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Taxation and Corporate Risk-Taking

Abstract

We study whether the corporate tax system provides incentives for risky firm investment. We analytically and empirically show two main findings: first, risk-taking is positively related to the length of tax loss periods because the loss rules shift some risk to the government; and second, the tax rate has a positive effect on risk-taking for firms that expect to use losses, and a weak negative effect for those that cannot. Thus, the sign of the tax effect on risky investment hinges on firm-specific expectations of future loss recovery.

JEL-Codes: H250, H320, G320.

Keywords: corporate taxation, risk-taking, net operating losses.

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1 Introduction

Firm risk-taking is essential for economic growth. While small, entrepreneurial firms are commonly viewed as the primary source of risky innovation, large public firms undertake approximately half to two-thirds of total private sector investment, and the riskiness of this investment is positively related to per capita growth.[1] Therefore, risk-taking by large, established firms can have considerable macroeconomic effects. In this paper, we study how the government, through the corporate tax system, can encourage large corporations to make appropriately risky investments.

This study examines the risk-taking effects of both tax rates and tax loss rules, which permit firms to use losses to reduce prior or future tax payments. We show that studying both elements is crucial when assessing how tax policies affect firm investment decisions. Our analysis demonstrates two key findings. First, our analytical model and empirical results show that the tax loss rules directly affect the amount of corporate risk-taking. Intuitively, the loss rules shift a portion of investment risk to the government, which induces firms to increase their overall risk-taking. This result shows that changing statutory loss rules is one channel through which the government can alter private sector risk-taking.

Second, we find that the sign of the tax rate effect on firm risk-taking depends on the extent to which a firm can use its tax losses. For firms likely to use tax losses to offset prior or future income, risk-taking is positively related to the tax rate. In this case, the government shares in both the profit and the loss related to the investment, decreasing the variance of returns and thus making risk-taking more attractive. In contrast, for firms that are unlikely to use losses (due to statutory limitations or lack of profitability), there is little relation between the corporate tax rate and risk-taking. In this second case, taxes decrease the firm's income

[1] Large U.S. corporations (i.e., corporations reporting greater than $2.5 billion in total assets) reported 74.3 percent of all fixed and intangible assets held by corporations in 2013. Furthermore, large firms claimed approximately 78 percent of the total U.S. R&D tax credit for the period 1990 through 2013 (I.R.S. 2013). In 2010, only 0.06 percent of U.S. firms were public, but these firms comprised 47.2 percent of total fixed investment (Asker, Farre-Mensa, and Ljungqvist 2015). John, Litov, and Yeung (2008) show that a one-standard deviation increase in firm risk-taking is associated with a 33.2 percent increase in real GDP per capita growth.

when the risky investment generates a profit, but the firm is unable to recover much, if any, of its loss through the tax system. Higher taxes thus make risk-taking less attractive for these low-loss-offset firms. These two differing effects demonstrate the importance of firm-specific characteristics and the interaction between tax rate and non-tax-rate aspects when assessing the investment implications of altering fiscal policy.

The results reconcile conflicting findings in the previous literature related to the effectiveness of tax loss incentives. The few papers that study non-tax-rate elements of the corporate tax system find only small effects of loss rules on the level of investment (e.g., Devereux, Keen, and Schiantarelli 1994; Edgerton 2010). This result is surprising given the large number of firms that report tax losses and the large aggregate loss amounts;[2] furthermore, firms take actions to preserve and maximize tax loss benefits (Maydew 1997; Erickson and Heitzman 2010; Albring, Dhaliwal, Khurana, and Pereira 2011; Sikes, Tian, and Wilson 2014). We address this conflicting evidence by studying how tax loss rules affect the riskiness, instead of the level, of corporate investment. Thus, earlier studies focusing only on the volume of investment may underestimate the total private sector response to tax policies because firms also respond with qualitative changes in the type of projects selected.

We first study the effects described above by developing an analytical model that identifies how the tax rate and tax loss rules affect a firm's risk-taking decision. This model yields two main predictions: first, that tax loss rules are positively related to firm risk-taking; and second, that the effect of the tax rate on risk-taking varies with firm-specific loss offset. We then empirically test these hypotheses using a measure of firm-specific operating risk developed by John, Litov, and Yeung (2008). This measure captures the variance of returns to firm investment, measured by a firm's return on assets, and is consistent with the risk construct included in our theoretical model. Furthermore, this measure removes the influence of home country and industry-specific economic cycles, which firm management cannot alter, and thus

[2] For the period 1993-2004, 45-52 percent of U.S. corporations reported total net operating losses valued at over $2.9 trillion (Cooper and Knittel 2010). In 2002 alone, U.S. firms reported over $418 billion in losses on their tax returns, equivalent to more than 50 percent of the $676 billion of income reported by profitable firms (Edgerton 2010).

directly reflects corporate investment decisions.

We test the first prediction in three ways. The first test is conducted on a cross-country panel, which exploits cross-country variation in the loss offset rules and examines the theoretical predictions on a large sample of firms. We find that loss carryback periods and, to a lesser extent, loss carryforward periods are positively and significantly related to the level of firm risk-taking. A one year longer loss carryback period is associated with 11.6 percent higher risk-taking for the average firm in the sample. A one year longer loss carryforward period implies 2.4 percent higher firm risk-taking for the average firm. The larger effect for loss carrybacks reflects that these rules deliver an immediate cash refund and are not conditional on future profitability.

To further study this relationship, we use a matched sample difference-in-differences test, in which we compare changes in risk-taking by firms operating in six countries that changed the loss offset periods to firms in countries with no change. This test is conducted on a smaller sample of firms relative to the cross-country panel, but the matched firm design attempts to control for unobserved characteristics that may also affect corporate risk-taking. We find that changes in the loss offset period are associated with changes in firm risk-taking. Consistent with the results of the cross-country panel, the results are stronger and more robust for loss carrybacks than loss carryforwards.

As a third test of our predictions, we employ a regression discontinuity design. Specifically, we study a 2011 Spanish tax loss rule change that limited the amount of available loss offset for Spanish firms with revenues above €20 million. Although this analysis is conducted on the smallest sample, this setting permits more precise identification of the risk-taking effects. We find that Spanish firms subject to the loss limitations take significantly less risk than similarly-sized firms immediately below the €20 million threshold that are not subject to the limitation. In sum, we find consistent results across all three of these analyses – more generous loss offset rules are positively associated with firm risk-taking.

To test the effect of the statutory tax rate on firm risk-taking (the model's second prediction), we partition the larger cross-country sample based on firm-specific expectations about future loss offset. We measure these expectations using data on prior profitability and the firm's home country statutory loss rules to create two groups for high or low loss offset. In each subsample, we regress the risk-taking measure on the corporate tax rate and control variables and find results consistent with our hypothesis. Specifically, higher tax rates are positively and significantly related to risk-taking for high loss offset firms; a three percentage point increase in the tax rate (equivalent to the change in tax rate from the mean to the 75th percentile of our sample) is related to a 13.9 percent increase in the risk-taking measure for the average firm. However, if loss offset is unlikely (i.e. for the low loss offset firms), we find little relation with risk-taking. We also test this relation using a first differences specification and find consistent results.

Finally, we perform several robustness analyses, including construction of five alternative risk measures, exclusion of multinational firms, estimation on four different subsamples, inclusion of additional control variables, and estimation at the country-level. Each of these tests confirms our main results.

This paper makes several contributions to the academic literature. First, we add to the literature that studies the determinants of firm risk-taking.[3] Prior papers study the effects of managerial incentives, including May (1995); Demski and Dye (1999); Rajgopal and Shevlin (2002); and Coles, Daniel, and Naveen (2006). More recently, the literature has shown that corporate governance (John, Litov, and Yeung 2008), creditor rights (Acharya, Amihud, and Litov 2011), shareholder diversification (Faccio, Marchica, and Mura 2011), inside debt (Choy, Lin, and Officer 2014), bank liquidity (Acharya and Naqvi 2012), financial market linkages (Brusco and Castiglionesi 2007), and regulatory acts such as the Sarbanes-Oxley Act of 2004 (Bargeron, Lehn, and Zitter 2010) also affect firm risk-taking decisions. We document that corporate tax rules, and most notably, the tax loss offset rules, are an important determinant

[3] Another line of research studies how tax avoidance strategies affect firm risk (Guenther, Matsunaga, and Williams 2017; Neuman, Omer, and Schmidt 2016). Unlike these papers about tax risk, we examine the tax system itself (and not tax avoidance strategies).

that the literature has not previously considered. Closest to our paper is a concurrent paper by Ljungqvist, Zhang, and Zuo (2017), who also study the effect of tax rules on firm risk-taking. They use U.S. state tax rules and conclude that firms increase risk in response to tax increases, but do not seem to respond to tax cuts. In contrast, we first provide an analytical model that predicts both direct and interactive effects of tax rates and tax losses on firm risk-taking. We then empirically test the model's predictions by studying how firms respond to national-level tax rates and loss rules.

We also contribute to the literature that examines the effect of taxes on firm investment. First, we extend existing models that focus on the level of investment (Hall and Jorgenson 1967; Auerbach 1983, 1986; Gordon 1985) or on specific types of risk strategies such as firm hedging (Graham and Smith 1999; Graham and Rogers 2002). Second, we examine the effects of both the tax rate and the tax loss rules, a non-rate aspect of a corporate tax system that few prior studies have considered (Devereux, Keen, and Schiantarelli 1994; Edgerton 2010; Dreßler and Overesch 2013; Dobridge 2016). While the prior literature finds mixed evidence of the effectiveness of the loss rules on investment, we analytically and empirically document that firms do take tax losses into account when determining the riskiness of their investments.[4] Third, we extend the literature that examines the relation between taxation and individual/entrepreneurial risk-taking to public firms (Asea and Turnovsky 1998; Poterba and Samwick 2002; Cullen and Gordon 2007; Djankov, Ganser, McLiesh, Ramalho, and Shleifer 2010) and show that the relation between taxation and firm risk-taking is not limited to individuals or small companies. Rather, these effects are both statistically and economically significant for large, publicly-traded corporations that are responsible for a significant portion of aggregate investment.

Finally, this paper informs policy-makers by demonstrating how the government can induce or reduce corporate risk-taking through tax loss rules. In particular, the results

[4]Dreßler and Overesch (2013) show a positive effect of loss carryforwards on investment levels, but they find no effect of loss carrybacks (a finding they themselves describe as "surprising"). Their study focuses only on investment levels (measured by fixed assets) and does not consider firm risk-taking.

suggest that financing tax reductions by shortening available tax loss offset periods may discourage private sector risk-taking and innovation.

This paper proceeds as follows. In Section 2, we provide an overview of corporate tax loss rules. Section 3 presents the theoretical model of how tax rates and tax loss rules affect risk-taking and outlines our empirical hypotheses. Section 4 describes the research design and data, and Section 5 discusses the results. In Section 6 we present robustness analyses. Section 7 concludes.

2 Overview of Tax Loss Rules

All developed countries impose a tax on corporate income. Many countries allow firms to recoup a portion of losses incurred by reducing prior or future taxable income. Specifically, if the tax loss is offset against prior taxable income (a loss *carryback*), the government refunds some portion of tax the firm previously paid. In countries that do not allow loss carrybacks, or in instances where the firm has not been sufficiently profitable in prior years, the company can instead use the losses to offset future taxable income (a loss *carryforward*). Generally, the loss carryback and loss carryforward periods are limited; Table 1 summarizes these periods for the countries studied in this paper.

[Insert Table 1 here.]

Firms generally prefer loss carrybacks to carryforwards. If a firm was sufficiently profitable in the past, a loss carryback allows it to immediately receive a refund of prior year taxes paid when the firm incurs a loss. Otherwise, the firm must wait until a future year in which it is profitable to carryforward the loss and reduce its corresponding future tax payment. Therefore, loss carrybacks generate real and immediate cash flow for companies in the loss year, whereas the economic benefit of a loss carryforward is a function of expected future profits, the expected year of profitability, the expected future tax rate, and the firm's discount rate. Carryforwards thus offer an inherently more uncertain tax benefit.

Prior studies demonstrate that tax losses are economically significant for many firms (Altshuler and Auerbach 1990; Altshuler, Auerbach, Cooper, and Knittel 2009) and that managers protect and preserve these tax loss assets. For example, Erickson and Heitzman (2010) and Sikes, Tian, and Wilson (2014) discuss the use of "poison pill" provisions as one real action that firms take to protect tax losses. These provisions effectively restrict certain changes in ownership that would otherwise trigger statutory limitations on the future utilization of loss carryforwards (and consequently reduce the value of the tax loss asset). We expect that the importance of losses is not limited to the *ex-post* preservation and utilization of losses once they have been incurred; we study whether these tax loss rules also create *ex-ante* incentives for corporate risk-taking.

3 Theoretical Model & Hypotheses

3.1 Model Set-up

Consider a firm planning a fixed amount of investment to be allocated among projects of varying risk, σ (such as highly risky research and development and less risky capital expenditures). The firm operates in a world with uncertainty, which has two potential states. In the "good" state (probability p), the firm generates a profit of $f_g(\sigma) > 0$. In the "bad" state (probability $1 - p$), the firm incurs a loss of $f_b(\sigma) < 0$. Greater risk-taking increases both the profit ($f_g'(\sigma) > 0$) and the loss ($f_b'(\sigma) < 0$). In other words, increasing the riskiness of investment leads to a higher variance of returns.[5] The cost of the investment is I. To guarantee interior solutions, $f_g''(\sigma), f_b''(\sigma) < 0$.

