

Corporate Profit Taxes, Capital Expenditure and Real Wages: The analytics behind a contentious debate*

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Abstract

The recent reduction in the US corporate profit tax rate from 35 percent to 21 percent has triggered renewed interest in the impact of a cut in the corporate tax rate on capital accumulation and real wages. This theoretical contribution demonstrates that the familiar proposition that a cut in the corporate profit tax rate boosts the capital intensity of production and the real wage is sensitive to a number of key assumptions. Even when the real interest rate is exogenously given, full deductibility of capital expenditure from the corporate profit tax base will result in no impact of a corporate profit tax rate cut on the incentive to invest. Adding deductibility of interest can result in a negative effect on the capital intensity of production of a corporate profit tax rate cut.

When the real interest rate is endogenous, we use the “perpetual youth” OLG model to demonstrate that the effects on consumption demand of a corporate profit tax cut will reduce the impact on capital intensity of a corporate profit tax cut if the tax cut is funded by higher lump-sum taxes on “permanent income” households. We have not been able to find examples where the capital intensity impact is reversed. Alternative funding rules (e.g. lower public consumption purchases) and the introduction of “Keynesian” consumers could lead to a larger positive effect on capital intensity from a cut in the corporate profit tax rate.

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1. INTRODUCTION

The impact of a cut in the corporate profit tax rate on capital accumulation and through that on real wages has long been the subject of scholarly and political debate.¹ The reduction in the U.S. federal corporate profit tax rate in December 2017 for from 35 to 21 percent has triggered renewed interest in this issue.² The debate has been vigorous and even sometimes rather ill-tempered (see, for example, Hassett (2017), Summers (2017 a, b, c), Mankiw (2017a, b), Mulligan (2017 a, b) and Furman (2017a, b)).³ In this paper we discuss the contrasting views of two prominent economists, Kevin Hassett (chairman of the Council of Economic Advisers) and Larry Summers (former Treasury Secretary and former head of the National Economic Council) and try to determine which is likely to be closer to the truth. It turns out that two other features of the corporate tax regime are central to the determination of the effects of a cut in the corporate profit tax rate. These are the deductibility of capital expenditure and interest payments from the corporate profit tax base. The December 2017 corporate tax reforms raised, for a period of 5 years, the first-year bonus depreciation percentage for capital expenditure from 50% to 100%. Unlimited interest deductibility was changed to net interest deductibility up to 30% of adjusted taxable income, with any excess carried forward up to 5 years.

In Section 2, we extend a simple exogenous constant real interest rate model proposed by Mankiw (2014a, b) and Mulligan (2017a, b) to make it applicable to the U.S. corporate tax proposals. In Section 3 we employ the general equilibrium closed-economy Yaari-Blanchard overlapping-generations model. For the special case of a zero birth rate this model becomes a conventional infinite-lived representative agent model where the steady state real interest rate is determined by the (constant) rate of time preference. Thus, it subsumes the discussion in Section 2.

1.A. The Debate

In recent publications the Council of Economic Advisers (CEA) (2017a, b) argues that reducing the federal corporate tax rate in the US from 35 to 20 percent would increase average household income in the United States by, very conservatively, 4,000 dollars annually and possibly by as much as 9,000 dollars annually. The idea is that a lower tax will result in higher investment, and thus a higher capital-labor ratio and higher real wages. (See, also, Hassett (2017)). Since then, the corporate tax rate has been reduced to 21 percent. As most of the debate was based on an assumption that the new tax would be 20 percent, that is the number we focus on in our calculations in Section 2.

Assume the cut in corporate tax rates from 35 to 20 percent is likely to cost around 200 billion dollars a year in the short run. This estimate is from the Committee for a Responsible Federal Budget (2017) and is also the number used by Summers (2017a) and Furman (2017b). Many estimates are lower—ranging from an short-run one-year revenue loss of 120 billion dollars (Hodge (2017)) to 150 billion dollars (Joint Committee on Taxation (2017))—and would make the wage gains relative to the tax revenue loss look even bigger. There were about 154 million workers in the U.S. economy in October 2017, of whom about 127 million were full-time

¹ Council of Economic Advisers (2017b) is a survey of the empirical research. It is problematic because of the combination of challenges in controlling for omitted variables and difficult identification issues in both time series and cross-country empirical studies.

² The corporate tax rate cut permanently cuts the corporate tax rate for profits in excess of \$10 million from 35% to 21.

³ Larry Summers' (2017a) response to Hassett (2017) and the Council of Economic Advisers (2017a, b) was that Hassett "deserved a failing grade" for his analysis. Hassett said of the Tax Policy Foundation's report on the Big 6 tax plan, "It's inaccurate. It's fiction." Of the negative public responses to it he said, "That's what happens when you behave irresponsibly." Hassett (2017, p.1).

employees.⁴ If total employment is what the average wage income increase applies to, a long run rise in the average wage income of 4,000 dollars—the conservative case—means that aggregate annual wage income would, in the long run, rise by 600 billion dollars, or 3.0 times the short-run loss in tax revenue. In the optimistic case where average household income rises by 9,000 dollars, the long-run increase in aggregate annual real wage income would be 1,350 billion dollars, or 6.75 times the short-run annual loss in revenue. Summers (2017a) uses the 150 million number in his calculations. If only the full-time employed workers benefit from these increases, aggregate wage income would rise by 508 billion dollars in the case of a 4,000 dollar wage increase per worker (a multiple of 2.54 of the short-run annual revenue loss) and 1,143 billion dollars in the case of a 9,000 dollar wage increase per worker (a multiple of 5.72).

The CEA/Hassett numbers, however, do not refer to average individual worker income but to *household* income. In 2016 there were almost 126 million households in the United States. Working households, those with at least one working adult, numbered close to 111 million. We use the household numbers to calculate the multiples. With are 126 million households, this gives a multiple of 2.52 in the case a wage income gain of 4,000 dollars per household and a multiple of 5.67 in the case of 9,000 dollars per household. With 111 million households this gives a multiple of 2.22 in the case of 4,000 dollars per household and a multiple of 5.00 in the case of 9000 dollars per household.⁵

Table 1: Ratio of Long-Run Annual Labor Income Gains to Short-Run Revenue Loss from a Cut in the Corporate Tax Rate from 35 to 20 Percent

The income gain is applied to:	Conservative Case (wage increase of 4,000 dollars per year)	Optimistic Case (wage increase of (9,000 dollars per year)
All workers	3.00	6.75
Full-time workers	2.54	5.72
All households	2.52	5.67
Full-time households	2.22	5.00

The multiples we have computed are shown in Table 1 and in what follows we ask, how plausible are these numbers? We consider only the impact of the proposed corporate profit tax cut rate from 35 to 20 percent and the expensing of investment and interest deductibility. There are many other fiscal measures that have been proposed by the White House, the House of Representatives and the Senate, that deal with other aspects of corporate and personal taxation. These other measures are not considered here.⁶

1.B. Outline of the Rest of the Paper

In Section 2 we show that if the real interest rate is exogenous and there is no expensing of investment, then the CEA’s proposition that a cut in the corporate tax rate increases long-run labor income is qualitatively correct, but the numbers in Table 1 greatly overstate the magnitude of the ratio of *long-run* labor income gains to the

⁴ “Labor Force Statistics,” database, *Bureau of Labor Statistics* (<https://bls.gov> : accessed 27 April 2018), specifically Table A-9 Selected Employment Indicators. We use the average of the numbers from the Current Population Survey and the Current Employment Statistics survey.

