Interest deductibility and capital investment

Efraim Berkovich Zheli He

The Wharton School, University of Pennsylvania

May 12, 2022

Overview

In partial equilibrium, value-maximizing firm

- investment, dividends, tax liability
- responses to tax rate, inflation rate changes

Findings:

1% increase in corporate tax rate decreases capital stock by 0.098%.

- Depreciation and interest deductions largely mitigate the negative effect of higher tax rate on capital.

1% increase in inflation rate increases capital stock by 1.057%.

- Higher inflation encourages more capital investment when partially financed by debt.

This work

- Detailed modeling of corporate taxation that reflects the current U.S. tax code.
- Tax shield (interest deductibility) determines the firm's optimal debt policy.
- Calibrate the model to match observed corporate credit spread, leverage ratio.

Firm's problem

A representative firm owns capital, takes as given wage, w_t, the discount factor, $\frac{1}{1+R_t}$. It chooses labor, l_t, next period's capital, k_{t+1}, debt, b_{t+1}.

$$V_t(k_t, b_t) = max_{\{l_t, k_{t+1}, b_{t+1}\}} d_t(l_t, k_t, k_{t+1}, b_t, b_{t+1}) + \frac{1}{1+R_t} V_{t+1}(k_{t+1}, b_{t+1})$$

subject to

$$0 < l_t \leq L_t(w_t)$$
$$b_{t+1} \geq 0, k_{t+1} > 0$$

Dividends

$$
\begin{aligned}
d_t = y_t & \qquad \text{(Output)} \\
- w_t l_t & \qquad \text{(Labor cost)} \\
- i_t & \qquad \text{(Investment)} \\
- C_k(k_t, k_{t+1}) & \qquad \text{(Capital adjustment cost)} \\
- \zeta_t^{otherExp} y_t & \qquad \text{(Other expenses)} \\
+ b_{t+1} & \qquad \text{(Business debt proceeds)} \\
- (1 + \rho_t) b_t & \qquad \text{(Business debt repayment)} \\
- T_t & \qquad \text{(Corporate taxation)}
\end{aligned}
$$

details

Corporate income tax liability

The total amount of corporate income tax liability is:

$$T_t = \tau_t \Pi_t^{taxable} - \zeta_t^{invCred} i_t - \zeta_t^{otherCred} y_t$$

where taxable income is:

$$\begin{aligned}
\Pi_t^{taxable} &= y_t && \text{(Sales)} \\
&- w_t l_t && \text{(Labor deduction)} \\
&- \phi_t^{int} \rho_t b_t && \text{(Interest deduction)} \\
&- x_t && \text{(Depreciation deduction)} \\
&- C_k(k_t, k_{t+1}) && \text{(Capital installation deduction)}
\end{aligned}$$

depreciation deduction

Tax shield

Tax shield is deductible amount ϕ^{int} of nominal interest payment:

$$\phi_t^{int}\rho_t b_t = \phi_t^{int}(R_{t-1}b_t + \nu(b_t, k_t))$$

The convex leverage cost function $\nu(\cdot)$ is defined by:

$$\nu\left(b_t, k_t\right) = \frac{1}{\nu_1}\left(\frac{b_t}{\nu_2 k_t}\right)^{\nu_1}\nu_2 k_t$$

Corporate debt

Firm chooses debt to maximize tax benefit net of leverage cost:

$$b^*_{t+1} = \left(\frac{\tau_{t+1}\phi^{int}_{t+1} R_t}{1 - \tau_{t+1}\phi^{int}_{t+1}} \right)^{\frac{1}{\nu_1 - 1}} \nu_2 k_{t+1}$$

- $\nu_1 = 2.92$: elasticity of corporate credit spread [1] w.r.t. debt to fixed assets using quarterly data between 1953Q2 and 2020Q3.
- $\nu_2 = 6.90$: given $R = 2.34\%$, debt to fixed assets ratio averaged between 2018Q1 and 2020Q3 (46.3%).

parameters

[1] Difference between Moody's seasoned AAA corporate bond yield and 20-year Treasury constant maturity rate.

