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Risky business: policy uncertainty and investment

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Abstract
Previous work has shown that nonlinear taxation can affect the willingness to undertake risky investments. We show that similar results can arise if agents are uncertain regarding future tax rates. Uncertain taxes distort investment decisions when tax rates are correlated with marginal productivity. We demonstrate this result in a simple theoretical framework, which can also explain some well-known results on the effects of tax progressivity and tax asymmetry on investment. Time-series estimates for the post-WW2 era suggest a negative correlation between effective tax rates and total factor productivity in the USA, yielding an effect on firm investment equivalent to an investment subsidy of around 1 percent. Our results have wide-ranging implications for a variety of tax-related work, including effective tax rates, optimal audit policy, and principal-agent problems between investors and managers.
Policy uncertainty · Investment · Tax asymmetry · Tax progressivity · Taxation asinsurance · Audit policy · Effective tax rate

JEL Codes H21 · H25 · H26 · H30 · H31 · H32

1 Introduction

It has long been known that tax progressivity and tax law asymmetries can dampen investment. We develop a simple yet general framework that explains several empirically documented effects of nonlinear tax policies on investment. Our model also offers the novel insight that a similar effect can arise if tax policy is uncertain when agents make decisions, even if agents know that tax rates will be linear. Facing higher tax rates in states of the world where investment happens to be more

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productive will depress the after-tax expected return, a mechanism largely ignored by previous work. We offer the first empirical estimate of this impact, finding a negative correlation between productivity shocks and tax burden that provides a stimulus to investment equivalent to a subsidy of around 1%. Our theoretical result has implications for disparate topics such as probabilistic tax policy (such as random auditing), estimates of effective tax rates, and principal-agent problems in firm management. While our main results hold under risk-neutrality, risk aversion entails a trade-off: a higher covariance between tax rates and productivity implies a higher expected (after-tax) return, but also greater risk.

To fix ideas, suppose a firm chooses how much to invest, x, to maximize expected after-tax profits. The firm faces an uncertain productivity shock, ϵ, and an uncertain tax rate, τ.

$$\max_{x\geq 0} \mathbb{E}\Big[(1-\tau)(\epsilon f(x) - x)\Big].$$

The production function $f(\cdot)$ satisfies $f''(\cdot) < 0 < f'(\cdot)$. Then optimal investment x^* satisfies:[1]

$$f'(x^*) = \frac{1-\bar{\tau}}{(1-\bar{\tau})\bar{\epsilon} - Cov(\epsilon,\tau)}. \tag{1}$$

Here $\bar{\epsilon}$ and $\bar{\tau}$ indicate $\mathbb{E}[\epsilon]$ and $\mathbb{E}[\tau]$, respectively. There are three main takeaways from Eq. 1. First, if $Cov(\epsilon,\tau) = 0$, then the choice of the firm will be identical to the efficient choice it would have made in the absence of taxation, namely x_0 satisfying $f'(x_0) = 1/\bar{\epsilon}$.

Second, if $Cov(\epsilon,\tau) > 0$, then $x^* < x_0$. A positive correlation between productivity and tax rate dampens investment for the simple reason that facing a higher tax rate when profits are higher means facing a higher tax rate on average. One cause of this correlation is tax progressivity or tax law asymmetries. In their study of how income taxation affected risk-taking, Domar and Musgrave (1944) were the first to note that failing to rebate taxes on losses would make risky investments less attractive. Subsequent work has expanded this reasoning and documented its effects empirically. For instance, Gentry and Glenn Hubbard (2000) showed that states with more progressive tax schedules induced slower entry into entrepreneurship. Their later work has shown that tax progressivity also dampens job turnover by making it less rewarding to invest time and effort looking for a new job (2004) and has ambiguous effects on innovation (2005). Others have documented the effects of tax law asymmetries—for example, how imperfections in the tax carryback and carryforward systems lead to an ultimately asymmetric treatment of profits and losses, thus dampening investment. See Auerbach (1986) and Altshuler and Auerbach (1990) for a discussion of the effects of tax asymmetries; see Devereux et al. (1994), Clifford (1999), Edgerton (2010), and Goodman et al. (2020) for empirical evidence.

[1] The first-order condition is $\bar{\epsilon}f'(x^*) - \mathbb{E}[\epsilon\tau]f'(x^*) - (1-\bar{\tau}) = 0$. Since $\mathbb{E}[\epsilon\tau] = \bar{\epsilon}\bar{\tau} + Cov(\epsilon,\tau)$ we can re-write this as $f'(x^*)(\bar{\epsilon} - \bar{\epsilon}\bar{\tau} - Cov(\epsilon,\tau)) = 1-\bar{\tau}$, which yields Eq. 1. We assume interior solutions throughout this paper.

