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N.9
2015

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ISBN 978-88-458-1836-3

Computing Effective Tax Rates in presence of Non-linearity in Corporate Taxation [1]

Antonella Caiumi [2], *Lorenzo Di Biagio* [3], *Marco Rinaldi* [4]

Sommario

Questo articolo presenta il calcolo delle aliquote effettive di imposta forward-looking *utilizzando l'approccio di Devereux–Griffith in presenza di limiti alla deducibilità e riporti in avanti delle quote non dedotte di specifiche componenti della base imponibile. Per quanto ne sappiamo questo è il primo contributo su questo tema. Più precisamente vengono misurati gli effetti sull'incentivazione agli investimenti di un limite alla deducibilità degli interessi basato sull'EBITDA (utili prima degli interessi, delle imposte e degli ammortamenti) della società. Si mostra come l'approccio di Devereux–Griffith possa essere impiegato anche in questo caso specifico e si calcola il cuneo d'imposta al variare dei coefficienti di ammortamento e del tasso di interesse. Inoltre, in presenza di un regime d'imposta del tipo ACE, si analizzano le implicazioni sulle scelte di finanziamento dell'impresa associate alla introduzione della limitazione alla deducibilità degli interessi. Più in generale, è stato predisposto uno specifico programma per il calcolo delle aliquote effettive d'imposta per qualsiasi forma, anche non lineare, della funzione del prelievo fiscale sui profitti.*

Parole Chiave: Tassazione societaria; Costo del capitale; Aliquote effettive di imposta; Metodologia di Devereux–Griffith; Deducibilità degli interessi; Aiuto alla crescita economica.

Abstract

The focus of this paper is how forward-looking effective tax rates can be computed in the presence of ceilings and carryovers in the taxable base using the Devereux–Griffith approach. As far as is known, this is the first contribution on this issue. More specifically, the paper examines the impact on investment incentives of a new treatment of interest expense which sets a ceiling, defined in terms of the firm's EBITDA, on net deductible interest expense allowing both non-deductible interests and unused EBITDA carryovers. The effects that interest deduction caps have on effective tax rates are not at all negligible. Further, the analysis illustrates the implications of the limitation on interest deductibility on the choice of funding by comparing alternative tax regime: a profit tax and an allowance for corporate equity (ACE) tax regime. Finally, a toolkit that allows to tackle any form of non-linear tax liabilities function is developed.

Keywords: Corporate taxation; Cost of capital; Effective tax rates; Devereux–Griffith methodology; Interest deductibility rules; Allowance for corporate equity.

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[1] Paper presented at the "Giornate della ricerca in Istat 2014", 10th-11th of November 2014, Roma, Italy. The views expressed in this paper are those of the authors and do not necessarily represent the institutions with which they are affiliated. Any errors or mistakes remain the authors' sole responsibility.

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Contents

1. Introduction

A country's tax regime is a key policy instrument that may negatively or positively influence investments. Policy analysts should regularly assess the tax burden on profits to determine whether the tax system is supportive of business investments. Forward-looking approaches are designed to capture incentives to undertake new investment projects and involve computing the effective tax burden for hypothetical future investment projects using statutory features of the tax regimes. These approaches are suitable for international comparisons and are tailored to disentangle the effects of specific provisions of the tax legislation, by providing an indication of general patterns of tax incentives to investments.

The most commonly used forward-looking concepts for analyzing the impact of taxation on investment behaviour are the Effective Marginal Tax Rate (EMTR) and the Effective Average Tax Rates (EATR). Originally proposed by King and Fullerton (1984), the EMTR captures the effect of the legislative tax parameters on an incremental business activity and shows how much to invest on the margin given a diminishing expected return on investment. The EATR, further developed by Devereux and Griffith (1998, 2003), summarizes the proportion of the expected total profits taken in taxes and shows the effect of the tax regime on a total investment project (national or international). This latter indicator is a more suitable measure than the EMTR for a highly profitable multinational to adopt when deciding where to invest, and a more general tax burden indicator in the analysis of the international location of capital.

Methods for computing EMTR and EATR have been extensively used in recent years to compare the effective tax rates levied on capital income from different domestic investments over time and across countries (OECD 1991, EEC 2001, Devereux et al. 2009, Bilicka et al. 2011, OECD 2013, Suzuki 2014, Spengel et al. 2014). Main statutory provisions usually taken into account in forward-looking tax burden indicators include – beyond statutory tax rates – capital depreciation allowances, cost allowance from taxable base, tax credits, the interest expense deducibility and so on. However, the synthetic measures computed so far do not allow to fully capture the complexity and heterogeneity of tax incentive schemes. For example, the tax burden consequences of carryovers schemes (i.e., losses carry forward or carry back, tax allowances carry forward) or the presence of ceilings on the deductibility of interest expense are typically ignored in this kind of analysis.

This paper contributes to fill the gap by extending the computation of effective marginal and average tax rates to incorporate earning-stripping style rules which introduce non-linearity in the tax liability function. New rules on interest deduction limitations have been recently enacted or proposed in several jurisdictions. Some of them apply only to potentially abusive situations, such as related party debt or the financing of shareholdings benefiting from a participation exemption. In this cases limitations are designed to avoid artificial allocation of financial resources within a group of companies aimed at reallocating income and expense within the group in order to benefit from tax arbitrage among jurisdictions with different tax rates and regulations, or between companies with and without tax credits. Other restrictions are in principle broader in scope being part of base broadening reforms and extended to all taxpayers. For example Germany, Italy and Spain, have recently overhauled their interest deduction rules based on a debt-to-equity test in favor of more effective interest barrier rules that allow interest deduction up to a fixed interest to income ratio.[5] The majority of countries which currently seek to address base erosion and profit shifting are also considering similar modifications (OECD, 2015). Recent theoretical and empirical findings also argue the relevance of interest deductibility rules in a tax competition environment (Altshuler and Grubert 2006, Haufler and Runkel 2012).

In particular, in this paper we develop the case of an interest deductibility rule that sets a ceiling on net deductible interest at a fixed percentage of EBITDA in each period allowing both non-deductible interests and unused EBITDA carry forwards. Because of non-linearity in the tax liability function it is no longer possible to compute the cost of capital separately for each asset and source of finance and then just take a weighted mean. We closely follow the Devereux–Griffith conceptual framework, however we rely on an additional assumption. Specifically, we assume that when the new treatment

[5] Detailed description of a number of existing thin capitalization rules is given by Webber (2010).

of interest expense is introduced a value-maximizing firm adjusts its indebtedness to exploit the permitted amount of interest deductions to the fullest possible extent, so as to avoid interest add-backs. Once the new investment is being undertaken, the binding constraint may turn out to be violated depending on the combination of sources of finance chosen. We show under which circumstances this assumption holds. Then, the expression for the post-tax economic rent and the cost of capital under the Devereux–Griffith methodology is derived.

Our model framework receives support from recent empirical studies on the effectiveness of thin capitalization rules on multinational firm capital structure (Buettner et al. 2012, Blouin et al. 2014). In particular, Blouin et al. (2014) show that MNEs respond quickly to the introduction of restrictions to the deductibility of interest expense. In contrast, the empirical literature on the impact of tax incentives on investment decisions find no evidence of negative investment effects in relation to interest barrier rules (Weichenrieder and Windischbauer 2008, Buslei and Simmler 2012). While this could be possibly due to a number of factors including the ability of multinational firms to exploit loopholes in the legislation, our analysis illustrates that the effects of interest barrier rules on tax investment incentives are significant, although there is great variability in the effects in relation to fiscal depreciation rules. We argue that incorporating interest barrier rules in the evaluation of tax investment incentive may give rise to significant changes in the ranking across countries (see Appendix A for some insights).

