AN INDEX OF TAX CONVEXITY ON CORPORATE INVESTMENTS

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Abstract. In this paper an index of tax convexity with meaningful bounds is given. A convex tax schedule is a progressive tax table in which a company's Effective Average Tax Rate (EATR) increases as pre-tax income rises. Considering as the pre-tax income the pre-tax profitability level generated by a hypothetical investment undertaken by a firm, we propose a forward-looking index of tax convexity on corporate investments for each interval of pre-tax profit. This index ranges between 0 and 1. It takes value 0 if the tax system is purely proportional, value 1 if taxation makes post-tax profits all the same, irrespective of pre-tax profits. According to this framework and comparing different theoretical tax systems, a concept of tax convexity wedge is given. As an example we apply this new index to the Italian tax system and we show that in the case of equity financing the system is neutral while in the case of debt financing is more progressive.

JEL classification codes: H25, H32

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1. Introduction

As discussed in the scientific literature, asymmetries in taxation, or tax convexity, can have relevant effects on many different economic decisions. Depending on the specific type of economic decision, different measures of tax convexity are used. Presenting evidence on the comparison on the use of derivatives to reduce earning volatility and the use of discretionary accruals and fiscal incentives as partial substitutes for smoothing earnings, Barton (2001) measures tax convexity by the excess of the Marginal Tax Rate over the Effective Tax Rate[1]. Answering the question if progressive marginal income tax rates discourage self-employment, Gentry and Hubbard (2000) measure tax convexity as the spread in the marginal (or average) tax rates for successful and unsuccessful self-employment outcomes, while Wen and Gordon (2014) measure it as the expected value of the tax liability of an entrepreneur facing a distribution of possible returns and compare this burden with the same individual tax liability at their predicted income. Tax convexity has also a relevant impact on entrepreneurship and tax avoidance (Baliamoune-Lutz and Garello 2014, Gentry and Hubbard 2000, Domar and Musgrave 1944) and on the valuation of the equity beta (Lei et al., 2013).
By charging less taxes to less profitable investments, tax convexity gives a measure of how the tax system affects investment decisions by fostering primarily marginal investments and penalizing extra-profits. Using a stochastic equilibrium model MacKie-Mason (1990) shows that this fact[2] may discourage some investments even though it is an unambiguous subsidy to asset values and encourage earlier shutdown of marginal projects. Further, smaller subsides are received by riskier projects. However under uncertainty the corporate tax shares in a risky value of waiting to invest (McDonald and Siegel, 1982) and may encourage investments. Sarkar (2008) uses a standard contingent claim structural model to show that tax convexity on investments reduces the optimal leverage ratio and raises the default trigger compared to a proportional taxation regime. It is also argued (Lei et al., 2013) that it could have non-monotonic relationship with both the default and investment

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[1]The former calculated as the present value of current and expected future taxes paid on an additional dollar of income earned and the latter as the rate of tax expenses to taxable profit (Graham, 1996).

[2]In MacKie-Mason's paper tax convexity is modeled by a particular nonlinear allowance called percentage depletion allowance.

triggers if a growth option[3] is incorporated in the model.

