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Taxation and the allocation of risk inside the multinational firm

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ABSTRACT

This paper provides the first theoretical and empirical analysis of how taxation shapes the joint allocation of risk and profits inside the multinational firm. Theoretically, we identify three mechanisms through which corporate taxes may shape the within-firm allocation of risk: (1) transfer pricing rules requiring risk to be compensated with higher expected returns create incentives to shift risk to low-tax jurisdictions as a means to shift profits; (2) risk-averse owners create incentives to allocate risk to high-tax affiliates to maximize risk-sharing with governments; (3) limited loss offset creates incentives to shift risk to affiliates in other countries. Empirically, we show that multinational firms disproportionately allocate risk to low-tax countries and that the key mechanism is the nexus between risk and profits established by transfer pricing rules. Within-firm differences in risk explain a significant fraction of the well-established correlation between profits and tax rates suggesting that risk shifting is a quantitatively non-negligible channel for profit shifting.

1. Introduction

With an ever larger share of economic activity being performed by global firms with operations in many countries, the tax rules determining *where* profits are taxed have taken center stage in recent policy debates about business taxation. The key concern is that multinational firms shift profits to countries with low or no taxation of corporate income, thus causing erosion of tax bases in countries with high and moderate tax rates. To prevent this, tax rules stipulate that transactions between affiliates must take place at arm's length prices, which ensures that the taxable profit recorded by each affiliate is commensurate with the value it creates. Ultimately, an affiliate's taxable profits should be determined by three value drivers: the *functions* it performs, the *assets* it employs and the *risk* it bears (OECD, 2017).

It is widely believed, however, that corporate tax systems remain vulnerable to base erosion for two reasons. First, firms may shift the functions, assets and risk that create value to countries with low tax rates and thus reduce the global tax bill in a manner that is fully consistent with arm's length pricing. Indeed, there is empirical evidence that multinational firms *shift functions*, such as manufacturing capacity (Mutti and Grubert, 2004) and headquarter functions (Voget, 2011), and *shift assets*, such as financial assets (Ruf and Weichenrieder, 2012), intangible assets (Dischinger and Riedel, 2011) and patents (Karkinsky and Riedel, 2012; Griffith et al., 2014), to affiliates facing low effective tax rates. Second, firms may misprice transactions between affiliates such that low-tax affiliates record a disproportionate share of firms' taxable profits given the value they create. Empirical studies find evidence that *transfer mispricing* occurs for trade in both goods (Cristea and Nguyen, 2016; Davies et al., 2018) and services (Hebous and Johannesen, 2015).

In this paper, we provide a first systematic analysis, theoretical and empirical, of how multinational firms *shift risk* in response to tax incentives. Our main premise is that firms face many types of risk - output prices may go down, input prices may go up, business partners may go bankrupt - and that firms can shift these risks across affiliates by changing where tasks are performed and by adjusting the contracts that govern intra-firm transactions. From this point of departure, we investigate how corporate taxes affect firms' choices regarding the allocation of risk and to what extent such risk shifting contributes to the erosion of tax bases in high-tax countries.

We first develop theoretical predictions in a simple model where a multinational firm operates in two countries with different corporate tax rates. The low-tax affiliate produces and sells an intermediate good to the high-tax affiliate, which produces and sells a consumer good. The revenue of the high-tax affiliate is stochastic because the consumer price is subject to a shock. The firm can flexibly shift *ex ante* income risk to the low-tax affiliate by conditioning the price of the intermediate good on the *ex post* realization of the shock.

As a theoretical benchmark, we show that, with no transfer price rules, no risk aversion and no restrictions of loss offset, the within-firm risk allocation is independent of tax rates. However, transfer pricing rules requiring risk to be compensated with higher expected returns create incentives to shift risk to the low-tax country as a means to also shift profits; risk aversion, conversely, creates an

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incentive to shift risk to the high-tax country to achieve more risk sharing with governments;[1] and limited loss offset induces the firm to allocate risk to other countries because of the probability that losses incurred in one period cannot shelter gains in other periods.

Starting from this theoretical understanding of the incentives underlying the allocation of risk and profits inside the multinational firm, we embark on an empirical analysis. We combine proprietary firm databases from Bureau Van Dijk to construct a dataset that covers the period 1995–2013. The dataset includes unconsolidated financial information about roughly 350,000 corporations with foreign affiliates as well as ownership information serving to identify corporations belonging to the same multinational firm. Following other recent studies of taxation and corporate risk (e.g. Langenmayr and Lester, 2018), our main measure of risk is the standard deviation of the annual return to equity taken over the sample period, but we conduct robustness checks with alternative risk measures.

To empirically motivate the premise that multinational firms can shift risk across affiliates, we compare the correlation between tax rates and risk in two samples of entities: those *with* foreign affiliates (multinational firms) and those *without* foreign affiliates (national firms). The difference is striking. In the sample of national firms, we observe that entities facing higher tax rates exhibit more risk as predicted by standard theory (Domar and Musgrave, 1944) whereas in the sample of multinational firms we observe just the opposite. A possible explanation is that the overall risk of multinational firms responds to tax incentives in the same way as national firms, but that risk is shifted across borders from high-tax affiliates to low-tax affiliates to facilitate profit shifting.

In the main empirical analysis, we focus on the sample of multinational firms and identify the effect of corporate taxes on the allocation of risk across affiliates from within-firm variation. Controlling for observable characteristics at the country level (such as size and per capita income) and the affiliate level (such as size and industry), we effectively ask whether affiliates facing relatively low tax rates bear more or less risk than affiliates of the same firm facing relatively high tax rates. The results indicate that risk is allocated predominantly to low-tax countries: we estimate a coefficient of around −0.2 on the tax variable suggesting that an increase in the tax rate of 10 percentage points is associated with a decrease in the standard deviation of ROE of around 0.02 (corresponding to around 6% at the sample mean). In robustness checks, we find qualitatively very similar results when we employ alternative measures of affiliates' income risk.

The basic cross-sectional specification may suffer from endogeneity: if countries with low tax rates, for instance, tended to have unobservable characteristics that attract particularly risky business activities (within industries and size groups), our main estimates would suffer from a negative bias. We address this concern in two ways. First, we estimate a panel version of the baseline model: we split the sample period in two subperiods, calculate affiliate-level risk for each subperiod separately and estimate an equation with period and affiliate fixed effects (nesting country fixed effects). Here, our identification strategy exclusively rests on reform variation in tax rates; we effectively ask whether affiliates facing a change in the corporate tax rate exhibit a systematic change in risk relative to affiliates experiencing no change in the tax rate. Second, we re-estimate the cross-sectional model augmented with country fixed effects (absorbing domestic tax rates) and a variable capturing the average foreign tax rate in the countries where the firm is operating. Here, our identification strategy is based on within-country variation in foreign tax rates; we effectively ask whether affiliates belonging to firms operating primarily in high-tax countries have different risk characteristics than affiliates in the same country belonging to firms operating primarily in low-tax countries.

The correlation between taxes and return variability could, in principle, reflect both, *ex ante* and *ex post* behavior. On the one hand, firms may allocate inherently more risky activities to low-tax affiliates or contractually shift risk to low-tax affiliates *before* uncertainty is resolved. On the other hand, firms may also be able to reallocate profits to low-tax affiliates *after* uncertainty has resolved. We have relatively strong priors that *ex post* profit shifting is of limited empirical relevance: ad hoc adjustments of the terms of a transaction between affiliates effectively violate the arms' length principle and some tax authorities explicitly consider it a reason to conduct an audit. Recent empirical work provides some evidence for these priors by showing that *ex post* profit shifting, if it occurs at all, is limited to adjustment of user fees for intangible assets (Hopland et al., 2018). Our own analysis suggests that it is *ex ante* risk shifting rather than *ex post* profit shifting that drive our main results. First, the effect of taxes on the allocation of risk is no larger for firms with large stocks of intangible assets (and hence a large scope for adjusting user fees ex post). Second, we find that the estimated tax effect on affiliate risk is qualitatively similar to our baseline results when we use a measure of *ex ante* risk taking: the "normal" return volatility associated with business operations in entities' 4-digit industries. In other words, firms appear to allocate activities in high-risk industries to low-tax countries and activities in low-risk industries to high-tax countries. To ensure that the industry risk measure is unconfounded by ex post profit shifting, the industries' return volatility is constructed from the universe of *national* firms in our data.

We conduct a number of tests to explore the mechanisms underlying the finding that more risk is allocated to affiliates in low-tax environments. We find evidence that the nexus between risk and profits established by transfer pricing rules plays an important role: the effect of taxes on risk is economically large and highly statistically significant in countries with formal transfer pricing rules but small and statistically indistinguishable from zero in countries without such rules. By contrast, risk aversion does not seem to be an empirically important driver of risk allocation: we find similar tax effects on risk for firms that are majority-owned by individuals with significant exposure to firms' risk, and firms with dispersed ownership. Loss offset rules affect the risk allocation directly but only marginally change the sensitivity of the risk allocation with respect to tax rates.

Finally, we explore the importance of risk shifting as a channel for profit shifting. Consistent with a large number of existing studies, we find a strong correlation between reported pre-tax profitability and corporate tax rates within firms, which can be interpreted as an overall measure of profit shifting through all channels. However, we also document that within-firm differences in risk contribute significantly to the observed correlation between tax rates and profitability suggesting that risk shifting to low-tax countries plays a relevant role in the erosion of corporate tax bases in high-tax countries.

