THE UNIVERSITY OF CHICAGO

OPTIMAL LABOR INCOME TAXES, INCOMPLETE MARKETS, AND LABOR MARKET POWER

A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE SOCIAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

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CHICAGO, ILLINOIS
JUNE 2022

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Acknowledgments

I am greatly indebted to my advisor, Prof. Simon Mongey, for his guidance and support in the development of my research. I am grateful for his constant encouragement, tremendous efforts, and insights he provided throughout the years.I have learned immensely from him in research and mentorship, and he greatly influenced the researcher I have become.

I am also extremely thankful to my committee members, Prof. Fernando Alvarez and Prof. Greg Kaplan for their invaluable guidance, encouragement, and support. I am also grateful to Michael Golosov for his insightful advice. In addition, I thank Erik Hurst, Veronica Guerrieri, Yu-ting Chiang, Negar Matoorianpour, Ali Shourideh, Thibaut Lamadon, and seminar participants at the University of Chicago for their constructive suggestions and feedback.

I am immensely grateful to my family for supporting me in every possible way. I thank my father for his encouragement, guidance, and utmost belief in my potential which always pushed me to improve myself. I thank my mother for her moral support at every step I took, and I am thankful to my sister for her continuous insights and support. I would like to express my gratitude to my friends for the moral support and joy that they brought throughout these years.

Abstract

What are the implications of imperfect competition in labor markets for optimal labor income taxes? I study this question in an Aiyagari (1994) incomplete-market economy with idiosyncratic risk, borrowing constraints, and a new feature that jobs are differentiated from workers' perspectives and firms have wage-setting power. First, under a restricted class of tax policies, as in Heathcote et al. (2017), the government can choose taxes such that the allocation coincides with the one implied by optimal taxes in an economy with competitive labor markets. Second, I develop intuition for this result by studying unrestricted tax policies in a static economy with fixed heterogeneity in skills. In particular, I provide analytical expressions that relate optimal taxes with and without labor market imperfections in this environment to their counterparts in the Aiyagari economy. Third, when calibrated to recent measures of labor market power, optimal taxes in the Aiygari economy increase welfare by 0.2% and output by 0.9% relative to US policy. Optimal taxes are less progressive, and implied markdowns are narrower. Finally, I provide expressions for how equilibrium markdowns are determined by the distribution of workers' assets and productivity, and I use these to unpack how changes in borrowing constraints and idiosyncratic risk affect labor market power and, hence, optimal taxes.

Chapter 1

Introduction

Redistributive policies are designed with considerations of the trade-off between equity and inefficiency. On the one hand, these policies decrease inequality and provide insurance against uninsured idiosyncratic income shocks, but, on the other hand, they create distortions in individuals' consumption, labor, and saving choices. Labor income taxes, in particular, target labor supply decisions in order to increase welfare through this trade-off. Imperfect competition in labor market, which has been studied extensively in the market power literature, influences the equity-efficiency trade-off; however, most works in the optimal taxation literature have abstracted away from it. In this paper, I study the link between labor market power and optimal labor income taxes, which is demonstrated in Figure 1.1. Labor income tax policy affects workers' decisions, and this policy especially targets labor supply decisions and, consequently, changes the elasticity of the labor supply. The elasticity of labor supply determines the level of markdowns and, hence, wages. Changes in wages influence the distribution of income and assets and distort workers' decisions; therefore they affect the equity-efficiency tradeoff, which lies at the center of tax policy design.

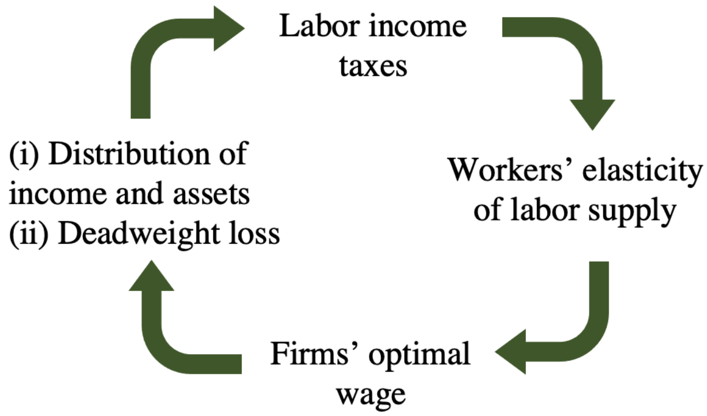


Figure 1.1: Relationship between optimal labor income taxes and labor market power

Therefore, a natural question that rises is, *"what are the implications of firms' labor market power for optimal labor income taxes"*? I answer this question by incorporating a model of monopsony into a dynamic heterogeneous agent framework with incomplete markets and parametric taxes (Aiyagari model) and derive *explicit theoretical* and *quantitative* results for optimal taxes. Additionally, to illustrate the intuition behind the results, I examine a simpler economy with unrestricted taxes (Mirrlees model) and infer analytical results that support findings of the Aiyagari model.

My main model builds on an Aiyagari [1994] economy, a canonical workhorse of incomplete markets that provides a rich framework for analyzing the cost-benefits of taxation. In this environment, individuals face private labor productivity shocks and a borrowing constraint, which prevents efficient sharing of idiosyncratic shocks. The embedded model of monopsonistic competition is based on the work of Card et al. [2018], wherein individuals have preferences for non-pecuniary characteristics of firms. These preferences create inelastic labor supplies for firms and generate variable markdowns. I demonstrate how the elasticity of the labor supply that firms face is related to the distribution of individuals' elasticity of labor supply and a structural parameter that controls the wage-amenity tradeoff. I assume firms have the same productivity, which results in the same markdown. The model abstracts from public debt and assumes that the government collects taxes to fund its expenditures, set at an exogenous level $\overline{G}$. Similar to Heathcote et al. [2017], I restrict labor income taxes to the following set of tax and transfer functions: $T(y) = y - \lambda y^{1-\tau}$. Heathcote et al. [2017] show that this class of functions provides a good approximation of the actual tax and transfer system in the U.S. In addition, Heathcote and Tsujiyama [2021] argue the optimal tax function in this class approximates the optimal non-parametric taxes closely in their setting.

The theoretical findings from the Aiaygari model are as follows:

i. Labor income taxes can remove the distortions caused by labor market power and the government can retain the same allocation as in an economy without labor market power.

ii. I link the optimal taxes in an economy with monopsonistic competition (a.k.a. "optimal taxes under monopsony") to the ones in an economy with a competitive labor market (a.k.a. "optimal taxes under perfect competition"). The optimal taxes under monopsony are equal to a stretch of the optimal taxes under perfect competition plus a subsidy. Proposition 1 explicates this relationship as follows:

$$T_m(y) = T_c\left(\frac{1}{v^*}y\right) - \frac{1-v^*}{v^*}y$$

iii. The optimal taxes under monopsony decrease as the level of monopsonistic competition increases. This implies that the level of optimal taxes under monopsony is lower than its counterpart under perfect competition. Although the level of optimal taxes is affected by the existence of labor market power, the progressivity of taxes stays untouched.

iv. As shown above, the expression for optimal monopsony taxes depends on the equilibrium level of markdowns, which are endogenous in the model. Hence, the key to finding the optimal policy is to derive the equilibrium level of the markdown, where markdown is determined by the elasticity of the labor supply as $v^* = \frac{\xi^*}{1+\xi^*}$. I provide a novel characterization of labor supply elasticity—expression (2.15)—which enables me to unravel the equilibrium level of labor supply elasticity and markdown

$$\xi = \int s(a_i, e_i; w)\Big(\eta l(a_i, e_i; w)^{1+\frac{1}{\psi}} + \frac{\partial \log l(a_i, e_i; w)}{\partial \log w}\Big) di$$

where $l(a_i, e_i; w)$ and $s(a_i, e_i; w)$ are the conditional labor supply and the effective employment share of worker i—with asset a_i and skill e_i—in a firm, respectively. Proposition 1 declares $s(a_i, e_i; w)$, $l(a_i, e_i; w)$, and $\frac{d \log l(a_i, e_i; w)}{d \log w}$ are all the same under the optimal policy in economies with or without labor market power. Therefore, knowing the optimal allocation in the competitive economy and the structural parameter η is sufficient for discovering the optimal elasticity and markdown, and consequently, for procuring the optimal income tax schedule.

v. I propose a recursive algorithm for setting taxes that allows the government to find the optimal policy without knowing η.

The quantitative analysis includes (i) quantifications of the optimal taxes and welfare gains and (ii) verification of the theory. First, I calibrate the model to the US economy and estimate the current taxes and the underlying parameter of monopsonistic competition. I estimate the optimal taxes and quantify the gains of moving from the current tax system to the optimal one. The optimal tax system is less progressive relative to the current system, the marginal and average tax rates are flatter, and high-earners pay lower taxes under the optimal tax scheme. This means optimal taxes improve the outcome by creating less distortion at the cost of less redistribution toward low-skilled workers. Moving from the actual tax system to the optimal one, welfare improves by 0.2 percent. Second, I validate the theory through numerical analysis. Estimates of the optimal taxes under monopsony and perfect competition verify that progressivity stays fixed and the level of taxes follows the theoretical derivations.

To illustrate the key insights, I introduce a static model with unrestricted taxes, in the spirit of Mirrlees [1971], and I derive optimal income taxes under monopsony. Mirrleesian models do not impose any parametric assumptions on the shape of the tax function and only consider informational frictions that restrain the government from implementing the first-best solution. In these settings, the problem is written as a mechanism design problem for a social planner that has imperfect information. The Revelation Principle is applied to solve for a direct mechanism that maximizes welfare subject to equilibrium conditions and incentive compatibility constraints. In my setting, workers have private information about their types (skills and preferences over jobs), which are unobserved by the government. The government imposes taxes on the firms' profits and workers' labor income. Labor income taxes are set to maximize social welfare subject to the government's budget constraint, equilibrium conditions, and incentive-compatibility constraints.

The analysis of the Mirrlees model suggests that, similar to the Aiyagari model, labor income taxes can correct the distortions caused by the labor market power and achieve the second-best allocation. The intuition becomes clear in the Mirrlees model: at each skill level, the optimal taxes under monopsony are equal to the ones under perfect competition plus a subsidy equal to the forgone income from the labor market power. This means that the government, through its use of labor income taxes, can incentivize workers to work as much as they would in an economy without labor market power.

Note that the findings of the two models indicate that even though the set of parametric taxes considered in the Aiyagari model is simple, it is flexible enough to undo the effect of labor market power.

Moreover, it is worth mentioning that perhaps the best tool to address market power is anti-trust policies. However, in the absence of such policies, or when their impact is insufficient to remove the market power, the labor income taxes can act as Pigovean taxes by offseting the distortions from labor market power.[1]

The framework I provide here is an important first step towards understanding the effects

1. Eeckhout et al. [2021] also show the role of taxes to correct externalities where there is market power in product market.

of monopsony on optimal tax design. It can be used as a benchmark to analyze the problem in more complex economies—for instance, in economies that have a richer asset structure or worker heterogeneity. It also can be employed to explore the effect of policies that target wages and inequality, such as a minimum wage policy. An important extension of the model is when firms have different productivities and wages are differentiated. Although the analytical results depend on the assumption of symmetry of the firms and do not carry over, I show that, with minimal modifications, the quantitative framework can be exploited to derive the optimal taxes under monopsony.

Related literature. My paper is related to several strands of literature. First, it is pertinent to the literature on optimal income taxation in incomplete markets models. Recent papers from Conesa and Krueger [2006], and Heathcote et al. [2017], Boar and Midrigan [2021], Heathcote and Tsujiyama [2021] have addressed the optimal taxation problem à la Ramsey [1927] in economies with worker heterogeneity and incomplete insurance markets. However, in these works firms are assumed to be wage-takers. My paper adds to this literature by introducing a new channel through which taxes affect the labor supply and wages—through elasticities of labor supply—and by proposing a new role for labor income taxes as Pigouvian taxes that correct for distortions from labor market power.

Second, it contributes to the recent and growing body of literature on market power and optimal income taxation. The concurrent works of Eeckhout et al. [2021], Boar and Midrigan [2021], Kaplow [2021], Gürer [2021], Jaravel and Olivi [2019], Kushnir and Zubrickas [2021], da Costa and Maestri [2019], and Cahuc and Laroque [2014] study optimal income tax in conjunction with market power. My work departs from this literature with regards to the source and nature of market power; all current papers, aside from da Costa and Maestri [2019] and Cahuc and Laroque [2014], have focused on market power in the product market. Moreover, the literature mainly—except for Boar and Midrigan [2021]—has focused on the static Mirrlees problem, whereas, in addition to Mirrlees, I consider a dynamic heterogeneous agents framework with parametric taxes and incomplete markets that links the distribution of workers' income and assets to markdowns. Cahuc and Laroque [2014] exploit a model of monopsony with reservation prices, and also depart significantly from the Mirrleesian setting by abstracting from the intensive margin of labor supply. da Costa and Maestri [2019] lay out a monopsony model in which workers are randomly matched with firms according to an exogenous function and that provides strong sufficient conditions for the implementability of the second-best solution. In my model, the matching of workers to firms (as well as markdowns) is endogenous and is based on the preferences of workers for firms. Moreover, I provide explicit theoretical results that link optimal taxes under monopsony to the ones under perfect competition in the Mirrleesian setting. Kaplow [2021], Gürer [2021], and Jaravel and Olivi [2019] consider a static economy with exogeneous markups and inspect the implications of the existence of markups for optimal income taxes. Eeckhout et al. [2021] examines the optimal Mirrleesian taxation problem with workers and entrepreneurs where the root cause of market power is the limited number of firms and product differentiation. Boar and Midrigan [2021] delve into a similar question in a setting where market power arises from the assumption of differentiated products and utilizes a Kimball aggregator to generate endogenous markups. I extend this literature by first providing a rich dynamic framework with worker heterogeneity and incomplete markets to study a Ramsey taxation problem in the presence of endogenous markdowns. Second, I describe optimal taxes in a static Mirrlees model and provide theoretical results, which confirm the results of the Ramsey problem.

Lastly, my work builds on and contributes to the literature on labor market power, inequality, and sorting, reviewed by Manning [2011] and Card et al. [2018]. It contributes to the literature by linking labor supply elasticities to the distribution of income and assets, which allows the examination of policies that affect labor market participation and the distribution of income and wealth. It also connects the worker-firm matchings to the distribution of income and wealth that can demonstrate how the within- and between-firm inequality changes as a result of employing different policies.

The paper is organized as follows: Section 2 develops the Aiyagari framework with embedded labor market power and restricted labor income taxes. It characterizes the equilibrium and provides a decomposition for the elasticities of labor supply. Section 2.6 demonstrates the partial equilibrium analysis, theoretical results for taxes, calibration, and quantitative analysis. Section 3 introduces the Mirrlees model and the social planner's problem. It describes the results for optimal labor income taxes under monopsony. Section 4 concludes my paper. The Appendix contains all proofs, derivations, and supplementary materials.

Chapter 2

Aiyagari Framework

In this section, I introduce an Aiyagari economy with heterogeneities in assets, skills, and preferences for the non-monetary characteristics of jobs. The model includes intertemporal decisions and allows individuals to accumulate wealth. In the spirit of Ramsey taxation, I impose parametric assumptions on the tax and transfer function; the government's policy is restricted to the set of functions, $T(y) = y - \lambda y^{1-\tau}$. In Section 2, I relax this assumption and consider unrestricted policies in a simpler setting.

