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ABSTRACT

The standard analysis of optimal fiscal policy in the neoclassical growth model, Chamley (1986) and Judd (1985), aggregates different types of assets into a unique capital good and all sorts of capital taxes into a unique capital tax. There, the optimal capital tax rate is extremely high in the short run and zero in the long run, and gives rise to a very severe problem of time inconsistency. We show that this result does not hold in a more disaggregated framework. As in McGrattan and Prescott (2005, 2007), we consider an economy with corporate and dividend taxes, where firms invest in both tangible and intangible assets. We consider two forms of intangible investment: expensed and sweat (managerial effort). In such a scenario all capital income taxes are levied on elastic tax bases and firms can respond to changes in the timing of taxation. Our main result is that constant capital taxes are optimal in our basic model (with only expensed investment) or generate 98 percent of the potential welfare gains of a Ramsey tax reform in a more general setup (with expensed and sweat investment). These results question the quantitative severity of the time inconsistency problem of capital taxation.

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1. Introduction

The study of optimal capital taxation stemming from the Ramsey tradition, e.g. Chamley (1986) and Judd (1985), aggregates different types of assets into a unique capital good and all sorts of capital taxes into a unique capital tax. The main lesson from this literature is that the optimal capital income tax is very high in the short-run and zero in the long-run and, as shown by Kydland and Prescott (1977), time-inconsistent. This is a very robust result and, as such, it has been generalized to a great variety of settings.[1]

We re-examine the properties of Ramsey capital taxation in a more disaggregated framework, similar to that proposed by McGrattan and Prescott (2005). They used such a framework in order to understand the implications of changes in corporate income and dividend taxation on the valuation of the stock market, while we use such a framework to perform a normative analysis. The framework is characterized by a corporate sector with perfectly competitive firms that pay corporate income taxes and distribute income to the shareholders, which is then subject to a dividend tax. These firms invest in both tangible and intangible assets. Tangible capital includes equipment, structures, land, and inventories, whereas intangible capital is made of brand names, copyrights, patents, customer lists, reputation and organizational capital. The distinctive feature of intangible capital is that it is unmeasured, and therefore, expensed. In this basic model, we establish and give the intuition of our main result: it is optimal to have zero corporate income taxes and constant dividend taxes.

Next, we extend our analysis to introduce another form of intangible investment, namely managerial effort (also called sweat investment in McGrattan and Prescott (2007)). We assume that this effort is necessary to transform resources into productive capital. Then, in our economy with both expensed and sweat investments, we perform a quantitative evaluation of the Ramsey plan. We show that, even though optimal taxes are not constant in general, 98 percent of the welfare gains can be attained with constant taxes. Our quantitative exercise shows that eliminating corporate income taxes, increasing dividend taxes to 28 percent and leaving labor income taxes unchanged would result in welfare gains equivalent to 2 percent higher consumption. Finally, we provide a sensitivity analysis with respect to the specification of the investment function

[1]See Atkeson, Chari and Kehoe (1999) for different extensions of this result. However the optimality of zero capital income taxes in the long run is not robust to the introduction of life-cycle features in the analysis, see Erosa and Gervais (2002) or Conesa, Kitao and Krueger (2009).

(i.e. how complementary are resources and managerial effort in building up new capital), and show our results are robust.

Our analysis has important implications for the issue of time inconsistency of capital income taxation.[2] In the standard framework the severity of the time inconsistency problem is very large, as has been emphasized by numerous contributions. For instance, Chari, Christiano and Kehoe (1994) find that Ramsey capital tax rates are as high as 796% in the initial period and that these initially high capital taxes result in about 80% of the welfare gains from switching to the Ramsey plan. As a result, the incentives to renege on the promised zero capital taxes are very high.

In contrast, our main result is that constant capital income taxes are optimal in the simplified version of the model, or generate 98 percent of the potential welfare gains in a more general setup. The intuition is very simple: in a more disaggregated framework the time asymmetry in the elasticity of tax bases is largely reduced (and under some conditions completely eliminated), and a benevolent fiscal authority chooses not to distort the timing of dividend payments by choosing constant dividend taxes and not to distort investment decisions by choosing zero corporate income taxes always, including period zero.

The standard result of initially very high and then zero capital taxes can never be optimal in the disaggregated framework. If dividend taxes are temporarily high, then firms choose not to distribute dividends. If corporate income taxes are high today then firms invest in intangibles and run down corporate income. The disaggregated framework allows firms to contemporaneously react to changes in capital taxation and, as a consequence, the bang-bang property of optimal capital taxation disappears.

A similar result has been recently shown in Abel (2006). He shows that immediate expensing of capital expenditures renders constant capital income taxation non-distortionary. Note that, under his assumption of complete deductibility, his capital income tax is equivalent to our dividend tax and, since he does not consider managerial effort (as in our simplified version), a constant dividend tax is non-distortionary.

Our paper highlights well known results in the public finance literature. In particular, the "new view" of dividend taxation, see Auerbach (2002), already points out that constant dividend taxes are lump-sum. In contrast, the "traditional view" finds dividend taxation to be distortionary and increasing the cost of capital. The "new view"

[2] The severity of the time inconsistency problem of taxation has generated a vast literature. See, among others, Lucas and Stokey (1983), Barro and Gordon (1983), Chari and Kehoe (1990), Phelan and Stacchetti (2001), Klein, Krusell and Ríos-Rull (2008), Domínguez (2007).

(Auerbach 1979a, Bradford 1981, King 1977) assumes that the marginal source of funds for new investment is retained earnings, while the "traditional view" (Harberger 1962, Feldstein 1970, Poterba and Summers 1985) assumes that it is share issuance. Our analysis allows for both, new investment can be financed through either retained earnings or share issuance. We find the following. If the relevant source of funds is the first, a constant dividend tax is lump-sum. If it is the latter, then a constant consumption tax (while there is issuance) followed by a constant dividend tax (once there are dividend payments) can replicate a lump-sum tax.

There is substantial empirical evidence that corporations do react very strongly to changes in the fiscal treatment of corporate income, fiscal deductions or dividends. This empirical evidence is consistent with the mechanism behind our results. Gravelle (1982) and Auerbach (1987) estimate the distortions in the composition of investment caused by corporate taxes. Feldstein, Slemrod and Yitzhaki (1980) find a very high elasticity of capital gains realizations with respect to tax rates. Poterba (2004) estimates the elasticity of corporate payout policy with respect to the differential between dividend taxes and capital gains taxes. Chetty and Saez (2005) document an unusual increase in dividend payments after the large tax cut on dividend income enacted in the U.S. in 2003. Many papers, see Gordon and Hines (2002) and Hines (2001) among others, suggest that corporations do respond to tax incentives when deciding the form of organization and where to locate, invest and report profits.

There is some theoretical work on heterogeneous capital and the effect on taxation. The general result stemming from Diamond and Mirrlees (1971) is that production efficiency should prevail and all types of capital should be taxed equally. However, there are some conditions as those pointed out by Auerbach (1979b) and Feldstein (1990) under which it might be optimal to tax different types of capital differently. These conditions include situations in which the tax on labor is not set optimally, the government cannot move the economy to the golden rule level of capital or, as in Feldstein (1990), when there is a factor that cannot be taxed and the optimal tax on each type of capital depends on the degree of complementarity or substitutability with the untaxed factor. In our simple framework it is optimal to tax both types of capital equally. However, this is not the driving force behind our results, what is important is that the presence of intangible investment makes capital income responsive to current changes in taxation.

