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The tax shield increases the interest rate ☆

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ABSTRACT

We study the general equilibrium implications of the corporate tax shield in a growth economy that taxes household income and firm profits and redistributes tax revenues. Our stylized model predicts that in general equilibrium the tax shield's reduction of the corporate after-tax borrowing rate is counteracted (but not fully eliminated) by an increase in the pre-tax rate.

1. Introduction

Building on the pioneering work of Modigliani and Miller (1958), an extensive literature examines corporate capital structure decisions. The tax-deductibility of corporate interest expenses, i.e., the corporate debt tax shield, has especially caught a great deal of attention in both the theoretical and the empirical literature. This literature demonstrates that the debt tax shield heavily affects corporate capital structure decisions. However, the implications of the debt tax shield for the interest rate, investments, and the intertemporal consumption pattern in general equilibrium, which our work focuses on, have been largely overlooked so far.

We set up a stylized general-equilibrium model with a representative firm, rational households that differ by their initial endowments, and a government that taxes household income as well as firm profits and redistributes tax revenues. Households earn income by investing in risky corporate equity, risk-free corporate debt, and risk-free bonds traded among the households.

In a partial equilibrium model with exogenous prices, the tax shield mechanically reduces the after-tax rate one-for-one, whereas the pre-tax borrowing rate is kept constant and independent of variations of the corporate tax rate. In our general equilibrium model with an endogenous interest rate, there are counteracting forces at play that increase the pre-tax rate relative to a situation with no tax shield. More specifically, our model predicts an increase in the pre-tax interest rate.

This increase of the pre-tax interest rate is affected through changes in both the supply of and the demand for corporate debt. When a tax shield is introduced, a higher degree of corporate leverage is optimal, thus increasing the supply of corporate debt. Simultaneously, the introduction of the tax shield makes investments in equity more attractive, causing a decrease in the demand for investments in corporate debt. To nevertheless raise the desired amount of debt, the corporation thus has

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to offer a higher interest rate. This increase in the interest rate partly offsets the decrease in the corporate after-tax borrowing rate, but does not completely eliminate it.

We model the economy using a representative firm and limit the degree of leverage such that the payout to shareholders is non-negative in all states of the world. This is in accordance with the original work of Modigliani and Miller (1958) and numerous subsequent papers. Although a single firm may be subject to default risk, a default of the representative firm would be unreasonable. If the tax burden on firm profits paid out to households as interest is lower than that paid out as dividend, there is a tax advantage to debt financing, and, in our model, the firm operates with leverage; otherwise, the firm remains unlevered. Whether such a tax advantage exists depends, among other things, on whether the tax shield applies.

The debt tax shield and the overall issue of discriminatory taxation between equity and debt has been on the political agenda for some time. It is the subject of analysis and discussion within the European Union, OECD and other international organizations. Different initiatives to reduce the discriminatory taxation have been proposed under various names like, e.g., ACE ("Allowance for Corporate Equity") and CBIT ("Comprehensive Business Income Tax"). Analyses of such potential policy initiatives are found in, e.g., Fatica et al. (2013), de Mooij and Devereux (2011), European Commission (2016b) and Spengel et al. (2016). The ATA directive (European Commission, 2016a) from the European Union, limiting the ability to deduct interest payments to 30% of EBITDA, constitutes an actual policy initiative. This makes it relevant to compare different scenarios – in particular with and without the tax shield, respectively – within our general-equilibrium model.

Our work contributes to a broader strand of literature investigating the macroeconomic effects of corporate taxation. Theoretical work going back to the seminal papers of Judd (1985) and Chamley (1986) argues that corporate taxes negatively impact capital accumulation and thus output. Empirically, the evidence is mixed. Some studies find positive effects of reductions in corporate tax rates on economic growth (e.g., Lee and Gordon, 2005, Arnold et al., 2011, Mertens and Ravn, 2013, Gechert and Heimberger, 2022), whereas other studies report negative, insignificant, or mixed results (e.g., Widmalm, 2001, Angelopoulos et al., 2007, Gale et al., 2015, Kate and Milionis, 2019).

These studies do, however, focus on economic growth and remain silent about the impact of changes in corporate tax rates on capital structure and the interest rate. Our stylized model is an attempt to better understand the effects of corporate taxation on macroeconomic variables more generally – and of the effect of the corporate debt tax shield in particular. Our work contributes to this strand of literature by exploring the impact of corporate taxation more generally, and the debt tax shield in particular, on the interest rate in general equilibrium.

Our work further contributes to a growing literature on the implications of the tax shield. It complements the literature dealing with the macroeconomic implications of taxes. It is a well-known fact that it is generally not optimal to tax accumulating production factors, because this discourages savings, slows down factor accumulation and thus, ultimately, economic growth (e.g., Chamley, 1986). Simultaneously, Hackbarth et al. (2006) and Chen (2010), among others, demonstrate that macroeconomic conditions affect corporate capital structure decisions. However, the reverse channel, i.e., how the tax shield and its effect on corporate capital structure decisions affect macroeconomic conditions, such as the interest rate, has received surprisingly little attention so far.

Empirical studies estimate that the tax shield accounts for about 10% of corporate values (e.g., Graham, 2000; Kemsley and Nissim, 2002; vanBinsbergen et al., 2010). These studies further document that taxes in general, and the tax shield in particular, significantly affect corporate capital structure decisions (e.g., Graham, 1996; Heider and Ljungqvist, 2015). However, these papers focus on the impact of the tax shield for corporate valuation and capital structure decisions, but do not investigate the effect of the tax shield for the interest rate.

Theoretical work, including Miles and Ezzell (1980) and Cooper and Nyborg (2006), has so far primarily focused on the valuation of the tax shield. Notable exceptions are the works of Glover et al. (2015) and Fischer and Jensen (2019). Glover et al. (2015) investigate how the tax shield affects corporate leverage, corporate defaults and credit spreads. However, in their work there is no government and, hence, taxes paid are dead-weight loss. The work of Fischer and Jensen (2019) examines how the tax shield affects households' consumption-investment strategies via the government's budget constraint. However, their work builds on an endowment economy model. In such a framework, the growth rate of the economy is exogenously given and the interest rate is unaffected by whether a tax shield applies or not. The present paper builds instead on a production economy and contributes to what Fama (2011) calls one of the big open challenges in financial economics: understanding the implications of corporate taxation. Our model predicts that the tax shield affects the interest rate. The effect on the interest rate also affects the growth rate of the economy and, through this channel, ultimately, welfare.

