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Progressive income taxation and consumption baskets of rich and poor ☆

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ABSTRACT

In this paper, I analyze the implications of differences in consumption baskets across income groups to evaluate the effects of redistributive taxation on efficiency and inequality. To this end, I develop a static multi-sector general equilibrium model incorporating a parametric tax function, non-homothetic consumption preferences, and endogenous labor supply, with varying compositions of skilled and unskilled labor in production across sectors. A calibrated version of the model captures the cross-sectional differences in the compositions of households' consumption baskets in the United States. I find that considering the differences in consumption baskets between high- and low-income households leads to a lower optimal choice of income tax progressivity compared to the conventional approach that ignores this feature of the data.

1. Introduction

How does progressive income taxation affect efficiency and inequality through changing the compositions of households' consumption baskets? A substantial body of literature in macroeconomics and public finance studies the effects of redistributive taxation on efficiency and inequality (e.g., Saez, 2001; Conesa and Krueger, 2006; Gorry and Oberfield, 2012; Heathcote et al., 2017). One of the assumptions in these studies is that preferences are homothetic in consumption.[1] However, a growing body of empirical work based on consumption microdata suggests that this assumption is strongly counterfactual as high-income households consume not only more goods but more income-elastic goods (e.g., Aguiar and Bils, 2015; Jaimovich et al., 2019, 2020; Comin et al., 2021).[2] On

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[1] The assumption that households' preferences over different consumption goods are homothetic is implicit in these papers, as their models contain only a single consumption good.

[2] Aguiar and Bils (2015) use Consumer Expenditure Survey (CEX) data and estimate that the income elasticity of demand is higher for luxuries (e.g., non-durable entertainment) than necessities (e.g., food at home). Jaimovich et al. (2019) and Jaimovich et al. (2020) find a positive correlation between the quality of goods and income elasticity. Comin et al. (2021) structurally estimate income elasticities to be the highest for services, followed by manufacturing and agricultural goods.

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the other hand, there is evidence that the productions of different goods and services require skilled (i.e., college graduates or above) and unskilled (i.e., non-college graduates) labor at different proportions (e.g., Buera and Kaboski, 2012). Thus, by changing the disposable income distribution, redistributive taxation may change the relative aggregate demand for goods and services produced in different sectors. Consequently, this can lead to changes in the demand for workers with different skill levels. Ignoring this fact may have consequences for understanding the macroeconomic effects of redistributive taxation.

In this paper, I incorporate differences in the compositions of household consumption baskets in different income groups to study progressive income taxation. The mechanism I highlight is typically absent in the extensive literature that examines the effects of alternative tax schemes on hours worked, output, and welfare. I fill this gap by linking the findings of the empirical consumption literature to the study of progressive income taxation in a macroeconomic framework. To this end, I make theoretical and quantitative contributions. On the theoretical side, I develop a static multi-sector general equilibrium model that features non-homothetic consumption preferences. In the model, agents differ in skill level. I incorporate a government that chooses a tax and transfer system to redistribute. Redistributive taxation affects the compositions of agents' consumption baskets, their working hours, occupation choice (i.e., sectoral allocation of labor), and composition of sectoral output. On the quantitative side, I take the model to United States data and analyze the effects of changing the degree of progressivity on labor reallocation, output, and welfare. I find that with non-homothetic consumption preferences, a planner's choice of income tax progressivity is lower than with homothetic consumption preferences.

The model economy is populated with a continuum of workers of two skill types, skilled and unskilled. The workers' labor supply decisions are elastic, and they receive their respective marginal products as wages. The government runs a tax and transfer system following a parametric class of tax functions as in Heathcote et al. (2017) (henceforth, HSV) and finances public consumption. Agents in the economy derive utility from leisure and consumption of both private and public goods. The publicly provided goods cannot be purchased privately. Private consumption is a combination of sectoral goods. Preferences over these sectoral goods follow a non-homothetic generalization of the constant elasticity of substitution (CES) aggregator, as in Comin et al. (2021). This particular class of preferences offers two advantages over other commonly used non-homothetic consumption preferences in the literature, such as Stone-Geary preferences. First, it generates non-homothetic sectoral demands for all income levels. Second, it allows for an arbitrary number of goods with different income elasticities, accommodating a more diverse range of consumer choices and preferences.[3]

The analytical expression for the income elasticity of demand, derived from my model, reveals that no good is intrinsically a luxury or a necessity good. Instead, the classification depends on an agent's current composition of consumption expenditures and, ultimately, on his disposable income. Since redistributive taxation changes the disposable income distribution, it changes the demand compositions of sectoral goods. Specifically, demand for income-elastic goods experiences a relatively higher impact.

The sectoral goods and services are produced by firms in each sector using both skilled and unskilled labor as factor inputs. Although firms in each of the sectors employ both skill types as imperfect substitutes, motivated by the data, production technologies are such that skilled workers are more heavily required to produce income-elastic goods, and unskilled workers are more heavily required to produce income-inelastic goods. The model features perfect labor mobility. Workers can work in only one sector at a time, and their occupations are driven by sectoral demand for workers' skill types. In the model, a progressive income tax system induces three effects. First, a decline in high-income (i.e., skilled) agents' disposable income due to progressive taxation reduces their private consumption. Since leisure is a normal good, as in most standard frameworks, agents trade off consumption against the value of leisure, resulting in a decline in their labor supply. Second, because of non-homothetic consumption preferences, while agents cut consumption due to low disposable income, they mostly give up income-elastic goods and shift their expenditures to income-inelastic goods. This adjustment allows high-income agents to partially offset the loss in the size of their consumption baskets, reducing net redistribution. Finally, with perfect labor mobility, lower demand for income-elastic goods decreases the relative demand for skilled labor and thus their wages, reducing their incentives to work and creating inefficiency in production. On the other hand, two forces affect low-income (i.e., unskilled) agents. The first one is that the higher demand for income-inelastic goods increases the relative demand and wages for unskilled agents. The second force is that prices for income-inelastic goods increase due to higher demand. The price and wage effect impact the welfare of unskilled workers in opposite ways and ultimately determine the overall willingness of the policymaker to raise the tax progressivity.

I calibrate the model to match U.S. data. The household-level data on consumption expenditures is drawn from the CEX. I classify the items within households' consumption baskets into goods and services. As in the data, in the calibrated model, the expenditure share on services relative to goods is higher for households in the high-income group than the low-income ones. I then ask how a benevolent planner would choose the tax and transfer system within the class of tax functions I use in my model. For the baseline analysis, I assume a planner that weights all agents equally, á la utilitarian planner. Since the agents in my model differ in skill level and pre-tax income, the planner wants a progressive tax system to redistribute against inequality in initial conditions. Nevertheless, a tax and transfer system with increasing marginal rates changes the compositions of agents' consumption baskets and occupations and distorts the labor supply, eventually shrinking the tax base and generating a deadweight loss. The planner knows the trade-offs and chooses a tax system that raises revenues and redistributes income according to society's preferences at the lowest possible cost while maximizing social welfare.

I use the calibrated model and solve for the optimal tax progressivity numerically. Under the baseline parameterization with non-homothetic consumption preferences, a utilitarian planner chooses a tax and transfer system that yields an average (income-

[3] There are other ways to incorporate non-homotheticity in consumption, for example, generalized Stone-Geary preferences (see, e.g., Buera and Kaboski, 2009) and price independent generalized linear (PIGL) preferences (see, e.g., Muellbauer, 1975; Boppart, 2014). Nonetheless, with Stone-Geary preferences, Engel curves level off quickly as income grows. On the other hand, PIGL preferences can accommodate only two goods with different income elasticities.

weighted) marginal tax rate of 21%. However, under the model that features homothetic consumption preferences, the utilitarian planner chooses a higher progressive tax system with an average marginal tax rate of 25%. To understand the results, note that higher progressivity decreases the disposable income of high-income agents, leading them to reduce their consumption. However, due to non-homothetic consumption preferences, agents primarily reduce services consumption while shifting toward goods consumption. This adjustment allows high-income agents to partially offset the loss in the size of their consumption baskets, weakening the redistributive purpose of progressive taxation. On the one hand, higher demand for goods raises wages for unskilled agents, accelerating redistribution. However, this also drives up the relative price of goods. Since the share of goods in the consumption basket is relatively greater for unskilled agents, the higher relative price partially shifts the tax incidence onto them. Thus, the price and wage effects impact the welfare of low-income agents in opposite ways, and one force can dominate the other depending on the degree of progressivity. Additionally, in the presence of perfect labor mobility, lower demand for services decreases the relative demand for skilled labor and thus their wages, which eventually diminishes their incentives to work and creates additional inefficiency in production. Therefore, in the model with non-homothetic consumption preferences, even with a relatively lower tax progressivity, efficiency cost exceeds gains from redistribution, limiting the planner's choice of tax progressivity. This result is robust to the planner's choice of redistribution.

Related Literature. This article relates and contributes to the macroeconomics and public finance literature that studies optimal income taxation using macroeconomic models and quantitative methods. Saez (2001) investigates the optimal marginal tax rate at the top of the income distribution in a static model using labor supply elasticities. In order to derive analytical results, he takes earnings as exogenous, and hence, general equilibrium effects are absent by construction. Rothschild and Scheuer (2013) and Ales et al. (2015) study optimal nonlinear taxes in static general equilibrium models. Similar to these papers, the production technology in my paper allows for imperfect substitutability across skill types where income taxes can affect intersectoral labor allocations. Bénabou (2002), Conesa and Krueger (2006), Bakış et al. (2015), and Heathcote et al. (2017) study optimal income taxation in dynamic life cycle models by restricting tax functions within a parametric class. I borrow the tax and transfer function from Bénabou (2002) and Heathcote et al. (2017).

The paper has several discernible features, including a multi-sector production structure, non-homothetic consumption preferences, imperfect substitutability in sectoral goods, and worker mobility across sectors. A key advantage of my framework lies in its ability to capture cross-sectional differences in consumption baskets and their implications for allocations and welfare. Recently, Jaravel and Olivi (2022) also studied optimal taxation in a framework with non-homothetic consumption preferences. However, they focus on the effects of exogenous price shocks on optimal taxation. In contrast, my paper studies how the optimal tax progressivity changes from the conventional approach when considering non-homothetic consumption preferences and variations in the relative requirement for skilled labor across sectors. Compared to my paper, the economic environment in some of the above studies (e.g., Conesa and Krueger, 2006; Bakış et al., 2015; Heathcote et al., 2017) is richer in certain dimensions (notably, idiosyncratic wage shocks, savings, human capital accumulation) while stylized in others (e.g., preference heterogeneity, policy effects on sectoral aggregates). Except Jaravel and Olivi (2022), all the papers discussed earlier assume preferences over a single consumption good as in canonical macroeconomic models (i.e., implicitly homothetic in consumption), and hence they ignore the differences in consumption baskets across income groups and their consequences for optimal income taxation. On the other hand, similar to Saez (2001), Jaravel and Olivi (2022) take earnings as exogenous, facilitating the derivation of analytical results. However, this approach inherently lacks general equilibrium effects on earnings. Consequently, I view my analysis as complementary to theirs.