Few papers contemplate intangible investment and its effect on taxation. To our knowledge, one of the first is that of Summers (1987), which criticizes the "level the playing field" doctrine because, among other things, it ignores the inherent non-neutralities of the tax system, such as the one between tangible and intangible investments. In the same spirit Fullerton and Lyon (1988) estimate the efficiency cost of taxation in a model that incorporates intangible capital. More recently, Grubert and Slemrod (1998) and Hanlon, Mills and Slemrod (2007) find that firms with more intangible assets have greater opportunities for tax planning.

To summarize, the mechanism behind our results is not new in the public finance literature, however our results are new to the Ramsey taxation literature and that is where our contribution lies. This paper shows that the standard result of initially extremely high and then zero capital taxes is not be robust to the analysis of a more disaggregated framework. Our central message is that constant capital taxes are good.

The rest of the paper is organized as follows. Section 2 describes the basic model, Section 3 characterizes the optimal corporate and dividend taxation. Section 4 extends the analysis by introducing managerial effort and Section 5 concludes. The proofs of the propositions are included in the Appendix.

2. The Basic Model

We follow the same formulation of McGrattan and Prescott (2005). The economy is composed of a household sector, a corporate sector and the government.

The Household Sector

We represent households' preferences by a utility function defined as the discounted infinite stream of the instantaneous flow of utility derived from consumption, c_t, and leisure, ℓ_t, so that preferences are defined as

$$\sum_{t=0}^{\infty} \beta^t u(c_t, \ell_t), \tag{1}$$

where $\beta \in (0,1)$, and $u(.,.)$ is strictly increasing, strictly concave and continuously differentiable in both arguments.

Households are worker-owners of the firms in the corporate sector. They own and trade shares in the ownership of corporations in a competitive market, and they receive every period a dividend d_t per share. They rent labor services to corporations in exchange of a competitive wage w_t. We normalize time available for the household to 1, so that time devoted to work is $n_t = 1 - \ell_t$.

The households' sources of income are labor income, dividends from corporations, together with the interest payments on government bonds. Total income is used to buy consumption goods, new shares of corporations and new government bonds. Hence the consumers' budget constraint of period *t* is given by

$$(1+\tau_t^{con})c_t + v_t(s_{t+1} - s_t) + (b_{t+1} - b_t) \leq (1-\tau_t^n)w_t n_t + (1-\tau_t^d)d_t s_t + \tilde{r}_t^b b_t, \qquad (2)$$

where v_t is the non-negative time *t* price of one share, s_t is the number of shares owned by the household at time t, τ_t^{con} is the tax rate on consumption, τ_t^n is the tax rate on labor income, τ_t^d is the tax rate on dividend payments, b_t denotes the household's holdings of government bonds and $\tilde{r}_t^b$ is the after-tax interest rate on bonds. We assume that $b_t \geq -B,$ where *B* is a positive constant big enough not to bind in equilibrium.

The following first order conditions are necessary for a solution to the household's maximization problem:

$$\begin{aligned}
&[c_t] \qquad \beta^t u_{c,t} - (1+\tau_t^{con})p_t = 0,\\
&[n_t] \qquad -\beta^t u_{\ell,t} + p_t(1-\tau_t^n)w_t = 0,\\
&[s_{t+1}] \qquad -p_t v_t + p_{t+1}\left[(1-\tau_{t+1}^d)d_{t+1} + v_{t+1}\right] = 0,\\
&[b_{t+1}] \qquad -p_t + p_{t+1}\left[1+\tilde{r}_{t+1}^b\right] = 0,
\end{aligned}$$

where p_t denotes the Lagrange multiplier on the budget constraint (2).

The Corporate Sector

The corporate sector is composed of a continuum (measure 1) of identical firms operating in a competitive environment. Each one of them produces output with a constant returns to scale production technology $y_t = f(k_{m,t}, k_{u,t}, n_t)$. The inputs in the production function are hours worked, n_t, physical (or tangible) assets, $k_{m,t}$, which are

measured, and intangible assets, $k_{u,t}$, which are unmeasured. These assets depreciate respectively at the rates δ_m and δ_u, both positive and smaller than one.

The corporate firm distributes income to the shareholders via dividends, which must be non-negative $d_t \geq 0$. We allow for equity issues but ignore share repurchases, i.e., we have $s_{t+1} \geq s_t$.[3] Corporate income Π_t is defined as the value added net of depreciation of tangible assets, labor income and investment in intangible assets, $x_{u,t}$, that is,

$$\Pi_t = f\left(k_{m,t}, k_{u,t}, n_t\right) - x_{u,t} - w_t n_t - \delta_m k_{m,t}.$$

If positive, corporate income is taxed at a rate τ_t^c. The after-tax corporate income is then used for investment in tangible capital, $x_{m,t}$. The difference, if positive, is distributed back as dividends and, if negative, is financed through new equity. Therefore, dividends and new equity issues are given by:

$$\begin{aligned} d_t s_t - v_t\left(s_{t+1} - s_t\right) &= \left[\left(1-\tau_t^c\right)\Pi_t - k_{m,t+1} + k_{m,t}\right] \\ &= \left[\left(1-\tau_t^c\right)\left[f\left(k_{m,t}, k_{u,t}, n_t\right) - x_{u,t} - w_t n_t\right] + \tau_t^c \delta_m k_{m,t} - x_{m,t}\right], \end{aligned} \tag{3}$$

where

$$\begin{aligned} x_{m,t} &= k_{m,t+1} - \left(1-\delta_m\right)k_{m,t}, \\ x_{u,t} &= k_{u,t+1} - \left(1-\delta_u\right)k_{u,t}. \end{aligned}$$

Notice how the presence of intangible assets affects corporations' decisions. Now corporations can react to changes in current taxes. If current corporate taxes are high, firms can lower current corporate income via investment in intangible assets, generating higher future corporate income. We think of a corporation devoting productive resources to activities such as advertisement, building a distribution network, developing new ideas, etc., which are expensed.[4] As a consequence of such activities measured value added, $f(k_{m,t}, k_{u,t}, n_t) - x_{u,t}$, will be smaller.

The corporations' objective function is to maximize the initial value of the firm. In our model this can be computed using the first order condition $[s_{t+1}]$ from the

[3] In our setup share repurchases could be incorporated as in Judd (1986). We ignore this possibility for expositional purposes as it does not affect the results.

[4] National Income and Product Accounts (NIPA) consider all intangible investment, except software, as expenditures not as an investment.

household's problem and substituting forward. The initial value of the firm is:

$$p_{-1}v_{-1}s_0 = \sum_{r=0}^{\infty} p_r\left[(1-\tau_r^d)d_r s_r - v_r\left(s_{r+1}-s_r\right)\right].$$

The corporate maximization problem is:

$$\max_{\{d_t,n_t,s_{t+1},k_{m,t+1},k_{u,t+1}\}_{t=0}^{\infty}} \quad \sum_{t=0}^{\infty} p_t\left[(1-\tau_t^d)d_t s_t - v_t\left(s_{t+1}-s_t\right)\right]$$

$$s.t. \quad d_t s_t - v_t\left(s_{t+1}-s_t\right) = \left[\left(1-\tau_t^c\right)\left[f\left(k_{m,t},k_{u,t},n_t\right) - x_{u,t} - w_t n_t\right] + \tau_t^c \delta_m k_{m,t} - x_{m,t}\right],$$

$$d_t \geq 0, \text{ and } s_{t+1}-s_t \geq 0.$$

Any solution to this problem must satisfy the following first order conditions:

$$\begin{aligned}
&[d_t] && (1-\tau_t^d)p_t s_t - \mu_t s_t + \kappa_t^d = 0,\\
&[s_{t+1}] && -p_t v_t + p_{t+1}v_{t+1} + \mu_t v_t - \mu_{t+1}v_{t+1} + \kappa_t^s - \kappa_{t+1}^s = 0,\\
&[k_{m,t+1}] && -\mu_t + \mu_{t+1}\left[1+(1-\tau_{t+1}^c)(f_{m,t+1}-\delta_m)\right] = 0,\\
&[k_{u,t+1}] && -(1-\tau_t^c)\mu_t + (1-\tau_{t+1}^c)\mu_{t+1}\left[1+f_{u,t+1}-\delta_u\right] = 0,\\
&[n_t] && f_{n,t} - w_t = 0;
\end{aligned}$$

where κ_t^d, κ_t^s are the multipliers on the inequality constraints on dividends and share issuance respectively, and the transversality conditions for tangible and intangible capital, which are respectively:

$$\lim_{t\to\infty} \mu_t k_{m,t+1} = 0 \text{ and } \lim_{t\to\infty}\left(1-\tau_t^c\right)\mu_t k_{u,t+1} = 0. \tag{4}$$