This paper proceeds as follows. Section 2 outlines our model. In section 3, we present its analytical solution and discuss our model's predictions. In section 4, we numerically illustrate the qualitative implications of the tax shield for the interest rate. Section 5 discusses alternative policies and interpretations of tax revenue neutrality. Section 6 concludes. The Online Appendix provides proofs of the statements in Theorems 1 and 2.

2. The tax shield in a production economy

2.1. The economy

We consider an economy populated by n households and a representative firm that makes up the production sector. The firm has a risky one-period production technology, in which the output produced and available at time 1 is given by $G \cdot I$, in which G is the gross growth factor per unit of investment made at time 0 and I denotes the aggregate investment in the production technology.[1] G is a random variable with M possible realizations, G_m, where $G_1 > G_2 > \cdots > G_M \geq 1$.[2] In the sequel we assume that these M realizations have equal probabilities $1/M$.[3]

2.2. Corporate leverage

To finance its investments, the firm issues equity and corporate debt that the households can invest into. The aggregate investment, I, made at time 0 is financed by the aggregate amount of equity invested, E, and the aggregate amount of corporate debt, D, outstanding from time 0 to time 1. The supply of corporate bonds is usually determined by the firm's optimal capital structure decision, and many models provide endogenous mechanisms that bound the degree of leverage, L, in case there is a tax advantage to debt. We follow this tradition and only allow the representative firm to issue bonds up to a limit for which there is no risk of bankruptcy. Apart from this constraint on the relation between

[1] For ease of notation, we focus on a one-period/two dates framework. We also explored a version of our model with a larger number of periods, which, however, did not provide any additional insights in excess of those derived in the one-period framework.

[2] The case $G_M < 1$ implies a negative return on the aggregate investment in the economy; i.e., a negative net value of the aggregate production in the economy. Unlike GDP growth, a negative return on aggregate investments appears rather unlikely and further bears the problem of a negative tax base. We therefore disregard the case $G_M < 1$ throughout.

[3] The assumption of equal probabilities is solely made to ease notation. Our results can be generalized to allow for unequal probabilities with similar qualitative conclusions, although with a significantly blown-up amount of notation.

E and D, the supply of aggregate investment opportunities is perfectly elastic.

If the total tax burden on firm profits paid out to households as interest on corporate debt is lower than that paid out as dividend to equity holders, i.e., if there is a tax advantage to debt financing, the firm operates with positive leverage. Otherwise, the firm remains unlevered. Since the total tax burden on firm profits paid out to households as interest depends on whether the tax shield applies, corporate leverage should be affected by whether the tax shield applies.

2.3. Traded assets

Households can trade three assets. First, households can trade a risk-free bond, paying a pre-tax return of r from time 0 to time 1. We denote household j's position in that asset by B_j. This asset comes in zero net supply. That is, if some households want to hold a long position in that asset, the market equilibrium has to bring about an interest rate that makes other households willing to issue such an asset.

Second, households can invest into the firm's equity that entitles them to the firm's payout in proportion to their share of equity. We denote household j's investment into the firm's equity by E_j and its share of aggregate equity E by $\alpha_j = \frac{E_j}{E}$. Third, households can invest into corporate bonds, issued by the firm. We denote household j's position in corporate bonds by D_j. Since the firm only issues bonds up to a limit for which the net return on equity is non-negative, corporate bonds are default-free and, therefore, perfect substitutes for the risk-free bond traded among households. Hence, they bear the same yield. Household j's initial endowment is denoted by $W_{0,j} > 0$ and its share of the total initial endowment $W_0 = \sum_{j=1}^{n} W_{0,j}$ is denoted by $\alpha_{0,j} = \frac{W_{0,j}}{W_0} > 0$.

2.4. The redistributive tax system

In our model, we also consider a government that wants to reduce the disparity in lifetime consumption opportunities across households that differ by their initial financial endowments. To attain this goal, the government taxes corporate profits at rate τ_C, households' profits from investments into firm equity at rate τ_E, and households' interest income at rate τ_B. The government implements a linear redistributive tax system, from which each household receives an identical share of tax revenues.[4] That is, poorer households pay less in taxes than they receive in transfer income. These households are, therefore, net recipients of transfer income. Richer households, on the other hand, pay more in taxes than they receive in transfers. Tax systems that allocate equal shares of tax revenues to citizens are commonly used in the public finance literature. Their use stretches back to the work of Romer (1975) and Meltzer and Richard (1981) and has later been frequently used.

The redistribution mechanism implies that the government accrues neither wealth nor debt. Within the time horizon of our model, any government debt must be settled through tax payments by the households. Consequently, government debt would never be considered net wealth by the households (Barro, 1974). We provide a formal argument that there is no room for an active fiscal policy in our model in Online Appendix B. This argument essentially relies on a standard replication argument and shows that government debt would crowd out corporate debt (Demirici et al., 2019).

2.5. The tax shield

Tax shields for corporate interest expenses exist in many countries to avoid a double-taxation of interest at the company level and at the level of the final recipient of the interest payment. Whether a tax shield exists or not directly affects corporate capital structure decisions, because the tax shield reduces the after-tax cost of debt, thus rendering debt-financed investments more appealing.[5] The tax shield also directly affects the payout, P, to equity holders at time 1:

$$P = I\left(1 + g\left(1 - \tau_C\right)\right) - D\widehat{R}, \tag{1}$$

in which $g = G - 1$ is the net growth rate of investments into the firm's production technology. $\widehat{R} = 1 + \widehat{r} = 1 + r\left(1 - \widehat{\tau}_C\right)$ is the firm's gross after-tax interest rate after accounting for whether the tax shield exists or not, and:

$$\widehat{\tau}_C = \begin{cases} \tau_C & \text{with the tax shield} \\ 0 & \text{without the tax shield} \end{cases} \tag{2}$$

is the tax rate applicable to the firm's interest payments.[6] With the leverage ratio $L \equiv D/E$, the payout to shareholders from Equation (1) can be rewritten as:

$$P = E\left[1 + g\left(1 - \tau_C\right) + L\left(g\left(1 - \tau_C\right) - \widehat{r}\right)\right]. \tag{3}$$

When the tax shield applies, the firm faces lower debt servicing costs, implying a higher amount remaining for its shareholders, which, in turn, renders equity investments more attractive.