By defining a convex tax schedule, a more specific definition of tax convexity is provided. A convex tax schedule is a tax table in which a company's Effective Average Tax Rate (EATR) increases as pre-tax profit p rises. According to this definition, a natural measure of tax convexity is provided by the slope of the EATR function of p: $\tau^{EATR}(p)$. Considering as pre-tax income the pre-tax profitability level generated by a hypothetical investment undertaken by a firm, the slope of $\tau^{EATR}(p)$ could be viewed as a measure of tax convexity in a framework of forward-looking models of investment decisions. Although this measure is used in issues devoted to tax policies, it is always presented only graphically (by the slope of $\tau^{EATR}(p)$) without using a suitable index (Finkenzeller and Spengel 2004, Giannini and Maggiulli 2002). It is commonly believed that a too high degree of convexity can have distorting effects on the efficient allocation of resources; it can even change the post-tax profitability ranking of the investments. Thus to better evaluate tax convexity it is important to get a measure of the distance from this latter threshold (which can be considered as an upper bound). The closer this threshold is, the greater the distorting effects. Obviously it is also important to know how far the system is distant from a point where convexity vanishes. This point coincides with a pure proportional regime. Although there have been corporate tax systems characterized by different statutory tax rates with respect to pre-tax income, the most common causes of tax convexity are provided by deductibility rules and allowances. Usually these are not easily dealt with when computing $\tau^{EATR}(p)$ (see Spengel et al. 2014, Caiumi et al. 2015). Moreover, the notion of convexity applies to the whole tax system, therefore it is important to consider not only the income business tax but all the taxes charged on investments and all the tax system features such as the ways of funding or the depreciation schemes. This high level of complexity in computing $\tau^{EATR}(p)$ often makes it burdensome to get a formula in closed form and usually numerical estimates are provided only at single points, making difficult to compute the derivative of $\tau^{EATR}(p)$. Moreover sometimes $\tau^{EATR}(p)$ is not smooth (for an example see section 4). Because of the reasons above, we address the problem to evaluate tax convexity on corporate investments in terms of intervals of p and using a suitable index with meaningful bounds.

In Section 2 we set up a index of tax convexity for each intervals of profitability of the hypothetical investment, starting from the slope of the $\tau^{EATR}(p)$ curve and rescaling by its upper bounds. The index ranges bewteen 0 (a completely proportional system) and 1 (when taxation levels all post-tax profits, irrespective of pre-tax profits). In Section 3 we connect the index with another well-known measure of tax progression, namely the liability progression, i.e.: the elasticity of the tax burden with respect to the income. In Section 4 we compare the tax convexity index for different theoretical tax systems and we give a characterization of a neutral tax system for investments decisions in terms of the convexity index. In Section 5 we compute the tax convexity index for the Italian corporate taxation system in 2017, giving evidence that this system is neutral for debt financing while it is more progressive in the case of equity financing. Finally Section 6 concludes.

2. Index set up

Starting from the slope of $\tau^{EATR}(p)$ as a measure of tax convexity, in this section an index of forward-looking tax convexity with meaningful bounds is given. Since this index is computed with respect to intervals of p, the pre-tax profitability rate, then it can be calculated even if $\tau^{EATR}(p)$ is known only at single points.
Let $\xi \in \Xi$ be a vector of economic parameters which identifies all the features of a corporate tax system, e.g. ξ could include a dummy variable which indicates if the investment is financed by equity or debt (see Section 4). Let $\tau_{\xi}^{EATR}(p)$ be the EATR with regard to ξ. Without considering personal taxation, according to Devereux and Griffith (2003) (D&G approach), $\tau_{\xi}^{EATR}(p)$ is given by the difference between the pre-tax and the post-tax economic rent (respectively: R^* and R) scaled by the present value of the pre-tax income

[3]As a firm decides to expand, it must pay a cost to increase its operations scale which produces a future earning.

stream, net of economic depreciation:

$$\tau_\xi^{EATR}(p) = \frac{R^*(p,\xi) - R(p,\xi)}{\frac{p}{1+r}} \tag{1}$$

where $R^* = \frac{p-r}{1+r}$ and r is the real interest rate. Note that r is a parameter of the system and therefore it belongs to the vector ξ. As showed in the Introduction, a straightforward measure of tax convexity related to the interval $[p', p'']$ is provided by the slope of $\tau_\xi^{EATR}(p)$:

$$\frac{\tau_\xi^{EATR}(p'') - \tau_\xi^{EATR}(p')}{p'' - p'} \tag{2}$$

with $p'' > p'$. Therefore if (2) is positive the taxation on investments is progressive, if negative it is regressive, if null it is simply proportional. It follows by (1) that