Note that, whenever corporate income is negative, the tax rate on corporations disappears from the above equations. The prices of tangible and intangible capital depend on whether corporate income is positive and thus taxed and whether the firm is issuing equity or paying dividends. For example, for a firm with positive corporate income that distributes dividends, the first order conditions for tangible and intangible capital can be rewritten as:

$$(1-\tau_t^d)p_t = (1-\tau_{t+1}^d)p_{t+1}\left[1+(1-\tau_{t+1}^c)(f_{m,t+1}-\delta_m)\right], \tag{5}$$

$$(1-\tau_t^d)(1-\tau_t^c)p_t = (1-\tau_{t+1}^d)(1-\tau_{t+1}^c)p_{t+1}\left[1+f_{u,t+1}-\delta_u\right]. \tag{6}$$

Alternatively, for a firm that issues equity in period s and, thus, $d_s = 0$, the relevant price of tangible and intangible capital is independent of the dividend tax and

therefore $(1-\tau_s^d)$ is substituted by 1 in the above equations. Also, if corporate income is negative, $(1-\tau_s^c)$ is substituted by 1.

Now, using the first order conditions for tangible and intangible capital (5)-(6), the transversality conditions (4), and the fact that the function *f* displays constant returns to scale, we obtain the initial value of the firm, which is

$$\sum_{t=0}^{\infty} p_t\left[(1-\tau_t^d)d_t s_t - v_t\left(s_{t+1}-s_t\right)\right] = V_0 = \frac{u_{c,0}}{\left(1+\tau_0^{con}\right)}\left[\left(1-\tau_0^d\right)\left\{1+\left(1-\tau_0^c\right)\left[f_{m,0}-\delta_m\right]\right\}k_{m,0}+\left(1-\tau_0^d\right)\left(1-\tau_0^c\right)\left\{1+f_{u,0}-\delta_u\right\}k_{u,0}\right]. \tag{7}$$

whenever $d_0 > 0$ and $\Pi_0 > 0$. As commented above, $(1-\tau_0^d)$ and $(1-\tau_0^c)$ are substituted by 1 if $d_0 = 0$ and $\Pi_0 \le 0$ respectively. We assume that for the corporate sector to be operative it must provide some positive value $V_0 \ge V_{\min}$. This $V_{\min} > 0$ can be thought of the opportunity cost for capital; such as being consumed by the household or used in the non-corporate sector. Harberger (1962) and Gravelle and Kotlikof (1989) illustrate how taxation shifts production between the corporate and non-corporate sectors.

The Government

The government collects tax revenues in order to finance an exogenously given stream of government consumption (unproductive and not valued by households), denoted by $\{g_t\}_{t=0}^{\infty}$, and issues one-period government bonds.[5] Tax revenues are collected through taxes on consumption, τ_t^{con}, on labor income, τ_t^n, on corporate income, τ_t^c, and on dividend payments, τ_t^d. We assume $b_t \le B$ in order to rule out government Ponzi schemes and that the initial tax rates belong to the set $\left[\underline{T},\overline{T}\right]$. These bounds are sufficiently large so that they do not bind in equilibrium. We assume that $\{g_t\}_{t=0}^{\infty}$ is such that distortionary taxation is required. The government sequential budget constraint is

$$\tau_t^{con}c_t + \tau_t^n w_t n_t + \tau_t^c \Pi_t + \tau_t^d d_t s_t + b_{t+1} \ge g_t + (1+\tilde{r}_t^b)b_t. \tag{8}$$

[5] Our results are not affected by the exogeneity of government spending.

Definition of a Competitive Equilibrium

Given a fiscal policy $\left\{\tau_t^{con}, \tau_t^n, \tau_t^c, \tau_t^d, g_t\right\}_{t=0}^{\infty}$, a competitive equilibrium is a sequence of households' allocations $\left\{\hat{c}_t, \hat{\ell}_t, \hat{b}_{t+1}, \hat{s}_{t+1}\right\}_{t=0}^{\infty}$, firms' production and distributions and issuance plans $\left\{\hat{d}_t, \hat{s}_{t+1}, \hat{k}_{m,t+1}, \hat{k}_{u,t+1}, \hat{n}_t\right\}_{t=0}^{\infty}$, and prices $\left\{\hat{w}_t, \hat{r}_t^b, \hat{p}_t, \hat{v}_t\right\}_{t=0}^{\infty}$ such that:

(i) Given prices and policies, the households' allocation maximizes welfare (1) subject to the budget constraint (2), $\hat{n}_t + \hat{\ell}_t \leq 1,$ and $\hat{b}_t \geq -B,$ for some initial conditions on b_0 and s_0.

(ii) Given prices and policies, the firms' production and distribution-issuance plan maximizes the initial value of the firm for some initial $k_{m,0}$, $k_{u,0}$, non-negativity constraints and transversality conditions (4).

(iii) The labor market is cleared ($\hat{\ell}_t + \hat{n}_t = 1$), the equity market is cleared, and the government budget constraint (8) is satisfied. Feasibility requires

$$\hat{c}_t + \hat{x}_{m,t} + \hat{x}_{u,t} + g_t \leq f(\hat{k}_{m,t}, \hat{k}_{u,t}, \hat{n}_t).$$

3. The Ramsey Policy Plan

We now turn to the government problem. To do that, we assume that there is a commitment technology that allows all future governments to commit to the sequence of taxes announced by the government at date 0. We also assume that $\tilde{r}_0^b$ is given, so that the initial government commits to honor debt payments.

To set up the government's optimization problem, we follow the primal approach. First, we find the Implementability Condition (IC) by adding up the budget constraint (2) over time and using the optimality conditions $[c_t]$, $[n_t]$, $[s_{t+1}]$ and $[b_{t+1}]$, which yields:

$$\sum_{t=0}^{\infty} \beta^t \left[c_t u_{c,t} + n_t u_{n,t}\right] = \frac{u_{c,0}}{\left(1+\tau_0^{con}\right)}[1+\tilde{r}_0^b]b_0 + V_0 = W_0.$$

Notice this is the standard (IC), where the right hand side expression is the value of

initial wealth W_0, which is composed by the initial bond holdings and the value of the households' ownership of the corporate sector.