Third, if $Cov(\epsilon, \tau) < 0$, then $x^* > x_0$. A negative correlation between tax rates and productivity will yield a higher expected payoff on investment, thus incentivizing it. While concave tax schedules tend not to be the norm, the correlation need not be driven by nonlinear tax *schedules*. A negative correlation may result from economies of scale in tax planning, whereby bigger, more productive firms face lower effective tax rates. Similarly, reported income may increase with positive income shocks, reducing audit risk and thus the effective tax rate. Alternatively, policy may depend on the business cycle, or the political process could correlate with economic conditions. Naturally, the correlation between tax rates and productivity resulting from policy uncertainty of this nature is ambiguous.

Our empirical exercise explores to what extent productivity covaries with average tax rates, yielding an implicit tax rate on investment. We find a negative correlation, which encourages aggregate investment to a degree dependent on the elasticity of investment. For instance, the estimate by Zwick and Mahon (2017) regarding the elasticity of equipment investment to the user cost of capital would imply that aggregate investment is 1.41% to 1.63% higher due to the correlation between productivity and tax rates. However, our aggregate estimate conceals heterogeneity in covariances that could result in greater distortions for specific investors.

This interpretation also depends on the assumption of risk neutrality. When agents are risk averse, a negative correlation between tax rates and productivity acts as insurance, potentially mitigating or even reversing our result. A thorough account of the impact of this covariance on investment would consider both investor preferences and principal-agent dynamics.

Previous literature has looked at the effect of policy uncertainty on investment, focusing on how uncertainty increases the option value of postponing irreversible or partially irreversible decisions. This line of reasoning traces back to Arrow (1968) and Pindyck (1988). Bloom (2009), Baker et al. (2016), Handley and Limão (2017), and Caggiano (2017) apply this reasoning to uncertainty about government policy. Yet we preclude this option value channel in our model, showing that ours is a distinct mechanism for distorting investment. We contribute to the literature on policy uncertainty by documenting a previously unexplored channel through which tax uncertainty can affect investment decisions.

Our paper focuses on a positive analysis of how uncertainty in the tax rate affects investment. Still, our analysis has clear normative takeaways. For instance, the efficient level of investment is the one undertaken in the absence of taxation, x_0. A linear tax on pure profits does not distort this choice, and so it would be reasonable to adopt such a tax and let the political process determine what rate to impose. Nonetheless, this simple fact introduces uncertainty regarding fiscal policy. Assuming that uncertainty in productivity is unavoidable and cannot be influenced by the government, the only way to diminish the distortions arising from the correlation of tax rates and productivity is to reduce uncertainty over tax policy. This could be done, for example, by avoiding tax changes that are likely to be reversed in the future.

The rest of the paper proceeds as follows. Section 2 presents a general version of the model. While allowing for an arbitrary tax schedule and deduction rate, the general model still yields results similar to Eq. 1. Sections 3 and 4 proceed to an empirical exercise, finding a negative relationship between US tax rates and total factor productivity over the post-war period. Section 5 relates our results to other work and suggests avenues for future research. Section 6 concludes.

2 Model

Consider a firm making a decision regarding the amount to invest x, and reaping its benefits in the following period. Investment only occurs in the initial period, precluding option value effects à la Pindyck (1988). For notational simplicity, assume the firm equally values profits in either period.

The firm chooses investment level x to maximize expected after-tax profits, which depend on stochastic productivity ϵ. Let $f(x)$ denote the normalized production function, so that $\epsilon f(x)$ is revenue given investment x. The firm faces an uncertain tax $T(\epsilon f(x), x, \epsilon)$ which may depend on total output $\epsilon f(x)$, input costs x, and the productivity ϵ. This representation emphasizes that the tax schedule can depend on a stochastic variable, so the firm is uncertain about the tax schedule it will face until after it chooses x.

$$\max_{x\geq 0} \mathbb{E}[\epsilon f(x) - x - T(\epsilon f(x), x, \epsilon))] \tag{2}$$

While ϵ is nominally a productivity term, it also incorporates the output price, and could be rephrased as the pre-tax return on investment (ROI).[2] As in Rodrik (1991), the "tax collected" can be any policy that affects the profitability of investment, as long as the policy depends on (uncertain) final output.[3]

