Optimal Taxation in the Automation Era

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Abstract

This paper studies the optimal tax-and-transfer policy when automation raises productivity but displaces unskilled workers. Using a general equilibrium model calibrated to the U.S. economy, we compute the steady-state social welfare-maximizing rate of each of four tax instruments: capital income taxation, unskilled wage taxation, taxation on automation capital (i.e., a robot tax), and consumption taxation. Following an increase in the productivity of automation-related capital, the welfare-maximizing capital income tax rate and robot tax rate are zero, as their long-run investment distortions outweigh their redistributive social benefits. In the baseline simulation, aggregate welfare is maximized by cutting the unskilled wage tax rate and, especially, the consumption tax rate. However, when unskilled labor and automation-related capital are highly substitutable, the optimal consumption tax rate increases, and the additional government revenue is redistributed to displaced unskilled workers.

Keywords: Automation, Optimal Taxation, Capital Income Tax, Labor Income Tax, Consumption Tax, Robot Tax

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1. Introduction

Technological progress has long been a key driver of economic growth. Recent advances in automation and artificial intelligence (AI), however, have intensified concerns that productivity gains may be accompanied by widening inequality, particularly for workers whose tasks can be replaced by new technology (Lankisch et al., 2019; Jaimovich et al., 2021; Acemoglu, 2023; Tyers and Zhou, 2023; Brezis and Rubin, 2024). A central policy question is how the tax-and-transfer system should respond when automation shifts income toward capital owners and skilled workers while reducing the welfare of unskilled workers.

This paper provides a quantitative answer using a general equilibrium model calibrated to the U.S. economy. We focus on four major fiscal policy instruments in the automation era: (i) capital income taxation, (ii) labor income taxation of unskilled workers, (iii) taxation on automation-related capital (a "robot tax"), and (iv) consumption taxation. We compute the steady-state social welfare-maximizing rate for each instrument in turn, following an increase in the productivity of automation-related capital, holding the remaining tax rates at their benchmark values. We then use the model to clarify the mechanisms through which each instrument affects capital accumulation, factor prices, redistribution, and group-specific welfare.

It is important to outline the core mechanism underlying the analysis and how it is fundamentally transformed by automation. The model captures an economy with distinct groups of agents—skilled workers, unskilled workers, and capitalists—who interact through labor markets and capital accumulation. Automation introduces a new productive input in the form of automation capital, such as robots and artificial intelligence, which can substitute for unskilled labor. This substitution alters the traditional production function by changing the relative productivity and demand for unskilled labor. As automation capital becomes more efficient, it can displace unskilled workers from certain tasks, leading to shifts in wages, employment, and overall income distribution across groups. The model explicitly represents these dynamics within a nested CES production framework, allowing us to trace how automation affects labor substitution, wage premium, and returns to capital.

If automation were not included in the analysis, a critical dimension of modern economic transformation would be absent. Standard models without automation rely solely on changes in capital or labor supply and productivity to explain inequality and growth, assuming constant technology that typically complements rather than substitutes labor types. Such models would miss the structural displacement effects from robots and the resulting pressures on unskilled wages created by automation capital. Moreover, policies targeting capital or labor income taxes would be evaluated without accounting for how automation reshapes factor substitutability and the scope for taxing robot capital specifically. Hence, excluding automation would limit the relevance of realistic optimal tax policy results and obscure the nuanced trade-offs policymakers face in addressing inequality in an era driven by rapid automation-related technological change.

The analysis delivers two main results. First, the social welfare-maximizing capital income tax rate and robot tax rate are zero in the new steady state: by discouraging capital accumulation—especially automation-related capital—these taxes generate long-run investment distortions that outweigh their redistributive social benefits. Second, in the baseline case, aggregate welfare is maximized by lowering the unskilled labor income tax rate and, in particular, the consumption tax rate, even though these reforms are not Pareto-improving and can reduce the welfare of displaced unskilled workers. This stems from the unexpected mechanism by which welfare gains for skilled workers and owners of capital from automation-related technological progress more than offset the worsened welfare of unskilled workers, when aggregated at the national level. Nevertheless, the optimal direction of consumption taxation is not invariant: when unskilled labor and automation-related capital are highly substitutable, the welfare-maximizing fiscal policy instead raises the consumption tax rate and redistributes the additional government revenue toward displaced unskilled workers.

This paper contributes to three related literatures. First, it adds to the growing body of work on robot taxation and automation policy, which analyzes whether and when automation capital should be taxed and how such policies interact with income taxation (e.g., Stiglitz, 2018; Zhang, 2019; Guerreiro et al., 2022; Thuemmel, 2023; Costinot and Werning, 2023). Relative to this work, we expand the policy menu to include capital income and consumption taxation and provide a quantitative comparison of these instruments within a unified general-equilibrium framework.

Second, our results speak to the long-run capital income taxation debate (Chamley, 1986; Judd, 1985; Judd, 2002; Abel, 2007; Straub and Werning, 2020), by showing that, in an economy where automation raises the return to capital, the welfare-maximizing long-run tax rate on capital remains zero once investment distortions are taken into account. Third, our analysis relates to the literature on optimal tax mixes and commodity taxation (Atkinson and Stiglitz, 1976; Naito, 1999) by highlighting that the welfare role of a uniform consumption tax can be sensitive to technology–labor substitutability in an automated economy.

Finally, we build on the quantitative automation framework of Berg et al. (2018) and Berg et al. (2021), focusing on steady-state optimality and comparing alternative tax instruments under a balanced-budget requirement with targeted transfers.

The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 discusses the calibration. Section 4 presents the results, and Section 5 provides a sensitivity analysis. Section 6 concludes.

2. The Model

The economy consists of firms, workers (skilled and unskilled), owners of capital (or capitalists), and the government. The numbers of skilled workers, unskilled workers, and capitalists are denoted by N_S, N_L, and N_C, respectively. Without a loss of generality, we normalize the total population to one. Thus, $N_S + N_L + N_C = 1$. We assume that these population shares are constant over time. Time is discrete and indexed by t = 0, 1, 2, ….

There are three types of firms: intermediate goods firms, final goods firms, and wholesale firms. The production of intermediate goods requires the combination of traditional capital K_d, automation-related capital (which comprises robots and the intangible capital related to AI) Z_d, skilled labor S_d, and unskilled labor L_d.

Final goods. The final goods Y are produced by combining a continuum of differentiated goods indexed by j, according to the Dixit-Stiglitz (1977) aggregator:

$$Y = \left[\int_0^1 y_{j,t}^{\frac{\epsilon-1}{\epsilon}}\, dj\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{1}$$

where y_j is the quantity of output sold by wholesale firm j and where ϵ is the elasticity of substitution across the differentiated goods, satisfying $1 < \epsilon < \infty$. The final goods producer maximizes profits as subject to the above production technology, taking the input price $p_{j,t}$ and the final goods price P_t as given. The profit maximization problem yields the following demand function:

$$y_{j,t} = \left(p_{j,t}/P_t\right)^{-\epsilon} Y_t, \tag{2}$$

and the aggregate price index $P_t = \left[\int_0^1 p_{j,t}^{1-\epsilon}\, dj\right]^{\frac{1}{1-\epsilon}}$. Without a loss of generality, we normalize the output price to one, i.e., $P_t = 1$.

Wholesalers and markups. There is a unit measure for wholesale firms. Wholesalers buy homogeneous goods from intermediate goods firms and transform them into heterogeneous goods, which are then sold to final goods firms. Their production technology is linear: $y_{j,t} = Q_{j,t}$. We assume that wholesalers are owned by capitalists and have monopolistic power to set the price of the goods they sell. This assumption reflects the fact that large tech companies enjoy monopolistic rent in the age of automation/AI/big data. Automation can increase the monopoly power of wholesalers by creating economies of scale, improving efficiency, and enhancing competitiveness, which allows larger superstar firms to dominate the market and gain a greater market share (Firooz et al., 2025). Hsieh and Rossi-Hansberg (2023) presented evidence that the concentration of top firm shares is the highest in the wholesale sector in the U.S. economy. Such concentration of superstar firms is driven by increased wholesaler market shares and markups (Ganapati, 2025). Given this, the representative wholesaler chooses $Q_{j,t}$ and $p_{j,t}$ to solve the following problem:

$$\max \Pi_{j,t} = \int_0^1 \left(p_{j,t} y_{j,t} - \theta_t Q_{j,t}\right) dj, \tag{3}$$

which is subject to the demand function (2). θ_t is the price of intermediate goods. Then, we have

$$p_{j,t} = \left(\frac{\epsilon}{\epsilon-1}\right) \theta_t, \tag{4}$$

and by normalizing the price of final goods to unity and assuming a symmetric equilibrium, the above equation (4) yields

$$\theta_t = (\epsilon - 1)/\epsilon. \tag{5}$$

Note that the markup can be expressed as $markup_t = 1/\theta_t$.