2.6. The household optimization problem

Each household maximizes its present discounted utility from consumption over the single-period investment horizon subject to its intertemporal budget constraint. Households have a common utility discount factor, ρ, and a time-additive constant relative risk aversion (CRRA) utility function with risk aversion parameter $\gamma > 0$. That is, the utility from a consumption of C is given by:

$$U(C) = \begin{cases} \frac{C^{1-\gamma}}{1-\gamma} & \text{if } \gamma \neq 1 \\ \ln(C) & \text{if } \gamma = 1. \end{cases} \tag{4}$$

The evolution of household j's wealth after accounting for taxes consists of three components. First, the household receives the payout from its equity investments. After taxation on the household level, this leaves the household with an income of:

$$\alpha_j\left((P - E)\left(1 - \tau_E\right) + E\right). \tag{5}$$

Second, the household receives income from its holdings of the risk-free asset and corporate debt of:

$$\left(B_j + D_j\right)\widetilde{R}, \tag{6}$$

in which

$$\widetilde{R} = 1 + r\left(1 - \tau_B\right) \tag{7}$$

is the gross interest rate, after taxation on the household level. Third, the household receives transfer income, the level of which depends on the government's tax revenues, which in turn, consist of three components. First, the government generates a tax revenue of $\tau_E(P - E)$ by taxing gains from equity investments. Second, the taxation of interest on the household level provides a tax revenue of $\tau_B r D$. Finally, the government taxes the firm profit, F:

[4] We discuss the implications of other public spending rules at the end of section 3.

[5] We assume throughout that tax rates are such that the representative firm operates with corporate debt when the tax shield applies. Otherwise, the firm would never operate with debt, and whether the tax shield applies or not would not have any consequences.

[6] We do not consider limitations on the amount of interest expenses that can be deducted, such as, e.g., given by the European Union's recent Anti-Tax-Avoidance Directive (European Commission, 2016a).

Table 1
Definition of variables.

Variable	Description
ρ	The households' common utility discount factor
γ	The households' common degree of relative risk aversion
$\alpha_{0,j}$	Household j's initial endowment share
α_j	Household j's share of equity investments in the production process
B_j	Number of risk-free assets held by household j from time 0 to 1
D_j	Number of corporate bonds held by household j from time 0 to 1
E_j	Household j's equity investment from time 0 to time 1
D	Number of corporate bonds outstanding from time 0 to 1
E	Aggregate equity investment from time 0 to time 1
I	Total investment in production process, $I = E + D$
τ_E	Tax rate applicable to household income from equity
τ_B	Tax rate applicable to household income from bonds
τ_C	Corporate tax rate
$\widehat{\tau}_C$	Corporate tax rate applicable to a firm's interest payments
$\widetilde{\tau}$	Total tax rate applicable to a household's equity income: $\widetilde{\tau} = \tau_C + \tau_E(1-\tau_C)$
$\ddot{\tau}$	Tax rate measuring the loss in tax revenues from corporate and equity taxation per unit of equity replaced with debt: $= \widehat{\tau}_C + \tau_E(1-\widehat{\tau}_C)$
L	Firm's leverage ratio: $L = D/E$
$\bar{L}$	The maximum degree of corporate leverage L
$C_{t,j}$	Household j's consumption at time t, $t = 0, 1$
C_t	Aggregate consumption at time t, $t = 0, 1$
R	Gross interest rate before taxes
$\widetilde{R}$	Gross interest rate after taxes on household level
$\widehat{R}$	Gross interest rate after taxes on corporate level
r	Net interest rate before taxes: $r = R - 1$
F	Taxable corporate income
P	Payout from the firm to equity holders
G	Gross growth factor of investments
$\{G_j\}_{j=1}^{j=M}$	Outcomes of G: $G_1, G_2, \ldots, G_M$
g	Net growth factor of investments $g = G - 1$
$\bar{g}$	Expected value of g under the risk-neutral measure
$W_{t,j}$	Household j's entering wealth level at time t, $t = 0, 1$
n	Number of households in the economy

$$F = \begin{cases} Ig - rD & \text{with the tax shield} \\ Ig & \text{without the tax shield} \end{cases} \tag{8}$$

at the corporate tax rate τ_C. Total tax revenues are thus given by:

$$\tau_E (P - E) + \tau_B r D + \tau_C I g - \widehat{\tau}_C r D, \tag{9}$$

of which each household receives an equal share. The evolution of household j's wealth is then given by:

$$\begin{aligned} W_{1,j} =& \alpha_j \left((P - E)\left(1 - \tau_E\right) + E \right) + \left(B_j + D_j\right) \widetilde{R} + \\ & \frac{1}{n}\left(\tau_E (P - E) + \left(\tau_B - \widehat{\tau}_C\right) r D + \tau_C I g \right). \end{aligned} \tag{10}$$

We denote the effective rate of (double) taxation that the equity return is subject to by $\widetilde{\tau}$:

$$\widetilde{\tau} \equiv \tau_C + \tau_E(1-\tau_C) = \tau_E + \tau_C(1-\tau_E) \Leftrightarrow 1 - \widetilde{\tau} \equiv (1-\tau_E)(1-\tau_C). \tag{11}$$

That is, we use the symbol $\hat{x}$ for variables x that relate to corporate taxation, $\tilde{x}$ for variables x that relate to household taxation, and $\ddot{x}$ for variables x that relate to combined household and corporate taxation. Table 1 summarizes the notation used in this paper.
Household j's optimization problem is then given by:

$$\max_{\{\{C_{t,j}\}_{t=0}^{t=1}, E_j, B_j, D_j\}} U\left(C_{0,j}\right) + \rho \mathbb{E}_0\left[U\left(C_{1,j}\right)\right] \tag{12}$$

$$\text{s.t. } W_{0,j} = C_{0,j} + E_j + B_j + D_j \tag{13}$$

$$W_{1,j} = C_{1,j}. \tag{14}$$

The households' preference structure ensures that, despite financial markets being incomplete in the sense that a complete set of state-contingent claims cannot be constructed from the given stock and bond market, it is effectively complete in the sense that the conditions for an unconstrained Pareto optimal allocation are satisfied.[7]

