On the Consequences of Eliminating Capital Tax Differentials

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Abstract

In the United States different types of capital are effectively taxed at different rates. In particular, effective tax rates on structures have been higher than those on equipments. Eliminating these differentials has been the subject of policy debates. This paper analyzes the consequences of eliminating capital tax differentials using an incomplete markets model with equipment-skill complementarity. The reform improves productive efficiency by eliminating distortions in capital accumulation. It also increases the degree of equality by reducing the skill premium. The reform increases average welfare by approximately 0.11%.

JEL classification: E62, H21.
Keywords: Uniform capital tax reform, equipment capital, structure capital, equipment-skill complementarity, efficiency, equality.

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1 Introduction

In the U.S. tax code, different types of capital have historically been taxed at different effective rates. In particular, effective tax rates on capital structures on average have been higher than those on equipments. Even though the Tax Reform Act of 1986 partially offset these differentials by amending tax depreciation allowances, legislative changes since then have reintroduced a significant difference between tax burdens on different capital assets. Moreover, since 2001, there have been temporary provisions (extended through multiple legislations until now by the U.S. Congress) that have made it possible to deduct an extra fraction of the value of capital in the first year of the capital's tax life (bonus depreciations). These provisions have only applied to assets with tax lives less than 20 years, and, therefore, have favored equipments over structures, which led to a widening of the differential treatment of structures and equipments. Currently, bonus depreciation allowances are scheduled to phase out by the end of 2019, although the recent history has proven that the legislative authority may decide to extend it beyond this date.

The differential tax treatment of different types of capital assets has been the subject of reform proposals since the 1980s. For instance, as a part of a comprehensive corporate tax reform, President Obama's administration proposed to eliminate differential depreciation treatment of various types of capital in the tax code, with the aim of eliminating capital tax differentials.[1] Equating tax rates on different types of capital would affect capital accumulation decisions, and, therefore, returns to capital as well as wages. This way, a policy reform that eliminates capital tax differentials would affect the majority of the U.S. population. Therefore, it is important to understand the aggregate implications of such a reform.

[1] As discussed in detail in President's Framework for Business Tax Reform (2012), this was a broad reform proposal which aimed at eliminating many types of "tax expenditures and loopholes in the U.S. tax system, [which] together with the structure of the corporate tax system, produce significant distortions that can result in a less efficient allocation of capital, reducing the productive capacity of the economy and U.S. living standards." One feature of the U.S. tax code that gives rise to inefficiencies and is explicitly considered to be reformed in the Framework is differential taxation across capital assets. See section *(i) Distorting the form of investment by industry and asset type* on page 4 of the President's Framework for Business Tax Reform (2012) for more details.

Interestingly, to our knowledge, there is no paper that has conducted such an analysis. The current paper does exactly this by analyzing the aggregate and distributional consequences of a reform that eliminates capital tax differentials in a budget-neutral way using a standard macroeconomic model with heterogenous agents.[2]

We build an infinite horizon model with two types of labor: those who have at least college degrees supply skilled labor while the rest supply unskilled labor. Both skilled and unskilled workers are subject to idiosyncratic labor productivity shocks, and markets are incomplete as in Aiyagari (1994). Following Gravelle (2003), capital assets are grouped into two categories: structure capital and equipment capital. 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). Finally, there is a government which taxes capital and labor income to finance government consumption and repay debt.

Gravelle (2003) estimates that the U.S. effective corporate tax rate on equipment capital is 15% and that on structure capital is 29% under the current bonus depreciation rules.[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 28% while the overall effective tax rate on structure capital is 40%. We use a calibrated version of the model outlined above to evaluate the effects of a uniform capital tax reform, which equalizes the tax rates on the two types of capital while keeping other policies intact. We find that the uniform capital tax rate is 33% in the post-reform steady state.

[2] Auerbach (1989) also analyzes the welfare gains associated with eliminating the capital tax differentials that existed prior to the U.S. Tax Reform Act of 1986. However, because he is not interested in the distributional consequences of his reform, Auerbach uses a model without heterogeneity. 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.

[3] Effective tax rates across capital types differ mainly because of differences between tax depreciation allowances and actual economic depreciation rates. For more details, see Gravelle (1994). Auerbach (1983) documents the historical evolution of the U.S. tax differentials prior to the U.S. Tax Reform Act of 1986. In addition, Bilicka and Devereux (2012) document differences in effective tax rates across different types of capital assets for a large set of countries.

The uniform tax reform has two effects on the economy. First, in line with the productive efficiency result of Diamond and Mirrlees (1971), eliminating capital tax differentials improves productive efficiency by reallocating a given capital stock more efficiently between the two types of capital. Intuitively, by taxing structures at a higher rate than equipments, the current tax code distorts firms' capital decisions in favor of using more equipments. The proposed reform eliminates this distortion through capital reallocation from the capital type with lower returns, equipments, to the one with higher returns, structures. This way, capital reallocation brings the economy closer to its production possibilities frontier.[4] Second, under equipment-skill complementarity, a lower level of equipment capital decreases the skill premium, indirectly redistributing from the skilled as a group to the unskilled. This implies a more egalitarian distribution of resources between skilled and unskilled agents. Consequently, the uniform tax reform not only increases efficiency, but also improves equality.

