Taxation and Corporate Risk-Taking

Dominika Langenmayr[a], Rebecca Lester[b,*]

[a] *University of Munich, Department of Economics, Akademiestr. 1, 80799 Munich, Germany*

[b] *Massachusetts Institute of Technology, Sloan School of Management, E62-676, Cambridge, MA, USA 02139*

Abstract

We study whether the corporate tax system provides incentives for risky firm investment. We first model the effects of corporate tax rates and tax loss offset rules on firm risk-taking. Testing the theoretical predictions, we find that firm risk-taking is positively related to the length of tax loss periods. This result occurs because the loss rules shift a portion of investment risk to the government, inducing firms to increase their overall level of risk-taking. Moreover, the corporate tax rate has a positive effect on risk-taking for firms that expect to use their tax losses, and a negative effect for those that cannot. Thus, the effect of taxes on risky investment decisions varies among firms, and its sign hinges on firm-specific expectations of future tax loss recovery.

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[*] Corresponding author.

Email addresses: `dominika.langenmayr@econ.lmu.de` (Dominika Langenmayr), `rlester@mit.edu` (Rebecca Lester)

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 of total private sector investment, and the riskiness of this investment is positively related to per capita growth.[1] Therefore, risk-taking by these large, established firms has considerable macroeconomic effects. We provide the first evidence on how the government, through the corporate tax system, can encourage large corporations to make appropriately risky investments.

This study tests 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 decisions. Our analysis makes two contributions. First, our analytical model and empirical results demonstrate 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 level of risk-taking. This finding shows that changing statutory loss rules is one channel through which the government can alter private sector risk-taking.

Second, we show 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 the statutory limitations or lack of profitability), risk-taking is negatively related to the tax rate. In this second case, taxes decrease the firm's income 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 make risk-taking less attractive for these low-loss-offset firms. The opposing effects demonstrate the importance of firm-specific characteristics and of the interaction between tax rate and non-tax-rate aspects when assessing the investment implications of changing tax policies.

[1] In 2010, only 0.06% of U.S. firms were public, but these firms comprised 47.2% of total fixed investment (Asker et al., 2015). John et al. (2008) show that a one-standard deviation increase in firm risk-taking is associated with a 33.2% increase in real GDP per capita growth.

These 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 et al., 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 the tax loss benefits (Maydew, 1997; Erickson and Heitzman, 2010; Albring et al., 2011). 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 underestimate the total private sector response to tax policies because firms also respond with qualitative changes in the type of projects selected.

We first determine the effects described above by developing an analytical model of 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 et al. (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 directly reflects corporate investment decisions.

We test the first hypothesis in three ways. The first test is conducted on a cross-country panel, which allows us to exploit cross-country variation in the loss offset rules and test the theoretical predictions on a large sample of firms. We find that loss carryback and carryforward periods are positively and significantly related to the level of firm risk-taking. A one year longer loss carryback period is associated with 12.9 percent higher risk-taking for the average firm in the sample. Similarly, a one year longer loss carryforward period implies 2.3 percent higher firm risk-taking for the average firm. The larger effect for loss carrybacks reflects that these rules provide greater risk-taking incentives than loss carryforwards, given that carrybacks deliver an immediate cash

[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).

refund and are not conditional on future profitability.

Because these tests may be affected by unobserved country characteristics, we perform two additional analyses to validate these results. In our second analysis, we use a matched sample difference-in-differences test to compare changes in risk-taking by firms operating in countries that had a change in the loss offset rules 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. Finally, in our third test, we employ a regression discontinuity design on a sample of Spanish firms to measure the effects of a Spanish tax loss rule change that limited the amount of available loss offset for firms with revenues above €20 million. Though this analysis is conducted on the smallest sample, this setting permits clean identification of the risk-taking effects. We find consistent results across all of these analyses – longer tax loss periods are positively associated with firm risk-taking.

To test the effect of the statutory tax rate on firm risk-taking (i.e., the model's second prediction), we partition the 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. For example, we identify a high loss offset firm as a firm that operates in a country that permits loss carrybacks and was profitable in the carryback years, as this firm can likely offset any future loss immediately. 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 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 an 18.2 percent increase in the risk-taking measure for the average firm. If loss offset is unlikely, however, we find that higher tax rates are negatively related to risk-taking. In this case, a three percentage point increase in the tax rate is associated with a 2.6 percent decrease in the risk taken by the average firm. We also test this relation using a first differences specification and find consistent results.

Finally, we perform several robustness analyses, including an instrumental variables test, construction of alternative risk measures, exclusion of multinational firms, inclusion of additional control variables, and alternative measurements at the firm- and 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. Prior papers have addressed the effects of managerial incentives, including May (1995); Demski and Dye (1999); Rajgopal and Shevlin (2002); and Coles et al. (2006). More recently, the literature has shown that corporate governance (John et al., 2008), creditor rights (Acharya et al., 2011), shareholder diversification (Faccio et al., 2011), inside debt (Choy et al., 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 et al., 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 that the literature has not previously considered.

We also contribute to the literature that examines the effect of taxes on firm investment decisions in three ways. First, by focusing on the relationship between corporate taxation and the riskiness (rather than the level) of investment, we show that firms may alter the type of investments in response to changes in tax laws. In particular, we extend existing models that focus on the level of investment (Hall and Jorgenson, 1967; Auerbach, 1983, 1986; Gordon, 1985) and also examine total firm risk-taking, rather than the specific relation between taxes and firm hedging that has been previously studied (Graham and Smith, 1999; Graham and Rogers, 2002). Second, we examine the effects of both the tax rate as well as the tax loss rules, a non-rate aspect of a corporate tax system that few prior studies have considered (Devereux et al., 1994; Edgerton, 2010; Dreßler and Overesch, 2013). Our theoretical model is the first (to our knowledge) that incorporates both the tax rate and tax loss rules to study firm risk-taking. While the prior literature finds mixed evidence of the effectiveness of the loss rules on investment, we theoretically and empirically document that firms do take tax losses into account when determining the riskiness of their investments.[3] 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 et al., 2010); we show that the relation between taxation and firm risk-taking is not limited to only individuals or small companies and that these effects

[3]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.

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, and how the tax rate effects vary across companies. It also points out that certain reforms which finance tax rate reductions by shortening available tax loss offset periods can hinder innovative private sector activities.

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 for the cross-country tests, and Section 5 discusses the cross-country results. In Section 6 we present the regression discontinuity analysis as well as several robustness tests. 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 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 et al., 2009). We expect that this importance is not only limited to the *ex-post* preservation and utilization of losses once they have been incurred (Maydew, 1997; Albring et al., 2011; Erickson and Heitzman, 2010). We study whether these tax loss rules also create *ex-ante* incentives for corporate risk-taking.

3. Theoretical Model and Hypotheses

This section develops a model to study the effects of the corporate tax rate and tax loss offset provisions on the riskiness of firm investment. We then use the insights from this model to formulate our hypotheses for the empirical tests.

3.1. Model Set-up

Consider a representative firm planning a fixed amount of investment. The firm allocates its funds among investments of varying risk, such as highly risky research and development and less risky capital expenditures.

The firm operates in a world with uncertainty. There are two potential states of the world. In the "good" state, occurring with probability p, the firm generates a profit of $f_g(\sigma) > 0$ from its investment. In the "bad" state (probability $1 - p$), the firm incurs a loss of $f_b(\sigma) < 0$. Both profit and loss are a function of the riskiness of the firm's investment, σ. Greater risk-taking increases the return in the good state ($f_g'(\sigma) > 0$) but decreases the return in the bad state ($f_b'(\sigma) < 0$). In other words, increasing the riskiness of investment leads to a higher variance of returns.[4] We assume that the cost of the investment, I, is fixed so as to focus on how taxes influence the allocation of funds among different projects.[5] To guarantee interior solutions, we assume that risk-taking has diminishing returns ($f_g''(\sigma), f_b''(\sigma) < 0$).