Following prior literature (Sandmo 1971; Appelbaum and Katz 1986; Asplund 2002; Janssen and Karamychev 2007), we allow for firm-level risk aversion in the model, which

[5] This construct is thus consistent with the common definition of risk as the variance of returns to some investment (Domar and Musgrave 1944; Feldstein 1969; Stiglitz 1969; Asea and Turnovsky 1998). In the same spirit, our empirical analysis uses a risk measure constructed from the standard deviation of returns on firm assets.

is reflected in the firm's concave objective function. One interpretation of this objective function is that it represents the utility the manager derives from the firm's returns.[6] The main advantage of modeling a utility function is that it permits us to take into account varying levels of risk aversion, including risk-neutrality as a special case.

The firm allocates I to maximize its objective function. It pays corporate income tax at rate t on its profit ($0 < t < 1$); if it incurs a loss, it receives a tax refund on some fraction $\lambda \in [0,\ 1]$ of the loss. Assuming a continuously differentiable and concave objective function, the expected utility of the firm is then given by

$$EU = pU\left[(1-t)\left(f_g(\sigma) - I\right)\right] + (1-p)\,U\left[(1-\lambda t)\left(f_b(\sigma) - I\right)\right]. \tag{1}$$

Figure 1 depicts the objective function of the firm. Assume the firm generates a profit of f_g; the utility associated with the pre-tax profit is $U[f_g]$; after-tax, the utility is $U[f_g(1-t)] = U[f_g] - B$. If the firm incurs a loss (f_b), the utility associated with the pre-tax loss, or a loss under a tax system that does not permit loss offset, is $U[f_b]$. However, if the tax system does permit loss offset, then the firm's utility is $U[f_b(1-t)] = U[f_b] + A$, and the firm's utility is higher than under a tax system with no loss offset.

[Insert Figure 1 here.]

The concavity of the objective function implies that the difference between the utility levels in the bad state of the world is larger than the difference between the corresponding utility levels in the good state of the world (in the figure: $A > B$). Thus, under a tax system that permits full loss offset, the use of the loss to offset income is worth more to the firm than paying the corresponding tax in the good state of the world.

The firm chooses the optimal riskiness of its investment by maximizing its expected utility.

[6] Purnanandam (2008) shows that firms avoid risky investments to lower the probability of financial distress. Firms with financial constraints hedge currency risks (Géczy, Minton, and Schrand 1997). Moreover, a risk-averse manager considers risk in investment decisions if compensation is linked to firm performance (Tufano 1996; Guay 1999; Hall and Murphy 2002; Coles, Daniel, and Naveen 2006; Lewellen 2006). See also Scholes et al. (2014) for a discussion of how tax rate progressivity may affect firm risk aversion and investment project selection.

The first order condition for the optimal σ is

$$\frac{\partial EU(\pi)}{\partial \sigma} = pU'[\pi_g](1-t)f_g'(\sigma) + (1-p)U'[\pi_b](1-\lambda t)f_b'(\sigma) = 0, \tag{2}$$

where $\pi_g = (1-t)(f_g(\sigma) - I) > 0$ denotes the after-tax profit in the good state of the world, and $\pi_b = (1-\lambda t)(f_b(\sigma) - I) < 0$ is the after-tax profit in the bad state. The first term in eq. (2) demonstrates that a riskier investment increases the firm's profit in the good state of the world, while the second term shows that the loss in the bad state also increases with the riskiness of the investment.

3.2 Effect of Tax Loss Offset Rules (λ) on Firm Risk-taking

3.2.1 Results of the Model

Implicit differentiation of eq. (2) with respect to λ results in the following:

$$\frac{d\sigma}{d\lambda} = \frac{t(1-p)f_b'(\sigma)}{SOC}\left[U'(\pi_b) + U''(\pi_b)\pi_b\right] > 0, \tag{3}$$

where the second order condition is given by $SOC = pU''(\pi_g)(1-t)^2\left(f_g'(\sigma)\right)^2 + pU'(\pi_g)(1-t)f_g''(\sigma) + (1-p)U''(\pi_b)(1-\lambda t)^2\left(f_b'(\sigma)\right)^2 + (1-p)U'(\pi_b)(1-\lambda t)f_b''(\sigma) < 0$.

Eq. (3) shows that greater loss offset results in riskier investment. Better loss offset reduces the downside of risk-taking (the loss) by increasing the firm's tax refund in the bad state of the world. Moreover, when there is a larger tax refund available, the loss occurs at a higher utility level and thus has a lower marginal effect on utility.

Eq. (3) also demonstrates that the size of the risk-taking effect of λ depends on the country's tax rate, t. Specifically, t enters eq. (3) in two places. The main effect is evident in the numerator, which shows that the tax refund in the bad state of the world is larger when the tax rate is higher (i.e., a positive relation), thereby increasing the risk-taking incentive provided by λ. The denominator of eq. (3) shows the indirect effects of t; in particular, the tax rate may decrease the effect of λ on firm risk-taking (i.e., a negative relation) because a higher tax rate and thus larger tax refund shifts the firm to a higher utility level in the bad state, where the marginal utility is lower. The firm is then less responsive to changes in λ.

We summarize the effects of loss offset rules on risk-taking in the following proposition:

Proposition 1 (The effect of loss offset provisions on risk-taking) *Better loss offset (higher λ) increases firm risk-taking. The size of the risk-taking effect of λ depends on the tax rate (t).*

Proof. Consider eq. (3). The second order condition SOC is fulfilled (i.e., negative) as $U''(\pi) < 0$ and $f_g''(\sigma)$, $f_b''(\sigma) < 0$. Note also that $U''(\pi_b)\,\pi_b > 0$ as $\pi_b < 0$. As $f_b'(\sigma) < 0$, $\frac{d\sigma}{d\lambda} > 0$. ■

3.2.2 Hypothesis 1

Proposition 1 shows that better loss offset reduces the potential downside of risk-taking. Empirically, loss offset can be measured by the statutory loss carryback/carryforward periods, as longer periods increase the likelihood that companies can recoup the losses incurred.[7] We predict the following:

Hypothesis 1a *Tax loss carryback and carryforward periods are positively related to corporate risk-taking.*

While the model predicts a positive relation between the loss offset period and firm risk-taking, prior literature studying firm investment levels suggests that the effect of loss offset, if any, is minimal. For example, Devereux, Keen, and Schiantarelli (1994) model firm investment by specifically taking into account tax losses and find that these tax-loss-specific models perform no better in predicting investment than models that ignore tax asymmetries. Similarly, Edgerton (2010) finds that the availability of loss carrybacks/carryforwards only marginally alters the effect of bonus depreciation incentives on investment.

Proposition 1 also states that the tax rate affects the magnitude of the relation between firm risk-taking and the available loss offset. The direct effect as seen in the numerator of eq.

[7] Here, we focus on the effects of statutory loss periods because the government can directly influence these rules. In practice, the amount of firm loss offset is a function of statutory rules (the loss carryback/carryforward period), the firm's prior profitability, and the firm's expectation of future income. We consider these other firm-specific characteristics in the second hypothesis.

(3) is positive; that is, the amount of the insurance payment from the government is higher when the tax rate is higher. For example, assuming that two companies have the same λ, the amount of recoverable loss is greater in a country with a higher tax rate because the firm originally paid taxes at a higher corporate tax rate. Therefore, we predict the following:

Hypothesis 1b *The effect of tax loss carryback and carryforward periods on corporate risk-taking increases with the tax rate.*

However, the model also shows that a negative effect is possible due to indirect effects of the tax rate in the denominator of eq. (3). If these indirect effects are sufficiently large, we might not observe a positive sign for the interaction of the tax rate and loss offset rules on firm risk-taking.

Finally, we expect that risk-taking is more responsive to the length of the loss carryback period rather than the length of the loss carryforward period. As discussed in Section 2, loss carrybacks allow for an immediate refund. Loss carryforwards, in contrast, are more uncertain as it is not clear if or when the firm will again be taxable. Therefore, we also predict the following:

Hypothesis 1c *The effect of tax loss carrybacks on risk-taking is greater than the effect of tax loss carryforwards on risk-taking.*

3.3 Effect of the Tax Rate (t) on Firm Risk-taking

3.3.1 Results of the Model

To study the effect of the tax rate on firm risk-taking, we implicitly differentiate eq. (2) with respect to t as follows:

$$\frac{d\sigma}{dt} = \frac{1}{-SOC}\left\{-pU''\left(\pi_g\right)\pi_g f_g'(\sigma) - pU'\left(\pi_g\right)f_g'(\sigma) - (1-p)\,U''\left(\pi_b\right)\lambda\pi_b f_b'(\sigma) - (1-p)\,U'\left(\pi_b\right)\lambda f_b'(\sigma)\right\}. \tag{4}$$

For ease of interpretation, we rewrite eq. (4) using the Arrow-Pratt coefficient of relative risk aversion, $R_R\left(\pi\right) = -\frac{U''(\pi)}{U'(\pi)}\left|\pi\right|$. As $\pi_b < 0$, we define $R_R\left(\pi\right)$ using the absolute value of π

such that $R_R(\pi)$ also has a positive value for firms that incur a loss. Then, after simplifying, $\frac{d\sigma}{dt}$ becomes:

$$\frac{d\sigma}{dt} = \frac{pU'(\pi_g) f_g'(\sigma) [R_R(\pi_g) - 1] - \lambda (1-p) U'(\pi_b) f_b'(\sigma) [R_R(\pi_b) + 1]}{-SOC}. \tag{5}$$

The first term in the numerator captures the effect of the tax rate on the profit in the good state of the world. The tax rate lowers the return to additional risk-taking by reducing after-tax profits, but it also increases the marginal utility of the additional profit. The level of the firm's risk aversion determines which of these two effects dominates. For low levels of risk aversion, higher taxes reduce firm risk-taking.

The second term shows the tax rate effect if the firm incurs a loss. The loss refund is a function of both the allowable loss offset (λ) and the tax rate (t). This effect arises only when some loss offset is available (i.e., $\lambda > 0$); if $\lambda = 0$, then the second summand is zero. Consequently, we next analyze the effects of the tax rate on firm risk-taking for the two extreme cases: full loss offset and no loss offset.

For full loss offset ($\lambda \to 1$), taxes decrease both the mean and the variance of returns; that is, the government shares equally in the profit (at tax rate t) and the loss (at $\lambda \cdot t = t$). Because of this risk-sharing, risk-averse firms will increase the amount of total risk-taking with an increase in the tax rate.

For no loss offset ($\lambda \to 0$), the tax effect on risk-taking depends on the level of firm risk aversion. If the firm's risk aversion is low ($R_R < 1$), or if firms are risk-neutral ($R_R = 0$), tax rates decrease risk-taking. The negative tax effect on the additional return in the good state of the world subsumes the positive effect, as the additional utility occurs at a higher marginal utility. If the firm is very risk-averse ($R_R > 1$), tax rates increase risk-taking.[8] These effects for corporate risk-taking are similar to the well-known effects of taxation on individual portfolio choice first described by Domar and Musgrave (1944) and further discussed by Stiglitz (1969) and Feldstein (1969).

[8] A higher tax rate with no loss offset has two effects: It lowers the additional profit earned from additional risk-taking, but the additional tax shifts the firm to a lower utility level where marginal utility is higher. If the firm is very risk-averse, the firm's utility function is very concave, and the marginal utility of additional profits is very high.