⁵ We assume a short-run revenue loss from the corporate profit tax cut of 200 billion dollars.

⁶ The complete set of tax reforms can be found in Joint Explanatory Statement of the Committee of the Conference, 18 December 2017, <https://docs.house.gov/billssthisweek/20171218/Joint%20Explanatory%20Statement.pdf>. This document is 570 pages long.

short-run revenue loss of a corporate tax cut. Even the ratio of the long-run wage gain to the *long-run* tax revenue only reaches 2.40 in our benchmark case, between the Conservative Case of All households and Full-time households in Table 1.

If there is partial expensing (that is, deductibility) of capital expenditure from the corporate tax base then the scenario may be even less rosy. Prior to the December 2017 reforms, 50 percent of capital expenditure could be expensed in the first year. Following the reform that number is 100 percent (for the next five years). With investment expensing, the cost of capital is less sensitive to the corporate tax rate than if there were no expensing. Thus, the capital-labor ratio and the real wage are less sensitive, as well. If all capital expenditure can be deducted, then the cost of capital, the real wage and the capital-labor ratio are insensitive to corporate tax rate. For a Cobb-Douglas production function, if there is full expensing of capital expenditures then there is a greater proportional response of corporate tax revenue to a cut in the tax rate than there would be with no expensing.

If there is full expensing of capital expenditure and deductibility (complete or partial) of interest from the corporate tax base, and if capital expenditure is at least in part funded by borrowing, a cut in the corporate profit tax rate reduces the benefit of interest deductibility and, thus, has the perverse effect of increasing the cost of capital. Hence it would lower the capital-labor ratio and the real wage as well. A higher degree of investment deductibility, like the increase from 50% to 100% in the US, boosts investment and real wages as long as the corporate profit tax rate and the cost of capital are positive. *Given* full deductibility of capital expenditure, as in now the case in the US, a lower corporate profit tax rate does not boost the capital intensity of production. If the interest rate and the corporate profit tax rate are positive and the amount of corporate debt increases when the capital stock increases, a lower degree of interest rate deductibility, as was introduced in the December 2017 reforms in the US, will raise the cost of capital and lower the capital-intensity of production.

In Section 2 we assume that the real interest rate is exogenous and constant. This is consistent with a representative infinite-lived agent model with a constant subjective discount factor. However, in overlapping-generations models an increase in the firms' demand for capital brought about by a decrease in the corporate tax rate requires that the interest rate adjust to restore equality between the firm's demand for capital and consumers' supply. In Section 3 of the paper we endogenize the real interest rate using a closed economy, full employment model with consumption determined by the "Perpetual Youth" Yaari-Blanchard overlapping generations model. In our closed economy model (and by extension in a large open economy with perfect capital mobility)⁷, a balanced budget cut in the corporate tax rate, with a lump-sum tax on households balancing the corporate tax cut, will, if there is no full expensing of investment, raise both the capital-labor ratio and the real interest rate. This reduces the long-run US real wage gains relative to the constant real interest rate benchmark of Section 2. The corporate tax cut will not only impact the optimal capital stock through the incentive to invest, it will also in general impact household consumption demand. When the corporate tax cut is funded through an increase in lump-sum taxes, consumption demand will, if households are permanent-income-consumers, be boosted at a constant interest rate and capital-labor ratio. A sufficiently large share of "Keynesian" households without access to financial markets can reverse that result. When the corporate profit tax cut is funded through a cut in public consumption expenditure, the aggregate demand effect (holding constant the interest rate and the capital-labor ratio) can go either way.

As noted earlier, if there is full expensing of capital expenditure, a cut in the corporate tax rate has no impact on the incentive to invest and therefore no impact on the capital stock and real wage income if the real interest

⁷ The global (large country) open economy models for which this would hold are the kind analyzed in Sibert (1985, 1990).

rate is exogenous. If the real interest rate is endogenous, the impact of the corporate profit tax cut on consumption demand (and possibly also on exhaustive public spending) will determine its effect on the long-run capital-labor ratio and real interest rate. The same conditions that generate a negative effect on the long-run capital-labor ratio from a balanced budget corporate tax cut/lump sum tax increase when there is no deductibility of capital expenditure imply a reduction in the long-run capital-labor ratio when there is full deductibility of capital expenditure.⁸ Again, with enough “Keynesian” households, the household demand effect can go the other way. If cuts in public spending on consumption balance the corporate profit tax cuts, the impact on aggregate demand and thus on the capital-labor ratio is ambiguous.

2. The Case of an Exogenous Real Interest Rate

In this Section the real interest rate is assumed to be exogenous and strictly positive. The analysis of the impact of corporate tax changes on capital formation, real wages and tax revenues is simple when the real interest rate is exogenous. Only the optimization problem of the representative firm has to be analyzed. The household sector and government budget constraint play no explicit role, although the implicit assumption is made that both are solvent. An exogenous real interest rate can be justified for a small open economy with perfect international capital mobility. In a closed economy it can be justified by assuming that the representative household is an infinite-lived optimizing agent with a constant rate of term preference and that the economy is in a steady-state equilibrium.

There is a single good, which can be used for capital or consumption. The infinite-lived representative competitive firm uses capital and labor to produce output. It issues debt and (non-negative) equity and pays interest to bondholders and (non-negative) dividends to shareholders. The firm also pays corporate profit taxes. Non-negative shares of net investment, capital depreciation, the wage bill and interest paid can be *expensed*, or deducted from the corporate income tax base. We assume the wage bill can be fully expensed. The time- t budget constraint of the firm is

$$K_{t+1} - K_t - B_{t+1} / r_{t+1} + B_t + Q_t(E_{t+1} - E_t) = Y_t - w_t L_t - \delta K_t - d_t E_t - T_t, \quad (1)$$

where K_t is the capital stock at the beginning of period t , B_t is the stock of one-period real discount bonds outstanding at the beginning of period t , E_t is the number of shares of equity outstanding at the beginning of period t , r_t is (one plus) the real interest rate between periods $t-1$ and t , Q_t is the price of equity at time t , Y_t is output at time t , L_t is labor at time t , w_t is the wage rate at time t , d_t is the dividend per share paid at time t on shares outstanding at the beginning of period t , T_t is the corporate tax paid at time t and $\delta \in [0,1]$ is the capital depreciation rate.

Corporate taxes paid by the firm are

⁸ This condition is that, *cet. par.*, a higher capital-labor ratio boosts household demand for consumption goods by more than it boosts the supply of consumption goods.

$$T_t = \theta[Y_t - w_t L_t - s(K_{t+1} - K_t) - s\delta K_t - s^r(r_t - 1)B_t], \quad (2)$$

where θ is the (constant) corporate tax rate, s is the fraction of net investment and depreciation that can be deducted and s^r is the fraction of interest payments that can be deducted.

Output is produced via a constant returns to scale production function $Y_t = F(K_t, L_t)$. The function F is assumed to have strictly positive and strictly decreasing marginal products and to satisfy the usual regularity conditions.⁹ The assumption of constant returns to scale implies that $F(K_t, L_t) = F(K_t / L_t, 1) = L_t f(k_t)$, where the function f is output per unit of labor and $k_t = K_t / L_t$ is the time- t capital-labor ratio.