We assume that the markup is constant. We introduce markup because large firms (e.g., big tech companies) can take advantage of owning the platform and other digitalization-related networks, which makes their marginal costs lower than the average costs (Nakatani 2023). This is because the costs of constructing such a network can be an entry barrier for other companies, which leads to both large market shares and markups.

Intermediate production. The intermediate goods firm produces output by using capital K_d, robots Z_d, skilled labor S_d, and unskilled labor L_d, according to the following triple-nested CES production function:

$$Q_t = \mathrm{A}\left[a^{\frac{1}{\sigma_1}} H_t^{\frac{\sigma_1 - 1}{\sigma_1}} + (1-a)^{\frac{1}{\sigma_1}} V_t^{\frac{\sigma_1 - 1}{\sigma_1}}\right]^{\frac{\sigma_1}{\sigma_1 - 1}}, \tag{6}$$

where A is the aggregate productivity and

$$V_t = \left[e^{\frac{1}{\sigma_2}} L_{d,t}^{\frac{\sigma_2 - 1}{\sigma_2}} + (1-e)^{\frac{1}{\sigma_2}} (b_t Z_{d,t})^{\frac{\sigma_2 - 1}{\sigma_2}}\right]^{\frac{\sigma_2}{\sigma_2 - 1}}, \tag{7}$$

$$H_t = \left[f^{\frac{1}{\sigma_3}} S_{d,t}^{\frac{\sigma_3 - 1}{\sigma_3}} + (1-f)^{\frac{1}{\sigma_3}} K_{d,t}^{\frac{\sigma_3 - 1}{\sigma_3}}\right]^{\frac{\sigma_3}{\sigma_3 - 1}}, \tag{8}$$

where σ_1 is the elasticity of substitution between composite inputs H and V, σ_2 is the elasticity of substitution between robots and unskilled workers, and σ_3 is the elasticity of substitution between capital and skilled labor. Depending on the values of these elasticities, this production technology allows for high substitution between unskilled labor and robots and complementarity between skilled labor and capital (Krusell et al. 2000) as well as between skilled labor and robots. Automation technologies displace certain worker groups from jobs for which they have a comparative advantage (Acemoglu and Restrepo 2022). In our model, we assume that unskilled workers are displaced by automation. Readers can understand automation technology in our model as industrial robots in manufacturing, for example. Although we treat both AI and robots in the automation capital in this paper, investments in these two types of automation technology have different spillover effects. Investments in robotics are generally characterized by physical hardware and subject to specific regulations concerning product safety. Robot investments result in tangible programmable machines and often used in manufacturing, logistics, and surgical assistance. In contrast, investment in AI could yield faster returns as it can be developed quickly with fewer physical constraints. AI investments provide intelligence and decision-making capabilities across various wider ranges of digital and service sectors, including financial services and autonomous driving software.

The intermediate goods firm maximizes its profit by choosing capital, robots, and two types of labor, subject to equations (6)-(8) according to

$$\max_{K_d, Z_d, S_d, L_d} \theta_t Q_t - r_{K,t} K_{d,t} - r_{Z,t} Z_{d,t} - w_{S,t} S_{d,t} - w_{L,t} L_{d,t}, \tag{9}$$

where r_K and r_Z are the rental rates of capital and robots, respectively, and where w_S and w_L are the wage rates for skilled and unskilled workers, respectively. The first-order conditions of this problem are as follows:

$$\theta_t \frac{\partial Q_t}{\partial K_{d,t}} = r_{K,t}, \qquad \theta_t \frac{\partial Q_t}{\partial Z_{d,t}} = r_{Z,t}, \tag{10}$$

$$\theta_t \frac{\partial Q_t}{\partial S_{d,t}} = w_{S,t}, \qquad \theta_t \frac{\partial Q_t}{\partial L_{d,t}} = w_{L,t} \tag{11}$$

Households. Workers consume all of their income. The representative skilled worker's utility function is calculated by preferences as proposed by Greenwood et al. (1988) to abstract from income effects[4]:

$$U(C_S, S) = \frac{1}{1-\sigma_S}\left(C_{S,t} - \Phi_S \frac{S_t^{1+\mu_S}}{1+\mu_S}\right)^{1-\sigma_S}, \tag{12}$$

where C_S is the consumption of skilled workers and S is the labor supply.[5] $\Phi_S > 0$ is a measure of the disutility parameter of working, and μ_S is the inverse of the Frisch elasticity. Since we know from Diamond (1998) that the optimal marginal tax rate at the bottom of the skill distribution becomes higher when there are no income effects on the utility function, we prefer this specification of the utility function to examine whether the progressive labor income tax rate is still optimal in this robust setting. The budget constraint of the skilled worker is

$$(1+\tau_c)C_{S,t} = \left(1-\tau_{w_S}\right)w_{S,t}S_t + \kappa, \tag{13}$$

where τ_c is the consumption tax rate, τ_{w_S} is the tax rate on skilled workers' income, and κ is the universal lump-sum transfer. The skilled worker chooses C_S and S to maximize the utility function in (12) subject to the budget constraint in (13). The hand-to-mouth assumption for skilled workers reflects the practice in the U.S. economy. It is empirically known that many U.S. households, including many high-income workers, have zero or insufficient savings to cope with income losses, expenditure shocks, and other financial emergencies (American Bankruptcy Institute, 2016). One reason is that they have a tendency to spend all their income instead of investing in financial assets due to the lack of financial capability (Despard et al., 2020). The first-order conditions correspond to equation (13), and

$$\Phi_S S_t^{\mu_S} = \frac{1-\tau_{w_S}}{1+\tau_c} w_{S,t}. \tag{14}$$

Similarly, the unskilled worker's problem can be written as

$$\max_{C_L, L} U(C_L, L) = \frac{1}{1-\sigma_L}\left(C_{L,t} - \Phi_L \frac{L_t^{1+\mu_L}}{1+\mu_L}\right)^{1-\sigma_L}, \tag{15}$$

which is subject to

$$(1+\tau_c)C_{L,t} = \left(1-\tau_{w_L}\right)w_{L,t}L_t + \kappa + s_L, \tag{16}$$

where τ_{w_L} is the tax rate on unskilled workers' income and s_L is the trageted transfer to unskilled workers. The first-order conditions are modeled by equation (16) and

$$\Phi_L L_t^{\mu_L} = \frac{1-\tau_{w_L}}{1+\tau_c} w_{L,t}. \tag{17}$$

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[4] If we introduce the income effects, the main resulting change would be that skilled labor decreases in response to technological progress (i.e., an increase in the productivity of automation technology). Such a difference occurs because under the separable utility function, the labor supply will depend not only on real wages but also consumption.

[5] We do not study the friction in the labor matching market. See Guimarães and Gil (2022), Charalampidis and Guillochon (2025), and Kudoh and Miyamoto (2025) for such topic in the context of automation.

Capitalists own firms, do not work, and save money to smooth consumption over time. These savings are invested in automation and traditional capital. This setup helps characterize the "winner-take-all" aspect of automation as well as the fact that "the rise of the top one percent is likely very tied up with technology." The representative capitalist chooses consumption c_t, investment in capital I_K, and investment in robots I_Z to maximize

$$\max_{C,I_K,I_Z} \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma_C}}{1-\sigma_C}, \tag{18}$$

subject to the following budget constraint and the capital and robot accumulation equations:

$$(1+\tau_c)C_t + I_{K,t} + I_{Z,t} = (1-\tau)\left[r_{K,t}K_t + r_{Z,t}Z_t\right] + (1-\tau_\theta)(1-\theta)\frac{Q_t}{N_C} + \kappa - \tau_Z Z_t, \tag{19}$$

$$K_{t+1} = (1-\delta_K)K_t + I_{K,t}, \tag{20}$$

and

$$Z_{t+1} = (1-\delta_Z)Z_t + I_{Z,t}, \tag{21}$$

where β is the discount factor, δ_K is the depreciation rate of capital, δ_Z is the depreciation rate of the robots, τ is the capital income tax rate, τ_θ is the tax rate on markup, and τ_Z is the robot tax rate. We assume that $\tau_\theta = \tau$ throughout the paper, i.e., the tax on markup is collected as a part of capital income taxation.