We also measure the welfare consequences of the uniform capital tax reform taking transition into account. Under a Utilitarian social welfare function that weighs all agents equally, the welfare gain of the uniform capital tax reform is equivalent to welfare gain of increasing consumption by 0.11% at every date and state. We also compute the welfare gains for skilled and unskilled agents separately. As expected, the unskilled agents as a group gain from the reform: unskilled average welfare increases by 0.30% in consumption equivalence units. The skilled agents' welfare, on the other hand, decreases by 0.44%. The overall welfare increases since there are many more unskilled than skilled in the economy. A number of robustness checks regarding parameters that govern utility and production functions and openness of the U.S. economy reveals that the main quantitative conclusions are robust.

Our earlier work, Slavík and Yazici (2014), studies optimal capital and labor taxation

[4] Some authors have argued that investment in equipment capital might create positive externalities on economic growth. If that is the case, efficiency could call for taxing equipments at a lower rate than structures. Thus, a reform that increases equipment capital taxes and decreases structure capital taxes could be detrimental to efficiency. However, Gravelle (2001) points out that it is hard to support the existence of such positive externalities on empirical grounds. Specifically, Auerbach, Hassett, and Oliner (1994) finds no empirical evidence of equipment investment having positive externalities in the context of a Solow growth model with multiple types of capital. On a similar note, Wolff (2002) finds no empirical evidence that computer investment is linked to TFP growth. The current paper abstracts from externalities.

in an environment with equipment-skill complementarity, and finds that the optimal tax system features a differential between taxes on equipments and structures. As such, that paper analyzes a comprehensive and optimal tax reform, and is silent on measuring the implications of uniform capital tax policy proposals since these proposals involve reforms that are partial (since they do not include labor income reforms) and not necessarily optimal (since there is no optimization over capital taxes).[5] This is where the main contribution of the current paper lies: this paper provides a quantitative evaluation of the aggregate, distributional and welfare consequences of this policy relevant tax reform.

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, and 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, a firm, and a government.

Endowments and Preferences. There is a continuum of measure one of agents who live for infinitely many periods. In each period, they are endowed with one unit of time. 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

[5] In fact, even the qualitative results regarding capital taxes in Slavík and Yazici (2014) do not have to hold in the context of uniform capital tax reforms, and hence, in the context of the current paper. First, the current paper analyzes a partial reform (as opposed to comprehensive) that keeps labor income taxes fixed. It is well-known from second-best tax theory that when there are restrictions on some fiscal policy instruments (such as labor taxes being fixed), this can overturn results about the qualitative features of optimal taxes (on capital here). Second, the current paper analyzes a relatively local reform of a potentially suboptimal capital tax code (as opposed to an optimal reform). As Sachs, Tsyvinski, and Werquin (2017) shows, the economic insights obtained for optimal taxes may be reversed when one considers local reforms of a suboptimal tax code.

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 to heterogeneity between skill groups, we model heterogeneity within each skill group by assuming that agents face idiosyncratic labor productivity shocks over time. The productivity shock, denoted by z, follows a type-specific Markov chain with states $Z_i = \{z_{i,1}, ..., z_{i,I}\}$ 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 separable utility function

$$E_i \sum_{t=0}^{\infty} \beta_i^t \Big(u(c_{i,t}) - v(l_{i,t}) \Big),$$

where β_i is the time discount factor which is allowed to be different across skill types.[6] For each skill type, the 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. δ_s and δ_e denote the depreciation rates of structure and equipment capital, respectively.

The key feature of 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

[6] Attanasio, 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. The calibration implies that the skilled discount factor is slightly larger than the unskilled discount factor which is in line with the empirical evidence provided by Attanasio, Banks, Meghir, and Weber (1999). We also perform a version of our benchmark quantitative exercise in which we assume that the discount factors are equal for the two types of agents. As we report in Appendix C, the main quantitative results are robust to this modification.

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) for the United States.[7] 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:

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

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 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

[7] Flug and Hercowitz (2000) provide evidence for equipment-skill complementarity for a set of countries.

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. This function allows us to model the progressivity of the U.S. labor income tax code. 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 the quantitative analysis the main focus is 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 $i \in \{u, s\}$:

$$\begin{aligned} V_i(z,a) = \max_{(c_i,l_i,a'_i)\geq 0} \quad & u(c_i) - v(l_i) + \beta_i \sum_{z'} \Pi_i(z'|z) V_i(z', a'_i) \qquad \text{s.t.} \\ (1+\tau_c)c_i + a'_i \quad \leq \quad & w_i z l_i - T(w_i z l_i) + Ra, \end{aligned}$$

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 the profit maximization problem each period.

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

$$\lambda_i(\bar{z}, \bar{a}) = \sum_{z \in Z_i} \Pi_i(\bar{z}|z) \int_{a: a_i'(z,a) \leq \bar{a}} d\lambda_i(z, a), \qquad \forall(\bar{z}, \bar{a}).$$

4. Markets clear:

$$\begin{aligned}
\sum_i \pi_i \int_z \int_a a \cdot d\lambda_i(z, a) &= K_s + K_e + D, \\
\pi_s \int_z \int_a z l_s(z, a) \cdot d\lambda_s(z, a) &= L_s, \\
\pi_u \int_z \int_a z l_u(z, a) \cdot d\lambda_u(z, a) &= L_u, \\
C + G + K_s + K_e &= F(K_s, K_e, L_s, L_u) + (1 - \delta_s)K_s + (1 - \delta_e)K_e,
\end{aligned}$$

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.