The corporate tax is the only tax on asset income in this economy. Thus, by consumer arbitrage:

$$r_{t+1} = (d_{t+1} + Q_{t+1}) / Q_t. \quad (3)$$

The period budget identity of the representative firm, equation (1), can be rewritten as:

$$\begin{aligned} Q_t E_t + B_t &= (Q_{t+1} E_{t+1} + B_{t+1}) / r_{t+1} + \Omega_t, \\ \Omega_t &= (1 - \theta)L_t[f(k_t) - w_t] - (1 - \theta s)(K_{t+1} - K_t) - (1 - \theta s)\delta K_t + \theta s^r(r_t - 1)B_t. \end{aligned} \quad (4)$$

We impose the standard “no Ponzi scheme” terminal condition:

$$\lim_{T \rightarrow \infty} (Q_{t+T} E_{t+T} + B_{t+T}) / \prod_{s=1}^T r_{t+s} = 0. \quad (5)$$

Solving equation (4) forward and substituting equation (5) into the result yields the firm’s intertemporal budget constraint:

$$Q_t E_t + B_t = \Omega_t + \sum_{s=1}^{\infty} \Omega_{t+s} / \prod_{u=1}^s r_{t+u}. \quad (6)$$

The firm maximizes the value of the outstanding stock of equity, taking interest rates, wages, the parameters of the corporate tax regime and the inherited stocks of debt, equity and capital as given. In this Modigliani-Miller world, the optimal capital structure (debt versus equity) is indeterminate in the absence of profit taxation and interest deductibility and there are corner solutions when they are present. Rather mechanically, we side-step this issue by assuming that the firm’s debt is a fraction of its capital stock:

$$B_t = \lambda K_t, \quad \lambda \in [0, 1]. \quad (7)$$

⁹ $K_t \geq 0$; $L_t \geq 0$; $f(0) = 0$; $\lim_{k \rightarrow \infty} f'(k) = 0$; $\lim_{k \rightarrow 0} f'(k) = +\infty$.

The first order conditions for K_t and L_t are:

$$f'(k_t) = R_t \equiv \frac{(r_t - 1 + \delta)(1 - \theta s) - \lambda \theta s^r (r_t - 1)}{1 - \theta} \quad (8)$$

$$w_t = f(k_t) - k_t f'(k_t). \quad (9)$$

Here R_t is the marginal cost of capital in period t . By equations (8) and (9) the equilibrium capital-labor ratio is a function solely of the exogenous cost of capital. Differentiating yields

$$\hat{k}_t = -\frac{\sigma_t}{1 - \alpha_t} \hat{R}_t, \quad \hat{w}_t = -\frac{\alpha_t}{1 - \alpha_t} \hat{R}_t, \quad (10)$$

where we use the notational convention that proportional rates of change are denoted by a caret, so that $\hat{x} = dx/x$, and where $\alpha \equiv kf'(k)/f(k)$, $\alpha \in (0, 1)$ is capital's competitive share of output and

$$\sigma_t \equiv d \ln k_t / d \ln \left(\frac{f(k_t) - k_t f'(k_t)}{f'(k_t)} \right) = -(1 - \alpha_t) f'(k_t) / (k_t f''(k_t)) > 0$$

is the elasticity of substitution between capital and labor, hereafter referred to as the elasticity of substitution.

It is assumed that aggregate employment is equal to the exogenous labor supply. It is further assumed that this labor supply is constant, and then without loss of generality, normalized to one. Then, equations (8) and (9) can be solved for the capital-labor ratio (and thus capital) and the real wage. We now turn to the Hassett-Summers debate. In the remainder of the Section we assume that the exogenous interest rate is a constant r .

No expensing of capital expenditure or interest

The social media contribution to the Hassett-Summers debate focuses on the case where there is no capital expenditure deductibility: $s = 0$. It also ignores the deductibility of interest: $s^r = 0$. We shall refer to this as the Hassett-Mankiw case (see Hassett (2017) and Mankiw (2017a,b)). In this case the cost of capital and the corporate tax are:

$$R_t = (r - 1 + \delta) / (1 - \theta) \quad (11)$$

$$T_t = \theta k_t f'(k_t). \quad (12)$$

Differentiating equation (11) yields $\hat{R}_t = d\theta / (1 - \theta)$. Substituting this into equation (10) yields

$$\hat{k}_t = -\frac{\sigma_t}{1 - \alpha_t} \left(\frac{d\theta}{1 - \theta} \right), \quad \hat{w}_t = -\frac{\alpha_t}{1 - \alpha_t} \left(\frac{d\theta}{1 - \theta} \right). \quad (13)$$

Thus, an increase (decrease) in the corporate tax rate increases (decreases) the cost of capital and, thus, decreases (increases) both the capital-labor ratio and the real wage.

Differentiating equation (12) and using equation (13) yields

$$\hat{T}_t = \frac{1 - \alpha_t - \sigma_t \theta}{\theta(1 - \alpha_t)} \left(\frac{d\theta}{1 - \theta} \right). \quad (14)$$

In the empirically reasonable case where the elasticity of substitution exceeds labor's share of output, $\sigma > 1 - \alpha$, corporate tax revenue is subject to a Laffer curve. An increase in the corporate tax rate increases corporate tax revenue up until $\theta = (1 - \alpha) / \sigma$, and then causes it to decrease. If the elasticity of substitution is less than labor's share of output, then there is no Laffer curve and corporate tax revenue is monotonically increasing in the corporate tax rate.

For the special case of the Cobb-Douglas production function, capital and labor's shares of output are constant and the elasticity of substitution is equal to one; hence, corporate tax revenue follows a Laffer curve. If we suppose that capital's share of output is about 40 percent, then increasing the corporate tax rate causes corporate tax revenue to go up until a corporate tax rate of about 60 percent and after that revenue begins to fall.¹⁰

The numbers in Table 1 are ratios of the change in wage income with respect to a change in the corporate tax to (minus one times) the change in corporate tax revenue with respect to the corporate tax. In using this model to check how reasonable they are, we might begin by using equations (13) and (14) to compute $\rho^{dd} := -(\partial w / \partial \theta) / (\partial T / \partial \theta)$. Both the effect of the tax rate change on the real wage and the effect on tax revenues are dynamic or long-run effects. The capital stock is endogenous and responds fully to the tax change. Note that with a constant interest rate, constant fiscal policy rules and no adjustment costs, the 'long run' or steady-state adjustment is achieved in a single period. Mankiw and Mulligan are also interested in the short-run impact on tax revenues. This can be interpreted as the impact of the unexpected announcement in period t (after the period t capital stock has been chosen) of a cut in the corporate profit tax rate in period t and afterwards, on period t corporate tax receipts. This short run effect on revenue, denoted $\frac{\partial T_t^s}{\partial \theta}$ is of course given

by $\frac{\partial T_t^s}{\partial \theta} = k_t^s f'(k_t^s)$ since the capital stock is, by assumption, held constant at $k_t = k_t^s$. The dynamic-static

Furman ratio can now be defined as $\rho^{ds} \equiv -(\partial w / \partial \theta) / (\partial T^s / \partial \theta)$. By equations (13) and (14), the dynamic-dynamic and dynamic-static Furman ratios are therefore given by:

$$\rho_t^{dd} = \frac{1 - \alpha_t}{1 - \alpha_t - \sigma_t \theta} \quad (15)$$

$$\rho_t^{ds} = \left(\frac{1}{1 - \theta} \right) \left(\frac{\alpha_t}{1 - \alpha_t} \right) \left(\frac{f(k_t) - k_t f'(k_t)}{k_t^s f'(k_t^s)} \right) = 1 / (1 - \theta) \text{ if } k_t^s = k_t \quad (16)$$

¹⁰ Labor's share of output declined from about two-thirds at the start of the 1960s to 56 percent in 2011Q4. It had increased to 58.4 percent by 2016Q4. See "Estimating the U.S. Labor Share," *Bureau of Labor Statistics*, Feb. 2017, online article, (<https://www.bls.gov> : accessed 5 Apr. 2018). There is no agreement on the size of the elasticity of substitution. Young (2013), Lawrence (2015), Herrendorf et al. (2017) and Chirinko and Mallinck (forthcoming) find it to be below one; Karabarounis and Neiman (2014) estimate it to be about 1.25; Piketty (2014) also estimates it to be greater than one.