If f is differentiable, increasing, and strictly concave, then the interior solution for investment satisfies:

$$f'(x^*) = \frac{1 + \bar{T}_2(x^*)}{\bar{\epsilon}(1 - \bar{T}_1(x^*)) - C(x^*)}, \tag{3}$$

Here T_1 and T_2 denote derivatives of $T(\cdot)$ with respect to its first and second arguments, respectively, and:

$$\begin{aligned} \bar{T}_1(x) &= \mathbb{E}[T_1(\epsilon f(x), x, \epsilon)]; \\ \bar{T}_2(x) &= \mathbb{E}[T_2(\epsilon f(x), x, \epsilon)]; \\ \bar{\epsilon} &= \mathbb{E}[\epsilon]; \\ C(x) &= Cov(T_1(\epsilon f(x), x, \epsilon), \epsilon). \end{aligned}$$

In words, $\bar{T}_1$ is the marginal tax rate that the firm expects to face on its revenue, while $-\bar{T}_2$ is the marginal rate at which it expects to deduct input costs, given investment x. $C(x)$ is the covariance between the marginal tax rate on revenue and productivity.

[2] Formally, the pre-tax ROI would be $\epsilon\frac{f(x)}{x} - 1$.

[3] For example, this might be the case for environmental or labor regulations that only apply to large firms.

Equation 3 reveals the main takeaways of this paper. Note that the covariance term $C(x)$ can be positive, thus deterring investment, or negative, thus encouraging it. When $C(x) \equiv 0$, we have the standard result that allowing firms to fully deduct their input costs induces the choice of investment that would be optimal in the absence of taxation. Indeed, in our setting this need only be true in expectation: $\bar{T}_1(x) = -\bar{T}_2(x)$.

Even given deterministic tax policy, the convexity of the tax schedule can induce a non-zero covariance between productivity and marginal tax rates. Equation 3 would then imply that the progressive corporate tax schedule would discourage investment, even if firms can perfectly deduct costs. This applied historically to US corporate taxation, and still holds for European countries such as France and the Netherlands. Alternatively, a concave tax schedule can do the opposite and encourage investment.

Additionally, Eq. 3 shows how uncertainty in tax policy can distort investment. As in Eq. 1, a positive correlation dampens investment, while a negative one incentivizes it. Intuitively, a firm's expected after-tax ROI is lower if it gets taxed more when investment is more productive, and vice versa. Further, for a given correlation, greater uncertainty about τ magnifies this effect.

3 Data and methodology

Estimating the size of the effect of this covariance requires measures of productivity and tax rates. We gathered data on total factor productivity (TFP) percent changes, here expressed in levels, from the non-utilization-adjusted series produced by the San Francisco Federal Reserve from 1947 to 2019.[4] While aggregate data cannot discern between firm productivity shocks and other profit shocks, such as changes in market power or demand, the ϵ variable in Eq. 2 encompasses all shocks to marginal value product.

Using statutory rates as measures of τ misses how effective tax rates change with details of the tax code, as well as the tax implications of changing firm structures and economic activities. Using effective tax rates (ETRs) as calculated by firms could give us the opposite problem, as firms may report ETRs greater than 100% or less than zero (Graham, 1996). Therefore, we elected to proxy effective tax rates via federal tax receipts. We gathered information on tax receipts as a percentage of US GDP from the Bureau of Economic Analysis.[5] We aggregate all variables at the annual level to control for seasonal effects.

[4] We normalize TFP by setting the initial value to one.

[5] While we cannot observe marginal tax rates, our results will hold to what degree marginal tax rates strictly increase with average tax rates.

We want the joint distribution of (τ, ϵ) given what an agent in period t knows from past data. To account for potential cointegration, consider a vector error correction model (VECM), following Johansen (1995):[6]

$$\begin{bmatrix} \Delta\tau_t \\ \Delta\epsilon_t \end{bmatrix} = \mathbf{v} + \mathbf{\Pi} \begin{bmatrix} \tau_{t-1} \\ \epsilon_{t-1} \end{bmatrix} + \mathbf{\Gamma} \begin{bmatrix} \Delta\tau_{t-1} \\ \Delta\epsilon_{t-1} \end{bmatrix} + \boldsymbol{\delta} t + \begin{bmatrix} \nu_{1t} \\ \nu_{2t} \end{bmatrix} \tag{4}$$