2.1 Setting

Environment. The model has an infinite horizon. There is a continuum of workers indexed by $i \in [0, 1]$. There is a large number of firms indexed by $j \in \mathcal{J}$. As in Lamadon et al. [2021], I rely on the assumption that the number of firms is large enough for the strategic interactions between firms to be ignored.[1]

Workers. Workers are heterogeneous in terms of skills e_{it}, assets a_{it}, and job-disutilities

1. An alternative is to assume there is a continuum of firms. This will lead to inifintely many choices for workers. Malmberg and Hössjer [2014] and Malmberg [2013] show how to lay out a probabilistic choice model with an inifite set of options.

$\boldsymbol{\varepsilon}_{it} = \{\varepsilon_{ijt}\}$. Their skill level follows a Markov process as

$$\log e_{it+1} = \rho \log e_{it} + \zeta_t, \quad \zeta_t \sim \mathcal{N}(0, \sigma_e) \tag{2.1}$$

In each period, workers draw a vector of job-disutilities—which are i.i.d across time, workers, and firms—from a Weibull distribution with shape parameter η; i.e.,

$$\varepsilon_{ijt} \overset{iid}{\sim} \mathcal{B}(\varepsilon; \eta) = \begin{cases} 1 - e^{-\varepsilon^{\eta}} & \varepsilon \geq 1 \\ 0 & \varepsilon < 1 \end{cases} \tag{2.2}$$

Workers' per period utility depends upon their choice of job, hours of work, and consumption as follows

$$U_{ijt} = u(c, l) - \log \varepsilon_{ijt}$$

Note ε_{ijt} is the disutility that worker i gets if he chooses to work at firm j and is different from the disutility of labor. This term reflects the preferences for the non-pecuniary characteristics of jobs, which are defined broadly and can include amenities, benefits, firm location, environment of work, and other features of the jobs. These preferences have been conventionally used in discrete choice models in IO and are also used by Card et al. [2018], Lamadon et al. [2021], Berger et al. [2021], and others in the labor literature. The differentiated preferences for the workplace is an essential feature that brings about the labor market power by generating an imperfectly elastic labor supply. Furthermore, I assume a separable isoelastic utility function for consumption and labor,

$$u(c, l) = \frac{c_{it}^{1-\sigma}}{1-\sigma} - \frac{l_{it}^{1+\frac{1}{\psi}}}{1+\frac{1}{\psi}}$$

The future discount rate is β. Workers own capital and can lend it to other workers or firms at a gross rate of return R. They earn labor income y_{it} and pay taxes $T(y_{it})$ that can be positive (taxes) or negative (transfers). Thus, their budget constraint is

$$a_{it+1} = Ra_{it} + y_{it} - T(y_{it}) - c_{it}$$

They face a borrowing constraint and can borrow up to a certain limit, b, i.e.,

$$a_{it} \geq -b \tag{2.3}$$

Firms. All firms use the same technology and produce a homogenous good according to the following Cobb-Douglas production function

$$q_{jt} = zn_{jt}^{\alpha} k_{jt}^{1-\alpha} \tag{2.4}$$

where n_{jt} is effective labor—the sum of all employees' labor productivities multiplied by their hours—and k_{jt} is capital. Capital depreciates at rate δ and firms rent capital at price $R-1+\delta$. Given their labor supply $l_{jt}^{s}(w_j)$ and interest rate, firms choose a wage and capital to maximize their profit. Firms cannot discriminate among workers; therefore, they post a single wage. Firms' profits are taxed by the government according to $t(\pi)$. [2]

Markets. Capital and goods markets are perfectly competitive; however, in the labor market firms compete monopsonistically in a Bertrand game by setting wages.

Government. Government chooses a tax and transfer function $T(y) \in \mathcal{C}$ to maximize the following utilitarian social welfare

$$\mathcal{W} = \int \widetilde{V}(a_i, e_i, \boldsymbol{\varepsilon}_i) di \tag{2.5}$$

2. I assume firms are owned by firm-owners whose values are not included in social welfare, and so the government optimally chooses to tax all the profits; however, firms remain pre-tax profit maximizers.

such that the aggregate taxes are equal to an exogeneous level of spending, $\overline{G}$, i.e., [3]

$$\overline{G} = \int T(y(a_i, e_i, \boldsymbol{\varepsilon}_i))di \tag{2.6}$$

Note that $\widetilde{V}(a_i, e_i, \boldsymbol{\varepsilon}_i)$ denotes the present value of worker i's utility.

Taxes. The class of tax functions $\mathcal{C}$ that the government has access to is defined as $\mathcal{C} = \{T(y;\tau,\lambda)|T(y;\tau,\lambda) = y - \lambda y^{1-\tau}, \forall\tau,\lambda \geq 0\}$. This class of tax functions was introduced by Feldstein [1973] and used by Persson [1983], Benabou [2000], Benabou [2002], Heathcote et al. [2017], etc, in the macro literature. Following Heathcote et al. [2017], I refer to this parametric class as HSV taxes. As noted in their paper, $1-\tau$ is the elasticity of disposable income to pre-tax income—i.e., $1-\tau = \frac{d\log(\lambda y^{1-\tau})}{d\log y}$, which is also equal to $\frac{1-T'(y)}{1-\frac{T(y)}{y}}$. Therefore, when $\tau > 0$, marginal tax exceeds average tax rate, and the tax system is considered progressive. On the other hand, when $\tau < 0$, the tax system is regressive. The case of $\tau = 0$ represents a proportional tax system. Therefore, parameter τ is a natural proxy for the degree of progressivity of taxes.

2.2 Characterization of Labor Supply and Elasticities

I begin here with the workers' problem and solve for the workers' labor supply and probabilities of selecting a job. I specify the elasticity of the labor supply, which is a key element in firms' wage-setting decisions. Furthermore, I discuss features of the monopsony model and the underlying parameter used to conduct comparative statics. One of the contributions of this paper is to solve the workers' dynamic problem with preferences over jobs—which, to the best of my knowledge, has not been tackled before—and to provide a novel decomposition of elasticity of labor supply. Throughout the paper, I analyze the stationary recursive

3. There is similar exercise in Boerma and Karabarbounis [2021].

equilibrium of the model. Thus, from now on I drop index t from the workers' and firms' problem and write the problems at the stationary state.

Workers' problem. The workers' dynamic problem can be written as follows:

$$\widetilde{V}(a_i, e_i, \boldsymbol{\varepsilon}_i) = \max_{c,l\geq 0,a',j} u(c,l) - \log(\varepsilon_{ij}) + \beta \mathbb{E}_{\boldsymbol{\varepsilon},e'|e} \widetilde{V}(a', e'_i, \boldsymbol{\varepsilon}'_i) \tag{2.7}$$

$$\text{s.t.} \quad a' = Ra_i + w_j l e_i - T(w_j l e_i) - c \tag{2.8}$$

$$a' \geq -b \tag{2.9}$$

To derive the labor supply, I reformat the workers' problem and define the conditional value function $V(a_i, e_i, w_j)$ (or simply V_{ij}) as "value of working at firm j receiving wage w_j excluding the disutility of work". I show that V_{ij} can be written as a dynamic problem independent of $\widetilde{V}_i$'s as follows

$$V(a_i, e_i, w_j) = \max_{(c,l,a')\in\Gamma(a_i,e_i,w_j)} u(c,l) + \beta \mathbb{E}_{e'|e,\boldsymbol{\varepsilon}'} \left[\max_k \left\{ V(a', e'_i, w_k) - \log(\varepsilon'_{ik}) \right\} \right] \tag{2.10}$$

where $\Gamma(a, e, w) = \{(c, l, a')|c, l \geq 0, a' \geq -b, a' = Ra + wle - T(wle) - c\}$ is the set of variables that satisfy the workers' budget constraint.

Given V_{ij}s, I derive the optimal job-choice by finding the job that maximizes $\max_j V_{ij} - \log(\varepsilon_{ij})$, and formulate individuals' stochastic labor supply. Moreover, I show (2.10) simplifies to [4]

$$V(a_i, e_i, w_j) = \max_{(c,l,a')\in\Gamma(a,e,w_j)} u(c,l) + \frac{\beta}{\eta} \Big(\mathbb{E}_{e'|e} \ln \sum_{k\in\mathcal{J}} \frac{1}{|\mathcal{J}|} e^{\eta V(a'_i, e'_i, w_k)} \Big) \tag{2.11}$$

This formula proposes a method to reduce the computational complexity of the workers' problem described in (2.7) when there are firms with different productivities and wages.

4. Proof in Appendix A.1

Job-choice probability function. I define $\rho(a_i, e_i, w_j)$ as the probability of choosing a firm with wage w_j. Because of the extreme value distribution assumption for job disutilities, the job-choice probabilities can be written in terms of the conditional value functions V_{ij}'s and the shape parameter η as follows: [5] [6]

$$\rho(a_i, e_i, w_j) = \frac{\exp(\eta V(a_i, e_i, w_j))}{\sum_k \exp(\eta V(a_i, e_i, w_k))} \tag{2.12}$$

Sorting in asymmetric firms model. Note that this expression casts light on the allocation of workers to firms—when there is heterogeneity in wages—and hints at the possibility of assortative matching. The cross-partial of $\rho(.)$ with respect to e and w indicates how the matching of workers and firms changes in response to skills and firms' productivity. I show

$$\frac{\partial \rho(a, e, w)}{\partial e \partial w} > 0, \quad \forall a, e, w$$

This implies that the more productive workers are more likely to work at high-paying firms (which are more productive firms), which, in turn, means there is *positive assortative matching.* The value of the cross-partial determines the strength of this complementarity. This result is consistent with the finding in the empirical literature regarding the assortative matching of firms and workers.

Labor supply. The labor supply for each firm is the sum of the workers' likelihood of selecting a firm times conditional labor supply scaled by skill; i.e.,

$$n^s(w_j) = \int \rho(a_i, e_i, w_j) l(a_i, e_i, w_j) e_i di \tag{2.13}$$

where $l(a_i, e_i, w_j)$ is the labor supply of worker i conditional on working at firm j.

5. See Appendix A.2

6. I write ρ as a function of the wage of a firm (w_j), not the firm itself (j), because it is the same function for all firms due to the symmetric preferences of workers.

Firms' problem. Given the labor supply from the workers' problem, each firm sets the optimal wage as follows:

$$\underbrace{\xi(w_j) := \frac{n'(w_j)w_j}{n(w_j)}}_{\text{labor supply elasticity}}, \qquad w_j = \underbrace{\frac{\xi(w_j)}{1+\xi(w_j)}}_{\text{Markdown},v_j} \tilde{z}_j \tag{2.14}$$

where $\tilde{z}_j = \alpha z_j^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{R-1+\delta}\right)^{\frac{1-\alpha}{\alpha}}$ is the marginal revenue product of labor (MRPL) at the optimal choice of capital. As expression (2.14) states, the optimal wage of monopsonist firms is less than MRPL by a markdown, which is determined by the elasticity of the labor supply.

2.3 Elasticity of labor supply

Here I characterize the elasticity of the labor supply that each firm faces. As we have seen, this elasticity is a key component in firms' decision-making processes. Firms consider two margins when choosing their wage: (i) how their wage rate affects the probability of being selected by different types of workers and (ii) how the wage affects hours each type works. The following decomposition shows how the elasticity of the labor supply is decomposed along these two dimensions and how it is linked to the distribution of workers' elasticities[7][8]

$$\xi(w_j) = \int \underbrace{\left(\frac{\rho\left(a_i,e_i,w_j\right) l\left(a_i,e_i,w_j\right) e_i}{\int \rho\left(a_h,e_h,w_j\right) l\left(a_h,e_h,w_j\right) e_h \, dh}\right)}_{\text{share of worker } i\text{'s labor out of } n_j} \times \left(\underbrace{\frac{\partial \log \rho(a_i,e_i,w_j)}{\partial \log w_j}}_{\text{Choice prob., } \xi^c_{ij}} + \underbrace{\frac{\partial \log l(a_i,e_i,w_j)}{\partial \log w_j}}_{\text{Intensive, } \xi^n_{ij}}\right) di \tag{2.15}$$

7. Note that the elasticity of the labor supply is defined for each firm, but because it is the same for all firms, I do not index it by j.

8. To derive this characterization, I assume that the number of firms is sufficiently large that the effect of an increase in one firm's wage on the distribution of assets and skills is insignificant. This is true if the number of firms goes to infinity.

The first term on the right is the expected employment share of worker i in firm j. The second term measures the sensitivity of job-choice probabilities to the wage of the firm, which I call worker-specific *elasticity of choice probabilities*. The last term represents the elasticity of hours of work (conditional on the choice of the job), namely worker-specific *elasticity of the intensive margin of the labor supply*. Hence, the elasticity of the labor supply for firm j is a weighted average of worker-specific elasticities of choice probabilities and the intensive margin of the labor supply, where weights are employment shares of different types of workers.

Using the expression for the workers' job-choice probability (2.12), applying the envelope theorem to $V(a_i, e_i, w_j)$, and employing the workers' first order condition for labor supply, we can express the cross-firm elasticity of labor supply as follows: [9]

$$\xi^c(a_i, e_i, w_j) = \eta \frac{\partial V(a_i, e_i, w_j)}{\partial w_j} w_j = \eta l_{ij}^{1+\frac{1}{\psi}} \tag{2.16}$$

The uncompensated elasticity of the intensive margin of the labor supply is linked to the marginal propensity to consume (MPC) and the elasticity of disposable income to pre-tax income as follows: [10]

$$\xi^n(a_i, e_i, w_j) = \frac{\left(1 - \sigma MPC\left(a_i, e_i, w_j\right)\right)(1-\tau)}{(1+\psi) - \left(1 - \sigma MPC\left(a_i, e_i, w_j\right)\right)(1-\tau)} \tag{2.17}$$

where, due to the form of taxes, $\tau(y)$ is constant and equal to parameter τ. Thus, I can write

$$\xi(w_j) = \eta \int \frac{\rho_{ij} l_{ij} e_i}{\int \rho_{ij} l_{ij} e_i di} l_{ij}^{1+\frac{1}{\psi}} di + \int \frac{\rho_{ij} l_{ij} e_i}{\int \rho_{ij} l_{ij} e_i di} \frac{\partial \log l_{ij}}{\partial \log w_j} di = \eta \widetilde{\xi}^c(w_j) + \xi^n(w_j)$$

9. Throughout the paper, x_{ij} is the abbreviate form of variable $x(a_i, e_i, w_j)$

10. See Appendix A.2

where ξ^n and $\widetilde{\xi}^c$ denote the overall elasticity of the intensive margin of the labor supply and the normalized (by η) elasticity of job choice probabilities, respectively.

Note that η governs the relative importance of the intensive margin to job-choice elasticities. As $\eta \to \infty$, the first term, $\eta\widetilde{\xi}^c$, goes to infinity; therefore, the elasticity of the labor supply that firms face is unbounded as well. This means firms have no market power and the labor market becomes perfectly competitive. On the other hand, when η goes to 0, workers do not switch between firms due to a change in wage ($\eta\widetilde{\xi}^c = 0$). Instead, they adjust the hours of work, and only the elasticity of intensive margin of labor supply matters for the firms. [11]

2.4 Proxy for Degree of Labor Market Power

For the purpose of the main experiment, I take η as the measure of the degree of monopsonistic competition. Here, I explain the reason for this choice. Parameter η determines the variance of job-disutility draws. Figure 2.1 displays how the variance of shocks changes with this parameter. As η goes to infinity, disutility draws become more similar and the non-monetary characteristics of firms become less important than wages; thus, firms lose market power. On the other hand, when η decreases, the dispersion of disutilities increases and firms become more distinctive from the workers' perspective; hence, the amenity-wage tradeoff changes in favor of amenities, and firms' labor market power increases. When η goes to 0, a firm faces a pool of workers who are less likely to switch their job if the firm increases its wage, although the workers respond on the intensive margin; hence, the degree of monopsonistic competition increases. At the lower bound, the labor markets for firms seem to be separated and, rather than competing monopsonistically, firms have monopsony

11. I would like to point out how the elasticity of labor supply moves along wealth, which is related to the tradeoff between the monetary and non-monetary characteristics of jobs. Ceteris paribus, a worker with higher assets cares less about the monetary benefits of a job and more about the preferences for jobs, and, thus, is less wage-sensitive and has a lower elasticity of labor supply, i.e., $\frac{\partial \xi(a_i, e_i, z_j)}{\partial a_i} < 0$.

