_0}^{n_1} (1-g(n))\phi(l(n)) f(n) dn. \end{aligned} \tag{4.85}$$

Because $g(n)$ is weakly decreasing in ability and averages to one, the second term on the last line of equation (4.85) is non-negative if labor effort is weakly increasing in ability. Therefore, $\Sigma^{\ell} \geq \Sigma^{\upsilon}$ if $l'(n) \geq 0$. In that case, an increase in monopsony power raises welfare only if

$$\mu\Sigma^{\ell} > (1-\mu)\Sigma^{k}. \tag{4.86}$$

Unlike equation (4.81), this condition is only necessary and not sufficient.

Appendix H: Additional figures

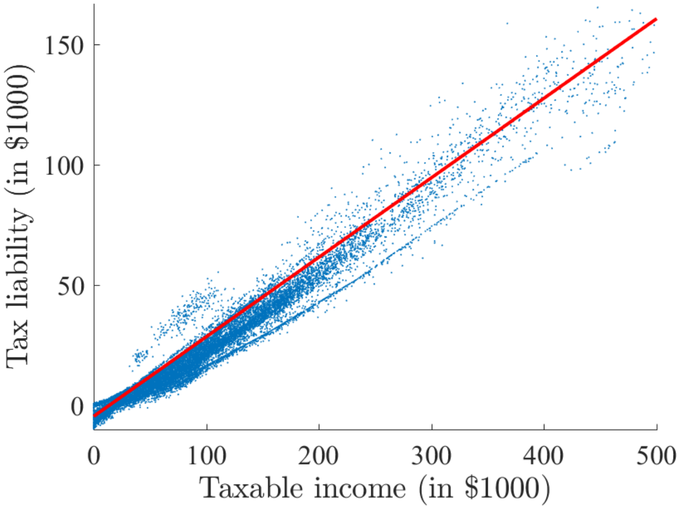


Figure 4.4: Current tax schedule

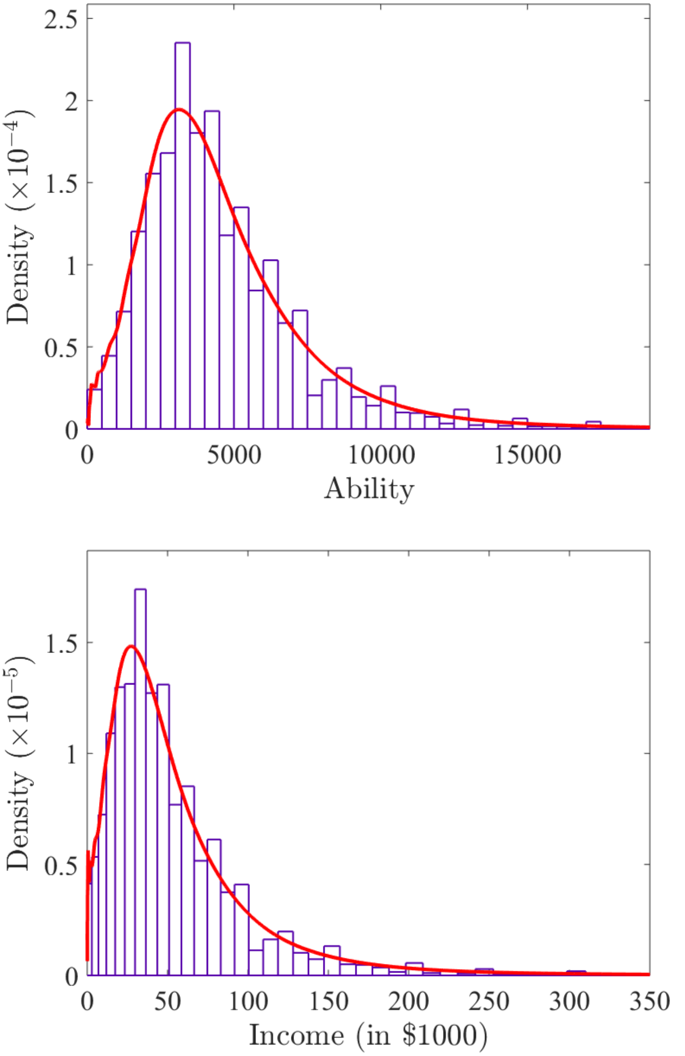


Figure 4.5: Distribution of ability and income

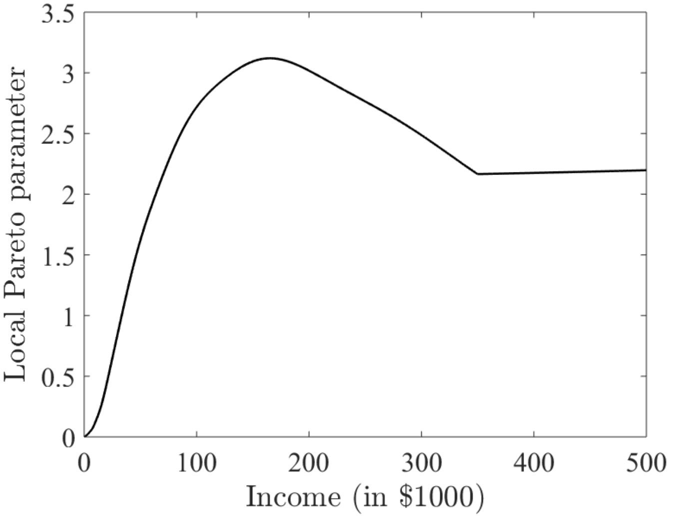


Figure 4.6: Local Pareto parameter

Nederlandse Samenvatting (Summary in Dutch)

De arbeidsmarkt wijkt in belangrijke opzichten af van het ideaalbeeld van perfecte concurrentie. Dit proefschrift onderzoekt de gevolgen van imperfecties in de arbeidsmarkt voor belastingbeleid en de maatschappelijke welvaart.