In terms of methodology, 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 Imrohoroglu (1998), Ventura (1999), Conesa, Kitao, and Krueger (2009), and Heathcote, Storesletten, and Violante (2017). Our paper is most closely related to Domeij and Heathcote (2004) in the sense that both papers provide positive analyses of capital tax reforms. While Domeij and Heathcote (2004) focuses on the consequences of capital tax cuts, we analyze an environment with multiple types of capital and focus on a policy reform which (by equalizing capital tax rates) changes the mix between equipment and structure capital taxation, but leaves the overall level of capital taxation virtually unaffected. Understanding the consequences of the uniform capital tax reform is relevant given the current policy debates fueled by the introduction of bonus depreciation rules and by the proposal of the Obama administration. Methodologically, we contribute to this literature by analyzing tax reforms in a quantitative model with equipment-skill complementarity.[8] Modeling equipment-skill complementarity creates a novel mechanism through which changes in technology (accumulation of different types of capital in our model) affect the wage distribution. This feature of the model is important as it allows us to take into account the effect of our tax reform on the wage distribution.

3 Calibration

To calibrate model parameters, we assume that the SRCE defined in the previous section - computed under 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.

One period in our model corresponds to one year. We assume that the period utility function takes the form

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

[8] There is a recent paper by Angelopoulos, Asimakopoulos, and Malley (2015), which analyzes optimal labor tax smoothing in a Ramsey model with capital-skill complementarity. Unlike our paper, Angelopoulos, Asimakopoulos, and Malley (2015) works with a representative household model with a single type of capital. He and Liu (2008) analyzes the effects of eliminating capital income taxes in a similar representative household environment with equipment-skill complementarity.

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.

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

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

Krusell, Ohanian, Ríos-Rull, and Violante (2000) estimate α, ρ, η, and we use their estimates, but they do not report their estimates of ω and η. 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 (2017) 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 the PSID data for 2000 – 2006 and the TAXSIM program, Heathcote, Storesletten, and Violante (2017) estimate $\tau_l = 0.18$. We use their estimate and calibrate λ to clear the government budget, following their procedure.[9]

Under the permanent U.S. tax laws, Gravelle (2003) and Gravelle (2011) compute the effective taxes on structure and equipment capital to be 32% and 26%, respectively. However,

[9] It is likely that estimations using different data sets might give different estimates. See, for instance, Bakis, Kaymak, and Poschke (2015) which uses CPS data for the period 1979-2009 and finds $\tau_l = 0.17$. To ensure that our results are not sensitive to this parameter value, we conduct our analysis for $\tau_l = 0.15$ and $\tau_l = 0.21$ in Appendix C.

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	π_s	0.3169	U.S. Census
Productivity			
Productivity persistence of skilled workers	ρ_s	0.9690	KL
Productivity volatility of skilled workers	$var(\varepsilon_s)$	0.0100	KL
Productivity persistence of unskilled workers	ρ_u	0.9280	KL
Productivity volatility of unskilled workers	$var(\varepsilon_u)$	0.0192	KL
Government polices			
Labor tax progressivity	τ_l	0.18	HSV
Overall tax on structure capital income	τ_s	0.397	Gravelle (2003)
Overall tax on equipment capital income	τ_e	0.278	Gravelle (2003)
Consumption tax	τ_c	0.05	MRT
Government consumption	G/Y	0.16	NIPA
Government debt	D/Y	0.60	St. Louis FED

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 (2017), Mendoza, Razin, and Tesar (1994) and Krueger and Ludwig (2015), respectively. NIPA stands for the National Income and Product Accounts.

since 2001, there have been temporary provisions that have made it possible to deduct an extra fraction of the value of capital in the first year of the capital's tax life (bonus depreciations). These provisions have only applied to assets with tax life less than 20 years, and, therefore, have included equipments, but have excluded most structures. As a result, these provisions have created an extra tax advantage for equipments. Gravelle (2003) calculates that with the 50% bonus depreciation, which has been in place for most of the last decade and has been extended through 2017, the effective taxes on equipments and structures are 15% and 29%. We use these values as our benchmark numbers.[10]

We assume that the capital income tax rate at the consumer level is 15%, which approximates the U.S. tax code.[11] This implies an overall tax on structure capital of $\tau_s = 1 - 0.85 \cdot (1 - 0.29) = 39.65\%$ and an overall tax on equipment capital of $\tau_e = 1 - 0.85 \cdot (1 - 0.15) = 27.75\%$. We follow Mendoza, Razin, and Tesar (1994) and assume that the consumption tax $\tau_c = 5.0\%$. Finally, we assume a government debt of 60% of GDP, as in the U.S. between 1990 and the Great Recession.

The fraction of skilled agents in 2010, π_s^{67}, is 0.3169 in the Current Population Survey (CPS) data. This number is calculated using educational attainment for males of 25 years and older who have earnings. To be consistent with Krusell, Ohanian, Ríos-Rull, and Violante (2000), skilled people are defined as those who have at least 16 years of schooling (college degree with 4 years).

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

[10]These bonus depreciations are scheduled to be reduced to 40% in 2018 and 30% in 2019 and then eliminated entirely. However, recent history suggests that they may be extended beyond this date. For the details regarding the historical evolution of these temporary tax provisions, see Guenther (2015).