Our analysis relates to a large literature on taxation and risk (surveyed by Sandmo, 1985; Buchholz and Konrad, 2014). This literature emphasizes that taxation may increase the risk appetite of private agents when gains and losses are treated symmetrically for tax purposes (Domar and Musgrave, 1944) whereas asymmetries (Auerbach, 1986; Mayer, 1986), for instance in the form of imperfect loss offset (Altshuler and Auerbach, 1990; Devereux et al., 1994; Edgerton, 2010; Dressler and Overesch, 2013; Ljungqvist et al., 2017; Langenmayr and Lester, 2018) or tax rate progressivity (Gentry and Hubbard, 2000; Cullen and Gordon, 2007; Mukherjee et al., 2017) deter risk. While existing studies have also analyzed how risk decisions are shaped by mergers and acquisitions (Auerbach, 1986) and business group affiliation (Khanna and Yafeh, 2005; Gopalan et al., 2007), the literature is generally concerned with the overall risk of the firm and not with the distribution of risk across the various parts of the firm which is

[1] Under a corporate income tax with symmetric treatment of gains and losses, the government effectively acts as a dormant partner with a stake equal to the tax rate.

the focus of our paper. Our analysis also contributes to a growing literature on the techniques used by multinational firms to shift profits to low-tax environments (see papers cited above). While legal scholars have argued that risk shifting may serve as a channel for profit shifting (Schön, 2014), we are not aware of any formal theoretical nor empirical analysis of this tax avoidance technique.

Our results are relevant for current policy discussions about base erosion and profit shifting. While governments have recently attempted to enhance the protection of corporate tax bases in high-tax countries within the framework of the arm's length principle (OECD, 2015), the *risk-cum-profit-shifting* identified in this paper highlights the limitations of this approach. The migration of risk to low-tax environments appears to contribute significantly to base erosion; yet it is perfectly legitimate under the prevailing approach to taxing multinational firms.

The paper proceeds as follows. Section 2 provides some institutional background. Section 3 lays out the theory. Section 4 describes the data. Section 5 presents the empirical results. Section 6 concludes.

2. Background

When a firm operates in several countries, it must decide not only how much risk to take but also how to allocate the risk across entities. The risk of a given entity depends partly on its real activities: How volatile are the markets where it acquires inputs? How much exposure does it have to exchange rate fluctuations through sales in foreign markets? How likely is it that competitors obtain a technological edge? However, the ultimate distribution of risk also depends on within-firm agreements that shift risk between affiliates. Consider a stylized example where a manufacturer in one country produces and sells a single good to an affiliated distributor in another country. At one extreme, they may fix the transfer price at production costs (plus a mark-up), which effectively allocates all the risk related to fluctuating prices in the market for final goods to the distributor. At the other extreme, they may agree to set the transfer price at the *ex post* realization of the sales price in the market for final goods (minus a mark-up), which allocates all the risk to the manufacturer. Any intermediate allocation of risk can be achieved by letting the transfer price have two components: one that is fixed and another that varies with the sales price.

While this example describes the risk allocation decision in the context of a transaction of substance, the transfer of final goods from a manufacturer in one country to a distributor in another, multinational firms often undertake transactions that serve primarily, or even exclusively, to achieve a specific intra-firm allocation of risk. This is most obvious when firms operate captive insurance companies whose sole activity is to insure affiliates against various types of risk. Cost-sharing arrangements, under which a specialized entity acquires the right to future intangible assets in exchange for a fixed payment to the affiliates undertaking research and development, may also serve primarily as risk shifting devices (Schön, 2014).

The within-firm allocation of risk has implications for taxation because transfer pricing rules impose a link between risk and expected returns. Specifically, the OECD Transfer Pricing Guidelines generally require that transactions between related parties be priced as if they were unrelated. Since "in the open market, the assumption of increased risk would also be compensated by an increase in the expected return" (OECD, 2017, p. 53), a firm is required to allocate more expected profits to affiliates that assume more of the group's risk holding other factors constant. In the example above, the transfer price received by the manufacturer, averaged across all states of the world, should be higher the more it varies with the uncertain sales price.

The nexus between risk and expected profits is, in principle, a straightforward application of the arm's length principle; but, in practice, it is complicated to implement because neither risk nor expected profits are directly observable in the firms' financial accounts. The OECD recommends that the effective allocation of risk is determined by analyzing the written contracts that define rights, obligations and contingencies in transactions between affiliates: the risk analysis must "...determine how specific, economically significant risks are contractually assumed by the associated enterprises" (OECD, 2017, p. 54). In the absence of a written contract, the "terms of a transaction may also be found in correspondence/communications between the parties" (p. 47).

While the tax rules generally require the *ex ante* terms of intra-firm transactions to satisfy the arm's length principle, firms will often have incentives to adjust the terms *ex post*. For instance, if a high-tax affiliate does unexpectedly well and is about to close the fiscal year with large profits, it becomes attractive to change the terms of its within-firm transactions retroactively (increasing the price of its purchases or decreasing the price of its sales) to shift some of the unexpected profits to low-tax affiliates. Such *ex post* profit shifting is conceptually different from *ex ante* risk shifting but not straightforward to distinguish from it empirically.

The OECD emphasizes, however, that *ad hoc* adjustments of transfer prices violate the arm's length principle since unrelated parties "will ordinarily seek to hold each other to the terms of the contract, and (...) contractual terms will be ignored or modified after the fact generally only if it is in the interests of both parties." If related parties do not adhere to their *ex ante* contractual agreement, tax authorities may therefore conclude "that the contractual terms have not been followed or are a sham" (1.53). The most prominent study of *ex post* profit shifting notes: "Following conventional wisdom among practitioners, it is very expensive to change transfer prices *ad hoc*, particularly on tangibles. In fact, the OECD recommends that such changes should trigger audits by tax authorities" (Hopland et al., 2018, p. 175). "However," it is added, "for invoicing the use of intangibles, there is still some flexibility" (p. 175). Consistent with the notion that *ex post* profit shifting is associated with significant audit risk with some room for manoeuvre left in case of intangibles, the available evidence suggests that it is of limited empirical importance, at least for tangible assets (Hopland et al., 2018).[2]

Drawing on this reading of the institutional setting and the empirical evidence, our theoretical analysis will assume that firms can engage in *ex ante* risk shifting whereby transfer prices vary with exogenous stochastic shocks; but that they cannot engage in *ex post* profit shifting whereby transfer prices are adjusted on an ad hoc basis. The subsequent empirical analysis will assess the importance of *ex post* profit shifting from two angles: (i) by using a measure of risk that is uncontaminated by *ad hoc* adjustments to transfer prices by construction (ii) by studying separately groups of firms with a different potential for making *ad hoc* adjustments to transfer prices.

3. Theory

In this section, we develop a theoretical framework to study the impact of taxation on the allocation of risk inside the multinational firm. We first derive a benchmark result: without transfer pricing rules, without risk aversion and with unlimited loss offset, differences in corporate tax rates have no bearing on the allocation of risk chosen by the firm. We then sequentially study how transfer pricing rules, risk aversion and limited loss offset change the firm's choice.

[2] Some caution is in order, though, when the Hopland et al. (2018) findings are to be extrapolated to other samples. The Norwegian data used by Hopland et al. differ from ours, especially in terms of average firm size.

3.1. The framework

Consider a world with two countries, a low-tax location (L) and a high-tax location (H).[3] In each of the two countries, there is a corporate entity which is part of the same multinational firm. The entity in L produces an intermediate good and sells it to the entity in H at the transfer price q. The entity in H uses the intermediate good to produce one unit of a consumer good and sells it at the market price p. We normalize the *expected* cost in both locations to zero.

We introduce risk by assuming that profits are subject to a shock $\varepsilon \in \mathbb{R}$ with $E[\varepsilon] = 0$.[4] In principle, the shock could reflect *ex ante* uncertainty about production costs, the consumer price or almost anything else. To facilitate the exposition, we assume that the consumer price is the only source of uncertainty and discuss alternative interpretations below. Hence, the realized price is given by:

$$p(\varepsilon) = \bar{p} + \varepsilon \tag{1}$$

where $\bar{p} > 0$ is the expected price. We assume that ε is realized *after* all of the firm's decisions have been made, which rules out *ex post* profit shifting as discussed above.

The distribution of real activities implies that only the entity in H is directly exposed to the external risk from the consumer good market. However, the firm can engage in *ex ante* risk shifting by having the two entities conclude a contract under which the transfer price depends on the realized shock to the consumer price:

$$q(\varepsilon) = \bar{q} + \alpha\varepsilon \tag{2}$$

The contract specifies two parameters: $\alpha \in [0, 1]$ shifts risk from H to L while leaving the expected profits of both entities unchanged and $\bar{q} \in [0, \bar{p}]$ shifts expected profit from H to L while leaving the allocation of risk unchanged. When $\alpha = 0$, entity L's income is certain and all the risk is in H. When $\alpha = 1$, the roles are reversed. When $\bar{q} = \bar{p}$, the entity in L appropriates all the expected profits and the entity in H just breaks even. When $\bar{q} = 0$, the roles are reversed. The parameter space between these extreme values encompasses any feasible allocation of risk and expected profits across the two entities.

To identify the effect of taxation on firm choices in the simplest possible way, we assume that the firm incurs two agency costs: $c_\alpha(\alpha)$ related to the allocation of risk and $c_{\bar{q}}(\bar{q})$ related to the allocation of expected profits. A possible interpretation is that principal-agent problems create a gain from incentivizing the local management in each affiliate with a combination of risk and expected profits (Jensen and Meckling, 1976; Williamson, 1981; Groves and Loeb, 1979; Prendergast, 1999).[5] To ensure an interior solution, we assume that there is a unique value α^C minimizing $c_\alpha(\alpha)$ with $c'_\alpha(\alpha)(\alpha - \alpha^C) \geq 0$ and $c''_\alpha(\alpha) > 0$ and a unique value $\bar{q}^C$ minimizing $c_{\bar{q}}(\bar{q})$ with $c'_{\bar{q}}(\bar{q})(\bar{q} - \bar{q}^C) \geq 0$ and $c''_{\bar{q}}(\bar{q}) > 0$. Note that both cost measures, $c_\alpha(\alpha)$ and $c_{\bar{q}}(\bar{q})$, are assumed to be non-deductible for tax purposes.[6] Under these assumptions and further assuming full offset of losses, the firm's after-tax profits are given by:

$$\pi(\varepsilon) = (1 - t_H)(p(\varepsilon) - q(\varepsilon)) + (1 - t_L)q(\varepsilon) - c_\alpha(\alpha) - c_{\bar{q}}(\bar{q}) \tag{3}$$

The preferences of the firm owner are represented by a von Neumann-Morgenstern utility function $u(\pi)$ with $u'(.) > 0, u''(.) \leq 0$. The firm owner chooses α and $\bar{q}$ in order to maximize her expected utility:

$$\max_{\alpha,\bar{q}} E\left[u\left(\pi(\varepsilon)\right)\right] \tag{4}$$

3.2. A benchmark result

Within this formal framework, we can now describe the benchmark allocation of risk and expected profits under idealized assumptions.