Even though the optimal income taxation literature has analyzed impacts through several channels, including household savings and physical capital accumulation (Ventura, 1999; Conesa and Krueger, 2006), human capital accumulation (Stantcheva, 2017), imperfect substitutability across worker types (Stiglitz, 1982; Rothschild and Scheuer, 2013), and skill-biased technical change (Ales et al., 2015), little is known about the consequences of cross-sectional differences in consumption baskets.

Finally, the article also relates to the literature that addresses heterogeneity in households' consumption choices and its consequences for the economy. Aguiar and Bils (2015) estimate income elasticities for twenty different goods and services using quarterly data from the CEX and showed that expenditure share on income-elastic commodities increases with income. Buera and Kaboski (2012), Boppart (2014), and Comin et al. (2021) analyze the effects of these demand-side forces on structural change. Along with the CEX, Jaimovich et al. (2019) use scanner data from Nielsen and document the differences in consumption baskets across income groups. They study the implications of heterogeneity in consumption choices for business cycle analysis. I contribute to this literature by analyzing the implications of differences in consumption baskets on the welfare consequences of redistributive taxation. I quantitatively document that embedding heterogeneity in agents' consumption baskets limits progressivity.

Outline. The remainder of the paper is organized as follows. Section 2 explains the basic mechanisms at work. Section 3 outlines the quantitative model and defines the equilibrium. Section 4 describes the calibration strategies of the model and examines how well the model fits the data. Section 5 explores the quantitative implications of the model and summarizes the results concerning the optimal income taxation. Section 6 presents concluding remarks. Appendix A contains proofs. Additional details about the data, calibration strategies, model solution, and robustness analysis are provided in the Online Appendix.

2. Building intuition: the impact of tax progressivity on the composition of the consumption basket and labor supply

2.1. Tax progressivity and consumption baskets

In order to build intuition on how progressive income taxation impacts the compositions of agents' consumption baskets across income groups, here I consider a simple partial equilibrium 2-agent model. In this economy, there is an equal measure of skilled and unskilled agents, and the return from work is higher for skilled agents than for unskilled ones. Each agent inelastically supplies one unit of labor endowment, which implies they are considered not to value leisure. Agents receive earnings, y, that they use to pay taxes and finance consumption. A parametric class of tax functions $\mathcal{T}(\cdot)$ maps an agent's pre-tax earnings y to disposable earnings $\tilde{y} = \lambda y^{1-\phi}$[4]:

$$\mathcal{T}(y) = y - \lambda y^{1-\phi}, \tag{1}$$

where $\phi \in [-1, 1]$ indexes the degree of tax progressivity such that $\phi \in [-1, 0)$ implies regressive tax system, $\phi = 0$ corresponds to flat tax system with a rate $1 - \lambda$, $\phi \in (0, 1)$ represents progressive tax system and, $\phi = 1$ means complete redistributive tax system. Given ϕ, the other parameter, λ, balances the government budget. It allows the tax function to shift without affecting tax progressivity and determines the average level of taxation in the economy.[5] Any tax revenue collected by the government is wasted.

Consider agents have preferences over two goods with different income elasticities, $u\left(\boldsymbol{x}(c_m, c_n)\right)$, where $u(\cdot)$ is strictly increasing, concave, twice continuously differentiable, $\boldsymbol{x}$ denotes agent's real consumption which is an aggregator of the two goods, and good-n is more income-elastic than good-m. The agent's problem is to maximize $u\left(\boldsymbol{x}(c_m, c_n)\right)$, subject to the budget constraint $\sum_{j=\{m,n\}} p_j c_j = \tilde{y} \equiv \lambda y^{1-\phi}$.

Let agent i be skilled and i' be unskilled, then according to the setup, $\tilde{y}_i > \tilde{y}_{i'}$. Now, in the presence of non-homothetic consumption preferences, $\frac{p_n c_{in}}{p_m c_{im}} > \frac{p_n c_{i'n}}{p_m c_{i'm}}$, implying that the relative expenditure on high-income elastic goods is higher for the agent with higher disposable income. Consider government changes the degree of tax progressivity ϕ. This will change the disposable income of the high-income (skilled) agent more, $\Delta\tilde{y}_i > \Delta\tilde{y}_{i'}$. In response to the change in disposable income, agents will change their expenditure on each good within their consumption baskets. However, since an agent consumes goods with different income elasticities, his expenditure on each good will change disproportionately. Furthermore, because the disposable income of the two agents changes differently, their expenditure share on each good will also change distinctively.

Nevertheless, if preferences are homothetic, then $\frac{p_n c_{in}}{p_m c_{im}} = \frac{p_n c_{i'n}}{p_m c_{i'm}}$ for all ϕ. Thus any change in ϕ will not impact the composition of agents' consumption baskets.

2.2. Tax progressivity and labor supply

To illustrate how the non-homotheticity in consumption interacts with labor supply decisions, now consider that in addition to having preferences over two goods, agents decide on hours, $u\left(\boldsymbol{x}(c_m, c_n)\right) - \varphi\, v(h)$, where φ captures the disutility of work, $v(\cdot)$ is strictly increasing, convex, and twice continuously differentiable, and $h \in [0, 1]$ is the number of hours that the agent decides to work. The agent's problem is to maximize $u(\boldsymbol{x}) - \varphi\, v(h)$, subject to the budget constraint $\sum_{j=\{m,n\}} p_j c_j = \lambda(wh)^{1-\phi} \equiv wh\left[1 - \tau(wh;\phi)\right]$, where w is the wage rate and $\tau\left(wh;\phi\right)$ denotes the average tax rate.[6]

First, taking wages and prices as given, the partial equilibrium effect on hours worked of increasing tax progressivity can be inferred from the first-order condition that characterizes the choice of hours worked in combination with the first-order conditions for consumption goods. In this setting, these intratemporal conditions are as follows[7]:

$$\varphi\, v'_h(h) = \frac{u'_{c_j}(\boldsymbol{x})}{p_j}\left[1 - \left(\tau(wh;\phi) + wh\tau'(wh;\phi)\right)\right] w, \qquad j \in \{m, n\}. \tag{2}$$

Equation (2) implies that holding consumption and thus the income effect on labor supply unchanged, an increase in tax progressivity ϕ (i.e., increase the slope of the average tax function τ') leads to a decrease in hours worked h. This relationship persists with homothetic consumption preferences as well. However, with non-homothetic consumption preferences, when we allow consumption to adjust (i.e., when income effects are at work), any change in progressivity differentially impacts the labor supply of skilled and unskilled types. This is driven by the fact that with such preferences, the compositions of agents' consumption baskets change

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[4] The tax function $\mathcal{T}(\cdot)$ was proposed by Feldstein (1969) and recently used by Bénabou (2000, 2002) and Heathcote et al. (2017). The three main reasons to employ this tax function are: (i) it fits the U.S. data well (see, e.g., Guner et al., 2014; Heathcote et al., 2017; Holter et al., 2019; Heathcote et al., 2020), (ii) the degree of tax progressivity and the level of tax rates are controlled by two separate parameters, hence not confounded by each other, and (iii) the functional form is flexible enough to incorporate a wide variety of transfer schemes.

[5] A tax schedule is commonly classified progressive (regressive) if the ratio of marginal to average tax rates is greater (smaller) than 1 for every level of income. According to my setup, I have

$$\frac{1 - \mathcal{T}'(y)}{1 - \frac{\mathcal{T}(y)}{y}} = 1 - \phi,$$

which implies that for $0 < \phi < 1$, marginal tax rates always exceed average tax rates. Consequently, with ϕ in that interval, the tax system is progressive, and conversely when $\phi < 0$ the tax system is regressive. The case $\phi = 0$ implies that marginal and average tax rates are equal, corresponding to the flat tax system. The case of $\phi = 1$ implies that disposable income always equals λ for any pre-tax income level. For any value of ϕ, at $y = \lambda^{1/\phi} > 0$, disposable income equals pre-tax income. Therefore, $y = \lambda^{1/\phi} > 0$ is called the break-even income level. With a progressive (regressive) tax system, the average tax rate is negative at every income level below (above) the break-even point, and agents obtain a net transfer from the government.

[6] It is equivalent to writing disposable income as $\lambda y^{1-\phi}$ or $y(1 - \tau(y;\phi))$. However, writing disposable income in terms of the average tax rate (i.e., $y(1 - \tau(y;\phi))$) is convenient for the discussion in this subsection.

[7] To derive equation (2), recall the average tax function $\tau(y) = \frac{\mathcal{T}(y)}{y}$ and thus the slope of the average tax function is $\tau'(y) = \frac{\mathcal{T}'(y) - \tau(y)}{y}$. Hence, we have $\mathcal{T}'(y) = \tau(y) + y\tau'(y)$.

with their disposable income, which causes the marginal utility of income to vary across income groups, distinctively affecting their incentives to work.

While valuable for analytical insight, the partial equilibrium structure restricts the prices and wage(s) to be constant when changing the degree of progressivity. In the next section, I develop a multi-sector general equilibrium model with non-homothetic consumption preferences where prices and wage(s) become equilibrium objects.

3. Economic model

The economy is populated by a continuum of agents indexed by $i \in [0,1]$. Agents differ ex-ante based on their skill types (i.e., skilled and unskilled) denoted as $a = \{s, u\}$, with f_s being the fraction of skilled agents and the remaining fraction, $f_u \equiv (1 - f_s)$, unskilled. All agents value both consumption and leisure. Each of them is endowed with a unit of time that can be allocated to work, h, or leisure. Agents can work in only one sector at a time and receive their respective marginal products as wages. Each agent uses their earnings to finance their consumption expenditures.