[11]In the United States, taxation of capital income at the individual level depends on the type of the asset. Certain types of capital (short-term) are taxed according to the individual income tax rate while other types (capital gains and qualified dividends) have been taxed at a flat rate of 15%. In order to avoid solving a portfolio allocation problem for each agent in the economy, we make a simplifying assumption that all capital income is taxed at the flat rate. This makes it possible to combine the tax rates faced by consumers and firms into two numbers, one for structures and one for equipments.

Table 2: Benchmark Calibration Procedure

Parameter	Symbol	Value	Target	Value	Source
Production function parameter	ω	0.5507	Labor share	2/3	NIPA
Production function parameter	ν	0.6023	Skill premium $\frac{w_s}{w_u}$	1.8	HPV
Disutility of labor	ϕ	62.23	Labor supply	1/3	
Skilled discount factor	β_s	0.9489	Capital-output ratio	2	NIPA, FAT
Unskilled discount factor	β_u	0.9441	Rel. skilled wealth	2.68	U.S. Census
Tax function parameter	λ	0.8476	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 skilled wealth refers to the ratio of the average skilled asset holdings to the average unskilled 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.

corresponds to the average wage rate of agents of skill type i. Thus, skill premium in the model economy is given by w_s/w_u. 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 (2015), we set $\rho_s = 0.9690, var(\varepsilon_s) = 0.0100$, $\rho_u = 0.9280$, $var(\varepsilon_u) = 0.0192$. We approximate these processes by finite number Markov chains using the Rouwenhorst method described in Kopecky and Suen (2010).

There are still six parameter values left to be determined: these are the two production function parameters, ω and ν, which govern the income shares of equipment capital, skilled labor and unskilled labor, the labor disutility parameter ϕ, the discount factors β_s and β_u, and the parameter governing the overall level of taxes in the tax function, λ. We calibrate ω and ν so that (i) the labor share equals 2/3 (approximately the average labor share in 1980 – 2010 as reported in the NIPA data) and (ii) the skill premium w_s/w_u equals 1.8 (as reported by Heathcote, Perri, and Violante (2010) for the 2000s). We choose ϕ so that the aggregate labor supply in steady state equals 1/3 (as is commonly assumed in the macro literature). We calibrate β_s and β_u so that: (a) The capital-to-output ratio in the model equals 2. This number is calculated using the NIPA and Fixed Asset Tables as the average over the period 1967 – 2010. Krusell, Ohanian, Ríos-Rull, and Violante (2000) exclude housing from both capital stock and output time series when they estimate the parameters of the production function. Since we use their estimates, we also exclude housing from both capital stock and output when we calculate the capital-to-output ratio.[12] (b) The asset holdings of an average skilled agent are 2.68 times those of an average unskilled agent (as in the 2010 U.S. Census). Finally, following Heathcote, Storesletten, and Violante (2017), we choose λ to clear the government budget constraint in equilibrium. Table 2 summarizes our calibration procedure.

4 Consequences of the Reform

This section uses 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, keeping other government policies, including the labor tax code, intact.[13] The government also needs to finance the pre-reform level of expenditure and debt after the reform.

We first analyze the long-run effects of the budget neutral uniform capital tax reform on prices and macroeconomic quantities. Second, we show that the reform improves both productive efficiency and equality. Third, we discuss the evolution of main variables of interest along the transition path between the pre-reform and post-reform steady states. Fourth, we compute the welfare implications of the reform. Finally, we conduct sensitivity analysis.

[12]Output is defined using Table 1.5.5 in NIPA as GDP (line 1) net of Housing and utilities (line 16) and Residential investment (line 41). Capital stock is calculated using the Fixed Asset Tables (FAT), Table 1.1 as the sum of the stocks of private and government structure and equipment capital (line 5 + line 6 + line 11 + line 12). The resulting annual capital-output ratio varies between 1.8 and 2.4 during the period of 1967-2010. To abstract from short-term fluctuations, the capital-output ratio value of 2, which we use as a calibration target, is computed by taking the average of annual capital-output ratios over this period.

[13]Observe, however, that even though the labor tax code remains intact, labor income tax revenue might still change since the reform affects prices and people's labor supply in equilibrium.

Table 3: Steady-State Taxes and Prices Before and After the Reform

Variable	Status Quo	Reform	Change
τ_s	39.65%	33.22%	-16.23%
τ_e	27.75%	33.22%	19.70%
avg. τ	32.89%	33.22%	0.99%
$r_s - \delta_s$	7.95%	7.19%	-9.53%
$r_e - \delta_e$	6.64%	7.19%	8.31%
avg. $r - \delta$	7.20%	7.19%	-0.19%
w_s/w_u	1.8	1.7818	-1.01%
w_s	0.4967	0.4840	-0.54%
w_u	0.2759	0.2773	0.48%

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.

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 at the new steady state. 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 33.2%. This means that the tax rate on equipment capital increases by about 5.5 percentage points whereas the tax rate on structure capital decreases by approximately the same amount. Importantly, as reported in the third row of the table, the average tax on capital stays almost the same. This implies that the reform changes the mix between equipment and structure capital taxes, but leaves overall capital taxation almost unaffected.

The three rows in the middle of Table 3 report the steady-state levels of 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.[14] This is because the reform gives rise to an

[14]The 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

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. The average return to capital is almost unchanged even though the aggregate capital stock increases substantially, and the level of both types of labor inputs decline (see Table 4 below). 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 significantly. 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 between the steady states. 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, the impact on skilled wages is larger. Quantitatively, the cumulative effect is negative for skilled wages and positive for unskilled wages.