The two-dimensional error vector $\boldsymbol{\nu}_t$ is drawn from a white noise process with mean zero. Eqs. 1 and 4 imply that the covariance $\sigma_{12} \equiv Cov(\nu_{1t}, \nu_{2t})$ affects period $t-1$ investment intended to obtain a return in period t equivalent to a tax on firm revenue of:[7]

$$\mathcal{T} = \frac{\sigma_{12}}{\mathbb{E}_{t-1}[\epsilon_t]\,(1 - \mathbb{E}_{t-1}[\tau_t])}. \tag{5}$$

We estimate the parameters of Eq. 4 as in Johansen (1995). We estimate σ_{12} by taking the average of the product of residuals:

$$\widehat{\sigma_{12}} = \frac{\sum_{t=1}^{T} \hat{\nu_{1t}}\,\hat{\nu_{2t}}}{T} \tag{6}$$

Under the null hypothesis that $\sigma_{12} = 0$, one can show that:[8]

$$\sqrt{T}\frac{\widehat{\sigma_{12}}}{\sqrt{\frac{\sum_{t=1}^{T} \hat{\nu_{1t}^2}\,\hat{\nu_{2t}^2}}{T} - \widehat{\sigma_{12}}^2}} \xrightarrow{d} N(0,1) \tag{7}$$

4 Results

Table 1 presents results. A time horizon of one year, per Eq. 5, increases investment as if it were subsidized by 0.89 percent. Similar results hold through a 20-year window: the investment subsidy that would yield the same behavioral response varies from 0.88 to 1.02 percent.[9]

We always reject the null hypothesis of zero covariance at 10% significance, and at 5% significance for the first eleven years of forecasts. However, the aggregate

[6] Here Δ denotes value changes, so Eq. 4 is a VECM with two lags. Choosing two lags minimizes the Hannan–Quinn information, Schwarz Bayesian information, and sequential likelihood-ratio criteria. The multiple trace test procedure from Johansen (1995) strongly rejects the null of zero rank condition, so we assume that the matrix $\mathbf{\Pi}$ is of rank one.

[7] Note that $\mathbb{E}_{t-1}[\epsilon_t\tau_t] = \mathbb{E}_{t-1}[\epsilon_t]\mathbb{E}_{t-1}[\tau_t] + \sigma_{12}$. Then we can re-write $\mathbb{E}_{t-1}[(1-\tau_t)(\epsilon_t f(x) - x)] = (1 - \mathbb{E}_{t-1}[\tau_t])\Big[\Big(1 - \frac{\sigma_{12}}{(1-\mathbb{E}_{t-1}[\tau_t])\mathbb{E}_{t-1}[\epsilon_t]}\Big)\mathbb{E}_{t-1}[\epsilon_t]f(x) - x\Big]$.

[8] This result requires that $\mathbb{E}[\nu_{1t}^2\nu_{2t}^2] > 0$.

[9] We get qualitatively similar results by fitting a vector autoregression model with ETRs and differences in TFP.

Table 1 Measures of Tax-Productivity Covariance

Years forecast Ahead	$\hat{\sigma}_{12}$	Correlation Coefficient	Coefficient of Variation (ETR)	Coefficient of Variation (TFP)	Equivalent investment Subsidy (%)
1	− 0.077**	− 0.187	0.456	0.062	0.89
2	− 0.088**	− 0.219	0.443	0.062	1.02
3	− 0.077**	− 0.203	0.407	0.062	0.89
4	− 0.082**	− 0.215	0.406	0.063	0.95
5	− 0.082**	− 0.213	0.410	0.062	0.95
6	− 0.084**	− 0.217	0.411	0.063	0.97
7	− 0.082**	− 0.211	0.406	0.064	0.94
8	− 0.077**	− 0.202	0.395	0.064	0.89
9	− 0.078**	− 0.202	0.399	0.064	0.90
10	− 0.080**	− 0.203	0.403	0.065	0.92
11	− 0.081**	− 0.207	0.396	0.065	0.94
12	− 0.079*	− 0.200	0.397	0.066	0.91
13	− 0.080*	− 0.200	0.402	0.066	0.93
14	− 0.077*	− 0.191	0.403	0.066	0.89
15	− 0.079*	− 0.191	0.408	0.067	0.091
16	− 0.081*	− 0.193	0.413	0.067	0.93
17	− 0.076*	− 0.188	0.391	0.069	0.88
18	− 0.077*	− 0.187	0.396	0.069	0.89
19	− 0.079*	− 0.188	0.406	0.069	0.91
20	− 0.080*	− 0.188	0.405	0.070	0.93

Results are the covariance between ETRs and TFP values in future years, given information available at the year of forecast. One star (two stars) denotes statistical significance at the 10% (5%) level. We find the equivalent investment subsidy from Eq. 5 using the sample average TFP and ETR, while the decomposition into correlation coefficient and coefficients of variation is from Eq. 8

covariance underestimates the effect on some firms. After all, firms care about the covariance between *their* productivity and ETRs. Thus, our aggregate results necessarily attenuate the most extremely positive covariances with the most extremely negative ones.

