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Conference Paper

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Beiträge zur Jahrestagung des Vereins für Socialpolitik 2014: Evidenzbasierte Wirtschaftspolitik - Session: Dynamic Public Finance, No. B03-V3

Provided in Cooperation with:

Verein für Socialpolitik / German Economic Association

Suggested Citation: Slavik, Ctirad; Yazici, Hakki (2014) : On the Consequences of Eliminating Capital Tax Differentials, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2014: Evidenzbasierte Wirtschaftspolitik - Session: Dynamic Public Finance, No. B03-V3, ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften, Leibniz-Informationszentrum Wirtschaft, Kiel und Hamburg

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On the Consequences of Eliminating Capital Tax Differentials

Ctirad Slavík and Hakki Yazici*

February 19, 2014

Abstract

In the United States structure and equipment capital are effectively taxed at different rates. Recently, President Obama joined the group of policy makers and economists who propose to eliminate these differentials. This paper analyzes the consequences of such a reform using an incomplete markets model with equipment-skill complementarity. We find that the reform increases average welfare by 0.1%. Importantly, we find that the reform does not involve the usual efficiency vs. equality trade-off: it improves both.

JEL classification: E62, H21.

Keywords: Uniform capital tax reform, equipment capital, structure capital, equipment-skill complementarity.

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1 Introduction

In the current U.S. tax code different types of capital are taxed at different rates effectively. Recently, President Obama’s administration has proposed to eliminate these differentials in a budget neutral way.¹ This paper analyzes the aggregate and distributional consequences of such a reform using an incomplete markets model with two types of capital and equipment-skill complementarity. We find that this reform creates economy-wide productive efficiency gains by reallocating capital from low to high return capital. In addition, by decreasing the skill premium, eliminating capital tax differentials redistributes from the rich to the poor. Therefore, the reform does not suffer from the usual efficiency vs. equality trade-off: it improves both.

Specifically, we build an infinite horizon model with heterogeneous agents with the following features. First, agents are either skilled or unskilled, and the skill type is permanent. Second, both skilled and unskilled agents are subject to idiosyncratic labor productivity shocks. Third, there are two types of capital, structure capital and equipment capital, and the production function features a higher degree of complementarity between equipment capital and skilled labor than between equipment capital and unskilled labor, as documented empirically for the U.S. economy by Krusell, Ohanian, Ríos-Rull, and Violante (2000).² Finally, the government uses linear taxes on capital income and a non-linear labor income tax schedule to finance government consumption and repay debt. We solve for the stationary competitive equilibrium of this model and calibrate the model parameters to the U.S. economy. The main objective of the paper is to use the calibrated model to evaluate the long-run effects of a uniform capital tax reform, which equalizes the tax rates on the two types of capital while keeping the rest of the fiscal policies intact.

Gravelle (2011) estimates that the effective corporate tax rate on equipment capital is 26% and that on structure capital is 32%.³ Combining the 15% flat capital income tax rate that consumers face with the differential capital tax rates at the corporate level, the overall effective tax rate on equipment capital is 37.1% while the overall effective tax rate on structure capital is 42.2%. We find that in our model a budget neutral tax reform that eliminates capital tax differentials equates the tax rates on both types of capital at 39.66%.

This uniform tax reform has two effects on the economy. First, it improves productive efficiency by increasing the average productivity of aggregate capital stock. Intuitively, by taxing structure capital at a higher rate than equipment capital, the current tax code distorts firms’

¹See the 2011 U.S. President’s State of the Union Address at <http://www.whitehouse.gov/the-press-office/2011/01/25/remarks-president-state-union-address>. For more details, see also the President’s Framework for Business Tax Reform (2012).

²Flug and Hercowitz (2000) provide evidence for equipment-skill complementarity for a large set of countries.

³Effective tax rates across capital types differ because of differences between tax depreciation allowances and actual economic depreciation rates. For more details, see Gravelle (1994).

capital decisions in favor of using more equipment capital: the marginal return to equipment capital is lower than the marginal return to structure capital under the current tax system. By eliminating the tax differentials, the proposed reform eliminates this distortion through capital reallocation from the capital type with lower returns, equipment capital, to the capital type with higher returns, structure capital. This capital reallocation increases the average return to capital and brings the economy closer to its production possibilities frontier. Second, due to equipment-skill complementarity, lower level of equipment capital in the new steady state decreases the skill premium, indirectly redistributing from the skilled to the unskilled. As a result, average consumption and labor supply of the skilled and unskilled agents become more equal. We conclude that the proposed reform does not involve the usual equality vs. efficiency trade-off: eliminating capital tax differentials not only increases efficiency, but also improves equality.

Next, we measure the steady-state welfare consequences of the uniform capital tax reform. We first consider a Utilitarian social welfare function that puts equal weights on all agents. Using this measure, we find that the overall steady-state welfare gains of the reform are 0.1% in terms of lifetime consumption. We also compute the welfare gains for skilled and unskilled agents separately. We find that the unskilled agents gain by 0.15% whereas the skilled agents lose by 0.009%. We interpret these findings as follows. By increasing productive efficiency, the reform increases welfare for both types of agents. Through indirect redistribution, the reform increases welfare of unskilled agents and decreases welfare of skilled agents. It turns out that, in our benchmark model, the efficiency gains and redistribution losses almost fully offset each other for the skilled agents, resulting in a small welfare loss. For the unskilled agents, the redistributive gains plus the efficiency gains sum up to a significant welfare gain.

The government could also accompany the capital tax reform by a modification of the labor tax code in order to distribute the efficiency gains across agents in a different way. In particular, the government could distribute a larger share of the efficiency gains to the skilled agents to ensure that they are not worse off. The important point is that the uniform capital tax reform makes Pareto improvements possible. We provide an example of a Pareto improving reform in Section 4.3.

In this paper, we compare welfare across steady states, which can be problematic. In an environment similar to ours, Domeij and Heathcote (2004) shows that a government that ignores short-run welfare finds it optimal to choose very low capital tax rates in order to encourage long-run capital accumulation, and that such a reform has dire welfare consequences in the short-run. Our reform does not suffer as much from this critique, because average capital taxes are almost unaffected by the tax reform, and there is only a small, 0.4%, increase in the aggregate capital stock from the initial to the new steady state. To check the validity of this argument, we analyze

another tax reform, in which the uniform capital tax is set so that the aggregate capital stock remains unchanged across steady states. This requires uniform capital taxes to be slightly higher than in the benchmark reform. We find that the welfare gains of this reform are over two thirds of the benchmark welfare gains, validating our argument.

Related Literature. This paper is related to a set of papers that evaluate the consequences of eliminating capital tax differentials. The closest to this paper is Auerbach (1989), who computes the welfare gains associated with eliminating the capital tax differentials that existed prior to the U.S. Tax Reform Act of 1986. Because he is not interested in the distributional consequences of his reform, he uses a model without heterogeneity. Modeling heterogeneity is crucial for our paper, however, because our main message is that a uniform capital tax reform improves not only efficiency, but also equality. Auerbach (1983) and Gravelle (1994) both compute the deadweight loss of misallocation of capital that is created by differential taxation of capital and find losses that are in the range of 0.10 to 0.15 % of U.S. GNP assuming Cobb-Douglas production technologies. Recently, Gravelle (2011) evaluates the implications of reforming the tax depreciation rules present in the U.S. tax code for the effective tax rates on different types of capital and for the corporate tax revenues. Unlike our paper, she is not interested in the economy-wide implications and the welfare consequences of her reform.