$$R(p,\xi) = \frac{p-r}{1+r} - \frac{p}{1+r}\tau_\xi^{EATR}(p). \tag{3}$$

By definition of the cost of capital w_ξ (see Devereux and Griffith 2003, King and Fullerton 1984), if $R(p,\xi) = 0$ then $p = w_\xi$ and $\tau_\xi^{EATR}(w_\xi)$ is the Effective Marginal Tax Rate (EMTR). Being the fiscal wedge the difference between the cost of capital and the interest rate $(w_\xi - r)$, it follows that if the tax wedge is zero then the EMTR is zero (and also the converse is true).
A tax system ξ does not distorce the ranking of profitability among investments if

$$p'' \geq p' \Longleftrightarrow R(p'',\xi) \geq R(p',\xi). \tag{4}$$

By Equations (3) and (4) it is easy to prove the following proposition:

Proposition 1. *Relation (4) holds if and only if for every $p'' > p'$*

$$\frac{\tau_\xi^{EATR}(p'') - \tau_\xi^{EATR}(p')}{p'' - p'} \leq \frac{1 - \tau_\xi^{EATR}(p')}{p''}. \tag{5}$$

Therefore the RHS of (5) can be considered as an upper bound of the tax convexity measure.
We propose as an index of tax convexity the rescaling of the slope of $\tau_\xi^{EATR}(p)$, that is

$$I_\xi[p', p''] = \frac{\tau_\xi^{EATR}(p'') - \tau_\xi^{EATR}(p')}{p'' - p'} \frac{p''}{1 - \tau_\xi^{EATR}(p')}. \tag{6}$$

The index $I_\xi[p', p'']$ is negative if the taxation is regressive, it can be greater than 1 if the tax system distorces the ranking of profitability among investments, but in the general case where the taxation is not regressive and (4) holds, the index varies between 0 and 1, taking the value 0 if the tax system is purely proportional and the value 1 if taxation makes post-tax profits all the same, irrespective of pre-tax profits.

3. Progressive taxation and tax convexity

One of the most popular local measure of tax progression is given by the elasticity of the tax burden with respect to what it is considered as a measure of taxable capacity (usually the income). This tax progression measure is known as liability progression (see Musgrave and Thin, 1948). Otherwise, if we consider the pre-tax profit as a measure of capacity to pay taxes for a company which undertakes a hypothetical investment, it is possible to set a forward-looking measure of liability progression of taxation on investments based on the ratio between the tax burden and the profit generated by the investment, that is τ^{EATR}. In particular, let $\xi^*(k)$ be a tax system characterized by liability progression equal to k. Related to the interval $[p', p'']$, it follows that

$$I_{\xi^*(k)}[p', p''] = \frac{(k-1)\tau_\xi^{EATR}(p')}{1 - \tau_\xi^{EATR}(p')}. \tag{7}$$

4. Tax convexity wedge

In this section we compute $I_\xi[p', p'']$ following the D&G approach for some corporate tax systems. Thanks to this approach many of the features of tax systems (included in ξ) can be considered in the computation. In particular, assuming for sake of simplicity no personal taxation and zero inflation (i.e. the nominal interest rate i is equal to $r > 0$), we compare the tax convexity degree of a profit tax system according to the ways of funding ($I_{PT,Equity}$, $I_{PT,Debt}$), of an ACE regime ($I_{ACE,Equity}$) and of a system in which a treatment of interest expenses that sets a ceiling in terms of the firm's EBITDA, say G, is included ($I_{Ebitda,Debt,\alpha}$). In particular, let Q be the EBITDA and iB the interest expenses, $G_t(\alpha) = \min\{\alpha Q_t, iB_{t-1}\}$ denotes the ceiling on interest deduction at time t. This rule is also known as EBITDA rule (see Caiumi et al., 2015). Note that this system is characterized by a non smooth point of the function $\tau^{EATR}_{Ebitda,Debt,\alpha}(p)$.
Set τ as the statutory tax rate. Then with respect to the interval $[ni, (n+1)i]$ (where n is a positive integer), we have