The first-order conditions of the capitalists' maximization problem include the following Euler equations:

$$\frac{\lambda_t}{\beta\lambda_{t+1}} = (1-\tau)\frac{\partial Q_{t+1}}{\partial K_{d,t+1}} + (1-\delta_K), \quad \text{and} \quad \frac{\lambda_t}{\beta\lambda_{t+1}} = (1-\tau)\frac{\partial Q_{t+1}}{\partial Z_{d,t+1}} - \tau_Z + (1-\delta_Z), \tag{22}$$

which at the initial steady state correspond to

$$1 = \beta\left[(1-\tau)\frac{\partial Q}{\partial K_d} + 1 - \delta_K\right], \quad \text{and} \quad 1 = \beta\left[(1-\tau)\frac{\partial Q}{\partial Z_d} + 1 - \delta_Z - \tau_Z\right]. \tag{23}$$

Government. The government has multiple instruments (taxes and expenditures) with which to implement fiscal policy, subject to a balanced budget in each period. If the government is allowed to borrow debt to finance targeted transfers to unskilled workers, it would make sense to borrow in the initial steady state and repay the debt in the final steady state. This is because after automation-augmented technological progress, the size of the economy becomes larger, and hence, the government has the ability to repay debt from collected tax revenues. However, as the size of government debt becomes larger, the interest rate increases, so it also affects capital income through the higher rate of returns from traditional capital and automation-related capital. The speed of automation augmented technological progress could be slower due to the higher costs of borrowing for firms. It is noteworthy that government borrowing might crowd out private sector investment in traditional and automation-related capital. Although capitalists could enjoy higher returns from such investments, if they anticipate future increases in taxes, it could cause Ricardian effects, as government debt must eventually be repaid through higher tax revenues. The government budget constraint is given by

$$\sum_{i=L,S,C} N_i\kappa + N_L s_L = N_C\left[\tau\{r_{K,t}K_t + r_{Z,t}Z_t\} + \tau_c C_t + \tau_Z Z_t\right] + \tau_\theta(1-\theta)Q_t + N_S\left[\tau_{w_S} w_{S,t} S_t + \tau_c C_{S,t}\right]$$
$$+ N_L\left[\tau_{w_L} w_{L,t} L_t + \tau_c C_{L,t}\right].$$

We impose a nonnegative constraint for targeted transfers to unskilled workers:

$$s_L \geq 0.$$

Equilibrium. The goods market is in equilibrium when the supply of firms equals the demand of capitalists, workers, and the government:

$$Q_t = N_c\left(C_t + I_{K,t} + I_{Z,t}\right) + N_s C_{S,t} + N_L C_{L,t}.$$

The labor markets are in equilibrium when the labor demand is equal to the labor services supplied by workers:

$$S_{d,t} = N_S S_t,$$

and

$$L_{d,t} = N_L L_t.$$

Similarly, the capital and robot markets are in equilibrium when

$$K_{d,t} = N_C K_t,$$

and

$$Z_{d,t} = N_C Z_t.$$

Welfare. The welfare gain for skilled workers Δ_S, as defined by Domeij and Heathcote (2004), satisfies the following equation:

$$U\left(C_{S,t}^R, S_t^R\right) = U\left((1+\Delta_S)C_{S,t}^{NR}, S_t^{NR}\right)$$

where equilibrium consumption is represented by C_S^R in the case of tax reform and C_S^{NR} in the case of no tax reform. The same applies to superscripts of labor supply. The above equation can be rewritten as follows:

$$\frac{1}{1-\sigma_S}\left\{C_{S,t}^R - \Phi_S \frac{(S_t^R)^{1+\mu_S}}{1+\mu_S}\right\}^{1-\sigma_S} = \frac{1}{1-\sigma_S}\left\{(1+\Delta_S)C_{S,t}^{NR} - \Phi_S \frac{(S_t^{NR})^{1+\mu_S}}{1+\mu_S}\right\}^{1-\sigma_S}$$

$$\therefore \Delta_S = \left[C_{S,t}^R - \Phi_S \left\{\frac{\left(S_t^R\right)^{1+\mu_S}}{1+\mu_S} - \frac{\left(S_t^{NR}\right)^{1+\mu_S}}{1+\mu_S}\right\}\right] / C_{S,t}^{NR} - 1.$$

The same calculation yields a welfare gain for unskilled workers Δ_L:

$$\Delta_L = \left[C_{L,t}^R - \Phi_L \left\{\frac{\left(L_t^R\right)^{1+\mu_L}}{1+\mu_L} - \frac{\left(L_t^{NR}\right)^{1+\mu_L}}{1+\mu_L}\right\}\right] / C_{L,t}^{NR} - 1.$$

The welfare gain for capitalists Δ_C satisfies the following equation:

$$\sum\nolimits_{t=0}^{\infty} \beta^t \frac{(C_t^R)^{1-\sigma_C}}{1-\sigma_C} = \sum\nolimits_{t=0}^{\infty} \beta^t \frac{\left((1+\Delta_C)C_t^{NR}\right)^{1-\sigma_C}}{1-\sigma_C}$$

$$\therefore \Delta_C = \left\{ \frac{\left(c_0^R\right)^{1-\sigma_C} + \beta\left(c_1^R\right)^{1-\sigma_C} + \beta^2\left(c_2^R\right)^{1-\sigma_C} + \cdots}{\left(c_0^{NR}\right)^{1-\sigma_C} + \beta\left(c_1^{NR}\right)^{1-\sigma_C} + \beta^2\left(c_2^{NR}\right)^{1-\sigma_C} + \cdots} \right\}^{\frac{1}{1-\sigma_C}} - 1.$$

Social welfare based on population shares, as introduced by Acemoglu and Autor (2011), is defined as follows:

$$\Delta = N_S \Delta_S + N_L \Delta_L + N_C \Delta_C.$$

3. Calibration

The model is calibrated to match the U.S. economy. Table 1 summarizes the parameter values for the initial steady state. Following Berg et al. (2018), we set the annual discount rate to 6 percent, implying the discount factor $\beta = 0.94$. The depreciation rate is higher for robots than for traditional capital, with $\delta_Z = 0.15$ and $\delta_K = 0.05$.

The shares in production of the composite input H, unskilled labor, and skilled labor are calibrated to match a capital income share of 0.35, an unskilled income share of 0.31, a skilled income share of 0.30, and a robot income share of 0.04. This yields a = 0.763, e = 0.958, and f = 0.103. Following Berg et al. (2018), we set the elasticity of substitution between H and V to 0.67 and the elasticity of substitution between skilled labor and capital to 0.335. We set the elasticity of substitution between unskilled labor and robots to 1.9, as estimated by DeCanio (2016). When the elasticity of substitution is less (greater) than one, two inputs are gross complements (substitutes). $\sigma_1 = 0.67 < 1$ means that skilled labor and robots are gross complements. Contrastingly, $\sigma_2 = 1.9 > 1$ indicates that robots and unskilled labor are gross substitutes. The markup is set to 1.21, based on Barkai (2020), for 2014.

For the inverse of the Frisch elasticity, we set $\mu_L = 2$ and $\mu_S = 2$, which are taken from the intensive margin as per Chetty et al. (2011). This means that the Frisch elasticity of both unskilled and skilled labor is 0.5, which is the median value suggested in the literature. Following Berg et al. (2018), we set the intertemporal elasticity of substitution to 0.5 (i.e., $\sigma = 2$), which is the same as the mean estimated by Havranek et al. (2015). The disutility parameter of working for unskilled workers is set by targeting the steady-state working hours to be one-third (i.e., eight hours per day). The steady-state wage premium for the U.S. economy—i.e., $w_S/w_L = 1.65$—is used to specify that the parameter of skilled workers' disutility from working as a steady-state skill premium depends on the difference in the advantage of skilled workers over unskilled workers (Afonso et al., 2023).

The population is normalized to 1, and the share of capitalists is one percent. When analyzing the distributional impact of wealth and income, it is a common approach to study top one percent income earners (Alvaredo et al., 2013; Saez and Zucman, 2020). Since there is no established way to define capitalists in practice, we use the top one percent of the population for this category. This assumption can be justified by the fact found by Saez (2017) that the top one percent income earners significantly respond their reported income with respect to the net-of-tax rate for tax avoidance purposes, particularly for realized capital gains and dividends, which can be proxied by capital income in our model. The share of skilled workers to total workers is 45 percent, as reported by Acemoglu and Autor (2011).