We summarize the effects of tax rates on firm risk-taking in the following proposition:

Proposition 2 (The effect of tax rates on risk-taking)

1. *With full loss offset ($\lambda \to 1$), a higher tax rate increases risk-taking by a risk-averse firm. If the firm is risk-neutral, taxes have no effect.*

2. *With no loss offset ($\lambda \to 0$), a higher tax rate decreases risk-taking if the firm is moderately risk-averse ($R_R < 1$) or risk-neutral ($R_R = 0$). For very risk-averse firms ($R_R > 1$), taxes always increase risk-taking.*

Proof. The denominator of eq. (5) is positive, as the second order condition is negative (see proof of Proposition 1). Examination of the numerator of eq. (5) is thus sufficient.
On 1): Taxes increase risk-taking for firms with $R_R > 0$ if $p\ U'(\pi_g)\, f_g'(\sigma) \leq -(1-p)\ U'(\pi_b)\,(1-p) f_b'(\sigma)$. From eq. (2) we know that this is fulfilled with equality when $\lambda = 1$. Thus, $\frac{d\sigma}{dt}\Big|_{\lambda\to 1} > 0$.
On 2). Inspection of eq. (5) shows that the sign of eq. (5) is fully determined by $[R_R(\pi_g) - 1]$ when $\lambda = 0$. ■

3.3.2 Hypothesis 2

For firms with full loss offset ($\lambda \to 1$), the government shares equally in the profit and the loss. That is, when a firm generates income, the government will tax the income; similarly, if the same firm incurs a loss, the government will share in this loss by returning some portion to the firm through the loss offset rules. Sharing in the tax loss is effectively insurance to the firm because the firm receives a government payout when it incurs the loss, and the insurance payment is greater when the tax rate is higher. Thus, a higher tax rate for firms with full loss offset should induce managers to assume more risk. Therefore, we predict the following:

Hypothesis 2a *Tax rates are positively related to risk-taking for firms that expect significant loss offset ("high λ firms").*

In contrast, Proposition 2 also shows that taxes and risk-taking are *negatively* related for firms that *expect no significant loss offset* (the "low λ" firms in the model). For these firms, taxation affects successful risky investments via a tax on income, but the firm does not receive much (if any) offset for losses incurred. Accordingly, risk-averse managers are less likely to engage in risk-taking and instead prefer to invest in safer projects that generate more predictable returns.[9]

For these firms, we predict the following:

Hypothesis 2b *Tax rates are negatively related to firm risk-taking for firms that expect no significant loss offset ("low λ firms").*

4 Research Design & Sample Selection

4.1 Loss Offset Rules and Risk-taking (H1)

4.1.1 OLS Panel Estimation

We first use the following regression specification to test H1a and H1b:

$$Risk_{it} = \beta_0 + \beta_1 LC_{jt} + \beta_2 StdCTR_{jt} + \beta_3 LC^{*} StdCTR_{jt} + \beta_n X_{ijt} + \theta_{kt} + \epsilon_{ijt}, \qquad (6)$$

where $Risk_{it}$ is a measure of the riskiness of firm i's investment in year t (discussed below); LC_{jt} captures the length of the statutory loss carryback or loss carryforward period in a firm's home country j in year t; and $StdCTR_{jt}$ is the statutory corporate tax rate. We

[9]The results in Proposition 2 for the case of no loss offset vary based on the level of firm risk aversion. To our knowledge, the empirical literature provides no estimates of a firm-based coefficient of risk aversion. Using estimates of individual risk aversion, we expect that the firm's risk aversion coefficient is less than one. For example, Chiappori and Paiella (2011) show that relative risk aversion is constant and relatively low. Using existing evidence on the effect of wage changes on labor supply, Chetty (2006) finds a mean estimate of the coefficient of relative risk aversion of 0.71, with all estimates in a range between 0.15 and 1.78 in the baseline case. We expect that the level of firm risk aversion is attenuated relative to estimates for individuals based on predictions derived from principal-agent contracting. Specifically, managers generally receive some fixed compensation (a salary) as well as a variable component (bonus or stock-based compensation) to align managerial incentives with those of the shareholders; because the manager receives some portion of the salary regardless of the firm's performance, he likely exhibits less risk aversion than if all of the compensation were a function of firm profits. In this case, taxes decrease firm risk-taking when no loss offset is expected.

standardize this tax rate to have a mean of zero and a standard deviation of one across the sample such that the coefficient β_1 represents the effect of the loss rules on risk-taking, given the average corporate tax rate in the sample. $LC^{*}StdCTR_{jt}$ interacts the loss carryback and loss carryforward variables with the statutory corporate tax rate. X_{ijt} is a set of firm- and country-specific controls, discussed below; and θ_{kt} captures industry-by-year fixed effects to control for time-varying heterogeneity across industries. We cluster standard errors by firm and country-year to account for within-firm and within-country-year correlation in our sample. Based on H1a, we expect the coefficient on LC_{jt}, β_1, to be positive and significant. We predict a positive coefficient on the interaction term, β_3, as a test of H1b. We also predict that the coefficient for LCB_{jt} is significantly greater than the coefficient for LCF_{jt} as a test of H1c.[10]

As discussed in Section 2, firm risk-taking is often measured as the variance of profits generated from a risky investment over different states of the world. Accordingly, we calculate our dependent variable $Risk_{it}$ as an adjusted standard deviation of a firm's return on assets (ROA) following John, Litov, and Yeung (2008), Faccio, Marchica, and Mura (2011), and Acharya, Amihud, and Litov (2011).[11] If a firm assumes more risk, its ROA will be higher in some periods when risky investment succeeds, and lower in other periods when the risky investment fails. Thus, we proxy for risk-taking by i) computing the difference between the industry-country-year ROA average and the firm's ROA, measured as the ratio of EBIT to assets in the same firm-year and ii) calculating the standard deviation of this difference over this year and the following two years.[12] Using the difference between a firm's ROA and the

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[10]Our analytical model shows that we must include the corporate tax rate in the regression specification because it affects the relation between the loss rules and risk-taking. We do not predict the sign of β_2 in Eq.(6) because Proposition 2 shows that the corporate tax rate effect varies based on firm-specific expectations of loss offset; we outline these predictions in discussion of the H2 tests.

[11]Specifically, John, Litov, and Yeung (2008) and Acharya, Amihud, and Litov (2011) use EBITDA in constructing the firm-level risk measure, whereas Faccio, Marchica, and Mura (2011) use EBIT. We follow Faccio, Marchica, and Mura (2011) and select EBIT when constructing the measure because it more accurately reflects firm investment decisions by including amortization (related to investment in intangibles) and depreciation (related to investment in capital expenditures) in the calculation.

[12]Results are also robust to using a five year measure of risk-taking instead of a three year measure.

industry-country-year ROA average ensures that we only capture variation in ROA that is directly attributable to the actions of the firm's manager and thus permits a cleaner analysis of firm-specific risk that directly reflects corporate operating and investment decisions. In Section 6, we show that our results are robust to using different risk measures and also to estimating eq. (6) at the country-level.

We measure LC with the number of years of a country's tax loss carryback (LCB) and carryforward (LCF) period. For countries with an indefinite loss carryforward period, we set LCF to 20 years (i.e., the maximum finite period in the sample) to estimate eq. (6). The country tax rate $StdCTR_{jt}$ is the average combined statutory tax rate of central and sub-central governments from the OECD tax database. If the tax system is progressive, we use the top statutory tax rate.[13]

We control for a firm's *Size* (log of total assets), as larger firms undertake the bulk of aggregate investment (Djankov, Ganser, McLiesh, Ramalho, and Shleifer 2010). However, larger firms also have fewer risky opportunities and lower overall operating risk (John, Litov, and Yeung 2008). Furthermore, prior literature documents that a firm's tax liability is correlated with firm size (Zimmermann 1983; Porcano 1986; Rego 2003). We include the market-to-book-ratio (MB, market capitalization to shareholders' equity) and *Sales Growth* (calculated as the one-year percentage change in revenues) to control for the firm's investment opportunity set, as firms with a greater set of possible investments engage in more risk-taking (Guay 1999; Rajgopal and Shevlin 2002), but these firms are also less profitable and pay fewer taxes. As in John, Litov, and Yeung (2008), we also control for ROA, measured as EBIT/assets, which captures a firm's ability to fund investments and risky projects. *Leverage* (ratio of total liabilities to total assets) controls for firm risk related to costly financial distress, interest

[13] Another tax rate that may be relevant is the applicable statutory tax rate for each firm based on annual profitability. However, this rate may be endogenous to the firm if firms manage earnings to be just below the thresholds for higher rates. Alternatively, the firm's marginal tax rate may also be relevant, as these rates reflect losses, tax credits, etc. However, we do not use marginal tax rates for two reasons. First, separating statutory rates and the tax loss rules allows us to study both the main effects, as well as the interactive effects of these features, which is important given that the theoretical model shows that they can independently affect risk-taking. Second, data on marginal tax rates for an international sample of firms is unavailable, and thus, we are not able to estimate the marginal tax rate effects, even in robustness tests.

tax shields that may contribute to a firm's tax status, and risky asset substitution concerns (Harris and Raviv 1991; Leland 1998).

We also include a number of measures to control for country-level characteristics that may affect the relation between corporate risk-taking and tax rules. Following John, Litov, and Yeung (2008), we control for *GDP Growth*, constructed with data from the IMF's World Economic Outlook Database and calculated as the one-year percentage change in a country's GDP. In addition, we include *Inflation* and the *Risk-free Rate*, measured with OECD data, as these variables affect firm-level investment and the cost of firm financing for investment projects. Moreover, following Acharya, Amihud, and Litov (2011), we include country-level macroeconomic risk (*Macro Risk*), measured by the standard deviation of the quarterly growth in real industrial production. Finally, the quality of a country's institutions might affect the relationship between risk-taking and tax rules. For example, the rule of law affects the extent to which tax rules are enforced or are effective, and it also captures how well investors can enforce claims against the firm related to sub-optimal risky investment decisions. To control for these country characteristics, we follow Mihet (2013) and include three measures from the World Bank's Worldwide Governance Indicators: the rank of a country's *Rule of Law*, *Regulatory Quality*, and *Control of Corruption*. Appendix A provides a summary of all variables and the data sources.

4.1.2 Matched Sample Difference-in-Difference Estimation

The matched sample difference-in-differences (DiD) specification exploits changes in the statutory loss offset rules for a subset of the sample countries. During the sample period, Germany decreased the loss carryback period; Netherlands decreased both the loss carryback and carryforward periods; and Denmark, France, Norway, and Spain increased their loss carryforward periods (see Table 1).[14]

For a valid DiD estimation, treated and control samples must exhibit similar risk trends

[14] We cannot separately test the effects of the decrease in the loss carryback and carryforward in the Netherlands because they occurred in the same year and should both result in lower risk-taking.

prior to the tax law change. Therefore, for each country with a loss carryback/carryforward change, we identify countries with similar pre-change risk time trends. We then employ a firm-specific matching approach to further improve the similarities between the treated and the control samples. Specifically, we match firms in countries with a statutory change in the tax loss rules (treated firms) with firms in countries with no statutory changes and similar aggregate risk time trends (control firms) using the Mahalanobis distance matching technique and, for robustness, propensity score matching. We match observations on fiscal year and on the control variables previously listed. As relatively few countries changed the loss offset periods, the sample is much smaller for this analysis (518 (829) treatment-control pairs for the decrease (increase) in loss offset period). However, the DiD approach offers a more precise identification of the treatment effect.

We calculate the DiD effect using the following regression:

$$Risk_{it} = \beta_0 + \beta_1 LossChangeInd_i + \beta_2 Post_{it} + \beta_3 LossChangeInd^{*} Post_{it} + \epsilon_{it}, \tag{7}$$

where $LossChangeInd_i$ is an indicator equal to one if firm i is in a country with a change in the loss carryback/carryforward period, or zero otherwise; $Post_{it}$ is an indicator equal to one for all treated and control observations in year t including and following the loss carryback or carryforward change; and $LossChangeInd^{*} Post_{it}$ is the interaction of the prior two terms. For firms in countries with a decrease in the loss period (Germany and Netherlands), we expect that risk should decrease for treated firms relative to control firms ($\beta_3 < 0$). For firms in countries with an increase in the loss period (Denmark, France, Norway, and Spain), risk should increase for the treated firms relative to control firms ($\beta_3 > 0$).[15]

[15] Both Norway (in 2008 and 2009) and the U.S. (in 2001, 2008, and 2009) increased their loss carryback periods, but as these increases were introduced retroactively, we do not include these loss carryback changes in our main analysis. Furthermore, we do not allow for Norwegian or U.S. firms to be control firms in the difference-in-difference tests. Section 5.2 discusses additional analyses that include these retroactive statutory tax loss carryback changes. We confirm using the IBFD European tax handbooks that none of the other changes in loss offset rules were introduced retroactively.

4.1.3 Regression Discontinuity Design

The third test of H1 examines the relation between risk-taking and tax loss rules with a regression discontinuity design using a Spanish tax law change that affected only firms with prior year revenues above €20 million. Although conducted on a very specific sample of small Spanish firms, this test provides better identification of the risk-taking effects.

In 2011 (2012-2013), Spain limited the amount of loss offset to 75% (50%) of the tax base for firms with prior year revenues of €20 million to €60 million.[16] This setting has four advantages: first, all firms are in Spain, which mitigates concerns of unobserved country factors that may affect the cross-country results; second, the revenue cut-offs are exogenously determined based on firm performance in the year *prior* to the passage of the law;[17] third, the law did not affect tax rates, depreciation allowances, or other significant corporate tax rules that could otherwise influence investment decisions; and fourth, Spain does not permit loss carrybacks, and therefore, the new loss carryforward limitations should directly affect firms' expected loss offset. Consequently, this setting permits us to infer that any risk-taking effects can be attributed to changes in loss offset rules.

The change in the Spanish loss offset limitation lowers λ for the affected firms. The regression discontinuity design compares firms just above and just below the €20 million cutoff. We predict that firms with prior year revenue above the €20 million revenue threshold engage in less risk-taking than firms below the corresponding cutoff following this statutory change.

We test for discontinuities using both a local linear regression and a quadratic polynomial, and we follow the method developed by Imbens and Kalyanaraman (2012) for the choice of

[16]The law changing the loss rules was passed via Royal Decree in August 2011 to meet an urgent need for tax revenues. We did not find any mention of planned tax loss changes in the main Spanish newspapers before August 2011. Thus, firm selection into or out of the treated group is unlikely. We also implement a manipulation test as suggested by McCrary (2008) and Cattaneo, Jansson, and Ma (2016). This test yields a p-value of 0.1699, suggesting that there is no statistical evidence of systematic manipulation of the lagged revenues.