3.1. Technology

The economy consists of J sectors, indexed by $j \in \mathcal{J} \equiv \{1, \cdots, J\}$. Each sector's production technology depends on sector-specific total factor productivity (TFP) and factor inputs. Firms in each sector use both skilled and unskilled labor hours as factor inputs. These two skill types are used as imperfect substitutes. A representative firm from sector j has the following constant returns to scale production technology:

$$Y_j = A_j H_j, \tag{3}$$

where A_j denotes sectoral TFP and H_j is the aggregate amount of efficiency units of labor in sector j, which is a CES aggregator of the two types of labor inputs, H_{aj}, indexed by skill type $a \in \{s, u\}$:

$$H_j = \left(\psi_j \left(H_{sj}\right)^{\frac{\rho-1}{\rho}} + \left(1-\psi_j\right)\left(H_{uj}\right)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}. \tag{4}$$

In this specification, ρ measures the elasticity of substitution between skilled and unskilled labor, which is the same in all sectors, and ψ_j denotes the importance of skilled labor within the skilled-unskilled labor composite in sector j. H_{sj} and H_{uj} are the aggregate effective labor hours of skilled and unskilled workers, respectively, who choose to work in sector j and are defined as

$$H_{sj} = f_{sj} \cdot \underbrace{\int_0^1 \mathbb{I}_{\{a_i = s\}} h_i \, di}_{\substack{\text{aggregate hours worked} \\ \text{by skilled}}}, \tag{5}$$

$$H_{uj} = f_{uj} \cdot \underbrace{\int_0^1 \mathbb{I}_{\{a_i = u\}} h_i \, di}_{\substack{\text{aggregate hours worked} \\ \text{by unskilled}}}. \tag{6}$$

In the above specifications, f_{sj} and f_{uj} are respectively the density of skilled and unskilled workers working in sector j, which are determined in competitive equilibrium such that $f_s = \sum_j^J f_{sj}$ and $f_u = \sum_j^J f_{uj}$.

The model does not include capital, and hence there is no capital accumulation. Output from each sector is devoted to private consumption and public goods. The rate of transformation between private consumption and public goods is unity. Therefore, the aggregate resource constraints can be read as follows:

$$Y_j = \int_0^1 c_{ij} \, di + \Theta_j G, \qquad j \in \mathcal{J}, \tag{7}$$

where the public good, G, is a combination of goods from different sectors, and Θ_j represents the fraction of sector j output devoted to public goods.

3.2. Earnings

An agent's pre-tax earnings y_i are the product of the corresponding skill price $w(a)$, which is decided in a competitive equilibrium that the agents take as given, and the number of hours worked h_i:

$$y_i = \underbrace{w(a_i)}_{\text{skill price}} \times \underbrace{h_i}_{\text{hours}}. \tag{8}$$

Therefore, an agent's earnings are determined by its (i) pre-labor-market skill level, which is exogenous, and (ii) work effort, the amount of time an agent chooses to work.

Progressive taxation will affect equilibrium pre-tax earnings by changing the skill prices, emerging from workers' reallocation, and their labor supply decisions.

3.3. Government

The government runs the tax and transfer system as in equation (1). It chooses the fiscal parameters ϕ and λ and finances expenditure on public goods using net revenue (i.e., taxes minus transfers). Since I abstract from public debt in the model, the government budget constraint is balanced and reads as

$$\bar{p}G = \int_0^1 \left(y_i - \lambda y_i^{1-\phi} \right) \, di, \tag{9}$$

where $\bar{p}$ is the price of the public good, which is defined as a weighted average of the sectoral prices, $\bar{p} \equiv \sum_j^J \Theta_j p_j$.

3.4. Preferences

Each agent's utility depends on his preferences over private consumption, hours worked, and publicly provided goods. The period utility function for an agent i is specified as

$$\mathcal{U}_i \left(\boldsymbol{x}_i, h_i, G \right) = \log \boldsymbol{x}_i - \varphi \frac{h_i^{1+\nu}}{1+\nu} + \chi \ \log \ G, \tag{10}$$

where $\varphi \geq 0$ determines the disutility from work, $\nu \geq 0$ denotes the inverse Frisch elasticity of labor supply, and the parameter $\chi \geq 0$ measures the taste for the public consumption relative to private consumption. $\boldsymbol{x}_i > 0$ represents agent i's basket of private consumption, consisting of a bundle of goods $\{c_{ij}\}_{j=1}^J$ defined over consumption from each sector. These sectoral goods enter the consumption basket according to a non-homothetic CES aggregator, building on Comin et al. (2021). Thus, the private consumption basket of an agent, $\boldsymbol{x}_i$, is expressed implicitly by the following function:

$$\sum_j^J \Omega_j^{\frac{1}{\sigma}} \left(\frac{c_{ij}}{\boldsymbol{x}_i^{\epsilon_j}} \right)^{\frac{\sigma-1}{\sigma}} = 1, \tag{11}$$

where $\sigma \geq 0$ measures the elasticity of substitution across sectoral goods, $\Omega_j \geq 0$ with $j \in \mathcal{J}$ are good-specific constant weight parameters, and ϵ_j with $j \in \mathcal{J}$ are good-specific non-homotheticity parameters that govern the agent's expenditure elasticity of demand across different goods. Equation (11) embeds the property of non-homothetic consumption preferences that it can rationalize the systemic variation in different types of goods demanded at different income levels.[8] The usual consumption aggregators typically assumed under homothetic CES preferences are a particular case of equation (11) with $\epsilon_j = 1$.

3.5. Budget constraint

Agents in the economy choose labor hours that entitle them to receive earnings. From their earnings, they pay a fraction as tax and receive transfers. Their post-government earnings (i.e., earnings minus taxes plus transfers) are entirely spent on consumption. Therefore, the budget constraint for an agent i is

$$\sum_j^J p_j c_{ij} = \lambda \left[w(a_i) h_i \right]^{1-\phi}, \tag{12}$$

where p_j is the price of the consumption good produced in sector j, determined in equilibrium that the agent takes as given.

3.6. Agent's problem

The problem for an agent is to choose consumption and labor hours to maximize utility defined in equation (10) subject to the constraint in equation (11) and the budget constraint expressed in equation (12), taking the wage rate and prices as given. In addition, agents face non-negativity constraints on consumption and labor choices.

3.7. Firm's problem

Production in each sector takes place in a perfectly competitive market. I assume that both types of workers (i.e., skilled and unskilled) can move across sectors, so that skill prices are equalized across sectors. Firms in both sectors take skill and output prices as given and maximize profits subject to the production technology in equation (3).

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[8] See Matsuyama (2019) and Comin et al. (2021) for details.

3.8. Equilibrium

Given the fiscal parameters, λ and ϕ, an equilibrium in my model is a set of model variables such that:

(i) Given prices and government policies, consumers solve the problem described in Section 3.6 and firms solve the problem described in Section 3.7.
(ii) Labor markets for each skill type clear:

$$H_a = \int_0^1 \mathbb{I}_{\{a_i=a\}} h_i \, di, \qquad a = \{s, u\}. \tag{13}$$

(iii) Skill prices satisfy marginal product pricing conditions:

$$w(a) = p_j \frac{\partial \left[A_j F_j \left(H_{sj}, H_{uj}\right)\right]}{\partial H_{aj}}, \qquad a = \{s, u\}. \tag{14}$$

(iv) Goods markets clearing conditions in equation (7) are satisfied with equilibrium sectoral prices p_j with $j \in \mathcal{J}$.
(v) Government policies satisfy the government budget constraint in equation (9).

Proposition 1 presents the equilibrium allocations. With non-homothetic consumption preferences and logarithmic utility, sectoral consumption allocations and labor supply allocation are endogenous in the agent's private consumption basket $\boldsymbol{x}_i$. The payoff from the non-homothetic demand system is that it well approximates the expenditure patterns in the data by allowing agents to adjust their sectoral consumption based on the expenditure elasticity of goods. I present the analytical expression for the expenditure elasticity of demand in Proposition 2. The equilibrium prices are expressed in Proposition 3.

Proposition 1 *(Hours and consumption). The equilibrium hours worked allocation is given by (for notational convenience here I omit individual subscripts)*

$$\begin{aligned}\log h\left(\sigma, \epsilon_1, \cdots, \epsilon_J, \Omega_1, \cdots, \Omega_J, \nu, \varphi, a; \lambda, \phi\right) = &\frac{1}{\nu+\phi}\Big(\log(1-\phi) - \log\varphi + \log\mu + \log\lambda \\ &+ (1-\phi)\log w(a;\lambda,\phi)\Big), \qquad j \in \mathcal{J} \equiv \{1, \cdots, J\},\end{aligned} \tag{15}$$

where $\mu = \dfrac{\boldsymbol{x}^{-1}}{\left(\sum_j \Omega_j \left(p_j \boldsymbol{x}^{\epsilon_j - 1}\right)^{1-\sigma}\right)^{\frac{\sigma}{1-\sigma}}} \cdot \dfrac{1}{\sum_j \Omega_j \left(p_j \boldsymbol{x}^{\epsilon_j-1}\right)^{1-\sigma} \epsilon_j}$. *The sectoral consumption allocations are given by*

$$\begin{aligned}\log c_j\left(\sigma, \epsilon_1, \cdots, \epsilon_J, \Omega_1, \cdots, \Omega_J, \nu, \varphi, a; \lambda, \phi\right) = &\log\Omega_j - \sigma\log p_j + \sigma\log\lambda + \sigma(1-\phi)\log w(a;\lambda,\phi) \\ &+ \sigma(1-\phi)\log h\left(\sigma, \epsilon_1, \cdots, \epsilon_J, \Omega_1, \cdots, \Omega_J, \nu, \varphi, a; \lambda, \phi\right) \\ &+ \epsilon_j(1-\sigma)\log\boldsymbol{x}, \qquad j \in \mathcal{J} \equiv \{1, \cdots, J\}.\end{aligned} \tag{16}$$

Proof. See Appendix A.1. ■

The hours allocation in equation (15) is additive in five separate terms (enclosed in parentheses). The first term shows that a more progressive tax system (higher value for ϕ) reduces labor supply. The second term suggests that a higher disutility of work leads to a choice of fewer hours to work. The third term captures the fact that an increase in consumption reduces the marginal utility of consumption, consequently lowering incentives to work. The next term indicates that an increase in the fiscal parameter λ decreases the average tax rate and increases the agent's disposable income. The last term implies that the agent's labor supply increases with its skill price $w(a)$.

The sectoral consumption allocations are broadly composed of six terms. A larger preference weight indicates that the agent has a relatively higher preference for the good. The second term captures the own-price effect, where less substitutability can weaken the price effect on sectoral consumption demand. The third term implies that λ has a positive effect on sectoral consumption (because an increase in λ decreases the average tax rate and increases the agent's after-tax income). The fourth term shows that consumption from each sector increases with the skill price. The fifth term captures the hours effect on consumption. An increase in labor supply increases the agent's earnings and, therefore, consumption. Factors that affect hours worked also affect consumption decisions. The final term indicates that the agent's sectoral consumption is increasing in his consumption basket. The magnitude of the rise in sectoral consumption depends on the elasticity of substitution σ and the income (expenditure) elasticity of that particular good.

Proposition 2 *(Income elasticities). The income (expenditure) elasticity of demand for sector j good is given by*

$$\eta_{ij} = \frac{\partial\log(c_{ij})}{\partial\log(\tilde{y}_i)} = \sigma + (1-\sigma)\frac{\epsilon_j}{\bar{\epsilon}_i}, \tag{17}$$

where $\bar{\epsilon}_i$ is defined as a weighted average of non-homotheticity parameters, $\bar{\epsilon}_i \equiv \sum_j^J \omega_{ij}\epsilon_j$, with ω_{ij} representing agent's expenditure share on sector j good.