$$
\begin{aligned}
I_{\tilde{\xi}} &= I_{PT,Debt} = I_{ACE,Equity} = \frac{\tau}{n - \tau(n-1)} \\
I_{\tilde{\xi}^*(k)} &= (n-1)(k-1)I_{\tilde{\xi}} \quad \text{if } \tau^{EATR}_{\tilde{\xi}^*(k)}(ni) = \tau^{EATR}_{\tilde{\xi}}(ni)\ \forall k \text{ and (7) holds.} \\
I_{PT,Equity} &= 0 \\
I_{Ebitda,Debt,\alpha} &= \begin{cases} I_{\tilde{\xi}} & \text{if } n \geq \frac{1}{\alpha} \\ \frac{\tau(\alpha(n+1)-1)}{1-\tau+\alpha\tau} & \text{if } \frac{1-\alpha}{\alpha} \leq n < \frac{1}{\alpha} \\ 0 & \text{otherwise} \end{cases}
\end{aligned} \tag{8}
$$

Note that the amplitude of the intervals is equal to the interest rate. Generally the higher the interest rate the greater the economic system capacity to make profits. Considering such variable intervals in computing the convexity index makes it possible to compare different economic systems. The tax regimes above mentioned are theoretical tax systems, adding deductibility rules or allowances changes tax convexity. Starting from a pure proportional regime we say that $\tilde{\xi}$ is a neutral tax system if the only allowed deduction is the deduction of the opportunity cost, i.e.:

$$
R(p, \tilde{\xi}) = \frac{(1-\tau)(p-i)}{1+i}. \tag{9}
$$

We call $\tilde{\xi}$ a neutral system since it does not distort investment or funding choices, and in particular the equivalence between the marginal investment and the alternative investment is preserved, assuming i as the opportunity cost (i.e., the tax wedge and the EMTR are zero). Moreover, considering an irreversible investment, Panteghini (2002) shows that under such a tax system, the investment trigger is unaffected by tax convexity, even assuming both capital and political uncertainty.

Proposition 2. *Let $\tau^{EATR}_{\tilde{\xi}}(p)$ be a smooth function. A tax system $\tilde{\xi}$ is neutral if and only if EMTR $= 0$ and*

$$
I_{\tilde{\xi}}[p', p''] = \frac{\tau i}{p' - \tau(p' - i)} \tag{10}
$$

Proof. The 'if' part follows directly from Equations (3), (6) and (9).
For the 'only if' part let us take the limit of the convexity index. We get

$$
\lim_{\Delta p \to 0} I_{\tilde{\xi}}[p, p + \Delta p] = \frac{\tau i}{p - \tau(p-i)} = \frac{d}{dp}\tau^{EATR}_{\tilde{\xi}}(p) \frac{p}{1 - \tau^{EATR}_{\tilde{\xi}}(p)}.
$$

Notice that if EMTR $= 0$ then by definition the cost of capital is equal to i. Then we need to solve the following Cauchy problem:

$$
\begin{aligned}
\frac{d}{dp}\tau^{EATR}_{\tilde{\xi}}(p) &= \frac{\tau i(1 - \tau^{EATR}_{\tilde{\xi}}(p))}{p(p - \tau(p-i))} \\
\tau^{EATR}_{\tilde{\xi}}(i) &= 0
\end{aligned}
$$

whose solution is

$$\tau_{\tilde{\xi}}^{EATR}(p) = \frac{\tau(p-i)}{p} \tag{11}$$

Substituting Equation (11) into Equation (3) concludes the proof.

□

Note that in the case of neutrality the index does not depend on p'' and if $i \to 0$ then $I_{\tilde{\xi}}[p', p''] \to 0$.