We can decompose the subsidy equivalent to the covariance between productivity and ETRs into three channels: uncertainty in τ, uncertainty in ϵ, and the correlation between τ and ϵ. Formally, let $\rho = corr(\nu_{1t}, \nu_{2t})$, so that $\sigma_{12} = \rho\sigma_1\sigma_2$, where $\sigma_i^2 = Var_{t-1}[\nu_{it}]$ for $i = 1, 2$. Then expression 5 for the equivalent tax/subsidy can be rewritten:

$$\begin{aligned}\mathcal{T} &= \frac{\rho\sigma_1\sigma_2}{\mathbb{E}_{t-1}[\epsilon_t](1 - \mathbb{E}_{t-1}[\tau_t])} \\ &= \rho \times \frac{\sigma_1}{1 - \mathbb{E}_{t-1}[\tau_t]} \times \frac{\sigma_2}{\mathbb{E}_{t-1}[\epsilon_t]} \\ &\equiv \rho CV_\tau CV_\epsilon\end{aligned} \tag{8}$$

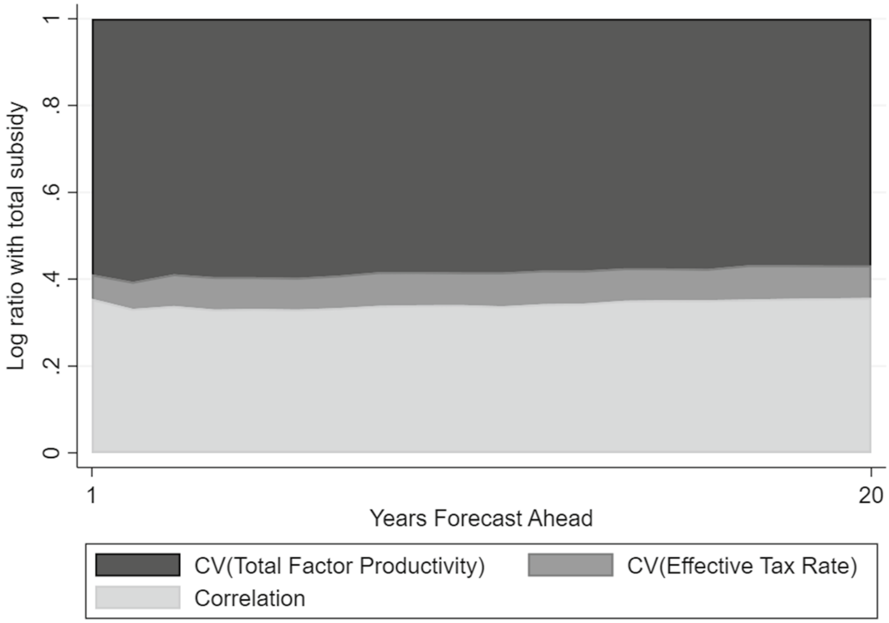

Fig. 1 Decomposition of the effects resulting in the estimated $\mathcal{T}$ over a 20-year window, as in Eq. 9

Here CV_τ and CV_ϵ are coefficients of variation that depend only on the marginal distributions of τ_t and ϵ_t, respectively. The decomposition results from taking log absolute values:

$$log(|\mathcal{T}|) = log(|\rho|) + log(|CV_\tau|) + log(|CV_\epsilon|) \tag{9}$$

We graphically present the results of this decomposition in fig. 1.

For all the time windows considered, over half of the equivalent subsidy is attributable to productivity uncertainty. Another sizable portion (some 30–40%) is attributable to the correlation between productivity and tax rates, while only a small sliver (5–10%) is due to tax rate uncertainty. Figure 1 shows that uncertainty in ETRs does not seem to generate big distortions in firm decisions. However, this necessarily implies that of the three distortion channels, marginally increasing uncertainty about τ would have a very large impact on firm incentives, as $\partial\mathcal{T}/\partial CV_\tau$ increases with ρ and CV_ϵ.