Proof. See Appendix A.2. ■

From equation (17), it is clear that the income elasticity of demand for any specific good can differ by consumer. This implies that no good is naturally a luxury or a necessity, rather it depends on the agent's current composition of consumption expenditures and, consequently, on disposable income. Income taxes can thus distort the demand for sectoral consumption by changing after-tax income. The size of the distortion depends on the price and expenditure elasticity of that particular good for the agent.

Proposition 3 *(Skill and consumption prices). Skill prices are determined by firms' first order conditions and clear the labor markets (i.e., one for each skill type) in equilibrium:*

$$w(s) = p_j A_j^{\frac{\rho-1}{\rho}} Y_j^{\frac{1}{\rho}} \psi_j H_{sj}^{-\frac{1}{\rho}}, \qquad j \in \mathcal{J} \equiv \{1, \cdots, J\}; \tag{18}$$

$$w(u) = p_j A_j^{\frac{\rho-1}{\rho}} Y_j^{\frac{1}{\rho}} (1-\psi_j) H_{uj}^{-\frac{1}{\rho}}, \qquad j \in \mathcal{J} \equiv \{1, \cdots, J\}. \tag{19}$$

Given wages, in a perfectly competitive market, prices are set to their respective marginal cost:

$$p_j = \frac{1}{A_j}\left[\psi_j^{\rho} w(s)^{1-\rho} + (1-\psi_j)^{\rho} w(u)^{1-\rho}\right]^{\frac{1}{1-\rho}}, \qquad j \in \mathcal{J} \equiv \{1, \cdots, J\}. \tag{20}$$

Proof. See Appendix A.3. ■

The hourly wage $w(a)$ is the marginal product of an additional effective hour supplied by a worker with skill level a. Wages are increasing in several factors, including sectoral prices, TFP, output, and the importance of the corresponding skill type in production technology. An increase in any of these factors enhances firms' profits, encouraging them to expand production, which, in turn, raises the demand for labor and leads to higher wages. On the other hand, an increase in the labor supply for a particular skill level lower the wage for that skill type. When a tax system becomes more progressive, it induces firms to reduce their production, reducing the demand for labor and leading to lower wages. Since the model does not include human capital accumulation, the proportions of skilled and unskilled workers are exogenous and remain constant. In this framework, a more progressive tax system reduces the relative demand for products from skilled-labor intensive sectors, pushing the demand for skilled labor and the skill premium down. This is because a decline in disposable income reduces demand for high income-elastic goods, which are relatively more skilled-labor intensive (see, e.g., Caron et al., 2014).

The sectoral prices in equation (20) depend on the respective TFPs, technological parameters, and equilibrium wages. Higher TFP increases firms' productivity, reducing the marginal cost of production and leading to lower prices. Sectoral prices are positively related to wages, as higher wages increase production costs. Since prices are determined to clear the labor and commodity markets, any change in progressivity that causes new equilibrium wages necessarily implies new equilibrium commodity prices. However, as firms in all sectors employ both skilled and unskilled workers, this may weaken the effect of a change in progressivity on relative sectoral prices.

4. Calibration

I now turn to the calibration of the model. I calibrate the model using micro-level and aggregate data for the U.S. economy. To reduce the computational burden, I group industries into two sectors: goods (m) and services (n), based on the income elasticities of their output. Overall I assign values to fifteen parameters, consisting of two tax function parameters (ϕ, λ), five technology parameters (ρ, ψ_m, ψ_n, A_m/A_n, Θ_n), and eight preference parameters (σ, ϵ_m, ϵ_n, Ω_m, Ω_n, ν, φ, χ). A set of these parameters is calibrated externally (either computed directly from the data or taken from the literature), which I explain in the first step, followed by the parameters obtained by estimating the demand system derived in equilibrium from the model. I then describe the calibration strategy of the remaining parameters, which are determined jointly by matching an equal number of model moments with their corresponding empirical counterparts. Table 2 summarizes the calibration strategy and reports the baseline parameter values.

4.1. Externally calibrated parameters

I begin describing the external calibration by setting the degree of tax progressivity parameter. The parameter is taken from Heathcote et al. (2017), who have estimated the tax function in equation (1) for the U.S. using data from the Panel Study of Income Dynamics (PSID) in combination with the NBER's TAXSIM program and reported an estimate of the degree of tax progressivity parameter of $\phi = 0.181$.[9]

[9] Guner et al. (2014) and Holter et al. (2019) also estimate the U.S. tax progressivity employing the same tax function. Guner et al. (2014) estimate the tax function using Internal Revenue Service (IRS) data and report a degree of progressivity parameter of $\phi = 0.053$. Holter et al. (2019) use Organisation for Economic Co-operation

Table 1
Demand Estimation.

Parameter	(1)	(2)	(3)
σ	−0.211 (0.089)	0.216*** (0.043)	0.257*** (0.059)
ϵ_n	1.294*** (0.033)	1.564*** (0.051)	1.610*** (0.076)
Region FE	✗	✗	✓
Year × Quarter FE	✗	✓	✓

Notes. All regressions include household controls: age (25-37, 38-50, 51-64), household size (≤2, 3-4, 5+), and the number of earners (1, 2+). Standard errors clustered at the household level are shown in parentheses. The number of observations is 87,077 in all regressions. *** indicates significance at the 1% level.

Turning to the production technologies, to be consistent with the theory, I divide workers into two broad categories based on their educational attainments (i.e., skilled and unskilled). To carry out this exercise, I rely on the World KLEMS data for the U.S. from 2000 to 2006.[10] World KLEMS contains data on labor compensation per hour worked, average hours worked per week, and the number of workers employed by industry, gender, class, educational attainment, and age groups.[11] I combine all workers with a college degree or more into the skilled group and all workers less than a college degree into the unskilled group. This strategy places one-third of workers in the economy in the skilled category. Following the literature, I set the elasticity of substitution between skilled and unskilled labor ρ to 1.50.[12] The parameter that measures the fraction of public goods adapted from the service sector is set to $\Theta_n = 1$, following the Bureau of Economic Analysis (BEA) definition of government consumption.[13]

Moving on to consumer preferences, I set the inverse Frisch elasticity ν to 2.0, which is consistent with the microeconomic evidence on the Frisch elasticity (see, e.g., Keane, 2011). The preference parameter that measures the relative weight on public consumption is set to $\chi = 0.15$, which is inferred using the identity that the relative taste for public to private consumption equals government consumption expenditures relative to households' consumption expenditures.[14]

4.2. Structurally estimated parameters

I estimate the elasticity of substitution and non-homotheticity parameters using quarterly U.S. household consumption expenditure data from the CEX, supplemented with the disaggregated regional quarterly price series from the Bureau of Labor Statistics (BLS). The estimation approach closely follows the methodology used in previous literature, particularly Comin et al. (2021). A concise description of the estimation exercise is provided in the main text, while further details are available in Online Appendix B. To obtain the estimating equation, I start by expressing a household's expenditure shares of goods (ω_{imt}) and services (ω_{int}) using equation (16):

$$\ln\left(\frac{\omega_{int}}{\omega_{imt}}\right) = (1-\sigma)\ln\left(\frac{p_{nt}}{p_{mt}}\right) + (1-\sigma)(\epsilon_n - 1)\ln\left(\frac{Exp_{it}}{p_{mt}}\right) + (\epsilon_n - 1)\ln\omega_{imt} + \underbrace{\ln\left(\Omega_n\right)}_{\text{constant}\equiv\zeta}, \tag{21}$$

where without loss of generality, I normalize $\epsilon_m = \Omega_m = 1$. The variables on the right- and left-hand side of equation (21) are observable in the data. I estimate an empirical counterpart of the above equation and report the estimation results in Table 1.

and Development (OECD) data and obtain an estimate of $\phi = 0.137$. I employ the estimate from Heathcote et al. (2017) because their data allows them to include most transfers, thus offering a relatively better measure of progressivity.

[10] I choose the sample period based on the availability of information across datasets. Moreover, U.S. tax progressivity is roughly constant over this period (Heathcote et al., 2017).

[11] There are two classes of workers (i.e., employees and self-employed) and eight age groups (i.e., 14-15, 16-17, 18-24, 25-34, 35-44, 45-54, 55-64, and 65 and over). To construct my sample, I include workers of age 25-64. The educational attainment data are classified into six categories (i.e., until 1992: 'less than high school', 'some high school', 'high school graduates', 'some college', 'college graduates', and 'more than college graduates'; after 1992: '8th grade or less', 'grades 9-12 no diploma', 'high school graduates', 'some college no degree, associate degree', 'BA, BS', and 'more than BA').

[12] Buera et al. (2022) use data from the World KLEMS and report an estimate of $\rho = 1.53$ for the elasticity of substitution between workers with and without a college degree. Following Katz and Murphy (1992), the literature commonly employs a value of around 1.5 for the parameter ρ. This value has been widely accepted, as Cantore et al. (2017) states 1.5 as the "consensus estimate" for ρ.

[13] Government consumption includes government-provided services to the public, such as national defense and education (see https://www.bea.gov/resources/learning-center/what-to-know-government for details).

[14] I do this exercise using the Penn World Table version 10.0 (Feenstra et al., 2015). I divide the share of government consumption in output (variable name csh_g) by the share of household consumption in output (variable name csh_c) and set it equal to χ.

Table 2
Summary of Baseline Parametrization.

Parameter	Description	Value	Source/Target
Tax function parameters:			
ϕ	Curvature of the tax function	0.181	Heathcote et al. (2017)
λ	Government budget balancer	0.881	Ratio of government expenditure to output (0.189)
Technology parameters:			
ρ	Elasticity of substitution between skilled and unskilled labor	1.500	Literature
ψ_m	Weight of skilled labor hours in sector m technology	0.419	Income share of skilled labor in goods sector (0.315)
ψ_n	Weight of skilled labor hours in sector n technology	0.572	Income share of skilled labor in service sector (0.537)
A_m/A_n	Ratio of sector m to sector n TFP	1.197	Log of relative price index of services (0.313)
Θ_n	Fraction of public consumption adapted from sector n	1.000	BEA
Preference parameters:			
σ	Elasticity of substitution between goods and services	0.257	Demand estimation (column 4 of Table 1)
ϵ_m	Non-homotheticity parameter of sector m product	1.000	Normalization
ϵ_n	Non-homotheticity parameter of sector n product	1.610	Demand estimation (column 4 of Table 1)
Ω_m	Weight of sector m product in the consumption basket	1.000	Normalization
Ω_n	Weight of sector n product in the consumption basket	1.619	Average consumption expenditure share on services (0.596)
ν	Inverse Frisch elasticity of labor supply	2.000	Literature
φ	Weight of the utility cost of labor supply	16.218	Average hours worked (0.333)
χ	Relative taste for the public good	0.150	Ratio of government CE to households CE (PWT 10.0)

Notes. BEA = Bureau of Economic Analysis; CE = Consumption Expenditure; PWT = Penn World Table.