A marginal increase in corporate tax rate

- $\tau = 21\%$, $R = 2.34\%$

	$\phi^{exp} = 0, \phi^{int} = 0$	$\phi^{exp} = 0, \phi^{int} \neq 0$	$\phi^{exp} \neq 0, \phi^{int} = 0$	$\phi^{exp} \neq 0, \phi^{int} \neq 0$
$\frac{\frac{dk}{k}}{d\tau}$	-2.129	-1.922	-0.393	-0.098
$\frac{\frac{dd}{k}}{d\tau}$	-0.141	-0.129	-0.038	-0.029
$\frac{\frac{dCTR}{k}}{d\tau}$	0.097	0.098	0.038	0.034

- Higher tax rate increases cost of capital, $\frac{r}{1-\tau}$, lowers capital stock.

equilibrium | comparative statics

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- Cost of capital increases by less, $\frac{r}{1-\tau} - \frac{\tau \phi^{exp} r}{1-\tau}$, since the firm is able to deduct investment over time and ϕ^{exp} is high.

A marginal increase in corporate tax rate

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- Cost of capital increases by less, $\frac{r}{1-\tau} - \frac{\tau\phi^{int}r}{1-\tau} - \frac{\tau\phi^{int}\pi}{1-\tau}$, since the firm is able to deduct nominal interest expense.

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- Deduction of inflation component of nominal interest rate and deduction of investment largely offset the increase in cost of capital, $\frac{r}{1-\tau} - \frac{\tau\phi^{int} r}{1-\tau} - \frac{\tau\phi^{int}\pi}{1-\tau} - \frac{\tau\phi^{exp} r}{1-\tau}$.

A marginal increase in corporate tax rate

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- Smaller decline in capital stock and lower tax liability restore dividends.

A marginal increase in corporate tax rate

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- Higher tax rate raises corporate income taxes for each dollar of profit.
- Depreciation and interest deductions increase, tax revenue decreases.
- Firm changes its investment and debt policies, which affects tax revenue.

A marginal increase in inflation rate

- $\tau = 21\%,\ R = 2.34\%$

	$\phi^{exp} = 0, \phi^{int} = 0$	$\phi^{exp} = 0, \phi^{int} \neq 0$	$\phi^{exp} \neq 0, \phi^{int} = 0$	$\phi^{exp} \neq 0, \phi^{int} \neq 0$
$\frac{\frac{dk}{k}}{d\pi}$	$\boxed{0}$	1.690	-1.026	1.057
$\frac{\frac{dd}{k}}{d\pi}$	$\boxed{0}$	0.056	-0.046	0.011
$\frac{\frac{dCTR}{k}}{d\pi}$	$\boxed{0}$	0.029	0.045	0.041

- Inflation has no effect on cost of capital, $\frac{r}{1-\tau}$. Capital stock, dividends and corporate tax revenue remain the same.

A marginal increase in inflation rate

- $\tau = 21\%$, $R = 2.34\%$

	$\phi^{exp} = 0, \phi^{int} = 0$	$\phi^{exp} = 0, \phi^{int} \neq 0$	$\phi^{exp} \neq 0, \phi^{int} = 0$	$\phi^{exp} \neq 0, \phi^{int} \neq 0$
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- Inflation decreases the present value of tax deduction of investment, increases cost of capital, $\frac{r}{1-\tau} - \frac{\tau\phi^{exp} r}{1-\tau}$, and lowers capital stock.
- Dividends drop: lower production and lower depreciation deduction.
- Tax revenue increases: lower depreciation deduction offsets lower corporate profits.

A marginal increase in inflation rate

- $\tau = 21\%,\ R = 2.34\%$

	$\phi^{exp} = 0, \phi^{int} = 0$	$\phi^{exp} = 0, \phi^{int} \neq 0$	$\phi^{exp} \neq 0, \phi^{int} = 0$	$\phi^{exp} \neq 0, \phi^{int} \neq 0$
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- Higher inflation lowers cost of capital, $\frac{r}{1-\tau} - \frac{\tau\phi^{int} r}{1-\tau} - \frac{\tau\phi^{int}\pi}{1-\tau}$,, and leads to higher capital stock.
- Dividends increase: higher production, higher interest deduction offset higher interest on debt.
- Tax revenue increases: higher tax revenue from interest income, corporate profits outweigh higher interest deduction.