Vakbonden spelen een belangrijke rol bij de totstandkoming van lonen en werkgelegenheid. In Hoofdstuk 2 onderzoek ik samen met Bas Jacobs hoe de overheid hiermee rekening dient te houden bij het bepalen van de inkomstenbelastingen. Hiervoor analyseren we een model waarin lonen worden bepaald tijdens onderhandelingen tussen vakbonden en werkgevers. Vakbonden zorgen ervoor dat lonen boven het marktruimende niveau komen te liggen, hetgeen resulteert in onvrijwillige werkloosheid. Als reactie hierop is het wenselijk dat de overheid de belastingen op arbeid verlaagt. Een lagere belastingdruk matigt de looneisen van vakbonden en zorgt ervoor dat bedrijven meer werknemers in dienst nemen. Optimale belastingen zijn daarom lager met vakbonden dan wanneer lonen enkel door vraag en aanbod worden bepaald. Daarnaast tonen we aan dat een verhoging van de invloed van vakbonden mogelijk een positief welvaartseffect heeft. Dit is het geval als subsidies op arbeidsparticipatie ervoor zorgen dat de werkgelegenheid inefficiënt hoog is. Echter, wanneer arbeidsparticipatie wordt belast – zoals het geval is in de meeste landen – zal een verhoging van de invloed van vakbonden een negatief effect hebben op de welvaart. We illustreren onze bevindingen door het model te kalibreren op basis van Nederlandse data. De resultaten suggereren dat optimale belastingen een stuk lager zijn als er rekening wordt gehouden met de invloed van vakbonden. Daarnaast hebben vakbonden in de meeste simulaties een negatief welvaartseffect, maar deze bevinding is gevoelig voor de aannames over de herverdelingsvoorkeuren van de overheid.

Het risico om werkloos te worden is slecht verzekerbaar en ongelijk verdeeld. Hoe dient de overheid met dit risico rekening te houden bij het bepalen van de inkomstenbelastingen? Deze vraag staat centraal in Hoofdstuk 3. Anders dan in het tweede hoofdstuk is werkloosheid niet het gevolg van te hoge loonkosten, maar van zoekfricties: het vinden van een geschikte baan kost tijd en moeite. De keuze om verder te zoeken naar een betere baan wordt op twee manieren beïnvloed door belastingen. Enerzijds verlaagt het *marginale* tarief de baten van een hoger loon. Anderzijds verlaagt het *gemiddelde* tarief het besteedbaar inkomen en daarmee de opportuniteitskosten van verder zoeken. Een stijging (daling) in het marginale (gemiddelde) tarief leidt daarom tot een daling in de werkloosheid, hetgeen een positief effect heeft op de openbare financiën. Ik laat zien dat de invloed van werkloosheid op de optimale tariefstructuur cruciaal afhangt van de elasticiteit van werkloosheid naar het gemiddelde en marginale tarief. Daarnaast laat ik zien dat als de overheid arbeidsparticipatie wenst te subsidiëren (bijvoorbeeld via de arbeidskorting), een dergelijke subsidie eerst zou moeten toenemen in arbeidsinkomen alvorens deze wordt weg belast. Tot slot doe ik een kwantitatieve analyse door het model te kalibreren op basis van Amerikaanse data. Hieruit blijkt dat werkloosheid de economische kosten van belastingheffing verhoogt, met name bij lage inkomens. Voor elke $1 die de Amerikaanse overheid ophaalt door de tarieven aan de onderkant te verhogen, verliest zij circa $0.03 als gevolg van de invloed van belastingen op de werkloosheid.

Een zeer actueel beleidsthema is de toenemende marktmacht van bedrijven, die met name in de VS vaak wordt gelinkt aan de groeiende ongelijkheid. In Hoofdstuk 4 stel ik de vraag hoe de overheid haar belastingbeleid hierop dient aan te passen en wat de welvaartseffecten van een dergelijke toename zijn. Hiervoor analyseer ik een model waarin bedrijven lonen betalen die lager liggen dan de arbeidsproductiviteit, bijvoorbeeld als gevolg van een gebrek aan concurrentie op de arbeidsmarkt. Individuen vergaren inkomen uit arbeid en kapitaal en verschillen in hun arbeidsproductiviteit en aandelenbezit. Een toename in de marktmacht voor bedrijven (in vaktermen, *monopsoniemacht*) verhoogt de ongelijkheid in kapitaalinkomen, maar verlaagt de ongelijkheid in arbeidsinkomen. De gevolgen voor de maatschappelijke welvaart zijn daarom niet eenduidig. Daarnaast zorgt een toename in monopsoniemacht ervoor dat een deel van de effectieve belastingdruk wordt verschoven van werknemers naar aandeelhouders. Zodoende kunnen belastingen op arbeidsinkomen worden gebruikt om indirect kapitaalinkomen te belasten, maar zijn ze een minder effectief middel om arbeidsinkomen te herverdelen. In een poging deze effecten te kwantificeren, kalibreer ik het model op basis van Amerikaanse data. De analyse suggereert dat monopsoniemacht de optimale marginale tarieven aan de onderkant verhoogt, terwijl de optimale tarieven bij middelhoge en hoge inkomens juist lager uitvallen. Daarnaast kunnen de baten van het terugdringen van monopsoniemacht (bijvoorbeeld door competitiebeleid) oplopen tot maar liefst 8.37% van het BBP.

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