The formulation of the Ramsey problem is to maximize households' welfare subject to feasibility and this (IC), i.e.:

$$\begin{aligned}
\max \quad & \sum_{t=0}^{\infty} \beta^t u(c_t, n_t) \\
s.t. \quad & c_t + k_{m,t+1} - (1-\delta_m)k_{m,t} + k_{m,t+1} - (1-\delta_m)k_{m,t} + g_t \le f(k_{m,t}, k_{u,t}, n_t) \\
& \sum_{t=0}^{\infty} \beta^t \left[c_t u_{c,t} + n_t u_{n,t} \right] = W_0, \\
& V_0 \ge V_{\min}, \ \tau \in \left[\underline{T}, \overline{T} \right], \text{ and } k_{m,0}, \ k_{u,0}, \tilde{r}_0^b \text{ given.}
\end{aligned}$$

The first order conditions for this problem at time $t > 0$ are:

$$[c_t] \qquad u_{c,t}(1+\lambda) + \lambda\left(u_{cc,t}c_t + u_{nc,t}n_t\right) = \phi_t,$$

$$[n_t] \qquad u_{n,t}(1+\lambda) + \lambda\left(u_{cn,t}c_t + u_{nn,t}n_t\right) = -f_{n,t}\phi_t,$$

$$[k_{m,t+1}] \qquad \phi_t = \beta\phi_{t+1}\left(1 + f_{m,t+1} - \delta_m\right), \tag{9}$$

$$[k_{u,t+1}] \qquad \phi_t = \beta\phi_{t+1}\left(1 + f_{u,t+1} - \delta_u\right), \tag{10}$$

and at date 0:

$$[c_0] \qquad u_{c,0}(1+\lambda) + \lambda\left(u_{cc,0}c_0 + u_{nc,0}n_0\right) - \lambda W_{c,0} = \phi_0,$$

$$[n_0] \qquad u_{n,0}(1+\lambda) + \lambda\left(u_{cn,0}c_0 + u_{nn,0}n_0\right) - \lambda W_{n,0} = -f_{n,0}\phi_0,$$

where $\beta^t\phi_t$ and λ are the Lagrange multipliers on the resource constraint and the implementability condition (IC), respectively. $\mathrm{W}_{h,0}$ denotes the partial derivative of W_0 with respect to *h*.

In our model we have more taxes than necessary for implementation of the competitive equilibrium. The specific necessary instruments (taxes) depend on whether the representative competitive firm is mature (and pays dividends) or is young (and issues equity). For the time being, we assume that the representative firm is mature, which is empirically the more relevant case as found by Sinn (1991), among others. Since the firm pays dividends, we decentralize the allocation with taxes on corporations, dividends and labor income. We later comment on the alternative case.

The optimal policy is characterized for general and specific utility functions. In particular, we will use the following assumption:

Assumption A1. *Let* $u(c,\ell)$ *be separable in c and* ℓ *and homothetic in c.*

Clearly, equations (9) and (10) imply the equalization of the net marginal returns to each type of capital, i.e. $f_{m,t}-\delta_m = f_{u,t}-\delta_u$, $\forall t \geq 1$. Using this, we obtain the following result:

Proposition 1. *The Ramsey policy plan is characterized by:*
(i) The optimal corporate tax rate is equal to zero at all dates $t \geq 0$.
(ii) Let A1 hold. Then, the optimal dividend tax rate is $\tau^{\max}$ *constant at all dates* $t \geq 1$.

Proof. See the Appendix.

We first explain the results. First, since any solution to the Ramsey problem must satisfy the equality of the net returns to tangible and intangible capital, then corporate taxes must be always zero, even at the initial date. In other words, a positive corporate tax is not efficient because it taxes tangible but it cannot tax intangible investment.

Second, we obtain that dividend taxes should be constant and set as high as possible. The intuition for constant dividend taxes is that, since firms can choose the timing of distributions, it is optimal not to distort this timing. Moreover, constant dividend taxes are non-distortionary and that is why they should be set as high as possible. As can be seen from the firm's first order conditions (5) and (6), the dividend tax rate in period *t* depends on the tax rate in period $t-1$. Thus, constant dividend taxes have no impact on the firm's allocation of real resources. Moreover, inspection of (2) indicates that dividend taxation, not only in period 0 but always, is non-distortionary from the households' perspective as well. Therefore, dividend taxes should be set high, $\tau^{\max}$, so as to make the minimum corporate value constraint $V_0 \geq V_{\min}$ bind.[6] In the next

[6] Alternatively we could have incorporated an initial upper bound on all taxes sufficiently low to bind. If we had done so, our Ramsey plan would be characterized by $(1-\tau^d)(1-\tau^c)$ constant for all $t \geq 1$ while taxes would be changing over time (corporate taxes approaching 1 and dividend taxes approaching -∞). We view the minimum value constraint for the corporate firm as a more meaningful and justifiable constraint (since firms can move to the non-corporate sector) than an ad hoc upper bound on taxes.

section we introduce and analyze a model with managerial effort, where dividend taxes will be distortionary.

Next, let us comment on the case of an immature representative firm. By immature we mean that it starts off with a low endowment of tangible and intangible capital and finances investment via equity issuance. In that case, and as shown in the proof of Proposition 1, we find that, while there is issuance, we require consumption taxes for decentralization. Moreover, the combination of constant consumption taxes (while there is issuance) with constant dividend taxes (while there are distributions) replicates a lump-sum tax.

In a different setup with only tangible capital, Abel (2006) assumes immediate expensing of all investment. He finds that a constant capital tax is lump-sum and could finance all government spending and debt obligations. He also points out that it is time-consistent. This is clear because, as Fisher (1980) points out, the time-inconsistency arises in these models because of the need to use distortionary taxation. Notice that Abel's constant capital tax is just equivalent to our constant dividend tax, and our results are consistent with his findings. The main difference is that we have assumed that distortionary taxation is required. Thus, this means that labor income in our economy is still positively taxed. Moreover, we believe that such a heavy taxation of the corporate sector would move firms from the corporate into the non-corporate sector, as suggested by Gravelle and Kotlikoff (1989).

Clearly, then, in our disaggregated framework the standard results of Ramsey capital taxation do not hold. As can be seen from (5) and (6), if the government chooses very high corporate taxes today and none for tomorrow, the price of intangibles plummets and the optimal decision of the firm is to invest in intangible and deplete all current corporate income. If the government chooses very high dividend taxes today and none for tomorrow, the prices of both tangible and intangible investment fall and the optimal decision of the firm is to invest a lot so that dividends are not distributed today and taxes are not paid.[7] All in all, through investment, firms can defer distributions and corporate income to the future.[8] The standard Ramsey capital taxation would not collect any pure rents and would provide a much lower welfare to the representative agent that one with constant capital taxes.

[7] Here, as in Sinn (1991), it can be seen how taxes affect the firm's transition from the old to the new view and vice versa.

[8] Note that our results are not be affected by non-negativity constraints in investment or adjustment costs. Regarding the first, notice that firms react to very high current taxation through investing a lot, not the other way around. Regarding the second, adjustment costs would affect the optimal decisions of agents and government symmetrically and, unless infinite, firms would still be able to respond to changes in taxation.

4. Introducing Managerial Effort

In this Section we incorporate managerial effort (sometimes referred to as sweat equity) in the model.[9] In order to do that, we follow McGrattan and Prescott (2007). They study the changes in hours and productivity in the 1990s and show the importance of intangible investment in expensed and sweat equity. According to their environment expensed investment in intangible assets increases future profits but is treated as an operating expense, and sweat equity is financed by workers-owners of the firm who spend hours in their business building equity. In the previous section we had an economy with expensed investment. Here we present a version of McGrattan-Prescott's model,[10] incorporating both expensed and sweat investment.