Table 3
Targeted Moments: Baseline.

Moment	Data	Model
Ratio of government expenditure to output	0.189	0.189
Income share of skilled labor in goods sector	0.315	0.315
Income share of skilled labor in service sector	0.537	0.537
Log of relative price index of services	0.313	0.313
Average expenditure share on services	0.596	0.596
Average hours worked	0.333	0.333

Notes. The table presents targeted moments in the baseline model calibration along with their empirical counterparts. The values of the empirical moments refer to the average over the sample period.

4.3. Internally calibrated parameters

Given the externally calibrated parameters, the final set of six parameters (λ, ψ_m, ψ_n, A_m/A_n, Ω_m, φ) are jointly determined in equilibrium, matching six moments from the model to their empirical counterparts (see Table 3). Although none of the parameters has a one-to-one relationship to a specific moment, there are strong economic relationships between particular moments and parameters.

Given the degree of tax progressivity parameter, ϕ, I choose the parameter $\lambda = 0.881$ to match the ratio of government consumption expenditure to output to 0.189 (Heathcote et al., 2017).

The parameters measuring the skill-biased demand shifts ψ_j with $j = \{m, n\}$ are calibrated by targeting sectoral factor income shares. Specifically, I set $\psi_m = 0.419$ and $\psi_n = 0.572$ to match the income share of skilled labor in goods sector (0.315) and service

Table 4
Non-Targeted Moments: Baseline.

Moment	Data	Model
Earnings premium	1.756	1.765
Ratio of skilled to unskilled labor hours in goods sector	0.251	0.259
Ratio of skilled to unskilled labor hours in service sector	0.608	0.654
Relative expenditure on services for skilled	1.509	1.637
Relative expenditure on services for unskilled	1.185	1.403

Notes. The table presents non-targeted moments computed using the baseline model along with their empirical counterparts. The values of the empirical moments refer to the average over the sample period. Relative expenditure on services refers to expenditure on services relative to goods.

sector (0.537) from the data, respectively.[15] I choose the value of relative sectoral TFP, $A_m/A_n = 1.197$, so that the log of the relative price index of services from the model matches its empirical counterpart (0.313).

I calibrate the weight parameter of service consumption Ω_n for the model to match the average expenditure share on services from the data (0.596). This procedure yields $\Omega_n = 1.619$. In addition to choosing consumption, agents in the model decide how to allocate their time between work and leisure. I set the weight of the utility cost of labor supply φ to 16.218, so that at equilibrium, on average, agents allocate one-third of their time to work.

4.4. Model validation

In order to verify that the benchmark model is a reasonable representation of the U.S. economy, I examine the model performance along five dimensions not targeted in the calibration. The moments of interest include the earnings premium, skilled to unskilled effective labor hours in goods and service sectors, and the relative expenditure on services for skilled and unskilled workers. Table 4 presents these moments obtained from the model along with their empirical counterparts.

I estimate the U.S. earnings premium using the World KLEMS data. In doing so, given the significant differences in hourly wage rates among sub-groups in each skill type, it seems ill-advised to use the average hourly wages within each skill category. Instead, I assume that wage differences between various demographic groups (i.e., age, gender) within a given skill type reflect differences in efficiency units. I normalize efficiency units within each skill type by assuming that one hour supplied by a prime-aged (i.e., age 35-44) male who has completed college (high school) is equal to one efficiency unit of skilled (unskilled) labor. Proceeding with this methodology, I define the earnings premium as the weekly labor compensation ratio of college-educated to high-school-educated prime-aged male. The estimated earnings premium over the sample period (i.e., 2000-2006) is 1.76, on average.[16] In the model, the ratio of the equilibrium average skilled and unskilled earnings represents the earnings premium.

Next, I estimate the ratio of skilled to unskilled effective labor hours in each sector of the economy. The data suggests that a larger share of skilled labor is employed in the service sector, which is consistent with the literature (see, e.g., Buera and Kaboski, 2012). In the model, both the goods and service sectors employ skilled and unskilled workers with imperfect substitutability. Importantly, the model successfully captures the higher skill intensity of the service sector compared to the goods sector.

Finally, using the CEX data, I find that, on average, skilled workers' expenditure on services relative to goods is higher than for unskilled workers.[17] Notably, as in the data, the model is able to account for this fact.

Overall, the model moments are consistent with their empirical counterparts. Consequently, I conclude that qualitatively and quantitatively, the model captures the most salient features of the U.S. data. I now use this calibrated model as an empirically informed laboratory for my quantitative analysis.

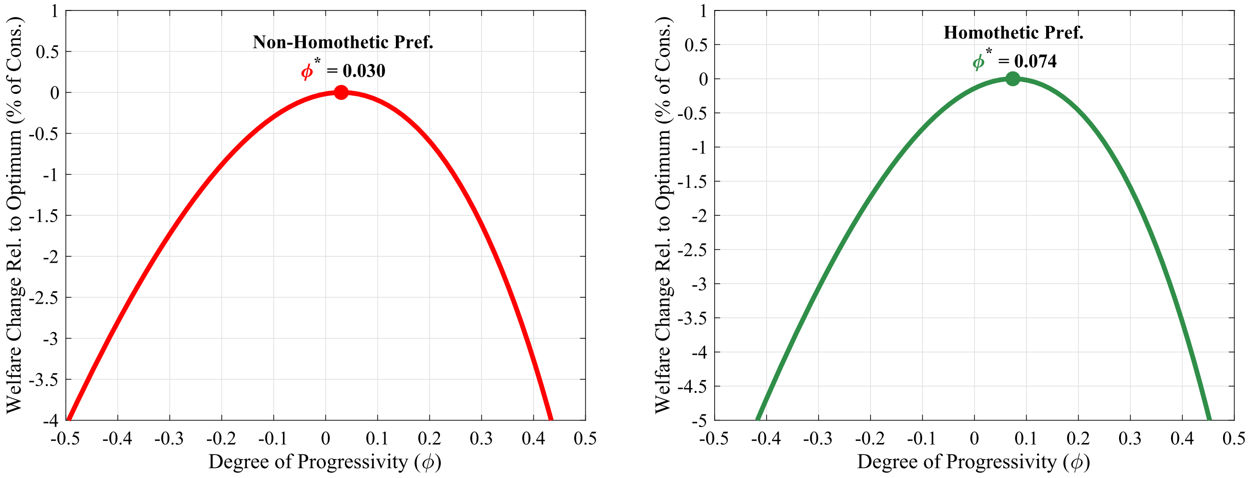
5. Quantitative analysis

In this section, I conduct a set of quantitative experiments. First, I characterize and then numerically compute the optimal degree of income tax progressivity for my model. Next, I analyze the quantitative implications of reforming the U.S. tax code toward a utilitarian planner's choice of tax code. This exercise is also useful for exploring the mechanisms at play within the model.

[15] I use data from the World KLEMS to compute the total annual labor compensation. The labor compensation variable of World KLEMS includes both wage and non-wage components (supplements to wages and salaries) of labor input costs and the compensation of the self-employed. In addition, the dataset adjusts the hours variable for the self-employed. Thus, World KLEMS provides reliable information on aggregate compensation and aggregate hours in the economy.

[16] I also use Current Population Survey (CPS) data to compute earnings premium. The result obtained from CPS data aligns closely with the one derived from World KLEMS (1.762 using CPS compared to 1.756 using World KLEMS).

[17] The educational attainment data in CEX are classified into nine categories (i.e., 'never attended', '1st-8th grade', '9th-12th grade, no high school diploma', 'high school graduate', 'some college, no degree', 'associate degree in college', 'bachelor's degree', 'master's degree', 'professional/doctorate degree'). I combine all households with the household head's educational attainment of bachelor's degrees or more into the skilled group, while the rest are merged into the unskilled group.



(A) **(B)**

Notes. Panel A plots social welfare as a function of ϕ from the baseline model with non-homothetic consumption preferences. Panel B plots social welfare as a function of ϕ with standard homothetic consumption preferences (i.e., $\epsilon_m = \epsilon_n = 1$).

Fig. 1. Optimal Income Tax Progressivity.

5.1. *The optimal income tax progressivity*

Methodology. Given the tax and transfer system in equation (1), a government or planner chooses the fiscal parameters ϕ and λ to maximize social welfare. With a given degree of progressivity ϕ, the other fiscal parameter λ is chosen to regulate the government net revenue to total labor compensation ratio. Let $\boldsymbol{r}$ denote the fraction of total labor compensation collected as net tax revenue (i.e., net tax revenue $= \boldsymbol{r} \times$ total labor compensation).[18] Then, for any given combination of $\boldsymbol{r}$ and ϕ, one can easily determine λ from the government budget constraint.[19] The social welfare function is then given by

$$SWF(\boldsymbol{r},\theta,\phi) = \int W_i(a_i;\theta)\, \mathcal{U}_i\left(\boldsymbol{x}_i, h_i, G\right)\, di, \qquad a_i \in \{s,u\}, \tag{22}$$

where $\mathcal{U}_i\left(\boldsymbol{x}_i, h_i, G\right)$ is agent i's utility and $W_i(a_i;\theta)$ is the Pareto weight function which is assumed to take the following form[20]:

$$W(a_i;\theta) = \frac{y(a_i)^{-\theta}}{\int y(a_i)^{-\theta} di} \quad \text{for} \quad a_i \in \{s,u\}. \tag{23}$$

Here the parameter θ controls the planner's taste for redistribution. With a negative (positive) θ, the planner puts relatively high weight on high-income (low-income) agents.

