LMU
LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
VOLKSWIRTSCHAFTLICHE FAKULTÄT

Dominika Langenmayr; Rebecca Lester:

Taxation and Corporate Risk-Taking

Munich Discussion Paper No. 2014-28

Department of Economics
University of Munich

Volkswirtschaftliche Fakultät
Ludwig-Maximilians-Universität München

Online at http://epub.ub.uni-muenchen.de/20977/

Taxation and Corporate Risk-Taking*

Dominika Langenmayr◇ | Rebecca Lester‡
University of Munich | Massachusetts Institute of Technology

June 20, 2014

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 can 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.

Keywords: Corporate taxation, firm risk-taking, net operating losses

JEL Classification: H25, H32, G32

---

*We thank Joshua Anderson, Mihir Desai, Martin Feldstein, Michelle Hanlon, Andreas Haufler, Jeff Hoopes, Zawadi Lemayian, Patricia Naranjo, Ray Rees, Leslie Robinson (discussant), Masaaki Suzuki (discussant), Johannes Voget, Brady Williams, Ben Yost, and seminar participants at the University of Munich, the University of Bayreuth, the London Business School Trans-Atlantic Doctoral Conference, the Harvard accounting doctoral seminar, the Oxford University Centre for Business Taxation Annual Symposium, and the 69th Annual Congress of the International Institute for Public Finance for helpful comments and suggestions. Work on this paper was started when Dominika Langenmayr visited Harvard University; she is grateful for their hospitality. Rebecca Lester also gratefully acknowledges financial support from the MIT Sloan School of Management and the Deloitte Foundation.

◇Department of Economics, Munich, Germany. E-mail: dominika.langenmayr@econ.lmu.de

‡Sloan School of Management, Cambridge, MA, USA. E-mail: rlester@mit.edu

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 could 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 able to use losses, 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. 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-rate aspects when assessing the investment implications of changing tax policies.

These results reconcile conflicting findings in the previous literature related to the

[1] In 2010, only 0.06% of U.S. firms were public, but these firms comprised 47.2% of total fixed investment (Asker, Farre-Mensa, and Ljungqvist, 2014). John, Litov, and Yeung (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.

effectiveness of tax loss incentives. The few papers that study non-tax-rate elements of the corporate tax system find only small effects of loss rules on the level of investment (e.g., Devereux, Keen, and Schiantarelli, 1994; Edgerton, 2010). This result is surprising given the large number of firms that report tax losses and the large aggregate loss amounts;[2] furthermore, firms take actions to preserve and maximize the tax loss benefits (Maydew, 1997; Erickson and Heitzman, 2010; Albring, Dhaliwal, Khurana, and Pereira, 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 clarify the tax rate and tax loss effects described above by analytically modeling how the corporate tax system affects 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.[3] We then test these hypotheses with an international firm-level panel dataset. This sample exploits differences in tax loss carrybacks and carryforwards across 17 different jurisdictions. Following John, Litov, and Yeung (2008), we measure firm-specific operating risk as the variance of returns to firm investment (measured by a firm's return on assets), consistent with the risk construct included in our theoretical model. 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.

Using panel regressions and a matched sample difference-in-difference analysis, 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 higher effect for loss carrybacks reflects that these rules provide

[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).

[3]Domar and Musgrave (1944) first explored the second effect in a model of individual portfolio choice. We build on their intuition to develop our model of corporate risk-taking.

greater risk-taking incentives than loss carryforwards, given that carrybacks deliver an immediate cash refund and are not conditional on future profitability. The results are robust to controlling for other factors that affect firm risk-taking and tax status, including firm size, the firm's investment and growth opportunity set, and leverage, as well as industry and year fixed effects.

To test the effect of the statutory tax rate on firm risk-taking, we then partition the sample based on firm-specific expectations about future loss offset. To measure these expectations, we use 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.

Next, we test the relation between tax loss rules and firm risk-taking within one country to mitigate concerns that the main results are driven by unobserved cross-country factors. We focus on statutory changes in Spanish tax loss rules in 2011 through 2013 that limited the amount of available loss offset for firms with revenues above €20 million. Using a regression discontinuity design, we find that firms with revenues immediately above €20 million took less risk in this period, relative to firms with revenues immediately below €20 million. This analysis confirms the main 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 confirm our main results.