Allocations. Table 4 displays the effects of the tax reform on steady-state aggregate allocations. The left panel shows how factors of production and total output are affected.

equal as well.

Table 4: Changes in Steady-State Allocations due to the Reform

Variable	Change	Variable	Change
K_s	5.98%	C_s	-0.12%
K_e	-2.33%	C_u	0.32%
K	1.26%	C	0.14%
ℓ_s	-0.10%	$(R-1)\cdot A_s$	1.09%
ℓ_u	-0.24%	$(R-1)\cdot A_u$	1.07%
ℓ	-0.20%		
Y	0.05%		

This table reports the effects of the uniform capital tax reform on allocations. "Change" refers to the percentage 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, ℓ denotes the average overall supply of labor, and 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.

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, the reform increases the steady state level of total capital stock by 1.26%. The increase in the total capital stock is due to the fact that the reform increases the average productivity of a given amount of capital by eliminating the distortion in capital allocation.

Skilled labor supply decreases by 0.10% and unskilled labor supply decreases by 0.24%. 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.[15] 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

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

panel of 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.

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 decline 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

This section discusses 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 between skilled and unskilled agents between the two steady states.

Productive Efficiency. 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.[16] Indeed, before the reform, the pre-tax return to structure capital is higher than the pre-tax return to equipment 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

[16]To the contrary, 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.

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 average returns to capital in the pre-reform and post-reform steady states.

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*.[17] We call the change in the average return 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 2.15% due to a more efficient allocation of capital. We find that the residual change is −2.34%, implying a cumulative effect of −0.19%.

Equality. Next, we discuss the consequences of the reform for the steady-state level of

[17]The 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 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.

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

Variable	Reallocation gains	Residual change	Total change
average $r-\delta$	2.15%	-2.34%	-0.19%

This table decomposes the change in the average net return on capital, i.e. "average $r-\delta$", 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.

equality between the skilled and the unskilled 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. 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.

Eliminating capital tax differentials improves productive 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 also increases equality between skilled and unskilled workers. As a result, this reform does not suffer from the efficiency vs. equality tradeoff, which is usually present in tax reforms. Section 4.4 evaluates how the efficiency and equality improvements of the reform manifest themselves in terms of welfare.

4.3 Transition

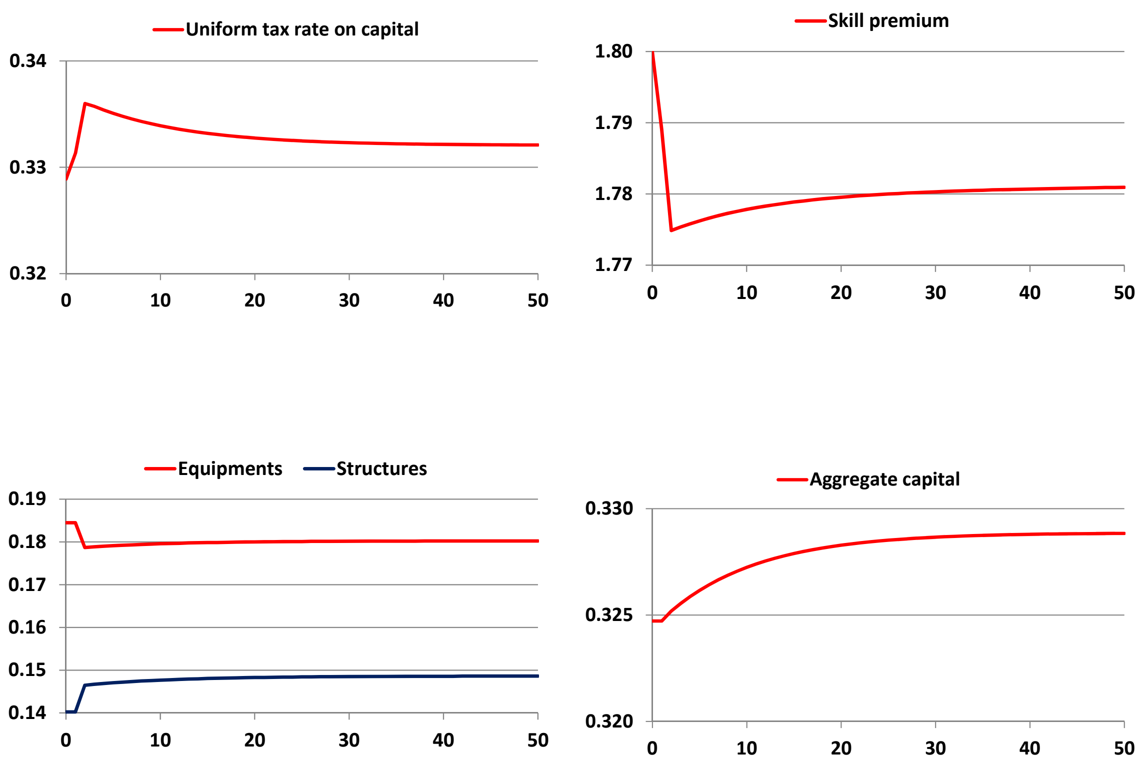
This section discusses the evolution of the main variables of interest along the transition path from the pre-reform to the post-reform steady state. Initially, the economy is at the pre-reform steady state. In the first period of transition, before any choices are made, the government announces a path of capital tax rates which satisfies $\tau_{e,t} = \tau_{s,t}$ in every period t along the transition path and leads to the new steady state at which $\tau_e = \tau_s = 33.22\%$. The capital tax sequence satisfies the condition that the government budget balances in every period along the transition path under the pre-reform government policies regarding government expenditure, debt, labor tax schedule and consumption. The evolution of the uniform capital tax is shown in Figure 1. In the figure, period 0 corresponds to the initial steady state.