We assume that households, as workers-owners of the firm, will devote some time to work n_t and some time or effort $e_t = e_{m,t} + e_{u,t} = 1 - \ell_t - n_t$ to manage investment projects. For this second activity, they receive no wage but the value of their firm increases. We assume this management time is necessary in order to ensure the transformation of resources into new productive capital. In other words, we assume that the production of both tangible and intangible capital requires investment (measured in units of the final good), $x_{m,t}$ and $x_{u,t}$, and managerial effort $e_{m,t}$ and $e_{u,t}$, that is:

$$I^m\left(x_{m,t}, e_{m,t}\right) = k_{m,t+1} - \left(1-\delta_m\right)k_{m,t}, \tag{11}$$

$$I^u\left(x_{u,t}, e_{u,t}\right) = k_{u,t+1} - \left(1-\delta_u\right)k_{u,t}. \tag{12}$$

The functions $I^j(.)$, $j=m,u$, are strictly increasing, homogeneous of degree 1, differentiable and concave. Note that we recover the model in the previous section if $I^j\left(x_{j,t},.\right) = x_{j,t}$ for any level of effort.

This feature changes the optimization problem of the households-managers as follows. They now maximize:

$$\sum_{t=0}^{\infty} \beta^t u(c_t, 1 - n_t - e_{m,t} - e_{u,t}),$$

[9] Zhu (1995) and Albanesi (2006) are examples of papers that also study the implications of managerial/entrepreneurial effort for the properties of optimal taxation.

[10] This version differs from the original in two features. First, in McGrattan and Prescott (2007), their model captures intangible investment (sweat and expensed) and sets the managers "compensation at lower than market rates" but it does not capture that managers put effort with "the expectation of realizing capital gains". As a short-cut of this, they assume that wage compensation is contemporaneous but not accounted. We incorporate this feature. Second, they assume that firms rent the capital and distinguish between capital owners and workers (fixing the proportions of intangible investment financed by each group). We assume that firms own the capital and that workers are themselves owners of the firm.

subject to the budget constraint:

$$\left(1+\tau_t^{con}\right)c_t + v_t(s_{t+1}-s_t) + b_{t+1} = \left(1-\tau_t^n\right)w_t n_t + (1+\tilde{r}_t^b)b_t$$
$$+\left(1-\tau_t^d\right)\left[\left(1-\tau_t^c\right)\left[f(k_{m,t},k_{u,t},\hat{n}_t) - w_t\hat{n}_t - x_{u,t}\right] + \tau_t^c\delta_m k_{m,t} - x_{m,t}\right]s_t,$$

equations (11) and (12), and the non-negativity constraints. Here $\hat{n}_t$ is the amount of labor the firm's owner hires from the market. We change notation just to make clear that the individual, as a worker, behaves competitively in the labor market but, as a manager, internalizes the effect of effort on the value of the firm. We assume the representative firm is mature.

Any interior solution must satisfy the following first order conditions:

$$[e_{m,t}] \quad -\beta^t u_{2,t} + \chi_t^m I_{2,t}^m = 0,$$
$$[e_{u,t}] \quad -\beta^t u_{2,t} + \chi_t^u I_{2,t}^u = 0,$$
$$[x_{m,t}] \quad I_{1,t}^m \chi_t^m - \left(1-\tau_t^d\right)p_t s_t = 0,$$
$$[x_{u,t}] \quad I_{1,t}^u \chi_t^u - \left(1-\tau_t^d\right)\left(1-\tau_t^c\right)p_t s_t = 0,$$
$$[k_{m,t+1}] \quad -\chi_t^m + \left(1-\tau_{t+1}^d\right)p_{t+1}\left[\left(1-\tau_{t+1}^c\right)f_{1,t+1} + \tau_{t+1}^c\delta_m\right]s_{t+1} + \left(1-\delta_m\right)\chi_{t+1}^m = 0,$$
$$[k_{u,t+1}] \quad -\chi_t^u + \left(1-\tau_{t+1}^d\right)\left(1-\tau_{t+1}^c\right)p_{t+1}f_{2,t+1}s_{t+1} + \left(1-\delta_u\right)\chi_{t+1}^u = 0,$$

where χ_t^m and χ_t^u are the Lagrange multipliers on equations (11) and (12), respectively. The remaining optimality conditions are just as before. Combining them, we obtain:

$$\left(1+\tau_t^{cons}\right)u_{2,t} = u_{1,t}(1-\tau_t^n)w_t, \tag{13}$$

$$\left(1+\tau_t^{cons}\right)\frac{u_{2,t}}{I_{2,t}^m} = \left(1-\tau_t^d\right)\frac{u_{1,t}}{I_{1,t}^m}, \tag{14}$$

$$\left(1+\tau_t^{cons}\right)\frac{u_{2,t}}{I_{2,t}^u} = \left(1-\tau_t^d\right)\left(1-\tau_t^c\right)\frac{u_{1,t}}{I_{1,t}^u}, \tag{15}$$

$$\left(1+\tau_{t+1}^{cons}\right)\left(1-\tau_t^d\right)\frac{u_{1,t}}{I_{1,t}^m} = \beta\left(1+\tau_t^{cons}\right)\left(1-\tau_{t+1}^d\right)\left[I_{1,t+1}^m\left[\left(1-\tau_{t+1}^c\right)\left(f_{1,t+1}-\delta_m\right)+\delta_m\right]+\left(1-\delta_m\right)\right]\frac{u_{1,t+1}}{I_{1,t+1}^m}, \tag{16}$$

$$\left(1+\tau_{t+1}^{cons}\right)\left(1-\tau_t^d\right)\left(1-\tau_t^c\right)\frac{u_{1,t}}{I_{1,t}^u} = \beta\left(1+\tau_t^{cons}\right)\left(1-\tau_{t+1}^d\right)\left(1-\tau_{t+1}^c\right)\left[I_{1,t+1}^u f_{2,t+1} + \left(1-\delta_u\right)\right]\frac{u_{1,t+1}}{I_{1,t+1}^u}. \tag{17}$$

Note the relevance of equations (14)-(15), they show that dividend and corporate taxes

are now distortionary in all periods. Using these equations, the initial value of the firm can be written as:

$$V_0 = \frac{u_{2,0}}{I^m_{2,0}}\left[I^m_{1,0}\left[\frac{I^u_{1,0}}{I^u_{2,0}}\frac{I^m_{2,0}}{I^m_{1,0}}\left(f_{1,0}-\delta_m\right)+\delta_m \right]+\left(1-\delta_m\right)\right]k_{m,0}+\frac{u_{2,0}}{I^u_{2,0}}\left[I^u_{1,0}f_{2,0}+\left(1-\delta_u\right)\right]k_{u,0}.$$

Now since all taxes are distortionary, the inequality $V_0 \geq V_{\min}$ will not be binding. The government problem must be modified as well in order to take into account managerial effort, the new implementability constraint and equations (11) and (12). Moreover, the number of taxes is less than the number of competitive equilibrium conditions. As can be seen from equations (13)-(17), we have 5 equations and 4 taxes. Furthermore, the tax rates are not linearly independent and effectively we have 3 unknowns $\left(\frac{1-\tau^n_t}{1+\tau^{cons}_t}\right)$, $\left(\frac{1-\tau^d_t}{1+\tau^{cons}_t}\right)$, and $\left(1-\tau^c_t\right)$. Then, we have a problem of decentralization and the next additional constraints must be added to the Ramsey maximization problem:

$$\frac{u_{2,t}}{I^m_{2,t}} = \beta\left[I^m_{1,t+1}\left[\frac{I^u_{1,t+1}}{I^u_{2,t+1}}\frac{I^m_{2,t+1}}{I^m_{1,t+1}}\left(f_{1,t+1}-\delta_m\right)+\delta \right]+\left(1-\delta_m\right)\right]\frac{u_{2,t+1}}{I^m_{2,t+1}}, \tag{18}$$