Our paper is part of growing literature that studies the determinants of firm risk-taking. Many papers address the effects of managerial incentives, including May (1995);

Demski and Dye (1999); Rajgopal and Shevlin (2002); and Coles, Daniel, and Naveen (2006). More recently, the literature has documented that corporate governance (John, Litov, and Yeung, 2008), creditor rights (Acharya, Amihud, and Litov, 2011), shareholder diversification (Faccio, Marchica, and Mura, 2011), and inside debt (Choy, Lin, and Officer, 2014) are important determinants of corporate risk-taking. Bargeron, Lehn, and Zitter (2010) examine how the Sarbanes-Oxley Act of 2002 affected U.S. firm risk-taking.[4]

To the best of our knowledge, no prior papers study the effect of the corporate tax system on the riskiness of corporate investments. Instead, the literature analyzing the effects of taxation on investment has thus far focused on the level of capital invested (Hassett and Hubbard (2002) survey the theoretical and empirical literature on this topic). While most papers only consider the tax rate, a few studies analyze loss offset provisions. For example, Devereux, Keen, and Schiantarelli (1994) find that tax asymmetries do not improve the performance of tax-adjusted Q equations in predicting the level of investment. Edgerton (2010) studies how the asymmetric tax treatment of profits and losses affects the size of firm investment. He finds that such asymmetries made bonus depreciation tax incentives at most four percent less effective than if all firms had been taxable. Using a sample of multinational subsidiaries of German multinationals, Dreßler and Overesch (2013) study how host country tax loss rules affect the level of investment, measured with fixed assets. They find no relation between a country's loss carryback rules and the level of investment, a result that they note is surprising.

Another line of literature studies how taxes affect firm hedging. Graham and Smith (1999) show in a simulation analysis that tax-function convexity (due primarily to tax loss rules) provides an incentive to hedge for 50 percent of firms. Graham and Rogers (2002) empirically test this prediction but find no evidence that tax convexity motivates firms to hedge. They show, however, that firms hedge to increase debt capacity, which also provides tax benefits. Our more general approach, which examines total firm risk-taking, takes into account that firms manage risk in several ways, including investment project selection, diversification, hedging, and insurance.

Other papers consider the effect of taxes on risk-taking for individual portfolio choice and entrepreneurial risk-taking with contradictory conclusions. While Asea and

[4]An emerging line of research studies how tax avoidance strategies affect firm risk (Guenther, Matsunaga, and Williams, 2013; Hutchens and Rego, 2012; Neuman, Omer, and Schmidt, 2013). Unlike these papers about tax risk, we examine the tax system itself (and not tax avoidance strategies).

Turnovsky (1998) find that higher taxes make it less likely that individuals hold risky assets, Poterba and Samwick (2002) conclude that households invest more in stock (and less in taxable bonds) when personal income tax rates rise due to the advantageous lower capital gains tax rates. Studying a sample of start-ups, Cullen and Gordon (2007) find that increases in personal income taxes have a negative effect on entrepreneurial risk-taking. Djankov, Ganser, McLiesh, Ramalho, and Shleifer (2010) test the effect of corporate tax rates (but not tax loss rules) on entrepreneurship, measured by business registrations, and find that taxes have an adverse effect.

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. Section 5 discusses our results and provides some robustness check. In Section 6 we perform an additional within-country test. 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, Auerbach, Cooper, and Knittel, 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, Dhaliwal, Khurana, and Pereira, 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

We first develop a model that captures the effect of both the corporate tax rate and tax loss offset provisions on firm risk-taking. We then use this model to generate the hypotheses for the empirical tests.

3.1 Model Set-up

Consider a representative firm, which operates in a world with uncertainty. There are two potential states of the world. In the "good" state of the world, occurring with probability p, the firm generates a profit (and taxable income) from selling its product. In the "bad" state of the world (probability $1-p$), the firm incurs a loss. The firm can invest in a technology that increases both the potential profit and the potential loss. For example, this investment may be a larger machine that can produce greater output but that also costs more, even when idle.

The firm has a return of $f_g(I) > 0$ in the good state of the world. When the investment I is higher, this return increases, but with diminishing returns: ${f_g}'(I) > 0,\ {f_g}''(I) < 0$. In the bad state of the world, the firm incurs a loss, $f_b(I) < 0$, which is greater when the investment is higher ($f_b'(I) < 0,\ f_b'' < 0$). The corresponding cost of the investment I increases linearly with the amount of investment, and we normalize this cost to 1 per unit of investment. To guarantee that some investment in I is optimal, we assume that, at low levels of I, the expected return to investment is greater than its marginal cost: $pf_g'(I=0) + (1-p)f_b'(I=0) > 1$.

A higher investment in this technology results in a higher variance of the possible returns of the firm. Defining the average profit $\overline{\pi} = pf_g + (1-p)f_b - I$, the variance of pre-tax profits is:

$$Var = p[f_g(I) - I - \overline{\pi}]^2 + (1-p)\left[f_b\left(I\right) - I - \overline{\pi}\right]^2 = p(1-p)[f_g(I) - f_b(I)]^2. \quad (1)$$

As the difference between the returns $f_g\left(I\right) - f_b(I)$ is increasing in I, the variance of profits is also rising in I.[5] Thus, in our model, we equate a larger investment in I with more risk-taking by the firm.[6]

Firms should select the appropriate level of risky investment 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). Purnanandam (2008) shows that firms avoid risky investments to lower the probability of financial distress. Firms with financial constraints hedge currency risks (Géczy, Minton, and Schrand, 1997). Moreover, a risk-averse manager considers risk in investment decisions if compensation is linked to firm performance (Tufano, 1996; Guay, 1999; Hall and Murphy, 2002; Coles, Daniel, and Naveen, 2006; Lewellen, 2006).