The uniform capital tax reform decreases the structure capital tax and increases the equipment capital tax immediately in the first period of transition. Therefore, agents adjust their investment decisions in the first period so that the returns to equipments and structures are equalized from the second period of transition onwards. This happens because capital depreciation rates are sufficiently high.[18] This means that all reallocation gains are realized by the second period of transition. From the second period of transition onwards, the behavior of the model resembles the transition to a new steady state in a standard growth model. The new steady state has a higher capital level, since average capital taxes decrease, as discussed above. The third and fourth panels of Figure 1 depict the dynamics of structures, equipments, and aggregate capital stock.

The second panel of Figure 1 shows that the skill premium drops in the first and second periods of transition. The drop in the first period is due to the fact that the reform implies a positive income effect for the unskilled and a negative income effect for the skilled. As a

[18]In fact, agents would prefer to respond immediately after uniform capital tax reform is announced in the first period by reverting equipment capital to structure capital until the rates of return on them are equalized. We assume, however, that capital is irreversible, which implies that such an adjustment is not possible within the first period.

Figure 1: Evolution of Main Variables along Transition



This figure plots the evolution of main variables of interest along the transition path. Period 0 corresponds to the pre-reform steady state. The reform is announced at the beginning of period 1. The tax rate reported in the first panel in period 0 is the weighted average of the structure and equipment capital tax rates.

response, the unskilled work less and the skilled work more, which drives the skill premium down.[19] In the second period of transition, equipment capital drops substantially, implying a further decline in the skill premium. On the rest of the transition path, wages increase steadily as both structure and equipment capital levels rise. This pushes the skill premium back up to some extent. As one can see, most of the equality gains are thus also realized shortly after the reform is started.

4.4 Welfare Gains

This section analyzes the aggregate welfare gains of the uniform capital tax reform under the assumption of a Utilitarian social welfare function. 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. We compute welfare gains across steady states as well as welfare gains that take transition into account.

Steady-State Welfare Gains. The welfare gains of the uniform capital tax reform between the two steady states are 0.33% in consumption equivalent units. The average skilled welfare declines by 0.11%, whereas the average unskilled welfare increases by 0.48%. These findings can be interpreted 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 redistribution losses accruing to the skilled agents dominate their efficiency gains, resulting in a welfare loss. For the unskilled agents, the redistributive gains plus the efficiency gains sum up to a significant welfare gain of 0.48%.

Welfare Gains with Transition. The welfare gains of the uniform capital tax reform

[19] We do not plot the time series for skilled and unskilled labor and consumption, as the changes along the transition are relatively modest.

are 0.11% in consumption equivalent units when we take into account the transition to the new steady state. The average skilled welfare declines by 0.44% whereas the average unskilled welfare increases by 0.30%.[20] Transition analysis enables us to see who gains and who loses from the reform. We find that while the reform benefits all unskilled agents, only 14% of the skilled agents gain from it. A closer look reveals that it is the wealthiest skilled agents who gain. This is because they are the ones that benefit the most from the rise of the return to capital.

Recall from Table 4 that aggregate capital increases from one steady state to another. The steady-state welfare gains are expected to be higher as they do not take into account the cost of raising the level of capital stock across steady states. In an environment similar to ours, Domeij and Heathcote (2004) show that a government that ignores transition welfare finds it welfare improving to eliminate capital taxes altogether while if transition is taken into account such a reform decreases welfare substantially. The two welfare measures do not provide such different gains in the context of the uniform capital tax reform analyzed in the current paper. This is because average capital tax is mostly unaffected by the reform, and while there is substantial reallocation between the two types of capital, there is only a small increase in the aggregate capital stock from the initial to the new steady state.

4.5 Sensitivity Analysis

This section analyzes the sensitivity of the main quantitative results to the parameters that control preferences, technology, progressivity of the labor tax code, and labor productivity risk. Specifically, we perform the following exercises. 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.

[20] Even though the decline in skilled welfare is larger than the increase in unskilled welfare, the overall welfare gains are positive. This is because (i) there are more unskilled agents and (ii) the utility function is concave in consumption.

Table 6: Sensitivity to Preference Parameters

	Benchmark			Benchmark		
σ	1	2	4	2	2	2
γ	1	1	1	0.5	1	2
uniform tax	33.01%	33.22%	33.32%	33.28%	33.22%	33.12%
reallocation gains	2.26%	2.15%	2.03%	2.11%	2.15%	2.19%
w_s/w_u	-0.69%	-1.01%	-1.47%	-1.10%	-1.01%	-0.91%
welfare gains	0.38%	0.33%	0.33%	0.30%	0.33%	0.36%
skilled gains	0.13%	-0.11%	-0.39%	-0.17%	-0.11%	-0.04%
unskilled gains	0.50%	0.48%	0.53%	0.47%	0.48%	0.50%

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). We always change a particular parameter and leave the rest of the parameters that are not calibrated unaffected. 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 change in net output 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.