Note that the simple version of the dynamic-static Furman ratio, $\rho^{ds} = 1 / (1 - \theta)$ requires that the capital-labor ratios in the dynamic and static calculations are the same. This will only be exactly correct for infinitesimal changes in the tax rate, not the change from 35 percent to 21 percent that was actually enacted. The theoretical values of the ratios given in Table 1 are therefore 1.54 when equation (16) is evaluated at $\theta = 0.35$ and 1.25 when equation (16) is evaluated at $\theta = 0.20$. Both numbers are well below 2.22, the lowest number in Table 1 – the Conservative Case for Full-time households.

For the special case of the Cobb-Douglas production function where capital's share of output is equal to 40 percent, the dynamic-dynamic Furman ratio is equal to about 2.40 when the corporate tax is equal to 35 percent and to about 1.5 when the corporate tax is equal to about 20 percent. A decrease in the corporate tax rate from 35 to 20 percent is associated with a ratio of the increase in wage income to the decrease in corporate tax revenue of between about 1.5 and 2.40. Independent of factor shares and the elasticity of substitution, the dynamic-static Furman ratio is equal to about 1.54 when the corporate tax is equal to 35 percent and to 1.25 when the corporate tax rate is 20 percent. Thus, an unanticipated decrease in the corporate tax rate from 35 to 20 percent is associated with a ratio of an increase in (long-run) wage income to the decrease in short-run tax revenue between about 1.25 and 1.54.

Clearly these numbers are lower than all but the most conservative in Table 1 and far lower than the ones of the optimistic scenario. The 'dynamic-dynamic' numbers are sensitive to the value of the elasticity of substitution, particularly for high tax rates. Even if the elasticity of substitution were as high as 1.25 and capital's share of output were about 40 percent, the dynamic-dynamic Furman ratio ranges from 2.4 to 3.69, still much lower than the even the lowest figure supported by the Optimistic Case

Expensing of Capital Expenditure

In what follows we only consider the dynamic –dynamic (capital-labor ratio endogenous) case. We now add the expensing of capital to the model. We assume that the shares of net investment and depreciation that can be expensed are constant and equal to s . Then by equation (2) corporate tax revenue is

$$T_t = \theta[K_t f'(K_t / L_t) - s(K_{t+1} - K_t) - s\delta K_t], \quad (17)$$

We now consider an unexpected permanent cut in the corporate profit tax rate in period t

By equation (8), the cost of capital is

$$R_t = \frac{(r-1+\delta)(1-\theta s)}{1-\theta} \quad (18)$$

Differentiating yields:

$$\begin{aligned} dR_t / d\theta &= (1-s)(r-1+\delta) / (1-\theta)^2 > 0 \text{ if } s < 1 \text{ and } r-1+\delta > 0 \\ &= 0 \text{ if } s = 1 \end{aligned} \quad (19)$$

The impact of a corporate tax change on the cost of capital, and hence on the real wage and capital-labor ratio, is smaller when capital expenditure can be deducted from the corporate profit tax base than when it cannot. If capital expenditure can be fully expensed ($s = 1$), then a change in the corporate tax has no effect on the cost of capital. In this case, the effect on long-run tax revenue is $\hat{T} = \hat{\theta}$. Comparing this with equation (14) it is seen that if capital expenditure can be fully expensed and there is a Cobb-Douglas production function corporate tax revenue is more sensitive to the corporate tax rate when capital expenditure is fully expensed than there is no expensing. Note that if there is more than 100% expensing of capital expenditure ($s > 1$) a lower corporate profit tax rate will result in capital shallowing. This is currently the case for certain kinds of capital expenditure in Italy.¹¹ A higher capital expenditure expensing share lowers the cost of capital and increases the capital-labor ratio if both the cost of capital and the corporate profit tax rate are positive:

$$dR_t / ds = -(r - 1 + \delta)\theta / (1 - \theta) \quad (20)$$

The impact effect of an unanticipated increase in the investment expensing share on tax revenues is obviously negative if the corporate profit tax rate is positive.¹² In the long run, the negative effect on corporate tax receipts of the higher deduction is at least partly offset by capital deepening (and may be turned into a positive effect if we are on the wrong side of the Laffer curve). For instance, if there is a Cobb-Douglas production function, then differentiating equation (2) with respect to the expensing share and using equations (10) and (19) yields:

$$\left. \frac{\partial T / \partial s}{T} \right|_{s=0} = \frac{\alpha\theta}{1 - \alpha} - \gamma, \quad \gamma = \delta k / f(k). \quad (21)$$

Expensing of Interest

We now consider the case of interest deductibility when there is also expensing of capital expenditure – the empirically relevant case for the USA, both before and after the tax reforms. Interest deductibility is of interest for capital expenditure only if borrowing and capital expenditure are linked. We achieve this by the ad-hoc requirement that λ , the ratio of the stock of corporate debt to the stock of capital is a positive constant. Assuming $(r - 1 + \delta)(1 - \theta s) - \lambda\theta s^r (r - 1) > 0$, the first-order condition for the optimal capital stock now is:

$$R = \frac{(r - 1 + \delta)(1 - \theta s) - \lambda\theta s^r (r - 1)}{1 - \theta}. \quad (22)$$

If $s = 1$, then equation (22) becomes

¹¹ See <http://taxsummaries.pwc.com/ID/Italy-Corporate-Deductions>.

¹² $\partial T_t^s / \partial s = \theta k_{t+1} (\alpha_t - 1 - \theta s \sigma_t) / (1 - \alpha_t)$.

$$R = r - 1 + \delta - \frac{\lambda \theta s^{rB} (r - 1)}{1 - \theta}. \quad (23)$$

If there were no borrowing ($\lambda = 0$), a cut in the corporate profit tax rate would have no effect on the capital-labor ratio. If capital expenditure has to be financed at least in part by borrowing, then the cost of capital is strictly decreasing in the corporate tax. A higher corporate tax rate increases the benefit to the firm of the interest deductibility and thus reduces the cost of capital. Thus, a cut in the corporate tax rate increases the cost of capital and decreases both the capital labor ratio and the real wage. Even if there is only partial expensing of capital expenditure, a cut in the corporate tax rate can have a negative effect on the capital-labor ratio and the real wage if the allowed expensing shares are sufficiently large. If λ , θ and $r - 1$ are positive, the reduction in the degree of deductibility of interest in the tax reform of December 2017 raised the cost of capital. It reduced the magnitude of the positive effect on the cost of capital of the cut in the corporate tax rate.

3. Corporate Tax Cuts in a Closed Economy with an Endogenous Interest Rate

The formal model we use is a discrete-time version of the Yaari-Blanchard OLG model or “perpetual youth” model, without intergenerational gift and bequest motives.¹³ It is presented in Appendix 1. The attraction of this model is that it has, in general, aggregate demand effects working through household consumption or public consumption from a cut in the corporate tax rate even when we consider a balanced-budget corporate tax cut, but also has the representative agent model without any such aggregate demand effects working through consumption in the special case where the birth rate is zero. In this special case, in steady state, the real interest rate is pegged by the subjective rate of time preference case, which therefore corresponds to the constant real interest rate analysis of Section 2 of this paper. We consider the constant population case of the model (equal and constant birth and death rates) for notational simplicity.