We calibrate the tax rates using the latest 2014 U.S. national accounts data. The labor income tax rate is set so that individual income tax revenue equals 9.3 percent of GDP, which is the actual ratio of the individual income tax revenue as a percentage of GDP. The capital income tax rate is set so that capital gains tax revenue equals 0.7 percent of GDP, which is the actual ratio of capital gains tax revenue as a percentage of GDP. The markup tax rate is set so that corporate income tax revenue equals 1.8 percent of GDP, which is the actual corporate income tax revenue as a percentage of GDP. The consumption tax rate is calibrated to match the actual ratio of 4.5 percent, which represents the indirect tax revenue (taxes on goods and services and on international trade) as a share of GDP. This procedure implies $\tau_w = 0.184$ for labor income, $\tau = 0.022$ for capital income, $\tau_\theta = 0.104$ for markup income, and $\tau_c = 0.053$ for consumption.

4. Results

As a benchmark, we first examine how social welfare and key macroeconomic variables respond to changes in tax rates in the absence of technological progress in automation. The results are reported in the Appendix. The consumption tax is the most powerful tax policy tool for influencing social welfare, without affecting the wage premium. In contrast, other taxes, such as capital income taxes or unskilled wage taxes, are effective policy tools for redistribution through influencing the wage premium.

In the baseline automation experiment, we focus on steady states and consider a 50 percent increase in the productivity of automation-related capital. For each instrument, we vary one tax rate while holding the remaining tax rates at their status-quo levels and adjust targeted transfers to unskilled workers to satisfy the balanced-budget constraint, subject to a nonnegativity constraint on the transfers. We refer to the resulting reform as “optimal” for that instrument if it maximizes social welfare. The results are shown in Figures 1-4 and discussed below.

Raising the capital income tax rate increases the welfare of unskilled workers by shifting part of capitalists’ gains from automation to unskilled workers through transfers (Figure 1). High capital income tax rates reduce the welfare of both capitalists and skilled workers by reducing the accumulation of capital that complements skilled labor. However, capitalists suffer a larger welfare loss. Social welfare in Figure 1 is maximized by a 0.13 percent increase in consumption equivalent under the zero optimal capital income tax rate. This optimal tax reform reduces unskilled workers’ welfare relative to the status quo because the total revenue from capital income taxation is relatively small, and the welfare loss of other agents exceeds. The reason why the optimal capital income tax rate is zero is that the calibrated level of the tax rate is low, around 2.2 percent, compared to other tax rates, such as the labor income tax rate. This reflects the practice that the share of capital income taxes in government revenue or economy is relatively smaller than other major taxes such as consumption taxes. If we assume the same tax rates for capital income and labor income and calibrate them jointly, then the optimal capital income tax rate under automation becomes positive, although we do not show such results because it does not reflect the reality of the U.S. economy.

The robot tax discourages the accumulation of automation-related capital and therefore limits gains from automation. This lowers capitalists' welfare while redistributing benefits from automation to unskilled workers through transfers (Figure 2). We find that the welfare gain is positive for unskilled workers at low robot tax rates. Since the tax on automation-related capital is very costly in the steady state, it is optimal not to impose such a tax, as shown in Figure 2. As we can see from the figure, the individual welfare of unskilled workers exhibits a concavity, as it even declines when the robot tax rate is very high. Our finding is consistent with Gasteiger and Prettner (2022), who reported that the robot tax cannot induce a takeoff toward positive long-run growth. Prettner and Strulik (2020) also reported that even the net income of high-skilled workers declines with the robot tax because the wage-depressing impact of reduced demand for machines and the complement of skilled workers apparently overcompensates the gains from redistribution.

A reduction in the tax rate on unskilled workers' wage income improves social welfare through an interesting channel (Figure 3). Unskilled workers actually lose welfare because lower unskilled labor prices increase labor demand, which in turn reduces the utility of unskilled workers. This disutility effect from increased labor more than offsets the positive utility from increased consumption by unskilled workers. The opposite holds for skilled workers. Capitalists also benefit from cheap unskilled labor when the unskilled wage income tax rate is lower than that of the status quo. As a result, the optimal tax rate is 12.2 percent. The welfare gain from the optimal unskilled wage income tax is a 0.16 percent increase in the consumption equivalent, which is greater than the optimal capital income taxation.

The optimal consumption tax rate is 3.8 percent (Figure 4). This is because the welfare gains for skilled workers and capitalists achieved through their increased consumption exceed the welfare loss for unskilled workers. The government can lower the consumption tax rate by only 1.5 percentage points from the status quo because it must balance the budget and ensure nonnegative transfers to unskilled workers. The social welfare gain from this optimal consumption tax reform (a 0.33 percent increase in consumption equivalent) is the largest among the tax reforms compared in Figures 1-4, as it improves consumption for skilled workers and capitalists, despite worsening the welfare of unskilled workers. Among all optimal tax reforms in Figures 1-4, capitalists and skilled workers gain the greatest welfare from the optimal consumption tax rate cut.

To further understand the mechanisms and economic impacts, we compare the impacts on key economic variables. We specifically discuss the effects on output, the wage premium, and targeted transfers to unskilled workers under various optimal tax rates. We do not discuss the case of optimal zero robot tax rate here because it corresponds to the status-quo economy given that there is no robot tax in the initial steady state. Regarding the impact on output, the optimal capital income taxation shows the greatest increase (8.3 percent from the initial steady state). This is because capital income taxation affects the accumulation of both traditional capital and automation-related capital. Compared with this case of optimal capital income taxation, the output increases under optimal unskilled wage income taxation and optimal consumption taxation are lower. However, the optimal unskilled wage income tax shows slightly higher output (8.2 percent) than the optimal consumption tax (7.4 percent). This is because unskilled workers increase their labor supply in response to the wage tax cut; hence, firms use more unskilled labor, which contributes to higher production volume.

With respect to the distributional impacts, all three types of optimal taxation increase the wage premium in the new steady state from its initial value of 1.65. This is because improvements in automation productivity increase the demand for skilled labor more than for unskilled labor, thereby raising the skilled wage relative to the unskilled wage. Among the three optimal taxes considered, the optimal unskilled wage income tax notably demonstrates the highest wage premium of 1.82 compared with the other two cases of optimal taxation (1.78 for optimal capital income taxation and 1.76 for optimal consumption taxation). As stated above, this is due to the mechanism through which a reduction in the tax rate on unskilled workers' wages increases their labor supply, which, in turn, lowers the unskilled wage relative to the wage of skilled workers. In contrast, the consumption tax does not influence the wage premium.

Targeted transfers to unskilled workers are modest under optimal capital income taxation. For example, targeted transfers to unskilled workers under optimal capital income taxation constitute 5.6 percent of government revenue and 2.6 percent of unskilled workers' income. Yet these targeted transfers are close to zero under the other two cases of optimal taxation, as they face the non-negativity constraint of transfers.

We also searched for a Pareto-improving policy mix by jointly varying two tax rates, but we did not find a combination that makes all agents better off.

5. Sensitivity Analysis

This section examines sensitivity to two particularly uncertain parameters: the size of automation-related technological progress and the elasticity of substitution between automation-related capital and unskilled labor. We focus on optimal unskilled wage taxation and optimal consumption taxation because the optimal capital income tax rate and the optimal robot tax rate are zero throughout. Figures 5 and 6 report the results for alternative sizes of automation productivity improvement.

Across different speeds of automation-related technological progress, changing the unskilled wage income tax rate delivers negligible aggregate welfare gains. This result can be attributed to the fact that monopolistic power increases the tax incidence that falls on firms under automation, thereby making labor income taxes less effective in income redistribution than in redistribution from profits. The optimal unskilled wage tax schedule is U-shaped because the targeted transfers to unskilled workers hit the nonnegativity constraint in the absence of a large productivity improvement.

Furthermore, we find that it is optimal to lower the consumption tax rate in the automated economy because the welfare loss for unskilled workers is more than offset by the welfare gains for skilled workers and capitalists. The optimal consumption tax rate is set at the point where the transfers to unskilled workers do not become negative. This means that as long as all three economic agents receive the same amount of universal lump-sum transfers as in the status-quo economy, the welfare gains from automation could be shared between skilled workers and capitalists under the optimal consumption tax, although unskilled workers do not receive additional transfers owing to the reduced consumption tax rate. Thus, the optimal consumption tax policy by itself is not an appropriate policy tool for rescuing losers in the automated economy—i.e., unskilled workers—from a distributional perspective.

Next, we conduct sensitivity analysis regarding the elasticity of substitution between unskilled labor and automation-related capital (σ_2).[11] Following Berg et al. (2018), we consider values up to $\sigma_2 = 20$. Holding

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[11] We also examined the other values of the elasticity of substitution (σ_1 and σ_3) in the production function, but the results did not change significantly.

all other parameters fixed at their baseline values (Table 1), we change only the value of σ_2 in the new steady state. The simulation results are shown in Table 2.