There is a related literature that analyzes optimal capital tax policy in environments with multiple types of capital. The productive efficiency result of Diamond and Mirrlees (1971) implies that, in an environment with multiple capital types, all capital should be taxed at the same rate. Auerbach (1979) shows that in an overlapping generations environment it might be optimal to tax capital differentially if the government is exogenously restricted to a narrower set of fiscal instruments than in Diamond and Mirrlees (1971). Similarly, Feldstein (1990) proves the optimality of differential capital taxation in a static model in which the government is restricted to set the tax rate on one type of capital equal to zero. Slavik and Yazici (2014) shows that a government that has redistribution and incentive provision goals generically finds it optimal to tax capital differentially if the production technology features equipment-skill complementarity. Conesa and Dominguez (2013) considers an economy with tangible and intangible capital where capital is taxed twice: first, through a corporate income tax, and second, at the consumer level, through a dividend tax. They find that the optimal long-run policy features zero corporate taxes and positive dividend taxes. These papers are normative, whereas the current paper is a positive analysis of the aggregate and distributional consequences of the uniform capital tax reform recently proposed by the Obama administration.

Finally, this paper is related to a growing literature, which analyzes the quantitative effects of tax reforms using incomplete markets models with heterogeneous agents, such as Domeij and Heathcote (2004), Conesa and Krueger (2006), Conesa, Kitao, and Krueger (2009) and

Heathcote, Storesletten, and Violante (2012), among others. We contribute to this literature by analyzing tax reforms in an environment with multiple capital goods and equipment-skill complementarity. Our paper is most closely related to Domeij and Heathcote (2004) in the sense that both papers provide positive analyses of capital tax reforms. However, while Domeij and Heathcote (2004) focuses on the consequences of capital tax cuts, we focus on a policy reform which changes the mix between equipment and structure capital taxation, but leaves the overall level of capital taxation unaffected.

The rest of the paper is organized as follows. In Section 2, we lay out the model. Section 3 discusses calibration. Section 4 provides our main quantitative findings. Finally, Section 5 concludes.

2 Model

We consider an infinite horizon growth model with two types of capital (structures and equipments), two types of labor (skilled and unskilled), consumers, firms, and a government.

Endowments and Preferences. There is a continuum of measure one of agents who live for infinitely many periods. Ex-ante, they differ in their skill levels: they are born either skilled or unskilled, $i \in \{u, s\}$. Skilled agents can only work in the skilled labor sector and unskilled agents only in the unskilled labor sector. The skill types are permanent. The total mass of the skilled agents is denoted by π_s , the total mass of the unskilled agents is denoted by π_u . In the quantitative analysis, skill types correspond to educational attainment at the time of entering the labor market. Agents who have college education or above are classified as skilled agents and the rest of the agents are classified as unskilled agents.

In addition, agents face idiosyncratic labor productivity shocks over time, which are denoted by z . The shock z follows a type-specific Markov chain with states $Z_i = \{z_{i,1}, \dots, z_{i,I}\}$ and transitions $\Pi_i(z'|z)$. An agent of skill type i and productivity level z who works l units of time produces $l \cdot z$ units of effective i type of labor. As a result, her wage per unit of time is $w_i \cdot z$, where w_i is the wage per effective unit of labor in sector i .

Preferences over sequences of consumption and labor, $(c_{i,t}, l_{i,t})_{t=0}^{\infty}$, are defined using a time-separable utility function

$$E_i \left(\sum_{t=0}^{\infty} \beta_i^t u(c_{i,t}, l_{i,t}) \right),$$

where β_i is the time discount factor which is allowed to be different across skill types.⁴ For

⁴Attanasio, Banks, Meghir, and Weber (1999) provide empirical evidence for differences in discount factors across education groups. In our quantitative analysis, we calibrate the discount factors so as to match the observed difference in wealth between skilled and unskilled agents. We perform a version of our benchmark

each skill type, unconditional expectation, E_i , is taken with respect to the stochastic processes governing the idiosyncratic labor shock. There are no aggregate shocks.

Technology. There is a constant returns to scale production function: $Y = F(K_s, K_e, L_s, L_u)$, where K_s and K_e refer to aggregate structure capital and equipment capital and L_s and L_u refer to aggregate effective skilled and unskilled labor, respectively. We also define a function \tilde{F} that gives the total wealth of the economy: $\tilde{F} = F + (1 - \delta_s)K_s + (1 - \delta_e)K_e$, where δ_s and δ_e are the depreciation rates of structure and equipment capital, respectively.

The key feature of the technology is equipment-skill complementarity, which means that the degree of complementarity between equipment capital and skilled labor is higher than that between equipment capital and unskilled labor. This implies that an increase in the stock of equipment capital decreases the ratio of the marginal product of unskilled labor to the marginal product of skilled labor. In a world with competitive factor markets, this implies that the skill premium, defined as the ratio of skilled to unskilled wages, is increasing in equipment capital. Structure capital, on the other hand, is assumed to be neutral in terms of its complementarity with skilled and unskilled labor. These assumptions on technology are in line with the empirical evidence provided by Krusell, Ohanian, Ríos-Rull, and Violante (2000). Letting $\partial F/\partial m$ be the partial derivative of function F with respect to variable m , we formalize these assumptions as follows.

Assumption 1. $\frac{\partial F/\partial L_s}{\partial F/\partial L_u}$ is independent of K_s .

Assumption 2. $\frac{\partial F/\partial L_s}{\partial F/\partial L_u}$ is strictly increasing in K_e .

There is a representative firm which, in each period, hires the two types of labor and rents the two types of capital to maximize profits. In any period t , its maximization problem reads:

$$\max_{K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t}} F(K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t}) - r_{s,t}K_{s,t} - r_{e,t}K_{e,t} - w_{s,t}L_{s,t} - w_{u,t}L_{u,t},$$

where $r_{s,t}$ and $r_{e,t}$ are the rental rates of structure and equipment capital, and $w_{u,t}$ and $w_{s,t}$ are the wages rates paid to unskilled and skilled effective labor in period t .

Asset Market Structure. There is a single risk free asset which has a one period maturity. Consumers can save using this asset but are not allowed to borrow. Every period total savings by consumers must be equal to total borrowing of the government plus the total capital stock in the economy.

Government. The government uses linear consumption taxes every period $\{\tau_{c,t}\}_{t=0}^{\infty}$ and linear taxes on capital income net of depreciation. The tax rates on the two types of capital are

quantitative exercise in which we assume that the discount factors are equal for the two types of agents. As we report in Section 4.4, our main quantitative results are robust to this modification.

allowed to be different. Let $\{\tau_{s,t}\}_{t=0}^{\infty}$ and $\{\tau_{e,t}\}_{t=0}^{\infty}$ be the sequences of tax rates on structure and equipment capital. It is irrelevant for our analysis whether capital income is taxed at the consumer or at the corporate level. We assume without loss of generality that all capital income taxes are paid at the consumer level. The government taxes labor income using a sequence of possibly non-linear functions $\{T_t(y)\}_{t=0}^{\infty}$, where y is labor income and $T_t(y)$ are the taxes paid by the consumer. The government uses taxes to finance a stream of expenditure $\{G_t\}_{t=0}^{\infty}$ and repay government debt $\{D_t\}_{t=0}^{\infty}$.

In our quantitative analysis we focus on the comparison of stationary equilibria. For that reason, instead of giving a general definition of competitive equilibrium, here we only define stationary recursive competitive equilibria. The formal definition of non-stationary competitive equilibrium is relegated to Appendix A. In order to define a stationary equilibrium, we assume that policies (government expenditure, debt and taxes) do not change over time.

Before we define a stationary equilibrium formally, notice that, in the absence of aggregate productivity shocks, the returns to saving in the form of the two capital types are certain. The return to government bond is also known in advance. Therefore, in equilibrium all three assets must pay the same after-tax return, i.e., $R = 1 + (r_s - \delta_s)(1 - \tau_s) = 1 + (r_e - \delta_e)(1 - \tau_e)$, where R refers to the stationary return on the bond holdings. As a result, we do not need to distinguish between saving through different types of assets in the consumer's problem. We denote consumers' asset holdings by a .