Differently from other studies (Zangari, 2009), our analysis does not rely on a fix parameter for the share of deductible interest expense. To show this, we examine the implications of interest deductibility restrictions on financing and investment decisions considering two alternative corporate tax regimes: a profit tax and an allowance for corporate equity. For these selected cases we compute effective marginal and average tax rates solving for the firm optimal debt ratio. Besides, to tackle any form of non-linear tax liability function we develop a toolkit that implicitly computes the post-tax economic rent as well as the associated ETRs. This allows us to evaluate the impact of interest barrier rules in combination with other aspects of the tax code on the competitiveness of the tax system as a whole.

The paper is organized as follows. In Section 2 we briefly introduce the Devereux–Griffith model in a domestic context. In Section 3 we illustrate the assumptions and the procedures underlying the calculation of the effective tax rates in the presence of a non-linear tax liabilities function. In Section 4 we examine the implications of introducing a partial interests deductibility rule within two different tax regimes, a profit tax and an incremental ACE. Section 5 concludes.

2. The Devereux–Griffith model in a domestic setting

The standard approach to compute measures of effective marginal and average tax rates is based on the following assumptions. Consider a profit-maximizing firm. In period t the firm increases capital stock K_t and investment I_t by one unit choosing among different sources of finance (or a combination of them): retained earnings, new equity or debt. In period $t+1$ the addition to K_t generates a change in output $\Delta Q = p + \delta$ and a change in net revenue of $\Delta Q_{t+1} = (p+\delta)(1+\pi)$, where π is the inflation rate and δ is the economic depreciation rate. In period t the additional investment is dismissed such that $\Delta I_{t+1} = -(1-\delta)(1+\pi)$. Contextually the debt (principal and interests) is reimbursed and the new equity repurchased at the original price. In the case of retained earnings, the investment is financed by a corresponding reduction in dividends, D_t. The additional post-tax net return is distributed as dividends to shareholders at time $t+1$. Typically, it is assumed that the firm is not tax-exhausted so as to exploit any form of tax advantage.

The net present value of post-tax economic rent, R_t realized at time t is defined as the change in the firm equity value, V_t:

$$V_t = \frac{\gamma D_t - N_t + V_{t+1}}{1+\rho},$$

where ρ is the shareholders' nominal discount rate, γ is the measure of the tax discrimination between new equity and distribution, D_t is the dividend paid in period t and N_t is the new equity issued in period t. After some algebraic manipulations we get the present value of the firm at time t

$$(1+\rho)V_t = \sum_{s=0}^{+\infty} \frac{\gamma D_{t+s} - N_{t+s}}{(1+\rho)^s}, \tag{1}$$

and so

$$R_t := (1+\rho)\Delta V_t = \sum_{s=0}^{+\infty} \frac{\gamma \Delta D_{t+s} - \Delta N_{t+s}}{(1+\rho)^s}. \tag{2}$$

Dividends D_t are the residuals of the model and are defined as

$$D_t = Q_t(K_{t-1}) + N_t - I_t + B_t - (1+i)B_{t-1} - T_t, \tag{3}$$

where $Q_t(K_{t-1})$ is output in period t which depends on the beginning of period capital stock K_{t-1}, I_t is the investment at time t, B_t is one-period debt issued at time t, i is the nominal interest rate (risk is ignored), and T_t is the tax liability at time t. In the case of a profit tax, T_t takes the following expression

$$T_t = \tau \left(Q_t(K_{t-1}) - \phi \left(I_t + K^T_{t-1} \right) - iB_{t-1} \right), \tag{4}$$

where τ is the statutory tax rate on profits and ϕ is the rate at which capital expenditure can be offset against tax and K^T_{t-1} is the tax-written-down value of capital stock.

Solving the Devereux–Griffith framework allows one to compute the effective tax rates (ETRs) which encompasses both EMTR for a marginal investment and the EATR for different levels of profitability. The EMTR is obtained setting the post-tax economic rent, R_t, to zero and solving it for p, thus deriving the minimum pre-tax real rate of return $\tilde{p}$, i.e., the cost of capital. The EATR can be measured for different values of the pre-tax real rate of return p higher than the minimum pre-tax rate of return required in order to undertake the investment, $\tilde{p}$. Both effective marginal and average tax rates depend on the statutory tax rate and the definition of the tax base, however the EMTR depends on the tax base to a greater degree. [6]

3. Conceptual framework to calculate forward-looking effective tax rates in the presence of ceilings in the taxable base

Suppose a limitation on interest deductibility comes into force. The new rule sets a ceiling on net deductible interest in each period allowing both non-deductible interests and ceiling leftovers carry forwards. Let G_t denote the ceiling on interests deduction at time t defined as a percentage α of the Gross Operating Profit (GOP).[7] Notice that Q_t provides a close approximation for the GOP, then $G_t = \min\{iB_{t-1}, \alpha Q_t\}$ in the simplified case of no carryovers. Taking into account for both unused GOP and interest add-backs carryovers, G_t can be expressed as $G_t = \min\left\{iB_{t-1} + [M_t]^-, \alpha Q_t + [M_t]^+\right\}$, where M_t is the GOP excess at time $t-1$ (if positive) or the excess of interest expense (if negative). As usual, $[\cdot]^+$ indicates the positive part, and $[\cdot]^-$ the negative part, i.e., $[a]^+ := \max\{0, a\}$, $[a]^- := -\min\{0, a\}$.

It is assumed that when the firm becomes aware that a new treatment of interest expense will come into force then it adjusts its debt ratio in the long-run path to take full advantage of the deductibility of interest expense, thus avoiding to sustain non-deductible interests. First, it is proved that this assumption holds in the more general case of an ACE tax regime. Then, it is shown how the Devereux–Griffith approach can still be applied to compute the ETRs.

The firm's tax liability function is modified as follows

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6 Refer to Appendix B for a detail illustration of the formal Devereux–Griffith model and the computation of the ETRs in a domestic setting.

7 The definition of GOP is closer to the EBITDA and corresponds to the difference between item A (Production Value) and item B (Production Costs) in the income statement excluding depreciation and amortization of property, plant and equipment, and intangible assets, interests and lease payments.

$$T_t = \tau(Q_t - \phi(I_t + K^T_{t-1}) - i_E E_{t-1} - G_t), \tag{5}$$

where i_E is the ACE notional rate of return, E_{t-1} the ACE base at time $t-1$ (i.e., the share of own capital that grants the ACE allowance) and $\tau i_E E_{t-1}$ is the ACE deduction. In order to incorporate any possible depreciation scheme, we denote by L_t, instead of $\phi(I_t + K^T_{t-1})$, the depreciation allowances in period t.

At time $t = 0$ the company becomes aware that in period $t = 1$ either the GOP rule or the ACE regime, or both will come into force. Prior to undertake the hypothetical investment, the firm follows a long-run path that consists in maintaining its capital stock constant in each year, $K_t = K_0$ (inflation is not considered) by replacing the economic depreciation, $I_t = \delta K_0$. Then the production Q_t is kept constant over time $Q_t = Q_0$. At time $t = 0$ the firm adjusts the combination of funding to maximize the post-tax income, i.e., $B_0 \neq B_{-1}$. Then for every $t \geq 0$, B_t is constantly equal to B_0. To simplify notation, in Proposition 1, it is assumed that retained earnings are the only source of internal finance.