Setting $p' = ni$ and $p'' = (n+1)i$, by (10) we get Equation (8). It follows that:

- the ACE regime $(ACE, Equity)$ and the profit tax system in the case of debt financing $(PT, Debt)$ are both neutral tax systems;
- the neutral system index is completely caracterized by the statutory tax rate ($I_{\tilde{\xi}}[ni, (n+1)i]$ depends only on τ[4]).

Thus for a fixed τ, the wedge between the convexity index computed for the neutral system $\tilde{\xi}$ and the same index computed for another systems ξ is a measure of the distortion in tax convexity of system ξ. This distortion can be considered as a similar concept to the tax wedge in a tax convexity framework: it is positive (negative) if the tax convexity generated by allowances provided by the tax system is greater (smaller) than the tax convexity provided by the deduction of the interest rate. By Proposition 2 it follows:

Corollary 3. *A tax system is neutral if and only if the tax wedge and the tax convexity wedge are both zero.*

In the table below $I_{\tilde{\xi}}$, $I_{\tilde{\xi}^*(k)}$, $I_{PT,Equity}$ and $I_{Ebitda,Debt,\alpha}$ values are listed if $\tau = 25\%$, $\tau = 35\%$ and $\alpha = 30\%$, $\alpha = 50\%$.

As one can see it is possible to change tax convexity by either varying the statutory tax rate τ or the strength of the deduction rules (for example varying the parameter α in Table 1) or both. Therefore, as already suggested in Lei et al. (2013), instead of cutting or increasing the statutory tax rate which increases fiscal deficit or tax burden, the desired effects in tax convexity can be achieved by varying asymmetries due to deduction rules.

Table 1. Tax convexity index for different tax systems

	$\tau = 25\%$					$\tau = 35\%$				
	$I_{\tilde{\xi}}$	$I_{\tilde{\xi}^*(k)}$	$I_{PT,Eq}$	$I_{Ebitda,Db,\alpha}$		$I_{\tilde{\xi}}$	$I_{\tilde{\xi}^*(k)}$	$I_{PT,Eq}$	$I_{Ebitda,Db,\alpha}$	
profitability				30%	50%				30%	50%
$i - 2i$	0.25	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00
$2i - 3i$	0.14	0.14 (k-1)	0.00	0.00	0.14	0.21	0.21 (k-1)	0.00	0.00	0.21
$3i - 4i$	0.10	0.20 (k-1)	0.00	0.06	0.10	0.15	0.30 (k-1)	0.00	0.09	0.15
$4i - 5i$	0.08	0.23 (k-1)	0.00	0.08	0.08	0.12	0.36 (k-1)	0.00	0.12	0.12
$5i - 6i$	0.06	0.25 (k-1)	0.00	0.06	0.06	0.10	0.39 (k-1)	0.00	0.10	0.10
$6i - 7i$	0.05	0.26 (k-1)	0.00	0.05	0.05	0.08	0.41 (k-1)	0.00	0.08	0.08
$7i - 8i$	0.05	0.27 (k-1)	0.00	0.05	0.05	0.07	0.43 (k-1)	0.00	0.07	0.07
$8i - 9i$	0.04	0.28 (k-1)	0.00	0.04	0.04	0.06	0.44 (k-1)	0.00	0.06	0.06
$9i - 10i$	0.04	0.29 (k-1)	0.00	0.04	0.04	0.06	0.45 (k-1)	0.00	0.06	0.06

[4]Observe that the index value concernig the interval $[i, 2i]$ is equal to the statutory tax rate.

5. An actual case

Figure 1. EATR for Italy, year 2017.