Stationary Recursive Competitive Equilibrium (SRCE). SRCE is two value functions v_u, v_s , policy functions $c_u, c_s, l_u, l_s, a'_u, a'_s$, the firm's decision rules K_s, K_e, L_s, L_u , government policies $\tau_c, \tau_s, \tau_e, T(\cdot), D, G$, two distributions over productivity-asset types $\lambda_u(z, a), \lambda_s(z, a)$ and prices w_u, w_s, r_s, r_e, R such that

1. The value functions and the policy functions solve the consumer problem given prices and government policies, i.e., for all $i \in \{u, s\}$:

$$v_i(z, a) = \max_{(c_i, l_i, a'_i) \geq 0} u(c_i, l_i) + \beta_i \sum_{z'} \Pi_i(z'|z) v_i(z', a'_i) \quad \text{s.t.}$$

$$(1 + \tau_c) c_i + a'_i \leq w_i z l_i - T(w_i z l_i) + R a_i,$$

where $R = 1 + (r_s - \delta_s)(1 - \tau_s) = 1 + (r_e - \delta_e)(1 - \tau_e)$ is the after-tax asset return.

2. The firm solves:

$$\max_{K_s, K_e, L_s, L_u} F(K_s, K_e, L_s, L_u) - r_s K_s - r_e K_e - w_s L_s - w_u L_u.$$

3. The distribution λ_i is stationary for each skill type, i.e. for all i : $\lambda'_i(z, a) = \lambda_i(z, a)$. This

means:

$$\lambda_i(\bar{z}, \bar{a}) = \int_z \int_{a: a'_i(z, a) = \bar{a}} \lambda_i(z, a) \cdot da \cdot d\Pi_i(\bar{z}|z).$$

4. Markets clear:

$$\begin{aligned} \sum_i \pi_i \int_z \int_a a \cdot d\lambda_i(z, a) &= K_s + K_e + D, \\ \pi_s \int_z \int_a z l_s(z, a) \cdot d\lambda_s(z, a) &= L_s, \\ \pi_u \int_z \int_a z l_u(z, a) \cdot d\lambda_u(z, a) &= L_u, \\ C + G + K_s + K_e &= \tilde{F}(K_s, K_e, L_s, L_u), \end{aligned}$$

where $C = \sum_{i=u,s} \pi_i \int_z \int_a c_i(z, a) \cdot d\lambda_i(z, a)$ denotes aggregate consumption.

5. Government budget constraint is satisfied.

$$RD + G = D + \tau_c C + \tau_e (r_e - \delta_e) K_e + \tau_s (r_s - \delta_s) K_s + T_{agg},$$

where $T_{agg} = \sum_{i=u,s} \pi_i \int_z \int_a T(w_i z l_i(z, a)) \cdot d\lambda_i(z, a)$ denotes aggregate labor tax revenue.

We explain how we solve for the SRCE in Appendix B.

3 Calibration

To calibrate model parameters, we assume that the SRCE defined in the previous section - computed using the current U.S. tax system - coincides with the current U.S. economy. We first fix a number of parameters to values from the data or from the literature. These parameters are summarized in Table 1. We then calibrate the remaining parameters so that the SRCE matches the U.S. data along selected dimensions. Our calibration procedure is summarized in Table 2.

We assume that the period utility function takes the form

$$u(c, l) = \frac{c^{1-\sigma}}{1-\sigma} - \phi \frac{l^{1+\gamma}}{1+\gamma}.$$

One period in our model corresponds to one year. In the benchmark case, we use $\sigma = 2$ and $\gamma = 1$. These are within the range of values that have been considered in the literature. We calibrate ϕ to match the average labor supply.

Table 1: Benchmark Parameters

Parameter	Symbol	Value	Source
Preferences			
Relative risk aversion parameter	σ	2	
Inverse Frisch elasticity	γ	1	
Technology			
Structure capital depreciation rate	δ_s	0.056	GHK
Equipment capital depreciation rate	δ_e	0.124	GHK
Share of structure capital in output	α	0.117	KORV
Measure of elasticity of substitution between equipment capital K_e and unskilled labor L_u	η	0.401	KORV
Measure of elasticity of substitution between equipment capital K_e and skilled labor L_s	ρ	-0.495	KORV
Relative supply of skilled workers	p_s/p_u	0.778	U.S. Census
Productivity			
Productivity persistence of skilled workers	ρ_s	0.9408	KL
Productivity volatility of skilled workers	$var(\varepsilon_s)$	0.1000	KL
Productivity persistence of unskilled workers	ρ_u	0.8713	KL
Productivity volatility of unskilled workers	$var(\varepsilon_u)$	0.1920	KL
Government polices			
Labor tax progressivity	τ_l	0.18	HSV
Overall tax on structure capital income	τ_s	0.422	Gravelle (2011)
Overall tax on equipment capital income	τ_e	0.371	Gravelle (2011)
Government consumption	G/Y	0.16	NIPA
Government debt	D/Y	0.6	U.S. data

This table reports the benchmark parameters that we take directly from the literature or the data. The acronyms GHK, KORV, HSV, and KL stand for Greenwood, Hercowitz, and Krusell (1997), Krusell, Ohanian, Ríos-Rull, and Violante (2000), Heathcote, Storesletten, and Violante (2012), and Krueger and Ludwig (2013), respectively. NIPA stands for the National Income and Product Accounts.

We further assume that the production function takes the same form as in Krusell, Ohanian, Ríos-Rull, and Violante (2000):

$$Y = F(K_s, K_e, L_s, L_u) = K_s^\alpha \left(\nu [\omega K_e^\rho + (1 - \omega)L_s^\rho]^\frac{\eta}{\rho} + (1 - \nu)L_u^\eta \right)^\frac{1-\alpha}{\eta}.$$

Krusell, Ohanian, Ríos-Rull, and Violante (2000) estimate α, ρ, η , and we use their estimates, but they do not estimate ω and ρ . We calibrate these parameters to U.S. data, as we explain in detail below.

As for government policies, we assume that the government consumption-to-output ratio equals 16%, which is close to the average ratio in the United States during the period 1980 – 2012, as reported in the National Income and Product Accounts (NIPA) data. To approximate

the progressive U.S. labor tax code, we follow Heathcote, Storesletten, and Violante (2012) and assume that tax liability given labor income y is defined as:

$$T(y) = \bar{y} \left[\frac{y}{\bar{y}} - \lambda \left(\frac{y}{\bar{y}} \right)^{1-\tau_l} \right],$$

where \bar{y} is the mean labor income in the economy, $1 - \lambda$ is the average tax rate of a mean income individual, and τ_l controls the progressivity of the tax code. Using 2005 CPS data, Heathcote, Storesletten, and Violante (2012) estimate $\tau_l = 0.18$. We use their estimate and calibrate λ to clear the government budget.

Gravelle (2011) documents that because of differences in tax depreciation rates, the effective tax rates on structure capital and equipment capital differ at the firm level. Specifically, the effective corporate tax rate on structure capital is 32% and the effective corporate tax rate on equipment capital is 26%. We assume that the capital income tax rate at the consumer level is 15%, which approximates the U.S. tax code. This implies an overall tax on structure capital of $\tau_s = 1 - 0.85 \cdot (1 - 0.32) = 42.2\%$ and an overall tax on equipment capital of $\tau_e = 1 - 0.85 \cdot (1 - 0.26) = 37.1\%$. These numbers are in line with a 40% tax, which Domeij and Heathcote (2004) report for aggregate capital stock. Finally, we assume a government debt of 60% of GDP, as in the U.S. in the late 2000's.