3. The tax shield and the interest rate

In this section, we present the general-equilibrium solution to our model introduced in section 2 in closed form. We impose the following upper bound on the degree of corporate levering, which, with Equation (3), corresponds to $P \geq E$ in all states, and implies that investments into corporate bonds are risk-free:

$$L \leq \frac{g_M}{\left(\bar{g} - g_M\right)} \frac{1 - \tau_B}{\left(1 - \widehat{\tau}_C\right)\left(1 - \tau_E\right)} = \frac{g_M}{\left(\bar{g} - g_M\right)} \frac{1 - \tau_B}{1 - \ddot{\tau}} \equiv \bar{L}, \tag{15}$$

in which $g_M = G_M - 1$ is the lowest possible net growth rate of the production technology, $\ddot{\tau} = \widehat{\tau}_C + \tau_E\left(1 - \widehat{\tau}_C\right)$ is the tax rate measuring the loss in tax revenues from corporate and equity taxation per unit of equity replaced with debt, and $\bar{g}$ is the expected value of the net growth rate g under the risk-neutral measure.[8] The maximum degree of corporate leverage, $\bar{L}$, increases in the lowest possible return, g_M, as a higher g_M implies that more debt can be taken out before the corporation faces a risk of bankruptcy. Likewise, $\bar{L}$, decreases with increasing $\bar{g}$. A higher value of $\bar{g}$ implies a higher risk-free rate (see Equation (18) in Theorem 1 below), and thus a lower amount of debt that can be taken out without risking bankruptcy.

$\bar{L}$ is also affected by taxation. It decreases in τ_B, because from Equation (18) a higher tax rate on bond income leads to a higher risk-free rate, thus reducing the amount of debt that can be taken out without

[7] A number of now classical papers have analyzed this property for HARA utility functions, covering our case as a particular example. See Rubinstein (1974) and Brennan and Kraus (1978), among others.

[8] It holds that $\bar{g} = \sum_{m=1}^{M} q_m g_m$, in which q_m is defined in Equation (16).

facing a risk of bankruptcy. Also for tax-reasons, $\bar{L}$ increases in the total tax-burden on equity income. The higher the total tax-burden on equity income, the lower the risk-free rate, and thus the higher the amount of debt that can be taken out without risking bankruptcy. In sum, the maximum degree of corporate levering, $\bar{L}$, is determined by the lowest possible return, g_M, and the factors, that jointly determine the risk-free rate, as g_M and the risk-free rate determine the maximum degree of corporate leverage that can be taken out without running a risk of bankruptcy.

We provide a formal derivation in the proof of Theorem 1 that Equation (15) not only ensures the solvency of the representative firm in all states of the world, but simultaneously also guarantees a non-negative tax base. In the proof of Theorem 1, we further show that the risk-neutral measure is independent of tax rates and whether the tax shield applies or not. This measure is given by:

$$q_m = \frac{G_m^{-\gamma}}{\sum_{k=1}^{M} G_k^{-\gamma}}. \tag{16}$$

We apply the following measures of the tax burden on equity relative to debt financing (cf. Miller, 1977):

$$\xi \equiv \frac{(1-\tau_E)(1-\tau_C)}{1-\tau_B} = \frac{1-\widetilde{\tau}}{1-\tau_B}, \quad \psi \equiv \frac{(1-\tau_E)(1-\widehat{\tau}_C)}{1-\tau_B} = \frac{1-\ddot{\tau}}{1-\tau_B}. \tag{17}$$

When the tax shield applies, $\xi = \psi$. If the tax shield does not apply, $\psi \equiv \frac{1-\tau_E}{1-\tau_B}$ and ψ is the relevant measure of the tax burden on equity relative to debt financing. In what follows, we apply the subscript/superscript TS (nTS) to indicate the value of a variable in a scenario where the tax shield applies (does not apply).

Theorem 1. *For the interest rate and its relation to the tax shield it holds that:*

1. *The interest rate r is given by:*

$$r = \frac{\bar{g}\left(1-\tau_C\right)}{\frac{1}{1+L}\frac{1-\tau_B}{1-\tau_E} + \frac{L}{1+L}\left(1-\widehat{\tau}_C\right)} = \frac{\bar{g}\xi(1+L)}{1+L\psi}. \tag{18}$$

   If there exists a tax advantage to debt, the interest rate is increasing in the degree of leverage L. Provided that $L_{nTS} \le L_{TS}$, it, ceteris paribus, holds that:

   (a) *The interest rate is higher when the tax shield applies, i.e., $r_{TS} > r_{nTS}$.*
   (b) *Despite the increasing effect of the tax shield on the pre-tax interest rate, the corporate after-tax borrowing rate remains lower with the tax shield, i.e., $r_{TS}\left(1-\tau_C^{TS}\right) < r_{nTS}$.*

2. *If a tax shield is implemented in a tax revenue-neutral way, i.e., if the corporate tax rate is adjusted in such a way that expected tax revenue per unit of wealth invested remains constant, Equation (18) remains valid. If the firm simultaneously maximizes corporate valuation and, thus, operates with the maximum possible degree of leverage from Equation (15), items 1a and 1b remain valid.*
3. *The aggregate investment I as well as the growth rates of consumption $C_{1,j}/C_{0,j}$ are endogenously determined and increasing functions of the risk-free rate after tax:*

$$I = W_0 \frac{1}{1+\left(\frac{\rho}{M}\sum_{m=1}^{M} G_m^{-\gamma}\widetilde{R}\right)^{-1/\gamma}} \equiv W_0\frac{1}{1+H} \tag{19}$$

$$C_{1,j}/C_{0,j} = \frac{G}{H} \quad \forall j, \quad H \equiv \left(\frac{\rho}{M}\sum_{m=1}^{M} G_m^{-\gamma}\widetilde{R}\right)^{-1/\gamma}. \tag{20}$$

   The utility of aggregate consumption is an increasing function of the risk-free rate after tax.

Proof. A formal proof of Theorem 1 that uses standard asset pricing techniques and arguments is provided in Online Appendix A. □

Theorem 1 reveals that the tax shield affects the interest rate, even when the corporate tax rate, after the introduction of a tax shield, is adjusted in a manner that keeps the expected total tax revenue constant.