Proposition 1. *If both an ACE regime and a GOP rule are in force and the following condition holds* $\frac{\rho-i}{\tau} \leq i_E \leq i + \frac{\rho-i}{\tau}$*, then a profit-maximizing firm will incur interest expense up to the ceiling set by the tax rule.*

Proof. In Equation (1) substitute Equation (3) at $t = 0$. Since $\epsilon := \sum_{s=0}^{+\infty} \frac{1}{(1+\rho)^s} = \frac{\rho+1}{\rho}$ we obtain

$$(1+\rho)V_0 = \epsilon\gamma Q_0 - \epsilon\gamma\delta K_0 + \gamma B_0 - \frac{\gamma i}{\rho} B_0 - \gamma i B_{-1} - \gamma B_{-1} - \sum_{s=0}^{+\infty} \frac{\gamma T_s}{(1+\rho)^s}.$$

By Equation (5), we need to specify E_s and G_s, i.e., the ACE base and the GOP rule. The incremental ACE base can be expressed as follows:

$$E_s = \left[I_0 - B_0 + B_{-1} + \sum_{n=1}^{s} (I_n - (B_n - B_{n-1})) \right]^+$$

and by the assumption that the indebtedness is kept constant over time we get

$$E_s = (s+1)\delta K_0 - B_0 + B_{-1},$$

for every $s \geq 0$. As for G_s, notice that the equation of motion of M_s is

$$M_{s+1} = \alpha Q_s - i B_{s-1} + M_s,$$

with $M_0 = M_1 = 0$, hence $M_s = (s-1)(\alpha Q_0 - i B_0)$ for each $s \geq 2$.

Therefore $G_0 = 0$ and for each $s \geq 1$

$$\begin{aligned} G_s &= \min\{iB_0 + [M_s]^-, \alpha Q_0 + [M_s]^+\} = \\ &= \min\{iB_0 + [(s-1)(\alpha Q_0 - iB_0)]^-, \alpha Q_0 + [(s-1)(\alpha Q_0 - iB_0)]^+\}. \end{aligned}$$

If $\alpha Q_0 - iB_0 \geq 0$ then $G_s = \min\{iB_0, \alpha Q_0 + c\} = iB_0$, while if $\alpha Q_0 - iB_0 \leq 0$ then $G_s = \min\{iB_0 + c', \alpha Q_0\} = \alpha Q_0$, where c, c' are positive constants. Thus $G_s = \min\{iB_0, \alpha Q_0\}$, as in the simpler case of carryforwards not allowed.

It follows that

$$T_0 = \tau\,(Q_0 - L_0)$$

and

$$T_s = \tau Q_0 - \tau i_E(s\delta K_0 - B_0 + B_{-1}) - \tau \min\{\alpha Q_0, iB_0\} - \tau L_s, \text{ for } s \geq 1.$$

Since the net present value of capital depreciation allowances $\sum_{s=0}^{+\infty} \frac{\gamma\tau L_s}{(1+\rho)^s}$ is finite (see Appendix B for further insights) then

$$(1+\rho)V_0 = \gamma B_0 - \frac{\gamma i}{\rho} B_0 - \frac{\gamma\tau_h i_E}{\rho} B_0 + \frac{\gamma\tau_h}{\rho} \min\{\alpha Q_0, iB_0\} + C,$$

where C is a constant that does not depend on B_0. The result follows. □

If personal taxation is not considered, or more generally if the personal tax rate on interest income is equal to the tax rate on capital gains, then $\rho = i$ (see Appendix B) and the following holds:

Corollary 2. *If both an ACE regime and a GOP rule are in force, and the ACE notional rate of return i_E is less than, or equal to, the nominal interest rate i, then a value-maximizing firm adjusts its debt ratio in order to incur interest expense up to the ceiling set by the tax rule.*

Corollary 2 allows to state that in the presence of the limitation on interest deduction the firm in its long-run path incurs interest expense just up to the allowed ceiling.[8]

In what follows we show how to compute ETRs following the Devereux–Griffith procedure. At time t the hypothetical investment is undertaken. From Corollary 2, provided that $i \geq i_E$, the change in the tax liability takes the following expression:

$$\Delta T_t = \tau \left(\Delta Q_t - i_E \Delta E_{t-1} - \min\{i \Delta B_{t-1}, \alpha \Delta Q_t\} - \Delta L_t \right).$$

We substitute $\gamma \Delta D_{t+s} - \Delta N_{t+s}$ for each $s \geq 0$. At time t: $\gamma \Delta D_t - \Delta N_t = -\gamma + \gamma \Delta B_t - \Delta N_t (1 - \gamma) + \gamma \tau \Delta L_t$. At time $t+1$:

$$\begin{aligned} \frac{1}{1+\rho} \left(\gamma \Delta D_{t+1} - \Delta N_{t+1} \right) = & \frac{\gamma}{1+\rho} \left((1+\pi)(p+\delta)(1-\tau) + (1+\pi)(1-\delta) - (1+i)\Delta B_t \right) + \\ & + \frac{\gamma}{1+\rho} \left(\tau i_E \Delta E_t + \tau \min \{ i \Delta B_t, \alpha (1+\pi)(p+\delta) \} \right) + \\ & - \frac{1}{1+\rho} \Delta N_{t+1} (1-\gamma) + \frac{\gamma}{1+\rho} \tau \Delta L_{t+1}. \end{aligned}$$

At time $t+s$, with $s \geq 2$: $\frac{1}{(1+\rho)^s} \left(\gamma \Delta D_{t+s} - \Delta N_{t+s} \right) = \frac{\gamma}{(1+\rho)^s} \tau \Delta L_{t+s}$.

The post-tax economic rent R_t of the incremental investment can then be derived from Equation (2). R_t can be split into two parts: $R_t = R_t^{\mathrm{RE}} + F_t$, where R_t^{RE} is common to all sources of finance while F_t changes with the source of finance[9]

$$R_t^{\mathrm{RE}} = -\gamma + \frac{\gamma}{1+\rho} \left((1+\pi)(p+\delta)(1-\tau) + (1+\pi)(1-\delta) \right) + \gamma \tau \sum_{s=0}^{+\infty} \frac{\Delta L_{t+s}}{(1+\rho)^s}, \tag{6}$$

$$\begin{aligned} F_t = & \gamma \Delta B_t \left(1 - \frac{1+i}{1+\rho} \right) + \frac{\gamma}{1+\rho} \tau \left(i_E \Delta E_t + \min \{ i \Delta B_t, \alpha (1+\pi)(p+\delta) \} \right) + \\ & - (1-\gamma) \Delta N_t \left(1 - \frac{1}{1+\rho} \right). \end{aligned} \tag{7}$$

If the ACE allowance is not considered ($i_E = 0$) then

$$F_t = \gamma \Delta B_t \left(1 - \frac{1+i}{1+\rho} \right) + \frac{\gamma}{1+\rho} \tau \left(\min \{ i \Delta B_t, \alpha (1+\pi)(p+\delta) \} \right) - (1-\gamma) \Delta N_t \left(1 - \frac{1}{1+\rho} \right).$$

In Table 1 are listed all the changes in the sources of funding.