We set the ratio of skilled to unskilled agents to be consistent with the 2011 US Census data. We cannot identify the mean levels of the idiosyncratic labor productivity shock z for the two types of agents separately from the remaining parameters of the production function and therefore set $E[z] = 1$ for both skilled and unskilled. This assumption implies that w_i corresponds to the average wage rate of agents of skill type i . We assume that the processes for z differ across the two types of agents. Specifically, we assume that for all $i \in \{u, s\}$: $\log z_{t+1} = \rho_i \log z_t + \varepsilon_{i,t}$. Following Krueger and Ludwig (2013), we pick $\rho_s = 0.9408$, $var(\varepsilon_s) = 0.0100$, $\rho_u = 0.8713$, $var(\varepsilon_u) = 0.0192$. We approximate these processes by finite number Markov chains using the Rouwenhorst method described in Kopecky and Suen (2010).

Finally, we calibrate the parameter that controls the income share of equipment capital ω , the parameter that controls the income share of unskilled labor ν , the labor disutility parameter ϕ , the discount factors β_s, β_u , and the labor tax parameter λ . We calibrate these parameters so that (i) the labor share equals 2/3 (approximately the average labor share in 1980 – 2010 as reported in the NIPA data), (ii) the skill premium w_s/w_u equals 1.8 (as reported by Heathcote, Perri, and Violante (2010) for the 2000s), (iii) the aggregate labor supply in steady state equals 1/3 (as is commonly used in the macro literature), (iv) the capital-to-output ratio equals 2.9 (approximately the average of 1980 – 2011 as reported in the NIPA and Fixed Asset Tables data), and (v) the asset holdings of an average skilled agent are 2.68 times those of an average

Table 2: Benchmark Calibration Procedure

Parameter	Symbol	Value	Target	Data and SRCE	Source
Production function parameter	ω	0.4800	Labor share	2/3	NIPA
Production function parameter	ν	0.6551	Skill premium $\frac{w_s}{w_u}$	1.8	HPV
Disutility of labor	ϕ	123.7	Labor supply	1/3	
Skilled discount factor	β_s	0.9825	Capital-to-output ratio	2.9	NIPA, FAT
Unskilled discount factor	β_u	0.9807	Relative wealth	2.680	Census
Tax function parameter	λ	0.8423	Gvt. budget balance		

This table reports our benchmark calibration procedure. The production function parameters ν and ω control the income share of equipment capital, skilled and unskilled labor in output. The tax function parameter λ controls the labor income tax rate of the mean income agent. Relative wealth refers to the ratio of the average skilled to average unskilled agents' asset holdings. The acronym HPV stands for Heathcote, Perri, and Violante (2010). NIPA stands for the National Income and Product Accounts, and FAT stands for the Fixed Asset Tables.

unskilled agent (as in the 2010 Census), and (vi) government budget is balanced in steady state. Table 2 summarizes our calibration procedure.

4 Consequences of the Reform

In this section, we use the model calibrated in Section 3 to analyze the aggregate and distributional consequences of a budget neutral capital tax reform that equates the tax rates on structure and equipment capital. We are interested in measuring the effects of reforming the capital tax system alone. Therefore, we keep other government policies intact. Specifically, the government needs to finance the pre-reform level of expenditure and debt in the new steady state. The labor income tax code is not modified either.⁵ To sum up, the reform finds the uniform tax rate on the two types of capital that clears the overall government's budget given that no other government policy instruments change.

We first analyze the effects of the budget neutral uniform capital tax reform on prices and macroeconomic quantities. Second, we show that the reform does not involve the usual efficiency vs. equality trade off. Third, we compute how the reform affects aggregate and individual welfare. Finally, we conduct sensitivity analysis.

A brief summary of our results is as follows. We find that the reform equates capital taxes

⁵Observe that labor income tax revenue might still change since the capital tax reform affects prices and people's labor supply in equilibrium.

at 39.66%. This means that the tax rate on equipment capital increases by about 3 percentage points whereas the tax rate on structure capital decreases by approximately the same amount. However, the change in the average capital tax is negligible. As a result of the tax changes, the amount of equipment capital decreases and the amount of structure capital increases. Interestingly, the average return to capital stays almost the same even though the total capital stock increases and the supply of both types of labor decline in the new steady state. This is due to the fact that the reform improves the productive efficiency of the economy by reallocating capital from low return capital to high return capital. In addition, we find that the reform makes the distribution of consumption and labor more equal across agents. The average steady-state welfare increases by 0.09%. This is a substantial welfare gain given that the reform involves a relatively modest change to the capital tax system. Now, we explain our findings in detail.

4.1 Macroeconomic Variables

Taxes and Prices. The first two rows of Table 3 display the current capital taxes as well as the uniform tax rate implied by the tax reform. We find that the uniform tax rate that applies to both types of capital and satisfies government’s budget given the status quo labor income taxes, debt, and spending policies is 39.66%. Importantly, as we report in the third row of the table, the average tax on capital is almost unchanged. This implies that the reform we analyze changes the mix between equipment and structure capital taxes, but leaves overall capital taxation virtually unaffected.⁶

The three rows in the middle of Table 3 report the pre-tax returns to capital net of depreciation before and after the reform. The fourth and the fifth rows show that after the reform the return to structure capital declines while the return to equipment capital increases until they are equalized.⁷ This is because the reform gives rise to an increase in the level of structure capital and a decrease in the level of equipment capital, as reported in Table 4. The sixth row of Table 3 displays the average returns to aggregate capital where the average is computed by weighing the return to each type of capital by its amount. We see, maybe somewhat surprisingly, that the average return to capital does not change much even though the aggregate capital stock increases and the level of both types of labor inputs decline (see Table 4 below).

⁶The tax numbers reported in the table are cumulative in the sense that they accumulate the capital income taxes that are paid at the firm level and at the consumer level. Alternatively, we can deduct the 15% flat capital income tax that consumers face to get the effective corporate capital income tax rates. In that case, while the pre-reform corporate effective tax rate on equipments is 26% and that on structures is 32%, the post-reform uniform effective corporate tax rate is 29.01%. This number could be interpreted as the statutory corporate tax rate if the equality of the effective tax rates on equipment and structure capital was achieved by setting the depreciation allowances for the two types of capital equal their actual economic depreciation rates.

⁷The non-arbitrage condition implies that after-tax returns to the two types of capital must be equal. After the reform, the capital tax is uniform and, thus, the pre-tax returns to the two types of capital are equal as well.

Table 3: Taxes and Prices Before and After the Reform

Variable	Status Quo	Reform	Change
τ_s	42.20%	39.66%	-6.0%
τ_e	37.10%	39.66%	6.9%
avg. τ	39.62%	39.66%	0.1%
$r_s - \delta_s$	2.56%	2.45%	-4.1%
$r_e - \delta_e$	2.35%	2.45%	4.3%
avg. $r - \delta$	2.46%	2.45%	-0.04%
w_s/w_u	1.8	1.7964	-0.20%
w_s	0.5495	0.5491	-0.09%
w_u	0.3053	0.3056	0.11%

This table reports the effects of the uniform capital tax reform on steady-state taxes and prices. τ_s denotes the tax on structure capital, τ_e denotes the tax on equipment capital, avg. τ denotes the average tax on capital. $r_s - \delta_s$ denotes the pre-tax return on structure capital net of depreciation δ_s , $r_e - \delta_e$ denotes the pre-tax return on equipment capital net of depreciation δ_e , and avg. $r - \delta$ denotes the average return on capital net of depreciation. w_s denotes the average wage of the skilled agents, w_u denotes the average wage of the unskilled agents, and w_s/w_u denotes ratio of skilled to unskilled wages, i.e. the skill premium.