In partial equilibrium with a given corporate pre-tax borrowing rate r, the tax shield decreases the corporate after-tax borrowing rate from r to $r\left(1-\tau_C\right)$. Theorem 1, item 1 documents that, in general equilibrium, this decrease is counteracted by an increase in the pre-tax interest rate. The increase in the pre-tax interest rate is driven through both demand- and supply-side effects. First, the introduction of the tax shield decreases the after-tax cost of corporate debt and causes corporations to aim for a higher degree of corporate leverage (Equation (15)) provided there exists a tax-advantage to debt after the introduction of the tax shield. In that case, the firm increases the supply of corporate debt. Second, the decreased after-tax cost of debt leaves more profits to distribute to equity holders, thus rendering equity investments more attractive. As a consequence, investors want to partly substitute debt with equity. To nevertheless raise the desired amount of debt, the firm thus has to offer a higher coupon rate. That is, with the tax shield, market clearing is only achieved with a higher pre-tax interest rate. This is so, even if the tax shield is introduced in a tax-revenue neutral way that keeps the government's expected tax revenues per unit of wealth invested constant. That is, Theorem 1, item 2 shows that even a tax-neutral implementation of a tax shield affects the interest rate.

To provide an intuition for Equation (18), the equilibrium value of the interest rate, we rewrite it as

$$r\left(1-\tau_B\right) = \bar{g}\left(1-\widetilde{\tau}\right) + L\left(r(1-\ddot{\tau}) - \bar{g}\left(1-\widetilde{\tau}\right)\right). \tag{21}$$

We first look at the case, in which the firm is fully equity-funded. In that case, it holds that $r\left(1-\tau_B\right) = \bar{g}\left(1-\widetilde{\tau}\right)$. That is, the return on the risk-free asset after taxes on the household level corresponds to the expected after-tax return on equity under the risk-neutral measure, which is what standard asset pricing theory would predict.

With a tax advantage to debt, the firm chooses a levered capital structure and the standard asset pricing result no longer holds. Instead, as can be seen from Equation (21), the additional term $L\left(r(1-\ddot{\tau}) - \bar{g}\left(1-\widetilde{\tau}\right)\right)$ becomes relevant. $r(1-\ddot{\tau}) - \bar{g}\left(1-\widetilde{\tau}\right)$ is the expected tax advantage under the risk-neutral measure per unit of debt relative to equity financing. Multiplied with the leverage ratio, it quantifies the total expected tax benefit under the risk-neutral measure per unit of wealth invested from operating with leverage. With a tax advantage to debt, it is positive and increases in the order of magnitude of the tax-advantage. Hence, it holds that $r\left(1-\tau_B\right) > \bar{g}\left(1-\widetilde{\tau}\right)$, and the after-tax interest rate exceeds the expected growth rate of the economy after taxation on the corporate level under the risk-neutral measure.[9] That is, the tax shield has an effect that extends beyond determining whether the firm operates with leverage or not. In particular, in general equilibrium it increases the interest rate, thus, partly undoing the reduction of the corporate after-tax rate.

This has important macroeconomic effects. In particular, our model predicts a positive relationship between the risk-free rate and the growth rate of the economy. This result is in direct contrast to the popular view that investment, ceteris paribus, should increase when the risk-free rate decreases. In our model, economic growth increases with the risk-free rate, because a high risk-free rate decreases the price of fu-

[9] Since households can only invest into the risk-free asset and levered firms, but not into the production technology itself, this it not a violation of the definition of the risk-neutral measure. As a matter of fact, it holds that $r(1-\tau_B) = \bar{g}(1+L)(1-\widetilde{\tau}) - rL(1-\ddot{\tau})$.

ture versus present consumption and thus increases household savings, which, in turn, has a positive impact on economic growth.[10]

In our model, interest expenses on corporate debt are fully tax-deductible. If the tax deductibility of interest would be limited, such as to 30% of EBITDA as under the ATA directive, our model predictions could be quantitatively affected if the limit is binding. In that case, it might be optimal for the corporation to fully exploit the limit, i.e., to choose the maximum possible level of debt that still qualifies for the tax deductibility, but not to choose a level of corporate debt extending beyond that limit. Then, introducing a tax shield with a limit on the tax-deductibility of corporate interest expenses would lead to a smaller increase in the demand for corporate equity and a smaller increase in the supply of corporate debt compared to introducing a tax shield when no limit on the tax-deductibility of interest expenses applies. The smaller increase in the demand for corporate equity and the smaller supply of corporate debt should then lead to a smaller increase in the level of the pre-tax interest rate required to bring financial markets back into equilibrium. That is, a limit on the tax-deductibility would quantitatively but not qualitatively affect our results.

In our model, public spending is a lump-sum transfer to households as commonly assumed in the public finance literature and pioneered by Romer (1975) and Meltzer and Richard (1981). However, public spending could also be made in other forms, such as through a public consumption good, or, when aiming at increasing production, as an output subsidy to firms. In both cases, households would still aim at a linear consumption sharing rule to maximize their welfare. When taxes are used to finance a public consumption good, households should benefit (roughly) equally from the public consumption good. A welfare maximizing government should only finance a public consumption good, if the households derive at least the same welfare from the public good as they would attain with a lump-sum transfer. If the public consumption good provides households with the same level of welfare as the lump-sum transfer, our results should correspond to those with lump-sum transfers.

If the government instead uses tax revenues to finance an output subsidy, then, as input and output are proportional to each other, the output subsidy would act as a positive multiplier on I. Consequently, firm profits would increase, which, in turn, would render equity investments more attractive and increase the risk-free rate for capital markets to clear. Yet, irrespective of the increase in the risk-free rate caused by the output subsidy, a tax shield makes equity even more desirable, thus leading to a further increase of the risk-free rate. Hence, our key finding that the tax shield increases the risk-free rate should remain valid when tax revenues are used to finance an output subsidy.