[17]As firms could manage earnings to self-select into treatment and control groups in later years, we only test the effect of the limitation of loss offset for 2011. This concern is confirmed by the Cattaneo, Jansson, and Ma (2016) manipulation test, which yields a p-value of 0.0764 for 2012.

bandwidth. In all regression discontinuity tests, we control for size, ROA, leverage and sales growth.[18]

4.2 Tax Rates and Risk-taking (H2)

To test the second hypothesis, which considers the tax rate effect on firm risk-taking, we partition the sample according to the firm-specific expectation of future loss offset (λ).[19] "High λ" observations include those firm-years in which i) the firm operates in a country that allows loss carryback, and ii) the firm previously reported positive earnings (as a proxy for unobservable taxable income) over the commensurate carryback period. Thus, this designation captures firms most likely to receive an immediate refund of prior taxes if they sustain a loss in the following year. Conversely, "low λ" firms are those firm-year observations in which i) the firm operates in a country that does not permit loss carryback, such that the firm must rely on future profitability to obtain any loss offset, but ii) profitability in the short term is unlikely based on historical operating performance.[20]

For each of the subsamples, we estimate the following regression models:

$$Risk_{it} = \gamma_0 + \gamma_1 CTR_{jt} + \gamma_n X_{ijt} + \theta_{kt} + \epsilon_{ijt}. \tag{8}$$

$$\Delta Risk_{it} = \gamma_0 + \gamma_1 \Delta CTR_{jt} + \gamma_n \Delta X_{ijt} + \theta_{kt} + \epsilon_{ijt}. \tag{9}$$

[18]We cannot control for the market-to-book ratio, as most firms in this Spanish sample (described in Section 5.3) are not publicly traded.

[19]Some firms we do not classify as either high or low λ because they do not meet either definition above. Dropping these firm-years and using only the tails of a hypothetical distribution of λ increases the precision of the tests of H2.

[20]These firm-specific expectations could alternatively be measured with changes in a firm's valuation allowance (related to the amount of deferred tax assets recorded on firm financial statements), which captures management's expectation of future loss utilization. However, the requirements for recording and changing valuation allowances differ across the countries in our sample, and furthermore, our dataset does not include information on these reserves. We also acknowledge that firm-specific λ may be affected by statutory provisions that limit use of a tax loss following a merger or acquisition. We do not expect that these limitations would affect the H1 empirical results because longer statutory periods increase the time over which a firm may be able to utilize any loss, including one that may be limited. For our second hypothesis, these limitations could alter the firm-specific λ because it affects whether and to what extent a firm can expect to use its losses to offset future income. Again due to data limitations, we are not able to observe the actual amount of a firm's loss carryover, nor the portion that may be limited under these statutory limitations. However, to the extent that we have incorrectly classified a firm as "high λ" when in fact its losses are limited, we would expect this to bias away from finding results because we should observe little to no change in risk-taking for these firms.

where CTR is the statutory corporate tax rate, and the other variables are as previously defined.[21] Δ denotes first differences. The coefficient of interest is γ_1. As outlined in Proposition 2, we predict a positive effect ($\gamma_1 > 0$) for high λ firms and a negative effect ($\gamma_1 < 0$) for low λ firms. Controls and fixed effects are as described for the first set of regressions in Section 4.1.1.

4.3 Sample Selection and Descriptive Statistics

To construct the cross-country firm-level panel dataset, we select all firms in Thomson Reuters' Worldscope from 1998 through 2009 for the United States and all major Western European countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Switzerland, United Kingdom).[22] These countries have comparable levels of tax enforcement, and prior cross-country taxation studies focus on a similar geographic sample (e.g., Devereux, Griffith, and Klemm 2002; Devereux and Griffith 2003).[23] Our sample ends in 2009, as we require data for two subsequent years (2010 and 2011) to calculate the three-year risk measure. This sample period includes differing levels of macroeconomic and industry-specific risk, including the dot-com bubble of 1999-2000, the post-9/11 contraction, global economic expansion in the 2000s, and the financial crisis. While we control for these macroeconomic shifts with year fixed effects, the opportunities for firm risk-taking fluctuated during these years, making it a suitable and recent period to examine.

From this sample of 195,762 firm-years, we drop observations for cross-listed firms (4,762

[21] Because the tax rate is the main variable of interest in these hypotheses (i.e., it is not controlling for a theoretical effect as in eq. (6)), we do not standardize the tax rate in eq. (8) and (9).

[22] Worldscope reports consolidated balance sheet data. As almost all countries in our sample (except Belgium and Greece) allow for some form of within-country group relief, consolidated data is appropriate in this setting. We exclude Sweden because of the country's rules related to specific tax reserves, which cannot be directly compared to carryback/carryforward rules in the other countries.

[23] Moreover, these countries had comparable and generally low inflation during the sample period, averaging 2.28%. Therefore, the value of losses within and across these countries should not be significantly affected by inflation concerns. We also control for country-level inflation to further mitigate concerns that inflation may be affecting our results.

firm-years) to ensure that we appropriately merge the correct country-specific tax rules with the firms included in our sample. We also eliminate observations related to financial and utilities firms (50,406 firm-years) because these firms are subject to regulatory rules that affect profitability, the firm's tax status, and the level of risk-taking. We drop 2,039 observations missing total assets or where total assets are less than zero, as well as observations missing the requisite time series data to calculate the three-year risk measure (32,833 firm-years). Finally, we eliminate observations missing data to calculate the control variables for a final sample of 84,222 firm-year observations.

This sample includes some multinational firms, which may introduce measurement error into our tests because we are unable to identify each relevant taxing jurisdiction. While we do not expect a systematic relationship between this measurement error and the variables of interest, we also present our main results using a smaller sample of firms with only domestic operations. We identify domestic-only firms if they report either zero values or missing values for foreign sales or assets. After imposing this additional data restriction, the sample of domestic firms reduces to 34,988 observations by including firm-years where missing values for the requisite foreign variables are set to zero.[24] We convert all data to US dollars using exchange rates provided by Officer (2011).

Table 2 provides the descriptive statistics for our sample. We winsorize firm-level variables at the 1% and 99% level. Firms in the sample report average (median) *Risk* of 0.294 (0.101). For validation, we compare the country-level average *Risk* to John, Litov, and Yeung (2008) and find that the measures are highly correlated (0.84). The average loss carryback period for our sample is 1.54 years; the average carryforward period is 17.82 years. The mean statutory corporate tax rate is 36.1 percent. Untabulated statistics show that the average tax rate has declined over time, from 38.5 percent in 1998 to 33.5 percent in 2009.

[Insert Table 2 here.]

[24] Results are robust to re-estimating results on a domestic-only sample constructed by dropping firm-year observations with missing values for foreign sales and foreign assets.

Our sample includes firms that, on average, exhibit sales growth of 29.0 percent (median: 8.9) and have a market-to-book ratio of 2.9 (median: 1.7). Thus, the sample appropriately includes firms that have risky investment opportunities. Furthermore, the mean ROA of -0.07 indicates that the sample includes loss firm-years, a necessary condition for investigating if losses and the corresponding tax rules are associated with risk-taking. However, the median firm-year is profitable with an ROA value of 0.06. The negative ROA observations are concentrated in 2001-2003 (following the dot-com bubble) and in 2008 and 2009 (following the financial crisis).

We include the United States in the sample because of its economic significance and note that this data selection step results in an unbalanced panel, in which approximately half of the total observations (44,088 out of 84,222) are from this country (see Panel B of Table 2).[25] In addition to the large size of the U.S. economy, such distribution also reflects the larger share of U.S. incorporated firms, relative to many European countries. France, Germany, and the U.K. report 7.3 percent (N=6,138), 7.3 percent (N=6,139), and 14.2 percent (N=11,940) of the sample, respectively. Observations are distributed equally across the sample period, as shown in Panel C.

5 Empirical Results

5.1 Loss Offset Rules: Cross-country Analysis

Table 3 presents the test of H1 using an OLS panel regression. We first regress *Risk* on the firm's home country statutory loss carryback/carryforward periods (col. 1) and control variables (col. 2) to test H1a. For the average firm in the sample, a one year longer loss carryback period is associated with 11.6 percent higher risk-taking (coefficient of 0.034); a one year longer loss carryforward period implies 2.4 percent higher risk-taking (coefficient of

[25] In Section 6.2, we show that results are robust to excluding U.S. firm-years from the sample.

0.007).[26]

To further evaluate these results, we compare the magnitudes calculated above to the effects of certain control variables. For example, an increase in leverage (size, performance, sales growth, and MB) from the first to third quartile is associated with a change in the volatility of ROA of 18.5 percent (-29.5, -25.6, 2.5, and 2.4 percent, respectively). These results are consistent with prior findings that show that leverage and firm characteristics such as size are important determinants of risk and further demonstrates that the corporate tax rules have a real and economically significant affect on corporate risk-taking.[27]

[Insert Table 3 here.]

Column (3) presents results for regressions including the interaction terms *LCB*StdCTR* and *LCF*StdCTR* as tests of H1b. The coefficients on *LCB* and *LCF* remain positive and statistically significant, and the economic significance of the coefficients increases slightly; a one year longer loss carryback (carryforward) period is associated with 15.3 (3.1) percent higher risk-taking for the average firm at the average tax rate. The coefficient on *LCB*StdCTR* is positive and significant, consistent with our hypothesis that loss offset provisions are more economically important to firms, the higher the country's tax rate. However, we find an insignificant coefficient on *LCF*StdCTR*; a higher tax rate has no effect on the relation between loss carryforwards and risk-taking. One *ex-post* explanation is that the tax rate may change prior to a firm's use of its loss carryforward, and this uncertainty regarding the future tax rate makes the current rate less relevant for firm risk-taking decisions.

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[26] We calculate this amount by multiplying the period change of one year by the coefficient and dividing by the mean *Risk* (0.034/0.294 = 11.6%). For an intuitive interpretation, consider the yearly change in *ROA* for a firm that has values of *ROA* and *Risk* identical to the average in our sample (*ROA* and *Risk* of -0.072 and 0.294, respectively). Assuming that the average country-industry *ROA* is constant over time, this firm's *ROA* ratios over a three-year period are, for example, -0.366, -0.072, and 0.222. A one year longer carryback period increases the average risk from 0.294 to 0.328, suggesting that the three-year ratios would instead be, for example, -0.395, -0.072, and 0.260. Therefore, we can also interpret the 11.6% increase in risk as an 11.6% increase in the span between the best and worst yearly *ROA* for the average firm.

[27] In additional analysis, we estimate eq. (6) separately for loss carrybacks and carryforwards and find consistent results.

As a test of H1c, we compare the coefficients on *LCB* and *LCB* and find that *LCB* is significantly greater (p=0.078). The larger coefficient reflects that loss carrybacks provide greater incentives for firm risk-taking than loss carryforwards, given the higher level of certainty and the more timely refund of prior cash taxes. Note also that loss carryback periods are short, ranging from zero to three years in our sample. Therefore, a one-year increase implies a large relative change in the loss offset possibilities.

We next add additional country-level controls to the regression specification. The inclusion of these controls mitigates some concern that omitted country-level characteristics could be driving the results. However, these controls are not available for all firm-years in our main sample, and the inclusion of these controls may subsume some of the effects of the loss offset period. Thus, we present these results separately in col. (4). We continue to find a positive and significant relation between loss carrybacks and firm risk-taking, but *LCF* is not significant after including these control variables.[28] These results also support the H1b and H1c predictions: the interaction term *LCB*CTR* remains positive and significant, and the coefficient on *LCB* continues to be significantly greater than the coefficient on *LCF* (p=0.000). In this specification, and throughout the regression results, the control variables exhibit the expected relation with firm risk-taking.

Column (5) presents results for estimating the full model on the sample of domestic firms. We find results consistent with those presented in col. (4) – *LCB* is positively associated with risk-taking, and this relationship is greater, the higher the corporate tax rate within this sample of domestic firms.

5.2 Loss Offset Rules: Difference-in-Difference Estimation

We present results of the matched sample DiD estimation in Table 4. The validity of the DiD approach depends on the similarity of pre-event time trends in the treated and control

[28]Untabulated tests show that the reduction in significance on *LCF* is related to the inclusion of additional control variables rather than a reduction in the sample size.

samples. Figure 2 presents evidence related to this key identification assumption; the figure shows that the average risk of treated firms (i.e., those that operate in a country with a statutory loss change) and control firms in each of the two matched DiD samples is similar in the three years preceding the carryforward or carryback period change (marked by the vertical line). This graph suggests that the matching process produced an appropriate control sample of comparable firms for the statistical tests.

[Insert Figure 2 here.]

Figure 2 also presents evidence that changes in the statutory loss offset rules affect firm risk-taking. In the upper panel, where the treatment consists of an increase in the loss offset period, risk-taking by the treated firms increases after the statutory change, while it continues to decline in the control sample. In the lower panel, where the treatment is a reduction in the loss offset period, we find that risk-taking by the treated firms declines compared to the control firms. Both changes are consistent with the predicted effects.