Given these empirical results, 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

---

[5]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), our empirical analysis in Section 4 uses a risk measure constructed from the standard deviation of profits to firm assets.

[6]The model directly links the riskiness and amount of firm investment by using only one investment parameter. In a more complicated model in which the firm has two distinct decision variables, we could separate the effects of taxation on the amount and riskiness of investment. Such a model, while more complicated, would not yield additional insights regarding the effect of taxation on risk-taking.

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. Assuming a continuously differentiable and concave utility function, the expected utility of the firm is given by

$$EU(\pi) = pU[(1-t)(f_g(I) - I)] + (1-p)U[(1-\lambda t)(f_b(I) - I)]. \tag{2}$$

The firm chooses the optimal level of investment in the risky technology by maximizing its expected utility. The first order condition for the optimal level of I is

$$\frac{\partial EU(\pi)}{\partial I} = pU'[\pi_g](1-t)\left[f_g'(I) - 1\right] + (1-p)U'[\pi_b]\ (1-\lambda t)[f_b'(I) - 1] = 0, \tag{3}$$

where $\pi_g = (1-t)(f_g(I) - I) > 0$ denotes the after-tax profit in the good state of the world, and $\pi_b = (1-\lambda t)(f_b(I) - I) < 0$ is the after-tax profit in the bad state. The first term of eq. (3) demonstrates that a higher investment in the risky technology increases the firm's profit in the good state of the world. The second term shows that the loss increases with the investment if the bad state occurs.

We now derive predictions for the relation between a country's tax system and firm risk-taking. 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. (3) with respect to λ shows that risk-taking increases when firms are better able to recoup economic losses (i.e., when λ is higher):

$$\frac{dI}{d\lambda} = \frac{t[1 - f_b'(I)](1-p)[U'(\pi_b) + U''(\pi_b)\pi_b]}{-SOC} > 0, \tag{4}$$

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

Eq. (4) shows that greater loss offset results in a higher investment in the risky technology. 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. (4) also shows that the size of the risk-taking effect of λ depends on the country's tax rate, t. Specifically, t enters eq. (4) 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. (4) 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, as measured by the variance of the returns in the different states of the world. The size of the risk-taking effect of λ depends on the tax rate (t).*

Proof. Consider eq. (4). The second order condition *SOC* is is fulfilled (i.e., negative) as $U''(\pi) < 0$ and $f_g''(I)$, $f_b''(I) < 0$. Thus, the denominator of eq. (4) is positive. Note that $U''(\pi_b)\,\pi_b > 0$ as $\pi_b < 0$. As $f_b'(I) < 0$, the numerator is also positive, so that $\frac{dI}{d\lambda} > 0$. ■

3.2.2 Hypothesis 1

Our first hypothesis considers how λ affects firm risk-taking by focusing on the statutory loss carryback/carryforward periods.[7] Longer carryback/carryforward periods increase the probability that companies can recoup losses incurred. Thus, based on Proposition 1, we predict the following:

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

[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 statutory loss periods because the government can directly influence these rules.

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 of the tax rate on this relation is positive. Intuitively, 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. (3):

$$\begin{aligned}\frac{dI}{dt} \;=\; & \frac{1}{-SOC}\left\{-pU''(\pi_g)\,\pi_g\left[f_g'(I)-1\right]-pU'(\pi_g)\left[f_g'(I)-1\right]-\right.\\ & \left.(1-p)\,U''(\pi_b)\,\lambda\pi_b\left[f_b'(I)-1\right]-(1-p)\,U'(\pi_b)\,\lambda[f_b'(I)-1]\right\}. \qquad (5)\end{aligned}$$

For ease of interpretation, we rewrite eq. (5) using the Arrow-Pratt coefficient of relative risk aversion, $R_R(\pi) = -\frac{U''(\pi)}{U'(\pi)}|\pi|$.[8] Then, after simplifying, $\frac{dI}{dt}$ becomes

$$\frac{dI}{dt} = \frac{U'(\pi_g)\,p\left[f_g'(I)-1\right]\left[R_R(\pi_g)-1\right]-\lambda U'(\pi_b)\,(1-p)\left[f_b'(I)-1\right]\left[R_R(\pi_b)+1\right]}{-SOC}. \qquad (6)$$

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 risky investment 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

[8] As $\pi^L < 0$, 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.

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.[9]

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 always increase risk-taking.

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

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

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

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

Proof. The denominator of eq. (6) is positive, as the second order condition is negative (see proof of proposition 1). Examination of the numerator of eq. (6) is thus sufficient.