4. An illustration of effects

In this section, we want to illustrate the implications of the tax shield for the interest rate in a simple numerical example with realistic parameter choices. We assume one period to correspond to one year. The degree of risk aversion is set to $\gamma = 10$. The tax rates are set to $\tau_E = 20\%$, $\tau_B = 39.6\%$, and $\tau_C = 35\%$, the top tax rates for U.S. households and corporations prior to the recent tax-cuts. We allow τ_C to vary in our illustration of effects. For simplicity, we focus on a setting with $M = 2$ possible realizations throughout our numerical analysis. We set the mean of the growth rate of our investment opportunity to 6.4%, corresponding to the average post-war GDP growth in the U.S. The standard deviation of the investment opportunity's growth rate is chosen to attain a level of corporate levering that is in line with the historical empirical evidence. More specifically, we set the standard deviation to 4.5%, implying a maximum debt-to-capital ratio of 46%, cf. Equation (15). This value is in the range of historical ratios reported by Graham et al. (2015) and used in our numerical examples throughout.

Fig. 1 depicts how the difference between the interest rate in the presence and in the absence of the tax shield varies with the level of the corporate tax rate. The left panel in Fig. 1 depicts the interest rate as a function of the corporate tax rate in a setting with the tax shield (solid line) and without (dashed line), when the corporate tax rate varies between $\tau_C = 0\%$ and $\tau_C = 99\%$.[11] The right panel depicts the change in the pre-tax interest rate, r (solid line), and the corporate after-tax borrowing rate, $\hat{r}$ (dashed line), due to the tax shield in basis points.

Fig. 1 illustrates how the interest rate decreases in the level of the corporate tax rate. For corporate tax rates below 22.25%, the firm operates without corporate debt; hence, whether the tax shield applies or not does not have an effect. For levels of the corporate tax rate exceeding 22.25%, it becomes optimal to operate with corporate debt when the tax shield applies. Given that the current combined federal and state corporate income tax rates in the US, ranging from 21% in a few states with no federal corporate income taxation to 30% in the state of New York, typically exceeds 22.25% it is typically optimal for the corporate to operate with leverage. It also remains optimal to be unlevered without the tax shield, which results in the linear relationship between the corporate tax rate and the interest rate when the tax shield does not apply. With the tax shield, there is a kink at a corporate tax rate of 22.25%. The tax shield reduces the after-tax cost of corporate debt, which makes investments into equity more desirable. The order of magnitude increases with the level of the corporate tax rate. To nevertheless find investors that are willing to hold corporate debt, the firm has to offer a higher interest rate when the tax shield applies. For example, when corporate taxes do not apply, i.e., for $\tau_C = 0\%$, the interest rate is 5.8%. It decreases to 3.6% with the tax shield and 2.9% without the tax shield for a corporate tax rate of $\tau_C = 50\%$.

From the right panel in Fig. 1, with a tax advantage to corporate debt, the pre-tax interest rate increases linearly in the level of the corporate tax rate. This increase in the pre-tax interest rate partly offsets, but does not completely eliminate, the decrease in the corporate after-tax borrowing rate stemming from the tax shield.

5. Alternative policies

This section has two goals. First, it explores an alternative policy, which also encourage firms to invest more in subsection 5.1. Second, it explores the implications of a policy that keeps total expected tax-revenues constant in subsection 5.2.

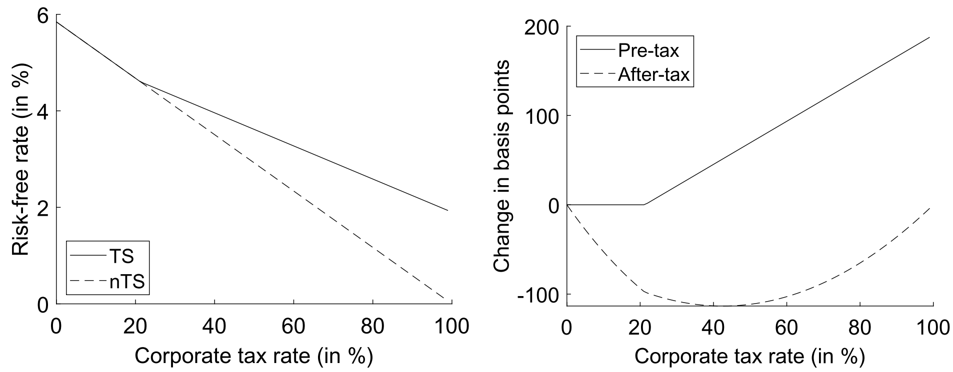
5.1. Alternative to debt tax shield

In this section, we explore to what extent the debt tax shield instrument is different from other policies. More specifically, as an alternative to introducing a debt tax shield, the legislator could also consider other revenue-neutral tax reforms in a manner similar to item 2 in Theorem 1, such as altering τ_E or τ_B. In this section, we focus on tax-reforms that alter τ_E. Similar considerations can, however, also be made for tax-reforms that alter τ_B.

Theorem 2. *For every tax-reform that reduces τ_E and keeps all other tax-rates constant, there exists a revenue-neutral tax reform, which reduces τ_C and keeps all other parameters constant, such that the total expected tax-revenue per unit of wealth invested is identical under both tax-reforms.*

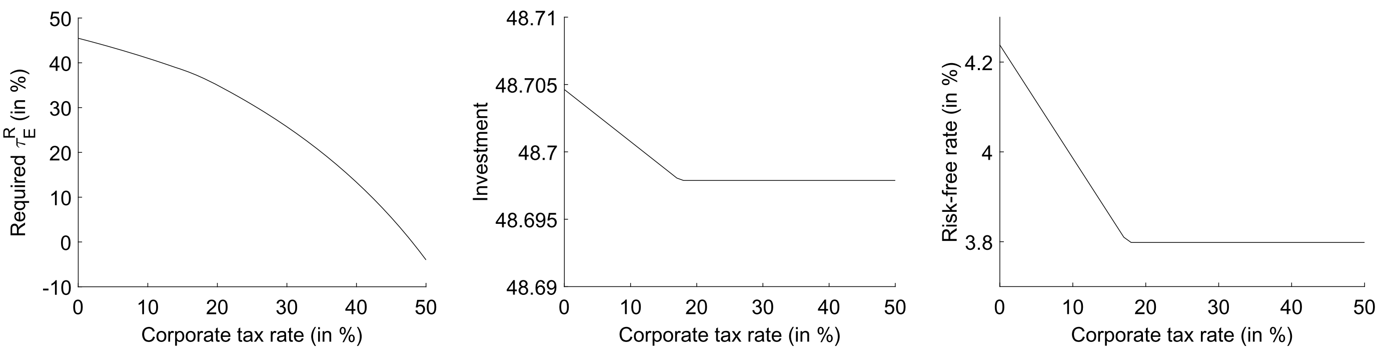
[10] On the other hand, the positive relation between the interest rate and consumption growth is a well-known phenomenon in consumption based asset pricing theory. See, e.g., Munk (2013), chapter 11: "The Economics of the Term Structure of Interest rates" for an extensive exposition of such models with an endogenously determined interest rate.