Column (1) of Table 4 presents the β_3 coefficient from estimating eq. (7) for the treated sample of firms with a statutory decrease in the loss offset period (Germany and Netherlands); col. (2) includes the coefficients for increases in the loss offset period (Denmark, France, Norway, and Spain). A decrease in the loss period is associated with a decrease in firm-risk; the coefficient of -0.015 implies that the average risk of the treated firms is 23 percent lower after the statutory change compared to the average risk of the matched control firms. We also find that, as predicted, an increase in the loss period is related to a 14 percent increase in average risk for the treated firms, relative to the control firms (coefficient of 0.008).[29] These results confirm that more generous tax loss rules induce greater firm risk-taking.

[Insert Table 4 here.]

[29]We calculate these effects by comparing the change in average risk for treated firms to control firms. These results are estimated using changes in carryback and carryforward periods of differing lengths and therefore can not be interpreted in the same manner as in Table 3.

For robustness, we present six additional sets of results. First, we match on industry affiliation in addition to the listed control variables and find similar coefficients, confirming that the results are not sensitive to the matching variables selected. Second, we employ three different matching approaches: i) Mahalanobis matching with four control matches; ii) propensity score matching with four nearest neighbors, and iii) propensity score matching with a specified caliper (= 0.0001).[30] We continue to find a negative and significant effect on risk-taking from a decrease in the loss period across each of these alternative matching procedures. However, we find an insignificant effect for the increase in loss period in col. (2). Because the decreases mostly relate to carryback periods (and all four increases relate to carryforward periods), these results reinforce that changing loss carryforward periods is less effective in influencing corporate risk-taking than altering loss carryback periods.

The last rows of the table show the DiD results on the smaller sample of domestic-only firms. The coefficient for the loss carryback is even larger within this sample, indicating that the carryback effects are even greater for firms operating entirely within the country that changes their loss rules.

Finally, in untabulated analyses, we follow Dobridge (2016) and consider additional statutory changes in loss carryback period. Specifically, we test the effect of the retroactive increases to the loss carryback period in both Norway (2008) and in the U.S. (2001 and 2008). We find little effect of this change in Norway, which suggests that Norwegian firms did not seem to respond to the temporary increase by increasing risk-taking. However, we observe that the increase in the U.S. loss carryback period is associated with a 24.4 percent increase on risk-taking, a similar effect as the other loss carryback changes. This result provides evidence that even some retroactive carryback extensions provide economically important incentives to firms.

[30] Untabulated analyses show that results are robust to using one, two, or three Mahalanobis and nearest neighbor matches, as well as using calipers set at 0.00001 and 0.000055.

5.3 Loss Offset Rules: Regression Discontinuity Design

For the regression discontinuity test of the Spanish tax law change, we use firm-level data from Bureau van Dijk's Amadeus data set.[31] We select all Spanish-incorporated firms from Amadeus and follow the same sample selection steps as the main sample. For validation, we compare the risk measure for the firms in this dataset to the last available year from the main Worldscope sample (2009) and find similar values.[32]

We use both a local linear and quadratic polynomial for the regression discontinuity estimation. Following Imbens and Kalyanaraman (2012), we identify an optimal bandwidth of €139,840. Thus, we compare risk-taking in 2011 for firms with revenues between €20.00 million and €20.14 million in 2010 to firms with revenues between €19.86 million and €20.00 million in 2010. To show that our results are robust, we also report results using double and triple the bandwidth.

Figure 3 plots *Risk* of Spanish firms in 2011 above and below the €20 million threshold. The top (bottom) plot presents results using the local linear estimation (quadratic polynomial estimation). The difference in the linear (convex) lines in the plots provides graphical evidence that firms above the threshold have lower *Risk* than those firms below the threshold following the statutory change in loss offset rules.

[Insert Figure 3 here.]

Table 5, Panel A reports the local linear results in cols. (1)-(3) and the quadratic polynomial results in cols. (4)-(6) for the different bandwidths. As expected, we find a negative

[31]The Worldscope-based data set used in the previous sections only has data on listed firms and includes very few (less than five) Spanish firms with revenues below €20 million. In contrast, the Amadeus database focuses on small firms and reports information on approximately one thousand firms within a five million window around the €20 million threshold. We note that the Spanish law change also affected firms with revenues greater than €60 million by limiting loss offset to only 50% (25%) of the tax base in 2011 (2012-2013). However, neither of the two data sets (Amadeus or Worldscope) provides sufficient observations to test the effects around this second threshold. Specifically, in Amadeus, we have ten times as many observations for the €20 million test as compared to the €60 million threshold. When running the regression discontinuity test with larger bandwidths for the €60 million threshold, we find insignificant results, likely as no clear identification is possible due to confounding effects that arise when using these larger bandwidths.

[32]In the Amadeus sample, *Risk* in 2009 has a median value of 0.030; Spanish firms in the Worldscope sample in the same year have a median *Risk* of 0.027.

and significant coefficient for the average treatment effect, which means that firms that can only offset 75% of a potential loss have significantly lower *Risk* than similarly-sized Spanish firms (i.e., firms immediately below the threshold) that can fully offset losses. The consistent results across all six columns show that this result is not sensitive to the choice of bandwidth or type of estimation.

[Insert Table 5 here.]

To confirm these results, we also perform three sets of falsification tests in Table 5, Panel B. First, we test if discontinuities exist at other levels of lagged revenues that were not affected by the law change, including €15 million, €19 million, €21 million, and €25 million of revenues. We find no significant effect at any of these levels. Second, we test for discontinuities at the same €20 million threshold in four years prior to the tax law change, to ensure that there are no general differences in risk-taking for firms above and below the €20 million cutoff. There is no significant negative effect for 2008 to 2010 (and the 2007 effect is in the opposite direction). Finally, we present the average treatment effects for other firm characteristics that should be unaffected by the tax rule change. We test for discontinuities related to employees, assets, EBIT, and sales growth. For employees and EBIT, we do not find a significant effect. For assets and sales growth, we find negative and significant effects, although the results are weaker than the main effects presented in Panel A. One possible explanation is that lower risk-taking may affect firms' assets and sales growth as well.

Collectively, these results reinforce the prior finding that tax loss rules have an economically and statistically significant effect on firm risk-taking.

5.4 Firm-level Effects of Corporate Tax Rates

In this section, we present results from testing our second hypothesis on the relation between the corporate tax rate and firm risk-taking. For these tests, we revert to the cross-country panel for purposes of identifying and partitioning firms on the basis of their expected future loss offset. Results are presented in Table 6. The first four columns of Panel A include the results for the full sample; cols. (5) and (6) repeat the analysis on the smaller sample of domestic firms. Columns (1), (3), and (5) present the results for the "high λ" firm-years. As predicted, higher tax rates are positively and significantly related to risk-taking for the high loss offset firms. A three percentage point increase in the tax rate (equivalent to the change in tax rate from the mean to the 75th percentile) is associated with an 13.9 percent increase in the risk measure for the average high λ firm.[33] Excluding multinational firms (cols. 5 and 6), we continue to find that the tax rate is positively related to corporate risk-taking for the subsample of high λ firms. With full loss offset, the government shares the firm's investment risk, making risk-taking more attractive to the firm.

[Insert Table 6 here.]

In contrast, the observations in cols. (2), (4), and (6) are those firm-years defined as "low λ". As predicted in H2b, we observe a negative and significant coefficient on CTR in col. (2). In this case, a three percentage increase in the tax rate is associated with an 8.6 percent decrease in firm risk for the average low λ firm. In the smaller samples that include additional control variables or exclude multinational firms, we continue to find a negative, but insignificant, result.

Table 6, Panel B presents results from estimating eq. (9), in which we regress *changes* in loss offset expectations on *changes* in the country's tax rate. Using this first difference specification improves identification as it controls for unobserved time-constant firm and country characteristics. Our results for the high λ firms continue to hold, as seen with the positive and statistically significant coefficient in cols. (1), (3), and (5). For the low λ firms, we find insignificant coefficients.

The Table 6 results show that risk-taking is positively related to the corporate tax rate for those firms most likely to use tax losses. In contrast, we generally find an insignificant relation

[33] We calculate this result by first multiplying the one quartile change in the tax rate by the coefficient ($0.032x0.913{=}0.029$). We then divide this amount by the average risk for the sample of high λ firms ($0.029/0.210 = 0.139$).

between the tax rate and risk-taking for the "low λ" firms in the sample. These results are consistent with the model if firms behave in a relatively risk-averse manner. Thus, while loss carrybacks and carryforwards provide economic incentives for firms to engage in risk-taking behavior (from Table 3), firm-specific expectation of loss utilization must be considered when determining how tax rates affect firm risk-taking.

6 Robustness Tests

6.1 Alternative Risk Measures

In Table 7, Panel A, we re-estimate our main results for both hypotheses using four alternative risk measures and including all control variables. In cols. (1) to (3), we use the firm-level standard deviation of ROA (without subtracting the country-industry-year average). This measure mitigates concerns that adjusting the dependent variable may bias the coefficient. Using this unadjusted measure, we continue to find a positive coefficient on *LCB* in col. (1), as well as on *CTR* in col. (2) for the subset of high λ firms.

In cols. (4) to (6), we use idiosyncratic volatility, a market-based measure of firm risk. Unlike the ROA measure that is calculated directly from annual firm accounting information, idiosyncratic volatility captures the unexplained changes in the *market* pricing of the firm as well as the market's assessment of firm-specific risk. Thus, idiosyncratic volatility may incorporate other information available to investors that may be informative about firm risk-taking. To calculate this measure, we follow Campbell, Lettau, Malkiel, and Xu (2001) and Fu (2009). We obtain data on firms' stock returns from Datastream and calculate the daily return residual for firms by regressing the firm's excess return on daily factor data. For US (European) firms, we use the daily US (European) factor data from Kenneth R. French's website. We then take the standard deviation of the daily return residual over the year. Using this alternative measure, we again find consistent results; both *LCB* and *LCF* are significantly positive in col. (4). In the tests of H2, we also find consistent results: *CTR* is positive (negative) and significant (insignificant) for high (low) λ firms in cols. (5) and (6), respectively.

Columns (7) to (9) present results using the log of R&D expenses as the dependent variable. We use this measure because one way that firms can increase risk-taking is to shift investment spending to risky R&D projects. Because many firms report either zero or missing values for this variable, the sample size is smaller for these tests. Consistent with expectations, we observe a positive and statistically significant coefficient for *LCB* in col. (7) and for the high λ firms in col. (8).

The fourth alternative risk measure is the standard deviation of cash flows over a three year period in cols. (10) to (12). Because this measure does not reflect accounting accruals, it should be less subject to earnings management actions taken by managers. Again, we find consistent results for *LCB* in col. (10).

Finally, in untabulated tests, we also re-estimate the firm risk measure over five years (year t to year $t+4$). The results continue to hold using this measure as well; the coefficient on *LCB* is 0.064 (t-stat=7.048), and the coefficient on *LCF* is 0.002 (t-stat = 0.603). The interaction term (*LCB*CTR*) is also significant at the one percent level. Collectively, these tests show that the main results are not sensitive to the definition of the risk measure.

[Insert Table 7 here.]

6.2 Alternative Samples

In Table 7, Panel B, we show that the results are robust to estimation on different subsamples of firms. First, to mitigate concerns that U.S. firms are driving the results, we present results including a smaller sample of U.S. firm-years, where we randomly select the same number of U.S. observations as the total number of U.K. firm-year observations (n=11,940). In cols. (4) to (6), we present results after dropping all U.S. companies from the sample (recall that there are no US firms in the low λ sub-sample due to our definition of low λ firms). We find that the results continue to hold for these smaller samples, as evidence that U.S. companies do not drive the results.

Of the countries studied, only seven permit loss carrybacks. We re-estimate results using only observations from these countries in cols. (7) and (8).[34] In col. (7), we first re-estimate eq. (6) on this sample. The coefficient on *LCB* continues to be positive and significant, and we observe no effect for *LCF*. Re-estimating the regressions without *LCF* in col. (8), we continue to observe a positive and significant coefficient on *LCB* as well. In both columns, the interaction term is positive and significant.

6.3 Tax Evasion Index

In additional untabulated analyses, we further examine how country-level characteristics affect our results. Specifically, in countries with greater levels of firm-level tax evasion, we predict that the tax rules - and tax loss incentives specifically - will be less important to firms. To test this prediction, we use the tax evasion indicator provided by the World Economic Forum (2002). Specifically, we create an indicator equal to one for high-tax-evasion countries, which we define as those countries with a tax evasion score of 1 or 2 (Greece, Italy, Portugal, and Belgium), and zero otherwise. Unfortunately, none of the four high tax evasion countries offer a loss carryback, and thus it is not possible to test if the economic results for the carryback are lower for high tax evasion firms.[35] When including the tax evasion indicator in our tests and interacting it with *LCF*, we find that the interaction term is negative and significant (coefficient of 0.006, t-stat = 2.159), as expected.

[34] We cannot re-estimate the results for H2 on this sample given that the the partitions between high and low λ are calculated based on whether or not countries permit a loss carryback; thus, within these sub-samples, there are no low λ firms.

[35] In additional tests, we re-define the high tax evasion indicator based on a tax evasion index score below 4. We do find a negative and significant coefficient on the interaction of the tax evasion indicator variable with *LCB*, but we note that defining the indicator in such a way results in the inclusion of Norway, Denmark, and Germany as high tax evasion countries.