Regarding optimal labor income taxation, as the elasticity of substitution between automation-related capital and unskilled labor increases, the redistribution mechanism of optimal fiscal policy changes. Specifically, the government should raise the labor income tax rate for unskilled workers to increase their wages, thereby reducing firms' demand for labor. Then, the disutility from working decreases for unskilled workers, improving their welfare. The additional tax revenues can be redistributed to unskilled workers, thereby increasing their consumption. Through both these channels of utility from working and consumption, unskilled workers' welfare increases. However, the welfare gain from changing taxes on unskilled workers' income remains negligible, regardless of the elasticity of substitution between automation-related capital and unskilled labor.

Finally, the optimal consumption tax response is highly sensitive to the elasticity of substitution between unskilled labor and automation-related capital. When the elasticity of substitution between unskilled labor and automation-related capital is relatively low, it is optimal to reduce the consumption tax rate from the status-quo level. Unskilled workers face a welfare loss, but it is more than offset by welfare gains for the other two agents. However, as the elasticity of substitution increases, the optimal consumption tax policy mechanism reverses. Specifically, it is optimal to collect consumption taxes from skilled workers and capitalists and then redistribute those resources to unskilled workers through transfers. Therefore, the welfare for unskilled workers improves significantly under the optimal consumption tax when the elasticity of substitution between them and automation-related capital is high.

6. Conclusion

This study evaluates how standard tax instruments perform as tools for redistribution and welfare maximization when automation-related productivity rises. Focusing on steady-state outcomes and imposing a balanced-budget requirement, the government adjusts transfers—targeted to unskilled workers and subject to a nonnegativity constraint—to finance each tax reform. This environment clarifies how different taxes trade off redistribution against long-run efficiency, as automation increases inequality.

Our main results show that consumption taxation is the most effective tax instrument for increasing social welfare, even though it reduces the welfare of unskilled workers. The optimal consumption tax cut yields the largest consumption-equivalent welfare gain among all tax reforms considered, driven by sizable improvements in the consumption of skilled workers and capitalists. In contrast, capital income taxation and robot taxation are not effective tools in an automated economy. The optimal capital income and robot taxes are both zero because the efficiency losses from these taxes outweigh their redistributive benefits. Although a higher capital income tax transfers some automation gains from capitalists to unskilled workers, the overall social welfare improvement is negligible. Similarly, taxing automation-related capital suppresses productivity-enhancing investment without offering meaningful long-run redistribution.

The unskilled wage income tax plays a more nuanced role. Reducing this tax rate increases firms' demand for cheaper unskilled labor, increasing the labor supply and reducing the utility of unskilled workers through increased work disutility. As a result, the welfare gain from optimal unskilled wage taxation is modest compared with that from consumption taxation. Across all optimal tax policies, automation-driven increases in the demand for skilled labor raise the wage premium, with the largest rise occurring under the optimal unskilled wage tax due to its direct effect on the unskilled labor supply and wages.

Sensitivity analyses confirm that changes in automation productivity have little effect on unskilled wage tax welfare, while the optimal consumption tax remains limited by transfer constraints. A higher elasticity of substitution can justify higher unskilled wage taxes, although welfare gains remain small. When elasticity crosses a threshold, the optimal consumption tax rises, with revenues benefiting unskilled workers, highlighting that the effectiveness of consumption taxes hinges on labor-automation substitutability.

Overall, the analysis implies that none of the tax reforms considered are Pareto improving. While consumption taxation is the most effective instrument for increasing aggregate welfare, it does not ensure protection for the workers most vulnerable to automation. This suggests a broader policy lesson: relying solely on conventional tax instruments may be insufficient to address the distributional challenges created by automation, and complementary measures—such as targeted subsidies, retraining, or reforms that expand the set of feasible transfers—may be required for automation gains to be more widely shared.

Appendix

In this Appendix, we study the effects of optimal tax reform on social welfare in the initial steady state without facing an improvement in automation-related productivity. Figure A.1 shows the welfare gains from changing the rate of each tax policy instrument. The figure shows that welfare always improves if any tax rate is reduced in the initial steady state in the absence of technological progress.

The optimal capital income tax rate is zero in the absence of robot technology improvement. This confirms the well-known results of Chamley (1986) and Judd (1985), as capital income taxation is very costly in the steady state. However, the welfare gain from optimal capital taxation is small, amounting to only 0.15 percent of consumption-equivalent welfare. This is attributed to the fact that the effective capital income tax rate calibrated in the initial steady state is relatively lower than the other tax rates. As the tax rate increases, the social welfare loss from capital income tax increases nonlinearly since it has a detrimental effect on capital accumulation (Figure A.2). Capital income tax also reduces the wage premium by reducing the demand of skilled workers, which complements traditional capital (Figure A.3).

In contrast, the social welfare gains from lowering the consumption tax rate are the largest among the tax reform options considered in this paper (Figure A.1). If the consumption tax rate is reduced to zero percent, social welfare increases by 1.8 percent. This is because a reduced consumption tax benefits all three types of consumers: skilled/unskilled workers and capitalists. However, the consumption tax does not affect the wage premium because it is taxed at the consumption stage and does not affect the relative labor supply of skilled workers and unskilled workers (Figure A.3).

On the other hand, if the unskilled wage tax rate is reduced from the original 18.4 percent, it will gradually improve social welfare through the improvement in unskilled workers' welfare. When the unskilled wage tax rate is reduced to the lowest zero percent, the social welfare gain becomes 0.28 percent, which is above the case of optimal capital income taxation but below the case of the zero-consumption tax rate. The changes in output in response to the unskilled wage tax are relatively smaller than those in response to the other tax instruments because it mainly affects the unskilled labor market and does not directly affect capital accumulation, such as capital income taxation or robot taxation (Figure A.2).

Finally, if the robot tax is introduced into the economy, it will lower social welfare by creating a deadweight loss from deterred automation-related investments. However, such taxation only causes distortions for automation-related capital (not for traditional capital), so the welfare-reducing effects are smaller than those of capital income taxation when higher tax rates are applied. When the robot tax is increased to a greater percentage, the output declines become smaller than in the case of capital income taxation because substitution between automation capital and unskilled labor takes place. As a result, the share of net transfers to unskilled workers in their incomes remains relatively flat (Figure A.4).

References

Abel, A. 2007. Optimal Capital Income Taxation. *NBER Working Paper* 13354.

Acemoglu, D. 2023. Harms of AI. in Justin B. Bullock, and others (eds), *The Oxford Handbook of AI Governance The Oxford Handbook of AI Governance*.

Acemoglu, D., & D. Autor. 2011. Skills, Tasks, and Technologies: Implications for Employment and Earnings. *Handbook of Labor Economics* 4B: 1043-1171.

Acemoglu, D., & P. Restrepo. 2022. Tasks, Automation and the Rise in US Wage Inequality. *Econometrica* 90 (5): 1973-2016.

Afonso, O. T. Sequeira, & D. Almeida. 2023. Technological-Knowledge and Wages: From Skill Premium to Wage Polarization. *Journal of Economics* 140: 93-119.

Alvaredo, F., A. Atkinson, T. Piketty, & E. Saez. 2013. The Top 1 Percent in International and Historical Perspective. *Journal of Economic Perspectives* 27 (3): 3-20.

American Bankruptcy Institute. 2016. Study Finds That Many High-Income Workers Have Zero Savings.

Atkinson, A., & J. Stiglitz. 1976. The Design of Tax Structure: Direct versus Indirect Taxation. *Journal of Public Economics* 6 (1–2): 55-75.

Barkai, S. 2020. Declining Labor and Capital Shares. *Journal of Finance* 75 (5): 2421-2463.

Berg, A., E. Buffie, & L. Zanna. 2018. Should We Fear the Robot Revolution? (The Correct Answer is Yes). *Journal of Monetary Economics* 97: 117-148.

Berg, A., L. Bounader, N. Gueorguiev, H. Miyamoto, K. Moriyama, R. Nakatani, & L. Zanna. 2021. For the Benefit of All: Fiscal Policies and Equity-Efficiency Trade-offs in the Age of Automation. *IMF Working Paper* 21/187.

Brezis, E., & A. Rubin. 2024. Will Automation and Robotics Lead to More Inequality? *Manchester School* 92 (3): 209-230.

Chamley, C. 1986. Optimal Taxation of Capital Income in General Equilibrium with Infinite Lives. *Econometrica* 54 (3): 607-622.

Charalampidis, N., & J. Guillochon. 2025. Searching for Robots. *Economic Modelling* 152: 107260.