5 Discussion

The preceding theoretical and empirical framework has the advantage of simplicity. This presents an opportunity for us to clearly discuss its underlying assumptions and how these relate to the broader literature on taxation, risk, and investment, with an eye on avenues for future research. We focus on three broad areas: first, we discuss what happens when we drop the risk-neutrality assumption. This lets us relate our results to previous work on taxation as insurance and CEO compensation. Second, we relate our result to the literature on effective tax rates, and discuss how our insights could be incorporated into ETR estimates. Finally, we provide some new insights from our result into the literature on probabilistic tax policy.

5.1 Risk aversion

So far, we have assumed that investment decisions maximize expected profit without regard to risk. However, as noted in Skinner (1988), a positive correlation between earnings and the tax rate can act as insurance.[10] In principle, this insurance effect could encourage investment. Yet our mechanism implies that a positive correlation would also effectively impoverish the investor, so that wealth effects may also affect investment.

To simplify, we preclude wealth effects by supposing an agent has utility $U(c)$ from consumption c that exhibits a constant coefficient of relative risk aversion (CRRA), $R \geq 0$.[11]

$$\mathbf{U}(\mathbf{c}) = \begin{cases} \frac{c^{1-R}}{1-R} & \text{if } R \neq 1 \\ ln(c) & \text{if } R = 1 \end{cases}$$

For ease of analysis, we assume in this subsection that income is taxed at (random) rate $\tau \in [0, 1)$. The agent now maximizes expected utility:[12]

$$\max_{x \geq 0 : \mathbb{P}(\epsilon f(x) - x > 0) = 1} \mathbb{E}[U((1 - \tau)(\epsilon f(x) - x))]$$

When $R = 1$, the first-order condition for this problem can be written as:

$$\mathbf{0} = \mathbb{E}\left[\frac{\boldsymbol{\epsilon}\mathbf{f}'(\mathbf{x}) - \mathbf{1}}{\boldsymbol{\epsilon}\mathbf{f}(\mathbf{x}) - \mathbf{x}}\right].$$

Thus, a CRRA of one implies that the linear income tax does not affect the choice of investment, regardless of the covariance between the tax rate and productivity. One interpretation of this result is that for an agent with $U(c) = ln(c)$, the disincentive to invest and the insurance value coming from a positive covariance perfectly cancel each other out.

[10] Skinner (1988) makes this point in the context of a welfare analysis of an agent choosing labor and savings while facing uncertain taxes that may correlate with future earnings. He uses an estimated distribution of earnings net of taxes (using a vector autoregression approach) rather than explicitly account for our mechanism.

[11] For $R > 0$, we have to restrict $c \geq 0$, and can restrict $c > 0$ without loss of generality because $\lim_{c \downarrow 0} U'(c) = \infty$.

[12] We assume that f(0) contains all pre-tax income other than from investment, taxed at the same rate as investment income.

The result with log utility suggests the broader possibility that risk-averse preferences can allow for the insurance effect to partially or completely counteract our mechanism. Formally, the marginal utility of pre-tax earnings with respect to investment is:

$$MU_x \equiv \frac{dU(\epsilon f(x) - x)}{dx} = (\epsilon f'(x) - 1)U'(\cdot) = (\epsilon f'(x) - 1)(\epsilon f(x) - x)^{-R} \quad (10)$$

Then plugging this expression into the first-order condition for the risk-averse agent yields:[13]

$$0 = \mathbb{E}[(1-\tau)^{1-R}]\frac{\mathbb{E}[MU_x]}{f'(x)} + \frac{Cov((1-\tau)^{1-R}, MU_x)}{f'(x)} \quad (11)$$

When $R = 0$, the right-hand term in Eq. 11 becomes $Cov(1-\tau, \epsilon)$, reflecting the result from sect. 2. More generally, if the pre-tax marginal utility of investment increases with ϵ, then we can formalize the intuition that the predicted change in investment from sect. 2 will hold if the agent is not excessively risk-averse. Again, supposing MU_x strictly increases with ϵ, and if the net-of-tax rate $1-\tau$ strictly increases with ϵ, then from Eq. 11:[14]

1. If $R < 1$, then investment is greater than if taxes were deterministically set at $\left[\mathbb{E}[(1-\tau)^{1-R}]\right]^{\frac{1}{1-R}}$.
2. If $R = 1$ (log utility), then investment is unaffected by the distribution of taxes.
3. If $R > 1$, then investment is less than if taxes were deterministically set at $\left[\mathbb{E}[(1-\tau)^{1-R}]\right]^{\frac{1}{1-R}}$.