6.4 Country-level Estimation

Following John, Litov, and Yeung (2008), we also test the relation between loss offset rules and firm risk-taking at the country-level. We compute the average *Risk* for each country-year in the sample and regress this amount on the country's loss carryforward and loss carryback periods, as well as the country tax rate, interaction terms, and country control variables available for all of the country-years. We find consistent results with positive and significant coefficients (t-statistics) of 0.047 (4.885), 0.006 (4.655), 0.039 (2.709), and 0.001 (1.680) on LCB, LCF, $LCB^{*}StdCTR$, and $LCF^{*}StdCTR$, respectively.

6.5 Overlapping Observations

Clustering standard errors by firm in the tests of our first hypothesis accounts for correlation introduced by calculating the risk measure over a multi-year period and testing the regression at the firm-year level. To further mitigate concerns of overlapping observations within the sample, we re-estimate the main regression using only every third year – 2000, 2003, 2006, and 2009. We find consistent results; the coefficients (t-statistics) are 0.068 (4.578) and 0.004 (1.387) on LCB and LCF, respectively. Furthermore, the two interaction terms report coefficients (t-statistics) of 0.121 (5.064) and -0.006 (-2.220). We conclude that the main results are not driven by multiple firm observations within the panel.

6.6 Stock Option Expense

Stock options could affect both firm risk-taking (by providing incentives to induce risk-averse managers to make risky firm investments) and the taxability of the firm (if options are deductible). Unfortunately, data on stock options is only available for a limited number of firms (N=17,211), and therefore we do not impose this data restriction when constructing the main sample. For robustness, we re-estimate eqs. (6) and (8) including this variable, and we find that the coefficients are very similar to the main results on this smaller sample.

7 Conclusion

This paper studies how a country's tax system affects corporate risk-taking. The effect of corporate taxation on firm risk is a function of the statutory tax loss offset rules and tax rates, as well as firm-specific expectation regarding loss offset possibilities. We empirically confirm the theoretical predictions using a cross-country sample of firms, as well as a sample of Spanish firms around a statutory Spanish rule change in 2011. We find that the level of corporate risk-taking is positively related to the available loss offset period. We infer from these results that these tax policies affect firms' investment project selection. We then partition firms based on the estimated expectation of available future loss offset. We also study the effects of tax rates on risk-taking: higher tax rates increase risk-taking for firms that expect to use their tax losses but have little effect for firms with very limited loss offset possibilities. Thus, our paper provides evidence that firms have differing investment responses to tax rate changes, and these responses depend on firm-specific characteristics, notably prior and expected future profitability.

The direct effects of tax loss rules on investment - as well as the indirect effects via the tax rate - have important implications for policymakers. To the extent that governments want to encourage risk-taking, longer tax loss periods, particularly for carrybacks, provide appropriate incentives. Our paper also shows that high tax rates do not necessarily inhibit risky investments; if governments provide sufficient loss offset (and if the company can use these losses), then higher rates may encourage risky corporate investments. Of course, changes in tax rates and other rules for risk purposes must be balanced against fiscal needs, as well as global competitiveness concerns. We look forward to further research that integrates these issues with the demand for risk-taking that is necessary for economic growth.

Appendix A: Variable Definitions

Variable	Definition	Source
Country level variables:		
Loss carryback (*LCB*)	Period for which losses can be carried back, in years.	IBFD European Tax Handbook, U.S. Internal Revenue Code
Loss carryforward (*LCF*)	Period for which losses can be carried forward, in years.	IBFD European Tax Handbook, U.S. Internal Revenue Code
Tax rate (*CTR*)	Statutory corporate tax rate. If applicable, central and sub-central/local rates are summed up, using an average sub-central rate. If the tax system is progressive, the top marginal tax rate.	OECD tax database
Standardized tax rate (*StdCTR*)	The tax rate (*CTR*) standardized so that it has a mean of zero and a standard deviation of one.	
GDP growth rate (*GDP Growth*)	Year-to-year percentage change in gross domestic product (GDP), measured in current prices.	IMF World Economic Outlook Database
Inflation (*Inflation*)	Change in the consumer price index	OECD
Risk-free rate (*Risk-free rate*)	Interest rate on government bonds government bonds maturing in ten years	OECD
Macro risk measure (*Macro risk*)	Standard deviation of the quarterly growth in real industrial production for each country	OECD
Regulatory Quality Rank (*Regulatory Quality*)	Value of the regulatory quality indicator as percentile rank	World Bank, Worldwide Governance Indicators
Rule of Law Rank (*Rule of Law*)	Value of the rule of law indicator as percentile rank	World Bank, Worldwide Governance Indicators
Control of Corruption Rank (*Control of Corruption*)	Value of the control of corruption indicator as percentile rank	World Bank, Worldwide Governance Indicators
Tax Evasion Indicator (*Tax Evasion*)	Assessment of how important tax evasion is in a country. The lower the measure, the more rampant is tax evasion.	World Economic Forum (2002)

Continued on the next page

Firm level variables:

Firm risk-taking proxy over three years (*Risk*)	Three-year earnings volatility measure, defined as $Risk = \sqrt{\frac{1}{2}\sum_{t=1}^{3}\left(D_{ijct} - \frac{1}{3}\sum_{t=1}^{3} D_{ijct}\right)^2}$, where $D_{ijct} = ROA_{ijct} - \frac{1}{N_{jct}}\sum_{k=1}^{N_{jct}} ROA_{kjct}$. N_{jct} indexes firms i in industry j and country c in year t. In words, this is the standard deviation over three years of a firm's ROA's deviation from the industry-country-year specific average ROA. ROA is winsorized at 1% to account for loss-making firms with extremely low assets.	Thomson Reuters' Worldscope
Unadjusted firm risk-taking proxy (*Unadjusted risk measure*)	Standard deviation of ROA over three years.	Thomson Reuters' Worldscope
Idiosyncratic volatility (*Idiosyncratic volatility*)	The standard deviation of the residuals from a regression of a firm's daily excess return on factor data.	Datastream
Research & development expense (*R&D*)	Direct and indirect costs related to the creation and development of new processes, techniques, applications and products (Worldscope data code: XWC01201).	Thomson Reuters' Worldscope
Cash flow-based risk measure (*Cash flow risk*)	Analogous to *Risk*, using operating cash flow relative to total assets instead of ROA.	Thomson Reuters' Worldscope
Firm size (*Size*)	Natural logarithm of total assets in 1000 US-$ (Worldscope data code: XWC02999).	Thomson Reuters' Worldscope
Return on asset (*ROA*)	Ratio of EBIT (XWC18191) over assets (XWC 02999), where EBIT are earnings before interest and taxes.	Thomson Reuters' Worldscope
Sales Growth (*Sales Growth*)	Year-to-year percentage change in revenues (XWC01001).	Thomson Reuters' Worldscope
Leverage (*Leverage*)	Ratio of total liabilities (XWC 03351) to total assets (XWC02999).	Thomson Reuters' Worldscope
Market-to-book ratio (*MB*)	Ratio of market capitalization (XWC08001) to common equity (XWC03501).	Thomson Reuters' Worldscope
Stock option expense (*Stock option expense*)	Total stock option expense (XWC18321) to total assets (XWC02999).	Thomson Reuters' Worldscope

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Figure 1: Illustration of the Firm's Objective Function

This graph shows the firm's utility when it is profitable and when it incurs a loss. The graph shows how utility in each case varies based on the tax rate and the available tax loss offset.

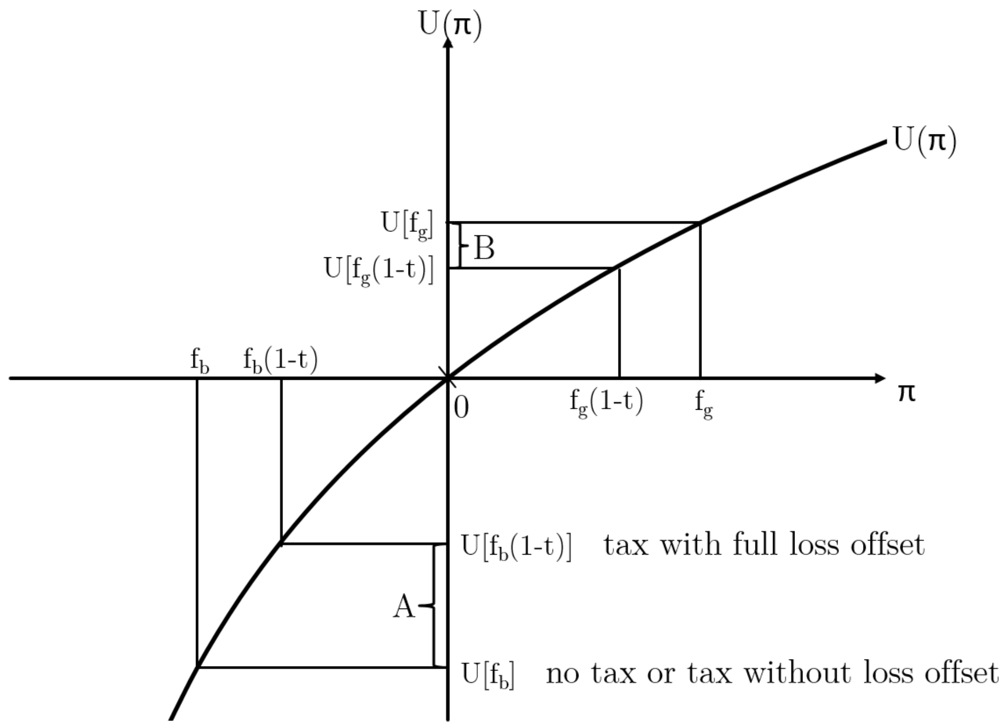

Figure 2: Difference-in-Difference Analysis for Changes in Loss Offset Periods

The upper panel shows the risk time-trends of firms operating in a country with a change in loss period (marked using a solid line), as well as the time trend for control firms (dotted line) three years before and one year after an increase in the loss period. The lower panel repeats the analysis for a reduction in the loss period. The vertical line marks the change of the statutory loss offset period.

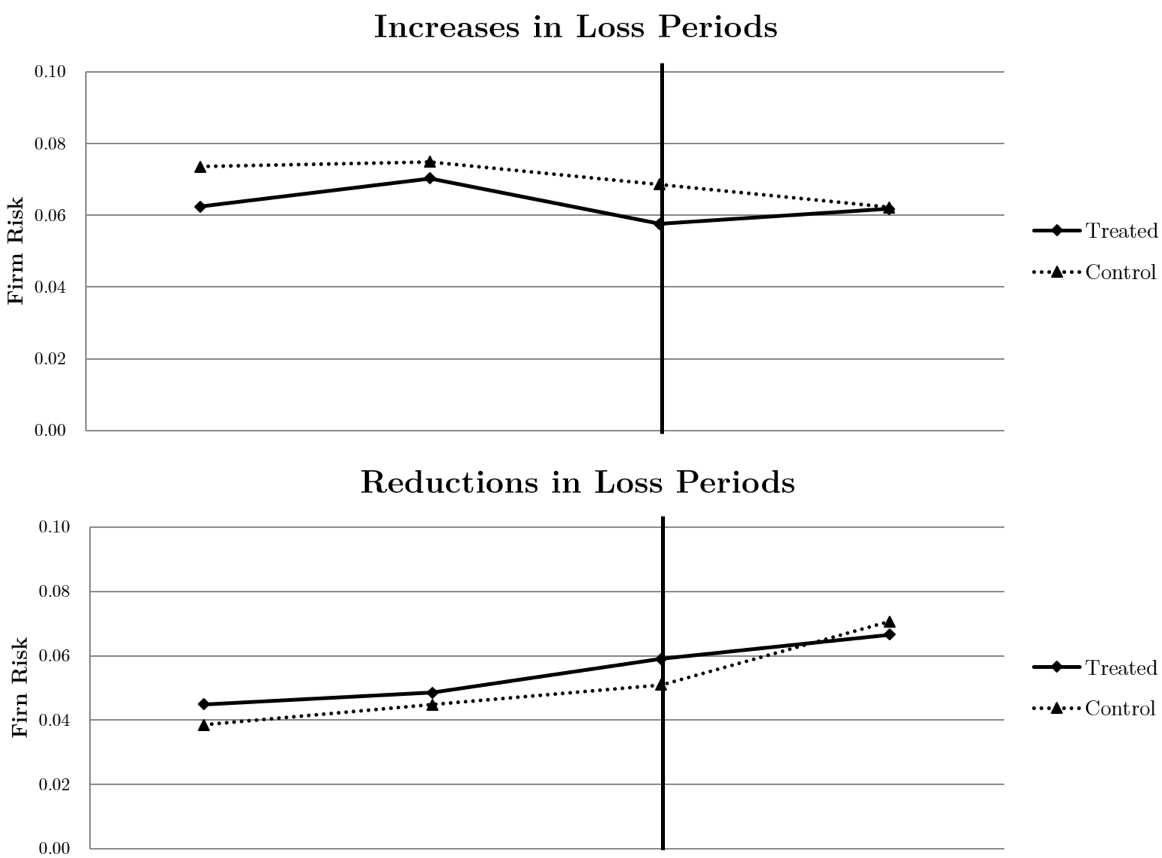

Figure 3: Regression Discontinuity

This figure plots the average firm risk-taking for evenly-spaced bins (with 95% confidence intervals) with linear trend lines (first plot) and second order polynomials (second plot) for the treatment and control groups. The dependent variable is *Risk*, and the x-axis measures revenues in million (€) in 2010.