In the presence of the GOP rule, raising debt at time t to finance the hypothetical investment may cause interest expense to exceed the allowed ceiling at time $t+1$ depending on the profitability rate which, in turn, affects the GOP rule. At time $t+2$ the investment is reversed and the binding constraint of the interest deductibility rule is restored. Notice that because of the GOP rule, R_t is no longer linear in p. It is rather a broken line, and the point at which R_t breaks depends on the debt ratio and the economic and fiscal depreciation allowances of the asset purchased.

8 Notice that Corollary 2 clearly holds also in the absence of an ACE regime (i.e., $i_E = 0$).

9 Since an ACE allowance is considered it is not longer true that F_t includes only the additional cost of raising external finance; F_t is now different from zero in the case of retained earnings. See (Bresciani and Giannini, 2003, par. 2.1).

Table 1: Financial constraints on investment according to different sources of finance

	Ret. Earnings	New Equity	Debt
ΔB_t	0	0	$1-\tau\Delta L_t$
ΔN_t	0	$1-\tau\Delta L_t$	0
ΔE_t	$1-\tau\Delta L_t$	$1-\tau\Delta L_t$	0
ΔB_{t+1}	0	0	0
ΔN_{t+1}	0	$-\Delta N_t$	0
ΔE_{t+1}	0	0	0
ΔB_{t+s} $(s \geq 2)$	0	0	0
ΔN_{t+s} $(s \geq 2)$	0	0	0
ΔE_{t+s} $(s \geq 2)$	0	0	0

Next the cost of capital $\tilde{p}$ is derived as the solution of the equation

$$R_t^{\mathrm{RE}}(p) + F_t(p) = 0. \tag{8}$$

Let R_t^{A} be the net present value of the capital depreciation allowances, i.e., $R_t^{\mathrm{A}} = \gamma\tau\sum_{s=0}^{+\infty}\frac{\Delta L_{t+s}}{(1+\rho)^s}$. Making explicit the GOP rule the following inequalities are obtained: $i\Delta B_t \leq \alpha(1+\pi)(p+\delta)$ and $i\Delta B_t \geq \alpha(1+\pi)(p+\delta)$. Solve (8) for p obtaining $\tilde{p}$ in both cases; substituting $\tilde{p}$ in the two inequalities, with some algebraic manipulations we get that if

$$\Delta B_t\left(\rho + \frac{i(1-\tau)(1-\alpha)}{\alpha}\right) \leq 1+\rho-(1+\pi)(1-\delta)-\frac{(1+\rho)R_t^{\mathrm{A}}}{\gamma}-\tau i_E\Delta E_t+\frac{1-\gamma}{\gamma}\rho\Delta N_t, \tag{9}$$

then

$$\begin{aligned}\tilde{p} = {} & \frac{1+\rho}{(1+\pi)(1-\tau)} - \frac{1-\tau\delta}{1-\tau} - \frac{(1+\rho)R_t^{\mathrm{A}}}{\gamma(1+\pi)(1-\tau)} + \Delta N_t\frac{(1-\gamma)\rho}{\gamma(1+\pi)(1-\tau)} + \\ & - \Delta B_t\frac{\rho - i + i\tau}{(1+\pi)(1-\tau)} - \Delta E_t\frac{\tau i_E}{(1+\pi)(1-\tau)};\end{aligned} \tag{10}$$

or if

$$\Delta B_t\left(\rho + \frac{i(1-\tau)(1-\alpha)}{\alpha}\right) \geq 1+\rho-(1+\pi)(1-\delta)-\frac{(1+\rho)R_t^{\mathrm{A}}}{\gamma}-\tau i_E\Delta E_t+\frac{1-\gamma}{\gamma}\rho\Delta N_t, \tag{11}$$

then

$$\begin{aligned}\tilde{p} = {} & \frac{1+\rho}{(1+\pi)(1-\tau(1-\alpha))} - \frac{1-\tau\delta}{1-\tau(1-\alpha)} - \frac{(1+\rho)R_t^{\mathrm{A}}}{\gamma(1+\pi)(1-\tau(1-\alpha))} - \frac{\tau\alpha\delta}{(1-\tau(1-\alpha))} + \\ & + \Delta N_t\frac{(1-\gamma)\rho}{\gamma(1+\pi)(1-\tau(1-\alpha))} - \Delta B_t\frac{\rho-i}{(1+\pi)(1-\tau(1-\alpha))} - \Delta E_t\frac{\tau i_E}{(1+\pi)(1-\tau(1-\alpha))}.\end{aligned} \tag{12}$$

Because of this non-linearity in R_t, in order to compute the cost of capital for a given combination of assets and sources of finance, it is no longer possible to separately compute $\tilde{p}$ for each asset/source of finance and then take a weighted mean.

Suppose now that the firm uses both debt and retained earnings to finance the additional investment. Let us find the optimal mix of sources of finance that minimizes the cost of capital. Denote b

the debt ratio, then from Table 1, $\Delta B_t = (1-\tau\Delta L_t)b$, $\Delta N_t = 0$ and $\Delta E_t = (1-\tau\Delta L_t)(1-b)$. Substituting into Equation (10) and Equation (12) we obtain the cost of capital as a function of b. If condition (9) holds then

$$\tilde{p} = c_1 + (1-\tau\Delta L_t)\frac{i-\rho-\tau(i-i_E)}{(1+\pi)(1-\tau)}b.$$

Similarly, if condition (11) holds then

$$\tilde{p} = c_2 + (1-\tau\Delta L_t)\frac{i-\rho+\tau i_E}{(1+\pi)(1-\tau(1-\alpha))}b,$$

where c_1, c_2 are constants that do not depend on b. Therefore if $\frac{\rho-i}{\tau} \leq i_E \leq i + \frac{\rho-i}{\tau}$, then in the former equation we have a negative slope for b, while in the latter a positive one. This is consistent with Proposition 1. The minimum cost of capital $\tilde{p}_{\min}$ is achieved when the equality holds in Equation (9) or (11), i.e., when

$$b(1-\tau\Delta L_t)\left(\rho + \frac{i(1-\tau)(1-\alpha)}{\alpha} - \tau i_E\right) = 1+\rho-(1+\pi)(1-\delta)-\frac{(1+\rho)R_t^{\mathrm{A}}}{\gamma}-\tau i_E(1-\tau\Delta L_t). \tag{13}$$

Given the optimal debt ratio b_{opt} from Equation (13), since $i(1-\tau\Delta L_t)b_{\mathrm{opt}} = \alpha(1+\pi)(\tilde{p}_{\min}+\delta)$, then

$$\tilde{p}_{\min} = \frac{i(1-\tau\Delta L_t)b_{\mathrm{opt}}}{\alpha(1+\pi)} - \delta. \tag{14}$$

4. A numerical analysis

To have a closer look at the impact of the partial interest deductibility rule on financing and investment decisions we present some numerical example. Table 2 shows the computed tax wedges (which algebraically relate to EMTR) and the EATRs in the case of a profit tax modified by a partial interest deductibility rule described above. The tax wedge is computed as the difference between the cost of capital (net of depreciation) and the interest rate, $\tilde{p} - i$. We set $\tau = 27.5\%$, $\alpha = 30\%$, $\pi = 0$, $\gamma = 1$ and, under Corollary 2, $\rho = i$. We consider one investment good and choose a range of depreciation allowance rates varying from 0% to 20% in order to cover all relevant cases, such as a non-depreciable capital good (like financial investments and inventories), buildings, equipments and so forth. Also, let the real interest rate range from 2% to 8%. Coherently with a profit tax regime the economic depreciation is set equal to the depreciation allowance and it is assumed that the depreciation scheme follows a declining balance ($s = 1$ first year of depreciation). Hence the net present value of depreciation allowances per unit of investment is $\frac{\tau\delta}{i+\delta}$ and $R_t^A = \frac{\tau\delta}{1+i}$ (see Equation (B.12)). Below the tax wedge in Table 2 we report the share of deductible interest expense, i.e., the ratio between $\min\{i, \alpha(\tilde{p}+\delta)\}$ and i, where $\tilde{p}$ is the cost of capital (Equation (10) or (12)).