Proposition 1 (Benchmark)**.** *Assuming no transfer pricing rules, risk neutral owners ($u'' = 0$) and no restrictions on loss offsets, the allocation of risk α and expected profits $\bar{q}$ satisfies the following first-order conditions:*

$$-c'_\alpha(\alpha) = 0 \tag{5}$$

$$t_H - t_L = c'_{\bar{q}}(\bar{q}) \tag{6}$$

implying that $\alpha = \alpha^C$ and $\bar{q} > \bar{q}^C$.

In the absence of transfer pricing rules, choices over risk and expected profits are made independently: Eq. (5) determines the allocation of risk whereas Eq. (6) determines the allocation of expected profits. With risk neutral owners, owners do not value risk sharing with governments and choose to allocate risk so as to minimize agency costs irrespective of the tax rates. As in standard models of profit shifting, the owners sacrifice some organizational efficiency to allocate more expected profits to the low-tax location. Starting from this benchmark result, we proceed by identifying three theoretical mechanisms through which tax rates may affect the allocation of risk.

3.3. Profit-risk nexus rules

Transfer pricing rules require transactions between related parties to be priced as if they were unrelated. Since unrelated enterprises can only be expected to assume more risk if compensated with higher expected profits, transfer pricing rules introduce a nexus between the chosen allocation of risk and the permissible allocations of expected returns: affiliates that take more risk should be rewarded with more profits.

We augment the baseline model with the assumption that tax rules specify the expected transfer price that is appropriate given

[3] We assume that the tax on corporate profits is proportional and thus abstract from complications due to progressive corporate tax schemes.

[4] Note that we do not impose symmetry of the shock distribution. Moreover, assuming an expected value of 0 does not imply a loss of generality since any shock with a non-zero expected value may be restated as a shock with $E[\varepsilon] = 0$ and an adjusted expected profit of $\bar{p}$.

[5] Elitzur and Mintz (1996) were among the first to consider agency problems within the multinational firm in the presence of tax competition. See also Koethenbuerger and Stimmelmayr (2016).

[6] In the Appendix, we present a model where this assumption is relaxed. Intuitively, when the share of agency costs that is deductible in an entity equals its share of the risk, α of the agency costs are deductible in L and $1 - \alpha$ in H, there is an additional incentive to allocate risk and profits to H due to lower tax-inclusive cost.

the risk: $\bar{\theta}(\alpha)$. Hence, the multinational firm is facing the following regulatory constraint when formulating its transfer pricing contract: $\bar{q} = \bar{\theta}(\alpha)$. The derivative $\bar{\theta}'(\alpha) > 0$ can be interpreted as the arm's length price of risk: the marginal increase in returns required to make a firm willing to take on more risk.[7]

Proposition 2. *Augmenting the baseline model with a profit-risk nexus, the first-order condition for the optimal α becomes:*

$$\left[(t_H - t_L) - c'_{\bar{q}}(\bar{q})\right]\bar{\theta}'(\alpha) \geq c'_{\alpha}(\alpha) \tag{7}$$

Starting from an interior solution, increasing the tax rate in a country induces the firm to allocate less risk to that country.

Proof. See the Appendix. ■

When the firm considers allocating more risk to the low-tax country in the presence of a profit-risk nexus, it equates the marginal benefit in terms of being able to allocate more profits to the low-tax country (left-hand side) and the marginal cost in terms of increasing agency costs (right-hand side). Intuitively, tax reforms that narrow the tax differential, by increasing t_L or decreasing t_H, reduce the marginal gain and thus induce the firm to allocate less risk and less profits to L.[8]

3.4. Risk aversion

Theory often assumes that firm owners are risk neutral. While this is justified when ownership is spread out on a large number of well-diversified shareholders, many real-world multinational firms are controlled by individuals and families with significant exposure to firm-specific risk (Shleifer and Vishny, 1986; Admati et al., 1994)[9] and there is empirical evidence that large shareholders exhibit risk averse behavior (e.g. Huddart, 1993; Minettia et al., 2015). The OECD Transfer Pricing Guidelines (2017) acknowledge this by assuming that firms usually demand a risk premium ("in the open market, the assumption of increased risk would also be compensated by an increase in the expected return", p. 53).

In light of this discussion, we derive the effect of tax rates on the allocation of risk in a modified version of the baseline model where firm owners are risk averse, $u'' < 0$.

Proposition 3. *Modifying the baseline model by assuming that owners are risk averse with decreasing absolute risk aversion (DARA), the first-order condition for the optimal α becomes:*[10]

$$(t_H - t_L)\frac{E\left[u'(\pi(\varepsilon))\cdot\varepsilon\right]}{E\left[u'(\pi(\varepsilon))\right]} \leq c'_{\alpha}(\alpha) \tag{8}$$

Starting from an interior solution, increasing the tax rate in a country induces the firm to allocate more risk to that country.

Proof. See the Appendix. ■

The left hand side of Eq. (8) is negative since $u'(\pi_i(\varepsilon))$ and ε are negatively correlated. This implies that the firm allocates *less* risk to the low-tax country than in the baseline with risk-neutral owners, $\alpha < \alpha^C$. Intuitively, holding everything else constant (including the allocation of expected return), it is desirable for the firm to allocate risk to the high-tax country where more of the income volatility falls on the government. When the firm considers allocating more risk to the high-tax country under risk aversion, it equates the marginal benefit in terms of increased risk sharing with governments (left-hand side) and the marginal cost in terms of increased agency costs (right-hand side).

3.5. Imperfect loss offsets

So far we have assumed that tax systems treat profits and losses symmetrically with profits creating tax liabilities and losses creating tax assets for the firm. Generally, firms are not allowed to exchange tax assets for cash, but they may typically use losses to offset taxable profits in other fiscal years. The symmetry assumption in the baseline model is a reasonable approximation if losses can be carried forward or backward over long time horizons, the discount factor is low and the tax base is non-negative in the average year.

Reflecting that some tax systems limit the right to carry losses across fiscal years, we derive how such limits shape the allocation of risk. Specifically, we modify the baseline model by assuming that country i only allows losses up to a limit of $b_i \leq 0$ to offset profits in other fiscal years. Under this assumption, $\bar{p} - \bar{q} + (1-\alpha)\varepsilon^H = b_H$ and $\bar{q} + \alpha\varepsilon^L = b_L$ implicitly define threshold values, ε^H and ε^L, which are the most negative realizations of the shock where losses can fully offset future income in each of the two countries. With this modification, we can write expected after-tax profits as:

$$\bar{p} - t_H B_H - t_L B_L - c_{\alpha}(\alpha) - c_{\bar{q}}(\bar{q}) \tag{9}$$

where $B_H = \bar{p} - \bar{q} - \int_{\varepsilon-\infty}^{\varepsilon^H}(p(\varepsilon) - q(\varepsilon) - b_H)f(\varepsilon)d\varepsilon$ and $B_L = \bar{q} - \int_{\varepsilon-\infty}^{\varepsilon^L}(q(\varepsilon) - b_L)f(\varepsilon)d\varepsilon$ are the expected tax bases in countries H and L, respectively, and $f(\varepsilon)$ is the density. In both countries, expected tax bases exceed expected profits by a term that captures the expected value of the losses that cannot be offset against profits in other fiscal years.

Proposition 4. *Augmenting the baseline model with limits on loss offset, the first-order condition for the optimal α becomes:*

$$t_H\int_{\varepsilon-\infty}^{\varepsilon^H}(-\varepsilon)f(\varepsilon)d\varepsilon - t_L\int_{\varepsilon-\infty}^{\varepsilon^L}(-\varepsilon)f(\varepsilon)d\varepsilon = c'_{\alpha}(\alpha) \tag{10}$$

Starting from an interior solution, the firm allocates less risk to a given country if the country (i) increases its tax rate or (ii) imposes a stricter limit on loss offset (less negative b).

Proof. See the Appendix. ■

In this framework, the allocation of risk affects expected tax bases in both countries through the loss offset rules. The first-order condition shows that allocating more risk to the low-tax country (higher α) decreases the tax cost of limited loss offset in H (first term on left-hand side) but increases it in L (second term on left-hand side) while also affecting organizational efficiency (right-hand side). The gain in

[7] In an earlier version of the paper, we interpreted $\bar{\theta}(\alpha)$ as the arm's length benchmark and allowed the firm to set another transfer price by incurring a concealment cost. The analysis showed that the results on the optimal allocation of risk are robust to adding another dimension of profit shifting to the model in this way.

[8] The above Proposition shows that both tax rates, t_H and t_L affect the risk allocation. The Appendix shows that, in a more general setting with more than two locations, all tax rates affect the risk allocation within the multinational firm. This outcome is due to locational cost of profit and risk allocation (see Huizinga and Laeven (2008) for a similar modeling approach) – which prevent the extreme outcome in which all profit and risk is allocated to the location with the lowest tax rate.

[9] See John et al. (2008) for the argument that the impact of concentrated ownership may be mitigated by better investor protection.

[10] *The first-order condition for the optimal $\bar{q}$ is still given by* Eq. (6).

the first term is larger when loss offset rules in H are stricter (because a smaller part of losses can offset profits in other periods) and when the tax rate in H is higher (because the tax value of offsetting profits in other periods is larger). Similarly, the cost in the second term is larger when loss offset rules in L are stricter and the tax rate in L is higher. Consequently, the firm responds to a tighter loss offset rule and a higher tax rate in a country by allocating less risk to the country.