We assume a balanced-budget rule so that the government’s budget constraint is

$$\tau_t^H = g - \tau_t, \quad (24)$$

where g is exogenous (constant) government spending per capita and τ_t^H is the per capita lump-sum tax on households at time t . Goods market clearing is given by

$$f(k_t) = c_t + g_t + k_{t+1} - k_t + \delta k_t. \quad (25)$$

Where c_t is per capita household consumption at time t .

In what follows we assume that labor costs are fully deductible and we consider two cases of the profit tax. The first case has no deductibility/expensing of capital expenditure and depreciation. The corporate profit tax function is therefore given by:

$$\tau_t = \theta [f(k_t) - w_t] = \theta k_t f'(k_t). \quad (26)$$

¹³ See Yaari (1965), Blanchard (1985), Weil (1985), Frenkel and Razin (1987) and Buiter (1990)).

The second case has full expensing of gross capital formation. The corporate profit tax function for this case is given by:

$$\tau_t = \theta [f(k_t) - w_t - k_{t+1} + (1 - \delta)k_t]. \quad (27)$$

Equations, (A.7), (A.8) and (A.10) in Appendix 1 permit us to derive the first-order difference equation for aggregate consumption given in equation (28); $q^{-1} = \frac{1}{1 + \mu} = \frac{1}{1 + \beta}$, $0 < 1 \leq 1, 0 \leq \mu, \beta$ where μ is the mortality rate or death rate, β is the birth rate, $\pi > 0$ is 1 plus the pure rate of time preference and a_t is financial wealth held at the beginning of period t .

$$c_{t+1} = \left[r_{t+1} \left(q^{-1} - \left(\frac{\pi - q}{\pi} \right) \right) - 1 \right] c_t + (q - 1) \left(\frac{\pi - q}{\pi q} \right) r_{t+1} (a_t + w_t - \tau_t^H). \quad (28)$$

When $q = 1$ (the representative agent special case associated with a zero birth rate), this simplifies to:

$$c_{t+1} = \frac{r_{t+1}}{\pi} c_t \quad (29)$$

In this case we have the familiar result that in the steady state the real interest rate equals the rate of time preference: $r = \pi$.

As shown in Appendix 1, aggregate consumption is linear in total wealth, $a + h$, where h is human capital, defined as the present discounted value of the future after-tax labor income of all households/workers currently alive (equations (33) and (35)). Aggregate demand effects from a balanced budget corporate tax cut when the birth rate is positive are the result of future lump-sum taxes on labor being paid in part by generations yet to be born. These taxes therefore will not impact current consumption.

Without expensing of capital formation, the stationary equilibrium is given by:

$$\tau = \theta k f'(k) \quad (30)$$

$$f'(k) = R \equiv \frac{r - 1 + \delta}{1 - \theta} \quad (31)$$

$$w = f(k) - k f'(k). \quad (32)$$

$$c = \left(\frac{\pi - q}{\pi} \right) (a + h) \quad (33)$$

$$a = \left(\frac{r}{1 - r} \right) (w - c - \tau^H) \quad (34)$$

$$h = \left(\frac{r}{r-q} \right) (w - \tau^H) \quad (35)$$

$$\tau + \tau^H = g \quad (36)$$

$$f(k) = c + g + \delta k. \quad (37)$$

From equations (30) to (37), we obtain the following two equations which determine the steady-state value of the capital-labor ratio and the interest rate for $q < 1$:

$$f(k) - \delta k - g = \left(\frac{\pi - q}{\pi q} \right) \left(\frac{r}{q^{-1}r - 1} \right) \left\{ f(k) - g - \delta k + \frac{q^{-1}(1-q)(1-\theta)kf'(k)}{q^{-1}r - 1} \right\} \quad (38)$$

$$r = (1-\theta)f'(k) - \delta + 1 \quad (39)$$

Note that, if $g = 0$, there always is an ‘extinction equilibrium’ in this model, that is an equilibrium in which $k = 0$.¹⁴

When $q = 1$ equations (38) and (39) are replaced by

$$(1-\theta)f'(k) + 1 - \delta = \pi \quad (40)$$

and

$$r = \pi \quad (41)$$

The tedious and not fully qualitatively conclusive algebra of the long-run comparative statics is given in Appendix 2. We next present some numerical calibrations:

Consider, for instance, a numerical example with the following parameter values and production function specification: $y = Ak^\alpha$; $A = 1.00$; $\alpha = 0.33$; $q^{-1} = 1.02$; $\delta = 0.05$; $\pi = 1.04$; $\bar{g} = 0$. We compute steady state equilibria for the following three values of the corporate profit tax rate: $\theta_1 = 0$; $\theta_2 = 0.21$; $\theta_3 = 0.35$.

This yields the following results for the capital-labor ratio and the real interest rate:

$$\theta = 0; \quad k \approx 6.39; \quad r - 1 \approx 0.0452$$

$$\theta = 0.21; \quad k \approx 4.58; \quad r - 1 \approx 0.0441$$

$$\theta = 0.35; \quad k \approx 3.47; \quad r - 1 \approx 0.0432$$

As expected, a lower corporate profit tax rate (absent full expensing of investment) results in a higher steady-state capital-labor ratio. A lower profit tax rate also raises the real interest rate: the lower corporate tax rate is not fully offset by the lower marginal product of capital associated with a higher capital intensity of production..

¹⁴ The full extinction equilibrium is characterized by: $k = a = h = w = \tau^P = \tau^H = 0$; $r = +\infty$.

Raising the depreciation rate to 10% ($\delta = 0.10$) and keeping the other parameter values unchanged yields the following results for the capital-labor ratio and the real interest rate:

$$\theta = 0; \quad k \approx 3.46; \quad r - 1 \approx 0.0437$$

$$\theta = 0.21; \quad k \approx 2.46; \quad r - 1 \approx 0.0426$$

$$\theta = 0.35; \quad k \approx 1.85; \quad r - 1 \approx 0.0420$$

Raising the share of labor in GDP to 75% ($\alpha = 0.25$) and keeping the other parameter values the same as in the first numerical example yields the following results for the capital-labor ratio and the real interest rate:

$$\theta = 0; \quad k \approx 3.57; \quad r - 1 \approx 0.0463$$

$$\theta = 0.21; \quad k \approx 2.75; \quad r - 1 \approx 0.0425$$

$$\theta = 0.35; \quad k \approx 2.45; \quad r - 1 \approx 0.0330$$

Because in our numerical examples the real interest rises when the corporate profit tax rate is cut, the impact of a lower tax rate on the capital-labor ratio, while still positive, is less than that obtained in the constant interest rate model of Section 2.

The representative agent special case

Equation (40) characterizes the steady-state capital-labor ratio in the representative agent special case ($q = 1$) It follows that, when $q = 1$,

$$\frac{dk}{d\theta} = \frac{f'(k)}{(1-\theta)f''(k)} < 0 \quad (42)$$

Equation (42) gives the familiar negative effect of a change in the corporate profit tax rate on the steady-state capital labor ratio for this case (consistent with Section 2).