A marginal increase in inflation rate

- $\tau = 21\%$, $R = 2.34\%$

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- Capital stock expands as higher deduction of inflation component of nominal interest dominates lower present value of depreciation deduction, $\frac{r}{1-\tau} - \frac{\tau\phi^{int} r}{1-\tau} - \frac{\tau\phi^{int}\pi}{1-\tau} - \frac{\tau\phi^{exp} r}{1-\tau}$.
- Dividends increase: higher production, higher interest deduction outweigh lower depreciation deduction, higher interest on debt.
- Tax revenue increases: higher tax revenue from interest income, corporate profits, lower depreciation deduction outweigh higher interest deduction.

Conclusion

- Changing statutory corporate tax rate alone does not have a big impact $\rightarrow$ other tax provisions matter.
- **Higher tax rate**: small negative effect on capital stock.
- **Higher inflation**: capital stock expands when partially financed by debt.

Appendix: Dividends

$$y_t = A_t k_t^{\alpha_k} l_t^{\alpha_l}$$
$$i_t = k_{t+1} - (1-\delta)k_t$$
$$C_k(k_t, k_{t+1}) = \frac{\eta}{2}\left(\frac{k_{t+1} - (1-\delta)k_t}{k_t}\right)^2 k_t$$

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Appendix: Depreciation deduction

In the present year t, the firm's depreciation deduction is:

$$x_t = \sum_{s=0}^{40} \psi_s i_{t-s}(1 - \zeta_{t-s}^{invCred})$$

- ψ_s is the allowed depreciation in schedule year s.

In steady state, present value of tax deduction of a dollar of current investment:

$$\phi^{exp} = \sum_{s=0}^{40} \frac{1}{(1+R)^s} \psi_s (1 - \zeta^{invCred})$$

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Appendix: Parameters

Description	Parameter	Value
adjustment cost	η	0.2
economic depreciation	δ	0.08
capital share	α_k	0.34
labor share	α_l	0.66
TFP	A	1
leverage sensitivity	ν_1	2.92
leverage scaling	ν_2	6.90
corporate tax rate	τ	0.21
depreciation deduction	ϕ^{exp}	0.879
interest deduction	ϕ^{int}	0.925
other expenses	$\zeta^{otherExp}$	0.095
investment credit	$\zeta^{invCred}$	0.053
other tax credit	$\zeta^{otherCred}$	0.012
interest rate	R	0.0234
inflation rate	π	0.02

Table: Parameter description and value

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Appendix: Optimal l

To condense notation, define in the steady state:

$$\chi_{div} = 1 - \zeta^{otherExp} - \tau + \zeta^{otherCred}$$
$$\chi_{debt} = \left(\frac{\tau\phi^{int}R}{1-\tau\phi^{int}}\right)^{\frac{1}{\nu_1 - 1}} \nu_2$$

The first-order condition with respect to the firm's labor demand implies that in the steady state,

$$l = \left[\frac{w(1-\tau)}{\alpha_l A k^{\alpha_k}\chi_{div}}\right]^{\frac{1}{\alpha_l - 1}}$$

Appendix: Optimal k

The first-order condition with respect to k_{t+1} implies:

$$\frac{\partial d_t}{\partial k_{t+1}} + \frac{1}{1+R_t}\frac{\partial d_{t+1}}{\partial k_{t+1}} + \ldots + \frac{1}{(1+R_t)\ldots(1+R_{t+40})}\frac{\partial d_{t+41}}{\partial k_{t+1}} = 0$$

and it follows that in the steady state,

$$-\eta(1-\tau)\delta - 1 + \tau\phi^{exp} + \zeta^{invCred} + \chi_{debt} + \frac{1}{1+R}\Bigg[\alpha_k A k^{\alpha_k-1} l^{\alpha_l}\chi_{div}(1+\pi)$$
$$-\frac{\eta}{2}(1-\tau)\left((1-\delta)^2-1\right)(1+\pi) + (1-\delta)(1-\tau\phi^{exp}-\zeta^{invCred})(1+\pi)$$
$$-\chi_{debt} - \chi_{debt}(1-\tau\phi^{int})R - (1-\tau\phi^{int})\frac{\nu_2^{1-\nu_1}}{\nu_1}\left(\frac{b}{k}\right)^{\nu_1}\Bigg] = 0$$

where π is the inflation rate. back

Appendix: Comparative statics

To a first-order approximation by using the implicit function theorem, the change in k and b caused by a small change in τ satisfies:[2]

$$\begin{bmatrix} \frac{\partial f_1}{\partial k} & \frac{\partial f_1}{\partial b} \\ \frac{\partial f_2}{\partial k} & \frac{\partial f_2}{\partial b} \end{bmatrix} \begin{bmatrix} dk \\ db \end{bmatrix} = \begin{bmatrix} -\frac{\partial f_1}{\partial \tau} d\tau \\ -\frac{\partial f_2}{\partial \tau} d\tau \end{bmatrix}$$