On 1): Taxes increase risk-taking for firms with $R_R > 0$ if $U'(\pi_g)\, p \left[f_g'(I) - 1\right] \leq -U'(\pi_b)(1-p)[f_b'(I) - 1]$. From eq. (3) we know that this is fulfilled with equality when $\lambda = 1$. Thus, $\frac{dI}{dt}\Big|_{\lambda=1} > 0$.

On 2). Inspection of eq. (6) shows that the sign of eq. (6) is fully determined by $[R_R(\pi_g) - 1]$ when $\lambda = 0$. ■

[9] This effect corresponds to the findings of Domar and Musgrave (1944), who evaluate individual portfolio investment risk-taking for a scenario with full, partial, or no loss offset.

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.[10] In this case, taxes decrease firm risk-taking in the case of no expected loss offset.

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). For these firms, taxation affects successful risky investments via a tax on income, but the firm does not receive much (if any) offset for losses incurred. Accordingly, risk-averse managers are less likely to engage in risk-taking and instead prefer to invest in safer projects that generate more predictable returns. 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").*

---

[10] Chiappori and Paiella (2011) show that relative risk aversion is constant and relatively low. Using existing evidence on the effect of wage changes on labor supply, Chetty (2006) finds a mean estimate of the coefficient of relative risk aversion of 0.71, with all estimates in a range between 0.15 and 1.78 in the baseline case. We expect that the level of firm risk aversion is attenuated relative to estimates for individuals based on predictions derived from principal-agent contracting. Specifically, managers generally receive some fixed compensation (a salary) as well as a variable component (bonus or stock-based compensation) to align managerial incentives with those of the shareholders; because the manager receives some portion of the salary regardless of the firm's performance, he likely exhibits less risk aversion than if all of the compensation were a function of firm profits.

4 Research Design & Sample Selection

Tax loss carryback and carryforward periods within a country exhibit little time-series variation. Therefore, we test our hypotheses in a cross-country setting to examine the effect of differing tax rules across many jurisdictions. In Section 6, we additionally provide a within-country analysis using a recent change of Spanish loss carryforward rules.

4.1 Testing the Effect of Loss Offset Rules (H1)

We test our first hypothesis with two different specifications: an OLS panel estimation and a matched sample difference-in-difference design.

4.1.1 OLS Panel Estimation

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

$$Risk_{it} = \beta_0 + \beta_1 LC_{jt} + \beta_2 StdCTR_{jt} + \beta_3 LC^{*}StdCTR_{jt} + \beta_n X_{ijt} + \theta_k + \rho_t + \epsilon_{it}, \quad (7)$$

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 industry fixed effects; and ρ_t are year fixed effects. 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.[11]

[11] 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.

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 the 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.[12] This approach follows John, Litov, and Yeung (2008), Faccio, Marchica, and Mura (2011), and Acharya, Amihud, and Litov (2011) and removes the influence of home-country and industry-specific economic cycles, which firm management cannot alter.[13] This measure thus permits a clean analysis of firm-specific risk that directly reflects corporate operating and investment decisions. In Section 5.4, 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) 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. (7). Therefore, to the extent we find a positive relation in eq. (7), this assumption should understate the result. 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, as lower rates generally apply to very small firms.

We control for a firm's *Size* (log of total assets), as larger firms undertake the bulk of aggregate investment (Djankov, Ganser, McLiesh, Ramalho, and Shleifer, 2010). However, larger firms also have fewer risky opportunities and lower overall operating risk (John, Litov, and Yeung, 2008). Furthermore, prior literature documents that a

[12]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 5.4.3) 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 5.4.4). In both tests we find consistent results.

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

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 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, Litov, and Yeung (2008), we also control for *ROA*, measured as EBIT/assets, which captures a firm's ability to fund investments and risky projects. 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

We also employ a matched sample difference-in-difference (DiD) analysis to test our first hypothesis. 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 years, and Denmark, France, Norway, and Spain increased the loss carryforward period (see Table 1 for details).

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 precise identification of the treatment effect by controlling for both observed and unobserved firm characteristics.

We calculate the DiD effect using the following regression:

$$Risk_{it} = \beta_0 + \beta_1 Treated_i + \beta_2 Post_{it} + \beta_3 Treated^* Post_{it}, \tag{8}$$

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 ($\beta_3 > 0$).[14]

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). "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.[15]

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

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

[14] The only countries in our sample to increase the loss carryback period are Norway (in 2008 and 2009) and the U.S. (in 2009), but as these increases were introduced retroactively, we do not include them in our analysis. 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.

[15] 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.

$$\Delta Risk_{it} = \gamma_0 + \gamma_1 \Delta CTR_{jt} + \gamma_n \Delta X_{ijt} + \rho_t + \epsilon_{it}. \tag{10}$$

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 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).[16] These countries have comparable levels of tax enforcement, and prior cross-country taxation studies focus on a similar geographic sample (e.g., Devereux, Griffith, and Klemm, 2002; Devereux and Griffith, 2003).[17] 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

[16] 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 for our research question. 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.