Steady-state consumption when $q = 1$ is then derived from

$$c = f(k) - g - \delta k \quad (43)$$

with

$$\frac{dc}{d\theta} = \frac{(f'(k) - \delta)f'(k)}{(1-\theta)f''(k)} < 0 \text{ iff } f'(k) - \delta > 0 \quad (44)$$

Even though all profit taxes are ‘refunded’ to the representative household as lump-sum transfer payments, a higher profit tax rate lowers the steady-state capital-labor ratio and thus, if the economy is dynamically efficient, reduces steady-state per capita consumption, through the familiar supply side incentive effects. All results from Section 2 of this paper about the model with the exogenous real interest rate go through for this ‘representative agent’ model. With full expensing of capital expenditure, a cut in the corporate profit tax rate will have no long-run effect on the capital-labor ratio and the real wage. With full expensing of capital expenditure and some degree of expensing of interest payments, a cut in the corporate profit tax rate will lower the long-run capital-labor ratio and real wage, if capital expenditure is financed at least in part by borrowing.

Full expensing of capital expenditure

With full expensing of capital expenditure all steady state equilibrium conditions except for equation (31) remain the same. Equation (31) is replaced by:

$$r = f'(k) + 1 - \delta \quad (45)$$

The steady-state capital-labor ratio and interest rate are now determined by:

$$f(k) - \delta k - g = \left(\frac{\pi - q}{q\pi} \right) r \left\{ \left[\frac{f(k) - g}{q^{-1}r - 1} \right] - \left[\frac{\delta k}{q^{-1}(r - 1)} \right] + \frac{q^{-1}(1 - q)(1 - \theta)kf'(k)}{\left[q^{-1}r - 1 \right] \left[q^{-1}(r - 1) \right]} \right\} \quad (46)$$

$$r = f'(k) - \delta + 1 \quad (47)$$

Note that the corporate profit tax rate only enters equations (46) and (47) through the 'aggregate demand effect' of the redistribution between owners of capital and all households/workers currently alive.

Making the same assumptions as before, the impact on the capital-labor ratio of a higher corporate tax rate with full expensing of investment is positive. This reflects the absence of any incentive effects and the presence of a particular kind of consumption demand effect, as discussed below. Our numerical examples support this proposition.

Using some of the same parameter values that we used before, let

$A = 1.0$; $\alpha = 0.33$; $q^{-1} = 1.02$; $\delta = 0.05$; $\pi = 1.04$; $\bar{g} = 0$. We obtain the following results for the three tax rates:

$$\theta = 0; \quad k \approx 6.39; \quad r - 1 \approx 0.0452$$

$$\theta = 0.21; \quad k \approx 6.63; \quad r - 1 \approx 0.0432$$

$$\theta = 0.35; \quad k \approx 6.81; \quad r - 1 \approx 0.0414$$

When we raise the depreciation rate to 10 percent ($\delta = 0.10$) keeping all other parameter values constant we get:

$$\theta = 0; \quad k \approx 3.46; \quad r - 1 \approx 0.0437$$

$$\theta = 0.21; \quad k \approx 3.56; \quad r - 1 \approx 0.0409$$

$$\theta = 0.35; \quad k \approx 3.63; \quad r - 1 \approx 0.0391$$

Lowering capital's share to 25% ($\alpha = 0.25$), with all other parameter values the same as in our first numerical exercise yields:

$$\theta = 0; \quad k \approx 3.57; \quad r - 1 \approx 0.0463$$

$$\theta = 0.21; \quad k \approx 3.68; \quad r - 1 \approx 0.0441$$

$$\theta = 0.35; \quad k \approx 3.75; \quad r - 1 \approx 0.0428$$

In the constant interest rate model of Section 2, there was no impact of a cut in the corporate profit tax rate on the capital intensity of production if there is also full expensing of capital expenditure. When the interest rate is endogenous, a cut in the corporate profit tax rate lowers the capital-labor ratio and raises the interest rate. The reason for this is that although, with full expensing of capital expenditure, the corporate profit tax rate does not affect the incentive to invest, the tax cut will impact household demand when g is exogenous and the corporate profit tax receipts are used to lower (lump sum) taxes on labor income; it would impact government demand if the government were to spend the proceeds of the corporate profit tax on purchases of real goods and services.

The demand effect of a corporate tax cut

Because of the OLG nature of the model (when $q < 1$) a cut in corporate taxes with higher lump-sum taxes on workers ensuring continued budget balance (exogenous g) will boost household consumption at a given interest rate and real wage. Consider a permanent corporate tax cut and assume, counterfactually, that neither the real interest rate nor the capital-labor ratio change. The corporate profit tax cut raises the value of these households' per capita financial assets by the capitalized value of this tax cut: $\frac{r}{1-r} \Delta \tau^P > 0$ (see equation (34)). All future corporate tax cuts are (in PDV terms) owned by those alive today. The impact on household per

capita consumption demand is $\left(\frac{\pi - q}{\pi}\right) \left(\frac{r}{1-r}\right) \Delta \tau^P > 0$.

By our balanced budget assumption, per capita (lump-sum) taxes on those households alive at the time of the corporate profit tax cut and subsequently increase each period by the same amount that the corporate profit tax falls: $\Delta \tau^H = -\Delta \tau^P > 0$. These lump-sum taxes are born equally by all those alive at the time the taxes are paid. That means that the share of these future taxes that will be paid by future generations that are not yet born (if $q < 1$), does not reduce the human capital of those currently alive. These are the only households that spend – the unborn don't consume or pay taxes. The PDV of the increase in future lump-sum taxes that will fall on those currently alive is $\frac{r}{r-q} \Delta \tau^H < 0$ (see equation (35)). . The impact on per capita consumption

is $-\left(\frac{\pi - q}{\pi}\right) \left(\frac{r}{r-q}\right) \Delta \tau^H = \left(\frac{\pi - q}{\pi}\right) \left(\frac{r}{r-q}\right) \Delta \tau^P < 0$ if $r > q$.

The net impact on household consumption demand of a permanent profit tax cut and a matching increase in lump-sum taxes on households, at a given real interest rate and real wage is therefore:

$$\Delta c = -\left(\frac{\pi - q}{\pi}\right) \left(\frac{r(q^{-1} - 1)}{(r-1)(rq^{-1} - 1)}\right) \Delta \tau^P \quad (48)$$

This is positive (for negative $\Delta \tau^P$) if viable Ponzi finance is ruled out ($r > 1$, which implies $r > q$). Thus, when $q < 1$ a balanced budget corporate tax cut will, *ceteris paribus*, boost household consumption demand.

The marginal propensity to consume out of comprehensive wealth, $\frac{\pi - q}{\pi}$, is independent of the real interest

rate. If $D(k) > S(k)$ the steady-state capital-labor ratio will have to fall and the real interest will have to rise to restore equilibrium following a corporate profit tax rate cut.

The conclusion that *cet. par.* a cut in the corporate profit tax rate boosts demand when tax receipts are refunded to workers as lump-sum transfers/tax cuts is dependent on the assumptions that all surviving households, regardless of age, have the same marginal propensity to consume, $\frac{\pi - q}{\pi}$, out of their comprehensive wealth (because they all have the same life expectancy, $\frac{q}{1 - q}$), and that they have access on the same terms to perfect capital markets.