When $\phi^{int} = 0$, $b = 0$. The change in k satisfies:

$$\frac{\frac{dk}{k}}{d\tau} = -\left(\frac{\partial f_1}{\partial k} k\right)^{-1} \frac{\partial f_1}{\partial \tau}$$

- f_1: first-order condition with respect to k_{t+1}.
- f_2: optimal debt equation.

[2] $\frac{\partial f_1}{\partial k}$ is the partial derivative of f_1 with respect to k.

Appendix: Comparative statics

Using Cramer's rule,

$$dk = \frac{\begin{vmatrix} -\frac{\partial f_1}{\partial \tau} d\tau & \frac{\partial f_1}{\partial b} \\ -\frac{\partial f_2}{\partial \tau} d\tau & \frac{\partial f_2}{\partial b} \end{vmatrix}}{\begin{vmatrix} \frac{\partial f_1}{\partial k} & \frac{\partial f_1}{\partial b} \\ \frac{\partial f_2}{\partial k} & \frac{\partial f_2}{\partial b} \end{vmatrix}}$$

After some algebra, we have:

$$\frac{\frac{dk}{k}}{d\tau} = \frac{-\frac{\partial f_1}{\partial \tau}\frac{\partial f_2}{\partial b} + \frac{\partial f_1}{\partial b} k \frac{\frac{\partial f_2}{\partial \tau}}{k}}{\frac{\partial f_1}{\partial k} k \frac{\partial f_2}{\partial b} - \frac{\partial f_1}{\partial b} k \frac{\partial f_2}{\partial k}}$$

Appendix: Comparative statics

Similarly,

$$db = \frac{\begin{vmatrix} \frac{\partial f_1}{\partial k} & -\frac{\partial f_1}{\partial \tau} d\tau \\ \frac{\partial f_2}{\partial k} & -\frac{\partial f_2}{\partial \tau} d\tau \end{vmatrix}}{\begin{vmatrix} \frac{\partial f_1}{\partial k} & \frac{\partial f_1}{\partial b} \\ \frac{\partial f_2}{\partial k} & \frac{\partial f_2}{\partial b} \end{vmatrix}}$$

which implies that,

$$\frac{\frac{db}{k}}{d\tau} = \frac{-\frac{\partial f_1}{\partial k} k \frac{\frac{\partial f_2}{\partial \tau}}{k} + \frac{\partial f_1}{\partial \tau}\frac{\partial f_2}{\partial k}}{\frac{\partial f_1}{\partial k} k \frac{\partial f_2}{\partial b} - \frac{\partial f_1}{\partial b} k \frac{\partial f_2}{\partial k}}$$

Appendix: Comparative statics

The comparative static derivative of k (in percentage) and b with respect to π can be analogously calculated as:

$$\frac{\frac{dk}{k}}{d\pi} = \frac{-\frac{\partial f_1}{\partial \pi}\frac{\partial f_2}{\partial b} + \frac{\partial f_1}{\partial b}k\frac{\frac{\partial f_2}{\partial \pi}}{k}}{\frac{\partial f_1}{\partial k}k\frac{\partial f_2}{\partial b} - \frac{\partial f_1}{\partial b}k\frac{\partial f_2}{\partial k}} \tag{1}$$

$$\frac{\frac{db}{k}}{d\pi} = \frac{-\frac{\partial f_1}{\partial k}k\frac{\frac{\partial f_2}{\partial \pi}}{k} + \frac{\partial f_1}{\partial \pi}\frac{\partial f_2}{\partial k}}{\frac{\partial f_1}{\partial k}k\frac{\partial f_2}{\partial b} - \frac{\partial f_1}{\partial b}k\frac{\partial f_2}{\partial k}} \tag{2}$$

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