[11] We also explored varying τ_E and τ_B, which resulted in similar results. The results mainly channel themselves through the variation of the parameters ξ and ψ as defined in Equation (17).



In the left panel, this figure depicts the interest rate in a setting with the tax shield (solid line, TS) and without the tax shield (dashed line, nTS) as a function of the corporate tax rate. The right panel depicts the change in the pre-tax interest rate, r (solid line), and the corporate after-tax borrowing rate, $\hat{r}$ (dashed line), due to the tax shield in basis points.

Fig. 1. The interest rate.



This figure depicts the impact of a tax-reform that varies the corporate tax rate τ_C and the tax rate on equity income τ_E in a manner that keeps tax-revenues per unit of wealth invested constant. The left panel depicts the required tax-rate on equity income (Required τ_E^R) for a given level of the corporate tax rate. The middle graph shows the total amount of wealth invested in the alternative tax-system when initial wealth in the economy is normalized to $W_0 = 100$. The right graph depicts the risk-free rate.

Fig. 2. Alternative tax-revenue neutral reform.

Proof. A formal proof of Theorem 2 is provided in Online Appendix A. □

Theorem 2 documents, that there exist revenue-neutral tax-reforms that reduce the tax rate on equity income or the corporate tax rate. In other words, as an alternative to introducing a debt tax shield, the legislator can also try to encourage investments through other policy tool, in particular, by altering the level of tax-rates. To address the implications of the tax reform characterized by Theorem 2 on important economic variables, such as aggregate investments in the economy as well as the risk-free rate, we perform a quantitative analysis.

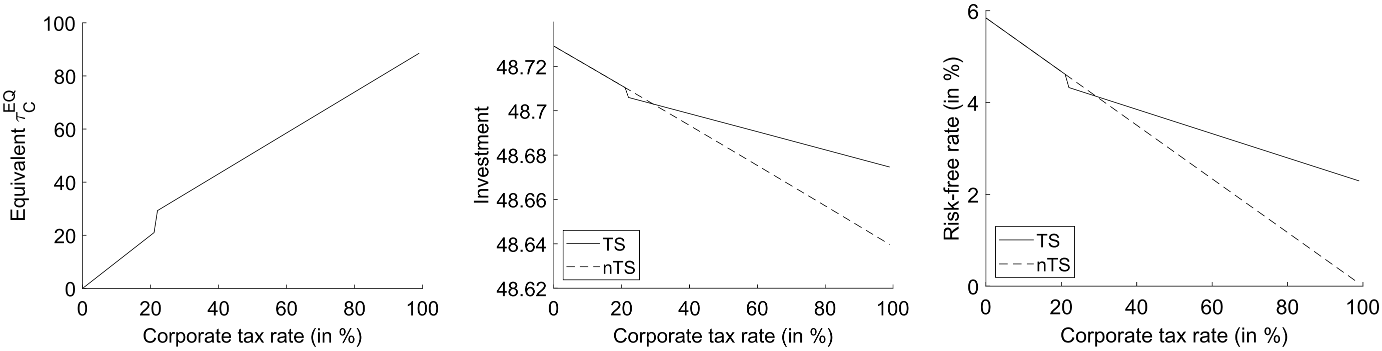
Fig. 2 depicts the impact of a tax-reform that varies the corporate tax rate τ_C and the tax rate on equity income τ_E in a manner that keeps tax-revenues per unit of wealth invested constant. The left panel depicts the required tax-rate on equity income (Required τ_E^R) for a given level of the corporate tax rate. The middle graph shows the total amount of wealth invested in the alternative tax-system when initial wealth in the economy is normalized to $W_0 = 100$. The right graph depicts the risk-free rate.

From the left panel of Fig. 2, the tax rate on equity income τ_E^R that is required to ensure tax-revenue neutrality decreases in the level of the corporate tax rate. This result makes intuitive economic sense as a higher corporate tax rate leads to higher tax revenues from taxing corporate profits, i.e., tax-revenue neutrality is achieved with a lower tax rate on equity income. For corporate tax rates exceeding 48%, the required tax rate on equity income even turns negative. For levels of the corporate tax-rate exceeding 17%, the firm does not operate with leverage as it then holds that $\tau_E^R < \tau_B$, i.e., there exists a tax advantage to equity for larger values of the corporate tax rate.

The middle graph of Fig. 2 shows that investments decrease in the level of the corporate tax rate as long as the firm operates with leverage. Again, this makes intuitive economic sense. As the corporate tax-rate increases, the tax advantage to debt-financing decreases, thus rendering investments less attractive, which in turn leads to lower investments. Once the corporate tax rate exceeds 17%, the firm solely operates with equity and the total tax burden on investment profits remains constant as by the definition of tax-revenue neutrality all increases in the corporate tax rate are perfectly offset by decreases in the tax rate on equity income and vice versa.

The right graph in Fig. 2 shows that the reduction in aggregate investments in the risk-free rate, as from Equation (19), higher interest rates imply higher investments. Once the corporate tax rate exceeds 17%, the firm operates without debt, and the risk-free rate remains constant as from Equation (18), the effect of increases in the corporate tax rate are perfectly offset by decreases in the tax rate on equity income and vice versa.