With diminishing returns to capital and capital-labor complementarity, one would expect the observed changes in aggregate capital stock and labor supply to decrease the average return to capital further. However, because of the uniform capital tax reform, there is capital reallocation from the capital with lower returns, equipment capital, towards the capital with higher returns, structure capital. This reallocation prevents the average return to capital from decreasing further. The fact that the average return to capital remains virtually unchanged suggests that the reform improves productive efficiency. We quantify and discuss the improvement in productive efficiency in detail in Section 4.2.

Finally, the last three rows of Table 3 report the effects of the reform on wages. First, the skill premium, w_s/w_u , decreases. This is a direct implication of the decline in the stock of equipment capital and the assumptions on technology. We also find that the average wage of the skilled agents, w_s , decreases whereas the average wage of the unskilled agents, w_u , increases. This is because the reform increases the amount of structure capital in the new steady state. This implies that wages of both types of agents increase by the same proportion since, by Assumption 1, the complementarity between structure capital and the two types of labor is the same. The reform also decreases the level of equipment capital which depresses the wages of both types of agents. However, because of equipment-skill complementarity formalized in Assumption 2, the impact on skilled wages is larger. Quantitatively, we find that the cumulative effect is negative for skilled wages and positive for unskilled wages.

Allocations. Table 4 displays the effects of the tax reform on aggregate allocations. The

left panel shows how factors of production and total output are affected. The right panel shows how net after-tax capital income and consumption for the two groups of agents change.

The lower tax rate on structure capital gives rise to an increase in its level in the new steady state. In contrast, the higher tax rate on equipment capital results in a lower level of equipment capital. Overall, we find that the reform increases the steady state level of total capital stock by 0.40%. We find that skilled labor supply decreases by 0.01% and unskilled labor supply decreases by 0.05%. The reason for the labor supply changes is as follows. As reported in Table 3, wages decrease for the skilled agents. A decline in wages pushes labor supply up due to an income effect and down due to a substitution effect. When $\sigma > 1$, as in our benchmark parameterization, the income effect dominates, which implies that skilled labor supply should increase with wage.⁸ In addition, skilled labor supply is pushed down because of an income effect related to the increase in the skilled agents' average net after-tax capital income $(R - 1) \cdot A_s$ (see the right panel of the Table 4). It turns out that these effects almost offset each other and the skilled labor supply decreases only slightly. In contrast, as reported in Table 3, unskilled wages increase, and this pushes unskilled labor supply down since $\sigma > 1$. In addition, average unskilled capital income $(R - 1) \cdot A_u$ increases which decreases their labor supply. In the end, unskilled labor supply decreases more than skilled labor supply. Overall, we find that changes in the levels of factors of production lead to an increase in output, as reported in Table 4.

The first two rows of the right panel of Table 4 report the average consumption levels of the skilled agents, C_s , and the unskilled agents, C_u . We find that consumption of the skilled agents decreases. The reason is that the negative effect of the decrease in the skilled agents' wages on their consumption dominates the positive effect of the increase in their capital income. Unskilled consumption, on the other hand, increases, because both wages and capital income of the unskilled agents increase.

4.2 Productive Efficiency and Equality

In this section, we discuss the efficiency and equality consequences of the uniform capital tax reform. We find that the reform improves productive efficiency and increases the degree of equality.

We first discuss the productive efficiency gains of the reform. Productive efficiency measures how efficient the economy is in turning inputs into output. The productive efficiency result of Diamond and Mirrlees (1971) suggests that the differential tax treatment of the two types of capital might create inefficiencies by distorting capital accumulation decisions. Indeed, before the reform, the pre-tax return to structure capital is higher than the pre-tax return to equip-

⁸This comparative statics result holds exactly in a static model without wealth. The presence of positive wealth weakens the income effect.

Table 4: Changes in Allocations due to the Reform

Variable	Change	Variable	Change
K_s	1.34%	C_s	-0.02 %
K_e	-0.53%	C_u	0.07%
K	0.40%	C	0.02%
L_s	-0.01%	$(R - 1) \cdot A_s$	0.50 %
L_u	-0.05%	$(R - 1) \cdot A_u$	0.42 %
L	-0.04%		
Y	0.02%		

This table reports the effects of the uniform capital tax reform on allocations. “Change” refers to the change between the pre-reform and post-reform steady state. K_e denotes equipment capital, K_s denotes structure capital, K denotes aggregate capital, L_s denotes the average supply of skilled labor, L_u denotes the average supply of unskilled labor, Y denotes output. C_s denotes the average skilled consumption, C_u denotes the average unskilled consumption, and C denotes average (aggregate) consumption. $(R - 1) \cdot A_s$ denotes the average after-tax return to skilled agents’ asset holdings, and $(R - 1) \cdot A_u$ denotes the average after-tax return to unskilled agents’ asset holdings.

ment capital. Intuitively, then, a reform towards uniform capital taxation should create capital reallocation from the capital with lower returns, equipment capital, towards the capital with higher returns, structure capital. This reallocation, then, would increase the average return to capital, bringing the economy closer to its production possibility frontier. To see to what extent this argument applies to the reform in our model, we need to compare the before and after reform average returns to capital.

However, the tax reform does not only affect the way aggregate capital is allocated across the two capital types but it also changes the level of aggregate capital and the supply of both types of labor. In fact, in our benchmark analysis, the total capital stock increases and the supply of both types of labor decrease, putting a downward pressure on the average return to capital. Thus, in order to isolate the capital reallocation gains of the reform, we decompose the total change in the average return to capital as follows.

We first define an auxiliary interim allocation in which the aggregate capital and the labor supplies of both skilled and unskilled agents are kept constant at the pre-reform steady-state levels. In this interim allocation, capital is allocated across the two capital types in a way that equates their marginal returns, which is what happens when taxes on the two types of capital are equalized. The change in the average return to capital from the pre-reform steady state to the interim allocation measures the gains of allocating aggregate capital across the two types more efficiently. We call these gains *reallocation gains*.⁹ We call the change in the average return

⁹The tax reform affects the allocation of labor as well. Our measure of reallocation gains, however, measures the gains coming from a better allocation of capital alone and deliberately ignores the gains arising from a better

Table 5: Decomposition of the Change in the Average Return to Capital

Variable	Reallocation gains	Residual change	Total change
avg. $r - \delta$	1.35%	-1.38%	-0.04%

This table decomposes the change in the average net return on capital, i.e. “avg. $r - \delta$ ”, implied by the uniform capital tax reform, into the reallocation gains and the residual change. The reallocation gains measure the change in net return, which is due to a better allocation of capital.

to capital from the interim allocation to the post-reform steady state the *residual change*. This component captures the change in average return to capital which is due to the changes in the level of aggregate capital and the changes in the labor supplies. This decomposition of the change in the average capital return is summarized in Table 5. The column named reallocation gains reports that the average return to capital increases by 1.35% due to a more efficient allocation of capital. We find that the residual change is -1.38% , implying a cumulative effect of -0.04% .

Next, we discuss the consequences of the reform for the degree of equality between the skilled and the unskilled agents. We focus on the average consumption and labor allocations of the two types of agents. Before the reform unskilled agents work more than skilled agents. As reported in Table 4, after the reform, both labor supplies decline but unskilled labor supply declines more, implying a more equal distribution of hours worked across agents. Second, skilled consumption declines and unskilled consumption increases, which makes the consumption distribution more equal.¹⁰ This is especially interesting given the fact that the labor tax code is kept intact. There is more equality after the uniform capital tax reform because the reform redistributes *indirectly* from the skilled to the unskilled agents by decreasing the skill premium. By increasing the tax rate on equipment capital, the reform decreases the level of equipment capital. Under the assumption of equipment-skill complementarity, the decline in equipment capital then decreases the skill premium as shown in the last row of Table 3.