3.6. Alternative interpretations

To simplify the exposition, we have so far focused on one specific interpretation of the model. In this subsection, we show that the insights we have obtained apply more generally.

First, the assumption that only consumer prices are stochastic is not crucial and not even an inherent feature of the model. Assume, for instance, that consumer prices are deterministic but that the production cost faced by the entity in L is subject to a shock ε. With *expected* cost normalized to zero, pre-tax earnings are still $p(\varepsilon) = \bar{p} + \varepsilon$; however $\bar{p}$ is now the deterministic consumer price received by the entity in H and ε is the stochastic cost incurred by the entity in L. The shock is 'located' in country L and 'shifted' to country H through the choice of α. All findings stay the same.

It is also possible to interpret α and $\bar{q}$ as indicators of real activity and not just properties of the tax accounting. Shifting profit must then be understood as shifting profitable activity and shifting risk as moving risky activities (like e.g. R&D). In the absence of taxes, the firm would have a preferred allocation of real activity across the two countries. Tax rate differences make it attractive to change this allocation. As above, the firm prefers an allocation of profit and risk that equates the tax inclusive benefits with the tax inclusive cost. All of the above findings can be interpreted in this way. We will come back to this interpretation in the empirical analysis.

4. Data

The empirical analysis uses unconsolidated balance sheet information and ownership links between corporations from the databases Amadeus and Orbis maintained by Bureau Van Dijk. The sample of European corporations was drawn from the online version of Amadeus in August 2014 (accounting years: 2003–2013) and from historical versions of Amadeus (for accounting years prior to 2003).[11] The sample of non-European corporations was drawn from the online version of Orbis in August 2014 (accounting years: 2003–2013).[12] While the sample period spans almost two decades, 1995–2013, the coverage is relatively poor in the early years and improves sharply in the early 2000s.

In the main analysis, we study the allocation of risk inside the multinational firm and therefore restrict the sample to corporations with either a foreign parent company, a foreign sister company or a foreign subsidiary.[13] This yields a sample of around 350,000 affiliates of multinational firms, for which financial information is available.[14] While these affiliates are spread out across 134 countries, most of them are located in Europe and very few are located in developing countries, as shown in Table 1. In the empirical analysis, we assess the robustness of our findings to excluding countries with poor coverage.[15]

Our main risk measure is the standard deviation of the annual return on equity (ROE) over the sample period (all years with non-missing ROE), where ROE is defined as businesses' pre-tax profits over shareholders' funds, drawn from the firms' profit and loss accounts and corporate balance sheets respectively.[16] The definition of the variable follows a large literature which acknowledges that 'ex ante information' on income in different states of the world is unobservable for empirical researchers and suggests to define risk as the volatility of *observed* outcomes over time (e.g. John et al., 2008; Armstrong and Vashishtha, 2012; Langenmayr and Lester, 2018; and a large literature on asset pricing). Given our interest in the within-firm allocation of risk, we measure risk at the affiliate-level (i.e. we define ROE from unconsolidated accounting data). To limit the influence of extreme observations and reduce measurement error, we winsorize ROE at the 5% level before calculating the standard deviation and drop years with negative shareholder funds. We also construct a corresponding affiliate-level measure of profitability as the average ROE taken over the sample period. The data is collapsed at the affiliate level and each affiliate enters the sample only once. Table 2 provides descriptive statistics for the risk and profitability measure.

For robustness, we also employ a number of alternative risk measures. First, we use binary measures of highly volatile returns: a dummy variable indicating that an affiliate has realized values of ROE both below the 10th percentile *and* above the 90th percentile during the sample period (and a similar measure indicating ROEs both below the 25th percentile *and* above the 75th percentile). Second, we use the variance of the annual ROEs (the square of the standard deviation), which places more weight on extreme observations.

[11] The current and historic versions of Amadeus can be linked by a unique firm identifier. In most cases, this identifier is constant over time and we account for changes when they occur achieving very high match rates between database versions.

[12] Our version of Amadeus comprises the full set of European firms known to Bureau van Dijk whereas our version of Orbis includes firms from all countries satisfying one of the following three criteria: (i) operating revenue exceeding €1 million; (ii) total assets exceeding €2 million EUR; (iii) the number of employees exceeding 15. As coverage is relatively poor for small non-European companies in any case, we lose few observations due to the size restriction in our version of Orbis.

[13] To delimit the sample of corporations belonging to a multinational firm, we proceed in the following steps. First, if the corporation's global ultimate owner (GUO) is itself a corporation, we identify the GUO's (directly and indirectly) majority-owned subsidiaries and augment this list by the (directly and indirectly) majority-owned subsidiaries of the corporation itself (in case they do not overlap). In doing so, we account for 10 levels of indirect ownership chains. Corporations are considered to belong to a multinational firm if either the GUO or one of the majority-owned subsidiaries is located in a foreign country. Second, if the GUO is an individual or a family, we identify all corporations that are directly and majority owned by these individuals and families and define them as 'top-level corporate owners'. Their (directly and indirectly) majority-owned subsidiaries constitute the set of affiliates. All corporations in this set (as well as the 'top-level corporate owners' themselves) are considered to be part of a multinational firm if at least two of them are located in different countries. Third, if information on the GUO is missing but information on the immediate majority shareholder (ISH) is available, we identify the 'highest' corporate ISH of the corporation by constructing direct majority shareholder-chains (10 levels upwards). The subsidiary list of the 'highest' corporate ISH augmented by the list of majority-owned subsidiaries of the corporation itself constitute the set of affiliates. All corporations in this set are considered to be part of a multinational firm if at least two of them are located in different countries. Fourth, if the firm is a GUO or information on both ISH and GUO are missing, it is classified as a multinational if it majority-owns (directly or indirectly) at least one foreign subsidiary.

[14] We will in the following refer to multinational 'affiliates', irrespective of whether the considered entity is a subsidiary or the parent firm of the multinational group.

[15] Bureau van Dijk's firm databases (AMADEUS/ORBIS) are Euro-centric in nature. Moreover, because we draw European and non-European samples from databases with different size thresholds, we mechanically have a better representation of small firms in Europe.

[16] We do not include affiliates with only one observation.

Table 1
Country distribution.

Country	Host	Home	Country	Host	Home
Argentina	300	45	Italy	37,701	33,784
Australia	581	1573	Japan	9865	16,137
Austria	4115	7111	Korea	1820	1315
Belgium	15,073	13,157	Latvia	1678	594
Bermuda	76	1236	Lithuania	794	428
Bosnia and Herzegovina	439	161	Luxembourg	2489	10,833
Brazil	829	353	Malaysia	34	178
British Virgin Islands	3	207	Malta	917	1156
Bulgaria	1503	508	Mexico	504	483
Canada	26	1235	Netherlands	8658	13,554
Cayman Islands	14	488	New Zealand	426	139
Chile	194	215	Norway	9407	8496
China	4174	1387	Peru	110	14
Colombia	778	179	Philippines	694	201
Croatia	2139	993	Poland	8904	2638
Curacao	2	111	Portugal	8906	6115
Cyprus	79	5375	Romania	5296	405
Czech Republic	9038	3623	Russia	7433	2277
Denmark	13,270	15,377	Serbia	1277	320
Estonia	2713	1561	Singapore	1135	588
Finland	4278	4618	Slovakia	3755	1059
France	40,606	40,066	Slovenia	1474	1448
Germany	25,307	30,176	South Africa	13	477
Great Britain	44,015	32,310	Spain	25,839	21,588
Greece	1723	1075	Sweden	21,580	22,654
Hong Kong	34	257	Switzerland	53	3651
Hungary	1842	742	Taiwan	407	654
Iceland	387	459	Thailand	18	111
India	2214	2220	Turkey	521	571
Ireland	3974	3046	Ukraine	1434	46
Israel	12	447	United States	863	21,453

Note: The table indicates for each country the number of affiliates belonging to multinational firms located in the country (Host) and owned by a parent corporation in the country (Home). We only report countries for which the sum of the two columns exceed 100.

Table 2 includes descriptive statistics of the alternative risk measures. Table 3 reports a correlation matrix for the risk measures.[17]

Note that the risk variables account for changes in the ownership structure of multinational groups over time: while Amadeus and Orbis provide ownership data for the last reporting date only, our database accounts for ownership changes through mergers and acquisitions (M&As) drawing on Bureau van Dijk's Zephyr database, which provides information on M&As worldwide since the late 1990s. Affiliate risk is calculated as the income volatility in years in which it belonged to a given multinational group. New affiliates, i.e. greenfield investments, are handled correctly in our dataset as balance sheet data is available in Amadeus and Orbis after the date of foundation only.

Finally, we include the following country-level variables that characterize the tax system as well as the general economic and institutional environment: statutory corporate tax rates (from KPMG's global corporate tax guides);[18] information about loss-offset provisions (from IBFD's European and Global Tax Handbooks); GDP, GDP per capita and the unemployment rate (from World Development Indicators), a governance indicator (i.e. control over corruption drawn from the World Governance Indicators) and the volatility of the national stock market index (drawn from the World Bank's Global Financial Development Database). The latter variable is included to absorb potential valuation effects. For all the country-level variables, we construct affiliate-level variables corresponding to the value in the base year (the first year with non-missing ROE) as well as the average value and the standard deviation taken over the sample period (all years with non-missing ROE). Descriptive statistics of these variables are reported in Table 2.

5. Empirical results

5.1. A first pass: multinational vs national firms

Before embarking on the main empirical analysis, we provide suggestive evidence that the tax incentives specific to multinational firms have a significant impact on the allocation of risk. We estimate the correlation between corporate tax rates and our preferred measure of risk in two distinct samples: affiliates belonging to multinational firms and purely national firms. In the former sample, the observed correlation between taxation and risk reflects the conflicting incentives created by intra-firm tax differences. In the latter sample, these incentives are entirely absent by construction.