It clearly makes empirical sense to assume that the beneficiaries of the cut in the profit tax (in a more realistic model that would be the old and the rich) have a lower marginal propensity to consume out of current disposable income than those who pay the lump-sum tax on labor income. In the model under consideration, this feature could be introduced by assuming that some fraction ϕ , $0 < \phi < 1$ of all surviving households and future households yet to be born always spends its entire disposable income, $w - \tau^H$ while the remaining fraction $1 - \phi$ follows the comprehensive wealth or permanent-income-driven consumption behavior characteristic of all consumers in our formal model. The “Keynesian”, current-disposable-income-constrained households never accumulate any financial wealth and therefore don’t benefit from the corporate profit tax cut. They do, however, pay the lump-sum tax on labor income. The resulting steady-state consumption equation becomes now:

$$c = (1 - \phi) \left(\frac{\pi - q}{\pi} \right) \left(a + \frac{r}{r - q} (w + \tau^P) \right) + \phi (w + \tau^P) \quad (49)$$

A sufficiently high value of ϕ will ensure that a corporate tax cut will depress aggregate consumption, *cet. par.*, that is, for a given real interest rate, wage rate and capital-labor ratio.

Note that if changes in corporate profit tax receipts are reflected one-for-one in changes in public spending on real goods and services, there still are, in general, demand effects from a cut in the corporate profit tax rate, even with full expensing of capital expenditure. For simplicity assume there are no lump-sum taxes paid by households at all, so $\tau^H = 0$ and $g = \theta k f'(k)$. With the corporate profit tax rate exogenous, real public spending now is endogenous. Equation (46) becomes:

$$f(k) - \delta k - \theta k f'(k) = \left(\frac{\pi - q}{\pi q} \right) r \left[\frac{(q^{-1} - 1) k f'(k)}{q^{-1}(r - 1)(q^{-1}r - 1)} + \frac{f(k)}{q^{-1}r - 1} + \left(\frac{\delta k - \theta k f'(k)}{q^{-1}(r - 1)} \right) \right] \quad (50)$$

The neutrality proposition, that with full expensing of capital expenditure, a cut in the corporate profit tax rate does not affect the capital-intensity of production, requires that there be no demand effect from the corporate tax rate cut. When $q < 1$ there always is a positive demand effect if the corporate tax cut is funded by an increase in lump-sum taxes on households. When the corporate profit tax cut is funded by a cut in public sector

purchases, equation (50) tells us that this will be neutral if $1 = \left(\frac{\pi - q}{\pi} \right) \frac{r}{(r-1)}$: the household's marginal propensity to consume out of a permanent cut in profit taxes equals one. This condition is automatically satisfied when $q = 1$.

A sufficiently high value of $\frac{\pi - q}{\pi}$ will result in total (private plus public) demand for consumption goods being higher, *cet. par*, at a lower corporate tax rate. In this case, the permanent cut in the profit tax rate boosts household consumption by more than the full amount of the cut in profit tax payments by firms, at the predetermined capital-labor ratio. Public spending, however falls by the same amount as the cut in profit tax receipts of the government; at the inherited capital-labor ratio, the change in public spending is given by: $dg = kf'(k)d\theta$. Thus aggregate demand is boosted and, given our earlier assumptions, a lower capital-labor ratio results - again for reasons that have nothing to do with the marginal incentive effects on capital expenditure of a cut in the corporate profit tax rate.

(4) Conclusion

The familiar proposition that a cut in the corporate profit tax rate boosts the capital intensity of production and the real wage is sensitive to a number of key assumptions. Even when the real interest rate is exogenously given, full deductibility of capital expenditure from the corporate profit tax base will result in no impact of a corporate profit tax rate cut on the incentive to invest. Adding deductibility of interest can result in a negative effect on the capital intensity of production of a corporate profit tax rate cut.

When the real interest rate is endogenous, a simple OLG model demonstrates that the effects on consumption demand of a corporate profit tax cut will reduce the impact on capital intensity of a corporate profit tax cut if the tax cut is funded by higher lump-sum taxes on 'permanent income' households. Alternative funding rules (e.g. lower public consumption purchases) and the introduction of "Keynesian" consumers could lead to a larger positive effect on capital intensity from a cut in the corporate profit tax rate.

Appendix 1. The perpetual youth overlapping generations model of Yaari and Blanchard

In period zero there is a unit interval of consumers. Each period a constant fraction $1 - q \in (0, 1]$ of the consumers die and a fraction $1 - q$ are born. Thus, the population size remains constant at one.¹⁵ When $q = 1$, the model becomes a representative agent model and is thus the model of Section 2.

Consumers consume the single capital-consumption good and supply labor inelastically. Thus, the labor supply is equal to the population. A consumer born at time s and alive at time $t \geq s$, has expected utility at time t represented by:

¹⁵ An earlier version of the paper allowed for population growth. This is straightforward but added to the notation and had little impact on our results.

$$\sum_{u=0}^{\infty} (q/\pi)^u \ln \bar{c}_{t-s,t+u}, \quad (\text{A.1})$$

where $\bar{c}_{t-s,t+u}$ is the consumption in period $t+u$, $u \geq 0$ of a household born in period $t-s$, $s \geq 0$ if it is still alive in that period and $\pi - 1 > 0$ is constant subjective rate of time preference.

It is assumed that there is a competitive annuities market. In period t all consumers born before or in period $t-1$ receive a (gross) return r_t/q on their savings if they are alive in period t and their savings accrue to the life insurance company if they die. Thus, life insurance companies make zero profits and the consumer's within-period budget constraint is:

$$\bar{a}_{t-s,t+u+1} = (r_{t+u+1}/q)(\bar{a}_{t-s,t+u} + w_{t+u} - \tau_{t+u}^H - \bar{c}_{t-s,t+u}), \quad (\text{A.2})$$

where $\bar{a}_{t-s,t+u}$ is his financial wealth at the beginning of period $t+u$ and τ_{t+u}^H is a lump-sum time- $t+u$ tax on consumers. Initial financial wealth is given and assumed to be zero: $\bar{a}_{t,t} = 0$.

Consumers maximize (A.1) subject to (A.2) and the no-Ponzi finance terminal condition:

$$\lim_{T \rightarrow \infty} \frac{q^T \bar{a}_{t-s,t+T}}{\prod_{s=1}^T r_{t+s}} \geq 0. \quad (\text{A.3})$$

Necessary and sufficient conditions for an optimum are equations (A.2), (A.3) with equality and

$$\bar{c}_{t-s,t+u} = r_{t+u} \bar{c}_{t-s,t+u-1} / \pi. \quad (\text{A.4})$$

Solving equation (A.2) forward and substituting in (A.3) (with equality) and (A.4) (solved backwards) yields

$$\frac{\pi \bar{c}_{t-s,t+u}}{\pi - q} = \bar{a}_{t-s,t+u} + w_{t+u} - \tau_{t+u}^H + \sum_{v=1}^{\infty} \frac{q^v (w_{t+u+v} - \tau_{t+u+v}^H)}{\prod_{s=1}^v r_{t+u+s}}. \quad (\text{A.5})$$

At time t there are $(1-q)q^s$ consumers alive that were born at time $t-s$. Thus, aggregate consumption and savings are given by:

$$c_{t+u} = \begin{cases} (1-q) \sum_{s=0}^{\infty} q^{t+u-s} \bar{c}_{t-s,t+u} & \text{if } q < 1 \\ \bar{c}_{0,t+u} & \text{if } q = 1 \end{cases}, \quad a_{t+u} = \begin{cases} (1-q) \sum_{s=0}^{\infty} q^{t+u-s} \bar{a}_{t-s,t+u} & \text{if } q < 1 \\ \bar{a}_{0,t+u} & \text{if } q = 1 \end{cases}. \quad (\text{A.6})$$