Chetty, R., A. Guren, D. Manoli, & A. Weber. 2011. Are Micro and Macro Labor Supply Elasticities Consistent? A Review of Evidence on the Intensive and Extensive Margins. *American Economic Review* 101 (3): 471-475.

Costinot, A., & I Werning. 2023. Robots, Trade, and Luddism: A Sufficient Statistic Approach to Optimal Technology Regulation. *Review of Economic Studies* 90 (5): 2261-2291.

DeCanio, S. 2016. Robots and Humans—Complements or Substitutes? *Journal of Macroeconomics* 49: 280-291.

Despard, M., T. Friedline, & S. Martin-West. 2020. Why Do Households Lack Emergency Savings? The Role of Financial Capability. *Journal of Family and Economic Issues* 42: 542-557.

Diamond, P. 1998. Optimal Income Taxation: An Example with a U-Shaped Pattern of Optimal Marginal Tax Rates. *American Economic Review* 88 (1): 83-95.

Dixit, A., & J. Stiglitz. 1977. Monopolistic Competition and Optimum Product Diversity. *American Economic Review* 67 (3): 297-308.

Domeij, D. & J. Heathcote. 2004. On the Distributional Effects of Reducing Capital Taxes. *International Economic Review* 45 (2): 523-554.

Firooz, H., Z. Liu, & Y. Wang. 2025. Automation and the Rise of Superstar Firm. *Journal of Monetary Economics* 151: 103733.

Ganapati, S. 2025. The Modern Wholesaler: Global Sourcing, Domestic Distribution, and Scale Economies. *American Economic Journal: Microeconomics* 17 (1): 1–40.

Greenwood, J., Z. Hercowitz, & G. Huffman. 1988. Investment, Capacity Utilization, and the Real Business Cycle. *American Economic Review* 78 (3): 402-417.

Gasteiger, E., & K. Prettner. 2022. Automation, Stagnation, and the Implications of a Robot Tax. *Macroeconomic Dynamics* 26: 218-249.

Guerreiro, J., S. Rebelo, & P. Teles. 2022. Should Robots Be Taxed? *Review of Economic Studies* 89 (1): 279-311.

Guimarães, L., & P. Gil. 2022. Looking Ahead at the Effects of Automation in an Economy with Matching Frictions. *Journal of Economic Dynamics and Control* 144: 104538.

Havranek, T., R. Horvath, Z. Irsova, & M. Rusnak. 2015. Cross-Country Heterogeneity in Intertemporal Substitution. *Journal of International Economics* 96: 100-118.

Hsieh, C. & E. Rossi-Hansberg. 2023. The Industrial Revolution in Services. *Journal of Political Economy Macroeconomics* 1 (1): 3-42.

Jaimovich, N., I. Saporta-Eksten, H. Siu, & Y. Yedid-Levi. 2021. The Macroeconomics of Automation: Data, Theory, and Policy Analysis. *Journal of Monetary Economics* 122: 1-16.

Judd, K. 1985. Redistributive Taxation in a Simple Perfect Foresight Model. *Journal of Public Economics* 28 (1): 59-83.

Judd, K. 2002. Capital-Income Taxation with Imperfect Competition. *American Economic Review* 92 (2): 417-421.

Krusell, P., L. Ohanian, J. Ríos-Rull, & G. Violante. 2000. Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis. *Econometrica* 68 (5): 1029-1053.

Kudoh, N., & H. Miyamoto. 2025. Robots, AI, and Unemployment. *Journal of Economic Dynamics and Control* 174: 105069.

Lankisch, C., K Prettner, & A. Prskawetz. 2019. How Can Robots Affect Wage Inequality? *Economic Modelling* 81: 161-169.

Naito, H. 1999. Re-Examination of Uniform Commodity Taxes under a Non-Linear Income Tax System and Its Implication for Production Efficiency. *Journal of Public Economics* 71 (2): 165-188.

Nakatani, R. 2023. Productivity Drivers of Infrastructure Companies: Network Industries Utilizing Economies of Scale in the Digital Era. *Annals of Public and Cooperative Economics* 94 (4): 1273-1298.

Prettner, K. & H. Strulik. 2020. Innovation, Automation, and Inequality: Policy Challenges in the Race Against the Machine. *Journal of Monetary Economics* 116: 249-265.

Saez, E. 2017. Taxing the Rich More: Preliminary Evidence from the 2013 Tax Increase. *Tax Policy and the Economy* 31 (1): 71-120.

Saez, E. & G. Zucman. 2020. The Rise of Income and Wealth Inequality in America: Evidence fro Distributional Macroeconomic Accounts. *Journal of Economic Perspectives* 34 (4): 3-26.

Stiglitz, J. 2018. Pareto Efficient Taxation and Expenditures: Pre- and Re-Distribution, *Journal of Public Economics* 162: 101–119.

Straub, L., & I. Werning. 2020. Positive Long-Run Capital Taxation: Chamley-Judd Revisited. *American Economic Review* 110 (1): 86-119.

Thuemmel, U. 2023. Optimal Taxation of Robots. *Journal of the European Economic Association* 21 (3): 1154-1190.

Tyers, R., & Y. Zhou. 2023. Automation and Inequality with Taxes and Transfers. *Scottish Journal of Political Economy* 70: 68-100.

Zhang, P. 2019. Automation, Wage Inequality and Implications of a Robot Tax. *International Review of Economics & Finance* 59: 500-509.