[4]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 in Section 4 uses a risk measure constructed from the standard deviation of profits to firm assets.

[5]The results are qualitatively the same in models with an endogenous amount of investment or in models where firms incur costs to reduce the riskiness of investment.

Firms should select the appropriate level of risk-taking to maximize after-tax returns to shareholders. However, empirical evidence shows that firms exhibit risk-averse characteristics, which in turn affect a firm's investment project selection (Hunter and Smith, 2002).[6] Therefore, we allow for firm-level risk aversion in our model. Following prior literature (Sandmo, 1971; Appelbaum and Katz, 1986; Asplund, 2002; Janssen and Karamychev, 2007), we model risk aversion by assuming a concave objective function of the firm (utility function). One interpretation of this objective function is that it represents the utility the manager derives from the firm's returns. More generally, this modeling approach is compatible with any of the aforementioned rationales for firm-level risk aversion. 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 maximizes this objective function, which depends on its after-tax profits, π. The firm pays corporate income tax at rate t on its profit ($0 < t < 1$). If the firm incurs a loss, it receives a tax refund on some fraction $\lambda \in [0,\ 1]$ of the loss. A loss offset parameter of $\lambda = 1$ applies to a firm that i) operates in a country that permits loss carrybacks and ii) has been profitable and paid taxes during the carryback period such that the firm could receive an immediate refund if it incurs a future loss. Otherwise, $\lambda < 1$, with the exact value of λ depending on statutory loss carryback and carryforward rules, as well as the firm's prior and expected future profitability and the existence of prior carryforward losses. Assuming a continuously differentiable and concave utility function, the expected utility of the firm is given by

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

The firm chooses the optimal riskiness of its investment by maximizing its expected utility. The first order condition for the optimal σ is

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

[6] For example, Purnanandam (2008) shows that firms avoid risky investments to lower the probability of financial distress. Firms with financial constraints hedge currency risks (Géczy et al., 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 et al., 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.

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.

We now derive predictions for the relation between a country's tax system and firm risk-taking (σ). We first consider the loss offset parameter λ in the next section and then the effects of a country's tax rate t in Section 3.3.

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

3.2.1. Results of the Model

Implicit differentiation of the first order condition in eq. (2) with respect to λ shows that risk-taking increases when firms are better able to recoup economic losses (i.e., when λ is higher):

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

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 shows 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, 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 because a higher tax rate (and thus larger tax refund) shifts the firm to a higher utility level in the bad state of the world, where the marginal utility is lower. In this case, the firm is 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 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 states a positive relation between loss offset and firm risk-taking. Loss offset is captured by the statutory loss carryback/carryforward periods, as longer periods increase the probability that companies can recoup losses incurred.[7] Therefore, we predict the following:

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

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 (i.e., the numerator effect in Eq. 3) of the tax rate on this relation 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 relatively higher corporate 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.*

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

3.3.1. Results of the Model

To see the effect of the tax rate on firm risk-taking, we implicitly differentiate the first order condition in eq. (2):

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

[7] As discussed in Section 2, the amount of firm loss offset (the firm-specific λ) is a function of statutory rules (the loss carryback/carryforward period), the firm's prior profitability, and the firm's expectation of future income. Here, we focus on the effects of statutory loss periods because the government can directly influence these rules.

For ease of interpretation, we rewrite eq. (4) using the Arrow-Pratt coefficient of relative risk aversion, $R_R(\pi) = -\frac{U''(\pi)}{U'(\pi)}|\pi|$.[8] 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.

First, 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.

Second, 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.[9]

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.*

[8] As $\pi_b < 0$, we define $R_R(\pi)$ using the absolute value of π so that $R_R(\pi)$ has a positive value also for firms that incur a loss.

[9] 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).

2. *With no loss offset ($\lambda \rightarrow 0$), 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, $\frac{d\sigma}{dt}\big|_{\lambda \rightarrow 1} > 0$.

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

Proposition 2 indicates that the tax rate effect on firm risk-taking depends on loss offset possibilities. Accordingly, we derive two separate predictions for firms with very high or very low values of λ. Taxes and risk-taking are *positively* related for risk-averse firms that *expect significant loss offset* (the "high λ" firms in the model). This relation occurs because these firms receive an "insurance" payment from the government via the tax loss rules if investment fails. This insurance effect induces 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).[10] For these firms, taxation affects successful risky investments via a tax on income, but

[10] 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

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.

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. Testing the Effect of Loss Offset Rules (H1)

We test our first hypothesis in three ways. We first employ cross-country panel data in two different specifications (an OLS panel estimation and a matched sample difference-in-difference design). We then use a within-country regression discontinuity design around a recent Spanish tax law change; as this latter test uses a different sample and research design, we describe it and the associated results in 6.1.

4.1.1. OLS Panel Estimation

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

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

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 in country j in year t. We standardize the tax rate to have a mean of zero and a standard deviation of one 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; θ_k captures

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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.

industry fixed effects, and ρ_t are year fixed effects.[11] We cluster standard errors by firm and country-year to account for within-firm and within-country-year correlation in our sample (Petersen, 2009). Based on H1a, we expect the coefficient on LC_{jt}, β_1, to be positive and significant. We also predict a positive coefficient on the interaction term, β_3, as a test of H1b.[12]

We modeled risk in Section 3 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). 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 country-industry ROA average and the firm's ROA, measured as the ratio of EBIT to assets and ii) calculating the standard deviation of this difference over a three-year period.[13] This approach follows John et al. (2008), Faccio et al. (2011), and Acharya et al. (2011) and removes the influence of home-country and industry-specific economic cycles, which firm management cannot alter.[14] This measure thus permits a clean analysis of firm-specific risk that directly reflects corporate operating and investment decisions. In Section 6.2, we show that our results are robust to using different risk measures, namely a similar measure defined over five years and a market-based measure.

We measure LC with the number of years of a country's tax loss carryback (LCB)

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[11]Industry fixed effects control for shocks that affect a whole industry (e.g. oil price changes). We also run the regressions with industry-by-country fixed effects, which control for shocks (such as a regulatory change) that affect only one industry in one country and obtain similar results.

[12]We do not predict the sign of β_2 because Proposition 2 shows that the relation between risk-taking and the corporate tax rate varies based on firm-specific expectations of loss offset; we outline these predictions below in discussion of the H2 tests.

[13]Clustering standard errors by firm accounts for correlation introduced by calculating the risk measure over this three-year period and testing the regression at the firm-year level. We also re-estimate eq. (7) in two alternative ways: first, at the country-level (see Section 6.2.3) and second, with data for every third year (2000, 2003, 2006, and 2009) only, so that the regression does not have overlapping observations (see Section 6.2.4). In both tests we find consistent results.

[14]Specifically, John et al. (2008) and Acharya et al. (2011) use EBITDA in constructing the firm-level risk measure, whereas Faccio et al. (2011) use EBIT. We follow Faccio et al. (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.

and carryforward (LCF) period. For countries with an indefinite loss carryforward period (see Table 1, Panel B), 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 tax rate of central and sub-central governments from the OECD tax database. If the tax system is progressive, we use the top marginal tax rate.[15]

We control for a firm's *Size* (log of total assets), as larger firms undertake the bulk of aggregate investment (Djankov et al., 2010). However, larger firms also have fewer risky opportunities and lower overall operating risk (John et al., 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 taxable. Given the cross-country sample used, 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. As in John et al. (2008), we also control for *ROA*, measured as EBIT/assets, which captures a firm's ability to fund investments and risky projects. Finally, we include *Leverage* (ratio of total liabilities to total assets) to control for firm risk related to costly financial distress, interest tax shields that may contribute to a firm's tax status, and risky asset substitution concerns (Harris and Raviv, 1991; Leland, 1998). Appendix A provides a summary of all variables and the data sources.