As known, under a profit tax with interest expense fully deductible the tax wedge is null, therefore the tax system is neutral on investment incentives. A positive tax wedge is an indicator of an activity that is discouraged by the tax system; a negative tax wedge is an indicator of an activity that is encouraged by the tax code. In the presence of a partial interest deductibility rule the tax wedge is not always null but turns out to be positive the lower is the depreciation allowance rate and the higher is the real interest rate (Table 2). The pattern between the tax wedge and the economic and fiscal parameters is straightforward. By definition, the ceiling to interest deductibility is computed gross of the economic depreciation, in addition $\delta = \phi$, hence the share of deductible interests increases with the depreciation coefficient. Hence, the highest tax wedge is associated with a non-depreciable asset. Further, the higher the interest rate the higher the tax wedge and the lower the tax-incentive to use external finance.

Looking at the share of deductible interests a changing pattern is also noticeable. From Equation (12) in the present simplified case we obtain the share of deductible interests as $\alpha' + \frac{\alpha\delta}{i}(1-\alpha'\tau)$, where $\alpha' := \alpha/(1-\tau(1-\alpha))$. Then, it can be easily checked that for a non-depreciable investment good, the share of deductible interests is invariant with respect to the interest rate. In contrast, for a

Table 2: Tax wedges, EATRs and the share of deductible interests when an interest stripping rule modifies a profit tax regime (*Percentage points*).

	fiscal wedge				EATR (p=10%)			
	i							
δ	2%	4%	6%	8%	2%	4%	6%	8%
0%	0.48 (37.2)	0.95 (37.2)	1.43 (37.2)	1.91 (37.2)	22.00 (100)	19.25 (75.0)	19.25 (50.0)	19.25 (37.5)
5%	0 (100)	0.44 (70.8)	0.92 (59.6)	1.4 (54.0)	22.00 (100)	16.50 (100)	15.13 (75.0)	15.13 (56.3)
15%	0 (100)	0 (100)	0 (100)	0.37 (87.7)	22.00 (100)	16.50 (100)	11.00 (100)	6.88 (93.8)
20%	0 (100)	0 (100)	0 (100)	0 (100)	22.00 (100)	16.50 (100)	11.00 (100)	5.50 (100)

Note: in parenthesis the share of deductible interests

depreciable investment good, the higher the interest rate the lower the share of deductible interests. Finally, the EATRs for a profitability rate $p = 10\%$ are computed. As expected, the effective tax rates increase with the share of undeductible interests which in turn depends on how binding is the constraint and on the level of the interest rate.[10]

Consider now an ACE regime. The tax wedge indicating investment neutrality is zero as in the previous case. In the absence of an interest stripping rule, for an investment fully financed by equity the fiscal wedge is null if $i_E = i$. In contrast, if $i_E < i$ the fiscal wedge is null only for an investment fully financed by debt. Let us now introduce the interest stripping rule as described in Section 3. Set $i_E = 0.9i$ and compute the optimal mix of funding that maximizes the post-tax income (Equation 13) (again: $\tau = 27.5\%$, $\rho = i$, $\gamma = 1$, $\pi = 0$, $\alpha = 30\%$). As in the previous example Table 3 shows the tax wedge associated to different values of the depreciation allowances and the interest rate. Notice that the ACE regime significantly reduces the impact on the tax wedge of the partial interest deductibility rule given that a tax disincentive to the use of external finance is partially compensated by a fiscal incentive targeted to the use of internal finance. According to our theoretical framework, the firm uses external funds up to the optimal debt ratio in a way consistent with tax minimization (see Equation (14)). It follows that the percentage of interest expense, over the potential amount i, is lower in an ACE regime than in the case of a profit tax. Analogously, the EATRs are lower than in the case of a modified profit tax regime when the firm incurs undeductible interests. Notice also that the pattern between the tax wedge and the economic and fiscal parameters is analogous to the previous case. The same holds for the share of deductible interests (Table 2).[11]

Our findings confirm that the potential impact of an interest deductibility rule – combined with other aspects of the tax code – on corporate effective tax rates may vary according to the chosen combination of assets and sources of finance. Hence, we argue that incorporating interest barrier rules in the evaluation of tax investment incentives may cause significant changes in the ranking across countries. Appendix A shows some new results for Italy about the effects of an interest limitation rule in force since 2008.

[10] By definition (B.13), substituting equations (B.14), (6) and (7), the EATR amounts to $\tau\left(1 - \frac{\min\{i, \alpha(p+\delta)\}}{p}\right)$. If interest expense are fully deductible, then the EATR is $\tau\left(1 - \frac{i}{p}\right)$, i.e., it does not depend on δ and it decreases when the interest rate increases. Otherwise, if interest expense are only partially deductible, then the EATR is $\tau\left(1 - \alpha\left(1 + \frac{\delta}{p}\right)\right)$. This implies that it does not change with i. On the other hand, the higher the depreciation rate δ, the smaller the EATR.

[11] In the presence of an ACE regime we compute the minimum value for the EATRs taking into account the optimal mix of funding which in turn depends on p, i.e., the debt ratio $\bar{b}$ such that $i\bar{b} = \alpha(p+\delta)$. The EATR amounts to $\tau\left(1 - \frac{i_E(1-\bar{b})}{p} - \frac{i\bar{b}}{p}\right)$. It follows that for those combinations of δ and i that imply interest expense fully deductible, the EATR decreases with i as in the modified profit tax regime; however, in the present case the EATR further decreases with i even when the GOP rule is binding. This is driven by our settings, i.e., $i_E = 0.9i$.