$$\frac{u_{2,t}}{I^u_{2,t}} = \beta\left[I^u_{1,t+1}f_{2,t+1}+\left(1-\delta_u\right)\right]\frac{u_{2,t+1}}{I^u_{2,t+1}}, \tag{19}$$

which are equations (16)-(17) once the tax rates have been substituted in. The Ramsey problem is now:

$$\begin{aligned}
\max \quad & \sum_{t=0}^{\infty}\beta^t u\left(c_t, 1-n_t-e_{m,t}-e_{u,t}\right) \\
s.t. \quad & c_t + x_{m,t} + x_{u,t} + g_t \leq f(k_{m,t}, k_{u,t}, n_t) \\
& I^u\left(x_{u,t}, e_{u,t}\right) = k_{u,t+1} - \left(1-\delta_u\right)k_{u,t} \\
& I^m\left(x_{m,t}, e_{m,t}\right) = k_{m,t+1} - \left(1-\delta_m\right)k_{m,t} \\
& \sum_{t=0}^{\infty}\beta^t\left[c_t u_{c,t} - u_{2,t}\left(n_t + e_{m,t} + e_{u,t}\right)\right] = W_0 \\
& \frac{u_{2,t}}{I^m_{2,t}} = \beta\left[I^m_{1,t+1}\left[\frac{I^u_{1,t+1}}{I^u_{2,t+1}}\frac{I^m_{2,t+1}}{I^m_{1,t+1}}\left(f_{1,t+1}-\delta_m\right)+\delta \right]+\left(1-\delta_m\right)\right]\frac{u_{2,t+1}}{I^m_{2,t+1}} \\
& \frac{u_{2,t}}{I^u_{2,t}} = \beta\left[I^u_{1,t+1}f_{2,t+1}+\left(1-\delta_u\right)\right]\frac{u_{2,t+1}}{I^u_{2,t+1}} \\
& k_{m,0},\ k_{u,0},\ \tilde{r}^b_0 \text{ given.}
\end{aligned}$$

In what follows, we provide a numerical characterization of the solution to the above Ramsey problem. Before that, it is worth pointing out that if the investment functions were separable and linear it could be shown that corporate income taxes should be zero always and dividend taxes should be constant, even though not necessarily at its maximum value. The reason is that with separability and linearity the solution would imply corner solutions (i.e. only resources or effort go into building new capital), nesting our simple specification, and there would be no decentralization problem. This result will become clear once we conduct sensitivity analysis in our numerical results.

Functional Forms and Parameterization

We assume the following functional form for the instantaneous utility function:

$$u\left(c, n+e_m+e_u\right)=\frac{c^{1-\sigma}}{1-\sigma}-\gamma\frac{\left(n+e_m+e_u\right)^{1+\frac{1}{\chi}}}{1+\frac{1}{\chi}}.$$

where $\gamma > 0$ measures the disutility of hours worked, $\sigma > 0$ is the coefficient of relative risk aversion and $\chi > 0$ is the intertemporal elasticity of labor supply. Notice that this utility function satisfies assumption A1. The production function for final output is assumed to be Cobb-Douglas:

$$f(k_{m,t}, k_{u,t}, n_t) = Ak_{m,t}^{\alpha_m} k_{u,t}^{\alpha_u} n_t^{1-\alpha_m-\alpha_u},$$

with $A > 0$ and $\alpha_m, \alpha_u \in (0,1)$. Finally, the functional form for investment in tangible and intangible capital is assumed of the CES type:

$$I_j = C_j\left[\mu_j x_j^{\rho_j} + \left(1-\mu_j\right)e_j^{\rho_j}\right]^{\frac{1}{\rho_j}}, \text{ for } j=\{m,u\},$$

with $C_j x_j^{\mu_j} e_j^{1-\mu_j}$, if $\rho_j = 0$, and $C_j > 0$ and $\mu_j \in [0,1]$. We will provide sensitivity analysis with respect to the curvature parameters ρ_j.

We take as our benchmark an equilibrium steady state with a given fiscal policy intended to represent the basic features of the tax structure of the U.S. economy. We will substantially rely on measurement done in McGrattan and Prescott (2005, 2007).

Table 1 summarizes our choice of parameter values.

Table 1: Calibrated Parameters

Parameter	Preferences				Production Technology					Inv.Tangible			Inv.Intangible		
	β	σ	γ	χ	A	α_m	α_u	δ_m	δ_u	C_m	μ_m	ρ_m	C_u	μ_u	ρ_u
Value	0.975	**2.00**	11.2	**0.80**	**2.00**	**0.26**	**0.076**	**0.067**	**0.10**	1.16	**0.99**	**−2.0**	7.8	0.09	**0.0**

In Table 1 parameter values in bold denote parameters that are exogenously fixed or assumed. The curvature parameters in the utility function are standard in the literature, representing a constant relative risk aversion of 2 and a Frisch labor supply elasticity of 0.8. The parameters of our production technology and the depreciation rates of both types of assets are taken from McGrattan-Prescott.

For the technology to build tangible capital it seems reasonable to assume that managerial effort is not very important, and consequently we fix the share of resources at 0.99. In our benchmark specification we assume that the curvature parameter is -2.0, and we will later conduct sensitivity analysis with respect to this assumption. Finally, we choose the constant C_m so that in the equilibrium of our benchmark economy tangible capital, k_m, is measured in the same units as the resources used to build it, i.e. we fix C_m to impose $I_m(x_m, e_m) = x_m$.

In our benchmark specification we assume a Cobb-Douglas specification for the technology to build intangible capital, and then we will conduct extensive sensitivity analysis about this assumption.

We are left now with four parameters. We determine in equilibrium these four parameters in order to target four key empirical observations:[11]

Table 2: Empirical Targets in the Benchmark Economy

Target	Tang.K. Return	Intang.K/GDP	Total Hours	Man.Effort/Total Hours
Value	0.026	1.083	0.35	0.10
Parameter	β	C_u	γ	μ_u

Targeting an after-tax return on tangible capital of 2.6 percent, given the production technology, is equivalent to targeting a ratio of tangible capital to GDP of 1.65, consistent with McGrattan-Prescott measurement. The ratios of tangible capital and intangible capital to output are respectively 1.65 and 1.083. These ratios are the

[11] Here we refer to the parameter that is most related to a particular empirical target, even though it is understood that the empirical targets are jointly determined as an equilibrium outcome.

equivalent of a tangible capital-output ratio of 3 and an intangible capital-output ratio of 0.65 once we take into account that the corporate sector is 60% of the US value-added and that 1/3 of all tangible assets are in the corporate sector.

Also, the empirical target of managerial effort being ten percent of aggregate hours worked comes from McGrattan-Prescott.

The government policy in our benchmark economy is given in the following table:

Table 3: Policy Parameters

Cons.Tax	Corpor.Tax	Lab.Inc.Tax	Divid.Tax	Gov.Cons/GDP	Debt/GDP
0.05	0.35	0.20	0.21	0.17	0.50

The results for our benchmark exercise

Given our benchmark economy, we now solve for the Ramsey plan numerically. We will solve for this maximization problem using a successive quadratic programming method provided by Schittkowski (1986) in the IMSL Fortran routines.

Given the second best allocation that solves the Ramsey problem, the corresponding taxes that decentralize it are represented in Figure 1.