Specifically, we estimate the following model for each of the two samples separately:

$$risk_{ic} = \alpha_1 + \alpha_2 tax_c + \alpha_3' X_i + \alpha_4' W_c + \varepsilon_{ic}$$

where $risk_{ic}$ measures the standard deviation of ROE at the level of affiliate i located in country c and tax_c is the mean statutory corporate tax rate in country c over the sample period. The vector X_i controls for affiliate characteristics that may affect risk: industry (ten industry dummies), size (ten dummies for deciles of total assets) and sample period (dummies for the first year in the sample). The vector W_c

[17] In the literature, risk is measured by a range of alternative measures, most prominently leverage (Acharya et al., 2011; Coles et al., 2006), business focus (Coles et al., 2006), the incidence of losses (Cullen and Gordon, 2007) and diversifying acquisitions (Acharya et al., 2011). Note that these measures are not well suited for our purposes. Leverage and the incidence of losses are directly affected by profit shifting strategies other than risk shifting. Diversifying acquisitions, moreover, capture aggregate risk-taking of the firm, while we are interested in risk allocation across affiliates.

[18] We generally use the top marginal corporate tax rate as a proxy for the actual marginal corporate tax rate. In most cases, this approximation is completely innocuous because the marginal corporate tax rate is the same at all income levels.

Table 2
Summary statistics.

Variable	Obs.	Mean	Std. dev.	Min.	Max.
Risk and return:					
Standard deviation of ROE	344,409	0.313	0.249	0	1.519
Extreme ROEs (deciles)	344,409	0.148	0.355	0	1
Extreme ROEs (quartiles)	344,409	0.368	0.482	0	1
Variance of ROE	344,409	0.160	0.242	0	2.308
Mean of ROE	344,409	0.184	0.360	−0.867	1.282
Taxation:					
Corporate tax rate	344,277	0.318	0.073	0	0.597
Other country characteristics:					
GDP (in logs)	329,276	27.327	1.332	19.918	30.280
GDP per capita (in logs)	329,276	10.139	0.765	5.362	11.674
Unemployment rate	326,129	8.345	3.624	0.1	37.6
Stock market volatility	318,280	21.173	9.065	2.394	99.030
Control over corruption	329,710	1.251	0.882	−1.576	2.586

Note: The table reports summary statistics for the variables used in the regression analysis. The standard deviation of ROE is taken over non-missing and winsorized (95% level) values of ROE for each affiliate separately; 'Extreme ROEs (deciles)' indicates that the affiliate has realized ROE-values in the upper and in the lower decile of the ROE-distribution during the sample period; 'Extreme ROEs (quartiles)' indicates that the affiliate has realized ROE-values in the upper and in the lower quartile of the ROE-distribution during the sample period; the 'Variance of ROE' is taken over non-missing and winsorized (95% level) values of ROE for each affiliate separately; the 'Corporate tax rate' is the statutory corporate tax rate in the country where a corporation is located; 'GDP (in logs)' is the Gross Domestic Product (in logs); 'GDP per capita' is the Gross Domestic Product per capita (in logs); 'Unemployment rate' is the unemployment rate. 'Control over corruption' is an indicator of governance, which is standardized (mean zero and unit standard deviation) in the global sample of countries. 'Stock market volatility' reflects the volatility of the national stock market index. Variables related to tax, macro-economics and governance refer to the value in the first year where we observe a non-missing value of ROE.

controls for country characteristics: size (GDP in logs), productivity (GDP/capita in logs) and labor market conditions (unemployment).

We present the results of the two regressions in the form of binned scatterplots. The left panel of Fig. 1 documents a positive relation between risk and taxation for purely national firms: an increase in the corporate tax rate of 10 percentage points is associated with an increase in the standard deviation of ROE of around 0.05, which corresponds to around 10% at the sample mean (which is just below 0.5). The effect is tightly estimated (the data points are relatively close to the regression line) and the linear functional form imposed by the regression model appears appropriate (there is no obvious non-linear relation between the data points). The estimated positive relation between taxation and risk is consistent with canonical theory (Domar and Musgrave, 1944) and with recent empirical evidence (Langenmayr and Lester, 2018).

Turning to affiliates belonging to multinational firms, the right panel of Fig. 1 documents a strikingly different relation between risk and taxation: an increase in the corporate tax rate of 10 percentage points is associated with a decrease in the standard deviation of ROE of around 0.05, which corresponds to around 15% at the sample mean (which is just above 0.3). It should be emphasized that the negative correlation is not inconsistent with the positive correlation in the sample of national firms or with the canonical theory of taxation and risk. Assuming that multinational firms exhibit a positive firm-level correlation between taxation and risk as well (i.e. multinational firms operating predominantly in high-tax environments take more risk than those operating predominantly in low-tax environments), it may still be that the within-firm allocation of risk is tilted toward low-tax countries.

In the rest of the empirical analysis, we pursue three goals: First, we estimate the effect of corporate taxes on the risk allocation within the multinational firm (Section 5.2). Second, we assess the importance of each of the transmission mechanisms identified in the theory section (Section 5.3). Third, we attempt to quantify the role of risk shifting as a channel for profit shifting (Section 5.4).

5.2. *Main empirical analysis*

5.2.1. *Baseline results*

To identify the effect of corporate taxes on the within-firm risk allocation, we estimate the following model:

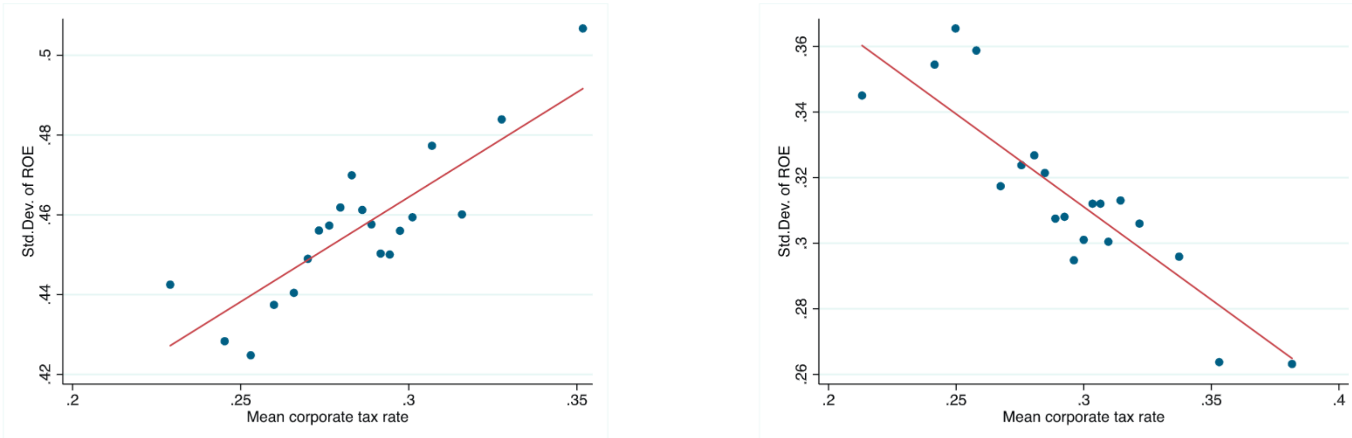
$$risk_{ijc} = \beta_1 + \beta_2 tax_c + \beta_3' X_i + \beta_4' W_c + \rho_j + \varepsilon_{ijc}$$

where $risk_{ijc}$ measures the standard deviation of ROE at the level of affiliate i located in country c belonging to multinational firm j and tax_c is the statutory corporate tax rate in country c. The vectors X_i and W_c represent affiliate and country characteristics respectively and ρ_j represents firm fixed effects. The effect of taxation on the intra-firm allocation of risk is identified from cross-sectional differences in the corporate tax rates faced by affiliates belonging to the same firm: we effectively ask whether affiliates facing higher taxes (compared to other affiliates of the same firm) exhibit more or less volatile

Table 3
Correlation between alternative risk measures.

	Std. dev. of ROE	Extreme ROEs (deciles)	Extreme ROEs (quartiles)	Var. of ROE
Std. dev. of ROE	1.0000			
Extreme ROEs (deciles)	0.6216	1.0000		
Extreme ROEs (quartiles)	0.5986	0.5477	1.0000	
Var. of ROE	0.9192	0.6184	0.4978	1.0000

Note: The table shows the correlation between the four alternative risk measures of our baseline analysis: (i) the standard deviation of ROE taken over all years with non-missing values of ROE; (ii) an indicator that the corporation has realized ROE-values in the upper and in the lower decile of the ROE-distribution during the sample period; (iii) an indicator that the corporation has realized ROE-values in the upper and in the lower quartile of the ROE-distribution during the sample period; (iv) the variance of ROE taken over years with non-missing observations of ROE.



National Firms   Multinational Firms

Fig. 1. Tax and risk. Notes: The figure shows binned scatterplots of the corporate tax rate and the standard deviation of ROE for the sample of corporations with no foreign affiliates (left) and the sample of corporations with foreign affiliates (right) respectively. The standard deviation of ROE is taken over all years for which non-missing values are available. The corporate tax rate is measured as the mean value over the same years. The set of controls includes dummies indicating the year of the first observation of ROE, dummies indicating the deciles of total assets and three macro-economic variables: GDP, GDP per capital and the unemployment rate (means over the years with non-missing values of ROE).

returns (again compared to other affiliates of the same firm), holding constant observable affiliate and country characteristics.