Given the social welfare function, for a specific planner's choice of redistribution (i.e., fixed θ), I define the optimal degree of tax progressivity as

$$\phi^\star = \arg\max_{\phi}\ SWF(\phi). \tag{24}$$

Since $\boldsymbol{r}$ is held constant (to keep the tax system revenue-neutral) when solving for optimal progressivity, social welfare solely becomes a function of ϕ. The implicit functional form of the consumption basket makes it infeasible to obtain an explicit analytical solution for the optimal degree of tax progressivity $\phi^\star$. Therefore, I determine $\phi^\star$ numerically.[21]

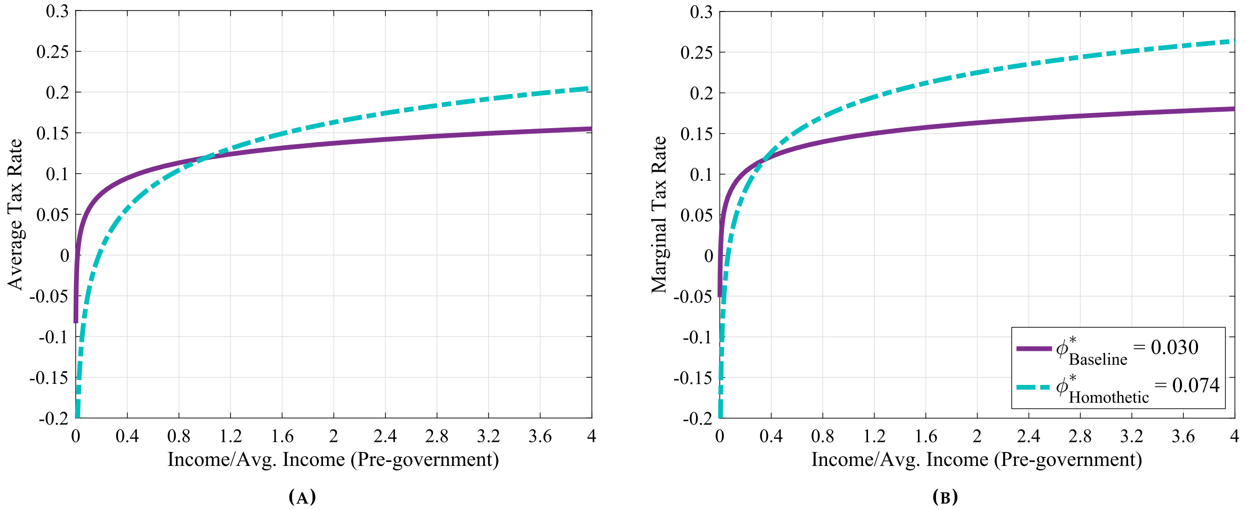
Results. In order to analyze optimal public policy, it is necessary to take an explicit stand on the planner's weights for all agents in the economy. In my baseline analysis, I focus on $\theta = 0$, which puts equal weight on all agents á la utilitarian social planner, the most common assumption in the literature.

[18] Given that the model abstracts from capital and international trade and assumes perfectly competitive markets, total labor compensation, output, and GDP are all equivalent within this framework. Consequently, $\boldsymbol{r}$ also represents the revenue-to-GDP ratio.

[19] The government budget constraint in equation (9) can also be written as $\boldsymbol{r}\int_0^1 y_i\, di = \int_0^1 \left(y_i - \lambda y_i^{1-\phi}\right) di$. From this equation, given the pair $(\boldsymbol{r},\phi)$, we can determine λ residually.

[20] The Pareto weight function is adapted from Heathcote and Tsujiyama (2021).

[21] To solve for $\phi^\star$ numerically, I first construct a grid in the space of fiscal parameters ϕ and $\lambda(\boldsymbol{r},\phi)$. I set $\boldsymbol{r}$ as fixed at the ratio of government expenditure to output from the data (0.189) and construct the grid for $\lambda(\boldsymbol{r},\phi)$. I then solve for the equilibrium allocations and compute the associated utility for all agents at each combination of ϕ and $\lambda(\boldsymbol{r},\phi)$ in the grid space to find the welfare-maximizing parameter combination.



Notes. Panel A plots the average tax rates and Panel B plots the marginal tax rates under the optimal tax systems obtained from the baseline model with non-homothetic consumption preferences and the model with homothetic consumption preferences.

Fig. 2. Comparison of the Utilitarian Planner's Choices of Income Tax Systems Under the Models with and without Non-Homothetic Consumption Preferences.

Fig. 1, Panel A plots social welfare as a function of the degree of progressivity ϕ under the baseline model with non-homothetic consumption preferences. The income tax progressivity parameter that maximizes social welfare is $\phi^\star = 0.030$. To investigate the impact of non-homothetic consumption preferences, I compare this $\phi^\star$ with the one obtained from a version of the model featuring standard homothetic consumption preferences (i.e., $\epsilon_m = \epsilon_n = 1$). Fig. 1, Panel B shows that the progressivity that maximizes social welfare under the model with homothetic consumption preferences is $\phi^\star = 0.074$, which is approximately 147% higher than the one obtained from the baseline model.[22]

To better understand the differences between the optimal tax schemes in models with non-homothetic and homothetic consumption preferences, in Fig. 2, I plot the average and marginal tax rates implied by the two values of the degree of optimal progressivity, $\phi^\star$. It shows that marginal tax rates (and consequently average tax rates) under the optimal tax system in the baseline model are considerably lower for high-income agents than for the model with homothetic consumption preferences. Specifically, the average (income-weighted) marginal tax rates suggested by the optimal progressivity under the two preference systems are 21% and 25%, respectively.[23]

Why is the optimal tax progressivity lower in the model that features non-homothetic consumption preferences? When formulating a tax code, a planner considers the impact of taxation on consumption dispersion, both directly (via redistribution) and indirectly via its impact on equilibrium wages, prices, and quantities. With non-homothetic consumption preferences, the indirect channel is vital in choosing a tax code. In the face of a policy shock—progressive income taxation—agents who experience a reduction in disposable income cut their consumption. However, under non-homothetic preferences, agents predominantly reduce services consumption (i.e., income-elastic consumption) while shifting to goods (i.e., income-inelastic consumption). As a result, the relative demand for goods rises in the economy. Higher demand drives the relative price of goods up, partially shifting the incidence onto low-income agents. This is because low-income agents allocate a larger share of their consumption expenditure to goods. However, the share of unskilled labor in the goods sector is relatively higher, resulting in higher relative demand and wages for unskilled labor. As long as the wage effect dominates the price effect, the unskilled agents will benefit from a higher income tax progressivity, and vice versa. On the other hand, in the presence of non-homothetic consumption preferences, high-income agents partly offset the negative effect of a higher marginal tax rate by adjusting the compositions of their consumption baskets (i.e., choosing a relatively cheaper consumption basket), weakening the redistributive purpose of progressive income taxation. Additionally, in the presence of perfect labor mobility, lower demand for services decreases the relative demand for skilled labor and thus their wages, reducing their incentives to work and creating inefficiency in production. Consequently, in the model with non-homothetic consumption preferences, even with a relatively lower income tax progressivity, the efficiency cost outweighs gains from redistribution, limiting the planner's choice of degree of tax progressivity.

In my framework, due to heterogeneity in agents' pre-tax earnings, a utilitarian planner would always choose $\phi > 0$ to redistribute against the income differentials. If redistribution were the planner's only concern, ϕ would optimally be set to 1. In that case, the tax and transfer system would equalize after-tax income across agents. Nonetheless, labor supply falls with progressivity, generating inef-

[22] In the case of an alternatively calibrated model with homothetic consumption preferences, the optimal degree of progressivity is $\phi^\star = 0.053$. See Online Appendix E for details.

[23] Given a balanced government budget: $\boldsymbol{r}Y^{LC} = \int_0^1 \left(y_i - \lambda y_i^{1-\phi}\right) di$, where $Y^{LC} = \int_0^1 y_i \, di$ is the economy wide total labor compensation, the income-weighted average marginal tax rate can be written as $\int_0^1 \left[1 - \lambda(1-\phi) y_i^{-\phi}\right] \left(\frac{y_i}{Y^{LC}}\right) di = 1 - (1-\phi)\int_0^1 \lambda y_i^{1-\phi} \left(\frac{1}{Y^{LC}}\right) di = 1 - (1-\phi)(1-\boldsymbol{r})$.

Table 5
Optimal Income Tax Progressivity Under Different Planners and Model Specifications.

Social Planner	Optimal Progressivity $\phi^\star$				
	Baseline	$\epsilon_m = \epsilon_n = 1$	$\chi = 0$	$f_s = f_u$	No Labor Mobility
Utilitarian ($\theta = 0$)	0.030	0.074	0.169	−0.195	0.053
Rawlsian ($\theta \to \infty$)	0.311	0.349	0.417	−0.040	0.321

Notes. The table presents the optimal degree of income tax progressivity under different planners and model specifications. The values in the first row exhibit results under a utilitarian social planner, and the second row shows results under a Rawlsian planner. Column 2 refers to the baseline case. Column 3 refers to the exercise with homothetic consumption preferences. Column 4 refers to the exercise in which agents get no utility from public consumption. Column 5 refers to the exercise with equal measures of skilled and unskilled workers. The last column refers to the exercise in which the measures of skilled and unskilled workers in the goods and service sectors remain fixed at the U.S. status quo.

ficiency in production. With a higher tax progressivity, efficiency cost exceeds gains from redistribution. The labor supply distortion depends on its elasticity—greater elasticity would create more distortion from a higher tax progressivity (see, e.g., Keane, 2011).[24] The presence of public consumption in agents' utility functions constitutes a force toward regressive taxation. This is because if all agents worked more, the quantity of the valued public goods would increase, ultimately increasing social welfare. In a version of my model where $\chi = 0$, the optimal degree of progressivity $\phi^\star$ (column 4 of Table 5) is greater than the baseline $\phi^\star$. Additionally, in the baseline model, I consider perfect labor mobility. However, when I keep the measures of skilled and unskilled workers in both sectors fixed, this leads to higher inequality and a greater optimal degree of progressivity (column 6 of Table 5).

Alternative Social Planner. To this point, I have explored the optimal degree of tax progressivity, assuming that the planner is utilitarian ($\theta = 0$). I now consider an alternative Pareto weight function with $\theta \to \infty$, corresponding to a Rawlsian planner.[25] With non-homothetic consumption preferences, the planner chooses $\phi^\star = 0.311$. When preferences are homothetic in consumption, the planner chooses $\phi^\star = 0.349$. These values of $\phi^\star$ translate to average marginal tax rates of 44% and 47%, respectively. Similarly to a utilitarian planner, a Rawlsian social planner chooses a less progressive tax code when agents' preferences are non-homothetic in consumption. However, regardless of the type of consumption preferences, a stronger taste for redistribution leads a Rawlsian planner to choose higher marginal tax rates than a utilitarian planner and allows him to tolerate the larger efficiency cost associated with increased transfers benefiting the poorest.

5.2. A tax reform

I now shift to the quantitative implications of switching the tax code from the U.S. status quo to a utilitarian planner's choice under the baseline parameterization in Section 5.1. This reform is revenue-neutral. Given the value of ϕ, $\lambda(\boldsymbol{r}, \phi)$ is adjusted to match the net tax revenue to labor compensation ratio of the counterfactual economy to that of the benchmark economy (i.e., U.S. status quo). All other parameters remain the same. In order to obtain a better understanding of the economic forces underlying the results concerning the optimal tax code, in Table 6 I compare the main economic aggregates obtained under the optimal tax system with those obtained under the U.S. tax system.