Of course, there are *many* situations in which risk-averse agents may face taxes that are correlated with ROI, a complete discussion of which is beyond the scope of this paper. For instance, a firm owned by risk-neutral shareholders will typically provide a risk-averse manager some stake in the uncertain profits of the firm to encourage the manager to maximize expected profit. Our work informs preexisting work on how the personal taxes faced by CEOs affects investment decisions (such as Lie & Lie, 1999; Coles et al., 2006; Coles et al., 2019). Depending on the risk preferences of the CEOs, any correlation between expected personal marginal tax rates and the compensation the CEO receives from investment decisions can have an ambiguous effect on the CEO's investment decision.

[13] The first-order condition can be written as:

$$\begin{aligned} 0 &= \mathbb{E}[(1-\tau)^{1-R} MU_x] \\ &= \mathbb{E}[(1-\tau)^{1-R}]\mathbb{E}[MU_x] + Cov((1-\tau)^{1-R}, MU_x) \end{aligned}$$

Dividing by $f'(x)$ yields the desired result.

[14] The concavity of $f(\cdot)$ implies that $f(x) > xf'(x)$, so that $\frac{f'(x)}{f(x)} > \frac{\epsilon f'(x)-1}{\epsilon f(x)-x} \geq R\frac{\epsilon f'(x)-1}{\epsilon f(x)-x}$ when $R \leq 1$. It follows that $\frac{d}{d\epsilon}MU_x > 0$, and so MU_x strictly increases with ϵ, when $R \leq 1$. One can also confirm that $\frac{dU}{d\epsilon}MU_x > 0$ when ϵ is restricted to a sufficiently small region around one.

Even supposing individual-level taxes were independent of ROI, a positive correlation between the firm's net-of-tax rate and ROI should cause risk-neutral shareholders (or shareholders with CRRAs below one) to want the firm to invest more. By contrast, a sufficiently risk-averse CEO who is compensated in proportion to firm profit may well respond to this correlation by *decreasing* firm investment. This discrepancy between the optimal choices of the shareholders and the CEO illustrates the potential for correlations between corporate tax rates and ROIs to exacerbate principal-agent problems.

Future research might apply these tools to uncover specific instances of the more general mechanism discussed in this paper. By extending our framework to human capital investments, one could study how choices like education affect the covariance of gross and net income shocks. Equation 11 then suggests how the effect on investment choices would depend on the risk preferences of individuals.

5.2 Effective marginal tax rates

As noted in sect. 3, ETRs can be negative or greater than 100%, often reflecting timing differences between earning income and accruing tax liability.[15] Computations of marginal tax rates normally involve expectations of the future, as they rely on projected profits or losses to appropriately account for considerations regarding tax loss carryback and carryforward. As Shevlin (1990) put it in his seminal work, a corporation's MTR is "the present value of the change in cashflow paid to (or recovered from) the tax authorities as a result of earning (or losing) one extra dollar of [taxable income] in the current tax period."

Graham (1996) assumes that taxable income for firm i in period t, TI_{it}, is given by:

$$\Delta TI_{it} = \mu_i + \epsilon_{it}, \tag{12}$$

where μ_i is firm-level average year-to-year change in taxable income, while ϵ_{it} is an error term. Given simulations based on these estimates, Graham is able to compute tax owed under each simulation, and expected tax owed is simply the average across these simulations. More recent literature has built upon this procedure, both to improve its accuracy and to investigate new questions. Plesko (2003) offers a nice overview and evaluation of several measures of effective tax rates. For example, Graham and Kim (2009) use a similar procedure to study the effects of lengthening tax-loss carryback periods. Blouin et al. (2010) critique other measures of marginal tax rate and develop a more accurate, semi-parametric version of Eq. 12. To the best of our knowledge, however, this literature does not discuss the effect of the correlation between tax rates and productivity.

[15] ETRs can also substantially differ from statutory tax rates due to permanent book-tax differences and aggressive tax planning. However, see Christensen et al. (2021) for evidence that most US firms have large net operating losses.

The mechanism presented in this paper adds a new perspective to the effective tax literature. It suggests that instead of simply modeling expected profits and losses, and computing tax owed based on those, one should model the joint distribution of profits and tax rates, in order to appropriately account for the correlation between the two when computing expected tax owed. For instance, suppose investment takes the form of non-deductible equity. Then, normalizing $\bar{\epsilon} = 1$, Eq. 3 may be written as:[16]

$$f'(x^*) = \frac{1}{1 - \bar{T}_1(x^*) - C(x^*)},$$

Computations of marginal tax rates typically estimate a (present-discounted generalization of) $\bar{T}_1(x^*)$, but we also require an estimate of $C(x^*)$, the covariance between marginal tax rates and pre-tax ROI, to infer the effect of corporate taxation on equity investment.