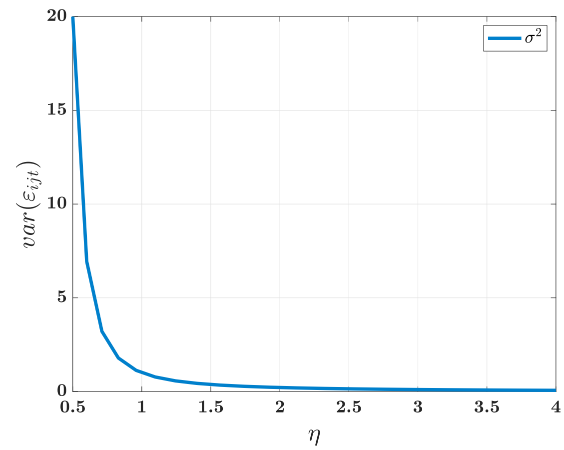


Figure 2.1: Variance of disutility draws vs parameter η

in their corresponding labor market.

Now, given any tax and transfer schedule, I characterize the stationary recursive equilibrium of the economy.

2.5 Stationary Recursive Equilibrium

Definition 1 *Given tax system $(T(y), t(\pi))$, stationary recursive equilibrium consists of (i) prices $\{w_j\}_{j\in[0,1]}$ and R, (ii) workers' and firms' decision rules $c(a_i, e_i, \boldsymbol{\varepsilon}_i)$, $l(a_i, e_i, \boldsymbol{\varepsilon}_i)$, $a'(a_i, e_i, \boldsymbol{\varepsilon}_i)$, $j(a_i, e_i, \boldsymbol{\varepsilon}_i)$, $n_j(w_j)$, and k_j, and (iii) the distribution of assets and skills $\phi(a_i, e_i)$ such that*

1. *Taking prices as given, $c(a_i, e_i, \boldsymbol{\varepsilon}_i)$, $l(a_i, e_i, \boldsymbol{\varepsilon}_i)$, $a'(a_i, e_i, \boldsymbol{\varepsilon}_i)$, $j(a_i, e_i, \boldsymbol{\varepsilon}_i)$ solve the workers' problem.*

2. *Taking $n_j(w_j)$ as given, w_j and k_j solve the firms' problem.*

3. *Capital and labor markets clear.*

4. The resource constraint and the government budget constraint are satisfied.

$$Y = C + G + \delta K, \quad G = \int T(y_i)di + \int t(\pi_j)dj$$

where Y, C, K denote the aggregate output, consumption, and capital, respectively.

5. Stationarity for the distribution of assets and skills holds.

$$\phi(a_i', e_i') = \int \int \phi(a_i, e_i) P(a_i'|a_i, e_i) P(e_i'|e_i) da_i de_i$$

$$P(a_i'|a_i, e_i) = \int \mathbf{1}\{a'(a_i, e_i, \boldsymbol{\varepsilon}_i) = a_i'\} d\mathcal{B}(\boldsymbol{\varepsilon}_i)$$

There is a symmetric equilibrium where $\forall j$, $w_j = w$, and I derive the optimal taxes under this equilibrium.

In the next section, I illustrate the relationship between elasticities and taxes and discuss the theoretical and quantitative results of the model.

2.6 Results for the Aiyagari Model

This section proceeds as follows. First, I demonstrate how taxes affect the elasticity of the labor supply. Second, I derive theoretical results that describe taxes under monopsony and display its relationship with taxes under perfect competition. Third, I calibrate the model to the US economy and specify the optimal taxes and gains from employing the optimal policy. Lastly, I propose an algorithm that converges to the optimal policy even when the preference parameter η is unknown.

2.7 Partial Equilibrium Analysis

Before laying out the optimal income tax policy, I examine how the elasticity of labor supply varies by the progressivity of taxes. I use the calibrated model[12] in section 2.9 to study the effects of a ceteris paribus change in τ—keeping w, R, $\phi(a, e)$, and λ fixed—on ξ. The elasticity of the labor supply consists of two components: the elasticity of the intensive margin of thelabor supply (elasticity of hours conditional on the job-choice) and the elasticity of job-choice probabilities. Recall the formulas for these elements,

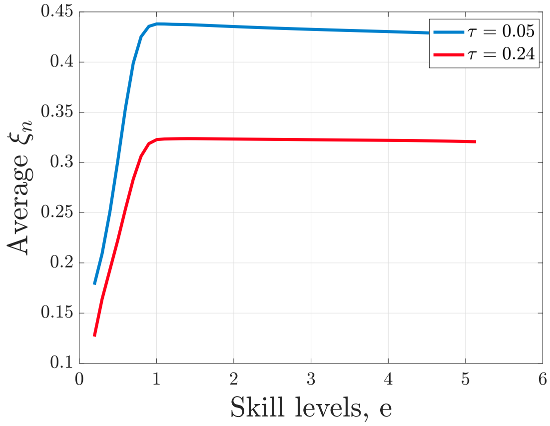
$$\xi(w_j) = \int \frac{l_{ij} e_i}{\int l_{hj} e_h dh} \left(\xi_{ij}^n + \eta \xi_{ij}^c \right) di \tag{2.18}$$

$$\xi_{ij}^n = \frac{\left(1 - \sigma MPC_{ij}\right)(1 - \tau)}{(1 + \psi) - \left(1 - \sigma MPC_{ij}\right)(1 - \tau)} \tag{2.19}$$

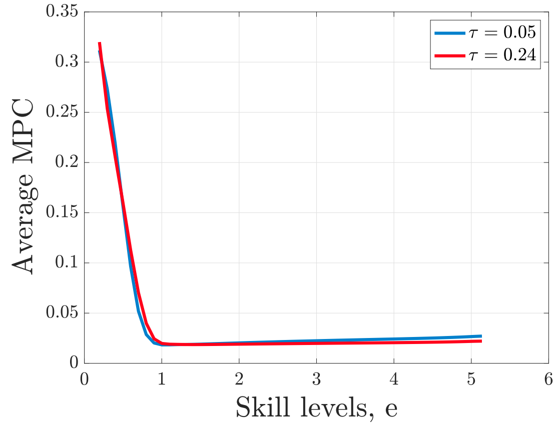
$$\xi_{ij}^c = l_{ij}^{1 + \frac{1}{\psi}} \tag{2.20}$$

To start, I explore how the first component changes in response to a change in τ. Figure 2.2a plots the average of $\xi^n(a_i, e_i, w_j)$ over a_i across different levels of e_i for two values of τ. When the progressivity increases the elasticity of hours for all individuals decreases; consequently, the overall elasticity of the intensive marginal declines. Equation (2.19) sheds light on the underlying reason: ξ_{ij}^n depends on τ directly and indirectly through MPC's. As it is shown in Figure 2.2b, while MPC's vary only slightly by τ, the direct effect of decline in τ on ξ_{ij}^n is significant and lowers the intensive margin of elasticity. Now, consider the second component of elasticity, the elasticity of job-choice probabilities (normalized by η). As equation (2.20) suggests, this term depends on the disutility of labor. Figure 2.3a shows that when τ increases, the labor supply and the disutility of labor for different workers fall, resulting in a decline in ξ^c. Figure 2.3b shows ξ^c for different values of τ. Just as both components of elasticity decrease by the progressivity of taxes, so the overall elasticity of

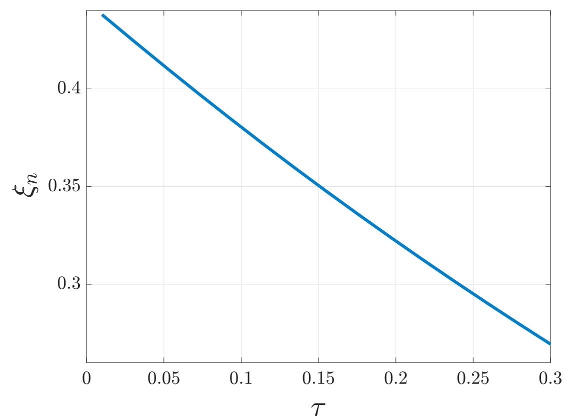
12. $\eta = 8.46, \sigma_e = 0.12, \rho_e = 0.982, \sigma = 2$



(a) Intensive margin of elasticity vs. skills



(b) MPC's vs. skills for two values of τ



(c) Intensive margin of elasticity vs. progressivity of tax

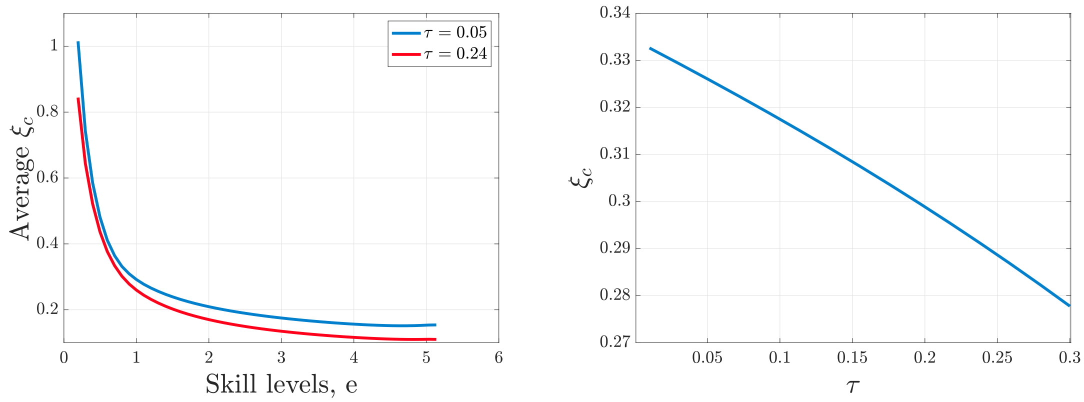
Figure 2.2: Intensive margin of labor supply elasticity

teh labor supply declines by τ as well (Figure 2.4).

2.8 Optimal Policy under Monopsony

Here I describe my key findings about optimal taxes. Because all firms set the same wage in the symmetric equilibrium, workers' choices of jobs do not interact[13] with decisions about consumption and labor and the government's problem can be written in terms of workers'

13. Workers choose their most-preferred job.



(a) Average elasticity of choice probabilities for different skills for two values of τ

(b) Elasticity of choice probabilities vs. progressivity

Figure 2.3: Elasticity of choice probabilities (extensive margin)

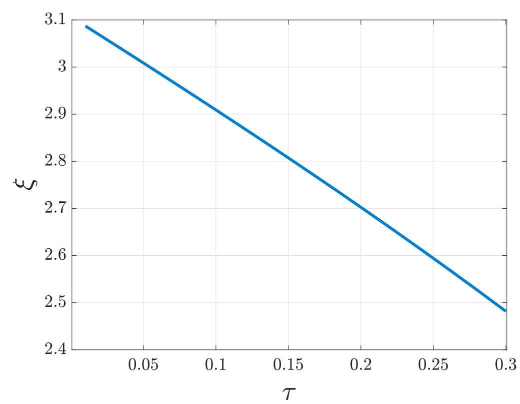


Figure 2.4: Elasticity of labor supply vs. progressivity of taxes

conditional value functions as follows:

$$
\begin{aligned}
\max_{\tau,\lambda} \quad & \mathcal{W} = \int V(a_i, e_i, w)di \\
s.t. \quad & \int \left(y_i - \lambda y_i^{1-\tau} \right) di + \Pi = \overline{G} \\
& (w, \phi(a, e), \Pi, V(.)) \in \text{symmetric equilibrium w.r.t } \tau, \lambda
\end{aligned}
$$

where Π is the aggregate profit of firms. Note that because firms' values are not weighed in the welfare function, the planner fully taxes firms—i.e., $t(\pi) = \pi$. Consequently, I have excluded this decision from the above problem.

Next I characterize the optimal labor income taxes in an economy with monopsonistic competition. The source of monopsony power in the model is the workers' idiosyncratic preferences over jobs; therefore, I study how the optimal labor income taxes change in relationship to a change in the dispersion of these preferences, which is determined by the shape parameter η. The following proposition describes the relationship between the optimal tax system under monopsonistic competition and the one under competitive labor markets[14].

From now on, I refer to an economy with labor market power as a "monopsonistic economy" and the optimal taxes and the resulting allocation in this economy as "optimal taxes and optimal allocation under monopsony". Similarly, I define "competitive economy" and "optimal taxes and allocation under perfect competition" for an economy with a perfectly competitive labor market.

Proposition 1. *Suppose* (τ_c, λ_c) *denote parameters of the optimal tax function under perfect competition, and* $l_c(a, e)$ *and* w_c *denote the equilibrium labor supply and wage in the competitive economy. In a monopsonistic economy, the government can achieve the optimal allocation of the competitive economy, while keeping its expenditure unchanged at* $\overline{G}$, *by employing labor income taxes* $T_m(y) = y - \lambda_m y^{1-\tau_m}$, *where*

$$\tau_m = \tau_c \tag{2.21}$$

$$\lambda_m = \Big(\frac{1}{v^*(\eta)}\Big)^{1-\tau_m}\lambda_c \tag{2.22}$$

$$v^*(\eta) = \frac{w_m}{w_c} = \frac{\xi^*(\eta)}{1+\xi^*(\eta)} \tag{2.23}$$

$$\xi^*(\eta) = \int \frac{e_i l_c(a_i, e_i)}{\int e_i l_c(a_i, e_i) di}\Big(\eta l_c(a_i, e_i)^{1+\frac{1}{\psi}} + \frac{\partial \log l_c(a_i, e_i; w)}{\partial \log w}\Big|_{w=w_c}\Big) di \tag{2.24}$$

14. Consider an economy without workplace differentiations or the nested case when $\eta \to \infty$.

Therefore, [15] [16] [17]

$$T_m(y) = T_c\left(\frac{1}{v^*(\eta)}y\right) - \frac{1-v^*(\eta)}{v^*(\eta)}y \tag{2.25}$$

In other words, Proposition 1 posits that the government can eliminate the inefficiencies that result from the labor market power simply by only employing a restricted labor income tax instrument, and the tax system that implements the optimal allocation in the monopsonistic economy has the same progressivity as the optimal taxes in the competitive economy.

Equation (2.25) states that the optimal taxes under monopsony are a horizontal stretch of optimal taxes under perfect competition plus a subsidy proportional to income[18]—I explain the intuition behind this relationship in more detail in Section (3). Moreover, it points out that the key to uncovering the right policy is to find the equilibrium level of markdown under this policy. Equation (2.24) provides a method to find this value using the equilibrium allocation of a competitive economy. Specifically, the government can internalize the effect of its policy on the labor supply and derive the elasticity of labor supply in the optimal allocation under perfect competition and then compute the equilibrium markdown and use it to recover the optimal taxes. However, calculating the equilibrium elasticity requires knowing η. In the next section, I calibrate the model to the current economy to estimate η and then use that estimate to find the optimal taxes. I also propose in Section 2.13 an algorithm that finds the optimal taxes without recognition of η.

Lastly, Equation (2.25) provides a basis for understanding how optimal taxes under

15. This is the elasticity w.r.t to a change in wage for one period.

16. I prove and use the fact that $\frac{\partial \log l_m(a,e;w_m)}{\partial \log w} = \frac{\partial \log l_m(a,e;w_c)}{\partial \log w}$.