Note that the tax reform results in higher labor supply (Panel D) and higher average disposable income (Panel B) than the benchmark economy. Due to the considerably lower marginal tax rates (average marginal tax rate drops from 34% to 21%), agents with the same level of pre-tax income experience higher after-tax income. The higher return from labor supply gives agents better incentives to work, increasing hours worked (on average, hours worked increase by 5.75%) and their earnings. Providing better incentives to work comes at the expense of creating more dispersed income and consumption. However, note that the average consumption increases after reform (an increment of 3.91%, see Panel C). Due to the higher after-tax income, relative expenditure on services rises for both skilled and unskilled agents. The increase is larger for skilled than unskilled as lower marginal tax rates raise skilled agents' income significantly relative to the benchmark.

The higher demand for services leads to a higher relative price (an increase in the log relative price index of services by 0.23%, see Panel A) and greater demand for skilled labor. Consequently, the skill premium goes up (Panel A), creating more income inequality. The increase in economic activity triggered by the tax reform raises total output (an increase of 5.59%, see Panel F). While both sectors experience higher output than the status quo, the increment is greater for the service sector.

To investigate the welfare effects of such a reform, I compute the consumption equivalent variation (CEV), which is the uniform percentage change in consumption needed to make an agent indifferent between the benchmark economy (i.e., U.S. status quo) and the counterfactual economy, while keeping hours worked and public consumption fixed. A positive (negative) CEV indicates a welfare gain (loss) due to the tax reform. Table 7 presents the results related to the welfare effects of tax reform. The first number of the second column shows that the optimal tax reform increases welfare by 0.23% in terms of CEV. A decomposition of the welfare

[24] A sensitivity analysis to the inverse Frisch elasticity ν is provided in Online Appendix C.

[25] To compute the Rawlsian case, I simply maximize welfare for the unskilled type in the economy, subject to the usual constraints. A numerical value for θ is not required computationally.

Table 6
A Summary of the Tax Reform Experiment Under the Baseline Model: Switching the Tax Code from the U.S. Status Quo to the Utilitarian Planner's Choice Under the Baseline Model.

Moment	Status Quo Tax Code ($\phi = 0.181$)	Optimal Tax Code ($\phi = 0.030$)	% Change
Panel A: Prices and Wages			
Log relative price index of services	0.313	0.314	0.232
Wage premium	1.774	1.780	0.328
Panel B: Earnings			
Ratio of skilled to unskilled pre-tax earnings	1.765	1.767	0.230
Ratio of skilled to unskilled after-tax earnings	1.592	1.739	9.197
Average after-tax earnings	1.241	1.311	5.707
Panel C: Consumption			
Average consumption	0.494	0.514	3.912
Rel. cons. exp. on services for skilled	1.637	1.694	3.532
Rel. cons. exp. on services for unskilled	1.403	1.411	0.596
Ratio of skilled to unskilled consumption	1.405	1.497	6.553
Panel D: Labor Hours			
Average hours	0.333	0.352	5.746
Ratio of goods to service sector labor hours	1.849	1.885	1.943
Panel E: Utility			
Ratio of skilled to unskilled utility	0.718	0.669	−6.778
Panel F: Output			
Rel. output of services	1.523	1.553	1.927
Total output	1.712	1.808	5.586

Notes. The table presents the results of the quantitative model using the baseline parameterization. It shows the values of different macroeconomic aggregates related to prices and wages (Panel A), earnings (Panel B), consumption (Panel C), hours worked (Panel D), utility (Panel E), and output (Panel F). The values in the second column refer to the benchmark case. The third column refers to the counterfactual exercise in which the tax code is set at the utilitarian planner's choice under the baseline model. The fourth column refers to the percentage change in the variables when the tax code changes from the U.S. status quo to the baseline utilitarian planner's choice. Abbreviations: Rel., Relative; cons., consumption; exp., expenditure.

Table 7
Welfare Effects of Reforming the Tax Code from the U.S. Status Quo to the Utilitarian Planner's Choice Under the Baseline Model.

Model Specification	Welfare Change Due to the Reform (% of Cons.)
Accounting for all forces	0.228
If wages & prices fixed	0.239
If hours fixed	−0.381
If occupation fixed	0.181

Notes. The table presents welfare calculations using the baseline quantitative model. It shows the uniform percentage change in consumption needed to make an agent indifferent between the U.S. status quo and the counterfactual economy. Abbreviations: Cons., Consumption.

gains by type shows that the optimal reform benefits skilled workers by 1.36%, in terms of consumption, and leads to small welfare losses among unskilled workers of −0.64%.

I investigate the distinct roles of various economic forces behind the welfare gains from this tax reform. First, I compute the welfare gains from the reform holding wages and prices fixed. This exercise distributes the reported welfare gains into two parts. One part is due to higher wages, and another part can be attributed to the rising labor supply in the face of lower marginal tax rates. The latter will still be visible in this experiment, whereas the part coming from higher wages will not. The second value in column 2 of Table 7 presents the result of this exercise. We see that the welfare gains are larger when abstracting from the increase in wages (welfare gains become 0.24% vs. the original of 0.23%). The result highlights that when allowing for both parts, a fraction of the welfare gain from increasing labor supply is lost due to a rising wage premium, creating greater inequality.

I then carry out another exercise in which I compute the welfare changes from the tax reform while fixing hours worked. This exercise yields welfare losses (see the third value in column 2 of Table 7). There are two reasons for this negative change in welfare. First, shifting to lower marginal tax rates increases the economy's income and consumption inequality. Second, a significant reduction in government tax revenue leaves fewer resources to finance public consumption, driving its quantity down, and ultimately reducing agents' utility. This exercise implies that quantitatively endogenous labor supply plays a vital role in progressive taxation analysis.

Finally, I explore the importance of worker mobility across sectors in the welfare changes from the tax reform. To do so, I fix the fraction of skilled and unskilled workers in each sector from the benchmark case, reported as the fourth value in column 2 of Table 7. The tax reform now yields lower welfare gains than the scenario with perfect labor mobility (0.18 % vs. 0.23% in CEV). This result is a consequence of an (on average) inefficient occupational fit and increased inequality. The rationale for this is as follows. Lower marginal tax rates boost the relative demand for services, increasing labor demand for both skill types in that sector. Since workers cannot move, firms need to pay higher wages to encourage labor supply to satisfy the higher production demand in the service sector. On the other hand, wages for both skilled and unskilled workers working in the goods sector decrease due to excess labor supply in that sector.

6. Concluding remarks

This paper relates insights from the empirical consumption literature to the redistributive taxation analysis. It does so by developing a static multi-sector general equilibrium model featuring a parametric tax and transfer schedule that fits U.S. data well, a flexible demand system that reproduces realistic consumption basket compositions across income groups, endogenous labor supply, and perfect labor mobility. The paper shows that a planner's choice of income tax progressivity is lower in a model with non-homothetic consumption preferences compared to a model considering homothetic consumption preferences.

In the presence of non-homothetic consumption preferences, redistributive taxation changes the compositions of agents' consumption baskets, allowing high-income agents to partially offset the loss in their consumption baskets, reducing net redistribution. Additionally, when labor is mobile between sectors, the efficiency cost of progressive income taxation rises due to a larger labor supply distortion induced by sectoral reallocation. Consequently, with non-homothetic consumption preferences, even under a relatively lower tax progressivity, efficiency cost exceeds gains from redistribution, limiting a planner's choice of tax progressivity.

Although the framework in my paper is stylized in some dimensions, it still provides valuable insight into the determinants of the optimal structure of income taxation. Margins that I abstract from in my analysis for tractability may also be important in any study concerning the welfare effects of progressive taxation. Including these margins would not invalidate my main results but may change the degree of optimal tax progressivity. For example, I do not model human capital accumulation, the extensive margin of labor supply, or household savings, which have significant implications for progressive taxation analysis. In addition, this paper uses a closed economy model. However, given the impacts of international trade on the prices of consumption goods and the labor market, exploring the proposed mechanism in an open economy framework may uncover intriguing insights and hence an avenue for future research.

Appendix A. Mathematical derivations

A.1. Proof of Proposition 1

Proof. The Lagrangian for an agent i is given by

$$\mathscr{L}_i = \left(\log \boldsymbol{x}_i - \varphi \frac{h_i^{1+\nu}}{1+\nu} + \chi \log G\right) - \mu_{1i}\left(\sum_j^J \Omega_j^{\frac{1}{\sigma}}\left(\frac{c_{ij}}{\boldsymbol{x}_i^{\epsilon_j}} - 1\right)^{\frac{\sigma-1}{\sigma}}\right) - \mu_i\left(\sum_j^J p_j c_{ij} - \lambda(h_i w_i)^{1-\phi}\right), \tag{A.1}$$

where μ_{1i} and μ_i denote the Lagrange multipliers. j denotes items in the agent's consumption basket.

The first order conditions are

$$[\boldsymbol{x}_i]: \ \frac{1}{\boldsymbol{x}_i} = \mu_{1i}\cdot\frac{1-\sigma}{\sigma}\cdot\frac{1}{\boldsymbol{x}_i}\left(\sum_j^J \Omega_j^{\frac{1}{\sigma}}\left(\frac{c_{ij}}{\boldsymbol{x}_i^{\epsilon_j}}\right)^{\frac{\sigma-1}{\sigma}}\epsilon_j\right) \tag{A.2}$$

$$[c_{ij}]: \ \mu_{1i}\cdot\frac{1-\sigma}{\sigma}\cdot\frac{1}{c_{ij}}\cdot\Omega_j^{\frac{1}{\sigma}}\left(\frac{c_{ij}}{\boldsymbol{x}_i^{\epsilon_j}}\right)^{\frac{\sigma-1}{\sigma}} = \mu_i p_j \tag{A.3}$$

$$[h_i]: \ \varphi h_i^{\nu} = \mu_i(1-\phi)\lambda w_i^{1-\phi} h_i^{-\phi} \tag{A.4}$$

$$[\mu_{1i}]: \ \sum_j^J \Omega_j^{\frac{1}{\sigma}}\left(\frac{c_{ij}}{\boldsymbol{x}_i^{\epsilon_j}}\right)^{\frac{\sigma-1}{\sigma}} = 1 \tag{A.5}$$

$$[\mu_i]: \ \sum_j p_j c_{ij} = \lambda(h_i w_i)^{1-\phi} \tag{A.6}$$

From equation (A.3), we have:

$$\mu_{1i} \cdot \frac{1-\sigma}{\sigma} = \mu_i \sum_j p_j c_{ij} = \mu_i Exp_i = \mu_i \tilde{y}_i; \tag{A.7}$$

$$\Rightarrow \mu_{1i} = \mu_i \frac{\sigma}{1-\sigma} \tilde{y}_i. \tag{A.8}$$

We now can substitute the expression for μ_{1i} from equation (A.8) into equation (A.3) and solve for the demand function of each item in agent's consumption basket:

$$c_{ij} = \Omega_j \left(\frac{p_j}{\tilde{y}_i}\right)^{-\sigma} \boldsymbol{x}_i^{\epsilon_j(1-\sigma)}; \tag{A.9}$$

$$\Rightarrow c_{ij} = \Omega_j \left(\frac{p_j}{\lambda (h_i w_i)^{1-\phi}}\right)^{-\sigma} \boldsymbol{x}_i^{\epsilon_j(1-\sigma)}. \tag{A.10}$$