4.1.2. Matched Sample Difference-in-Difference Estimation

In addition to OLS estimation, we also test our first hypothesis using a matched sample difference-in-differences (DiD) specification. This approach exploits changes in the statutory loss offset rules for a subset of the sample countries. In particular, Germany and the Netherlands decreased the loss carryback period during our sample

[15] 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. Moreover, the large public firms in our sample likely use the top tax rates when making investment decisions. That said, we do re-estimate using these other rates and find similar results.

years, and Denmark, France, Norway, and Spain increased the loss carryforward period (see Table 1).

For a valid DiD estimation, treated and control samples must exhibit similar risk trends 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. We match observations on fiscal year and on the control variables previously listed. As relatively few countries changed the loss offset period, the sample is much smaller for this analysis (970 and 1,395 treatment-control pairs for the loss carryback and carryforward tests, respectively). However, the DiD approach offers a more precise identification of the treatment effect by controlling for both observed and unobserved characteristics.

We calculate the DiD effect using the following regression:

$$Risk_{it} = \beta_0 + \beta_1 Treated_i + \beta_2 Post_{it} + \beta_3 Treated^{*} Post_{it}, \tag{7}$$

where $Treated_i$ 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 following the loss carryback/carryforward change; and $Treated^{*} Post_{it}$ is the interaction of the prior two terms. For firms in countries with a decrease in the loss carryback period, 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 carryforward period, risk should increase for the treated firms relative to control firms ($\beta_3 > 0$).[16]

[16] The only countries in our sample to increase the loss carryback period are Norway (in 2008 and 2009) and the U.S. (in 2001, 2008, and 2009), but as these increases were introduced retroactively, we do not include them in our analysis. The U.S. also extended the carryback period in March of 2002 for the 2002 tax year, but given the timing of this change and the temporary nature of the carryback period, we do not include this change. For the Netherlands, we cannot separate the effects of the decrease in both loss carryback and carryforward periods and therefore include this change in the "decrease in loss carryback" group.

4.2. Testing the Effect of Tax Rates (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).[17] "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 it sustains 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.[18]

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

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

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

where CTR is the statutory corporate tax rate, and the other variables are as previously defined. Δ denotes first differences. The coefficient of interest is γ_1. As outlined in

[17]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.

[18]These firm-specific expectations could alternatively be measured with changes in a firm's valuation allowance (related to the amount of NOL 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, there are no data in Worldscope to measure 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 NOL, including one that is limited. For our second hypothesis, these limitations could alter the firm-specific lambda 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 lambda" when in fact its NOLs 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.

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 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Switzerland, United Kingdom).[19] These countries have comparable levels of tax enforcement, and prior cross-country taxation studies focus on a similar geographic sample (e.g., Devereux et al., 2002; Devereux and Griffith, 2003).[20] 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 195,163 firm-years, we drop observations for cross-listed firms (4,743 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 (49,851 firm-years) because these firms are subject to regulatory rules that affect profitability, taxability, and the level of risk-taking. We drop 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 84,214 firm-year observations.

[19]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.

[20]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.

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 two smaller samples of firms with primarily domestic operations. We identify firms as domestic if they report less than 10 percent of income, sales, and assets as foreign, following Creal et al. (2013). After imposing this additional data restriction, the sample of domestic firms reduces to 43,245 observations by including firm-years where missing values for the requisite foreign variables are set to zero. We also present results after dropping firm-year observations with missing foreign values (N=23,756). We convert all data to US dollars using exchange rates provided by Officer (2011). We merge the sample with country-level tax loss carryback/carryforward data collected from the yearly IBFD European Tax Handbook and the U.S. Internal Revenue Code, as well as OECD statutory corporate tax rate data.

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 et al. (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. The average tax rate has declined over time, from 38.5 percent in 1998 to 33.5 percent in 2009.

[Insert Table 2 here.]

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 (-0.07) indicates that the sample includes loss firms, a necessary condition for investigating if losses and the corresponding tax rules are associated with risk-taking. Note, however, that the median firm is profitable (ROA 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 (44,088/84,214) are from this country.[21] 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, with an average of 7,018 observations per year.

5. Empirical Results

5.1. Loss Offset Provisions

Table 3 presents the test of H1 using an OLS panel regression (Panel A) and a difference-in-difference test (Panel B). In Panel A, 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 12.9 percent higher risk-taking (coefficient of 0.038); a one year longer loss carryforward period implies 2.3 percent higher risk-taking (coefficient of 0.007).[22] The higher coefficient on *LCB* 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.

[Insert Table 3 here.]

[21] In untabulated analyses, we exclude the U.S. firm-years from the sample and find the same association between risk-taking and the statutory loss offset rules. We discuss the results of these tests in Section 5.

[22] We calculate this amount by multiplying the period change of one year by the coefficient and dividing by the mean *Risk* (0.038/0.294 = 12.9%). 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, 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 0.332, suggesting that the three-year ratios would instead be, for example, -0.404, -0.072, and 0.260. Therefore, we can also interpret the 12.9% increase in risk as a 12.9% increase in the span between the best and worst yearly *ROA* for the average firm.

Columns (3) and (4) present 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 16.8 (3.2) percent higher risk-taking for the average firm, given 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. Column (5) presents results for estimating the full model on the domestic sample of firms, where we set missing values of foreign variables to zero. Column (6) drops firm-years with missing foreign values from the sample. We find consistent results for both samples.[23]

The coefficients on the standardized country tax rate are insignificant in cols. (3) to (6), consistent with the model's finding that the tax rate has opposing effects on firm risk for firms with different loss offset expectations. Throughout the regression results, the control variables exhibit the expected relation with firm risk-taking.

Next, we present results of the matched sample DiD estimation (Table 3, Panel B). The validity of the DiD approach depends on the similarity of pre-event time trends in the treated and control samples. Figure 1 presents evidence related to satisfying this key identification assumption. The figure shows that the average risk of treated 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 suggests that the matching process produced an appropriate control sample of comparable firms, thus ensuring that changes in risk-taking can be attributed to the changes in statutory loss offset rules.

[Insert Figure 1 here.]

[23]In additional analysis, we first estimate eq. (7) separately for loss carrybacks and carryforwards and find consistent results. Second, we estimate eq. (7), dropping U.S. firm-years from the sample. The coefficients and their significance are slightly lower but overall consistent with our main results.

Figure 1 also presents evidence that changes in the statutory loss offset rules affect firm risk-taking as predicted. In the upper panel, where the treatment consists of an increase in the loss carryforward 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 carryback period, we find that risk-taking by the treated firms declines compared to the control firms. Both changes are consistent with the expected effects of changes in the loss offset periods.

Column (1) of Table 3, Panel B presents the β_3 coefficient from estimating eq. (7) for the treated sample of firms with a statutory decrease in the loss carryback period; col. (2) includes the coefficients for increases in the loss carryforward period. A decrease in the loss carryback period is associated with a decrease in firm-risk; the coefficient of -0.018 implies that the average risk of the treated firms is 21 percent lower after the statutory change compared to the average risk of the matched control firms. We also find, as predicted, that an increase in the loss carryforward period is related to a 12 percent increase in average risk for the treated firms, relative to the matched control firms (coefficient of 0.008). These results confirm that more generous tax loss rules induce greater firm risk-taking.[24]

As a test of H1b, we partition the difference-in-difference sample based on the tax rate of the countries with statutory changes in the loss carrryback and carryforward periods. We first present results for treated firms operating in Germany (col. 1) and France (col. 2), which have the highest statutory tax rate of countries with changes in the loss carrryback or loss carryforward period. For both, we observe significant DiD coefficients of -0.018 and 0.010, respectively. In contrast, the coefficients for the treated firm-years in the lowest tax rate countries (Netherlands for *LCB* decrease, Norway for *LCF* increase) have DiD coefficients of the correct sign, but neither are significant. These results confirm that the tax rate increases the relation between statutory loss offset periods and firm risk-taking.