It is important to realize that eliminating capital tax differentials always improves efficiency in our model. Because of the nature of the pre-reform capital tax differentials in the U.S. tax code (structure capital tax rate being higher than equipment capital tax rate), the uniform capital tax reform that we consider also increases equality. As a result, this reform does not suffer from the efficiency vs. equality tradeoff, which is present in many other tax reforms. In the next section, we evaluate how the efficiency and equality improvements of the reform manifest themselves in terms of welfare.

allocation of labor by not optimizing over labor in the interim allocation. In this sense, our measure provides a lower bound for total reallocation gains.

¹⁰We find that the reform decreases inequality also when measured by the Gini coefficient. The pre-tax total income Gini decreases by 0.32%, while the wealth Gini decreases by 0.03%.

4.3 Welfare Gains

Now, we analyze the welfare gains of switching from the current capital tax system to a system with a uniform 39.66% capital tax rate. Our measure of welfare gains and losses is standard. The welfare gains of allocation x relative to allocation y are defined as a fraction by which the consumption in allocation y would have to be increased in each date and state in order to make its welfare equal to the welfare of allocation x .

First, we want to evaluate the effect of the reform on aggregate welfare. To do so, we consider a Utilitarian social welfare function which puts an equal weight on every agent. This welfare criterion also represents the ex-ante welfare of an individual who has a probability p_s of being born as a skilled agent and a probability p_u of being born as an unskilled agent. The welfare gains of the uniform capital tax reform are 0.09% in consumption equivalent units. Then, we evaluate the welfare consequences of the reform for skilled and unskilled agents separately. We find that the average skilled welfare declines by 0.009% whereas the average unskilled welfare increases by 0.150%. We interpret these findings as follows. The reform, by abolishing tax differentials, increases productive efficiency, which increases welfare for both types of agents. However, the reform also depresses equipment capital accumulation, and hence, decreases the skill premium, which implies indirect redistribution from the skilled agents to the unskilled agents. It turns out that, under our benchmark parameterization, the efficiency gains and redistribution losses incurring to the skilled agents almost fully offset each other, resulting in a small welfare loss. For the unskilled agents, the redistributive gains plus the efficiency gains sum up to a significant welfare gain of 0.150%.

Pareto Improving Reform. We also conduct a uniform capital tax reform, in which we keep skilled welfare unchanged and calculate welfare gains for the unskilled agents. In this reform, the uniform tax rate on capital is slightly below the benchmark reform level. This implies a smaller decrease in the skill premium and, hence, less indirect redistribution from the skilled to the unskilled. To make up for the capital tax revenue loss, we decrease λ , which increases the overall level of labor taxes, but does not change labor tax progressivity. In particular, the parameter τ_l , which controls labor tax progressivity, is kept constant in this reform. This reform is Pareto improving in the sense that skilled welfare does not change by construction and unskilled welfare goes up by 0.147%.¹¹

Notice that by choosing a lower level of the uniform capital tax rate and the appropriate λ , the government can distribute a larger share of the welfare gains of the reform to the skilled agents. What is important is that the uniform capital tax reform makes Pareto improvements possible. This is yet another manifestation of the efficiency gains that the reform provides.

¹¹Pareto improvement refers to an ex-ante improvement in both the skilled welfare and the unskilled welfare.

Fixed Aggregate Capital Stock. Our benchmark reform increases the total capital stock by 0.4% from the initial to the the new steady state. Comparing welfare across steady states with different capital levels can be problematic since raising capital from one steady state to the next might be costly over the transition. Therefore, to abstract from the steady-state welfare gains coming from the increase in aggregate capital, we consider an alternative reform, in which we choose the uniform capital tax rate so that the aggregate capital stock is constant across steady states.¹² We find that aggregate welfare increases by 0.06%, which implies that two thirds of the welfare gains in the benchmark reform are coming from a more efficient allocation of the pre-reform amount of aggregate capital between equipment and structure capital.

4.4 Sensitivity

In this section, we analyze the sensitivity of our quantitative results to the parameters that control preferences, technology, wage dispersion, and progressivity of the labor tax code. Specifically, we perform the following exercise. We change the parameter of interest and keep all other parameters that we do not calibrate fixed. We recalibrate the model under this new parameterization. Then, we conduct the uniform capital tax reform, and evaluate the changes in macroeconomic aggregates and welfare in the new steady state. The results are summarized in Table 6 and Table 7. We find that our main results are quite robust to changes in all four types of parameters.

In particular, we find that the reform decreases the steady state level of equipment capital and increases the steady state level of structure capital in all the sensitivity exercises we conduct. Similarly, it is always the case that consumption and hours worked become more equally distributed between skilled and unskilled agents. In Table 6 and Table 7, we do not report these results, but instead focus on the efficiency and equality consequences of the reform.

Sensitivity to Preference Parameters. Table 6 shows that our main results are robust to changes in preference parameters. First, the uniform capital tax rate is very close to the benchmark value in all the exercises. Second, as in the benchmark case, there are significant productive efficiency gains from capital reallocation as shown in the row called “reallocation gains.” Third, the skill premium decreases by roughly 0.2% in all the exercises, which implies a more equal distribution of consumption and labor across agents. We conclude that our finding that the uniform capital tax reform improves both efficiency and equality is robust to preference parameters. Aggregate welfare gains are around 0.1%, they increase with σ , but do not change much with γ . Typically, skilled agents lose and unskilled agents gain from the reform. An

¹²The uniform capital tax rate that keeps the aggregate capital at the pre-reform steady-state level is 40.55%, which is higher than the one in the benchmark reform, 39.66%. This creates extra revenues for the government, and thus, to keep the government budget balanced, we decrease the total labor tax revenue by increasing λ .

Table 6: Sensitivity to Preference Parameters

σ	Benchmark			Benchmark		
	1	2	4	2	2	2
γ	1	1	1	0.5	1	2
uniform tax	39.62%	39.66%	39.68%	39.67%	39.66%	39.64%
reallocation gains	1.38%	1.35%	1.32%	1.34%	1.35%	1.36%
w_s/w_u	-0.15%	-0.20%	-0.27%	-0.21%	-0.20%	-0.18%
welfare gains	0.04%	0.09%	0.12%	0.09%	0.09%	0.09%
skilled gains	0.01%	-0.01%	-0.07%	-0.02%	-0.01%	-0.001%
unskilled gains	0.06%	0.15%	0.21%	0.16%	0.15%	0.14%

This table reports the sensitivity of our main quantitative results to preference parameters. Each column reports the results for a particular combination of σ (the curvature of utility from consumption) and γ (the curvature of disutility of labor). Regarding the rows of the table, “uniform tax” refers to the uniform tax on equipment and structure capital that leaves steady state government budget balanced, “reallocation gains” refers to the gains associated with a more efficient allocation of capital, “ w_s/w_u ” denotes the ratio of skilled to unskilled wages. “Welfare gains” denote the aggregate steady state welfare gains of the reform, while “skilled gains” (“unskilled gains”) refers to the skilled (unskilled) agents’ steady state welfare gains.

interesting case is the one with $\sigma = \gamma = 1$, in which both types of agents gain. The reason is that in this parameterization, the decline in skilled consumption is very modest and is more than offset by the decrease in skilled labor supply. This case shows that the uniform capital tax reform is Pareto improving for a set of reasonable parameter values, even without being accompanied by a modification of the labor tax code.

Additional Sensitivity. Each column in Table 7, starting with the second one, reports an additional sensitivity exercise. The first row of the table shows that, in all these exercises, the uniform capital tax rate is very close to the benchmark value. In addition, the second and third rows of Table 7 show that the reform improves both efficiency and equality as in the benchmark case.