From equation (A.4), we obtain agent's labor supply allocation:

$$h_i = \left[\mu_i \frac{1-\phi}{\varphi} \lambda w_i^{1-\phi}\right]^{\frac{1}{\nu+\phi}}. \tag{A.11}$$

We can solve for μ_i by combining equations (A.2) and (A.8):

$$\mu_i = \frac{\boldsymbol{x}_i^{-1}}{\left(\sum_j \Omega_j \left(p_j \boldsymbol{x}_i^{\epsilon_j - 1}\right)^{1-\sigma}\right)^{\frac{\sigma}{1-\sigma}}} \cdot \frac{1}{\sum_j \Omega_j \left(p_j \boldsymbol{x}_i^{\epsilon_j - 1}\right)^{1-\sigma} \epsilon_j}. \quad \blacksquare \tag{A.12}$$

A.2. Proof of Proposition 2

Proof. An agent's demand for sector j good is given by equation (A.9). It can also be written in logarithmic form:

$$\log c_{ij} = \log \Omega_j - \sigma \log p_j + \sigma \log \tilde{y}_i + \epsilon_j (1-\sigma) \log \boldsymbol{x}_i. \tag{A.13}$$

To solve for the expenditure elasticity of demand for the sector j good, take the partial derivative of both sides of equation (A.13) with respect to $\log \tilde{y}_i$:

$$\eta_{ij} = \frac{\partial \log c_{ij}}{\partial \log \tilde{y}_i} = \sigma + (1-\sigma)\epsilon_j \frac{\partial \log \boldsymbol{x}_i}{\partial \log \tilde{y}_i}. \tag{A.14}$$

Since an agent's total consumption expenditure is equal to their disposable income, it can be written as

$$\sum_j^J p_j c_{ij} = \tilde{y}_i. \tag{A.15}$$

Substituting the expression for c_{ij} into equation (A.15), we have

$$\tilde{y}_i = \left[\sum_j^J \Omega_j \left(\left(\boldsymbol{x}_i^{\epsilon_j}\right) p_j\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{A.16}$$

It can also be written as follows:

$$\log \tilde{y}_i = \frac{1}{(1-\sigma)} \log \left(\sum_j^J \Omega_j \boldsymbol{x}_i^{\epsilon_j(1-\sigma)} \left(p_j\right)^{(1-\sigma)}\right). \tag{A.17}$$

Take the partial derivative of both sides of equation (A.17) with respect to $\log \boldsymbol{x}_i$:

$$\frac{\partial \log \tilde{y}_i}{\partial \log \boldsymbol{x}_i} = \frac{\boldsymbol{x}_i}{(1-\sigma)} \frac{\partial}{\partial \boldsymbol{x}_i} \left[\log \left(\sum_j^J \Omega_j \boldsymbol{x}_i^{\epsilon_j(1-\sigma)} \left(p_j\right)^{(1-\sigma)}\right)\right] \tag{A.18}$$

$$= \sum_j^J \underbrace{\left(\frac{\Omega_j \left(\left(\boldsymbol{x}_i^{\epsilon_j}\right) p_j\right)^{1-\sigma}}{\left[\left(\sum_j^J \Omega_j \left(\left(\boldsymbol{x}_i^{\epsilon_j}\right) p_j\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}\right]^{1-\sigma}}\right)}_{\equiv \omega_{ij}} \epsilon_j$$

$$\frac{\partial \log \tilde{y}_i}{\partial \log \boldsymbol{x}_i} = \sum_j^J \omega_{ij} \epsilon_j \equiv \bar{\epsilon}_i, \tag{A.19}$$

ω_{ij} is defined as agent i's expenditure share on consumption from sector j, and $\bar{\epsilon}_i$ represents the weighted average of non-homotheticity parameters of items within agent i's consumption basket.

Since consumption basket ($\boldsymbol{x}_i$) has a monotonic relationship with expenditure ($\tilde{y}_i$), from equations (A.14) and (A.19) we can get the expenditure elasticity of demand:

$$\eta_{ij} = \frac{\partial \log(c_{ij})}{\partial \log(\tilde{y}_i)} = \sigma + (1-\sigma)\frac{\epsilon_j}{\bar{\epsilon}_i}. \quad \blacksquare \tag{A.20}$$

A.3. Proof of Proposition 3

Proof. Firms in each sector maximize profits taking wages and output prices as given:

$$\max_{\{H_{sj},H_{uj}\}} \quad p_j A_j \left(\psi_j H_{sj}^{\frac{\rho-1}{\rho}} + (1-\psi_j) H_{uj}^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} - w_s H_{sj} - w_u H_{uj}. \tag{A.21}$$

First order conditions with respect to H_{sj} and H_{uj} are

$$[H_{sj}]: \quad p_j A_j^{\frac{\rho-1}{\rho}} Y_j^{\frac{1}{\rho}} \psi_j H_{sj}^{-\frac{1}{\rho}} = w_s, \tag{A.22}$$

$$[H_{uj}]: \quad p_j A_j^{\frac{\rho-1}{\rho}} Y_j^{\frac{1}{\rho}} (1-\psi_j) H_{uj}^{-\frac{1}{\rho}} = w_u. \tag{A.23}$$

Combining equations (A.22) and (A.23) yields the skilled-unskilled labor ratio in sector j

$$\frac{H_{sj}}{H_{uj}} = \left(\frac{w_u}{w_s} \cdot \frac{\psi_j}{1-\psi_j} \right)^{\rho}. \tag{A.24}$$

From equation (A.24), solve for H_{uj} in terms of H_{sj} and wages:

$$H_{uj} = \frac{H_{sj}}{\left(\frac{w_u}{w_s} \cdot \frac{\psi_j}{1-\psi_j} \right)^{\rho}}. \tag{A.25}$$

Substituting equation (A.25) into the production function, we have

$$Y_j = A_j \left[\psi_j H_{sj}^{\frac{\rho-1}{\rho}} + (1-\psi_j) H_{sj}^{\frac{\rho-1}{\rho}} \left(\frac{w_u}{w_s} \cdot \frac{\psi_j}{1-\psi_j} \right)^{-(\rho-1)} \right]^{\frac{\rho}{\rho-1}}. \tag{A.26}$$

Rearranging equation (A.26), we can solve for the demand for skilled labor in sector j:

$$H_{sj} = \frac{Y_j}{A_j \left[\psi_j + (1-\psi_j) \left(\frac{w_u}{w_s} \cdot \frac{\psi_j}{1-\psi_j} \right)^{-(\rho-1)} \right]^{\frac{\rho}{\rho-1}}}. \tag{A.27}$$

Similarly, the demand for unskilled labor in sector j is

$$H_{uj} = \frac{Y_j \left(\frac{w_u}{w_s} \cdot \frac{\psi_j}{1-\psi_j} \right)^{-\rho}}{A_j \left[\psi_j + (1-\psi_j) \left(\frac{w_u}{w_s} \cdot \frac{\psi_j}{1-\psi_j} \right)^{-(\rho-1)} \right]^{\frac{\rho}{\rho-1}}}. \tag{A.28}$$

Using equations (A.27) and (A.28), we can solve for the firm's marginal cost. In a perfectly competitive market, firms set prices equal to their respective marginal costs:

$$p_j = \frac{1}{A_j} \left[\frac{\psi_j^{\rho}}{w_s^{\rho-1}} + \frac{(1-\psi_j)^{\rho}}{w_u^{\rho-1}} \right]^{\frac{1}{1-\rho}}. \tag{A.29}$$

Therefore, the equilibrium price of any sectoral good is a function of sectoral TFP and equilibrium factor prices. $\blacksquare$

A.4. Demand estimation equation

Recall, household i's equilibrium allocation for any good j:

$$c_{ij} = \Omega_j \left(\frac{p_j}{Exp_i} \right)^{-\sigma} \boldsymbol{x}_i^{\epsilon_j(1-\sigma)}. \tag{A.30}$$

Given the expression for c_{ij}, we can obtain household i's expenditure share of that good:

$$\omega_{ij} \equiv \frac{c_{ij} p_j}{Exp_i} = \Omega_j \left(\frac{p_j}{Exp_i} \right)^{1-\sigma} \boldsymbol{x}_i^{\epsilon_j(1-\sigma)}. \tag{A.31}$$

Therefore, the household's expenditure shares of a pair of goods, j and k, satisfy:

$$\frac{\omega_{ij}}{\omega_{ik}} = \frac{\Omega_j}{\Omega_k} \left(\frac{p_j}{p_k} \right)^{1-\sigma} \boldsymbol{x}_i^{(\epsilon_j-\epsilon_k)(1-\sigma)}. \tag{A.32}$$

Equation (A.32) can also be written in log form:

$$\ln\left(\frac{\omega_{ij}}{\omega_{ik}}\right) = \ln\left(\frac{\Omega_j}{\Omega_k}\right) + (1-\sigma)\ln\left(\frac{p_j}{p_k}\right) + (\epsilon_j - \epsilon_k)(1-\sigma)\ln \boldsymbol{x}_i. \tag{A.33}$$

Now, using the log-linear nature of the demand system, the household's real consumption index, $\boldsymbol{x}_i$, can be represented as a function of observables and preference parameters. In doing so, I can normalize $\epsilon_k = \Omega_k = 1$ without loss of generality and obtain:

$$\ln \boldsymbol{x}_i = \ln\left(\frac{Exp_i}{p_k}\right) + \frac{1}{(1-\sigma)} \ln \omega_{ik}. \tag{A.34}$$

By combining equations (A.33) and (A.34), we obtain:

$$\ln\left(\frac{\omega_{ij}}{\omega_{ik}}\right) = (1-\sigma)\ln\left(\frac{p_j}{p_k}\right) + (1-\sigma)(\epsilon_j-\epsilon_k)\ln\left(\frac{Exp_i}{p_k}\right) + (\epsilon_j-\epsilon_k)\ln\omega_{ik} + \ln\left(\frac{\Omega_j}{\Omega_k}\right). \tag{A.35}$$

By incorporating, $\epsilon_k = \Omega_k = 1$, equation (A.35) can be written as follows:

$$\ln\left(\frac{\omega_{ij}}{\omega_{ik}}\right) = (1-\sigma)\ln\left(\frac{p_j}{p_k}\right) + (1-\sigma)(\epsilon_j-1)\ln\left(\frac{Exp_i}{p_k}\right) + (\epsilon_j-1)\ln\omega_{ik} + \underbrace{\ln\left(\Omega_j\right)}_{\text{constant}\equiv\zeta}. \tag{A.36}$$

In my demand estimation, I use the empirical counterpart of equation (A.36).

Appendix. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jedc.2023.104758.

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