For robustness, we present two 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,

[24] We calculate these effects by comparing the relative average risk for treated firms to control firms both before and after the change. 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 Panel A.

we perform the DiD analysis on the smaller sample of domestic firms and again find similar results.[25]

In Panel C of Table 3 we further explore the relationship between tax loss offset periods and corporate risk-taking. First, we test if the effect of loss offset on risk-taking differs by firm size. Second, we study whether the effect of additional years of the loss offset period is nonlinear.

Larger firms have a greater number of investments that provide more opportunities for intra-firm loss offset. For example, when a firm incurs a loss on one investment, it can directly use this loss to offset other profitable investments (Mirrlees et al., 2011). In a large firm, highly risky investments in one division thus lead to overall losses less frequently. Therefore, we predict that the positive effect of statutory loss offset incentives on firm risk-taking is weaker for larger firms because these firms rely less on the statutory tax provisions to recoup losses.

We test this prediction by interacting both loss offset variables (LCB/LCF) with *Size* in Table 3, Panel C, cols. (1) and (2). The coefficients on the interaction terms for both loss carrybacks and loss carryforwards are negative and significant, consistent with the prediction. Specifically, in the full specification in col. (2), we find that the marginal effect of a one-year increase in the loss carryback (carryforward) period implies an increase in *Risk* of 0.075 (0.012) for a firm at the first quartile of the size distribution, whereas the same change in the loss offset period implies only an increase in *Risk* of 0.037 (0.006) for a firm at the third quartile. Thus, the effects of loss carrybacks and carryforwards are approximately twice as large at the lower end of the interquartile range.

In a second test, we study the incremental benefit of an additional year of loss offset, conditional on the total loss offset period. For example, an additional loss carryforward year could induce a larger increase in risk-taking when the loss carryforward period prior to a statutory change was five years rather than twenty years.

To test this relationship, we include the square of the loss carryback and loss carryforward variables in the results presented in Table 3, Panel C, cols. (3) to (4). The coefficients on LCB and LCF remain positive and significant as in the main results.

[25] Because the U.S. had only a retroactive change in the loss offset period during our sample (which we code as no change), the DiD results exclude U.S. effects. This exclusion provides additional evidence that the U.S. firm-years do not drive our main results.

However, the coefficients on the squared terms LCB^2 and LCF^2 are negative and significant. Overall, the slope of the loss carryback/carryforward function is positive (longer loss offset periods increase firm risk-taking), but the relation becomes "flatter" as the loss carryback and carryforward periods increase. Thus, additional years in the loss offset period have diminishing benefits.

In summary, the results from Table 3 support the prediction that a country's loss carryback and carryforward periods are positively associated with firm risk-taking.

5.2. Firm-level Effects of Corporate Tax Rates

This section discusses results from testing H2, related to the direct relation between the tax rate and firm risk-taking. Table 4, Panel A includes results from regressing *Risk* on the firm's country-level tax rate and control variables, as a test of H2. The first two columns include the results for the full sample; cols. (3) to (6) repeat the analysis on the smaller samples 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 18.2 percent increase in the risk measure for the average high λ firm.[26] Excluding multinational firms (cols. 3 and 5), we find a change in risk of 16.0 percent and 21.2 percent, respectively, for the average firm in these samples. With full loss offset, the government shares the firm's investment risk, making risk-taking more attractive to the firm.

[Insert Table 4 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 this case, a three percentage increase in the tax rate is associated with a 2.6 percent decrease in firm risk for the average low λ firm. In the smaller samples that exclude

[26] We calculate this result by first multiplying the one quartile change in the tax rate by the coefficient (0.032∗1.194=0.038). We then divide this amount by the average risk for the sample of high λ firms (0.038/0.210 = 0.182). Note that the magnitude of this effect is similar to results from studies of entrepreneurial risk-taking: Cullen and Gordon (2007) finds that a five percentage point decrease in the personal income tax decreases entrepreneurial risk-taking by 40%.

multinational firms, we find similar, but weaker, results (ranging from a 3.5 percent to 5.4 percent decrease in risk-taking for the average firm in the respective sample).

Table 4, 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. Our results for the high λ firms continue to hold. For the low λ firms, we find mostly an insignificant effect, although the sign of the coefficient is negative in cols. (4) and (6).[27]

Importantly, these results show that the effect of taxation on corporate risk-taking is not uniform across firms. 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 risk-taking more broadly.

6. Additional Analyses

6.1. Within-Country Analysis

While the international setting allows for analysis on a large sample of firms with cross-country variation, other unobserved factors could influence our results. Therefore, we also examine the relation between risk-taking and tax loss rules using a sample of smaller Spanish firms around a statutory change in Spanish tax law.

Specifically, Spain limited the amount of loss offset to 75% (50%) of the tax base in 2011 (2012-2013) for firms with prior year revenues of €20 million to €60 million. This setting has three advantages: first, the revenue cut-offs are exogenously determined based on firm performance in the year prior to the passage of the law; second, the law did not affect tax rates, depreciation allowances, or other significant corporate tax rules; and third, Spain does not permit loss carrybacks, and therefore, the new loss carryforward limitations should directly affect firms' expected loss offset possibilities. Consequently, this setting permits us to infer that any risk-taking effects can be attributed to changes in loss offset rules.[28]

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[27] Because the U.S. federal and state tax rates had little variation during the sample period, these results provide further evidence that the main results are robust to the exclusion of many U.S. firm-year observations.

[28] To reduce the impact of these restrictions, loss carryforwards for this period were extended by three years for a total of 18 years. Given our findings on the nonlinearity of the tax loss effects at the end of Section 5.1, we expect that the loss offset limitations will have a larger immediate effect than

6.1.1. Research Design and Data

The change in the Spanish loss offset limitation lowers λ for the affected firms. Therefore, we predict that firms with revenue above the €20 million revenue threshold engage in less risk-taking than firms below the corresponding cutoff following this statutory change. To test this prediction, we employ a regression discontinuity design in which we compare *Risk* across these two groups of firms.

For this test, we use firm-level data from Bureau van Dijk's Amadeus data set.[29] We select all incorporated Spanish firms from Amadeus and then follow the same sample selection steps as the main sample. Given that the statutory change occurred in 2011, but that data is only available through 2012, we define the risk measure over two years. For validation, we compare this two-year risk measure for the firms in this dataset to the last available year from the main Worldscope sample (2009) and find similar values.[30]

We choose the bandwidth for the regression discontinuity test following Imbens and Kalyanaraman (2012).[31] This yields an optimal bandwidth of €130,642. Thus, we compare risk-taking in 2011 for firms with revenues between €20.00 million and €20.13 million in 2010 to firms with revenues between €19.87 million and €20.00 million in 2010.[32] To show that our results are robust, we also report results using double and

the extension of the overall loss offset period.

[29]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. Amadeus has been widely used in other papers examining the effects of taxation on firms' financial decisions, see, e.g., Huizinga and Laeven (2008); Egger et al. (2010); or Karkinsky and Riedel (2012).

[30]In the Amadeus sample, *Risk* in 2011 has a median of 0.021 and a mean of 0.051; Spanish firms in the Worldscope sample in 2009 have a median *Risk* of 0.027 and a mean *Risk* of 0.035.

[31]To implement the regression discontinuity test, we use the Stata program developed by Nichols (2007).