Now we discuss each robustness exercise reported in Table 7 in more detail. The column denoted by “ $\eta = 0.79$ ” reports the consequences of the reform in an economy with higher elasticity of substitution between equipment capital and unskilled labor. Specifically, we set $\eta = 0.79$.¹³ For this elasticity value, we observe that skilled welfare decreases more and unskilled welfare increases more relative to the benchmark case. This is intuitive: higher η means a lower degree of complementarity between equipment capital and unskilled labor. In that case, a decline in equipment capital decreases unskilled wages less and, therefore, depresses the skill premium more relative to the benchmark case, as reported in the third row of Table 7. This means that

¹³This value has been used, for example, in He and Liu (2008), who use the same production function, and comes from an empirical study by Duffy, Papageorgiou, and Perez-Sebastian (2004).

Table 7: Additional Sensitivity

	Benchmark	$\eta = 0.79$	High risk	$\tau_l = 0.15$	$\tau_l = 0.21$	Uniform β
uniform tax	39.66%	39.67%	39.69%	39.65%	39.67%	39.29%
reallocation gains	1.35%	1.26%	1.35%	1.35%	1.35%	1.36%
w_s/w_u	-0.20%	-0.28%	-0.23%	-0.20%	-0.20%	-0.17%
welfare gains	0.09%	0.10%	0.08%	0.09%	0.09%	0.10%
skilled gains	-0.01%	-0.05%	-0.01%	-0.01%	-0.01%	-0.02%
unskilled gains	0.15%	0.19%	0.15%	0.15%	0.15%	0.17%

This table reports additional sensitivity results. Each column reports the results for a particular parameter specification. We always change a particular parameter and leave the rest of the parameters unaffected. “ $\eta = 0.79$ ” refers to an exercise in which we increase the elasticity of substitution between equipment capital and unskilled labor by increasing η from its benchmark value of 0.401 to 0.79. The column “High risk” refers to an exercise in which we increase the variance of the idiosyncratic shocks three times. The columns “ $\tau_l = 0.15$ ” and “ $\tau_l = 0.21$ ” refer to exercises in which we change the labor progressivity parameter τ_l from its benchmark value of 0.18. The column “Uniform β ” refers to an exercise in which all agents are assumed to have the same discount factor. Regarding the rows of the table, “uniform tax” refers to the uniform tax on equipment and structure capital that leaves steady state government budget balanced, “reallocation gains” refers to the gains associated with a better allocation of capital, “ w_s/w_u ” denotes the ratio of skilled to unskilled wages. “Welfare gains” denote the aggregate steady state welfare gains of the reform, while “skilled gains” (“unskilled gains”) refers to the skilled (unskilled) agents’ steady state welfare gains.

there is a higher degree of indirect redistribution from the skilled to the unskilled. The average welfare gain is higher relative to the benchmark case because of the concavity of the utility function.

Our benchmark model does not generate quite enough within group wage inequality relative to the data (the overall wage Gini implied by our benchmark wage process is 0.23). We increase the standard deviation of the wage shocks 3 times for both skilled and unskilled agents to see to what extent our results depend on within group inequality (this change doubles the overall wage Gini). The results are summarized in the column called “High risk” in Table 7. We find that our results are by and large unaffected by this change. To the extent that one interprets the wage risk as the residual uninsured wage risk, this robustness suggests that our results are not sensitive to the degree of market incompleteness.

We take the estimate of the progressivity of the labor income tax code τ_l from a study by Heathcote, Storesletten, and Violante (2012). It is likely that different approaches would yield different results. We, therefore, report the sensitivity of our results to the progressivity of the labor tax code in the next two columns of Table 7. We decrease and increase τ_l by 1/6 to $\tau_l = 0.15$ and $\tau_l = 0.21$, respectively, and find that our results are robust to this change.

Finally, we calibrate a version of our model in which all agents have the same discount factor. The results of the uniform tax reform are reported in Table 7 in the column entitled “Uniform

β'' . We find that our main quantitative results do not depend on the assumption of heterogeneous discount factors. With a uniform discount factor, however, the calibrated model is not able to match the observed wealth distribution across skilled and unskilled agents.

5 Conclusion

This paper analyzes the aggregate and distributional consequences of a reform that eliminates capital tax differentials. We find that such a reform leads to improvements in productive efficiency. We also find that by decreasing the skill premium, the reform increases the degree of equality in the economy. This implies that the reform does not suffer from the usual efficiency vs. equality trade-off. As result of the reform, skilled agents' steady-state welfare decreases by 0.009%, while unskilled agents' welfare increases substantially by 0.15%, resulting in aggregate welfare gains of 0.09%.

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A Definition of Competitive Equilibrium

First, denote the partial history of productivity shocks up to period t by $z^t \equiv (z_0, \dots, z_t)$. Also, denote the unconditional probability of z^t for agent of skill type i by $P_{i,t}(z^t)$. For each agent type, this unconditional probability is achieved by applying the transition probability matrix $\Pi_i(z'|z)$ recursively. We denote by Z_i^t the set in which z^t lies for an agent of type i .

Equilibrium. A competitive equilibrium consists of a policy $(\tau_{c,t}, T_t(\cdot), \tau_{s,t}, \tau_{e,t}, D_t, G_t)_{t=0}^\infty$, an allocation $((c_{i,t}(z^t), l_{i,t}(z^t), a_{i,t+1}(z^t)))_{z^t \in Z_i^t, i}, K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t})_{t=0}^\infty$, and a price system $(r_{s,t}, r_{e,t}, w_{s,t}, w_{u,t}, R_t)_{t=0}^\infty$ such that:

1. Given the policy and the price system, the allocation $((c_{i,t}(z^t), l_{i,t}(z^t), a_{i,t+1}(z^t)))_{z^t \in Z_i^t, i}$ solves each consumer i 's problem, i.e.,

$$\max_{\{(c_{i,t}(z^t), l_{i,t}(z^t), a_{i,t+1}(z^t))_{z^t \in Z_i^t}\}_{t=0}^\infty} \sum_{t=0}^{\infty} \sum_{z^t \in Z_i^t} P_{i,t}(z^t) \beta_i^t u(c_{i,t}(z^t), l_{i,t}(z^t)) \quad s.t.$$

$$\forall t \geq 0, z^t, \quad (1 + \tau_{c,t})c_{i,t}(z^t) + a_{i,t+1}(z^t) \leq l_{i,t}(z^t)w_{i,t}z_t - T_t(l_{i,t}(z^t)w_{i,t}z_t) + R_t a_{i,t}(z^{t-1}),$$

given $a_0^i > 0$,

where $R_t = [1 + (1 - \tau_{s,t})(r_{s,t} - \delta_s)] = [1 + (1 - \tau_{e,t})(r_{e,t} - \delta_e)]$ is the after-tax return to savings via holding bonds, structure capital, or equipment capital.

2. In each period $t \geq 0$, taking factor prices as given, $(K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t})$ solves the following firm's problem:

$$\max_{K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t}} F(K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t}) - r_{s,t}K_{s,t} - r_{e,t}K_{e,t} - w_{s,t}L_{s,t} - w_{u,t}L_{u,t}.$$

3. Markets for assets, labor, and goods clear: for all $t \geq 0$,

$$K_{s,t} + K_{e,t} + D_t = \sum_{i=u,s} \pi_i \sum_{z^{t-1} \in Z_i^{t-1}} P_{i,t-1}(z^{t-1}) a_{i,t}(z^{t-1}), \text{ where } z^{-1} \text{ is the null history,}$$

$$L_{i,t} = \pi_i \sum_{z^t \in Z_i^t} P_{i,t}(z^t) l_{i,t}(z^t) z_t \text{ for } i = u, s,$$

$$G_t + \sum_{i=u,s} \pi_i \sum_{z^t \in Z_i^t} P_{i,t}(z^t) c_{i,t}(z^t) + K_{s,t+1} + K_{e,t+1} = \tilde{F}(K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t}).$$

4. The government's budget constraint is satisfied every period: for all $t \geq 0$,

$$G_t + R_t D_t = D_{t+1} + \sum_{j=s,e} \tau_{j,t}(r_{j,t} - \delta_j) K_{j,t} + \sum_{i=u,s} \pi_i \sum_{z^t \in Z_i^t} P_{i,t}(z^t) \left(T_t(l_{i,t}(z^t)w_{i,t}z_t) + \tau_{c,t}c_{i,t}(z^t) \right).$$

B Numerical Method

In this section, we outline our solution method.