Figure 1: Welfare Changes in Response to Capital Income Tax Rate

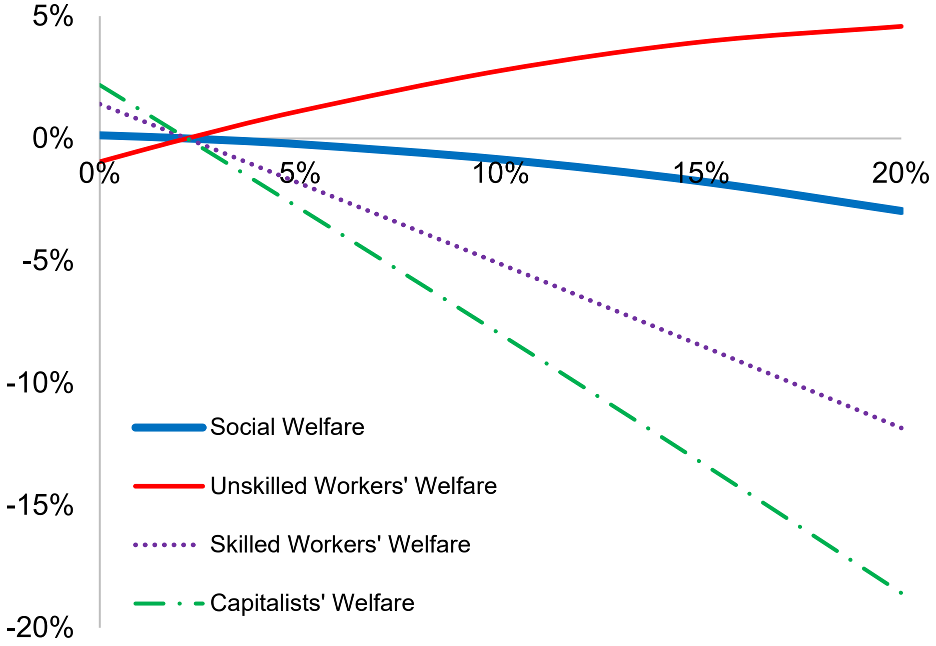


Figure 2: Welfare Changes in Response to Robot Tax Rate

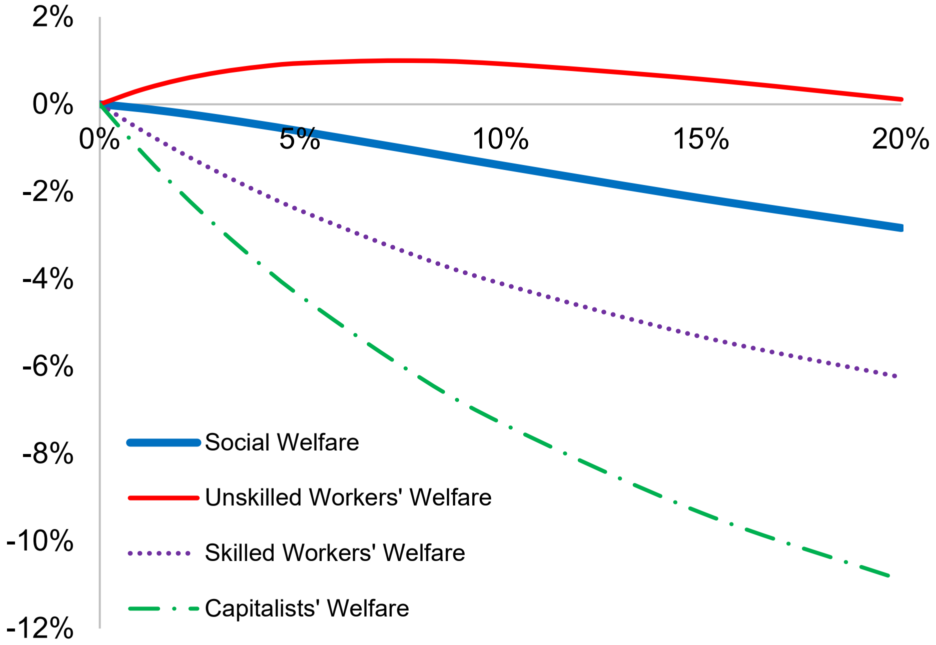


Figure 3: Welfare Changes in Response to Unskilled Wage Income Tax Rate

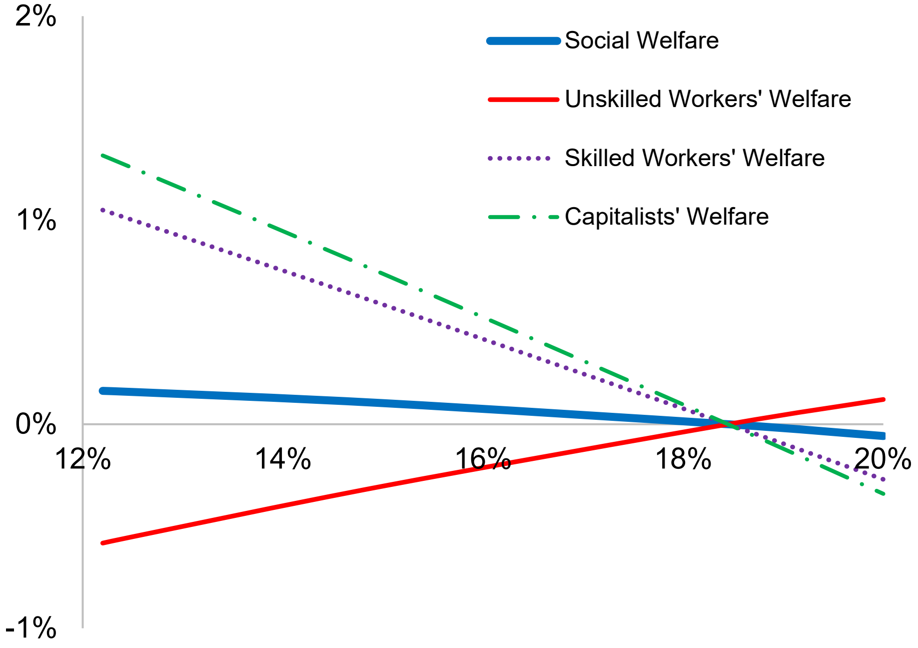
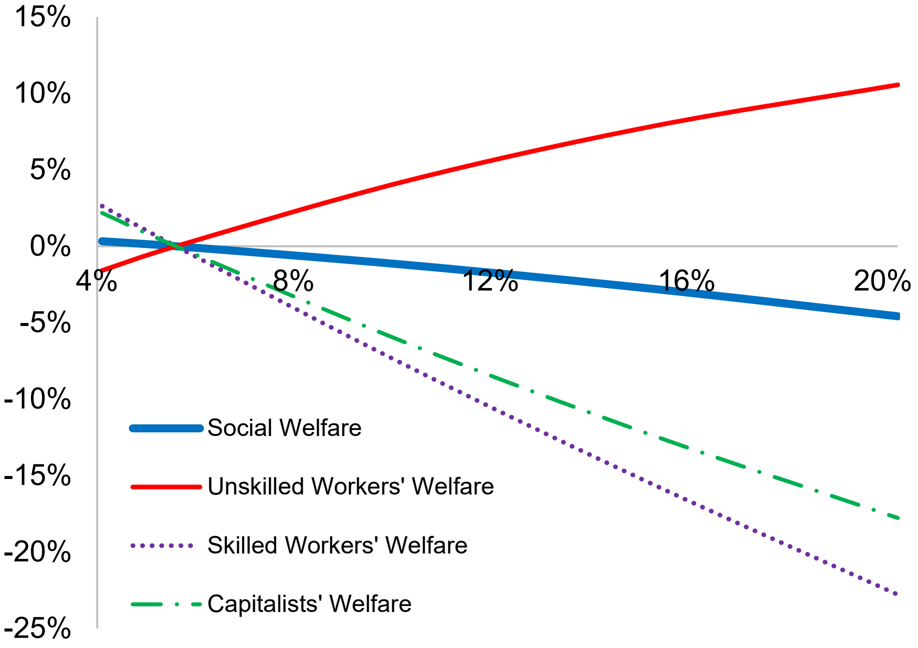


Figure 4: Welfare Changes in Response to ConsumptionTax Rate



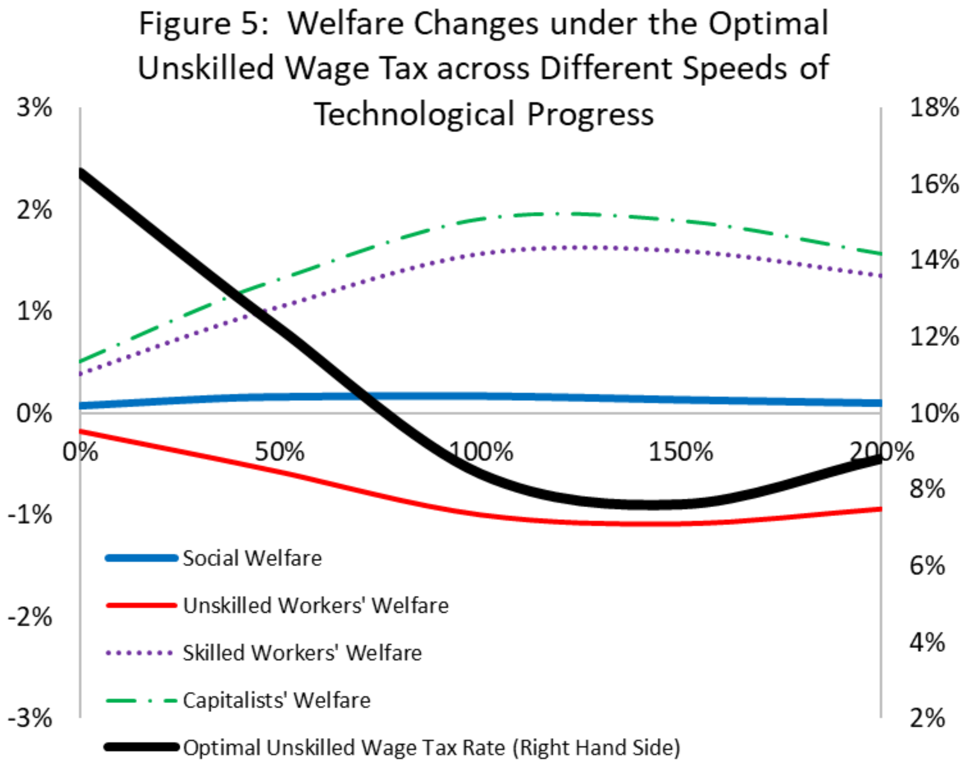


Figure 5: Welfare Changes under the Optimal Unskilled Wage Tax across Different Speeds of Technological Progress