The model presented in Sect. 2, with investment made in one period and realized in the next, cannot properly accommodate loss carryback and carryforward considerations. Future work could develop a more involved theoretical framework that might appropriately take these considerations into account.

5.3 Probabilistic tax policy

So far, we have focused primarily on a positive analysis of how uncertain tax policy affects investment. However, our work also has novel normative implications with respect to the optimal tax literature. After briefly summarizing relevant previous work on optimal tax policy, we can illustrate where this paper suggests new directions for work on optimal tax.

One strand of the optimal tax literature describes a tax planner who assigns to ex ante identical agents identical lotteries of tax schedules. It is only after agents make (irreversible) decisions that the tax uncertainty resolves.[17] For instance, Weiss (1976) and Stiglitz (1982) show that audits, and more generally uncertain tax policy, can increase taxable income when agents are risk averse. Intuitively, agents may work more as a precautionary response to tax uncertainty, offsetting the distortion to labor supply. Similarly, Alm (1988) and Scotchmer and Slemrod (1989) show that uncertainty as to the taxable income assessed by the tax authority can increase taxpayers' reported income, thereby creating welfare improvements over deterministic tax bases. These models all rely critically on the risk aversion of the taxpayer.

Stiglitz (1982), followed by Chang and Wildasin (1986); Brito et al. (1995), and Hines and Keen (2021), considers a tax planner randomly assigning distinct tax policies to otherwise identical agents *before* agents make decisions.[18] Since agents

[16] We can still allow for debt investment by reinterpreting $\epsilon * f(x)$ as earnings after interest (but before tax).

[17] Stiglitz (1982) refers to this as *ex post randomization*.

[18] Stiglitz (1982) refers to this as *ex ante randomization*, whereas Hines and Keen (2021) refer to this as *random taxation*.

do not face any uncertainty, risk aversion plays no role in the resulting analysis.[19] Instead, when the tax base becomes less elastic as the tax rate increases, randomly increasing the tax rate for some and decreasing it for others can reduce the tax distortion while raising the same amount of tax revenue.

In contrast, sect. 2 shows how a correlation between tax rates and productivity can distort investment behavior even though (i) tax policy remains uncertain in our model until *after* agents make choices, and (ii) agents are risk neutral. Extending this paper to agents supplying labor and reporting income could yield normative insights into uncertain tax policy. For instance, Scotchmer and Slemrod (1989) models audit risk as exogenous, whereas Reinganum et al. (1985) and later work on optimal audit policy suggest that the risk of audit should *decrease* with reported income. If a higher reported income reduces audit risk, then greater productivity may yield a lower effective tax rate. This negative correlation between earnings and tax rates could increase reported income, thereby mitigating tax distortions.

6 Conclusion

In our model, a non-zero correlation between marginal tax rates and the marginal product of a firm results in a distortion to a firm's choice of investment. This mechanism can explain phenomena documented in the literature on the effects of progressive income taxation and tax law asymmetries. Further, if tax policy is uncertain and correlated with the outcome of the investment, whether due to political mechanisms or macroeconomic policy, this correlation can encourage or discourage investment, depending on the sign of the correlation. For a given correlation, higher policy uncertainty magnifies this effect.

Using aggregate data from the post-WW2 period, we find a negative correlation between tax rates and productivity, which would generate a response similar to that of an investment subsidy of around 1 percent. The elasticity of equipment investment estimate from Zwick and Mahon (2017) would imply that investment is around 1.6% higher than it would be absent this correlation. However, this result might conceal heterogeneity in correlations, possibly resulting in much larger distortions.

We see several promising avenues for future research. By modeling the *joint* process of taxable income and tax rates at the firm level, one could obtain firm-level measures of marginal tax rates that incorporate the effect discussed in this paper. This could be useful both to investigate whether firms react to this incentive in the way predicted by our model, but could also be used beyond this. In sect. 5.1, we argue that a higher covariance between tax rates and productivity could exacerbate principal-agent problems between (risk-averse) CEOs and (risk-neutral) shareholders. Future empirical work might further investigate this relationship. Finally, we discuss potential implications of our work for probabilistic tax policy. If audit risk decreases with reported income, as suggested by some optimal audit policy

[19] Of course, societal preferences may embody a sense of risk aversion via a concave social welfare function.

literature, it might generate a negative correlation between productivity and the tax rate. This, in turn, might mitigate tax distortions by giving agents an incentive to increase reported income.

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