Figure 1: Optimal Ramsey Taxes

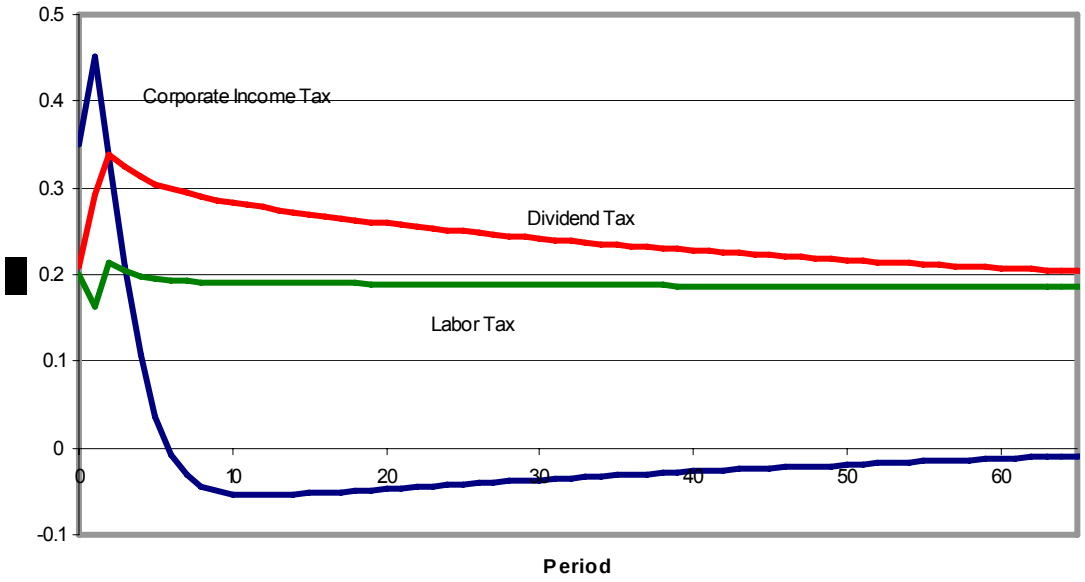


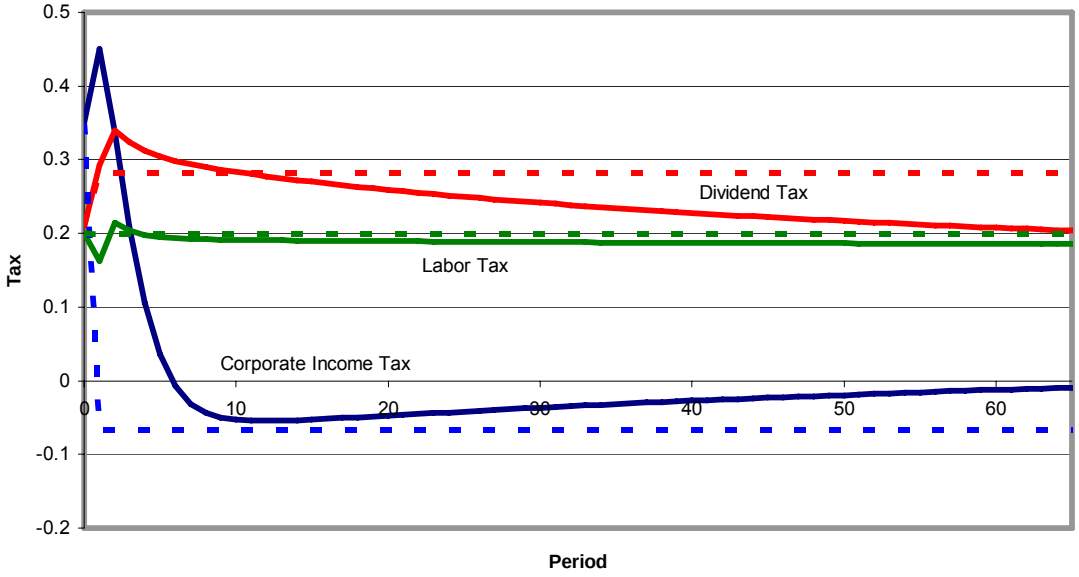
Figure 1 shows that the current dividend tax rate is very close to its optimal long-run level but that it would be optimal to eliminate corporate taxes. During the

transition, dividend tax rates should be increased and corporate income should be slightly subsidized. Labor taxes should remain roughly at the current level. As a result of this policy welfare increases by 2 percent, measured in consumption equivalent units.

There are some incentives for an initial capital levy, as shown by the initial jump in corporate income and dividend taxes. The reason is that now, as opposed to our basic model, it is costly (in terms of managerial effort) to build capital in order to avoid taxation. This initial increase in tax rates, however, is very small compared to the figures found in Chari, Christiano and Kehoe (1994).

In order to understand how quantitatively important this initial capital levy is, we compare the Ramsey policy with the best constant tax policy. This comparison is reported in Figure 2, where the best constant tax policy is represented by the dashed lines.

Figure 2: Optimal Ramsey and Constant Taxes



Corporate income taxes are eliminated and even become slightly negative (a seven percent subsidy), dividend taxes are increased to 28 percent (relative to the initial value of 21 percent) and labor income taxes are kept roughly unchanged. As a result of this policy the economy experiments welfare gains equivalent to 1.95 percent higher consumption in every period. Notice that this welfare gains are 98 percent of the welfare gains attained with the Ramsey policy, or in other words, the initial higher capital taxes result in only 2 percent of those gains. Therefore, in contrast with the standard

framework of Chamley-Judd, the time-inconsistency problem of capital taxation is not that quantitatively relevant in welfare terms.

Sensitivity with respect to the curvature parameters in the investment functions

Since we have arbitrarily chosen the degree of complementarity between resources and effort in building both types of capital, now we conduct sensitivity analysis with respect to these key parameters. For each of these exercises we recalibrate our economy, so that our economies are observationally equivalent.

First, we examine the importance of the curvature in building tangible capital. In our benchmark this parameter was fixed at -2.0. We perform the same policy exercise for a set of values for this parameter between -10 and 0.95 (a value of 1 would imply perfect substitutability between resources and managerial effort). The results of this sensitivity analysis are summarized in Table 4.

Table 4: Sensitivity analysis with respect to ρ_m

ρ_m	Ramsey Taxes at 1			Ramsey Taxes at ss			Welfare Gain R	Best Constant Taxes			Welfare Gain C	C / R
	τ_t^c	τ_t^d	τ_t^n	τ_t^c	τ_t^d	τ_t^n		τ_t^c	τ_t^d	τ_t^n		
-10	0.41	0.34	0.16	−0.05	0.25	0.18	0.01998	−0.15	0.34	0.20	0.01956	0.9793
-5	0.43	0.32	0.16	−0.02	0.22	0.18	0.01994	−0.11	0.32	0.20	0.01951	0.9783
-4	0.44	0.31	0.16	−0.01	0.21	0.18	0.01993	−0.10	0.31	0.20	0.01949	0.9781
-3	0.44	0.30	0.16	−0.01	0.21	0.18	0.01992	−0.08	0.30	0.20	0.01948	0.9777
-2	0.45	0.29	0.16	0.00	0.20	0.18	0.01991	−0.07	0.28	0.20	0.01946	0.9774
-1	0.46	0.28	0.16	0.00	0.19	0.18	0.01990	−0.05	0.26	0.20	0.01945	0.9770
0	0.48	0.26	0.17	0.00	0.19	0.19	0.01994	−0.02	0.24	0.20	0.01948	0.9770
0.50	0.49	0.24	0.17	0.00	0.19	0.19	0.02006	0.00	0.22	0.20	0.01961	0.9776
0.95	0.49	0.20	0.18	0.00	0.19	0.19	0.02229	0.02	0.21	0.20	0.02189	0.9817

The more substitutable resources and effort are in building tangible capital the more the initial capital levy relies on taxation of corporate income rather than on dividend taxation. Second, higher complementarity implies that in the long run it becomes optimal to subsidize corporate income (both with the Ramsey policy and with constant taxes). Finally, the welfare gains are not substantially changed, and a strategy of constant taxes achieves 98 percent of the potential welfare gains irrespectively of the parameter value chosen.