[17] 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.

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.

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, Robinson, Rogers, and Zechman (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, Litov, and Yeung (2008) and find that the measures are highly correlated (0.84). The average loss carryback period for our sample is 1.54 years; the average carryforward period is 17.82 years. The mean statutory corporate tax rate is 36.1 percent. 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.[18] 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. Considering 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).[19] 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.

[18]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.

[19]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.

[Insert Table 3 here.]

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.[20]

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 that this key identification assumption is satisfied. 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 differential changes in risk-taking can be attributed to the changes in statutory loss offset rules.

[Insert Figure 1 here.]

[20]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. (8) 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.[21]

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,

[21]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.[22]

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, and this relation is affected by the level of the country's tax rate.

5.2 Firm-level Effects of Corporate Tax Rates

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.[23] 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 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 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).

[22]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.

[23]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 ($0.038/0.210 = 0.182$).

Table 4, Panel B presents results from estimating eq. (10), 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).[24]

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.

We next conduct several additional tests to explore the relation between a country's tax system and firm risk-taking, as well as to ensure the robustness of the main results.

5.3 Size and Nonlinear Effects

First, we test if the effect of loss offset on risk-taking differs by firm size. 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). 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 5, 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.

[24]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.

[Insert Table 5 here.]

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 5, cols. (3) to (4). The coefficients on LCB and LCF remain positive and significant as in the 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.

5.4 Robustness Tests

5.4.1 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 approach, 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. In this section, we use an instrumental variables specification to mitigate this concern.

We re-estimate eq. (7) 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.[25] Columns (3) and (6) include the results from the second-stage regression. The coefficients are positive and significant, confirming that our main results are robust even when considering potential endogeneity issues.

[Insert Table 6 here.]

5.4.2 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, evidence 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, Lehn, and Zitter (2010). This measure captures how volatile firm value is over a one-year period. We again find consistent results.

[25] 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 suggested by Stock, Wright, and Yogo (2002).

5.4.3 Country-level Estimation

Following John, Litov, and Yeung (2008), we also test the relation between loss offset rules and firm risk-taking at the country-level. We compute the average *Risk* for each country-year in the sample and regress this amount on the country's loss carryforward and loss carryback periods, as well as the country tax rate 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.

5.4.4 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.

5.4.5 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. (7) and (9) 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.

6 Within-Country Analysis

While the international setting provides heterogeneity for testing the effect of loss offset rules, other unobserved cross-country factors could influence our results. Therefore, we also test how changes in Spanish tax loss rules imposed from 2011 to 2013 affect Spanish firms' risk-taking.

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.[26]

6.1 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 groups of firms.

For this test we use firm-level data from Bureau van Dijk's Amadeus data set.[27] We select all incorporated Spanish firms from Amadeus and then follow the same sample

[26]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 in Section 5.3, we expect that the loss offset limitations will have a larger immediate effect than the extension of the overall loss offset period.

[27]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, Eggert, Keuschnigg, and Winner (2010); or Karkinsky and Riedel (2012).

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.[28]

We specify a bandwidth of €150,000 for the regression discontinuity test, which means that we compare risk-taking for firms with revenues between €20.00 million and €20.15 million to firms with revenues between €19.85 million and €20.00 million in 2010.[29] We also report results using half and double this bandwidth (€75,000 and €300,000, respectively).

6.2 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 7 reports results from the regression discontinuity analysis. As expected, we find a negative and significant coefficient for the Average Treatment Effect. This result 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 confirms the Section 5 results that show that tax loss rules are an important determinant of firm risk-taking.

[28] 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.

[29] 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.

[Insert Table 7 here.]

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. 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

References

Acharya, Viral V., Yakov Amihud, and Lubomir Litov, 2011, Creditor rights and corporate risk-taking, *Journal of Financial Economics* 102, 150–166.

Albring, Susan M., Dan S. Dhaliwal, Inder K. Khurana, and Raynolde Pereira, 2011, Short-term incentive effects of a reduction in the NOL carryback period, *Journal of the American Taxation Association* 33, 67–88.

Altshuler, Rosanne and Alan J. Auerbach, 1990, The significance of tax law asymmetries: An empirical investigation, *The Quarterly Journal of Economics* 105, 61–86.

Altshuler, Rosanne, Alan J. Auerbach, Michael Cooper, and Matthew Knittel, 2009, Understanding U.S. corporate tax losses, *Tax Policy and the Economy* 76, 73–122.

Appelbaum, Elie and Eliakim Katz, 1986, Measures of risk aversion and comparative statics of industry equilibrium, *The American Economic Review* 76, 524–529.

Asea, Patrick K. and Stephen J. Turnovsky, 1998, Capital income taxation and risk-taking in a small open economy, *Journal of Public Economics* 68, 55–90.