17. To prove this, I show that the optimal allocation under perfect competiton is feasible in the other economy (and government's budget is balanced), and vice versa.

18. Similar results are yielded if the profits were rebated to workers equally and the government's tax and transfer has a constant term, i.e., $T_m(y) = y - \lambda_m y^{1-\tau_m} + \iota$. In this case, in addition to the relationships for tau and λ, we would have, $\iota_m = \iota_c + \pi$.

monopsony vary in response to the degree of monopsonistic competition. The next corollary illustrates this relationship.

Corollary 1. *For every income level y, the optimal taxes under monopsony are lower when the degree of labor market power—defined by the inverse of η—is higher. That is,*

$$\frac{\partial T_m(y;\eta)}{\partial \eta}\bigg|_y > 0, \quad \forall y \tag{2.26}$$

Proof. Using Proposition 1, I show that $\frac{\partial T_m(y;\eta)}{\partial \eta}\Big|_y = -\left(yT_c'(\frac{y}{v^*}) - y\right)\frac{\xi^c}{(\eta\xi^c+\xi^n)^2}$, and since $T_c'(.) < 1$, the derivative of T_m with respect to η, is always positive.

It is worth mentioning that these results depend on the assumption of the symmetry of firms. When the model is extended to firms with heterogenous productivity, Proposition 1 does not hold. Stated differently, with asymmetric firms, taxes alone cannot remove the deadweight loss from labor market power—the allocation of the competitive economy is not feasible—and there is no explicit relationship between optimal taxes under monopsony and perfect competition. The quantitative framework can be extended to determine how the optimal taxes should be adjusted in a setting with heterogenous firms.

In the following section, I calibrate the model to the current economy and estimate the structural parameter η. Then, I derive the optimal taxes under the estimated η and calculate the welfare gains of moving from the current to the optimal schedule. Finally, I analyze the effects of an increase in η on equilibrium variables under the optimal taxes.

2.9 Quantification

First, I numerically solve for the stationary recursive equilibrium of the Aiyagari economy for a given pair of (τ, λ), and then I look for the parameters that maximize the social welfare subject to the government's budget constraint. Note that for an economy with symmetric firms the workers' dynamic problem is equal to the one that exists in an economy without preferences for jobs;[19] i.e.,

$$V(a_i, e_i; w) = \max_{(c,l,a')\in\Gamma(a,e,w)} u(c,l) + \beta\mathbb{E}_{e'|e}V(a_i', e_i'; w)$$

Extension for asymmetric firms. Here I show that similar numerical analyses can be performed for asymmetric firms through simple modifications of the value function and welfare function. Equation 2.9 proposes a method to calculate the value function when wages are differentiated,

$$V(a_i, e_i, w_j) = \max_{(c,l,a')\in\Gamma(a,e,w_j)} u(c,l) + \frac{\beta}{\eta}\Big(\mathbb{E}_{e'|e}\ln\sum_{k\in\mathcal{J}}\frac{1}{|\mathcal{J}|}e^{\eta V(a_i', e_i', w_k)}\Big)$$

I show that the social welfare is equal to

$$\mathcal{W} = \frac{1}{\eta}\log\left(\sum_j\int\exp\big(\eta V(a_i, e_i, w_j)\big)di\right) + \kappa_0 \tag{2.27}$$

Using these formulas, optimal taxes can be derived for an economy with heterogeneous firm productivities.

Calibration. Now I describe the calibration strategy (for the economy with symmetric firms). I assign values to a set of parameters to estimate the actual value of η. I set the discount rate $\beta = 0.96$ and the risk aversion parameter of CRRA utility $\sigma = 2$. I take the estimate of the Frisch elasticity of the labor supply from Chetty et al. [2011], $\psi = 0.5$. The depreciation rate is $\delta = 0.06$. I take the estimates of standard deviation and the persistence of the process of skills from Boar and Midrigan [2021] and assign $\sigma_e = 0.2$ and $\rho_e = 0.982$. I set $\alpha = 0.7$ and $b = 0$. I normalize z to 1. I set $g = \frac{G}{Y} = 0.1$ to match the average ratio of

19. The firms' problem is still different because of the existence of markdowns, and it requires calculating elasticities.

personal current taxes to income, taken from Boerma and Karabarbounis [2021].

Table 2.1: Assigned parameters

Parameter	Description	Value
β	Discount factor	0.96
σ	Relative risk aversion	2
ψ	Frisch elasticity	0.5
ρ_e	Variance of process of skills	0.982
σ_e	Variance of process of skills	0.2
b	Borrowing limit	0
z	TFP	1
α	Weight of labor in production	0.7
δ	Depreciation rate	0.06
g	Government spending to GDP ratio	0.1
v	Markdown	0.74

I take the estimate of τ from Heathcote et al. [2017]. They exploit the fact that $y_{posttax} = \lambda y_{pretax}^{1-\tau}$ and match $1-\tau$ to the elasticity of post-tax income to pretax income from data, which yields an estimate of $\tau = 0.18$. Estimating η requires matching another equilibrium variable to the data. Consistent with estimates of average markdowns from Berger et al. [2021], I set v to 0.74. Using these parameters, I proceed as follows to estimate η: for a range of values of η, I find λ that satisfies the government's budget constraint and calculate the equilibrium markdown, $\widehat{v}$. Next, I find the η that minimizes the difference between the estimated and the actual markdown, $|\widehat{v} - v|$. This procedure yields estimates of η and λ. The estimated values are $\widehat{\eta} = 8.64$ and $\widehat{\lambda} = 0.68$.

Now, by maintaining the level of government expenditure as $\overline{G} = g\widehat{Y}$, I find the tax function that maximizes the utilitarian welfare under estimated $\widehat{\eta}$. The resulting parameters of the optimal tax schedule are $\tau^* = 0.15$ and $\lambda^* = 0.66$.

Table 2.2: Estimates of parameters of tax system

Parameter	Current	Optimal
τ	0.18	0.15
λ	0.68	0.66

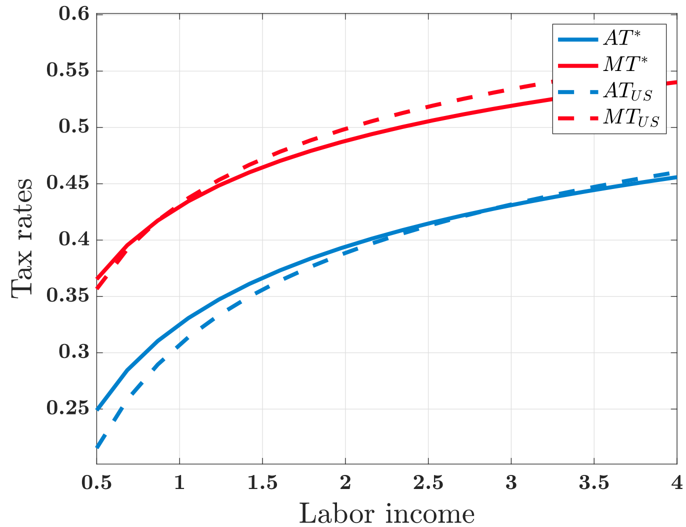
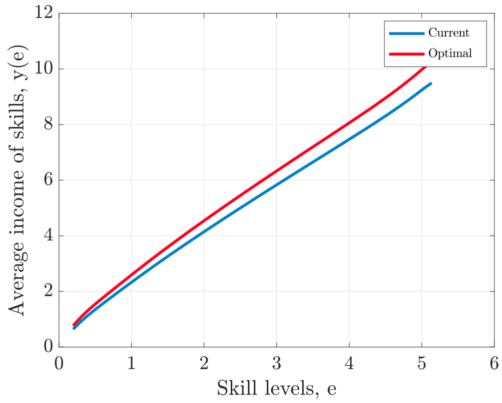


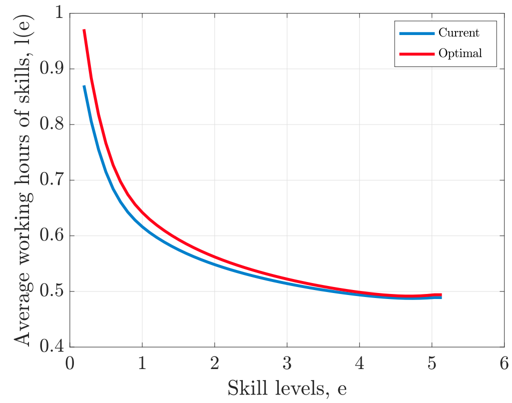
Figure 2.5: Average and marginal tax rates for optimal and real tax functions (in $100,000)

Figure 2.5 demonstrates the average and marginal tax rates for the optimal tax system versus the estimate of the current tax system. As it is apparent from the figure, the current tax system is more progressive than the optimal system. The current average and marginal tax functions are steeper and the current tax rates are higher for more productive workers. This means that the government can improve social welfare by decreasing the redistribution in favor of efficiency in order to offset the distortionary effects of labor market power. I calculate welfare and aggregate output under the estimates of optimal and actual income tax schedules. Moving from the current system to the optimal system, welfare improves by 0.2% and output by 0.9%.

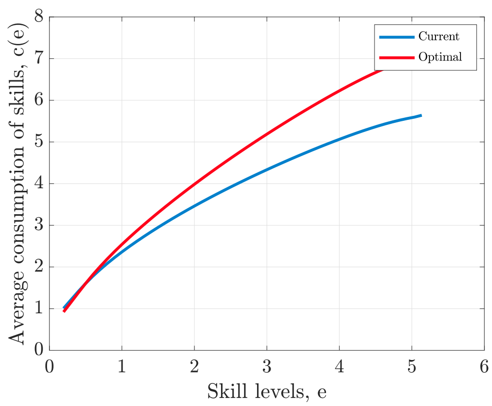
Figure 2.6 shows the average consumption, labor, assets, and income across different skill levels for the two tax systems. Under optimal taxes, due to lower progressivity, the labor supply and the pre-tax labor income are higher at all skill levels; consumption and savings of high-skilled (low-skilled) workers are higher (lower); markdown is 0.75, which is slightly higher than the estimate of markdown in the current economy (0.74). Table 2.3 summarizes these results. Less redistribution towards low-skilled increases the elasticity of the labor supply and tightens markdowns. Redistribution affects the elasticity through two



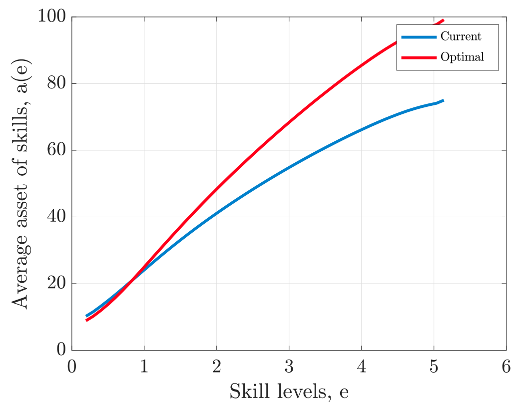
(a) Average earnings across skills



(b) Average labor across skills



(c) Average consumption across skills



(d) Average asset/saving across skills

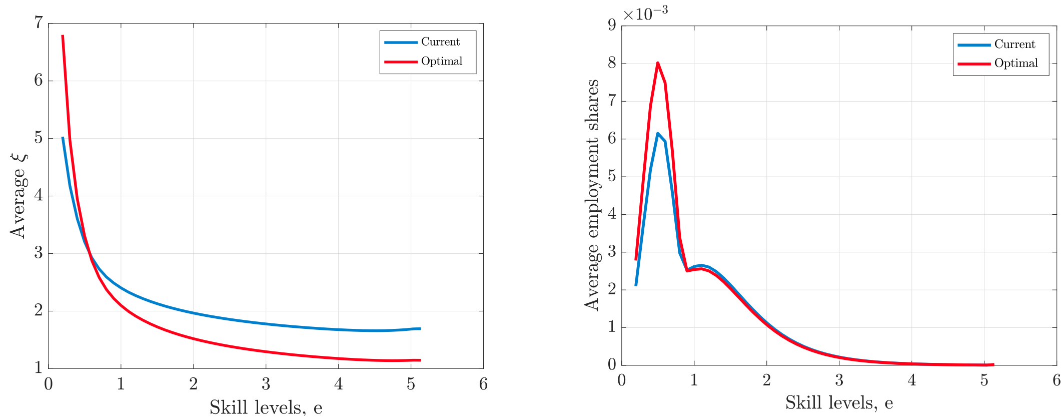
Figure 2.6: Workers' decision rule under optimal and current tax systems

Notes: Figure (a) depicts for each skill level, the average consumption across workers with different assets. Figures (b) and (c) show the similar values for saving and working hours.

channels: it changes the elasticity of individuals' labor supplies unproportionally; and it changes the employment share of workers with different skill levels. Figure 2.7a and 2.7b depict the average elasticity and employment share across skills for the two tax systems. Under optimal taxes, the elasticity of the labor supply for low-skilled workers increases, while for high-skilled workers it decreases. On the other hand, the employment share of low-skilled workers (with high elasticity) increases more as their labor supply increases relative to high-skilled workers. The aggregate effects result in an increase in the elasticity of the labor supply.

Table 2.3: Change in variables by moving to optimal tax system

Variable	Actual	Optimal	Δ%
τ	0.18	0.15	-
λ	0.68	0.66	-
υ	0.74	0.75	-
$\mathcal{W}$	-	-	0.2%
Y	5.6591	5.7046	0.9%



(a) Average elasticity of labor supply across skills

(b) Average employment share of different skills

Figure 2.7: Elasticity and employment share across skills under optimal and current tax systems

2.10 Change in Dispersion of Preferences over Jobs

This section investigates how optimal taxes and the corresponding equilibrium variables change in relationship to η—which affects the degree of monopsonistic competition. As explained in Section 2.4, the shape parameter η governs the dispersion of preferences over jobs. The smaller η is, the more dispersed disutilities are, and the more distinguished jobs are from the workers' viewpoint. In other words, workers are more attentive to the characteristics of jobs and are less wage-sensitive. This prompts the elasticity of the labor supply to be lower and consequently increases the firms' monopsony power, which translates into wider markdowns. On the other hand, as η goes to infinity, the distribution of disutilities converges to a degenerate distribution that has a single value. Therefore, at the limit, jobs are indistinguishable and the labor market becomes perfectly competitive. I start by looking for optimal taxes in such an economy where $\eta = \infty$, then I increase the degree of monopsonistic competition by lowering η, and I find the optimal policy.

2.11 Perfectly competitive labor market

Given the assigned parameters, I compute the optimal taxes that deliver $\overline{G}$ (from the previous section) in an economy with competitive labor markets. Table 2.4 summarizes values of parameters of optimal tax function and equilibrium variables. Figure 2.8 shows the optimal

Table 2.4: Optimal parameters of tax function in the competitive economy

Parameter	Value
τ_c	0.15
λ_c	0.52

marginal and average tax rates in the competitive labor market. The dashed line represents the estimate of the current tax rates.