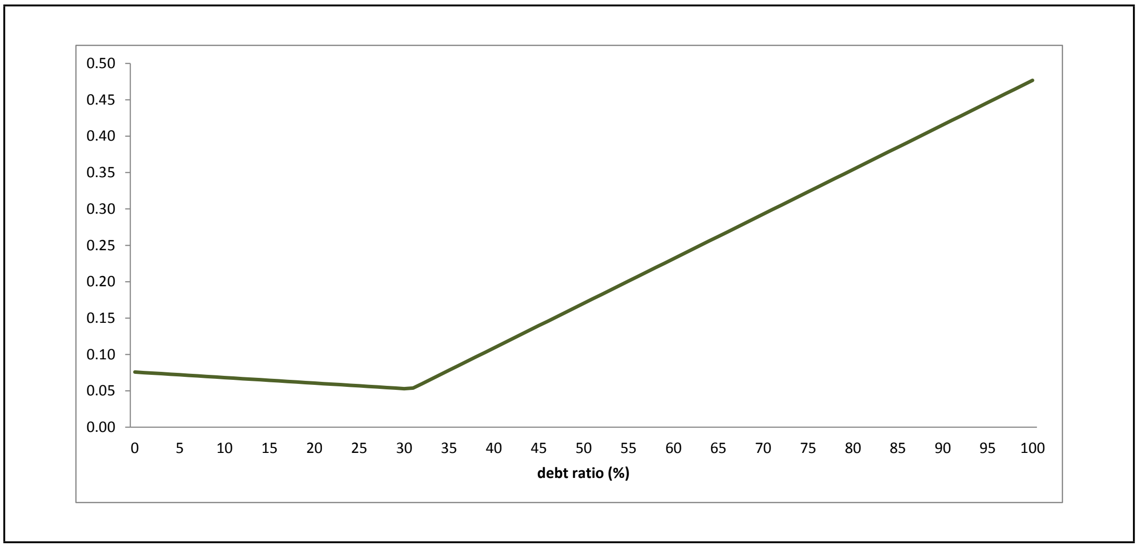
Table 3: Tax wedges, EATRs and the percentage of interest expense in the presence of both an interest stripping rule and an ACE regime (*Percentage points*).

	fiscal wedge				EATR (p=10%)			
	i							
δ	2%	4%	6%	8%	2%	4%	6%	8%
0%	0.05 (30.8)	0.14 (30.8)	0.16 (30.8)	0.21 (30.8)	22.00 (100)	16.78 (75.0)	11.83 (50.0)	6.88 (37.5)
5%	0 (100)	0.05 (67.9)	0.1 (55.5)	0.15 (49.3)	22.00 (100)	16.50 (100)	11.41 (75.0)	6.46 (56.3)
15%	0 (100)	0 (100)	0 (100)	0.04 (86.4)	22.00 (100)	16.50 (100)	11.00 (100)	5.64 (93.8)
20%	0 (100)	0 (100)	0 (100)	0 (100)	22.00 (100)	16.50 (100)	11.00 (100)	5.50 (100)

Note: in parenthesis the percentage of interest expense

Differently from conventional effective marginal and average tax rates, to account for restrictions to the deductibility of interest expense our measures are computed taking into account the firm's response to tax changes, in particular the optimal debt ratio. Figure 1 shows the computed cost of capital for a non-depreciable investment, $i = 2\%$, $i_E = 1.8\%$ and for values of the debt ratio in the interval 0% - 100%. The tax wedge is approximately 0.08% for an investment fully financed by equity (debt ratio = 0). By increasing the debt ratio up to its optimal value the tax wedge slightly decreases (Equation (13)). Then, the higher the debt ratio the higher the share of non-deductible interests. The tax wedge rises up to 0.48% for an investment fully financed by debt, while it reaches a minimum (0.05%) for a debt ratio exactly equal to 30.8% (see Table 3 - first row, first column).

Figure 1: The impact of the interest stripping rule on the fiscal wedge by debt ratio in presence of an ACE tax regime for a non-depreciable asset (*Percentage points*)



To cover more complex nonlinear tax rules that do not simply result in a broken line at only one point, we develop a toolkit (a code in Excel/VBA) that can handle any tax liability function T_t, as long as the Devereux–Griffith approach can be applied. Our code simulates the new unitary investment at time t and all related variables. Given the economic and fiscal parameters, it implicitly computes

$R_t(p)$ for any p, any mix of assets and sources of funding. It follows that it is not necessary to algebraically recover R_t for each function T_t: it is only required to specify the expression for T_t and make the program run. The cost of capital is then obtained applying the secant method, a well-known root-finding algorithm. [12]

5. Concluding remarks

This paper applies and extends the Devereux and Griffith methodology (1998, 2003) to calculate effective marginal and average tax rates in the presence of ceilings and carryovers in the taxable base. We illustrate the potential importance of taking into account interest deductibility rules in evaluating tax incentives on corporate decisions through a numerical example. We identify a clear negative impact on both investment and financing choices but the extent of the tax bias varies according to depreciation allowances and the interest rate. We also show that an ACE regime reduces the disincentive effect of a limitation on interest deductibility, provided that the debt ratio is optimized accordingly.

As argued in other studies (Haufler and Runkel, 2012), tax provisions like interest barrier rules, that are explictly targeted at mobile capital, may be a more important determinant for multinational enterprises' location decisions than statutory tax rates. We deem that the omission of interest stripping rule in the computation of effective tax rates may lead to misleading results in international comparisons on corporate tax regimes.

Also these findings suggest a much larger variation in effective tax rates at the firm level not captured by conventional effective tax measures. Hence, the methodology developed in this paper may prove useful in empirical analysis on the behavioural response to taxation exploiting firm-specific forward-looking effective tax rates (Egger et al., 2009). Our model could be further extended within a multiperiod framework following the approach proposed by Klemm (2012) to analyze the effects of carryover schemes (such as losses carry forwards and tax allowances carry forward) on investment tax incentives.

Acknowledgements

We are grateful to Sebastien Bradley, Davide Castellani, Silvia Giannini, Paolo Panteghini, participants at the 69th annual meeting of the International Institute of Public Finance (2013 IIPF), and seminar participants at the “Giornate della ricerca" in ISTAT, 10-11 November 2014, Rome, Italy for helpful comments and suggestions to an earlier version.

[12] In numerical analysis, the secant method is an iterative root-finding algorithm that uses a succession of roots of secant lines to better approximate a root of a function f. In our case the recurrence relation is defined as $p_n := p_{n-1} - R_t(p_{n-1}) \frac{p_{n-1}-p_{n-2}}{R_t(p_{n-1})-R_t(p_{n-2})}$.

A An example — the Italian case

In this appendix we refer to Spengel et al. (2014). To show the impact of the methodology developed in this paper we compare results for Italy. Our computation differs from the report only for the modeling of a partial interest deductibility rule in force since 2008. The rule restricts net interest expense to 30 percent of EBITDA and applies also to interest paid to non-related parties, such as bank. All parameters are those used in the report (Spengel et al., 2014, Tables A-1–A-8, Section B.1).

In Table A.1 we show the cost of capital, EMTR and EATR for each asset and way of funding both when the interest deductibility rule is not considered (as in Spengel et al., 2014) as well as when the EBITDA rule is applied. Notice that the average cost of debt increases of 1.2 percentage points. As underlined above, the impact of the EBITDA rule is higher on investment of low or null economic depreciation rate δ (buildings ($\delta = 3.1\%$), inventory ($\delta = 0\%$), financial assets ($\delta = 0\%$)). As expected, the EBITDA rule has a limited impact on the EATR: the higher the profitability, the less binding the EBITDA rule is. Notice also the non-linear effects introduced by the EBITDA rule: the average cost of capital by source of finance does not correspond to the mean of the cost of capital of the different ways of funding.

Finally, Table A.2 ranks EU member states, FYROM and Turkey as well as Norway, Switzerland, Canada, Japan and the United States on the basis of the cost of debt. Taking into account the EBITDA rule Italy slips from the 11th position at the bottom of the ranking.