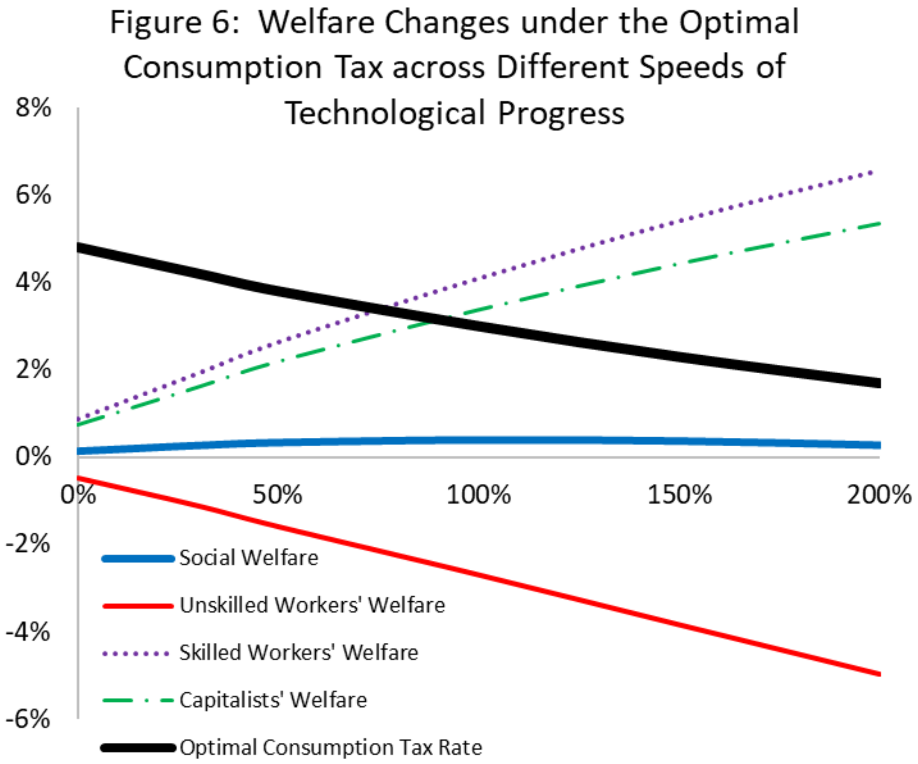


Figure 6: Welfare Changes under the Optimal Consumption Tax across Different Speeds of Technological Progress

Table 1. Calibration

Parameter	Description	Value	Source or Target
Parameters Borrowed from the Literature			
b	Productivity of automation technology	0.5	Berg et al. (2018)
σ_1	Elasticity of substitution between composite capital and composite labor	0.67	Berg et al. (2018)
σ_2	Elasticity of substitution between unskilled labor and automation capital	1.9	DeCanio (2016)
σ_3	Elasticity of substitution between skilled labor and capital	0.335	Berg et al. (2018)
σ_L	The inverse of intertemporal elasticity of substitution for unskilled workers	2	Berg et al. (2018)
σ_S	The inverse of intertemporal elasticity of substitution for skilled workers	2	Berg et al. (2018)
σ_C	The inverse of intertemporal elasticity of substitution for capitalists	2	Berg et al. (2018)
μ_L	The inverse of Frisch elasticity of unskilled labor supply	2	Chetty et al. (2011)
μ_S	The inverse of Frisch elasticity of skilled labor supply	2	Chetty et al. (2011)
β	Discount factor	0.94	Berg et al. (2018)
δ_K	Depreciation rate of capital	0.05	Berg et al. (2018)
δ_Z	Depreciation rate of robots	0.15	Berg et al. (2018)
Parameters Jointly Calibrated			
a	Share parameter of composite labor in production	0.763	Berg et al. (2018)
e	Share parameter of unskilled labor in composite labor	0.958	Berg et al. (2018)
f	Share parameter of skilled labor in composite capital	0.103	Berg et al. (2018)
Φ_L	Disutility of unskilled work	9.84	L=1/3 (i.e., 8 hours)
Φ_S	Disutility of skilled work	31.6	Afonso et al. (2023)
A	Total factor productivity	0.478	Berg et al. (2018)
τ_{w_L}, τ_{w_S}	Tax rate on income from skilled/unskilled labor	0.184	U.S. data (9.3% of GDP)
τ	Tax rate on income from capital	0.022	U.S. data (0.7% of GDP)
τ_θ	Tax rate on markup	0.104	U.S. data (1.8% of GDP)
τ_c	Tax rate on consumption	0.053	U.S. data (4.5% of GDP)
ϵ	The elasticity of substitution (implied markup is 1.21)	5.762	Barkai (2020)

Table 2. Changes in the Welfare and Economic Variables under Optimal Taxation against Different Elasticities of Substitution

Elasticity of Substitution: σ_2	***1.9***	***2.5***	***5***	***10***	***15***	***20***
Optimal Unskilled Wage Tax Rate	**12.2%**	**10.6%**	**13.3%**	**16.9%**	**15.2%**	**14.7%**
Social Welfare Gain	0.16%	0.07%	-0.02%	0.00%	0.00%	0.00%
Unskilled Workers' Welfare Gain	-0.58%	-0.67%	-0.10%	-0.00%	0.00%	0.00%
Skilled Workers' Welfare Gain	1.05%	0.96%	0.09%	0.00%	0.00%	0.00%
Capitalists' Welfare Gain	1.32%	1.04%	0.00%	-0.01%	-0.02%	-0.02%
Optimal Consumption Tax Rate	**3.8%**	**3.6%**	**44.5%**	**59.3%**	**62.0%**	**63.1%**
Social Welfare Gain	0.33%	0.03%	15.59%	29.12%	31.91%	32.95%
Unskilled Workers' Welfare Gain	-1.58%	-2.49%	76.38%	116.39%	124.25%	127.29%
Skilled Workers' Welfare Gain	2.63%	3.05%	-57.51%	-75.85%	-79.17%	-80.53%
Capitalists' Welfare Gain	2.18%	2.48%	-37.76%	-46.23%	-47.57%	-48.10%

Appendix Figures: Initial Steady State without Automation-Related Technological Progress under Different Tax Rates

Figure A.1. Social Welfare Changes

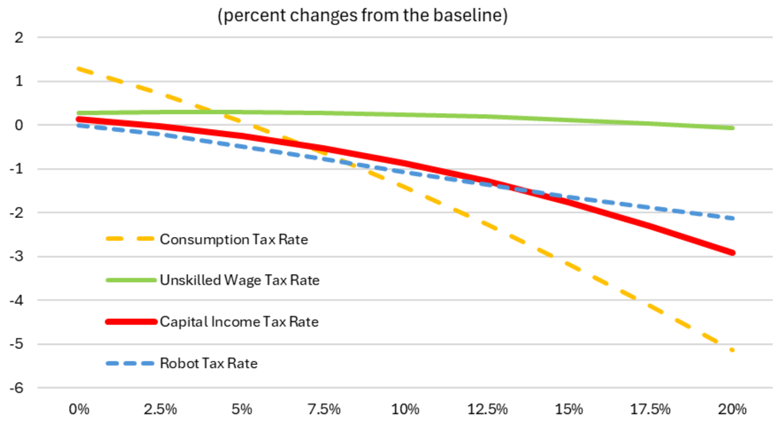


Figure A.2. Output Changes

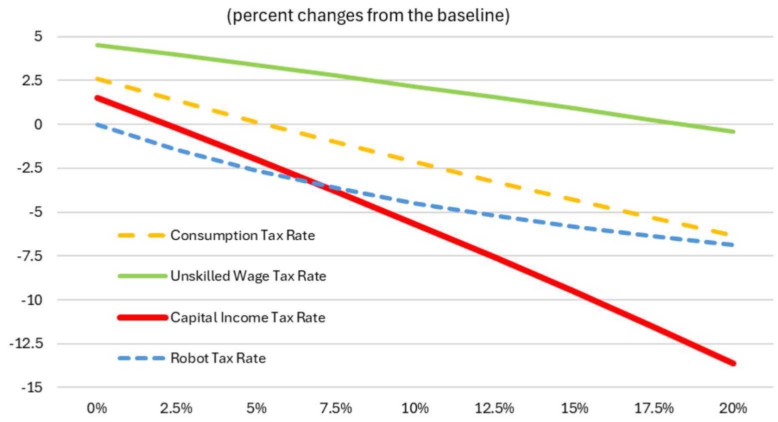


Figure A.3. Wage Premium

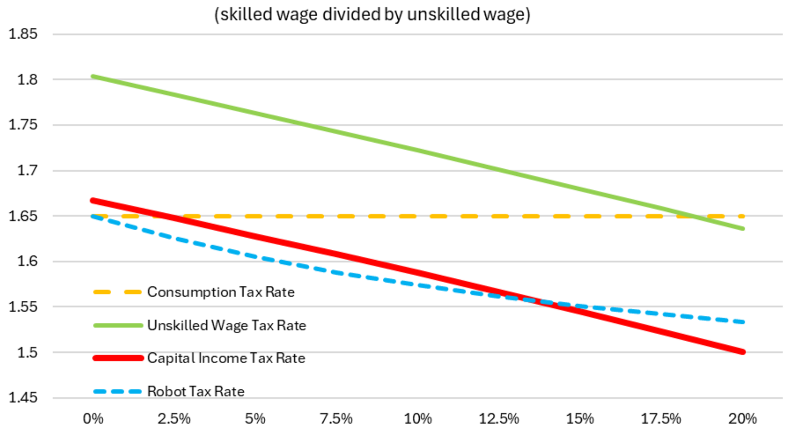


Figure A.4. Net Transfers to Unskilled Workers