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. In what follows, we do not report these results, but instead discuss the efficiency and equality consequences of the reform. We focus on the steady state comparisons rather than calculating the transition paths for the sensitivity exercises because robustness of results to various parameterizations are readily seen from steady state comparisons.

Preference Parameters. Table 6 summarizes our sensitivity results with respect to changes in preference parameters. First, the uniform capital tax rate is very close to the benchmark value in all the exercises. Second, the productive efficiency gains from capital reallocation are close to the gains in the benchmark case as shown in the row called "reallocation gains." Third, while the effect of the reform on the skill premium is quite robust to alternative specifications of γ, it depends on σ in a quantitatively meaningful way. In particular, for higher values of σ, the reform decreases skill premium significantly more. Intuitively, the reform redistributes from skilled agents to unskilled agents, which via the income effect, motivates skilled agents to increase their labor supply. The strength of the income effect increases with σ, which is why the reform results in higher skilled labor supply and lower skilled wages with higher with σ. Aggregate steady-state welfare gains are around the benchmark level of 0.33%. Typically, skilled agents lose and unskilled agents gain from the reform. An interesting case is the one with $\sigma = \gamma = 1$, in which both the average skilled and unskilled agents gain from the reform.

Elasticities of Substitution. Table 7 reports sensitivity with respect to production function parameters. 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.[21] Specifically, we set $\eta = 0.79$ instead of the benchmark value of $\eta = 0.401$.[22] For this elasticity value, we observe that skilled welfare decreases more and unskilled welfare increases more relative to the benchmark parameterization. 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 (1.51% vs. 1.01%), as reported in the third row of Table 7. This means that 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. As for the productive efficiency gains, they are lower than those in the benchmark reform. This is also intuitive. A higher value of η makes equipment capital more substitutable with unskilled labor. When an input is more substitutable by other inputs to production, the distortions in its accumulation are less costly in terms of productive efficiency. Therefore, a uniform capital tax reform that eliminates such distortions implies lower efficiency gains.

The column denoted by "$\rho = -1$" reports the consequences of the reform in an economy with an ad hoc chosen lower elasticity of substitution between equipment capital and skilled

[21]Given the aggregate production function specified in equation (1), the elasticity of substitution between unskilled labor and equipment capital is $1/(1-\eta)$, while the elasticity of substitution between skilled labor and equipment capital is $1/(1-\rho)$.

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

Table 7: Sensitivity to Technology Parameters

	Benchmark ($\eta = 0.401, \rho = -0.495$)	$\eta = 0.79$	$\rho = -1$
uniform tax	33.22%	33.27%	33.17%
reallocation gains	2.15%	1.81%	3.09%
w_s/w_u	-1.01%	-1.53%	-1.21%
welfare gains	0.33%	0.37%	0.40%
skilled gains	-0.11%	-0.38%	-0.12%
unskilled gains	0.48%	0.63%	0.58%

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 that are not calibrated 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 "$\rho = -1$" refers to an exercise in which we decrease the elasticity of substitution between equipment capital and skilled labor by decreasing ρ from its benchmark value of -0.495 to -1. 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 the change in net output 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.

labor (in the benchmark $\rho = -0.495$). The productive efficiency gains of eliminating the distortions in capital accumulation are significantly larger relative to the benchmark case because now it is harder to substitute equipment capital (whose accumulation is distorted) by one of the other inputs, namely, skilled labor. Also, higher productive efficiency gains imply a higher average welfare gain: 0.40% relative to 0.33% in the benchmark case. Regarding equality, we observe that skill premium declines more compared to the benchmark case. The intuition is similar to the one in the previous sensitivity exercise: lower ρ means a higher degree of complementarity between equipment capital and skilled labor, which is similar to a lower degree of complementarity between equipments and unskilled labor.

Additional Sensitivity. In Appendix C, we report sensitivity with respect to the discount factor, the openness of the economy, labor income tax progressivity and labor productivity risk. We find that our main conclusions are robust to these alternative specifications.

5 Conclusion

The U.S. tax code taxes different types of capital at different rates effectively. In particular, capital structures have traditionally been favored by the tax code relative to capital equipments. Even though there have been policy debates and reform proposals to eliminate capital tax differentials, aggregate and distributional impacts of such a policy reform have not been thoroughly analyzed. This paper conducts exactly this analysis.

We find that the reform leads to improvements in productive efficiency as it eliminates production distortions created by differential capital taxation. Moreover, by decreasing the skill premium, the reform increases the degree of equality between skilled and unskilled workers. This implies that the reform does not suffer from the usual efficiency vs. equality trade-off. The reform implies that the welfare of the skilled workers as a group declines while the welfare of the unskilled increases. The overall welfare gain of the reform is 0.11% in consumption equivalence units. Moreover, the transition analysis shows that virtually all the equality and efficiency gains are realized in a short period of time in the aftermath of the reform.