Asker, John, Joan Farre-Mensa, and Alexander Ljungqvist, 2014, Corporate investment and stock market listing: A puzzle?, Working Paper, ECGI - Finance.

Asplund, Marcus, 2002, Risk-averse firms in oligopoly, *International Journal of Industrial Organization* 20, 995–1012.

Bargeron, Leonce, Kenneth Lehn, and Chad J. Zitter, 2010, Sarbanes-Oxley and corporate risk-taking, *Journal of Accounting and Economics* 49, 34–52.

Chetty, Raj, 2006, A new method of estimating risk aversion, *American Economic Review* 96, 1821–1834.

Chiappori, Pierre-Andrè and Monica Paiella, 2011, Relative risk aversion is constant: Evidence from panel data, *Journal of the European Economic Association* 9, 1021–1052.

Choy, Helen, Juichia Lin, and Micah S. Officer, 2014, Does freezing a defined benefit pension plan affect firm risk?, *Journal of Accounting and Economics* 57, 1–21.

Coles, Jeffrey L., Naveen D. Daniel, and Lalitha Naveen, 2006, Managerial incentives and risk-taking, *Journal of Financial Economics* 79, 431–468.

Cooper, Michael G. and Matthew Knittel, 2010, The implications of tax asymmetry for US corporations, *National Tax Journal* 63, 33–62.

Creal, Drew, Leslie Robinson, Jonathan Rogers, and Sarah Zechman, 2013, The multinational advantage, Research Paper 11-37, Chicago Booth.

Cullen, Julie B. and Roger H. Gordon, 2007, Taxes and entrepreneurial risk-taking: Theory and evidence for the US, *Journal of Public Economics* 91, 1479–1505.

Demski, Joel S. and Ronald A. Dye, 1999, Risk, return, and moral hazard, *Journal of Accounting Research* 37, 27–55.

Devereux, Michael P. and Rachel Griffith, 2003, Evaluating tax policy for location decisions, *International Tax and Public Finance* 10, 107–126.

Devereux, Michael P., Rachel Griffith, and Alexander Klemm, 2002, Corporate income tax reforms and international tax competition, *Economic Policy* 17, 451–195.

Devereux, Michael P., Michael Keen, and Fabio Schiantarelli, 1994, Corporation tax asymmetries and investment. Evidence from U.K. panel data, *Journal of Public Economics* 53, 395–418.

Djankov, Simeon, Tim Ganser, Caralee McLiesh, Rita Ramalho, and Andrei Shleifer, 2010, The effect of corporate taxes on investment and entrepreneurship, *American Economic Journal: Macroeconomics* 2, 31–64.

Domar, Evsey D. and Richard A. Musgrave, 1944, Proportional income taxation and risk-taking, *Quarterly Journal of Economics* 58, 388–422.

Dreßler, Daniel and Michael Overesch, 2013, Investment impact of tax loss treatment – empirical insights from a panel of multinationals, *International Tax Public Finance* 20, 513–543.

Edgerton, Jesse, 2010, Investment incentives and corporate tax asymmetries, *Journal of Public Economics* 94, 936–952.

Egger, Peter, Wolfgang Eggert, Christian Keuschnigg, and Hannes Winner, 2010, Corporate taxation, debt financing and foreign plant ownership, *European Economic Review* 54, 96–107.

Erickson, Merle and Shane Heitzman, 2010, NOL poison pills: Selectiva v. selectiva, *Tax Notes*, June 23.

Faccio, Mara, Maria-Teresa Marchica, and Roberto Mura, 2011, Large shareholder diversification and corporate risk-taking, *Review of Financial Studies* 24, 3601–3641.

Feldstein, Martin S., 1969, The effect of taxation on risk-taking, *Journal of Political Economy* 77, 755–764.

Géczy, Christopher, Bernadette A. Minton, and Catherine Schrand, 1997, Why firms use currency derivatives, *Journal of Finance* 52, 1323–1354.

González, Francisco, 2005, Bank regulation and risk-taking incentives: An international comparison of bank risk, *Journal of Banking & Finance* 29, 1153 – 1184.

Graham, John R. and Daniel A. Rogers, 2002, Do firms hedge in response to tax incentives?, *Journal of Finance* 57, 815–839.

Graham, John R. and Clifford W. Smith, 1999, Tax incentives to hedge, *Journal of Finance* 54, 2241–2262.

Guay, Wayne R., 1999, The sensitivity of CEO wealth to equity risk: An analysis of the magnitude and determinants, *Journal of Financial Economics* 53, 43–71.

Guenther, David A., Steven R. Matsunaga, and Brian M. Williams, 2013, Tax avoidance, tax aggressivness, tax risk and firm risk, available at SSRN: http://dx.doi.org/10.2139/ssrn.2153187.

Hall, Brian J. and Kevin J. Murphy, 2002, Stock options for undiversified executives, *Journal of Accounting and Economics* 33, 3–42.

Harris, Milton and Artur Raviv, 1991, The theory of capital structure, *Journal of Finance* 46, 297–356.