[32]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. We therefore focus on the €20 million test. 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 larger bandwidths.

triple bandwidth size for robustness.

6.1.2. Results

Figure 2 plots *Risk* of Spanish firms in 2011 above and below the €20 million threshold. This figure offers 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 2 here.]

Table 5 reports results from the regression discontinuity analysis. As expected, we find a negative and significant coefficient for the Average Treatment Effect, which means that those firms that can only offset 75% of a potential loss have significantly lower *Risk* than similar-sized Spanish firms (i.e., immediately below the threshold) that can fully offset losses. Overall, this regression discontinuity analysis validates the Section 5 cross-country results that show that tax loss rules are an important determinant of firm risk-taking.

[Insert Table 5 here.]

To confirm these results, we also carry out three falsification tests in Panel B of Table 5. First, we test if discontinuities exist at other levels of lagged revenues. We find no significant effect at any of these levels. Second, we test if discontinuities exist in other firm-level characteristics and again find none. Third, we test for discontinuities at the 20 million threshold in prior years. There is no significant negative effect for 2008 to 2010 (and the 2007 effect is in the opposite direction). From these results, we conclude that the loss offset limitation likely caused the change in corporate risk-taking for Spanish firms in 2011. In summary, this analysis suggests that the loss rules do have a causal effect on firm risk-taking.

6.2. Robustness Tests

This section discusses the results of additional robustness tests, including an instrumental variables analysis, as well as use of alternative risk measures, country-level estimation, exclusion of overlapping observations, and inclusion of an additional control variable.

6.2.1. Instrumental Variables Estimation

The tests of Hypothesis 1 in Table 3 show a positive and significant association between statutory tax loss rules and firm risk. While we attempt to identify a causal relation between tax rules and firm risk using the DiD specification, we acknowledge that the results could reflect an endogenous relation. Specifically, firm risk-taking may induce governments to change the tax rules (rather than the government inducing firms to alter their risk-taking), and the results could potentially suffer from reverse causality. To mitigate this concern in a setting broader then the Spanish test discussed in Section 6.1, we use an instrumental variables specification in this section.

We re-estimate eq. (6) using the inverse of the per capita cost to start a new business (*COB*) from the World Bank's Doing Business report (available from 2004) as an instrument for the loss carryback/carryforward periods. This instrument should be correlated with the potentially endogenous *LCB*/*LCF* variables because both measures capture a country's attitude toward private enterprise; that is, we expect that more business-friendly countries have longer loss carryback/carryforward periods and should similarly impose low costs on establishing new businesses. Indeed, the instrument is positively and significantly correlated with both loss carrybacks and carryforwards (correlations of 0.60 and 0.59, respectively). This instrument should also meet the exclusion restriction because these costs affect only start-up ventures and should not influence the risky investment project selection of established corporations, such as the large, listed firms included in our sample. For these reasons, we believe that our instrument is valid.

Table 6, Panel A presents the results from estimating the instrumental variable regressions. Columns (1) to (3) present the results for instrumenting the loss carryback period; cols. (4) to (6) present results for instrumenting loss carryforwards. Columns (1) and (4) include the OLS results for separately regressing firm risk-taking on *LCB* and *LCF*, respectively. In the first-stage instrumental variables regressions (cols. (2) and (5)), the coefficients on *COB* have the expected sign and are significant at the one percent level.[33] Columns (3) and (6) include the results from the second-stage regression. The

[33]In addition to including the R-squared statistic for both models, we also present the partial R-square, which measures the explanatory power of the model excluding controls variables. From this statistic, we note that the models continue to have sufficient explanatory power. The p-values for the F statistic and the partial F statistic indicate that the regression specification does not suffer from a weak instrument problem; specifically, the partial F statistic exceeds the critical value of 8.96 as

coefficients are positive and significant, confirming that our main results are robust even when considering potential endogeneity issues.

[Insert Table 6 here.]

6.2.2. Alternative Risk Measures

As discussed in Section 5.1, we measure firm risk using the standard deviation of ROA ratios over three years (year *t*, *t+1*, and *t+2*). In Table 6, Panel B, we re-estimate our main results for both hypotheses using two alternative risk measures. In cols. (1) to (4), we re-estimate the firm risk over five years (year *t* to year *t+4*). The results continue to hold, showing that the results are not sensitive to the period over which the risk measure is defined. In cols. (5) to (8), we estimate the regressions using a market-based measure of firm risk – price volatility, following González (2005) and Bargeron et al. (2010). Price volatility is the standard deviation of daily returns for each year. Unlike the ROA-based measure that is calculated directly from annual firm accounting information (EBIT and total assets), price volatility captures the changes in the *market* pricing of the firm as well as the market's assessment of firm risk. Thus, price volatility may incorporate various information available to investors that may be informative about firm risk-taking. Using this alternative measure, we again find consistent results.

6.2.3. Country-level Estimation

Following John et al. (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 and interaction terms. We find consistent results with positive and significant coefficients (t-statistics) of 0.047 (4.743), 0.004 (3.788), and 0.034 (2.358) on *LCB*, *LCF*, and $LCB^{*}StdCTR$, respectively. The coefficient of 0.001 on $LCF^{*}StdCTR$ is insignificant (t-statistic of 0.772), also consistent with the Table 3 results. We conclude that the main results measured at the firm-level are robust to this alternative country-level measurement.

suggested by Stock et al. (2002).

6.2.4. *Overlapping Observations*

As discussed in Section 4, the risk measure is defined over a three-year period. To mitigate concerns of overlapping observations within the sample, we re-estimate the main regression using only 2000, 2003, 2006, and 2009 (every third year). We find consistent results; the coefficients (t-statistics) are 0.063 (3.451), 0.009 (3.733), and -0.014 (-0.449) on LCB, LCF, and $StdCTR$, respectively. Furthermore, the two interaction terms have coefficients (t-statistics) of 0.127 (4.122) and -0.003 (-1.192), also consistent with the main results. We conclude that the main results are not driven by multiple firm observations within the panel.

6.2.5. *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=17,195), 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 as a control, and we find that the size and significance of 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 analytical model shows that 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 firms view these tax rules as important when selecting the riskiness of firm investments. We then partition firms based on the estimated expectation of available future loss offset. In both subsamples, we find significant effects of tax rates on risk-taking, but with opposing signs: higher tax rates increase risk-taking for firms that expect to use their tax losses and decrease risk-taking for firms with very limited loss offset possibilities. Thus, our paper provides first evidence that firms have different investment responses to tax rate changes, and these responses depend on firm-specific characteristics, particularly 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 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 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
Inverse of cost to open a new Business (*Inverse of COB*)	Cost of opening a new business as % of income per capita.	The World Bank's Doing Business project
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 specific average *ROA*. *ROA* is winsorized at 1% to account for loss-making firms with extremely low assets. *Risk* is winsorized at 1% on both sides of the sample distribution.	Thomson Reuters' Worldscope

Firm risk-taking proxy over five years (*Risk_5Y*)	Five-year earnings volatility, defined as $Risk\_5Y = \sqrt{\frac{1}{4}\sum_{t=1}^{5}\left(D_{ijct} - \frac{1}{5}\sum_{t=1}^{5} D_{ijct}\right)^2}$, 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 five years of a firm's ROA's deviation from the industry-country specific average ROA. ROA is winsorized at 1% to account for loss-making firms with extremely low assets. *Risk_5Y* is winsorized at 1% on both sides of the sample distribution.	Thomson Reuters' Worldscope
Stock price volatility (*Price Volatility*)	A measure of a stock's average annual price movement to a high and low from a mean price for each year. For example, a stock's price volatility of x% indicates that the stock's annual high and low price was between $+x$% and -x% of its annual average price.	Thomson Reuters' Worldscope
Firm size (*Size*)	Natural logarithm of total assets in 1000 US-$ (Worldscope data code: XWC02999), winsorized at 1% and 99%.	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), winsorized at 1% and 99%.	Thomson Reuters' Worldscope
Leverage (*Leverage*)	Ratio of total liabilities (XWC 03351) to total assets (XWC02999), winsorized at 1% and 99%.	Thomson Reuters' Worldscope
Market-to-book ratio (*MB*)	Ratio of market capitalization (XWC08001) to common equity (XWC03501), winsorized at 1% and 99%.	Thomson Reuters' Worldscope