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Appendix

A Definition of Competitive Equilibrium

First, denote the partial history of productivity shocks up to period t by $z^t \equiv (z_0, ..., z_t)$. 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 $((c_{i,t}(z^t),\ l_{i,t}(z^t),\ a_{i,t+1}(z^t))_{,z^t})_{t=0}^{\infty}$ solves each consumer i's problem, i.e.,

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

$$\forall t \geq 0, z^t,$$

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

$$\forall t \geq 0, z^t, \qquad c_{i,t}(z^t) \geq 0, a_{i,t+1}(z^t) \geq 0, l_{i,t}(z^t) \geq 0,$$

$$\text{given } a_0^i > 0,$$

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:

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

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

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

where z^{-1} 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 $t \geq 0$,

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

B Numerical Method

This section outlines the 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 a 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, ω, ν, ϕ, β_s, β_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, but 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

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

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):

$$\lambda(1 - \tau_l)(w_t z_t l_t)^{-\tau_l} w_t z_t u'(c_t) = -(1 + \tau_c) v'(l_t) \tag{3}$$

Therefore the system we need to solve is:

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

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, ω, ν, β_s, β_u, λ, $\bar{y}$.

    (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 (2). Observe that to use equation (2), 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 (3). 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.

C Additional Sensitivity

This section reports the results of additional sensitivity exercises. As in Section 4.5, we change the parameter (model feature) of interest and keep all other parameters that we do not calibrate fixed. We recalibrate the model under this new specification. Then, we conduct the uniform capital tax reform, and evaluate the changes in macroeconomic aggregates and welfare in the new steady state.

Uniform Discount Factors. First, we calibrate a version of our model in which all agents have the same discount factor. This calibration drops the relative wealth of the skilled and unskilled agents as one of the calibration targets. The results of the uniform tax reform are reported in Table 8 in the column entitled "Uniform β". We find that our main quantitative results do not depend on the assumption of heterogenous discount factors.[23]

Open Economy. The United States is not literally a closed economy, but following the literature, we consider that scenario a useful benchmark. This section considers the polar opposite case and analyzes the consequences of the uniform capital tax reform assuming that the United States is a small open economy that faces a fixed world interest rate. This exercise illustrates to what extent the implications of the uniform capital tax reform depend on the degree of openness. In particular, we calibrate the after-tax interest rate so that in the steady state, the net foreign asset position is -20% of GDP, which is approximately the

[23] With a uniform discount factor, however, the calibrated model does not match the observed average wealth difference between skilled and unskilled agents.

Table 8: Sensitivity to Patience, and Openness

	Benchmark	Uniform β	Open Economy
uniform tax	33.22%	33.18%	32.91%
reallocation gains	2.15%	2.21%	2.15%
w_s/w_u	-1.01%	-1.08%	-1.02%
welfare gains	0.33%	0.38%	0.27%
skilled gains	-0.11%	-0.25%	-0.33%
unskilled gains	0.48%	0.60%	0.48%

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 that are not calibrated unaffected. The column "Uniform β" refers to an exercise in which all agents are assumed to have the same discount factor. The column "Open Economy" refers to an exercise in which the after-tax interest is kept fixed. 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 the change in net output 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.

Table 9: Sensitivity to Progressivity and Risk

	Benchmark	$\tau_l = 0.15$	$\tau_l = 0.21$	Higher risk	Lower risk
uniform tax	33.22%	33.20%	33.23%	33.22%	33.21%
reallocation gains	2.15%	2.15%	2.15%	2.15%	2.15%
w_s/w_u	-1.01%	-1.01%	-1.01%	-1.02%	-1.00%
welfare gains	0.33%	0.34%	0.32%	0.32%	0.33%
skilled gains	-0.11%	-0.12%	-0.10%	-0.12%	-0.10%
unskilled gains	0.48%	0.50%	0.47%	0.48%	0.48%

This table reports the results of the reform for different levels of labor tax progressivity and labor productivity risk. The column "Benchmark" refers to the benchmark quantitative analysis. 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 columns "Higher risk" and "Lower risk" refer to exercises in which we increase and decrease the variance of the idiosyncratic shocks by 25%, respectively. In both exercises, we keep the skill persistence parameters unchanged. 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 change in net output 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.

number for the U.S. economy as reported by the Bureau of Economic Analysis. The results of the uniform capital tax reform for this environment are reported in the last column of Table 8. We find that the reallocation gains and the skill premium changes are very similar to the closed economy benchmark. The welfare are smaller relative to the benchmark, because the welfare losses of the skilled agents are larger.

Labor Tax Progressivity. We take the estimate of the progressivity of the labor income tax code τ_l from Heathcote, Storesletten, and Violante (2017). It is likely that estimations using different data sets would give different estimates. To ensure that our results are not sensitive to this parameter value, we conduct our analysis for $\tau_l = 0.15$ and $\tau_l = 0.21$ as well. The results are reported in the second and third columns of Table 9. We find that our results are robust to small changes in the progressivity parameter.

Productivity Risk. In our benchmark exercise, we parameterize the labor productivity processes for skilled and unskilled agents following Krueger and Ludwig (2015). This section analyzes whether the consequences of the uniform capital tax reform are sensitive to the amount of idiosyncratic labor productivity risk present in the economy. We do so by conducting the uniform capital tax reform first in an economy in which the variance of the idiosyncratic shock is 25% higher for both skilled and unskilled agents. The fourth column of Table 9, called "Higher risk,' summarizes the effects of the reform under this parameterization. We also conduct our reform for an economy in which the variance of idiosyncratic shock is 25% lower for both groups. The results of this exercise are reported in the column called "Lower risk" in Table 9. We find that the consequences of the reform are quantitatively not different from the benchmark case for both higher and lower risk economies. Thus, we conclude that the main results are not sensitive to changes in labor productivity risk around the benchmark level of risk.