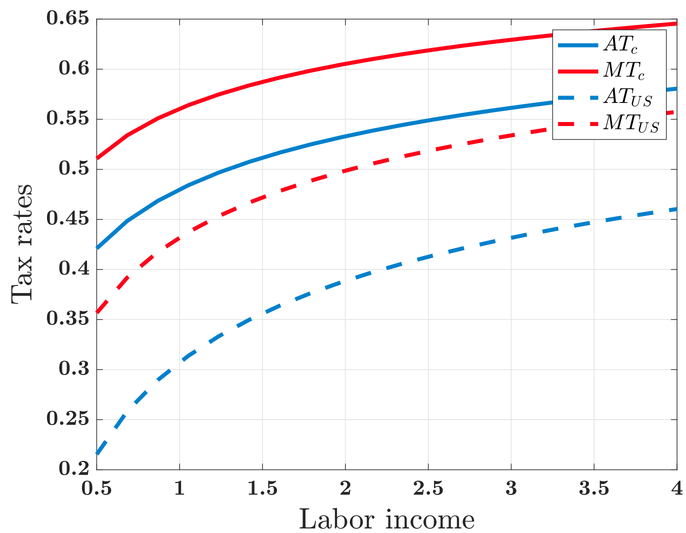


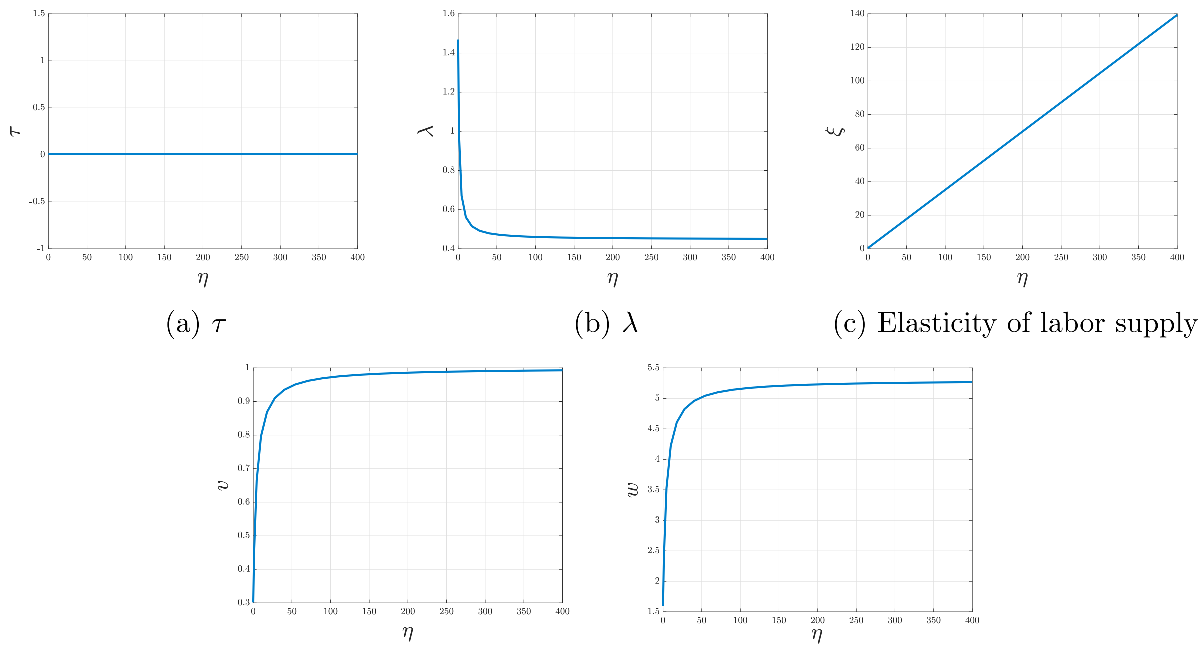
Figure 2.8: Optimal average and marginal tax rates in competitive labor market model (c) and actual tax system (US)

2.12 Monopsonistic labor market

Proposition 1 states that under the optimal policy, the government is able to eradicate the inefficiencies that result from labor market power by forcing markdowns to a level that leads to the same allocation as in an economy with no market power. Hence, under the optimal policy, a change in η does not change the equilibrium values of labor, consumption, output, welfare, and the interest rate, but it does change the wage, markdown, elasticity of the labor supply, and earnings.

I derive the optimal taxes and the resulting elasticity and markdown from the competitive market solution according to Proposition 1. Recall, $\tau_m = \tau_c$ and $\lambda_m = (\frac{1}{v^*})^{1-\tau}\lambda_c$, where $v^* = \frac{\xi^*}{1+\xi^*}$ and $\xi^* = \eta\widetilde{\xi^c} + \xi^n$; therefore, the labor supply elasticity increases linearly with η, as illustrated in Figure 2.9c. I find the values of $\widetilde{\xi^c}$ and ξ^n from the solution of the economy with a competitive labor market and infer the optimal solution for the economy with labor market power. Figure 2.9 displays how optimal parameters of the tax function and corresponding equilibrium values of labor supply elasticity, markdown, and wage vary by η. Figures 2.10a and 2.10b demonstrate how the optimal tax function changes with η. The top line in both figures represents the optimal tax rate in the competitive economy. As η decreases (the labor market becomes more monopsonistic), the government needs to lower marginal and average tax rates for all individuals to compensate for the foregone income. For any τ and λ, $y_0 = \lambda^{\frac{1}{\tau}}$ marks the level of income for which taxes are zero. Below this level, individuals receive a subsidy and above it they pay taxes. When labor market power is higher, λ_m is larger, and, consequently, y_0 is higher. The skill level that corresponds to this level under the optimal tax system e_m is where $w_m e_m l(e_m) = \lambda_m^{\frac{1}{\tau}}$, which means $e_m l(e_m) = (\frac{1}{v})^{\frac{1}{\tau}} e_c l(e_c)$. Therefore with wider v and more market power, more compensation is required and the skill level that the transfer system switches to tax, e_m, is higher.

Validation. I verify Proposition 1 through quantitative analyses. First, I calculate the



(a) τ (b) λ (c) Elasticity of labor supply

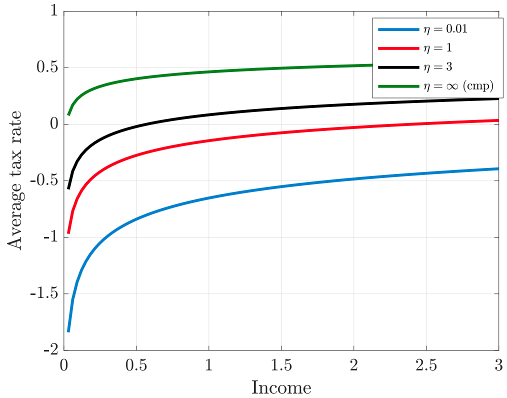
(d) Markdown (e) Wage

Figure 2.9: Optimal parameters of the tax system and implied values of ξ^*, υ^*, and w^* for different values of η.

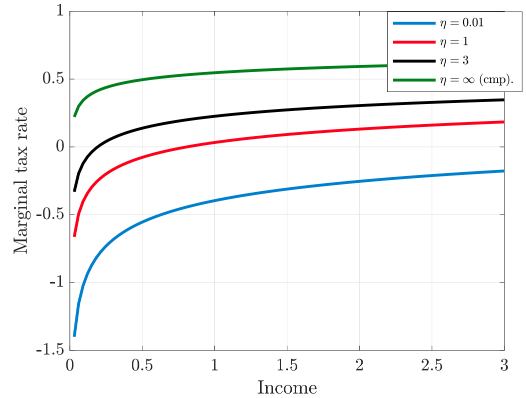
optimal tax function directly by optimizing the taxes in an economy associated with η. Second, I solve for the optimal taxes in an economy with competitive labor market and apply formula (2.22) to derive the optimal taxes under monopsony. The numbers obtained in the two approaches are consistent, which supports the theory's validity.

2.13 Robust Algorithm for Optimal Income Tax

One of the key takeaways from Proposition 1 is that the progressivity of optimal income tax does not vary by the structural parameter for the degree of monopsonistic competition, η. A consequence of this result is that if the planner in this environment fails to consider the existence of labor market power and designs an optimal tax system within the class of HSV tax and transfer functions, the planner still finds the right degree of progressivity, but the level of taxes may not be correct. This fact allows us to propose an algorithm for finding



(a) Optimal average tax



(b) Optimal marginal tax

Figure 2.10: Optimal average and marginal tax rates for different η's

the optimal labor income tax even if the policymaker does not know the underlying degree of labor market power or ignores it.

If the policymaker runs an allegedly optimal tax scheme that corresponds to a false level of η—represented by (τ, λ_0)—they encounter a budget surplus or deficit. The policymaker can then rebate the excess amount to workers or tax the shortfall from them and update λ as follows: $\lambda_1 = \lambda_0 + \frac{T_0 - G}{\int y_{i0}^{1-\tau} di}$. In the next period, the policymaker can run a tax scheme associated with the updated λ, and repeat the same process as before. I show that this algorithm converges to the λ corresponding to the true value of η.

Chapter 3

Mirrleesian Framework

The key results from the Aiyagari model are: (i) in an economy with labor market power, HSV taxes can remove the distortions from labor market power and acquire the optimal allocation in an economy with a competitive labor market; (ii) optimal taxes under monopsony are related to optimal taxes under perfect competition by $T_m(y) = T_c\left(\frac{1}{v}y\right) - \frac{1-v}{v}y$; and (iii) optimal taxes under monopsony are lower than those under perfect competition, but have the same progressivity.

To illustrate the intuition, I lay out a simpler economy with richer taxes—non-parametric Mirrleesian taxes. While I abstract away from complications in multiple dimensions, I maintain the main features of the Aiyagari framework—i.e., incomplete markets and labor market power. As in the previous model, the labor market features monopsonistic competition, which results from the workers' preferences for non-monetary characteristics of jobs. There is a benevolent planner who seeks to maximize social welfare and has access to an unrestricted labor income tax instrument. The skills and preferences (types) of individuals are unobserved by the social planner. Therefore, in addition to the budget constraint, the planner faces informational frictions, and this prevents it from attaining the first-best allocation.

Here I describe the principal characteristics that distinguish this model from the previous one:

(i) *Time:* The model is static.

(ii) *Workers:* Skills are distributed according to $F_e(e)$. Markets are still incomplete in a sense that there are idiosyncratic skill endowments that cannot be insured ex-ante.

(iii) *Inputs:* There is no capital, and labor is the only input of production.

(iv) *Production:* Each firms' production function is linear in labor, $q_j = zn_j$.

(v) *Taxes:* The government chooses an unrestricted labor income tax policy to maximize social welfare.

I call the problem that represents this economy *"Problem I."*

3.1 Equilibrium without Taxes

Before solving for the optimal taxes, I show what the equilibrium looks like without any government intervention. I assume profits are rebated to workers equally.

Allocation under monopsonistic competition with no taxes. Looking at the symmetric equilibrium of this economy, every firm faces a labor supply that has the same shape; consequently, they all set the same wage. Due to the symmetry of wages, workers' decisions about consumption and labor are not affected by the choice of workplace. I index workers by their skill level e. [1]

(i) Workers' budget constraint and first-order condition yield

$$u'(c_m(e)) = \frac{h'(l_m(e))}{w_m e} \tag{3.1}$$

$$c_m(e) = w_m e l_m(e) + \Pi, \qquad \text{where } \Pi := (z - w_m) \int e l_m(e) dF(e) \tag{3.2}$$

1. When wages are different, workers' consumption and labor decisions interact with their job choice; thus, conditional labor supply and consumptions need to be derived.

(ii) Resource constraint implies

$$\int c_m(e)dF(e) = z \int el_m(e)dF(e) \tag{3.3}$$

(iii) The equilibrium wage and markdown are determined by

$$w_m = v(w_m)z = \frac{\xi(w_m)}{1+\xi(w_m)}z \tag{3.4}$$

where ξ is the elasticity of the labor supply that firms face and v is the firms' markdown. The labor supply elasticity can be written in terms of workers' labor supplies, disutility of labor, and the shape parameter of the distribution of job-disutilities as follows: [2]

$$\xi(w_m) = \int \frac{el_m(e;w_m)}{\int el_m(e;w_m)dF(e)} \Big(\eta h'(l_m(e;w_m))l_m(e;w_m) + \frac{d\log l_m(e;w_m)}{d\log e} \Big) dF(e) \tag{3.5}$$

Competitive economy vs. monopsonistic economy. The economy with perfectly competitive labor markets can be represented either by $\eta \to \infty$ or by assuming no preferences over jobs.

The existence of labor market power and non-competitive wages affects workers' marginal rate of substitution between consumption and labor, and, thus, changes the equilibrium choices. Markdowns determine the ratio of the marginal rate of subsititution between consumption and labor in a competitive economy to that ratio in a monopsonistic economy,

$$\frac{MRS_{c,l}^{comp}}{MRS_{c,l}^{mono}} = v$$

2. Proof in Appendix [A.2].

The difference in the welfare of competitive and monopsonistic economies is

$$\Delta\mathcal{W} = \int \left(V_c(e) - V_m(e)\right) dF(e)$$

where V_c and V_m are the utility of individuals under competitive and monopsonistic competition. In an illustrative example below, I show how the welfare gap changes in response to markdowns. Note that when profits are rebated to workers, the effect of labor market power is not necessarily manifested as a loss.

Example. For quasi-linear preferences $V = \log c - l - \log \varepsilon$,[3] the difference in social welfare of monopsonistic and competitive economies is

$$\Delta\mathcal{W} = -\log v(\eta) - (1 - v(\eta))\chi$$

where $\chi = \left(\int edF(e)\right)\left(\int \frac{1}{e}dF(e)\right)$. I show that as η varies in $(0, \infty)$, markdowns vary from[4] $\frac{1}{\chi}$ to 1 (where $v = \frac{1}{\chi}$ reperesent the case of monopsony). Figure 3.1 shows how ΔW varies by markdown. Note that the negative sign of ΔW means that the welfare is higher in the economy with monopsonistic competition. This is due to the rebate of profits and the increase in leisure. Therefore, markdowns and the redistribution of profits work as a tool to increase equality. If the profits had not been distributed among workers, social welfare in a monopsonistic economy would be lower than in the competitive economy.

Now I return to the problem of the social planner described at the beginning of this section.

3. I also assume $z = 1$ and $\overline{G} = 0$.

4. Note that χ is always greater than 1.

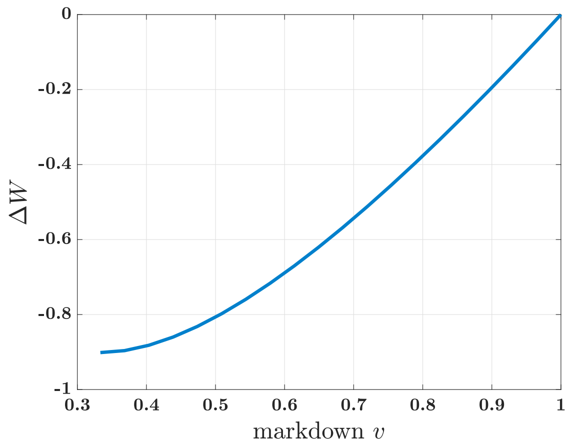


Figure 3.1: Difference in the social welfare of competitive and monopsonistic economies

3.2 Social Planner's Problem

To solve for the optimal taxes and equilibrium allocation, I assume the government takes the behavior of firms as a given and solves for the optimal taxes, subject to the workers' problem and its budget constraint. I then apply the revelation principle to the government's problem. Using the revelation principle, the allocation in this problem can be implemented by a direct and incentive-compatible mechanism. Here I explain in detail the problem with a direct truth-telling mechanism.