Table A.1: ETRs by assets and source of finance — with and without the EBITDA rule (2014)

Cost of capital EMTR EATR %	Retained earnings New equity	Debt without EBITDA rule	Debt with EBITDA rule	Mean (all sources of finance) without EBITDA rule	with EBITDA rule
Buildings	6.2	5.0	6.6	5.8	5.8
	19.3	-0.5	24.3	13.6	13.6
	27.6	23.4	23.5	26.2	26.2
Intangibles	4.6	3.4	3.9	4.2	4.2
	-8.6	-47.5	-29.3	-19.0	-19.0
	22.1	17.9	17.9	20.7	20.7
Machinery	6.3	5.1	5.2	5.9	5.9
	20.8	1.9	3.1	15.3	15.3
	28.0	23.8	23.8	26.6	26.6
Financial	6.2	5.0	6.9	5.8	6.0
assets	18.7	0.0	27.1	13.3	16.2
	24.8	20.6	21.9	23.4	23.4
Inventory	5.7	4.5	6.5	5.3	5.6
	12.4	-11.3	23.0	5.7	10.1
	25.9	21.7	23.0	24.5	24.5
Mean (all assets)	5.8	4.6	5.8	5.4	5.4
	13.8	-8.8	13.9	7.4	7.4
	25.7	21.5	21.5	24.3	24.3

Table A.2: Country ranking by cost of debt (2014) — Source: Spengel et al. (2014) and our calculations

(a) without EBITDA rule

Ranking	Country	Cost of debt
		%
1	Belgium	3.9
2	Luxembourg	4.1
3	Croatia	4.2
4	Malta	4.4
4	Portugal	4.4
4	Switzerland	4.4
7	Czech Republic	4.5
7	Denmark	4.5
7	Netherlands	4.5
7	Slovakia	4.5
11	Austria	4.6
11	Greece	4.6
11	**Italy**	**4.6**
11	Sweden	4.6
11	Turkey	4.6
16	Finland	4.7
16	Germany	4.7
16	Norway	4.7
16	Poland	4.7
16	Slovenia	4.7
21	Bulgaria	4.8
21	Lithuania	4.8
21	Romania	4.8
21	USA	4.8
25	Cyprus	4.9
25	Hungary	4.9
25	Ireland	4.9
25	Latvia	4.9
29	Canada	5.0
29	Estonia	5.0
29	FYROM	5.0
32	Spain	5.3
33	UK	5.5
34	France	5.6
35	Japan	5.9

(b) with EBITDA rule

Ranking	Country	Cost of debt
		%
1	Belgium	3.9
2	Luxembourg	4.1
3	Croatia	4.2
4	Malta	4.4
4	Portugal	4.4
4	Switzerland	4.4
7	Czech Republic	4.5
7	Denmark	4.5
7	Netherlands	4.5
7	Slovakia	4.5
11	Austria	4.6
11	Greece	4.6
11	Sweden	4.6
11	Turkey	4.6
15	Finland	4.7
15	Germany	4.7
15	Norway	4.7
15	Poland	4.7
15	Slovenia	4.7
20	Bulgaria	4.8
20	Lithuania	4.8
20	Romania	4.8
20	USA	4.8
24	Cyprus	4.9
24	Hungary	4.9
24	Ireland	4.9
24	Latvia	4.9
28	Canada	5.0
28	Estonia	5.0
28	FYROM	5.0
31	Spain	5.3
32	UK	5.5
33	France	5.6
34	**Italy**	**5.8**
35	Japan	5.9

B Effective tax rates in a domestic setting using the Devereux-Griffith approach

In this section the methodology for calculating effective tax rates in a domestic setting following Devereux and Griffith (1998) is briefly introduced. Consider a profit-maximizing firm. Ignoring risk, the value of the firm can be derived from the following capital market equilibrium condition:

$$(1 - m_i)iV_t = \frac{1 - m_d}{1 - c} D_t + (1 - z)(V_{t+1} - V_t - N_t), \tag{B.1}$$

where:

- V_t is the value of the firm's equity at time t;
- i is the nominal interest rate;
- D_t is the dividend paid in period t;
- N_t is the new equity issued in period t;
- m_i is the personal tax rate on interest income;
- m_d is the personal tax rate on dividend income;
- c is the rate of tax credit available on paid dividends;
- z is the tax rate on capital gains.

The RHS of equation (B.1) represents the post-tax return at time $t + 1$ from purchasing the equity V_t at time t, while the LHS represents the post-tax return from lending V_t in period t. According to this condition, the representative shareholder will hold equity up to the point where the net return is equal to the net return from selling the equity and investing the assets in the best alternative available investment (i.e., bonds). Hence, ignoring arbitrage opportunities and risk, V_t represents the value of the firm's equity.

Net dividends paid by a company can be derived from the equality of sources and uses of funds for each period:

$$D_t = Q_t(K_{t-1}) + N_t - I_t + B_t - (1 + i)B_{t-1} - T_t, \tag{B.2}$$

where Q_t is the value (at time t) of the revenue at t; this value depends on the value K_{t-1} of the physical capital stock at time $t - 1$; I_t is the investment at time t; B_t is one-period debt issued at time t; T_t is the tax liability at time t.

The tax liability T_t of the firm is defined as:

$$T_t = \tau[Q_t(K_{t-1}) - L_t - iB_{t-1}], \tag{B.3}$$

where τ is the statutory tax rate on incomes and L_t is the depreciation expense at time t (for tax purposes). In general

$$L_t = \phi(I_t + K^T_{t-1}),$$

where ϕ is the rate at which capital expenditure can be offset against tax and K^T_{t-1} is the tax-written-down value of the capital stock (at time $t - 1$).

Equation (B.1) can be rewritten as:

$$(1 + \rho)V_t = \gamma D_t - N_t + V_{t+1}, \tag{B.4}$$

where

$$\gamma = \frac{(1 - m_d)}{(1 - c)(1 - z)},$$

and

$$\rho = \frac{(1 - m_i)i}{1 - z}.$$

Notice that γ can be interpreted as a way of measuring the tax discrimination between new equity and distributions, while ρ is the shareholders' nominal discount rate.

The equation of motion of the value of the capital stock in (B.2) is defined as:

$$K_t = (1+\pi)(1-\delta)K_{t-1} + I_t,$$

where π is the nominal annual inflation rate and δ is the one-period economic depreciation (due to wear and tear).

Proceeding recursively, from Equation (B.4) the value of the firm at time t is derived:

$$(1+\rho)V_t = \sum_{s=0}^{+\infty} \frac{\gamma D_{t+s} - N_{t+s}}{(1+\rho)^s}. \tag{B.5}$$

In order to compute the effective tax rates, consider a perturbation of the capital stock in one period. At time t investment I_t, and hence capital stock K_t, increase by one unit. At time $t+1$ the firm goes back to its original condition, selling the piece of physical capital purchased at time t and contextually repaying the debt or buying back the equity at the original price. Because of the shock [13] $\Delta Q_{t+1} = (1+\pi)(p+\delta)$, where p represents the financial return of the new investment due to the shock at time t. The firm chooses to finance the investment in period t through a combination of sources of funds: retained earnings, new equity and debt.

By (B.5) it is straightforward that R_t is given by

$$R_t := (1+\rho)\Delta V_t = \sum_{s=0}^{+\infty} \frac{\gamma \Delta D_{t+s} - \Delta N_{t+s}}{(1+\rho)^s}. \tag{B.6}$$

Independently of the firm's source of finance, we have that $\Delta I_t = 1$, $\Delta K_t = 1$, $\Delta Q_t = 0$, $\Delta T_t = -\tau \Delta L_t$ and hence, by Equation (B.2), $\Delta D_t = \Delta B_t + \Delta N_t - 1 + \tau \Delta L_t$ and $\gamma \Delta D_t - \Delta N_t = -\gamma + \gamma \Delta B_t - \Delta N_t(1-\gamma) + \gamma\tau\Delta L_t$.