General Solution Method for the Calibration Exercise. Traditionally, one would solve for a SRCE for a fixed set of parameters, including those that will be calibrated (i.e., $\omega, \nu, \phi, \beta_s, \beta_u$). This is done in the following way.

1. Start with an initial guess on prices w_s, w_u, R , government expenditure G and transfers T .
2. **Inner loop:** Solve for the policy functions given these parameters. The details of this computation are explained below.
3. Find the stationary distributions λ_s, λ_u implied by the policy functions.
4. Compute aggregate capital and labor supplies along with output. Given these, compute prices w_s, w_u, R implied by demand, government expenditure G as a fraction of output. Compute the implied transfers T that clear government budget.
5. Check if these prices and government policies coincide with the initial guesses. If not, update the guesses on prices, transfers and government expenditure and iterate.

One would normally solve this problem for each set of parameters during the calibration procedure, in which we are calibrating $\omega, \nu, \phi, \beta_s, \beta_u$ to hit a selected set of targets. We found it useful to include the calibration procedure directly into the loop above. Our procedure that combines solving for the SRCE with the calibration procedure is as follows.

1. Start with an initial guess on $w_s, w_u, R, G, T, \omega, \nu, \phi, \beta_s, \beta_u$.
2. Repeat steps 2. - 4. from above.
3. Check if the prices and government policies coincide with the initial guesses. Check if the aggregate labor supply, the skill premium, the labor share, the capital-to-output ratio and the relative asset holdings match the targets (see Table 2). If not, update the guesses on $w_s, w_u, R, G, T, \omega, \nu, \phi, \beta_s, \beta_u$ and iterate.

Solving the Inner Loop. Next, we briefly outline our version of the endogenous grid method (EGM) for the incomplete markets model with endogenous labor, i.e. how we solve the ‘inner loop’ above. The policy function iteration version of the standard EGM with fixed labor and income shocks captured by shocks to y_t can be summarized as follows (we find it useful to use time indices, although this method can be used for stationary problems as well):

1. With an initial guess on a_{t+2} and a fixed a_{t+1} , we use the Euler equation to recover a_t

$$\begin{aligned}
u'(c_t) &= \beta R_{t+1} E_t [u'(c_{t+1})] \\
u'(R_t a_t + y_t - a_{t+1}) &= \beta R_{t+1} E_t [u'(R_{t+1} a_{t+1} + y_{t+1} - a_{t+2})] \\
a_t &= \frac{1}{R_t} \left\{ (u'^{-1} (\beta R_{t+1} E_t [u'(R_{t+1} a_{t+1} + y_{t+1} - a_{t+2})])) - y_t + a_{t+1} \right\} \quad (1)
\end{aligned}$$

2. Once we have $a_t(a_{t+1}, y_t)$ we ‘invert’ it to get $a_{t+1}(a_t, y_t)$. We also recover $c_t(a_t, y_t)$. Then we go backward starting in the last period in a finite horizon problem. We iterate until $a_{t+1} = a_{t+2}$ in an ∞ problem.

Our Method with Endogeneous Labor. In our model the complication is that income is endogeneous, because the labor choice is endogeneous, so that labor income of type $i \in \{s, u\}$ agent in period t is: $y_{i,t} = w_{i,t} z_t \cdot l_{i,t}$ with $l_{i,t}$ endogenous. To take care of endogenous labor (and consumption taxes, which were not included in the discussion above), we need to take into account the intratemporal optimality condition (dropping the index i for type for simplicity):

$$\lambda(1 - \tau_l)(w_t z_t l_t)^{-\tau_l} w_t z_t u'(c_t) = -(1 + \tau_c)v'(l_t) \quad (2)$$

Therefore the system we need to solve is:

$$\begin{aligned}
u'(c_t) &= \beta R_{t+1} E_t [u'(c_{t+1})] \\
\lambda(1 - \tau_l)(w_t z_t l_t)^{-\tau_l} w_t z_t u'(c_t) &= -(1 + \tau_c)v'(l_t) \\
(1 + \tau_c)c_t + a_{t+1} &= \lambda(w_t z_t l_t)^{1-\tau_l} + R_t a_t
\end{aligned}$$

The intratemporal optimality condition is non-linear and thus costly to solve numerically. We therefore solve the non-linear intratemporal optimality condition only occasionally, similarly to the method proposed by Barillas and Fernandez-Villaverde (2007). In our model, we assume that government debt is a given fraction of output. Transfers are included in the labor tax function. We also need to take into account that the tax function takes mean income \bar{y} as an argument. Our method can thus be summarized as follows:

1. **Loop in labor policies:** Fix an initial guess on policy $l_t(a_t, z_t)$ and labor disutility parameter ϕ .
2. **Loop in prices and calibrating the parameters:** Fix $w_s, w_u, R, B, \omega, \nu, \beta_s, \beta_u, \lambda, \bar{y}$.
 - (a) We use $y_t = \lambda(w_t z_t l_t)^{1-\tau_l}$ and solve for policies c_t and a_{t+1} as if y_t was exogenous using equation (1). Observe that to use equation (1), we need to express the labor policy

as $l_t(a_{t+1}, z_t)$ rather than $l_t(a_t, z_t)$. We use $l_t(a_t, z_t)$ and $a_t(a_{t+1}, z_t)$ to get $l_t(a_{t+1}, z_t)$. This approach is in fact very similar similar to the original endogeneous grid idea.

- (b) We find the stationary distributions λ_s, λ_u implied by the policy functions.
 - (c) We then compute aggregate capital and labor supplies along with output. Observe that while labor policies are constant in this loop, labor supply will depend on the stationary asset distributions. Given these, we compute prices w_s, w_u, R implied by demand, mean labor income \bar{y} , government debt B and government expenditure G as a given fraction of as a fraction of output.
 - (d) We then check if the prices coincide with the initial guesses. We check if the new \bar{y} and B coincide with the guesses and whether the government budget balances (given that G is a given fraction of output). We check if the aggregate labor supply, the skill premium, the labor share, the capital-to-output ratio and the relative asset holdings match the targets (see Table 2). If not, we update the guesses on $w_s, w_u, R, B, \omega, \nu, \beta_s, \beta_u, \lambda, \bar{y}$ and iterate.
3. Given the policy c_t we find the labor policy \hat{l}_t that satisfies the intratemporal first order condition (2). We set ϕ so that aggregate labor hits the target.
 4. We then use $\alpha l_t + (1 - \alpha)\hat{l}_t$ (with $\alpha \in (0, 1)$) as a new guess for the labor policy and iterate until convergence. While we have no theorem that guarantees convergence, we find that the procedure performs well in our model.

Solution Method for the Reform Exercise. We use the same method as just outlined with one difference. In Step 2., we keep $B, \omega, \nu, \beta_s, \beta_u, \lambda, \bar{y}$ fixed and search for equilibrium w_s, w_u, R , as well as for $\tau_s = \tau_e$ that clear government budget.