Overall, this section shows that in addition to introducing a debt tax-shield, there exist other reforms that may encourage firms to undertake more investment and affect the interest rate. Reforms altering the corporate tax rate and simultaneously the tax rate on equity income to preserve tax-revenue neutrality can also stipulate investments. However, unlike a policy that introduces a debt tax shield, the reform investigated in this section can only achieve the goal of encouraging firms to invest more when a low corporate tax rate is chosen. A debt tax shield, on the other hand, is able to encourage firm investments ir-



This figure depicts the impact of a tax-revenue neutral tax-reform that introduces a debt tax shield while simultaneously increasing the level of the corporate tax-rate τ_C to a level that ensures the same level of expected total tax-revenues as before the introduction of the debt tax shield. The left panel depicts the corporate tax-rate that is required in the setting with the debt tax shield to attain the same level as in the tax-system without the debt tax shield for a given level of the corporate tax-rate in the setting without the debt tax shield (Equivalent τ_C^{EQ}). The middle graph shows the total amount invested in the tax-system with the debt tax shield (solid line, TS) and the tax-system without the debt tax shield (dashed line, nTS) as a function of the corporate tax-rate in the tax-system without the debt tax shield. The right graph depicts the risk-free rate in the tax-system with the debt tax shield (solid line, TS) and the tax-system without the debt tax shield (dashed line, nTS). Initial wealth in the economy is normalized to $W_0 = 100$.

Fig. 3. Total tax-revenue neutrality.

respective of the level of the corporate tax rate as long as there is a tax-advantage to debt after the introduction of the debt tax shield – a condition which is typically met in industrialized countries around the world. In addition, a policy that substantially reduces corporate tax rates may lead to a bigger public debate than introducing a debt tax shield.

5.2. *Tax-revenue neutrality*

In Theorem 1, item 2, we document that our key findings of introducing a corporate debt tax shield on the interest rate remain valid when the debt tax shield is introduced in a tax-revenue neutral way in the sense that it keeps the expected tax-revenue per unit of wealth invested constant. Tax-revenue neutrality that keeps the expected tax-revenue per unit of wealth invested constant is useful for a legislator that aims at keeping unintended side-effects from changes in taxation on investments low; in particular, the per unit of wealth invested point of view ensures that tax revenues and the associated degree of redistribution is kept constant as a share of GDP.

Another widely used concept of tax-revenue neutrality asks for a tax-reform that keeps the total level of tax-revenues constant. This concept should be particularly important for the government's budget. While we are able to provide closed-form solutions for the former concept (see Theorem 1, item 2 and Theorem 2), closed-form solutions generally do not exist for the latter, because changes to the tax-system affect the rate of intertemporal substitution as can be seen from Equation (19) combined with (7) and therefore lead to a non-linear impact of such tax-reforms on investments.

The primary goal of our work is to provide closed-form solutions to the question of how the corporate debt tax shield affects the interest rate. We therefore only briefly illustrate the impact of a tax-reform that is revenue-neutral in the latter sense, i.e., a tax-reform that keeps the total (expected) tax-revenue constant. We proceed in a similar way to Theorem 1, item 2 and ask how the corporate tax-rate needs to be changed in reaction to the introduction of a debt tax shield to reach the desired form of tax-revenue neutrality.

Fig. 3 graphically summarizes the impact of a tax-revenue neutral tax-reform that introduces a debt tax shield while simultaneously increasing the level of the corporate tax-rate τ_C to a level that ensures the same level of expected total tax-revenues as before the introduction of the debt tax shield. The model parameter values used are the same as in Section 4 and for Fig. 1. Unlike in Fig. 1, Fig. 3 depicts results for a tax-revenue neutral tax-reform. The left panel depicts the corporate tax-rate that is required in the setting with the debt tax shield to attain the same level as in the tax-system without the debt tax shield for a given level of the corporate tax-rate in the setting without the debt tax shield (Equivalent τ_C^{EQ}). The middle graph shows the total amount invested in the tax-system with the debt tax shield (solid line, TS) and the tax-system without the debt tax shield (dashed line, nTS) as a function of the corporate tax-rate in the tax-system without the debt tax shield. The right graph depicts the risk-free rate in the tax-system with the debt tax shield (solid line, TS) and the tax-system without the debt tax shield (dashed line, nTS). Initial wealth in the economy is normalized to $W_0 = 100$.

From the left panel of Fig. 3, the equivalent corporate tax-rate, τ_C^{EQ}, in the tax-system with debt tax shield increases in the level of the corporate tax-rate in the tax-system without. This makes intuitive economic sense as an increase in the tax-rate in the former tax-system leads to higher tax-revenues in that system and thus also needs to lead to higher tax-revenues in the latter system, i.e., to a higher equivalent corporate tax rate, τ_C^{EQ}. When the corporate tax rate in the tax-system without the debt tax shield reaches 22%, which is slightly smaller than without total tax-revenue neutrality, the equivalent corporate tax-rate in the tax-system with debt tax shield jumps up. This jump reflects that for lower levels of the corporate tax-rate, the firm operates without corporate debt and from that level on, it operates with corporate debt. That is, at that level of the corporate tax rate, corporate debt jumps up, thus leading to a jump in τ_C^{EQ}, as forgone tax-revenues from the introduction of the debt tax shield have to be made up for by a higher equivalent corporate tax rate. From the middle graph in Fig. 3, the higher equivalent corporate tax-rate, τ_C^{EQ}, leads to a drop in total investments, as the benefits from the more beneficial taxation of corporate debt, are outweighed by the higher cost on equity investments. However, this effect is quantitatively very small. The reduction in aggregate investments leads to a reduction in the risk-free rate. However, the reduction in the risk-free rate is also quantitatively very small.

6. Conclusion

Our stylized general-equilibrium model predicts that the tax shield increases the interest rate. This increase partly offsets the reduction in the corporate after-tax interest rate implied by the tax shield, but does not fully eliminate it. Through its effect on the interest rate, the debt tax shield affects economic growth, and thereby, ultimately, welfare.

Extending beyond the scope of our work, it would be interesting to explore how the tax shield affects macroeconomic variables, such as aggregate productivity and welfare if firms differ in their capital structures for reasons outside our model. While this may not have a first-order effect on the interest rate, it should have distributional effects. Intuitively, firms with higher leverage ratios should benefit more from the presence of a tax shield. If leverage ratios differ systematically between traditional and new emerging industries, this may be of relevance for a nation's future economic development. The tax shield can support the new emerging industries, if they operate with higher leverage ratios. In that case, the tax shield could positively affect productivity in these sectors and welfare in the long run. We leave these interesting questions, that extend beyond the scope of our model, for future research.

CRediT authorship contribution statement

Marcel Fischer: Formal analysis, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Bjarne Astrup Jensen:** Conceptualization, Formal analysis, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None.

Data availability

No data was used for the research described in the article.

Appendix A. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jbankfin.2024.107096.

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