The results are reported in Table 4. Standard errors are in brackets and account for two-way clustering at the country-year and multinational group level (where 'year' refers to the first year with non-missing ROE information).[19] In Columns (1)–(5), the tax variable expresses the mean tax rate across the (affiliate-specific) period with available information on ROE, which is also the period used to compute the risk measure. In the most parsimonious specification where the only controls are firm dummies and time dummies indicating the year in which an affiliate enters the sample, we estimate a coefficient of around −0.25 suggesting that a decrease in the tax rate of 10 percentage points is associated with an increase in ROE of around 0.025 (Column 1) corresponding to around 8% at the sample mean. When adding macro-economic control variables (GDP, GDP per capita and unemployment), the governance indicator and a control for stock market volatility, the estimated coefficient becomes larger and is around −0.36 (Column 2). Absorbing effects related to affiliate industry, affiliate size (Column 3) and the business cycles (Column 4) has little effect on the estimate.[20] Additionally introducing a full set of dummies indicating the number of observations used to calculate risk and a set of dummies indicating the deciles of the distribution of firm age (Column 5) reduces the effect of the tax variable to −0.21, but the estimate remains statistically significant at the 1% level.[21]

While explaining the risk observed over a time period with the mean tax rate observed over the same period is intuitive, it also raises concerns about endogeneity. For instance, an adverse shock to corporate profitability in year t is likely to increase the volatility of returns taken over the sample period (an increase in risk) and may also induce a policy response in the form of a change in the corporate tax rate in year $t+1$ or later (a change in the mean tax rate).[22] To address this concern, we reestimate the model while letting the tax variable (as well as the other explanatory variables) take the value observed in the (affiliate-specific) first year with available information on ROE. As shown in Columns (6)–(9), using first-year values of the independent variables yields somewhat smaller tax effects than using mean values. For the purposes of the robustness tests and model extensions in the remainder of the paper, we take a prudent approach, using first-year values of explanatory variables and including the full set of country and corporate controls (Column 9) in the vector of regressors.

Additional robustness checks are presented in Table A1 in the Appendix. The table shows that the baseline estimate (Column 1) remains qualitatively and quantitatively unchanged when we augment the vector of regressors with a measure of exchange rate risk (Column 2). The measure is constructed as the standard deviation of monthly nominal exchange rates of the host country currency against a weighted average of foreign currencies (drawn from the IMF's International Financial Statistics database). Moreover, the results are unchanged when the model is reestimated in subsamples of affiliates located in European and non-European countries (where the former are defined as the 28 member countries of the European Union plus Switzerland and Norway, cf. Columns 3 and 4). The same holds true when we focus on core industries by eliminating firms in the insurance and banking industry as well as the public sector, which may be considered to have limited profit shifting incentives (Column 5).[23] When reestimating the baseline model for subsamples of subsidiary and parent firms, we find that risk allocated to subsidiaries responds more to taxation than risk allocated to parent firms (Columns 6 and 7), which is in line with prior studies reporting similar results in

[19] We prefer two-way clustering at the country-year and firm level to two-way clustering at the country and firm level as our sample observations are concentrated in a limited set of countries.

[20] Specifically, we include a full set of fixed effects indicating affiliates' one-digit NACE industries and a full set of fixed effects indicating affiliates' size as determined by deciles of the total asset distribution. Business cycle controls are defined as the standard deviation of GDP, GDP per capita and the unemployment rate in affiliates' host countries during our sample period respectively.

[21] Our risk measure, the standard deviation of ROE, is calculated from a limited number of observations. While we apply the usual (n-1) correction when calculating the standard deviation, the measure becomes noisier as n decreases. By explicitly controlling for the number of observations used for the construction of the risk measure, we hedge against a correlation of n and host country corporate tax rates that may bias our results.

[22] For instance, consider a country where businesses suffer an adverse shock to profitability in year t. Such a shock is likely to increase the observed return volatility over the period between year t-s and year t+e. If the government responds to the adverse shock by lowering the tax rate in order to stimulate the economy, we observe a negative correlation between risk and average tax rates reflecting a reverse causality from risk to taxation. We address this concern by using first-year tax rates, where reverse causality is not a concern, in our baseline model.

[23] An emerging literature, however, challenges this view and presents evidence for significant profit shifting in the financial sector (e.g. Merz and Overesch, 2016).

Table 4
Baseline results.

Standard deviation of ROE	Mean values on RHS					First-year values on RHS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Corporate tax rate	−0.2520***	−0.3637***	−0.3310***	−0.3365***	−0.2122***	−0.2030***	−0.2990***	−0.2650***	−0.2262***
	(0.0374)	(0.0549)	(0.0470)	(0.0472)	(0.0409)	(0.0305)	(0.0427)	(0.0395)	(0.0366)
Observations	344,409	335,018	315,092	311,326	306,786	344,256	299,051	280,555	276,314
R-squared	0.2299	0.2297	0.2658	0.2640	0.2862	0.2298	0.2307	0.2657	0.2861
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country controls	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Corporate controls	No	No	Yes	Yes	Yes	No	No	Yes	Yes
Business cycle controls	No	No	No	Yes	Yes	No	No	No	No
Age and # of years controls	No	No	No	No	Yes	No	No	No	Yes

Note: Standard errors that account for two-way clustering at the country-year and firm level are reported in brackets (where 'year' refers to the affiliate's first year with non-missing ROE information). The table shows regression results from the cross-sectional model specified in Section 5.2.1. The dependent variable is the standard deviation of ROE taken over all years with non-missing values of ROE. In Columns (1)–(5), all explanatory variables take the mean value across all years where an affiliate has non-missing values of ROE. In Columns (6)—(9), all explanatory variables take the value of the first year with non-missing values of ROE. The main explanatory variable is the statutory corporate tax rate. Control variables: Time fixed effects are dummy variables indicating the first year where a non-missing value of ROE is observed; Firm fixed effects are dummy variables indicating the ultimate owner of the corporation; Country controls comprise macro-economic control variables (GDP, GDP per capita and unemployment), a measure for the volatility of the local stock market and a governance indicator (control over corruption); Business cycle controls are the standard deviation of the macro-economic controls taken over all the years with non-missing values of ROE; Corporate controls are dummy variables indicating the deciles of the distribution of total assets and dummy variables indicating the industry of the firm (1-digit NACE). 'Age and # of years controls' are dummy variables indicating the deciles of the age distribution as well as dummy variables indicating the number of years used for the calculation of the risk measure (the standard deviation of ROE).

other tax planning dimensions (see e.g. Dischinger et al., 2013).[24] Restricting the sample to affiliates with at least five observations of ROE yields a statistically significant but slightly smaller effect of taxes than the baseline (Column 8). Finally note that Table A1 also presents coefficient estimates for the country control variables. The estimates largely show expected signs: Country size (log GDP), productivity (log GDP per capita), stock market volatility and exchange rate volatility tend to positively correlate with corporate ROE variation.

5.2.2. *Alternative measures of risk and tax*

In a next step, we reestimate the baseline model using three alternative measures of risk and report the results in Table 5. The first measure is a dummy variable indicating that an affiliate has realized values of ROE below the 10th percentile *and* above the 90th percentile during the sample period. This binary measure of return volatility yields results that are similar to the baseline measure (Column 1): an increase in the corporate tax rate of 10 percentage points lowers the propensity to realize returns in both the upper and lower decile of the ROE distribution by around 1.4 percentage points (around 9% at the sample mean). These results are unchanged when we set the thresholds for extreme returns at the 25th percentile and the 75th percentile (Column 2): the same tax increase of 10 percentage points lowers the propensity to realize returns in both the upper and lower quartiles by around 3.1 percentage points (around 8% at the sample mean). Finally, this pattern also emerges when we use the variance (instead of the standard deviation) of the annual ROEs as a risk measure (Column 3): an increase in the corporate tax rate of 10 percentage points lowers the variance of ROE by around 0.014 (around 9% at the sample mean).

5.2.3. *Panel model*

The identifying assumption underlying the cross-sectional results reported in Table 4 is that tax rates do not correlate with unobserved determinants of risk (conditional on controls). To relax that assumption, we exploit the time dimension of the data to estimate a panel model:

$$risk_{ijct} = \theta_1 + \theta_2 tax_{ct} + \theta_3' W_{ct} + \mu_i + \delta_t + \nu_{ijct}$$

where $risk_{ijct}$ measures the standard deviation of ROE at the level of affiliate i located in country c belonging to multinational firm j in period t and tax_{ct} is the statutory corporate tax rate in country c in period t. The vector W_{ct} controls for time-varying country characteristics; μ_i represents affiliate fixed effects (nesting both firm and country fixed effects).

The panel model allows us to fully control for time invariant characteristics of multinational firms and countries and, thus, to

Table 5
Alternative risk measures.

	(1)	(2)	(3)
	ROE in top and bottom decile	ROE in top and bottom quartile	Variance of ROE
Corporate tax rate	−0.1360***	−0.3111***	−0.1398***
	(0.0361)	(0.0493)	(0.0283)
Observations	276,314	276,314	276,314
R-squared	0.2216	0.2839	0.2548
Firm fixed effect	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes
Country controls	Yes	Yes	Yes
Corporate controls	Yes	Yes	Yes
Age and # of obs. controls	Yes	Yes	Yes

Note: Standard errors that account for two-way clustering at the country-year and firm level are reported in brackets (where 'year' refers to the affiliate's first year with non-missing ROE information). The table shows regression results from the cross-sectional model specified in Section 5.2.1, where alternative measures of risk are used as dependent variable: an indicator that the corporation has realized ROE-values in the upper and in the lower decile of the ROE-distribution during the sample period (Column 1); an indicator that the corporation has realized ROE-values in the upper and in the lower quartile of the ROE-distribution during the sample period (Column 2); the variance of ROE taken over years with non-missing observations of ROE (Column 3). The main explanatory variable is the statutory corporate tax rate. See the notes to Table 4 for a description of the other control variables. Note that all explanatory variables take the value of the first year with a non-missing observation of ROE.

[24] Note that the specification, where the sample is restricted to parent firms, does not allow for the inclusion of multinational group fixed effects.

identify the effect of taxation on risk from corporate tax *reforms*. We effectively compare affiliates belonging to the same firm and ask whether those facing a (differential) change in the tax rate exhibit a (differential) change in risk. The identifying assumption in the panel model is that *tax rate changes* do not correlate with changes in unobserved determinants of risk (conditional on the control variables).