Hassett, Kevin A. and R. Glenn Hubbard, 2002, Tax policy and business investment, in A. Auerbach and M. Feldstein, eds.: *Handbook of Public Economics* 3, Elsevier, Chap. 20, 1293–1343.

Huizinga, Harry and Luc Laeven, 2008, International profit shifting within multinationals: A multi-country perspective, *Journal of Public Economics* 92, 1164–1182.

Hunter, William C. and Stephen D. Smith, 2002, Risk management in the global economy: A review essay, *Journal of Banking & Finance* 26, 205 – 221.

Hutchens, Michelle and Sonja Rego, 2012, Tax risk and the cost of equity capital, available at SSRN: http://dx.doi.org/10.2139/ssrn.2186564.

Janssen, Maarten C.W. and Vladimir A. Karamychev, 2007, Selection effects in auctions for monopoly rights, *Journal of Economic Theory* 134, 576 – 582.

John, Kose, Lubomir Litov, and Bernhard Yeung, 2008, Corporate governance and risk-taking, *Journal of Finance* 63, 1679–1728.

Karkinsky, Tom and Nadine Riedel, 2012, Corporate taxation and the choice of patent location within multinational firms, *Journal of International Economics* 88, 176–185.

Leland, Hayne E., 1998, Agency costs, risk management and capital structure, *Journal of Finance* 53, 1212–1243.

Lewellen, Katharina, 2006, Financing decisions when managers are risk averse, *Journal of Finance* 82, 551–589.

May, Don O., 1995, Do managerial motives influence firm risk reduction strategies?, *Journal of Finance* 50, 1291–1308.

Maydew, Edward L., 1997, Tax induced earnings management by firms with net operating losses, *Journal of Accounting Research* 35, 83–96.

Mirrlees, James, Stuart Adam, Tim Besley, Richard Blundell, Steve Bond, Robert Chote, Malcolm Gammie, Paul Johnson, Gareth Myles, and James Poterba, 2011, Small business taxation, in *Tax By Design: The Mirrlees Review*, Oxford University Press, Chap. 19, 451–469.

Neuman, Stevanie S., Thomas C. Omer, and Andrew Schmidt, 2013, Risk and return: Does tax risk reduce firms' effective tax rates?, available at SSRN: http://ssrn.com/abstract=2216878.

Officer, Lawrence H., 2011, Exchange Rates Between the United States Dollar and Fortyone Currencies, Measuring Worth, available online at www.measuringworth.com/exchangeglobal.

Petersen, Mitchell A., 2009, Estimating standard errors in finance panel data sets: Comparing approaches, *Review of Financial Studies* 22, 435–480.

Porcano, Thomas M., 1986, Corporate tax rates: Progressive, proportional or regressive, *Journal of the American Taxation Association* 7, 17–31.

Poterba, James M. and Andrew Samwick, 2002, Taxation and household portfolio composition: US evidence from the 1980s and 1990s, *Journal of Public Economics* 87, 5–38.

Purnanandam, Amiyatosh K., 2008, Financial distress and corporate risk management: Theory and evidence, *Journal of Financial Economics* 87, 706–739.

Rajgopal, Shivaram and Terry Shevlin, 2002, Empirical evidence on the relation between stock option compensation and risk taking, *Journal of Accounting and Economics* 33, 145–171.

Rego, Sonja O., 2003, Tax-avoidance activities of U.S. multinational corporations, *Contemporary Accounting Research* 20, 805–833.

Sandmo, Agnar, 1971, On the theory of the competitive firm under price uncertainty, *The American Economic Review* 61, 65–73.

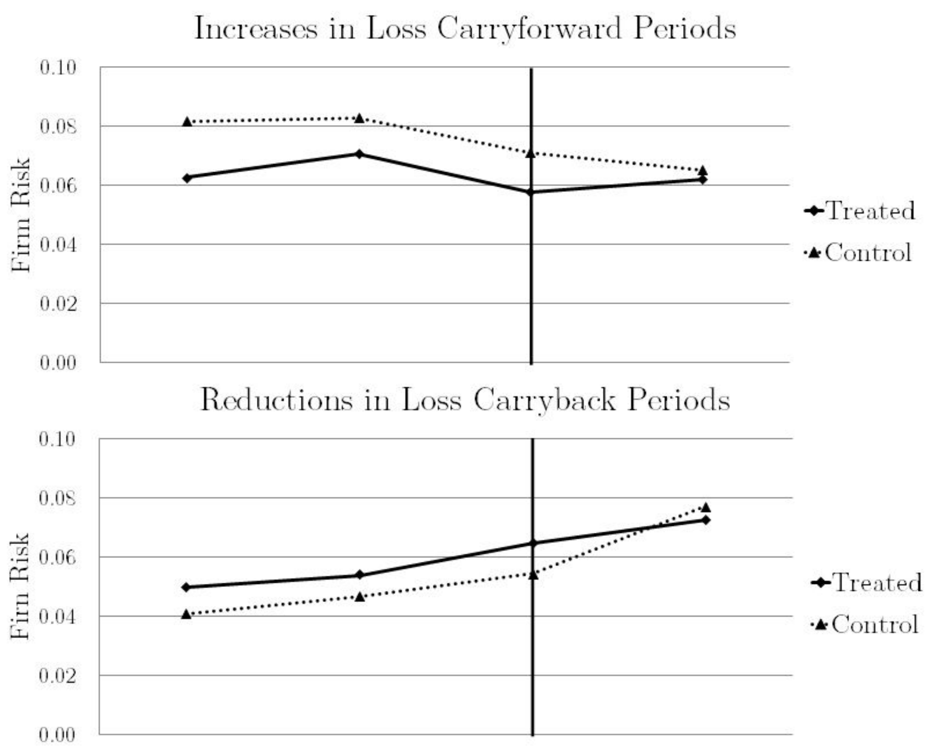
Stiglitz, Joseph E., 1969, The effects of income, wealth and capital gains taxation on risk-taking, *Quarterly Journal of Economics* 83, 263–283.