Suppose $\theta = (e, \boldsymbol{\varepsilon})$ denotes the type of workers[5] and is distributed according to $F(\theta)$. Workers' types are unobserved by the planner; the government only observes income and knows the distribution of θ. The planner chooses a direct mechanism $\mathcal{M} = (c(\theta), y(\theta))$ such

5. Hereafter, I iindex workers by θ instead of i.

that

$$\max_{c(\theta),y(\theta)} \int \left(u(c(\theta)) - h\left(\frac{y(\theta)}{ew_{\mu(\theta)}}\right) - \log \varepsilon_{\mu(\theta)} \right) dF(\theta) \tag{3.6}$$

$$s.t. \quad \mu(\theta) = \arg\max_j -h\left(\frac{y(\theta)}{ew_j}\right) - \log \varepsilon_j \tag{3.7}$$

$$\int c(\theta)dF(\theta) + \overline{G} = \sum_j \int \frac{z}{w_j} y(\theta) 1\{\mu(\theta) = j\} dF(\theta) \tag{3.8}$$

$$u(c(\theta)) - h\left(\frac{y(\theta)}{ew_{\mu(\theta)}}\right) - \log \varepsilon_{\mu(\theta)} \geq u(c(\widehat{\theta})) - h\left(\frac{y(\widehat{\theta})}{ew_j}\right) - \log \varepsilon_j \quad \forall \theta, \widehat{\theta}, j \tag{3.9}$$

$$w_j = w(z_j, \mathcal{M}, W_{-j}) \tag{3.10}$$

Equation (3.7) defines $\mu(\theta)$ as a worker's optimal choice of job given an income level. Condition (3.8), the resource constraint, states that the sum of aggregate consumption and government expenditure should be equal to the aggregate production. Condition (3.9) represents the incentive compatibility constraints for the workers. It posits that a worker of type θ is better off telling the truth than imitating any other type $\widehat{\theta}$. RHS of (3.9) represents the utility of worker θ from a deviation, where he works at firm j for $\frac{y(\widehat{\theta})}{ew_j}$ hours and consumes according to $c(\widehat{\theta})$. Condition (3.10) states that the government takes a firm's wage-setting behavior as a given. The firms set their wages according to workers' decision rules—resulted from mechanism $\mathcal{M}$—as follows:

$$w(z_j, \mathcal{M}, W_{-j}) = \arg\max_{\widetilde{w}} (z_j - \widetilde{w}) \int el_j(e, \widetilde{w}) \rho_j(e, \widetilde{w}, W_{-j}) dF(\theta)$$

where $l_j(e, \widetilde{w})$ denotes the labor supply given the choice of job and its wage and $\rho_j(e, \widetilde{w}, W_{-j})$ denotes the probability of selecting firm j.

I show that the optimal allocation of this problem is equal to the optimal allocation of the following problem—call it *"Problem II"*—wherein worker-job matches and wages are set by the government (firms' problem is ignored),

$$\max_{c(\theta),l(\theta),\mu(\theta),\{w_j\}} \int \left(u(c(\theta)) - h\left(l(\theta)\right) - \log \varepsilon_{\mu(\theta)}\right) dF(\theta) \tag{3.11}$$

$$s.t. \quad \int c(\theta) dF(\theta) + \overline{G} = \sum_j \int z l(\theta) 1\{\mu(\theta) = j\} dF(\theta) \tag{3.12}$$

$$\forall \theta, \hat{\theta}, j \quad u(c(\theta)) - h\left(l(\theta)\right) - \log \varepsilon_{\mu(\theta)} \geq u(c(\hat{\theta})) - h\left(\frac{w_{\mu(\hat{w})} l(\hat{\theta})}{e w_j}\right) - \log \varepsilon_j \tag{3.13}$$

I show that the mechanism in which all wages are the same and all workers are matched to their most-preferred firm is an optimal allocation of this problem and is the same allocation as in the classic Mirrlees problem with no preferences over firms (competitive economy), which is defined below,

$$\max_{c(e),l(e)} \int (u(c(e)) - h(l(e))) dF(e)$$

$$s.t. \int c(e) dF(e) + \overline{G} = z \int e l(e) dF(e) \qquad [RC]$$

$$u(c(e)) - h(l(e)) \geq u(c(\hat{e})) - h\left(\frac{l(\hat{e})\hat{e}}{e}\right), \quad \forall e, \hat{e} \qquad [IC]$$

I call this problem *"competitive Mirrlees"* and the resultin taxes the *"optimal competitive Mirrleesian taxes"*. This means that the optimal allocation in Problem I is the same as the one in competitive Mirrlees, called the *"second-best"* or *"constrained-efficient"* allocation. The first-best allocation is not feasible because of the informational friction and workers' private information about their type.

Although the optimal allocation (of consumption and labor) in Problem I and the competitive Mirrlees problem are the same, the equilibrium wages are different; consequently, the indirect taxes that implement the optimal allocation in the two economies are different. The following Proposition outlines these results.

3.3 Optimal Taxes

Proposition 2. *Suppose $T_c(y)$ represents the optimal labor income taxes in the economy with competitive labor markets and $l_c(e)$ denotes workers' labor supply in the equilibrium. In the monopsonistic economy associated with η, the planner can achieve the constrained-efficient allocation by setting labor income taxes $T_m(y)$ as follows*

$$T_m(y) = T_c\left(\frac{1}{v^*(\eta)}y\right) - \frac{1 - v^*(\eta)}{v^*(\eta)}y \tag{3.14}$$

where

$$v^*(\eta) = \frac{\xi^*(\eta)}{1 + \xi^*(\eta)} \tag{3.15}$$

$$\xi^*(\eta) = \int \frac{el_c(e)}{\int el_c(e)dF(e)}\left(\eta h'(l_c(e))l_c(e) + \frac{d\log l_c(e)}{d\log e}\right)dF(e) \tag{3.16}$$

Note that (3.14) is independent of the assumption regarding the shape of the distribution of disutilities. However, the extreme-value distribution assumption is needed for the derivation of (3.16).

Proposition 2 implies that the planner can eliminate inefficiencies caused by the labor market power using only labor income taxes, which is similar to the results of the Aiyagari-Ramsey model with HSV taxes. Note that although in the Aiyagari-Ramsey model the set of tax policies is restricted to a class of two-parameter functions, this set is still flexible enough to remove the deadweight loss from the labor market power and achieve the competitive Ramsey allocation. Therefore, the loss from using optimal HSV taxes instead of optimal unrestricted taxes in an economy with labor market power is equal to the same loss in an economy with a competitive labor market.

Now I explain the intuition behind equation (3.14): First, I rewrite this equation in terms of labor productivity as follows:

$$T_m(y_m(e)) = T_c(y_c(e)) - \big(y_c(e) - y_m(e)\big) \tag{3.17}$$

where $y_m(a) = w_m l_m(e)e$ denotes the pre-tax income of an individual with skill e in the economy with monopsonistic competition and taxes $T_m(.)$ and $y_c(e) = w_c l_c(e)e$ denotes the income of an individual with skill e in the economy with a competitive labor market and tax $T_c(.)$. In addition, $T_c(y_c(e)) = zel_c(e) - c_c(e)$[6]. That is, the optimal monopsony taxes comprise the optimal competitive Mirrleesian taxes, and a subsidy equal to the earning gap has resulted from the market power. Furthermore, the government is redistributing firm profits among workers in a way that motivates them to work as much as they would in an economy with a competitive labor market under optimal taxes. Under this policy, the government is able to implement the second-best allocation and dismantle the distortions caused by monopsony.

Progressivity. I define measure

$$\tau^{HSV}(y) = 1 - \frac{d\log(y - T(y))}{d\log y} \tag{3.18}$$

to match the definition of progressivity in the Aiyagari-Ramsey model and parameter τ of HSV taxes. Other measures of the progressivity of taxes, such as the first derivative of average tax and marginal tax rates, have been used in Public Finance (e.g. Kakwani [1977]). I define

$$\tau^{AT} = \frac{\partial\left(\frac{T(y)}{y}\right)}{\partial y} = \frac{T'(y) - \frac{T(y)}{y}}{y} \tag{3.19}$$

as another measure of the progressivity of taxes. The following corollary indicates how the average and progressivity of optimal taxes—defined by the aforementioned measures—are

6. $c_c(e)$ is the consumption schedule of the second-best solution

changed by market power.

Corollary 2. *The average optimal monopsony tax rate increases when there is less labor market power; i.e.,*

$$\frac{\partial\left(\frac{T_m(y;\eta)}{y}\right)}{\partial\eta} > 0 \tag{3.20}$$

The measure $\tau^{HSV}(y)$ for the optimal monopsony taxes is the same as the one for the optimal competitive Mirrleesian taxes; i.e., $\tau_m^{HSV}(y;\eta) = \tau_c^{HSV}(y)\ \forall y$.[7]
Moreover, the progressivity measure τ^{AT} varies by η as

$$\frac{d\tau^{AT}(y;\eta)}{d\eta} \propto -yT_c''\left(\frac{y}{v^*(\eta)}\right) \tag{3.21}$$

Corollary 2 posits that a higher degree of monopsonistic competition (lower η) requires lower optimal income taxes.

Additionally, expression (3.21) implies that if in an economy with perfect competition the marginal optimal tax rate is increasing; then in an economy with monopsonistic competition, the progressivity of optimal taxes, defined by τ^{AT}, increases by the degree of labor market power (inverse of η). However, the progressivity measure τ^{HSV} does not change by η.

Example. I derive the optimal taxes in an economy with quasi-linear preferences $V = \frac{c^{1-\sigma}}{1-\sigma} - l - \log\varepsilon$ and a Paretian distribution for skills. I solve the model for the competitive labor market and apply the theory in Proposition 2 to derive the optimal monopsony taxes. I assume that the solution to the competitive Mirrlees is continuous and differentiable.[8] To solve the problem, I use the first-order approach and replace the incentive-compatibility constraints with a local constraint (it is assumed θ is a local maximizer of the right-hand

7. We have

$$1-\tau_m(y_m(e)) = \frac{1-T_m'}{1-\frac{T_m}{y_m}} = \frac{1-T_c'}{1-\frac{T_c}{y_c}} = 1-\tau_c(y_c(e))$$

8. Weibull [1989] shows that if there is a solution, there exists also a "continuous" solution as well.

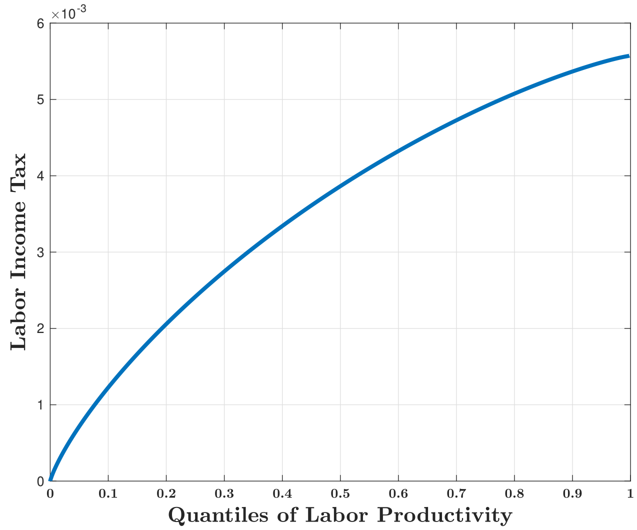


Figure 3.2: Optimal taxes (regressive system) across quantiles of labor productivity in a competitive economy

side of the IC constraint).[9] The resulting tax system under a perfectly competitive labor market is regressive, and it is shown in Figure 3.2.

Figure 3.3 shows the optimal marginal taxes under monopsony for different ηs and their associated markdowns. The red line on the top shows the optimal marginal tax for the competitive labor market. As the markdown widens and labor market power increases, the taxes that implement the second-best allocation are lower and the optimal marginal tax falls.

Government's Preferences for Redistribution. Here I briefly discuss the results for alternative social welfare functions. In general, redistributive policies depend on the taste of the social planner for redistribution, which is determined by the shape of the social welfare function. So far, I have assumed a utilitarian social welfare function. Here, I consider a more

9. The assumptions about preferences enforce the implementability of the solution from the first-order approach. Under these assumptions, the Spence-Mirrlees condition is satisfied; i.e., the net and gross income schedules are strictly increasing in types, and bunching is avoided,Ebert [1992].

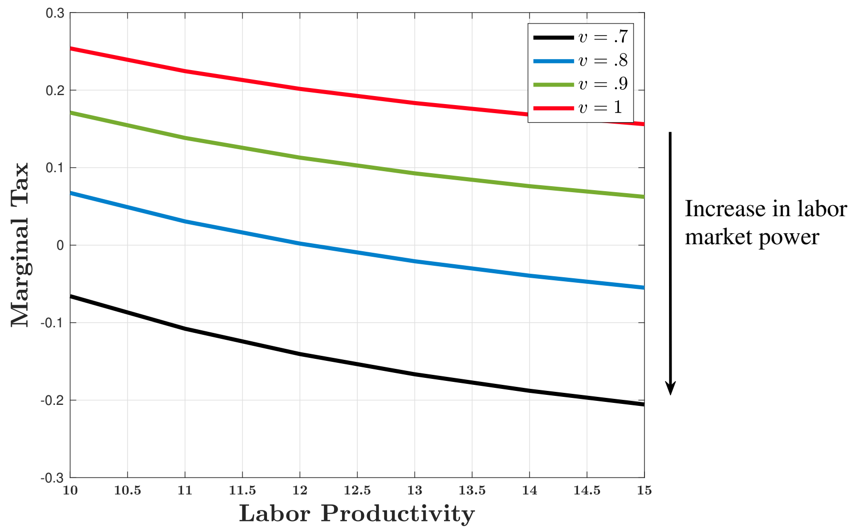


Figure 3.3: Optimal marginal taxes across skills for different levels of markdown

general form for the welfare function as follows:

$$\widetilde{\mathcal{W}} = E \int \Omega(V_i) di$$

where Ω is a concave and strictly increasing function. Under this welfare function, the optimal tax policy is different than the one with the utilitarian function. Nevertheless, the results of Proposition 1 carry over. That is,

$$\begin{aligned} T_m(y;\eta) &= T_c\left(\frac{y}{v^*(\eta)}\right) - \frac{1 - v^*(\eta)}{v^*(\eta)} y \\ v^*(\eta) &= \frac{\xi^*(\eta)}{1 + \xi^*(\eta)} \\ \xi^*(\eta) &= \eta \xi^c + \xi^n \end{aligned}$$

where $T_c(.)$ depends on the shape of Ω. Since different Ω functions lead to different optimal taxes in the competitive economy, the equilibrium allocation as well as elasticities and markdowns also are different. Note that ξ^c and ξ^n determine how markdowns and elasticities vary by η; therefore, they control the relationship between taxes under monopsony and perfect competition.

Chapter 4

Conclusion

This paper develops a framework for studying the implications of labor market power for optimal labor income taxes. The model features endogenous markdowns that depend on the elasticity of the labor supply, which, in turn, depends on taxes. I propose a characterization of labor supply elasticities that links (a) markdowns and elasticities of the labor supply that firms face to (b) the distribution of income and assets, worker-specific elasticities, and a structural parameter for the degree of monopsonistic competition. Through this characterization, I provide analytical results that relate the optimal taxes under monopsonistic competition to those under perfect competition, and I specify the optimal labor income taxes. I discover that labor income taxes are sufficient to remove distortions from labor market power and implement the second-best allocation of the competitive economy. Specifically, I show that the class of HSV tax functions is flexible enough to eliminate the effect of labor market power. The results indicate that the optimal taxes under monopsony are less than the optimal taxes under perfect competition at all income levels.

Quantifications of the model suggest, first, that optimal labor income taxes are less progressive than the actual schedule of taxes in the US and, second, that welfare improves by 0.2% and output by 0.9% as we move from the current tax system to the optimal one.

Note that the theoretical results depend on the assumption of the symmetry of firms.

With asymmetric firms and differentiated markdowns, taxes have limited capacity to correct for distortions caused by markdowns. A change in the dispersion of preferences η, affects firms with different productivities disproportionately. Thus, wage distribution changes, and workers of different firms are heterogeneously affected. Additionally, a change in the degree of market power not only affects the hours; it also distorts the matching of workers to firms. Therefore, the analytical results do not hold in the setting with heterogeneous firms. Nevertheless, in an extension of this paper, I show that with proper modifications of the quantitative framework, the numerical analysis can be conducted to study how optimal income taxes vary by η for the heterogeneous firms model.