To implement the model, we restrict the sample to affiliates with non-missing ROE in all the years between 2001 and 2012, the years with the best sample coverage, to obtain a balanced sample. We then split the sample into two subperiods, 2001–2006 and 2007–2012, and define risk in each period as the standard deviation of ROE over the six years, respectively. The observational unit is the multinational affiliate i in subperiod t. To address concerns about endogeneity, we use the values of tax rates and other control variables in the first year of each subperiod. The set of controls comprises all country-level variables included in the baseline regression.

The results are presented in Table 6 with standard errors accounting for two-way clustering at the country-year and affiliate level. The effect of the tax rate on risk remains negative and statistically significant when identified by tax *reforms* and also quantitatively resembles our baseline estimate. The result is robust to adding interactions between size and time, which controls for differential trends in risk across the size distribution (Column 2); interactions between industry and time, which further controls for differential trends in risk across industries (Column 3); and both of these controls jointly (Column 4).

5.2.4. *Foreign tax variation*

We also address concerns about endogeneity by exploiting cross-sectional variation in the tax rates faced by *foreign* affiliates for empirical identification (Johannesen et al., 2016). It follows from our theoretical analysis that the risk allocated to an affiliate depends not only on the tax rate where it is located but also on the tax rates where its foreign affiliates are located (see also the Appendix for a model version with more than two countries which shows that all tax rates affect the risk allocation within the firm). For instance, Proposition 2 implies that, in the presence of transfer pricing rules, the risk optimally allocated to the entity in H is decreasing in t_H and increasing in t_L. The key advantage of identifying from foreign tax variation is that it allows us to include country fixed effects that absorb unobserved country-level determinants of risk.[25] Hence, we effectively compare the risk across entities *in the same country* whose foreign affiliates face different tax rates. In practice, we capture the foreign tax rates relevant for a given entity with a single variable: the average tax rate taken across all its foreign affiliates weighted by their total assets.[26] We omit group fixed effects, which are highly collinear with the average foreign tax rate.

The estimation results are presented in Table 7. We first regress affiliate risk on the foreign tax variable and a full set of country fixed effects (Column 1) and subsequently add control variables for the asset-weighted average of other country characteristics at foreign group locations (Column 2). In both specifications, the coefficient on the foreign tax variable is positive and statistically significant. Qualitatively, this is consistent with our earlier estimates of a negative coefficient on the domestic tax variable. Quantitatively, however, the estimated coefficients are smaller and thus suggestive of a smaller effect of the tax differential on the allocation of risk. A possible explanation is that incomplete coverage in Amadeus and Orbis as well as noisy ownership links create measurement error in the foreign tax variable and, thus, attenuation bias in the estimates.

5.2.5. *Ex ante risk shifting vs ex post profit shifting*

The empirical analysis so far has established a robust negative within-firm correlation between corporate tax rates and return volatility. Following a large literature, we have referred to return volatility as risk and thus interpreted the results as evidence of *ex ante* risk shifting through real activity or contracts. However, as discussed in Section 2, the negative correlation between tax rates and return volatility could also arise from ad hoc adjustments in transfer prices after uncertainty has resolved: *ex post* profit shifting. We use two complementary strategies to empirically disentangle these distinct margins of response: (i) estimating the tax-risk correlation separately for groups of firms with a different potential for making

Table 6
Panel model.

	Standard deviation of ROE			
	(1)	(2)	(3)	(4)
Corporate tax rate	−0.1809***	−0.1875***	−0.1448***	−0.1568***
	(0.0465)	(0.0515)	(0.0472)	(0.0514)
Observations	156,740	156,738	155,206	155,204
R-squared	0.6851	0.6865	0.6853	0.6866
Affiliate fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
Country controls	Yes	Yes	Yes	Yes
Size decile X time	No	Yes	No	Yes
Industry decile X time	No	No	Yes	Yes

Note: Standard errors that account for two-way clustering at the country-year and firm level are reported in brackets (where 'year' refers to the affiliate's first year with non-missing ROE information). The table shows regression results from the panel model with various sets of controls. The sample includes all multinational affiliates with non-missing values of ROE in each of the years 2001–2012. There are two time periods: 2001–2006 and 2007–2012. The dependent variable is the standard deviation of ROE taken over a time period. Control variables: Affiliate fixed effects are dummy variables indicating the affiliate; Size decile X time are interactions between dummies indicating the decile of the size distribution and dummies indicating the period; Industry X time are interactions between dummies indicating the industry of the firm (1-digit NACE) and dummies indicating the time period. See the notes to Table 4 for a description of the other control variables. All explanatory variables take the value of the first year in the time period.

Table 7
Foreign tax variation.

	Standard deviation of ROE	
	(1)	(2)
Avg. foreign corporate tax rate	0.0427**	0.0658***
	(0.0215)	(0.0247)
Observations	213,370	207,776
R-squared	0.1238	0.1246
Firm fixed effect	Yes	Yes
Country X time fixed effect	Yes	Yes
Country controls	Yes	Yes
Corporate controls	Yes	Yes
Age and # of obs. controls	Yes	Yes
Foreign controls	No	Yes

Note: Standard errors that account for two-way clustering at the country-year and firm level are reported in brackets (where 'year' refers to the affiliate's first year with non-missing ROE information). The table shows regression results from the cross-sectional baseline model specified in Section 5.2.1. Next to the baseline controls (cf. Table 4), the model includes a full set of host country-year fixed effects (where the 'year' dimension refers to the first year with non-missing ROE) and the total asset-weighted average tax rate at foreign corporations that are affiliated with the same multinational group ('Avg. foreign corporate tax rate'). Column (2), additionally, includes asset-weighted averages of all other macro-economic and governance controls at foreign group affiliates. See the notes to Table 4 for a description of the other control variables. Also note that all explanatory variables take the value of the first year with a non-missing observation of ROE.

[25] To be precise, we control for country-time fixed effects where the time dimension refers to the (affiliate-specific) first year with non-missing ROE information.

[26] This weighted average is computed based on the multinational group structure and asset values in the first year with non-missing ROE information for the considered entity.

ad hoc adjustments to transfer prices and (ii) estimating the tax-risk correlation with a measure of risk that is uncontaminated by *ad hoc* adjustments to transfer prices by construction.

Our first approach starts from the empirical finding in Hopland et al. (2018) that only transfer prices related to the use of intangibles exhibit patterns consistent with *ex post* profit shifting.[27] We therefore assess whether the correlation between tax rates and return volatility is stronger for multinational firms that are richer in intangibles. In the main analysis, we capture intangibles with information on corporate patent filings from the Patstat database, which includes data on the universe of patent applications to all major patent offices worldwide during our sample period.[28] We measure patent intensity at the level of the multinational firm as the number of granted patents filed by all affiliates of the firm during the sample period.

We estimate our baseline model (Table 4, Column 9) for subsamples of affiliates with different patent intensity and plot the coefficients on the tax variable in Fig. 2. Panel A compares firms with zero granted patent applications during our sample period and firms with a positive number of patent applications; Panel B compares firms with granted patent applications above the 75th, 90th and 95th percentile of the distribution.[29] The point estimates are very stable across subsamples. To rule out that the findings are driven by other differences, we estimate matching models that account for heterogeneity in two dimensions: (i) the overall size of the multinational group (measured by the sum of affiliates' total assets) and (ii) the host countries where affiliates are located. Specifically, we apply coarsened exact matching (Iacus et al., 2012) to compare affiliates that belong to multinational firms with zero and non-zero patent counts during our sample period within size-country cells. Panel C shows that the matching leaves our findings largely unchanged. The results hence suggest that firms with different potential for making *ad hoc* adjustments to transfer prices exhibit similar correlations between tax rates and return volatility indicating that *ex post* profit shifting is not driving the correlation.[30]

As patents are just one type of intangible asset, we run robustness checks where the sample split is based on patent counts as well as the ratio of intangibles to total assets on firms' balance sheets. The latter variable has the advantage to capture different types of intangible property; on the downside, local GAAP regulations differ in their capitalization requirements for intangible property on balance sheets, which makes measurement to a certain degree imprecise. It is, nevertheless, reassuring that the results of this exercise, presented in Fig. A.1, resemble the baseline findings in Fig. 2.[31]

Our second strategy is to define a measure for *ex-ante* risk taking. This is not straightforward since readily available balance sheet items may be affected by ex post shifting. We therefore exploit that the business units within MNEs often differ in their activities and risk characteristics - and therefore belong to different 4-digit industry classes. Specifically, the analysis tests whether MNEs have affiliates from high-risk industries in low-tax jurisdictions and affiliates from

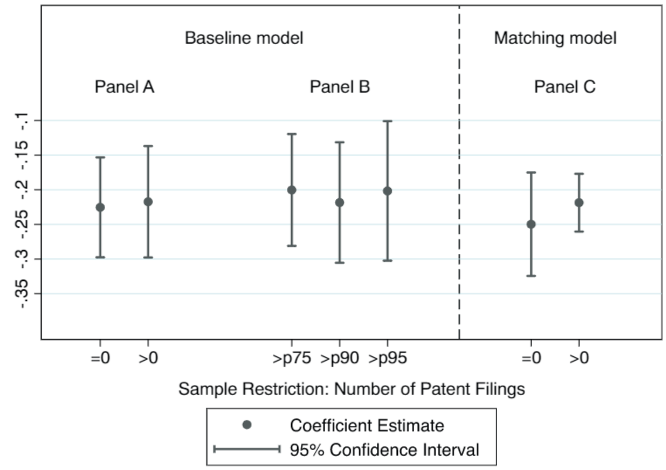


Fig. 2. Effect heterogeneity - IP intensity. Notes: Panels A and B depict coefficient estimates and 95% confidence intervals for the baseline model (Specification (9) of Table 4) estimated in subsamples of multinational firms with no granted patent application within our sample period (= 0); multinational firms with a positive number of granted patent applications (>0); multinational firms whose number of granted patent applications is above the 75th/90th/95th percentile of the sample distribution (>p75/>p90/>p95). Panel C depicts coefficient estimates and 95% confidence intervals from models estimated on subsets of multinational firms with zero and a positive number of granted patent applications respectively, where we use coarsened exact matching to balance the two samples on the overall size of the group and the host countries of affiliates.

low-risk industries in high-tax jurisdictions. We calculate the 'normal' return volatility associated with business operations in 4-digit industries from national firms only, which provides us with a purely *ex ante* measure of risk. That is, the measure arguably captures approximately the risk inherent to the activities performed by a given entity that is operating in the specific industry – and is independent from any ad hoc adjustments of transfer prices within a multinational firm. Note, however, that the measure only captures effects related to the strategic location of business units and, therefore, not all dimensions of *ex ante* risk shifting. Importantly, contractual risk shifting is not reflected.