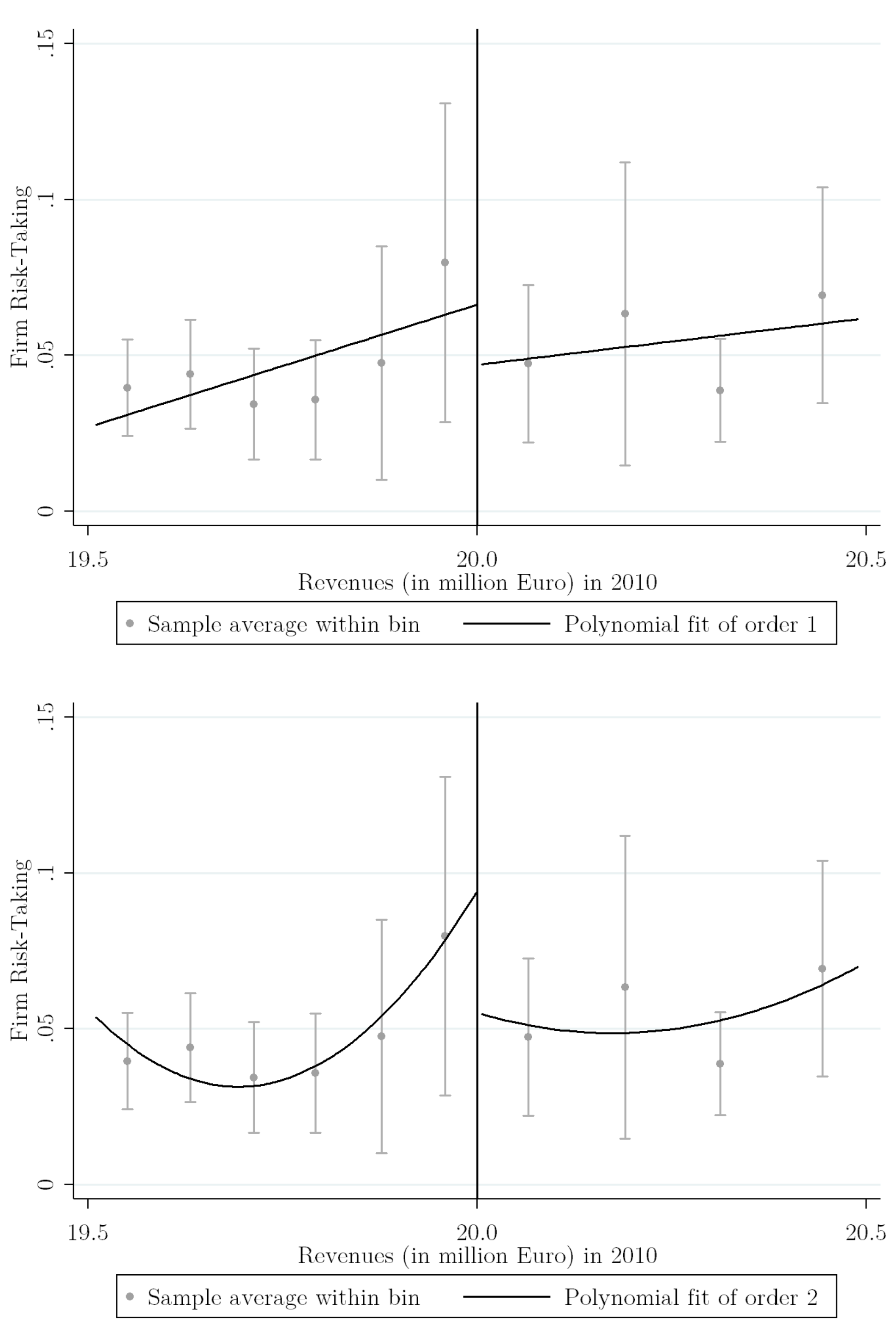

Table 1
Statutory Loss Carryback and Carryforward Periods

This table provides the statutory loss carryback periods (Panel A) and loss carryforward periods (Panel B) from 1998 through 2009 for the countries represented in the empirical sample. Data is from the yearly European Tax Handbook of the International Bureau of Fiscal Documentation (IBFD) and the U.S. Internal Revenue Code. In Panel A, $^{\diamond}$ indicates no immediate tax refund; a tax credit is instead paid after five years. $^{\circ}$ indicates temporary rule in the U.S. and Norway. Due to the retroactive nature of these rules, we code 2008 and 2009 for Norway as no loss carryback, and 2001, 2002, 2008, and 2009 as 2 years loss carryback for the U.S. In Panel B, *I* indicates an indefinite carryforward period.

Panel A: Statutory Loss Carryback Periods

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Austria	0	0	0	0	0	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	0	0	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0
France	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$	$3^{\diamond}$
Germany	2	1	1	1	1	1	1	1	1	1	1	1
Greece	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	1	1	1	1	1	1	1	1	1	1	1	1
Italy	0	0	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	3	3	3	3	3	3	3	3	3	1	1	1
Norway	0	0	0	0	0	0	0	0	0	0	0°	0°
Portugal	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0
Switzerland	0	0	0	0	0	0	0	0	0	0	0	0
United Kingdom	1	1	1	1	1	1	1	1	1	1	1	1
United States	2	2	2	2°	2°	2	2	2	2	2	2°	2°

Panel B: Statutory Loss Carryforward Periods

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Austria	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*
Belgium	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*
Denmark	5	5	5	5	5	*I*	*I*	*I*	*I*	*I*	*I*	*I*
Finland	10	10	10	10	10	10	10	10	10	10	10	10
France	5	5	5	5	5	5	*I*	*I*	*I*	*I*	*I*	*I*
Germany	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*
Greece	5	5	5	5	5	5	5	5	5	5	5	5
Ireland	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*
Italy	5	5	5	5	5	5	5	5	5	5	5	5
Luxembourg	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*
Netherlands	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	9	9	9
Norway	10	10	10	10	10	10	10	10	*I*	*I*	*I*	*I*
Portugal	6	6	6	6	6	6	6	6	6	6	6	6
Spain	7	10	10	10	15	15	15	15	15	15	15	15
Switzerland	7	7	7	7	7	7	7	7	7	7	7	7
United Kingdom	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*
United States	20	20	20	20	20	20	20	20	20	20	20	20

Table 2
Descriptive Statistics

This table presents descriptive statistics. Panel A shows summary statistics of key variables. All firm-level variables are winsorized at 1% and 99%. Variable definitions and data sources are in Appendix A. Panel B (C) shows the number of observations by country (year).

Panel A: Summary Statistics of Key Variables

	# Obs.	Mean	Median	Std. Dev.	5%	95%
Risk	84,222	0.294	0.101	0.665	0.007	1.246
LCB	84,222	1.536	2.000	0.868	0.000	3.000
LCF	84,222	17.821	20.000	5.023	5.000	20.000
CTR	84,222	0.361	0.393	0.055	0.260	0.394
Std. CTR	84,222	0.000	0.572	1.000	-1.838	0.606
Size	84,222	11.900	11.872	2.323	8.051	15.833
ROA	84,222	-0.072	0.057	0.531	-0.763	0.237
Sales Growth	84,222	0.290	0.089	1.089	-0.387	1.310
Leverage	84,222	0.606	0.534	0.626	0.111	1.131
MB	84,222	2.857	1.733	6.957	-1.061	10.870
GDP Growth	84,222	0.051	0.055	0.067	-0.076	0.164
Inflation	84,222	2.183	2.200	1.046	0.190	3.840
Risk-free Rate	84,222	4.574	4.610	0.749	3.260	6.030
Macro Risk	84,222	1.152	0.738	1.194	0.254	3.493
Regulatory Quality	69,274	92.651	93.780	5.305	79.126	99.020
Rule of Law	69,274	91.574	92.344	5.872	74.519	98.565
Control of Corruption	69,274	91.059	92.683	6.418	78.049	97.073

Panel B: Observations by Country

	# Obs.	% of sample
Austria	701	0.83
Belgium	1,009	1.20
Denmark	1,590	1.89
Finland	1,279	1.52
France	6,138	7.29
Germany	6,139	7.29
Greece	2,440	2.90
Ireland	497	0.59
Italy	1,882	2.24
Luxembourg	209	0.25
Netherlands	1,480	1.76
Norway	1,401	1.66
Portugal	510	0.61
Spain	1,087	1.29
Switzerland	1,832	2.18
United Kingdom	11,940	14.18
United States	44,088	52.35
Total	84,222	100.00

Panel C: Observations by Year

Year	# Obs.	% of sample
1998	6,586	7.82
1999	7,449	8.84
2000	7,571	8.99
2001	7,499	8.90
2002	7,388	8.77
2003	7,044	8.36
2004	6,908	8.20
2005	6,842	8.12
2006	6,942	8.24
2007	6,942	8.24
2008	6,723	7.98
2009	6,328	7.51
Total	84,222	100.00

Table 3

Relation Between Firm Risk and Tax Loss Rules (OLS Panel Estimation)

This table presents the relation between firm risk and statutory loss rules for a cross-country sample of firms. It includes results from OLS regressions of firm risk-taking on country-level tax variables and firm characteristics. Columns (1) to (4) use the full sample; col. (5) includes results for domestic firms, where firms are defined as "domestic" if the firm reports no or missing foreign income or assets. Each specification is estimated with an intercept and industry-by-year fixed effects (FE). We cluster standard errors by firm and by country-year and present t-statistics in parentheses. Appendix A describes all variables. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Dependent Variable: Firm Risk-Taking				
	All Firms				Domestic Firms
	(1)	(2)	(3)	(4)	(5)
LCB	0.052**	0.034**	0.045***	0.056***	0.060***
	(2.243)	(2.292)	(3.802)	(4.209)	(3.248)
LCF	0.011***	0.007***	0.009***	-0.001	-0.001
	(6.501)	(5.975)	(7.081)	(-0.521)	(-0.415)
StdCTR	0.070***	0.042**	-0.037	0.052	0.077*
	(3.138)	(2.463)	(-1.478)	(1.550)	(1.869)
LCB*StdCTR			0.061**	0.065**	0.066**
			(2.570)	(2.585)	(2.165)
LCF*StdCTR			0.001	-0.003*	-0.004*
			(0.501)	(-1.825)	(-1.855)
Size		-0.028***	-0.028***	-0.027***	-0.043***
		(-7.334)	(-7.521)	(-7.121)	(-7.242)
ROA		-0.508***	-0.502***	-0.474***	-0.470***
		(-17.381)	(-17.095)	(-16.494)	(-16.621)
Sales Growth		0.024***	0.024***	0.021***	0.017***
		(7.033)	(7.016)	(5.984)	(5.319)
Leverage		0.151***	0.153***	0.162***	0.160***
		(9.313)	(9.466)	(9.518)	(9.047)
MB		0.003***	0.003***	0.003***	0.003***
		(4.858)	(4.944)	(4.093)	(2.801)
GDP Growth		0.266	0.214	0.134	0.191
		(1.031)	(0.930)	(0.666)	(0.839)
Inflation		0.039**	0.031*	0.011	0.028
		(2.166)	(1.836)	(0.691)	(1.266)
Risk-free Rate		-0.048**	-0.019	-0.024	-0.025
		(-2.315)	(-0.839)	(-0.896)	(-0.708)
Macro Risk		-0.021*	-0.017	-0.009	-0.006
		(-1.956)	(-1.592)	(-0.936)	(-0.494)
Regulatory Quality				0.018***	0.017***
				(5.069)	(3.996)
Rule of Law				0.001	0.001
				(0.287)	(0.221)
Control of Corruption				-0.010*	-0.010
				(-1.839)	(-1.630)
Industry-by-Year FE?	Yes	Yes	Yes	Yes	Yes
Observations	84,222	84,222	84,222	69,274	34,988
R^2	0.058	0.359	0.362	0.371	0.422

Table 4
Relation Between Firm Risk and Tax Loss Rules (Matched Sample DiD)

This table presents results of the matched sample difference-in-difference analysis comparing risk levels for firms in countries with changes in the statutory tax rules to those firms in countries with no changes. Column (1) presents results for countries with a decrease in the loss offset period (Germany and the Netherlands); col. (2) presents results for countries with an increase in the loss offset period (Denmark, France, Norway, and Spain). We cluster standard errors by firm and present t-statistics in parentheses. Appendix A describes all variables. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Mean Difference-in-Difference	
	Decrease in Loss Period	Increase in Loss Period
Matching Characteristics	(1)	(2)
Size/ROA/Sales Growth/Leverage/MB	-0.015***	0.008**
(Mahalanobis match)	(-2.682)	(2.107)
Size/ROA/Sales Growth/Leverage/MB/Industry	-0.016***	0.008**
(Mahalanobis match)	(-2.854)	(2.080)
Size/ROA/Sales Growth/Leverage/MB/Industry	-0.010**	0.002
(4 Mahalanobis matches)	(-2.355)	(0.432)
Size/ROA/Sales Growth/Leverage/MB/Industry	-0.011**	0.000
(Propensity score match, 4 nearest neighbor)	(-2.129)	(0.019)
Size/ROA/Sales Growth/Leverage/MB/Industry	-0.010*	0.005
(Propensity score match, caliper)	(-1.820)	(0.844)
Size/ROA/Sales Growth/Leverage/MB	-0.039**	0.002
(Domestic Firms, Mahalanobis match)	(-2.095)	(0.220)
Size/ROA/Sales Growth/Leverage/MB/Industry	-0.036**	0.007
(Domestic Firms, Mahalanobis match)	(-1.985)	(0.853)

Table 5
Within-Country Analysis: Spanish Tax Change

This table presents results from a regression discontinuity analysis of Spanish firms in 2011. In Panel A, firms are identified as "treated" if their 2010 revenue exceeds €20 million. In col. (1)-(3), we use a local linear regression; in col. (4)-(6), we use a quadratic polynomial. The bandwidths used are €139,840 (the optimal bandwidth according to Imbens and Kalyanaraman 2012) in col. (1) and (4), €279,680 in col. (2) and (5), and €419,519 in col. (3) and (6). Panel B presents results from several falsification tests for the local linear regression and using the €139,840 bandwidth. In Part I, firms are identified as "treated" if their 2010 revenue exceeds €15 million (col. 1), €19 million (col. 2), €21 million (col. 3), and €25 million (col. 4). In Part II, we test for discontinuities in earlier years. In Part III, we consider different dependent variables (employees, assets, EBIT and sales growth). In all tests, we control for firm size, ROA, leverage and sales growth (except in the falsification test using sales growth as the dependent variable). We cluster standard errors by firm and present z-statistics in parentheses. ** and * indicate statistical significance at the 5% and 10% levels, respectively.