Stock, James H., Jonathan H. Wright, and Motohiro Yogo, 2002, A survey of weak instruments and weak identification in generalized method of moments, *Journal of Business & Economics Statistics* 20, 518–529.

Tufano, Peter, 1996, Who manages risk? An empirical examination of risk management practices in the gold mining industry, *Journal of Finance* 51, 1097–1137.

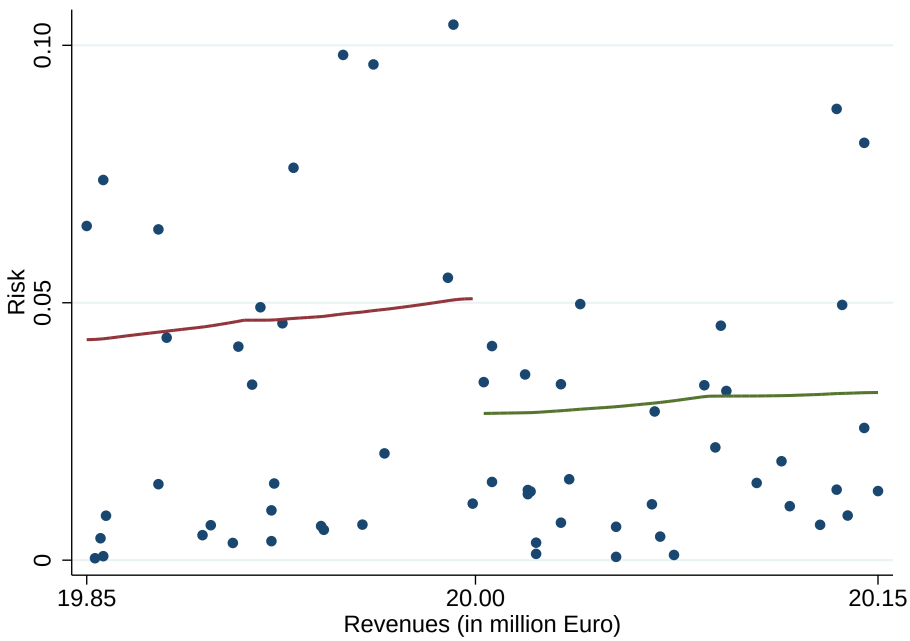
Zimmermann, Jerold L., 1983, Taxes and firm size, *Journal of Accounting and Economics* 5, 119–149.

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 local polynomial regressions on 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 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 results from testing 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) present results for the full sample. Columns (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 includes 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. T-statistics are presented in parenthesis; in Panel A (B), standard errors are clustered by firm and by country-year (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)

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

Size and Nonlinear Effects

This table presents size and nonlinear analysis of the effect of loss offset provisions on firm risk-taking. Columns (1) and (2) provide results from an OLS regressions of firm risk-taking on country tax variables and firm characteristics, interacting 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 in the regression. Control variables are as in Table 3. Appendix A describes all variables. Each specification is estimated with an intercept and includes industry and year fixed effects (FE). In the nonlinear specification, LCB and LCF are centered to avoid multicollinearity. 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.

	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 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)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All Firms	All Firms	High λ	Low λ	All Firms	All Firms	High λ	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

Table 7

Within-Country Analysis

This table presents results from a regression discontinuity analysis of Spanish firms in 2011. 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 €150,000 in col. (1), €75,000 in col. (2), and €300,000 in col. (3). T-statistics in parenthesis. ** indicate statistical significance at the 5% level.

	Dependent Variable: Firm Risk-Taking		
	(1)	(2)	(3)
Average Treatment Effect	-0.055**	-0.053	-0.044**
	(-2.31)	(-1.58)	(-2.41)
Bandwidth	150,000	75,000	300,000