Now we turn to the sensitivity analysis with respect to the degree of complementarity between resources and effort in building intangible capital. The results are reported in Table 5.

Table 5: Sensitivity analysis with respect to ρ_u

ρ_u	Ramsey Taxes at 1			Ramsey Taxes at ss			Welfare Gain R	Best Constant Taxes			Welfare Gain C	C / R
	τ_t^c	τ_t^d	τ_t^n	τ_t^c	τ_t^d	τ_t^n		τ_t^c	τ_t^d	τ_t^n		
-10	0.93	0.32	0.17	0.00	0.19	0.18	0.01991	−0.07	0.28	0.20	0.01900	0.9544
-5	0.89	0.32	0.16	0.00	0.19	0.18	0.01987	−0.07	0.28	0.20	0.01904	0.9584
-4	0.87	0.32	0.16	0.00	0.19	0.18	0.01985	−0.07	0.28	0.20	0.01906	0.9598
-3	0.84	0.32	0.16	0.00	0.19	0.18	0.01984	−0.07	0.28	0.20	0.01910	0.9618
-2	0.79	0.32	0.15	0.00	0.19	0.18	0.01983	−0.07	0.28	0.20	0.01913	0.9648
-1	0.68	0.31	0.15	0.00	0.20	0.18	0,01982	−0.07	0.28	0.20	0.01921	0.9694
0	0.45	0.29	0.16	0.00	0.20	0.18	0.01991	−0.07	0.28	0.20	0.01946	0.9774
0.50	0.27	0.28	0.17	0.00	0.20	0.19	0.02021	−0.07	0.28	0.20	0.01988	0.9836
0.95	0.18	0.26	0.17	0.00	0.20	0.19	0.02217	−0.07	0.28	0.20	0.02187	0.9861

Notice that the only substantial change is in the nature of the capital levy. The more complementary resources and effort are the higher the capital levy, especially in the form of an initial jump in corporate income taxes. However, both the long run and the constant optimal policies are unaffected by this parameter value. Again, welfare gains from the Ramsey policy are roughly unchanged and a substantial fraction of those (between 95 and 99 percent) are already achieved with constant taxes. In particular the more substitutable resources and effort become the lower the incentive for an initial capital levy, and constant taxes achieve virtually all of the welfare change.

Overall, the degree of complementarity between resources and effort in building tangible capital determines whether it is optimal or not to subsidize corporate income in the long run, while the degree of complementarity in building intangible capital determines the desirability and the nature of the capital levy. However, it is a robust finding that most of the gains from changing to the optimal policy can be achieved with constant taxes.

5. Discussion and conclusions

The literature in optimal taxation has found that the result of initially extremely high and then zero capital taxes is robust to different economic environments. In all these alternative environments initial capital income taxes are levied on an inelastic tax base. In this paper we show that this result does not generalize to a more disaggregated framework that allows for different capital taxes (corporate income and dividend taxes) and different types of capital (tangible and intangible). This simple departure from the

standard framework implies that capital income taxes are levied on explicitly elastic tax bases. As a result, constant capital taxes are the best policy option (or very close in the presence of managerial effort).

Our quantitative exercise shows that eliminating corporate income taxes, increasing dividend taxes to 28 percent and leaving labor income taxes unchanged would result in welfare gains equivalent to 2 percent higher consumption.

An alternative policy option (see Smith 1963, Sandmo 1974 and Abel 2006) would be to change the tax system and allow for a full deductibility of all capital expenditures. In that case, at least qualitatively, our results would go through even in the absence of intangible investment.

In addition to its implications for actual policy design, this result is important because it questions the quantitative importance of the time inconsistency of capital income taxation that arises in more simplified economic environments.

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Appendix

Proof of Proposition 1

As mentioned in the text, we first look at the case of a representative mature firm that pays dividends. We then decentralize the Ramsey allocation with taxes on corporations, dividends and labor income. We first prove (i). First, note that the inequality $V_0 \geq V_{\min}$ will be binding because this reduces the need for distortionary taxation and loosens up the implementability constraint. Next, from the planner's first order conditions, we have

$$\phi_t = \beta\phi_{t+1}\left[1 + f_{m,t+1} - \delta_m\right],$$
$$\phi_t = \beta\phi_{t+1}\left[1 + f_{u,t+1} - \delta_u\right].$$

From the firm's and household's first order conditions, we obtain

$$u_{c,t} = \left(\frac{1-\tau^d_{t+1}}{1-\tau^d_t}\right)\beta u_{c,t+1}\left[1 + (1-\tau^c_{t+1})(f_{m,t+1} - \delta_m)\right],$$
$$u_{c,t} = \left(\frac{1-\tau^d_{t+1}}{1-\tau^d_t}\right)\left(\frac{1-\tau^c_{t+1}}{1-\tau^c_t}\right)\beta u_{c,t+1}\left[1 + f_{u,t+1} - \delta_u\right].$$

By comparing both sets of conditions, we find the following. First of all, the first two equations imply $f_{m,t} - \delta_m = f_{u,t} - \delta_u$ for all $t \geq 1$. Second, note that a constant allocation implies a constant product $\left(1-\tau^d_t\right)\left(1-\tau^c_t\right)$ and, since taxes must be finite $\tau \in \left[\underline{T}, \overline{T}\right]$, it also implies constant individual taxes at steady state. Next, looking at the steady state, the equality of marginal returns to both types of capital implies that the optimal corporate tax is zero at the steady state. Moreover, working backwards, it is obvious that the corporate tax must be zero in all previous periods, including period 0.

We now prove (ii). First, the initial dividend tax τ^d_0 is determined by the binding constraint $V_0 = V_{\min}$. Next, for utility functions that are separable in consumption and leisure and homothetic in consumption, the government's first order condition for consumption can be written as

$$\phi_0 = u_{c,0}\left[1 + \lambda\left(1-\sigma\right)\right] - \lambda W_{c,0}, \quad \text{for the initial period,} \tag{20}$$
$$\phi_t = u_{c,t}\left[1 + \lambda\left(1-\sigma\right)\right], \quad \text{for all periods } t \geq 1, \tag{21}$$

where $\sigma = -\frac{u_{cc,t}}{u_{c,t}}c_t$ is the coefficient of relative risk aversion. Then, the first order

conditions for tangible and intangible capital imply that

$$\left(1-\tau_0^d\right)=\left[1-\frac{\lambda W_{c,0}}{u_{c,0}\left[1+\lambda\left(1-\sigma\right)\right]}\right]\left(1-\tau_1^d\right).$$

Thus, as $W_{c,0} < 0$, we obtain $\tau_1^d = \tau^{\max} > \tau_0^d$. Moreover, from period 1 onwards, it is obvious that $1-\tau_{t+1}^d = 1-\tau_t^d = 1-\tau^{\max}$, i.e. the optimal dividend tax is constant.

Next, we consider the case of a representative immature firm that pays no dividends and issues equity. In this case the decentralization requires consumption taxes while there is equity issuance. First note, that as above, the optimal corporate tax is zero in all periods. Next, the optimal consumption tax at date 0 is very high, specifically the rate dictated by $V_0 = V_{\min}$. Moreover, for utility functions that are separable in consumption and leisure and homothetic in consumption, the government's first order conditions (20)-(21) imply constant consumption taxes. Once dividends are paid, these constant consumption taxes can be replaced by constant dividend taxes. The combination of constant consumption taxes (while there is issuance) with constant dividend taxes (while there are distributions) replicates a lump-sum tax. ■