By equations (A.2) and (A.6),

$$a_{t+1} = r_{t+1}(a_t + w_t - \tau_t^H - c_t). \quad (\text{A.7})^{16}$$

By equations (A.5) and (A.6),

$$c_t = \frac{(\pi - q)(a_t + h_t)}{\pi}, \quad (\text{A.8})$$

$$h_t = w_t - \tau_t^H + \sum_{u=1}^{\infty} \frac{q^u (w_{t+u} - \tau_{t+u}^H)}{\prod_{s=1}^u r_{t+s}} \quad (\text{A.9})$$

From the definition in equation (A.9),

$$h_{t+1} = (r_{t+1} / q)(h_t - w_t + \tau_t^H). \quad (\text{A.10})$$

Appendix 2: The steady-state comparative statics

Substituting equation (39) into equation (38) and totally differentiating, the effect of a change in the corporate profit tax rate on the steady-state capital-labor ratio is for $q < 1$ given by:

$$\frac{dk}{d\theta} = \frac{\alpha_1}{\alpha_2} \quad (\text{A.11})$$

$$\alpha_1 = \frac{(\pi - q)}{\pi q} f'(k) \left[\frac{f(k) - g}{(q^{-1}r - 1)^2} - \frac{\delta k}{q^{-1}(r - 1)^2} + \right. \\ \left. \frac{(q^{-1} - 1)(1 - \theta)(q^{-1}r^2 - 1)kf'(k)}{q^{-1}(q^{-1}r - 1)^2(r - 1)^2} - \frac{r(q^{-1} - 1)k}{q^{-1}(q^{-1}r - 1)(r - 1)} \right] \quad (\text{A.12})$$

$$(\text{A.13})$$

¹⁶ Note that $a_t = Q_t E_t + B_t$

$$\alpha_2 = f'(k) - \delta$$

$$-\left(\frac{\pi - q}{\pi q}\right) \left\{ (1 - \theta) f''(k) \left[-\left(\frac{(f(k) - g)}{(q^{-1}r - 1)^2} - \frac{\delta}{q^{-1}(r - 1)^2} k\right) - \frac{(q^{-1} - 1)(1 - \theta)kf'(k)}{(q^{-1}r - 1)^2 q^{-1}(r - 1)^2} (q^{-1}r^2 - 1) \right] + r \left[\frac{f'(k)}{q^{-1}r - 1} - \frac{\delta}{q^{-1}(r - 1)} + \frac{(q^{-1} - 1)(1 - \theta)(f'(k) + kf''(k))}{(q^{-1}r - 1)q^{-1}(r - 1)} \right] \right\} \quad (\text{A.14})$$

Further assumptions

The assumptions that follow are satisfied in the numerical examples we provide below.

The condition for dynamic efficiency is $f'(k) > \delta$. We assume it holds. $r > 1$ is the condition ruling out viable Ponzi finance. We assume it holds. Note that, since $q \leq 1$, $r > 1$ implies $q^{-1}r - 1 > 0$ and

$q^{-1}r^2 - 1 > 0$. The term $\frac{f'(k)}{q^{-1}r - 1} - \frac{\delta}{q^{-1}(r - 1)}$ becomes $\left(\frac{1}{r - 1}\right)(f'(k) - \delta) > 0$ when $q = 1$ and the

conditions for dynamic efficiency and no viable Ponzi finance hold. We assume $\frac{f'(k)}{q^{-1}r - 1} - \frac{\delta}{q^{-1}(r - 1)} > 0$ in

what follows. The term $-\left(\frac{(f(k) - g)}{(q^{-1}r - 1)^2} - \frac{\delta}{q^{-1}(r - 1)^2} k\right)$ becomes

$-\left(\frac{1}{r - 1}\right)^2 (f(k) - g - \delta k) = -\left(\frac{1}{r - 1}\right)^2 c \leq 0$ when $q = 1$. We assume

$-\left(\frac{(f(k) - g)}{(q^{-1}r - 1)^2} - \frac{\delta}{q^{-1}(r - 1)^2} k\right) < 0$ in what follows. The term $f'(k) + kf''(k)$ is in general ambiguous in

sign. In the Cobb-Douglas case, with $f(k) = Ak^\alpha$, $A > 0$; $0 < \alpha < 1$, we have $f'(k) + kf''(k) = k^{\alpha - 1} > 0$. We assume $f'(k) + kf''(k) > 0$ in what follows.¹⁷

Given these assumptions, the sum of the first three terms of α_1 is positive. These can be viewed as reflecting the incentive effects of a change in the corporate profit tax rate on the capital stock, working through the after-tax rate of return on capital. The last term of α_1 is negative. This last term represents the aggregate demand effect of a higher corporate tax rate, funded through a cut in lump-sum taxes on households. We discuss this below. With no expensing of capital expenditure, all numerical examples we considered have $\alpha_1 > 0$. This is obviously the case when $q = 1$ and the last term of α_1 vanishes. Even a high depreciation rate like $\delta = 0.20$ or public spending equal to half of GDP ($g = 0.5f(k)$) does not reverse the sign of α_1 .

¹⁷ From the definition of the elasticity of substitution it follows that $f'(k) + \left(\frac{\sigma}{1 - \alpha}\right)kf''(k) = 0$.

What about the sign of α_2 ? Decompose α_2 as follows: $\alpha_2 = S(k) - D(k)$, where $S(k) \equiv f'(k) - \delta$ and

$$D(k) \equiv \left(\frac{\pi - q}{\pi q} \right) \left\{ (1 - \theta) f''(k) \left[\begin{array}{l} - \left(\frac{(f(k) - g)}{(q^{-1}r - 1)^2} - \frac{\delta}{q^{-1}(r - 1)^2} k \right) \\ - \frac{(q^{-1} - 1)(1 - \theta)kf'(k)}{(q^{-1}r - 1)^2 q^{-1}(r - 1)^2} (q^{-1}r^2 - 1) \end{array} \right] \right. \\ \left. + r \left[\frac{f'(k)}{q^{-1}r - 1} - \frac{\delta}{q^{-1}(r - 1)} + \frac{(q^{-1} - 1)(1 - \theta)(f'(k) + kf''(k))}{(q^{-1}r - 1)q^{-1}(r - 1)} \right] \right\}.$$

Given dynamic efficiency, $S(k) > 0$. Given the further assumptions we made, $D(k) > 0$. The term $S(k)$ measures the effect of a small increase in the capital-labor ratio on the steady-state per capita *supply* of consumer goods. The term $D(k)$ measures the effect of a small increase in the capital-labor ratio on the steady-state per capita *demand* for consumer goods. We consider it intuitively plausible that $D(k) > S(k)$, in part because the supply effect of a higher capital stock is subject to diminishing returns. If we make this assumption, $\alpha_2 < 0$ and $\frac{dk}{d\theta} < 0$: a higher corporate profit tax rate reduces the steady-state capital-labor ratio. Although we cannot claim that there exist no reasonable functional forms and parameter values for the production function and utility function that would support the opposite result, all our numerical solutions for the model have supported $\frac{dk}{d\theta} < 0$ when there is no expensing of capital expenditure.

For the case of full expensing of capital expenditure, given in equations (46) and (47), it is easily checked that:

$$\frac{dk}{d\theta} = \frac{\bar{\alpha}_1}{\bar{\alpha}_2} \quad (\text{A.15})$$

where

$$\bar{\alpha}_1 = -r \left(\frac{\pi - q}{\pi q} \right) \left(\frac{(1 - q)kf'(k)}{(q^{-1}r - 1)(r - 1)} \right) \quad (\text{A.16})$$

$$\bar{\alpha}_2 = \alpha_2 \quad (\text{A.17})$$

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