Panel A: Main Test

	Dependent Variable: Firm Risk-Taking					
	Local linear regression			Quadratic polynomial regression		
	(1)	(2)	(3)	(4)	(5)	(6)
Avg. Treatment Eff.	-0.142**	-0.117**	-0.084**	-0.131**	-0.146**	-0.131**
	(-2.57)	(-2.46)	(-2.07)	(-2.34)	(-2.40)	(-2.52)
Bandwidth	139,840	279,680	419,519	139,840	279,680	419,519

Panel B: Falsification Tests

I. Levels of Lagged Revenues				
	Dependent Variable: Firm Risk-Taking			
	(1)	(2)	(3)	(4)
Average Treatment Effect	0.073	-0.000	0.019	-0.013
	(0.77)	(-0.02)	(0.60)	(-0.59)
Cutoff	€15m	€19m	€21m	€25m
II. Other Years				
	Dependent Variable: Firm Risk-Taking			
	(1)	(2)	(3)	(4)
Average Treatment Effect	0.041*	-0.046	-0.040	-0.019
	(1.90)	(-0.79)	(-0.53)	(-0.79)
Year	2007	2008	2009	2010
III. Other Firm Characteristics				
Dependent Variable:	Employees	Assets	EBIT	Sales Growth
	(1)	(2)	(3)	(4)
Average Treatment Effect	2.212	-84.49**	-3.353	-0.212*
	(-0.04)	(-1.98)	(-0.46)	(-1.85)

Table 6
Relation Between Firm Risk and the Statutory Tax Rate

This table presents analysis of the association between a country's tax rate and firm risk, partitioning the sample on the estimated level of expected loss offset. Panel A (B) presents results from a levels (changes) regression. In both panels, cols. (5) to (6) provide results for domestic firms only, where firms are defined as "domestic" if they report no or missing foreign income or assets. Columns (1), (3), and (5) present results for firms that are likely to recover any losses immediately ("high λ" firms); cols. (2), (4), and (6) include those firms that would be unlikely to receive immediate loss offset ("low λ" firms). Appendix A describes all variables. Each specification is estimated with an intercept and includes industry-by-year fixed effects (FE). The t-statistics in parentheses are based on standard errors clustered by firm and by country-year. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Levels Specification

	Dependent Variable: Firm Risk-Taking					
	All Firms				Domestic Firms	
	(1) High λ	(2) Low λ	(3) High λ	(4) Low λ	(5) High λ	(6) Low λ
CTR	0.913**	-0.304**	1.019***	-0.107	1.135***	-0.126
	(2.575)	(-2.602)	(4.519)	(-0.597)	(3.551)	(-0.457)
Size	-0.027***	-0.006*	-0.027***	-0.006*	-0.045***	-0.001
	(-7.544)	(-1.839)	(-7.686)	(-1.782)	(-7.333)	(-0.243)
ROA	-0.541***	-0.323***	-0.510***	-0.320***	-0.492***	-0.271***
	(-14.083)	(-6.233)	(-10.948)	(-5.177)	(-10.645)	(-7.024)
Sales Growth	0.025***	0.002	0.021***	0.003	0.018***	-0.001
	(5.845)	(0.524)	(5.291)	(0.618)	(4.077)	(-0.214)
Leverage	0.157***	-0.041	0.168***	-0.030	0.174***	-0.068***
	(7.434)	(-1.466)	(6.625)	(-1.023)	(6.397)	(-2.746)
MB	0.004***	0.000	0.004***	0.000	0.003**	0.000
	(4.354)	(0.179)	(3.587)	(0.018)	(2.599)	(0.253)
GDP Growth	0.504	0.162	0.366	0.195*	0.553	0.058
	(1.223)	(1.457)	(0.902)	(1.830)	(1.109)	(0.459)
Inflation	0.059**	0.003	0.029	0.005	0.060**	0.010
	(2.319)	(0.378)	(1.470)	(0.754)	(2.217)	(1.077)
Risk-free Rate	0.004	0.007	-0.106*	0.006	-0.138**	0.020
	(0.078)	(0.858)	(-1.959)	(0.545)	(-2.057)	(1.022)
Macro Risk	-0.055**	-0.001	-0.032**	-0.002	-0.046**	-0.000
	(-2.607)	(-0.142)	(-2.279)	(-0.527)	(-2.524)	(-0.067)
Regulatory Quality			0.031***	-0.000	0.034***	0.001
			(5.225)	(-0.052)	(4.238)	(0.256)
Rule of Law			-0.033**	0.001	-0.036*	0.002
			(-2.061)	(0.609)	(-1.746)	(1.018)
Control of Corruption			-0.027**	0.000	-0.025**	-0.001
			(-2.664)	(0.093)	(-2.088)	(-0.519)
Industry-by-Year FE?	Yes	Yes	Yes	Yes	Yes	Yes
Observations	52,014	2,463	41,978	2,233	20,535	1,200
R^2	0.344	0.249	0.352	0.234	0.426	0.231

Panel B: Changes Specification

	Dependent Variable: Δ Firm Risk-Taking					
	All Firms				Domestic Firms	
	(1) High λ	(2) Low λ	(3) High λ	(4) Low λ	(5) High λ	(6) Low λ
Δ CTR	1.038***	0.015	1.506***	0.172	3.087**	-0.240
	(4.686)	(0.064)	(3.437)	(0.554)	(2.672)	(-0.754)
Δ Size	-0.620*	0.011	-0.705	0.001	-1.079	0.020
	(-1.846)	(0.821)	(-1.385)	(0.097)	(-1.353)	(1.262)
Δ ROA	0.045	-0.159***	0.159	-0.152***	0.167	-0.194***
	(1.031)	(-7.499)	(1.088)	(-5.629)	(1.094)	(-5.663)
Δ Sales Growth	0.000	0.000	-0.000	0.000**	-0.000	0.000***
	(0.318)	(1.448)	(-0.553)	(2.381)	(-0.095)	(4.301)
Δ Leverage	0.009	0.081***	0.010	0.086***	0.009	0.069***
	(0.849)	(3.541)	(0.740)	(3.557)	(0.701)	(2.672)
Δ MB	0.000	-0.000	0.000	0.000	0.000	0.000***
	(0.700)	(-0.325)	(0.248)	(1.141)	(0.480)	(3.784)
Δ GDP Growth	1.052***	-0.079	0.520***	-0.177	1.003***	-0.193
	(4.178)	(-0.524)	(3.187)	(-0.988)	(2.775)	(-0.979)
Δ Inflation	0.009	-0.013	-0.050**	-0.020	-0.082*	-0.006
	(0.343)	(-1.316)	(-2.715)	(-1.650)	(-1.807)	(-0.501)
Δ Risk-free Rate	-0.140***	-0.009	-0.123***	0.011	-0.231**	0.021
	(-3.443)	(-1.010)	(-3.068)	(0.667)	(-2.170)	(0.927)
Δ Macro Risk	0.031	0.000	0.017	-0.001	0.004	0.004
	(1.371)	(0.118)	(1.463)	(-0.314)	(0.136)	(0.801)
Δ Regulatory Quality			-0.004	-0.001	0.002	-0.010**
			(-0.711)	(-0.214)	(0.178)	(-2.035)
Δ Rule of Law			0.002	0.007*	0.001	0.012**
			(0.264)	(1.700)	(0.069)	(2.292)
Δ Control of Corruption			-0.007	0.000	-0.001	-0.002
			(-0.761)	(0.133)	(-0.044)	(-0.667)
Industry-by-Year FE?	Yes	Yes	Yes	Yes	Yes	Yes
Observations	40,951	2,463	25,005	1,858	10,936	994
R^2	0.004	0.197	0.041	0.202	0.046	0.309

Table 7
Robustness Analysis

This table presents robustness analysis; Panel A repeats the analyses from Table 3 and Table 6, using four alternative risk measures – an adjusted measure of risk that does not remove the industry-country-year average ROA (cols. (1) to (3)); firms' idiosyncratic volatility (cols. (4) to (6)); the log of R&D expenses (cols. (7) to (9)); and the standard deviation of operating cash flows (cols. (10) to (12)). Panel B repeats the analyses from Table 3 and Table 6 on different subsamples – a random sample of U.S. observations (cols. (1) to (3)); a sample excluding U.S. firms (cols. (4) to (6)); and the sample of countries that permit loss carrybacks (cols. (7) and (8)). Control variables are the same as in Table 3, including all country-level controls. Appendix A describes all variables. Each specification is estimated with an intercept and includes industry-by-year fixed effects (FE). The t-statistics in parentheses are based on standard errors clustered by firm and by country-year. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Alternative Risk Measures

	Unadjusted Measure			Idiosyncratic Volatility			Log(R&D)			Cash Flow Risk		
	(1) Risk	(2) High λ	(3) Low λ	(4) Risk	(5) High λ	(6) Low λ	(7) Risk	(8) High λ	(9) Low λ	(10) Risk	(11) High λ	(12) Low λ
LCB	0.009***			0.005***			0.279***			0.006***		
	(3.018)			(5.410)			(6.191)			(3.535)		
LCF	-0.000			0.001***			0.002			0.001**		
	(-0.326)			(2.707)			(0.153)			(2.179)		
StdCTR	0.006			-0.005**			-0.156			-0.008*		
	(0.651)			(-2.296)			(-1.338)			(-1.947)		
CTR		0.232***	-0.190		0.053***	-0.024		4.522***	4.047		-0.015	-0.100
		(4.108)	(-1.043)		(3.366)	(-1.096)		(5.209)	(1.456)		(-0.314)	(-1.017)
LCB*StdCTR	0.026***			0.005**			0.217***			0.010***		
	(3.104)			(2.189)			(3.161)			(4.031)		
LCF*StdCTR	-0.001*			0.000*			0.007			-0.000		
	(-1.781)			(1.793)			(1.081)			(-0.861)		
All controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-by-Year FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	69,274	41,978	2,233	67,287	41,031	2,070	27,206	16,329	686	42,101	27,447	955
R^2	0.537	0.544	0.274	0.456	0.462	0.288	0.667	0.693	0.513	0.443	0.388	0.218

Panel B: Estimation on Sub-samples

	Random sample US			Drop US firms			LCB-only countries	
	(1) Risk	(2) High λ	(3) Low λ	(4) Risk	(5) High λ	(6) Low λ	(7) Risk	(8) Risk
LCB	0.048***			0.014***			0.094***	0.095***
	(5.110)			(3.669)			(4.451)	(4.514)
LCF	-0.002			-0.002**			0.000	
	(-0.711)			(-2.250)			(0.006)	
StdCTR	0.028			0.022**			0.028	-0.102**
	(0.857)			(2.349)			(0.237)	(-2.513)
CTR		0.917***	-0.107		0.245***	-0.107		
		(5.315)	(-0.597)		(2.698)	(-0.597)		
LCB*StdCTR	0.053***			0.010**			0.117***	0.122***
	(2.655)			(2.474)			(3.026)	(3.203)
LCF*StdCTR	-0.002			-0.002***			-0.006	
	(-1.594)			(-3.239)			(-1.435)	
All controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-by-Year FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	43,157	22,363	2,233	33,454	15,093	2,233	57,532	57,532
R^2	0.350	0.337	0.234	0.219	0.176	0.234	0.370	0.369