At time $t+1$: $\Delta N_{t+1} = -\Delta N_t$, $\Delta B_{t+1} = 0$, $\Delta I_{t+1} = -(1+\pi)(1-\delta)$, $\Delta K_{t+1} = 0$, $\Delta Q_{t+1} = (1+\pi)(p+\delta)$, $\Delta T_{t+1} = \tau(1+\pi)(p+\delta) - \tau i \Delta B_t - \tau \Delta L_{t+1}$ and hence $\Delta D_{t+1} = (1+\pi)(p+\delta)(1-\tau) + (1+\pi)(1-\delta) - \Delta N_t + \Delta B_t(-1-i(1-\tau)) + \tau \Delta L_{t+1}$. The second term ($s=1$) of the series in Equation (B.6) can then be re-written as:

$$\begin{aligned} &\frac{\gamma}{1+\rho}\left((1+\pi)(p+\delta)(1-\tau) + (1+\pi)(1-\delta) + \Delta B_t(-1-i(1-\tau))\right) + \\ &+ \frac{1}{1+\rho}\Delta N_t(1-\gamma) + \frac{\gamma}{1+\rho}\tau\Delta L_{t+1}. \end{aligned}$$

Let us consider the terms of the series in Equation (B.6) when $s \geq 2$. $\Delta N_{t+s} = 0$, $\Delta B_{t+s} = 0$, $\Delta I_{t+s} = 0$, $\Delta K_{t+s} = 0$, $\Delta Q_{t+s} = 0$, $\Delta T_{t+s} = -\tau \Delta L_{t+s}$ and hence $\Delta D_{t+s} = \tau \Delta L_{t+s}$. Thus the s-term of the series can be re-written as

$$\frac{\gamma \Delta D_{t+s}}{(1+\rho)^s} = \frac{\gamma\tau\Delta L_{t+s}}{(1+\rho)^s}.$$

Putting everything together we get

$$R_t = R_t^{\text{RE}} + F_t, \tag{B.7}$$

where R_t^{RE} is the rent attributable to investments financed by retained earnings and F_t is the additional cost of raising external finance. In particular, as in (Devereux and Griffith, 1998, Equations 3.9, 3.10),

$$R_t^{\text{RE}} := -\gamma(1-A) + \frac{\gamma}{1+\rho}((1+\pi)(p+\delta)(1-\tau) + (1+\pi)(1-\delta)(1-A)), \tag{B.8}$$

$$F_t := \gamma \Delta B_t \left(1 - \frac{1+i(1-\tau)}{1+\rho}\right) - (1-\gamma)\Delta N_t \left(1 - \frac{1}{1+\rho}\right), \tag{B.9}$$

[13] Please, be aware that Δ always indicates the difference between the value of the variable in the presence and in the absence of a perturbation in the capital stock and not a difference between consecutive time periods.

where A is the net present value of depreciation allowances per unit of investment.

The tax-written-down value of the capital stock depends on the method applied for computing depreciation expenses: declining balance, straight line or other special provisions. For instance in the case of exponential, or declining balance, depreciation we have that K_t^T varies according to

$$K_t^T = (1-\phi)(K_{t-1}^T + I_t).$$

In this case

$$A = \tau\phi\left(1 + \frac{1-\phi}{1+\rho} + \frac{(1-\phi)^2}{(1+\rho)^2} + \cdots\right) = \frac{\tau\phi(1+\rho)}{\rho+\phi}.$$

In the case of straight line depreciation:

$$A = \tau\phi\left(1 + \frac{1}{1+\rho} + \cdots + \frac{1}{(1+\rho)^{\bar{s}-1}}\right) + \frac{\tau\lambda}{(1+\rho)^{\bar{s}}} = \frac{\tau\phi(1+\rho)}{\rho}\left(1 - \frac{1}{(1+\rho)^{\bar{s}}}\right) + \frac{\tau\lambda}{(1+\rho)^{\bar{s}}}, \tag{B.10}$$

where $\bar{s} := \left[\frac{1}{\phi}\right]$ is the integer part of $\frac{1}{\phi}$ and $\lambda := 1 - \bar{s}\phi$.

It is convenient to single out the depreciation allowances from R_t^{RE}:

$$R_t^{\mathrm{RE}} = \overline{R_t^{\mathrm{RE}}} + R_t^{\mathrm{A}},$$

where R_t^{A} is the net present value of depreciation allowances taking into account the tax benefit over the whole life of the investment good less what is lost due to the disinvestment, while $\overline{R^{\mathrm{RE}}}_t = R^{\mathrm{RE}}{}_t - R_t^{\mathrm{A}}$. In particular R_t^{A} includes both the fiscal allowances related to the investment at time t and the (negative) fiscal allowances due to the disinvestment at time $t+1$. In particular

$$\overline{R_t^{\mathrm{RE}}} := -\gamma + \frac{\gamma}{1+\rho}\left((1+\pi)(p+\delta)(1-\tau) + (1+\pi)(1-\delta)\right), \tag{B.11}$$

$$R_t^{\mathrm{A}} = \gamma\tau\sum_{s=0}^{+\infty}\frac{\Delta L_{t+s}}{(1+\rho)^s} = \gamma A\left(1 - \frac{(1+\pi)(1-\delta)}{1+\rho}\right). \tag{B.12}$$

As conventional for this literature, R_t is computed using (B.7), reducing the possible combinations of financing the investment to three cases: through retained earnings, new equity, and debt. The financial constraints with respect to the three strategies are summarized in the table below:

Table B.1: Financial constraints on investment according to different sources of finance

	Ret. Earnings	New Equity	Debt
ΔB_t	0	0	$1-\tau\Delta L_t$
ΔN_t	0	$1-\tau\Delta L_t$	0

Observe that if the investment is financed by retained earnings F_t is always zero, thus $R_t = R_t^{RE}$. If personal taxation is not considered then $\gamma = 1$ and $\rho = i$, therefore $F_t = 0$ also if the investment is financed by new equity.

By setting the post-tax economic rent R_t to zero and solving for p we get the minimum required rate of return, the so-called cost of capital, denoted by $\tilde{p}$

$$\tilde{p} = \frac{1-A}{(1-\tau)(1+\pi)}[\rho + \delta(1+\pi) - \pi] - \frac{F_t(1+\rho)}{\gamma(1-\tau)(1+\pi)} - \delta.$$

The EMTR is defined as

$$\frac{\tilde{p} - h}{\tilde{p}},$$

where h is the post tax real rate of return to the shareholder:

$$h = \frac{(1-m_i)i - \pi}{1+\pi}.$$

Let us call R_t^* the pre-tax economic rent at time t. The EATR is defined as

$$\text{EATR} = \frac{R_t^* - R_t}{\frac{p}{(1+r)}}. \tag{B.13}$$

In a world without corporate and personal taxation (i.e., $\gamma = 1$, $\rho = i$, $\tau = 0$, $A = 0$) by Equation (B.7) we get:

$$R_t^* = -1 + \frac{1}{1+i}\left((1+\pi)(p+\delta) + (1+\pi)(1-\delta)\right) = \frac{p-r}{1+r}, \tag{B.14}$$

where r is the real interest rate: $(1+r)(1+\pi) = (1+i)$. The value of the EATR now follows.

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