An extension of the model that includes asymmetric firms can speak to within-firm and between-firm inequality among workers and provides a baseline to explore the relationship of markdowns and inequality—that is, how wage and income inequality are linked to the degree of imperfect competition in the labor market, and how markdowns are determined by the distribution of income and assets among workers.

This framework is suitable for studying the distributional effects of policies that impact wages, such as a minimum wage policy. The minimum wage policy adds a constraint to firms' problem and affects the distribution of markdowns and wages. Markdowns are determined by elasticities of the labor supply, which themselves depend on the distribution of wages. The proposed decomposition of the elasticity of the labor supply sheds light on how labor supply elasticities vary under this policy. The framework in this paper allows me to study how such policies change the distribution of markdowns and contribute to wage inequality.

Some other extensions of the model may be of interest for future work. The current model can be extended to accommodate the endogenous choice of amenities by considering a vertical differentition of jobs and relaxing the assumptions on preferences over jobs. One can assume that firms have inherently different amenities or can choose the quality of their amenities, which influences the preferences of workers. In this case, one might ask: What level of amenity and wages do firms optimally choose, and how are markdowns and inequality affected?

Another interesting direction to explore is the implications of having entrepreneurs whose efforts affect the productivity of firms and whose utilities are included in welfare for optimal income taxes.

At last, as the model highlights, different heterogeneities, such as labor productivity and assets, are crucial for determining labor supply elasticities. Therefore, any features—like borrowing constraints—that affect the distribution of workers are important for labor supply elasticity and markdowns. This raises the question of how labor supply elasticities and the distribution of markdowns would change in a setting with richer worker heterogeneity.It is hoped that the quantitative framework in this paper provides a benchmark that can be used to answer these questions and other extensions.

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Appendix A

Proofs and Derivations

A.1 Derivation of Value Function

I write the problem for the heterogenous firms case. Suppose there are J types of firms and within each type there are Δ_j firms. In the stochastic steady state with a fixed menu of wages, the value of working at a firm with wage w_j is:

$$V(a, e, w_j) = \max_{(c,l,a') \in B(a,e,w_j)} u(c, l) + \beta \underbrace{E_{e'|e}\Big\{ \max_k V(a', e', w_k) - \log(\varepsilon'_k) \Big\}}_{V_e(a',e')}$$

where $\Gamma(a, e, w_j) = \{(c, l, a')|c, l \geq 0, a' + c = Ra + \lambda(w_j el)^{1-\tau}, a' \geq -b\}$. We can simplify the second term on the RHS as follows:

$$\begin{aligned}
V_e(a', e') &= \sum_j \int_{\Lambda'} [V(a', e', w_j) - \log(\varepsilon'_j)]\rho(a', e', w_j|\boldsymbol{\varepsilon'})dP_{\boldsymbol{\varepsilon}}(\boldsymbol{\varepsilon'})\Delta_j \\
&= \sum_j \int_{\varepsilon'_j} [V(a', e', w_j) - \log(\varepsilon'_j)]\rho(a', e', w_j|\varepsilon'_j)dP(\varepsilon'_j)\Delta_j \\
&= \sum_j V(a', e', w_j)\rho(a', e', w_j)\Delta_j - \sum_j \int_{\varepsilon'_j} \log(\varepsilon'_j)\rho(a', e', w_j, \varepsilon'_j)d\varepsilon'_j\Delta_j
\end{aligned}$$

$\rho(a', e', w_j|\boldsymbol{\varepsilon'})$ denotes the probability of selecting firm j given $\boldsymbol{\varepsilon'} = \{\varepsilon'_j\}_{j\in[0,1]}$, i.e., $\rho(a', e', w_j|\boldsymbol{\varepsilon'}) = P\Big\{V(a', e', w_j) - \log\varepsilon'_j \geq V(a', e', w_k) - \log\varepsilon'_k, \forall k\Big\}$. Now, using the assumption of i.i.d. Weibull distribution for ε_j, the probability of choosing a firm is [1]

$$\rho(a', e', w_j) = \frac{e^{\eta V(a', e', w_j)}}{\sum_k e^{\eta V(a', e', w_k)} \Delta_k}$$

$$\rho_j(a', e', w_j, \varepsilon'_j) = \eta \varepsilon_j'^{\eta-1} e^{-\sum_k \Delta_k \exp(\eta(V_k - V_j))\varepsilon_j'^{\eta}}$$

2

1.

$$\begin{aligned}
\rho_j(a, e, w_j, \varepsilon_j) &= \Pi_{k\neq j_0}(P(V_j - \log\varepsilon_j \geq V_k - \log\varepsilon_k|\varepsilon_j))^{\Delta_k}.f_\varepsilon(\varepsilon_j) \\
&= \Pi_{k\neq j_0}(P(\log\varepsilon_k \geq \log\varepsilon_j + V_k - V_j|\varepsilon_j))^{\Delta_k}.f_\varepsilon(\varepsilon_j) \\
&= \Pi_{k\neq j_0}\left(e^{-\exp(V_k - V_j + \log\varepsilon_j)^\eta}\right)^{\Delta_k}.f_\varepsilon(\varepsilon_j) \\
&= e^{-\sum_{k\neq j_0}\Delta_k \exp(\eta(V_k - V_j))\varepsilon_j^\eta}.f_\varepsilon(\varepsilon_j) \\
&= e^{-\sum_{k\neq j_0}\Delta_k \exp(\eta(V_k - V_j))\varepsilon_j^\eta}.\eta\varepsilon_j^{\eta-1}e^{-\varepsilon_j^\eta} \\
&= e^{-(1+\sum_{k\neq j_0}\Delta_k \exp(\eta(V_k - V_j)))\varepsilon_j^\eta}.\eta\varepsilon_j^{\eta-1} \\
&= e^{-\sum_k \Delta_k \exp(\eta(V_k - V_j))\varepsilon_j^\eta}.\eta\varepsilon_j^{\eta-1} \\
&= \eta\varepsilon_j^{\eta-1}e^{-A\varepsilon_j^\eta} \qquad\qquad \text{where } A := \sum_k \exp(\eta(V_k - V_j))\Delta_k
\end{aligned}$$

2. The job-choice probability is:

$$\rho_j(a, e, w_j) = \int \rho_j(a, e, w_j, \varepsilon_j)d\varepsilon_j = -\frac{e^{-A\varepsilon_j^\eta}}{A}\Big|_0^\infty = \frac{1}{A} = \frac{exp(\eta V_j)}{\sum_k \Delta_k exp(\eta V_k)}$$

We can continue simplifying $V_e(.)$ as follows: [3]

$$\begin{aligned}
V_e(a',e') &= \sum_j V_j' \frac{e^{\eta V_j'}}{\sum_k e^{\eta V_k'}\Delta_k}\Delta_j + \sum_j \int_{\varepsilon_j'} \eta \varepsilon_j'^{\eta-1} e^{-\sum_k \Delta_k \exp(\eta(V_k - V_j))\varepsilon_j'^{\eta}} d\varepsilon_j' \Delta_j \\
&= \sum_j V_j' \frac{e^{\eta V_j'}}{\sum_k e^{\eta V_k'}\Delta_k}\Delta_j + \frac{1}{\eta}\sum_j \left(\frac{\gamma - \ln(\sum_k \exp(\eta(V_k' - V_j'))\Delta_k)}{\sum_k \exp(\eta(V_k' - V_j'))\Delta_k} \right) \Delta_j \\
&= \sum_j V_j' \frac{e^{\eta V_j'}}{\sum_k e^{\eta V_k'}\Delta_k}\Delta_j + \frac{\gamma}{\eta}\sum_j \frac{e^{\eta V_j'}}{\sum_k e^{\eta V_k'}\Delta_k}\Delta_j \\
&\quad - \frac{1}{\eta}\sum_j e^{\eta V_j'} \left(\frac{(\ln(\sum_k e^{\eta V_k'}\Delta_k) - \eta V_j')}{\sum_k e^{\eta V_k'}\Delta_k} \right) \Delta_j \\
&= \left(\frac{\gamma}{\eta} + \frac{1}{\eta}\ln\Big(\sum_k e^{\eta V_k'}\Delta_k\Big) \right) \frac{\sum_j e^{\eta V_j'}\Delta_j}{\sum_k e^{\eta V_k'}\Delta_k} \\
&= \frac{\gamma}{\eta} + \frac{1}{\eta}\ln \sum_k e^{\eta V_k'}\Delta_k
\end{aligned}$$

Therefore, we can write

$$V(a,e,w_j) = \max_{(c,l,a')\in\Gamma(a,e,z)} u(c,l) + \frac{\beta}{\eta}\left(\ln \sum_k e^{\eta V(a',e',w_k)}\Delta_k + \gamma \right) \tag{A.1}$$

3.

$$\chi_0 := \int_0^\infty \log \varepsilon_j \rho(a,e,w_j,\varepsilon_j) d\varepsilon_j = \frac{Ei(-A\varepsilon_j^\eta) - \eta \log \varepsilon_j e^{-A\varepsilon_j^\eta}}{\eta A}\Big|_0^\infty, \qquad Ei(x) := \int_x^\infty \frac{e^{-u}}{u} du$$

Define $x = A\varepsilon_j^\eta$, therefore,

$$\chi_0 = \frac{1}{\eta A}\int_0^\infty (\log x - \log A) e^{-x} dx = \frac{1}{\eta A}\int_0^\infty \ln x e^{-x} dx - \frac{\log A}{\eta A}\int_0^\infty e^{-x} dx = \frac{\gamma}{\eta A} - \frac{\ln A}{\eta A}$$

Where γ is the Euler–Mascheroni constant.

A.2 Derivation of Labor Supply Elasticity

Note that

$$\xi(w_j) = \frac{dn(w_j)}{dw_j}\frac{w_j}{n(w_j)}, \quad n(w_j) = \int \rho(a_i, e_i, w_j) l(a_i, e_i, w_j) e_i di$$

where

$$\rho(a_i, e_i, w_j) = \frac{\exp(\eta V(a_i, e_i, w_j))}{\sum_k \exp(\eta V(a_i, e_i, w_k))\Delta_k}$$

Hence,

$$\begin{aligned}
\xi_j &= \left(\frac{w_j}{n(w_j)}\right) \times \int \left(\frac{\partial \rho_{ij}}{\partial w_j} l_{ij} e_i + \frac{\partial l_{ij}}{\partial w_j}\rho_{ij} e_i\right) di \\
&= \left(\frac{1}{\int \rho_{ij} l_{ij} e_i \, di}\right) \times \int (\rho_{ij} l_{ij} e_i) \left(\frac{\partial \rho_{ij}}{\partial w_j}\frac{w_j}{\rho_{ij}} + \frac{\partial l_{ij}}{\partial w_j}\frac{w_j}{l_{ij}}\right) di \\
&= \int \left(\frac{\rho_{ij} l_{ij} e_i}{\int \rho_{ij} l_{ij} e_i \, di}\right) \left(\frac{\partial \log \rho_{ij}}{\partial \log w_j} + \frac{\partial \log l_{ij}}{\partial \log w_j}\right) di \\
&= \int \left(\frac{\rho_{ij} l_{ij} e_i}{\int \rho_{ij} l_{ij} e_i \, di}\right) \left(\frac{\partial V_{ij}}{\partial w_j}\eta w_j - \frac{\partial \log\left(\sum_k \exp(\eta V_{ik})\Delta_k\right)}{\partial w_j} w_j + \frac{\partial \log l_{ij}}{\partial \log w_j}\right) di \\
&\simeq \int \left(\frac{\rho_{ij} l_{ij} e_i}{\int \rho_{ij} l_{ij} e_i \, di}\right) \left(\frac{\partial V_{ij}}{\partial w_j}\eta w_j + \frac{\partial \log l_{ij}}{\partial \log w_j}\right) di \qquad \text{(Large number of firms)} \\
&= \int \left(\frac{\rho_{ij} l_{ij} e_i}{\int \rho_{ij} l_{ij} e_i \, di}\right) \left(\eta u'(c_{ij})(1 - T'(w_j e_i l_{ij})) e_i l_{ij} + \frac{\partial \log l_{ij}}{\partial \log w_j}\right) di, \qquad \text{(Envelope Theorem)} \\
&= \int \left(\frac{\rho_{ij} l_{ij} e_i}{\int \rho_{ij} l_{ij} e_i \, di}\right) \left(\eta h'(l_{ij}) l_{ij} + \frac{\partial \log l_{ij}}{\partial \log w_j}\right) di, \qquad \text{(F.O.C)}
\end{aligned}$$

Note that in step 5, I assumed that the number of firms is large enough that the term $\frac{d\log(\sum_k \exp(\eta V_{ik})\Delta_k))}{dw_j}$ can be ignored (As $J \to \infty$, this term goes to 0).

Moreover, in the symmetric equilibrium with single wage (i.e. $w_j = w$), we have $\rho(a_i, e_i, w) = 1$.

Therefore, assuming $h(l) = \frac{l^{1+\frac{1}{\psi}}}{1+\frac{1}{\psi}}$, we have:

$$\xi = \int \frac{e_i l(a_i, e_i, w)}{\int e_i l(a_i, e_i, w) di} \Big(\eta l(a_i, e_i, w)^{1+\frac{1}{\psi}} + \frac{\partial \log l(a_i, e_i, w)}{\partial \log w} \Big) di$$

And in the Mirrlees economy with no assets,

$$\xi = \int \frac{el(e, w)}{\int el(e, w) dF_e(e)} \Big(\eta l(e, w)^{1+\frac{1}{\psi}} + \frac{\partial \log l(e, w)}{\partial \log w} \Big) dF_e(e)$$

Additionally, note that the static Mirrlees model yields $\frac{\partial \log l(e,w)}{\partial \log w} = \frac{\partial \log l(e,w)}{\partial \log e}$.