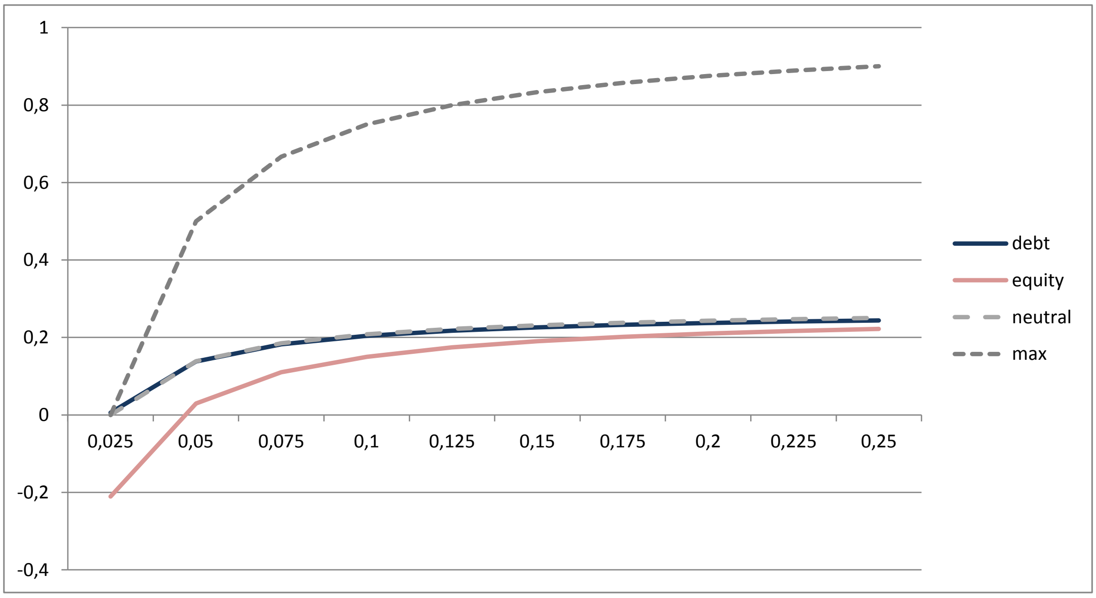

Table 2. Tax convexity index for Italy, year 2017.

profitability	$I_{\tilde{\xi}}$	$I_{IT,Eq}$	$I_{IT,Db}$
2.5%-5%	0.28	0.40	0.27
5%-7.5%	0.16	0.25	0.15
7.5%-10%	0.11	0.18	0.12
10%-12.5%	0.09	0.14	0.08
12.5%-15%	0.07	0.12	0.07
15%-17.5%	0.06	0.10	0.06
17.5%-20%	0.05	0.09	0.05
20%-22.5%	0.05	0.08	0.04
22.5%-25%	0.04	0.07	0.04

In this section the tax convexity index is computed for Italy[5] (see Bresciani and Giannini 2003, Caiumi et al. 2015). The Italian corporate taxation is characterized by an ACE system in the case of equity financing and by an EDIBTA rule system (with $\alpha = 30\%$, see section 4) in the case of debt financing. In Figure 1 the Italian EATR functions, according to the source of funding and for the year 2017[6], are compared with theoretical functions having the same (overall) statutory tax rate ($\tau = 27.81\%$)[7]. These theoretical functions represent the case of neutrality ($\tilde{\xi}$) and the case of the maximum convexity index (i.e., $I = 1$). In Table 2 the related convexity index values are listed. Let us observe that the index values relative to the Italian system are greater than those relative to the neutral system, in the case of equity financing and of low profitability, when the index reaches the value $I_{IT,Equity}[i, 2i] = 0.39$. Therefore when the investment is financed by new

[5]IRES, IRAP and IMU are considered.

[6]In accordance to the recent government provisions (Legge di Stabilità 2016)

[7] Interest rate i is set to 2.5% and inflation is set to 0.

Figure 2. EATR for Italy. Non depreciable asset, year 2017.