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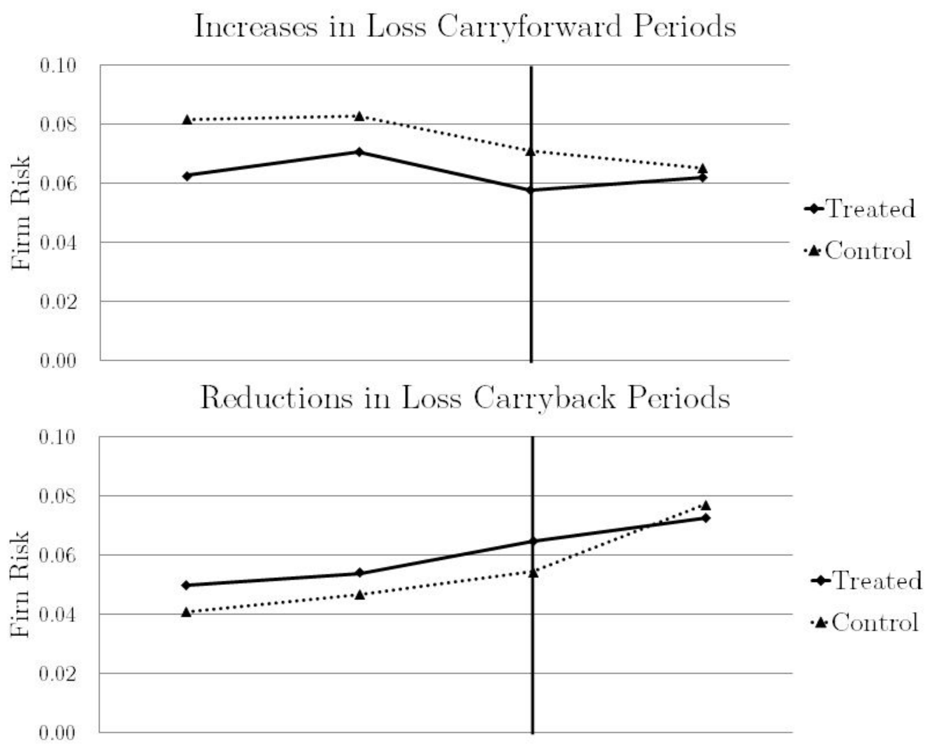
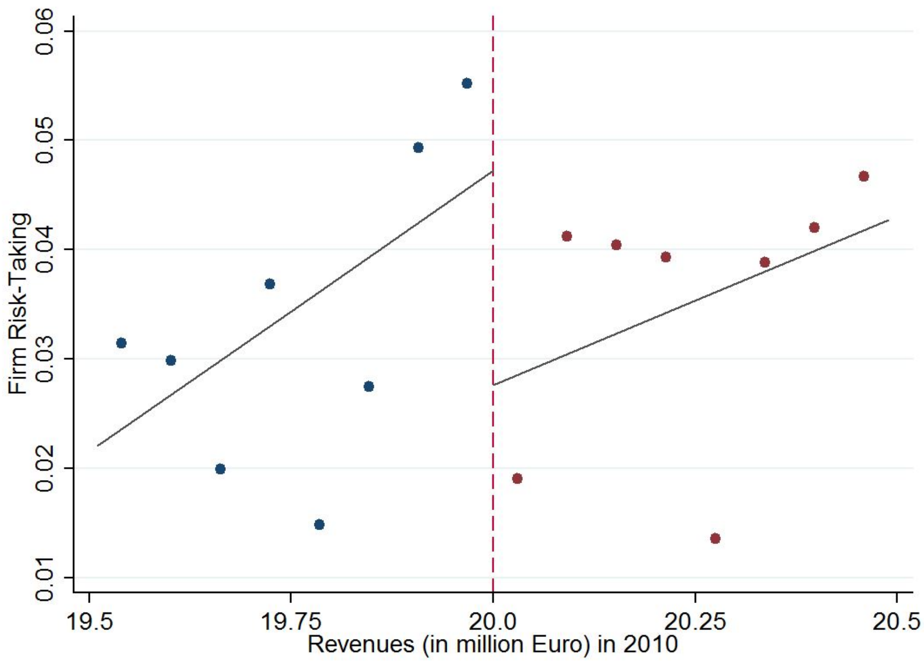
Figure 1: Difference-in-Difference Analysis for Changes in Loss Offset Periods



The upper panel shows the risk time-trend of treated firms (continuous line) and control firms (dotted line) three years before and one year after an increase in the loss carryforward period. The lower panel repeats the analysis for a reduction in the carryback period. The vertical line marks the change of the statutory loss offset period.

Figure 2: Regression Discontinuity



This figure plots the average firm risk-taking for equal-sized bins as well as linear trend lines for the treatment and control group. The dependent variable is *Risk*, and the x-axis measures revenues in million € in the year before.

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 the empirical study. In Panel B, *I* indicates an indefinite carryforward period.

Panel A: Statutory Loss Carryback Periods

Country	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998
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	1	1	1	1	1	1	1	1	1	1	1	2
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	1	1	1	3	3	3	3	3	3	3	3	3
Norway	2°	2°	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	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998
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	*I*	*I*	*I*	*I*	*I*	*I*	*I*	5	5	5	5	5
Finland	10	10	10	10	10	10	10	10	10	10	10	10
France	*I*	*I*	*I*	*I*	*I*	*I*	5	5	5	5	5	5
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	9	9	9	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*
Norway	*I*	*I*	*I*	*I*	10	10	10	10	10	10	10	10
Portugal	6	6	6	6	6	6	6	6	6	6	6	6
Spain	15	15	15	15	15	15	15	15	10	10	10	7
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 for the main variables in our sample. Appendix A describes all variables. All firm-level variables are winsorized at 1% and 99%.

	# Obs.	Mean	Median	Std. Dev.	5%	95%
Risk	84,214	0.294	0.101	0.665	0.007	1.250
LCB	84,214	1.536	2.000	0.868	0.000	3.000
LCF	84,214	17.821	20.000	5.023	5.000	20.000
CTR	84,214	0.361	0.393	0.055	0.260	0.394
Size	84,214	11.899	11.872	2.322	8.050	15.831
ROA	84,214	-0.072	0.057	0.532	-0.764	0.237
Sales Growth	84,214	0.290	0.089	1.089	-0.387	1.310
Leverage	84,214	0.606	0.534	0.626	0.111	1.131
GDP Growth	84,214	0.051	0.055	0.067	-0.076	0.164
MB	84,214	2.857	1.733	6.957	-1.062	10.871

Table 3

Relation Between Firm Risk and Loss Carrybacks & Carryforwards

This table presents the association between firm risk and statutory loss rules. Panel A 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; cols. (5) to (6) include results for domestic firms, where firms are defined as "domestic" if foreign income, assets, and sales are each less than 10% of the corresponding total value. Each specification is estimated with an intercept and industry and year fixed effects (FE). Panel B 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 with no changes. Column (1) presents results for countries with a decrease in the loss carryback period; col. (2) presents results for countries with an increase in the loss carryforward period. Panel C presents size and nonlinear analysis. Columns (1) and (2) interact the tax variables of interest with *Size*. Columns (3) and (4) test for nonlinear effects by including squared terms of the loss carryback and loss carryforward variables (LCB and LCF are centered to avoid multicollinearity). Control variables are as in Panel A. T-statistics are presented in parenthesis; in Panels A and C, standard errors are clustered by firm and by country-year, and in Panel B by firm. Appendix A describes all variables. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: OLS Panel Estimation