Now, I derive expressions for the intensive and extensive margins of the elasticity. Using the expression for the probability of job-choice, we have:

$$\begin{aligned}
\xi^c &:= \frac{\partial d \log \rho(a, e, w)}{\partial \log w} \\
&= \eta \frac{\partial V}{\partial w} w \\
&= \eta \phi \lambda (1-\tau) w^{-\tau} (el)^{1-\tau} \times w && \text{Envelope theorem, } \phi : \text{Lagrangian mult.} \\
&= \eta u_l(c, l) l && \text{F.O.C for [l]}
\end{aligned}$$

Now, I derive an expression for $\xi^n := \frac{\partial \log l_{ij}}{\partial \log w_j}$. The first-order conditions of the conditional problem yield:

$$\begin{aligned}
l^{\frac{1}{\psi}} &\propto c^{-\sigma} (we)^{1-\tau} l^{-\tau} \\
\frac{1}{\psi} d \log l &= -\sigma d \log c + (1-\tau) d \log w - \tau d \log l \\
\left(\frac{1}{\psi} + \tau \right) d \log l &= -\sigma d \log c + (1-\tau) d \log w \\
\left(\frac{1}{\psi} + \tau \right) \frac{d \log l}{d \log w} &= -\sigma \left[\frac{d \log c}{d \log w} \right] + (1-\tau)
\end{aligned}$$

Define μ as the marginal propensity to consume (MPC); hence,

$$\begin{aligned}
\mu &:= \frac{d\log c}{d\log y^{post-tax}} \\
&= \frac{d\log c}{d\log w}.\frac{d\log \lambda y^{1-\tau}}{d\log w} \\
&= \frac{d\log c}{d\log w} \times (1-\tau)\frac{d\log y}{d\log w} \\
&= \frac{d\log c}{d\log w} \times (1-\tau)\frac{d\log y}{d\log w} \\
&= \frac{d\log c}{d\log w} \times (1-\tau)\left(1+\frac{d\log l}{d\log w}\right)
\end{aligned}$$

Therefore, the elasticity of hours is:

$$\begin{aligned}
\xi^n &= \frac{(1-\tau)}{\left(\frac{1}{\psi}+\tau\right)} - \frac{\sigma}{\left(\frac{1}{\psi}+\tau\right)}\mu \times (1-\tau)\left(1+\xi^n\right) \\
\left[1+\frac{\sigma}{\left(\frac{1}{\psi}+\tau\right)}\mu\,(1-\tau)\right]\xi^n &= \frac{(1-\tau)}{\left(\frac{1}{\psi}+\tau\right)} - \frac{\sigma}{\left(\frac{1}{\psi}+\tau\right)}\mu\,(1-\tau) \\
\xi^n &= \frac{\frac{(1-\tau)}{\left(\frac{1}{\psi}+\tau\right)} - \frac{\sigma}{\left(\frac{1}{\psi}+\tau\right)}\mu\,(1-\tau)}{1+\frac{\sigma}{\left(\frac{1}{\psi}+\tau\right)}\mu\,(1-\tau)} \\
\xi^n &= \frac{(1-\tau)-\sigma\mu\,(1-\tau)}{\left(\frac{1}{\psi}+\tau\right)+\sigma\mu\,(1-\tau)} \\
\xi^n &= \frac{(1-\tau)-\sigma\mu\,(1-\tau)}{\left(1+\frac{1}{\psi}\right)-(1-\tau)+\sigma\mu\,(1-\tau)} \\
\xi^n &= \frac{(1-\sigma\mu)\,(1-\tau)}{\left(1+\frac{1}{\psi}\right)-(1-\sigma\mu)\,(1-\tau)}
\end{aligned}$$

It is worthwhile to look at some special cases:

$$\xi^n(\mu=1)=\frac{(1-\sigma)(1-\tau)}{\left(1+\frac{1}{\psi}\right)-(1-\sigma)(1-\tau)} \qquad \text{In a static model, so } MPC=1 \text{ (c=y)}$$

$$\xi^n(\mu=1,\tau=0)=\frac{1-\sigma}{\sigma+\frac{1}{\psi}} \qquad \text{Corollary 4 in Krueger-Kindermann}$$

$$\xi^n(\mu=1,\tau=0,\sigma=0)=\psi \qquad \text{+log utility so inc/sub effects on LS offset}$$

The following expression links (i) the household's asset and income position as reflected through its MPC_i, (ii) tax progressivity τ, and (iii) the individual's Frisch elasticity of the labor supply and the degree of risk aversion:

$$\xi_i^n=\frac{(1-\sigma\mu_i)(1-\tau)}{\left(1+\frac{1}{\psi}\right)-(1-\sigma\mu_i)(1-\tau)} \qquad (*)$$

Comparative statics:

- If μ is larger:

$$\xi^n=\downarrow\left(\frac{\downarrow}{\uparrow}\right)\frac{\downarrow(1-\sigma\uparrow\mu)(1-\tau)}{\left(1+\frac{1}{\psi}\right)-\downarrow(1-\sigma\uparrow\mu)(1-\tau)}$$

  Economics: A worker with a high MPC has consumption that is very responsive to changes in after-tax income. Consumption and leisure are both normal goods. The worker's leisure is also more responsive, leading to a muted response of l to a change in w

- If τ is larger (assuming μ is fixed)

$$\xi^n=\downarrow\left(\frac{\downarrow}{\uparrow}\right)\frac{\downarrow(1-\sigma\mu)(1-\uparrow\tau)}{\left(1+\frac{1}{\psi}\right)-\downarrow(1-\sigma\mu)(1-\uparrow\tau)}$$

  Economics: Same as before.

A.3 Proof of Proposition 1

First, I show that the optimal solution (excluding wage) under perfect competition is feasible in an economy with labor market power. Suppose λ_c and τ_c are parameters of the optimal tax function in a counterfactual economy with no labor market power and $l_c(a,e), c_c(a,e), \Phi_c(a,e)$, R_c and w_c are the equilibrium labor supply, consumption, distribution of assets and skills, interest rate, and wage, respectively. For an economy associated with η, set $\tau_m = \tau_c$ and $\lambda_m = \left(\frac{1}{v^*}\right)^{1-\tau_c} \lambda_c$, where v^* is the expression in Proposition 1. I show that all of the following statements hold.

1. Given τ_m, λ_m, $R_m = R_c$, and $w_m = v^* w_c$, schedules $l_c(a,e)$ and $c_c(a,e)$ solve workers' problem.

2. Given $l_m(a,e) = l_c(a,e)$ and $c_m(a,e) = c_c(a,e)$, the interest rate and the distribution of skills and assets are the same as in the competitive economy; i.e. $\phi_m(a,e) = \phi_c(a,e)$ and $R_m = R_c$.

3. v^* is the equilibrium markdown under the aforementioned taxes; i.e. $v^* = \frac{MRPL}{w_m}$ and MRPL is equal to w_c, given $l_m(a,e) = l_c(a,e)$, $c_m(a,e) = c_c(a,e)$, $R_m = R_c$, and $\phi_m(a,e) = \phi_c(a,e)$.

4. The government budget is balanced; i.e. $T_m + \pi = \overline{G}$, given τ_m, λ_m, $l_m(a,e) = l_c(a,e)$, $R_m = R_c$, $w_m = v^* w_c$, and $\phi_m(a,e) = \phi_c(a,e)$.

Proof of 1: The after tax income is

$$\lambda_m (w_m el)^{1-\tau_m} = \lambda_c \left(\frac{w_m}{v^*} el\right)^{1-\tau_c} = \lambda_c (w_c el)^{1-\tau_c}$$

This implies workers' budget constraints, $a' = R_m a + \lambda_m (w_m el)^{1-\tau_m} - c$, are the same as in the economy with a competitive labor market. Hence, (l_c, c_c) is a solution to the workers' problem.

Proof of 2: Supply and demand for capital is the same as before; therefore, the interest rate is the same as in the competitive economy. This implies that the stationary distribution of assets and skills is also equal to its counterpart in the competitive equilibrium.

Proof of 3: I showed before that

$$MRPL_m = \alpha z^{\frac{1}{\alpha}} \Big(\frac{1-\alpha}{R_m - 1 + \delta} \Big)^{\frac{1-\alpha}{\alpha}}$$

Since $R_m = R_c$, and in the competitive economy $MRPL_c = w_c$, thus, $MRPL_m = w_c$. In addition, given the labor supplies and distribution of assets and skills, the markdown and elasticity of the labor supply are:

$$\begin{aligned}
v_m &= \frac{\xi_m}{1+\xi_m} \\
\xi_m &= \int \frac{e_i l_m(a_i,e_i)}{\int e_i l_m(a_i,e_i) di} \Big(\eta l_m(a_i,e_i)^{1+\frac{1}{\psi}} + \frac{\partial \log l_m(a_i,e_i;w_m)}{\partial \log w_m} \Big) di
\end{aligned}$$

Since $l_m = l_c$, I only need to show $\frac{\partial \log l_m(a_i,e_i;w_m)}{\partial \log w_m} = \frac{\partial \log l_c(a_i,e_i;w_c)}{\partial \log w_c}$, which is true because w_m is a product of w_c and a constant.

Proof of 4: Total taxes are

$$\begin{aligned}
T_m &= \int w_m e l_m(a,e) - \lambda_m (w_m e l_m(a,e))^{1-\tau_m} d\Phi(a,e) \\
&= \int w_m e l_m(a,e) - \left(\frac{1}{v^*}\right)^{1-\tau_c} \lambda_c (w_m e l_m(a,e))^{1-\tau_c} d\Phi(a,e) \\
&= \int w_m e l_m(a,e) - \lambda_c (w_c e l_m(a,e))^{1-\tau_c} d\Phi(a,e) \\
&= \int (w_m - w_c) e l_c(a,e) + w_c e l_c(a,e) - \lambda_c (w_c e l_c(a,e))^{1-\tau_c} d\Phi(a,e) \\
&= \int (w_m - w_c) e l_c(a,e) d\Phi(a,e) + \overline{G} \\
&= -\pi + \overline{G}
\end{aligned}$$

Therefore, the optimal allocation under perfect competition is feasible in the economy with labor market power. The argument is also valid when the opposite is the case; that is, the optimal allocation under monopsony is feasible in the economy with no labor market power. Therefore, the optimal allocations in an economy with a competitive labor market and in an economy with labor market power are the same.

The labor income taxes under monopsony are

$$\begin{aligned}
T_m(y) &= y - \lambda_m y^{1-\tau_m} \\
&= y - \left(\frac{1}{v^*}\right)^{1-\tau_c} \lambda_c y^{1-\tau_c} \\
&= \left[y - \frac{y}{v^*}\right] + \left[\frac{y}{v^*} - \lambda_c \left(\frac{y}{v^*}\right)^{1-\tau_c}\right] \\
&= -\left(\frac{1-v^*}{v^*}\right) + T_c\left(\frac{y}{v^*}\right)
\end{aligned}$$

A.4 Taxes under Monopsony vs. η

Are taxes under monopsony higher when η is higher?

$$\left.\frac{\partial T_m(y;\eta)}{\partial \eta}\right|_y = \left(yT_c'(.) - y\right) \frac{\partial(\frac{1}{v^*(\eta)})}{\partial \eta}$$

We know

$$\frac{1}{v^*} = \frac{1}{\xi^*} + 1, \quad \xi^*(\eta) = \eta\xi^c + \xi^n$$

Thus,

$$\frac{\partial(\frac{1}{v^*(\eta)})}{\partial \eta} = -\frac{\xi^c}{(\eta\xi^c + \xi^n)^2}$$

Therefore,

$$\left.\frac{\partial T_m(y;\eta)}{\partial \eta}\right|_y = -\left(yT_c'(.) - y\right) \frac{\xi^c}{(\eta\xi^c + \xi^n)^2}$$

If $T_c'(y) < 1$, then $T_m(y)$ is increasing in η.

A.5 Derivation of Welfare for Heterogeneous Firms

For the case in which firms have different productivities, I derive a simple form for welfare that helps me carry out the quantitative analysis. When firms are heterogeneous productivity, welfare is:

$$\begin{aligned}
\mathcal{W} &= \int \widetilde{V}(a_i, e_i, \boldsymbol{\varepsilon}_i) di \\
&= \int \max_j \{V(a_i, e_i, w_j) - \log(\varepsilon_j)\} d\mathcal{B}(\boldsymbol{\varepsilon}) di \\
&= \int \sum_j \left[V(a_i, e_i, w_j) - \log(\varepsilon_j)\right] \rho(a_i, e_i, w_j, \varepsilon_j) \Delta_j d\mathcal{B}(\varepsilon_j) di \\
&= \int \sum_j V(a_i, e_i, w_j) \rho(a_i, e_i, w_j) \Delta_j di - \int \sum \log(\varepsilon_j) \rho(a_i, e_i, w_j, \varepsilon_j) \Delta_j d\mathcal{B}(\varepsilon_j) di \\
&= \int \sum_j V(a_i, e_i, w_j) \frac{e^{\eta V_j}}{\sum_k e^{\eta V_k} \Delta_k} \Delta_j di - \int \sum \log(\varepsilon_j) \rho(a_i, e_i, w_j, \varepsilon_j) \Delta_j d\mathcal{B}(\varepsilon_j) di \\
&= \frac{1}{\eta} \left(\ln \sum_k e^{\eta V(a_i, e_i, w_j)} \Delta_j + \gamma \right), \qquad \text{As in the first section}
\end{aligned}$$

A.6 Quantitative Method Algorithm

Pseudocode for symmetric firms case:

1. Define a grid for $s = (a, e)$.
2. Given $\overline{G}$, define a grid for τ. For each τ (15 points) repeat 2-5.
3. Generalized bi-section search for λ. Consider an interval for λ with 10 points; for each point do the following:
   (a) Bi-section algorithm to find w: consider an interval for w. Given $w = \frac{w_l + w_u}{2}$, do:

i. Bi-section to find R: consider an interval for w. Given $R = \frac{R_l + R_u}{2}$, do:

ii. Estimate value function (using splines), consumption, labor, capital and the distribution of $s = (a, e)$.

iii. Find $\hat{R}$ that clears capital market: $A = K$ and $R = F_k(K) + 1 - \delta$.

iv. Update the interval for R. Repeat (i-iv) until it $|R - \hat{R}| < \epsilon_R$

(b) Calc MPL, elasticity—to calc ξ, I need to estimate $\frac{d \log l(a,e,w)}{d \log w}$(*)—, and mark-down. Then calc $\widehat{w} = v.MPL$.

(c) Update the grid for w, repeat (a-b) until $|\widehat{w} - w| < \epsilon_w$

4. Calculate governments' budget gap given λ and the resulting distribution of income. Find λ that minimizes the $|G(\lambda) - \overline{G}|$.

5. Update the interval for λ and repeat 3 until $|G(\lambda) - \overline{G}| < \epsilon_G$. $\rightarrow \lambda^*(\tau)$

6. For each τ and $\lambda^*(\tau)$ calculate welfare and find τ that maximizes welfare.

(*) To estimate $\frac{d \log l(s,w)}{d \log w}$, I use the formula for the intensive margin of elasticity, which involves calculating MPC's.

A.7 Welfare and wedges

To understand how different heterogeneities and forces create distortions and welfare loss, I write the model in terms of wedges and compare with a representative agent model. The equivalent Representative Agent (RA) model for the Aiyagari framework is as follows:

$$
\begin{aligned}
&\max \sum_t \beta^t \bar{\kappa}_C \Big(\frac{c_t^{1-\sigma}}{1-\sigma} - \bar{\kappa}_L \frac{l_t^{1+\frac{1}{\psi}}}{1+\frac{1}{\psi}} \Big) \\
&s.t. \quad a' + c = Ra + \lambda(\overline{w} l e)^{1-\tau}, \quad a' \geq -b \\
&\max \quad \bar{\kappa}_Z N^\alpha K^{1-\alpha} - \frac{\overline{w}}{\bar{\kappa}_W} N - rK
\end{aligned}
$$

where $\overline{\kappa}_C$, $\overline{\kappa}_L$, $\overline{\kappa}_Z$, $\overline{\kappa}_W$ are the following wedges (the model with heterogeneous firms and a continuum of firms is considered below):

(i) **Labor wedge:**

$$\bar{\kappa}_L = \Big(\int \Big(\kappa_j(a_i, e_i) \hat{c}_j(a_i, e_i)^{-\sigma} e_i \frac{w_j}{\overline{w}} \Big)^{\psi} \rho_j(a_i, e_i) edj di \Big)^{\frac{1}{\psi}} \tag{A.2}$$

(ii) **Investment wedge:**

$$\bar{\kappa}_C = \int \beta E \Big[\int (\frac{\hat{c}'_k}{\hat{c}_j})^{-\sigma} (1 + r\kappa_j) \rho_k(a_i, e_i) dk \Big] \rho_j(a_i, e_i) dj di \tag{A.3}$$

(iii) **Efficiency wedge:**

$$\bar{\kappa}_Z = \int_j z_j \Big(\frac{n_j}{N} \Big)^{\alpha} \Big(\frac{k_j}{K} \Big)^{1-\alpha} dj \tag{A.4}$$

(iv) **Markdown:**

$$\bar{\kappa}_W = \frac{\int \frac{\xi_j}{1+\xi_j} \tilde{z}_j n_j dj}{\int \tilde{z}_j n_j dj}, \quad \overline{w} = \bar{\kappa}_W MRPL \tag{A.5}$$

where $\hat{c}_j = \frac{c_j(a,e)}{C}$, $\kappa_j = \lambda(1-\tau)(w_j l_i e_i)^{-\tau}$.