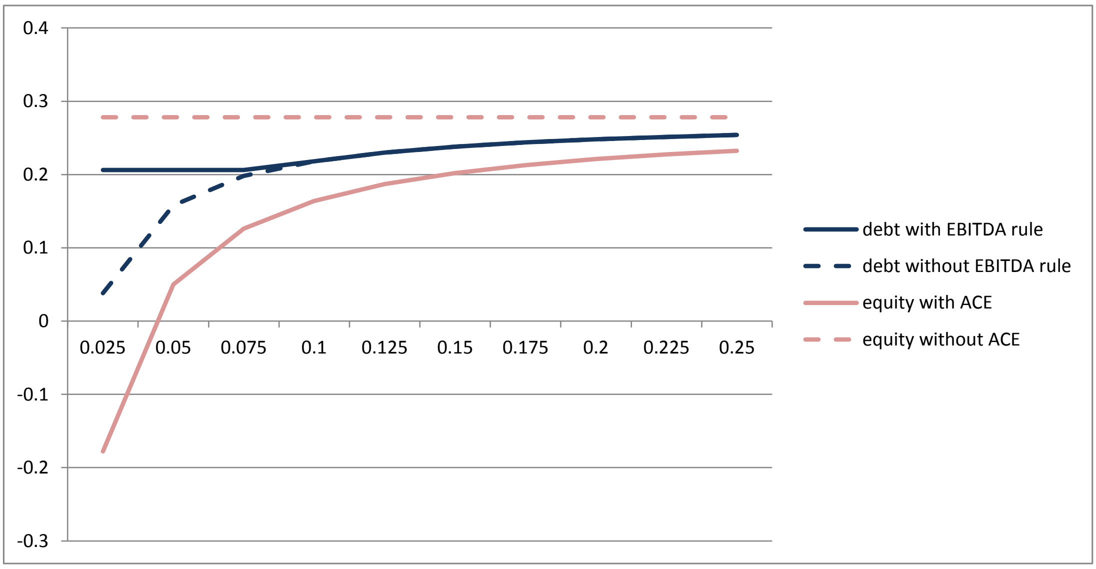

Table 3. Tax convexity index for Italy. Non depreciable asset, year 2017.

profitability	$I_{\bar{\xi}}$	$I_{IT,ACE,Eq}$	$I_{IT,noACE,Eq}$	$I_{IT,Ebitda,Db}$	$I_{IT,noEbitda,Db}$
2.5%-5%	0.28	0.39	0.00	0.00	0.25
5%-7.5%	0.16	0.24	0.00	0.00	0.14
7.5%-10%	0.11	0.17	0.00	0.06	0.10
10%-12.5%	0.09	0.14	0.00	0.08	0.08
12.5%-15%	0.07	0.11	0.00	0.06	0.06
15%-17.5%	0.06	0.10	0.00	0.05	0.05
17.5%-20%	0.05	0.08	0.00	0.05	0.05
20%-22.5%	0.05	0.07	0.00	0.04	0.04
22.5%-25%	0.04	0.07	0.00	0.04	0.04

equity or retained earnings the Italian taxation system on investments is more progressive than the provisions of the neutral system, carrying a large positive tax convexity wedge.

To better illustrate the contribution to tax convexity by the ACE and by the EBITDA rule, the same graphs and tables are given for non-depreciable assets (see Figure 2 and Table 3).

6. Concluding remarks

Tax convexity is important in corporate decisions and can not be ignored by policy makers. In this paper we propose a convexity index based on the effective average tax rates which allows to measure the tax convexity degree of a hypothetical investment undertaken by a firm in a forward-looking framework and using the Devereux–Griffith approach to compute the EATR. This index is defined for each interval of pre-tax income p, however it is possible to construct an analogous index for each value of p. This index ranges between 0 and 1. It takes value 0 if the tax system is purely proportional, value 1 if taxation makes post-tax profits all the same, irrespective of pre-tax profits. Furthermore we characterize a neutral tax system in terms of this convexity index and use it as a benchmark to evaluate asymmetries in taxation. Finally we use this new index to evaluate the tax convexity of the Italian tax system, concluding that the Italian system is neutral in the case of debt financing while it is more progressive in the case of equity financing. Our contribution fills shortcomings in literature devoted to the comparisons of different tax systems, where tax convexity is usually evaluated only graphically.

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