	Dependent Variable: Firm Risk-Taking					
	All Firms				Domestic Firms Only	
	(1)	(2)	(3)	(4)	(5)	(6)
LCB	0.052**	0.038**	0.067***	0.049***	0.054***	0.096***
	(2.25)	(2.31)	(3.60)	(3.68)	(2.94)	(3.15)
LCF	0.011***	0.007***	0.014***	0.009***	0.009***	0.003
	(6.44)	(5.42)	(7.00)	(6.35)	(4.43)	(1.04)
StdCTR	0.070***	0.051***	-0.041	-0.035	-0.016	0.020
	(3.11)	(3.10)	(-1.45)	(-1.60)	(-0.54)	(0.54)
LCB*StdCTR			0.094***	0.065**	0.062*	0.008
			(2.62)	(2.46)	(1.90)	(0.18)
LCF*StdCTR			0.000	0.001	0.000	0.001
			(0.18)	(0.47)	(0.21)	(0.36)
Size		-0.027***		-0.028***	-0.043***	-0.055***
		(-7.30)		(-7.54)	(-6.99)	(-7.88)
ROA		-0.512***		-0.505***	-0.503***	-0.504***
		(-17.18)		(-16.92)	(-15.96)	(-13.60)
Sales Growth		0.024***		0.024***	0.021***	0.024***
		(7.19)		(7.23)	(6.09)	(6.08)
Leverage		0.150***		0.152***	0.151***	0.141***
		(9.17)		(9.35)	(8.71)	(7.77)
GDP Growth		0.176		0.177	0.323	0.721***
		(0.74)		(0.88)	(1.51)	(3.15)
MB		0.003***		0.003***	0.002***	0.003**
		(4.74)		(4.87)	(3.28)	(2.34)
Industry/Year FE?	Yes	Yes	Yes	Yes	Yes	Yes
Observations	84,214	84,214	84,214	84,214	43,245	23,756
R^2	0.055	0.354	0.062	0.358	0.406	0.409

Panel B: Matched Sample Difference-in-Difference Estimation

	Mean Difference-in-Difference	
	Decrease in LCB (-)	Increase in LCF (+)
Matching Requirements	(1)	(2)
Size/ROA/Sales Growth/Leverage/MB	-0.018***	0.008**
	(-2.623)	(2.054)
Size/ROA/Sales Growth/Leverage/MB	-0.018***	0.010**
(Highest tax rate country)	(-2.568)	(2.132)
Size/ROA/Sales Growth/Leverage/MB	-0.005	0.014
(Lowest tax rate country)	(-0.650)	(1.097)
Size/ROA/Sales Growth/Leverage/MB/Industry	-0.015***	0.008**
	(-2.741)	(2.009)
Size/ROA/Sales Growth/Leverage/MB	-0.037*	0.006
(Domestic Firms only)	(-1.949)	(0.724)
Size/ROA/Sales Growth/Leverage/MB/Industry	-0.033*	0.008
(Domestic Firms only)	(-1.862)	(1.017)

Panel C: Size and Nonlinear Effects

	Dependent Variable: Firm Risk-Taking			
	Size Interaction		Nonlinear Specification	
	(1)	(2)	(3)	(4)
LCB	0.208***	0.199***	0.041***	0.051***
	(4.28)	(4.22)	(3.22)	(4.44)
LCF	0.032***	0.033***	0.007***	0.009**
	(4.64)	(4.82)	(2.70)	(1.99)
StdCTR	0.051***	-0.021	0.040***	0.136***
	(3.10)	(-0.96)	(2.75)	(4.25)
Size	0.033***	0.028***	-0.027***	-0.028***
	(3.08)	(2.72)	(-7.16)	(-7.27)
LCB*Size	-0.014***	-0.012***		
	(-4.30)	(-3.80)		
LCF*Size	-0.002***	-0.002***		
	(-3.81)	(-3.68)		
LCB^2			-0.082***	-0.090***
			(-6.22)	(-4.34)
LCF^2			-0.002***	-0.002***
			(-3.71)	(-2.95)
Interaction LCB/LCF*StdCTR?	No	Yes	No	Yes
Interaction LCB^2/LCF^2*StdCTR?	–	–	No	Yes
Controls?	Yes	Yes	Yes	Yes
Industry/Year FE?	Yes	Yes	Yes	Yes
Observations	84,214	84,214	84,214	84,214
R^2	0.357	0.360	0.359	0.362

Table 4

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. Appendix A describes all variables. In both panels, cols. (3) to (6) provide results for domestic firms only, where firms are defined as "domestic" if foreign income, assets, and sales are each less than 10% of the corresponding total value. 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). Each specification is estimated with an intercept and includes industry and year fixed effects (FE). The t-statistics in parenthesis are based on standard errors clustered two-ways, 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 Only			
	(1)	(2)	(3)	(4)	(5)	(6)
	High λ	Low λ	High λ	Low λ	High λ	Low λ
CTR	1.194***	-0.235**	1.301***	-0.317*	1.523***	-0.497
	(4.02)	(-2.30)	(3.37)	(-1.79)	(4.53)	(-0.92)
Size	-0.017***	-0.005	-0.027***	-0.002	-0.035***	0.019
	(-5.07)	(-1.32)	(-4.95)	(-0.40)	(-5.85)	(0.81)
ROA	-0.360***	-0.327***	-0.318***	-0.257***	-0.381***	-0.226**
	(-6.89)	(-5.98)	(-4.38)	(-6.89)	(-5.30)	(-2.59)
Sales Growth	0.018**	0.001	0.010	-0.001	0.015	0.045
	(2.07)	(0.28)	(0.69)	(-0.26)	(1.01)	(1.51)
Leverage	0.134***	-0.052	0.197***	-0.107***	0.182***	0.019
	(2.72)	(-1.44)	(3.28)	(-4.99)	(3.50)	(0.46)
GDP Growth	0.059	0.113	0.176	-0.131	0.614**	-1.070
	(0.18)	(1.07)	(0.44)	(-1.21)	(2.01)	(-0.91)
MB	0.007***	0.000	0.009***	0.000	0.010***	-0.000
	(4.05)	(0.02)	(2.88)	(0.58)	(2.93)	(-0.02)
Industry/Year FE?	Yes	Yes	Yes	Yes	Yes	Yes
Observations	35,238	2,007	14,721	1,139	9,154	100
R^2	0.088	0.287	0.140	0.326	0.160	0.206

Panel B: Changes Specification

	Dependent Variable: Firm Risk-Taking					
	All Firms		Domestic Firms Only			
	(1)	(2)	(3)	(4)	(5)	(6)
	High λ	Low λ	High λ	Low λ	High λ	Low λ
Δ CTR	0.420**	0.083	0.688**	-0.110	1.473**	-0.503*
	(2.06)	(0.36)	(2.08)	(-0.38)	(2.30)	(-1.95)
Δ Size	-0.058	0.013	-0.117	0.008	-0.070	0.072
	(-1.21)	(0.85)	(-1.20)	(0.48)	(-0.97)	(1.36)
Δ ROA	0.112	-0.174***	0.114	-0.172***	0.313***	-0.327***
	(1.43)	(-7.14)	(1.41)	(-5.01)	(4.49)	(-10.25)
Δ Sales Growth	-0.000	0.000	0.000	0.000	-0.000	0.000**
	(-1.18)	(1.47)	(0.78)	(0.69)	(-0.11)	(2.32)
Δ Leverage	-0.001	0.085***	-0.001	0.087***	-0.004***	-0.071
	(-0.54)	(3.61)	(-0.58)	(3.52)	(-4.05)	(-0.84)
Δ GDP Growth	0.076	0.038	0.070	0.008	0.276	0.545
	(0.67)	(0.30)	(0.46)	(0.06)	(1.62)	(1.37)
Δ MB	-0.000	0.000	-0.000	0.000	-0.000	0.000
	(-0.55)	(0.26)	(-0.37)	(0.67)	(-0.18)	(1.22)
Industry/Year FE?	Yes	Yes	Yes	Yes	Yes	Yes
Observations	35,238	2,007	14,721	1,139	9,154	100
R^2	0.083	0.271	0.100	0.477	0.146	0.221

Table 5

Within-Country Analysis

This table presents results from a regression discontinuity analysis of Spanish firms in 2011. In Panel A, the dependent variable is a two-year measure of risk, and firms are identified as "treated" if their 2010 revenue exceeds €20 million. The bandwidth used is €130,642 (the optimal bandwidth according to Imbens and Kalyanaraman, 2012) in col. (1), €261,284 in col. (2), and €391,925 in col. (3). In part I of Panel B, the dependent variable is the two-year measure of risk, and firms are identified as "treated" if their 2010 revenue exceeds €15 million (col. 1), €19 million (col. 2), €21 million (col. 3), €25 million (col. 4) as falsification tests. In a second falsification test, we consider different dependent variables (employees, assets, EBIT and sales growth). In the final falsification tests in part III, we test discontinuities in other time periods. z-statistics are in parenthesis. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Main Test

	Dependent Variable: Firm Risk-Taking		
	(1)	(2)	(3)
Average Treatment Effect	-0.056**	-0.048**	-0.031*
	(-2.07)	(-2.51)	(-1.86)
Bandwidth	130,642	261,284	391,925

Panel B: Falsification Tests

I. Levels of Lagged Revenues				
	Dependent Variable: Firm Risk-Taking			
	(1)	(2)	(3)	(4)
Average Treatment Effect	0.084	-0.074	-0.008	0.027
	(1.30)	(-1.24)	(-0.32)	(0.91)
Cutoff	€15m	€19m	€21m	€25m

II. Other Firm Characteristics				
Dependent Variable:	Employees	Assets	EBIT	Sales Growth
	(1)	(2)	(3)	(4)
Average Treatment Effect	-54.628	-229.059	-4.199	-0.120
	(-1.16)	(-1.58)	(-0.23)	(-0.95)

III. Other Years				
	Dependent Variable: Firm Risk-Taking			
	(1)	(2)	(3)	(4)
Average Treatment Effect	0.036*	-0.061	0.002	0.014
	(1.87)	(-1.08)	(0.07)	(0.63)
Year	2007	2008	2009	2010

Table 6

Robustness Tests

This table presents robustness analysis; Panel A includes an instrumental variable analysis of the effect of loss offset provisions on firm risk-taking. The instrument for the loss carryback (cols. (1) to (3)) and loss carryforward (cols. (4) to (6)) rules is the inverse of the cost to open a new business (COB). Control variables are the same as in Table 3. Appendix A describes all variables. Each specification is estimated with an intercept and includes industry and year fixed effects (FE). The t-statistics in parenthesis are based on standard errors clustered by firm and by country-year. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The partial R^2-statistic calculates how well the model fits using only the instrument (and no control variables) in the regressions; this statistic indicates that the model still has significant explanatory power. Similarly, the partial F-statistic provides additional information on how well the model fits by analyzing the ratio of explained variance to unexplained variance after removing the control variables from the regression specification. P-values are presented in parentheses. Panel B repeats the analyses from Table 3 (Panel A) and Table 4 (Panel A), using two alternative risk measures – risk defined over five years (cols. (1) to (4)) and the volatility of stock prices (cols. (5) to (8)).

Panel A: Instrumental Variables Analysis

	LCB instrumented			LCF instrumented		
	(1) OLS	(2) 1^{st} Stage 2SLS	(3) 2^{nd} Stage 2SLS	(4) OLS	(5) 1^{st} Stage 2SLS	(6) 2^{nd} Stage 2SLS
LCB	0.059***		0.237***			
	(3.73)		(5.85)			
LCF				0.010***		0.040***
				(9.13)		(3.27)
Inverse of COB		0.605***			3.575***	
		(6.16)			(4.13)	
StdCTR	0.004	0.439***	-0.019	0.010	1.428***	0.028
	(0.19)	(10.79)	(-0.84)	(0.50)	(3.91)	(0.83)
Controls?	Yes	Yes	Yes	Yes	Yes	Yes
Ind./Year FE?	Yes	Yes	Yes	Yes	Yes	Yes
Partial R^2		0.180			0.190	
F-statistic		32.51 (p=0.000)			4.94 (p=0.000)	
Partial F-statistic		37.95 (p=0.000)			17.05 (p=0.000)	
Observations	84,214	39,670	39,670	84,214	39,670	39,670
R^2	0.354	0.552	0.345	0.353	0.438	0.349

Panel B: Alternative Risk Measures

Dep. Variable:	5-Year Risk				Price Volatility			
	(1) All Firms	(2) All Firms	(3) High λ	(4) Low λ	(5) All Firms	(6) All Firms	(7) High λ	(8) Low λ
LCB	0.052***	0.060***			1.449*	1.930***		
	(2.79)	(3.80)			(1.81)	(2.68)		
LCF	0.009***	0.011***			0.129	0.218*		
	(6.20)	(6.62)			(1.41)	(1.86)		
std. CTR	0.033*	-0.055**			1.827**	-0.865		
	(1.84)	(-2.16)			(2.55)	(-0.59)		
CTR			0.812**	-0.301**			32.500***	-15.158
			(2.38)	(-2.10)			(3.10)	(-0.87)
LCB*CTR		0.073**				2.202*		
		(2.11)				(1.75)		
LCF*CTR		0.001				0.014		
		(0.30)				(0.13)		
Size	-0.028***	-0.029***	-0.015***	-0.008**	-2.884***	-2.899***	-2.297***	-1.195***
	(-7.96)	(-8.26)	(-3.90)	(-2.05)	(-14.40)	(-14.56)	(-10.35)	(-3.04)
ROA	-0.498***	-0.490***	-0.325***	-0.277***	-7.144***	-6.921***	-12.997***	-9.659***
	(-23.20)	(-22.65)	(-5.63)	(-5.12)	(-7.39)	(-7.33)	(-8.50)	(-6.21)
Sales Growth	0.031***	0.031***	0.005	0.005	1.766***	1.765***	2.504***	1.432***
	(7.59)	(7.56)	(0.77)	(0.90)	(17.59)	(17.61)	(6.66)	(2.68)
Leverage	0.149***	0.153***	0.103	-0.085***	0.777**	0.858***	1.738**	4.820*
	(7.59)	(7.84)	(1.59)	(-3.18)	(2.53)	(2.78)	(2.36)	(1.85)
GDP Growth	-0.241	-0.156	-0.557	0.163	1.521	2.662	-5.194	54.104**
	(-0.85)	(-0.65)	(-1.29)	(1.48)	(0.16)	(0.33)	(-0.45)	(2.13)
MB	0.003***	0.003***	0.009***	0.000	0.068***	0.067***	0.054*	0.154***
	(4.23)	(4.36)	(3.95)	(0.30)	(3.42)	(3.29)	(1.72)	(3.33)
Industry/Year FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	58,535	58,535	24,439	1,249	61,837	61,837	31,033	1,478
R^2	0.320	0.325	0.076	0.237	0.397	0.404	0.218	0.216