We define the industry risk measure in two ways: The baseline analysis draws on cross-sectional variation in returns; that is we calculate the standard deviation of ROE across national firms in a given industry in a given year. We only use national firms for the calculation to ensure that the ROE measure is unaffected by *ex post* profit shifting and require industries to comprise 100 national firms or more with non-missing ROE information in a given year to enter the exercise (whereas the latter restriction is not decisive for our results). In the baseline model, we use cross-sectional ROE variation in 2004 as the relevant industry risk measure, but results are similar when ROE variation in other years is used.[32] We assign the industry-specific risk measure to MNE affiliates in the same industry and then assess whether multinational affiliates in high-risk industries are systematically located in low-tax jurisdictions.

[27] The evidence in Hopland et al. (2018) also indicates that firms have no flexibility to adjust transfer prices on tangibles or financing structures in the short run to relocate profits to lower-tax entities.

[28] To avoid double counting of patents that protect the same technology but for which protection is sought in multiple markets, we focus on priority patents.

[29] This corresponds to affiliates that are part of multinational groups with more than 1, 82 and 356 granted patent applications during our sample period.

[30] We represent firm size with 10 dummies indicating the deciles of the distribution of total assets (whereas other binning strategies, including binning algorithms, yield similar results).

[31] The first specification is estimated for a subsample of firms with no patent applications and no intangibles on the balance sheet (=0); subsequent specifications employ subsamples of firms where either the number of patent applications or the ratio of intangible to total assets is above the 25th/50th/75th/90th/95th percentile of the respective distribution. The matching models account for heterogeneity in group size and host countries when estimating the tax effect for firms with patent applications and balance sheet immaterial assets below/above the sample median.

[32] Note that the assigned risk values are broadly in line with expectations: R&D intensive industries, for example, tend to exhibit above average ROE variation: the correlation of our industry risk measure with industries' R&D intensity, as defined in Galindo-Rueda and Verger (2016), is 0.3 and statistically significant; firms that engage in research and development in natural sciences and engineering (belonging to NACE group 721) exhibit ROE variation that places them between the 81st and 94th percentile of our industry risk distribution; on top of that, many of the 4-digit industry classes that score high with our index belong to broader industry groups that rank high in the Standard & Poor's Industry Risk Assessment, including e.g. information technology related industries and natural resource industries (see Standard & Poors, 2013).

Table 8
Ex ante risk measure.

	Industry risk (4-digit level)			
	(1)	(2)	(3)	(4)
Corporate tax rate	−0.0483***	−0.0204**	−0.1245***	−0.0501**
	(0.0092)	(0.0082)	(0.0336)	(0.0194)
Observations	308,712	309,553	177,855	178,233
Firm fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
Country controls	Yes	Yes	Yes	Yes
4-digit industry info	Base	Base	2004	2004
Risk calculation	Cross-sectional	Longitudinal	Cross-sectional	Longitudinal

Note: Standard errors that account for two-way clustering at the country-year and firm level are reported in brackets (where 'year' refers to the affiliate's first year with non-missing ROE information). The table shows regression results from the cross-sectional baseline model specified in Section 5.2.1. The dependent variable is an *ex ante* risk measure, namely the industry risk associated with business operations in affiliates' 4-digit industry. The variable is constructed from all national firms in a given industry. In Columns (1) and (3), we consider a particular year, 2004, and define industry risk as the standard deviation of the ROE values of all national firms in a given 4-digit industry ('cross-sectional'). In Columns (2) and (4), we exploit the panel dimension of the data and take the standard deviation of ROE for each national firm in the data based on all non-missing observations within our sample period. The 'normal' return volatility of the industry is then defined as the average of this variable across all national firms in a 4-digit industry ('longitudinal'). In Columns (1) and (2), information on entities' 4-digit industries is taken from the main data and stems from 2013 in most cases. In Columns (3) and (4), we use the 4-digit industry information from a prior version of AMADEUS, which stems from 2004 in most instances. See the notes to Table 4 for a description of the other control variables.

The results are presented in Column (1) of Table 8. The coefficient estimate on the tax rate variable is negative and significant, suggesting that the *ex ante* risk associated with specific business activities is disproportionally allocated to low-tax locations. In Column (2), we use an alternative industry risk measure, which is constructed based on longitudinal ROE variation. That is, we compute the standard deviation of ROE across sample years for all national firms in our data. Industry risk is then determined as the average of this volatility in a 4-digit industry class. The calculation only accounts for firms, for which we observe ROE information for 5 or more sample years and for 4-digit industries with more than 100 national firms (whereas these restrictions are not decisive for our results). The findings are similar to the ones in Column (1).

The models in Columns (3) and (4), moreover, address potential measurement issues. Specifically, in Amadeus/Orbis, information on industry affiliations is available in cross-sectional format for the last reported date only, which is the year 2012/2013 for most firms in our database. If industry affiliations vary across time, 4-digit industries in 2012/13 do not necessarily have to coincide with 4-digit industries in firms' base years (i.e. their first sample year with non-missing ROE) for which we measure tax incentives (and control variables). We hence draw on 4-digit industry information from a prior Amadeus version - including industry data for the year 2004 - and regress the industry risk related to affiliates' industry affiliation in 2004 on corporate tax rates and control variables in 2004, also accounting for MNE group structures in 2004. In absolute terms, the coefficient estimate for the tax regressor turns out larger than in Columns (1) and (2), which, in part, reflects the improved - that is aligned - measurement of industry affiliations and tax incentives and is, in part, driven by the sample adjustment (reestimating the model in Column (1) with the sample in Column (3) yields a tax coefficient estimate of −0.079, which is statistically significant at the 1% level).[33]

Concluding, the results in this subsection suggest that MNEs distort ex-ante risk towards low-tax countries. While the exercises rely on proxies for IP intensity and *ex ante* risk only, the findings are consistent across the two sub-analyses and indicative of *ex ante* risk shifting. Future research will hopefully corroborate these results based on more refined measures of IP intensity and *ex ante* risk taking.

5.3. Transmission channels

The empirical analysis so far has produced robust evidence that multinationals distort the intra-firm allocation of risk towards low-tax affiliates. The theoretical analysis proposed three potential mechanisms that may create a link between corporate taxes and the optimal risk allocation: (1) the risk-profit nexus established by transfer pricing rules; (2) risk aversion and (3) limited loss offset. In the following, we will assess the importance of each of these channels for the observed tax-risk correlation.

5.3.1. Risk-profit nexus

To investigate whether transfer pricing rules explain the negative correlation between risk and tax rates, we estimate the baseline model for affiliates located in countries with and without formal transfer pricing legislations separately and report the results in Table 9.[34] While the estimated tax coefficient is small and insignificant where transfer pricing rules do not exist (Column 1), it is large and significant where they do (Column 2). The coefficient estimates are statistically different from each other (p-value<0.01).[35] This suggests that the regulatory nexus between risk and profits created by the arm's length principle contributes materially to the empirical correlation between tax rates and risk.

Addressing the concern that risk allocated to an affiliate may depend not just on the transfer pricing rules in the country where the affiliate itself is located but on transfer pricing rules in all countries where the firm is present, we also estimate the baseline model separately for firms where *all* affiliates and *no* affiliates face formal transfer pricing rules and find similar results (Columns 3–4). The same holds

[33] Table A2 in the appendix, moreover, shows that intangible asset intensity does not negatively correlate with the tax sensitivity of ex ante risk allocation. This reassures us that that the findings in Fig. 2 do not reflect that IP intensive multinational groups engage in more ex post profit shifting but less ex ante risk shifting, with a zero net effect on return volatility.

[34] We use the coding of transfer pricing legislations from Mescall and Klassen (2014) evaluated, for each affiliate, in the first year with non-missing ROE information.

[35] Adjusting the risk variable to only account for sample years without transfer pricing legislations yields results comparable to Column 1 (not reported).

Table 9
Transfer pricing rules.

	Standard deviation of ROE							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Corporate tax rate	−0.0413	−0.3510***	−0.0608	−0.2601***	−0.0438	−0.4367***	−0.0395	−0.3510***
	(0.0359)	(0.0460)	(0.0832)	(0.0488)	(0.0460)	(0.0761)	(0.0400)	(0.0460)
Observations	55,767	204,788	22,861	117,751	40,263	131,053	55,767	204,781
R-squared	0.3658	0.2937	0.4514	0.3366	0.3787	0.2958	0.3364	0.2470
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Corporate controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age and # of obs. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Transfer pricing rules	No	Yes	No (all)	Yes (all)	Lax	Strict	No	Yes
Matching	No	No	No	No	No	No	Yes	Yes

Note: Standard errors that account for two-way clustering at the country-year and firm level are reported in brackets (where 'year' refers to the affiliate's first year with non-missing ROE information). The table shows regression results from the cross-sectional baseline model specified in Section 5.2.1. In Columns (1) and (2), the sample is restricted to affiliates in countries without and with formal transfer pricing rules in the first year with non-missing ROE information. In Columns (3) and (4), the sample is restricted to affiliates that belong to multinational firms where all group affiliates are located in sample countries without and with formal transfer pricing rules in the first year with non-missing ROE information. In Columns (5) and (6), the sample is split in affiliates located in countries with lax and strict transfer pricing rules, defined based on the transfer pricing index of Mescall and Klassen (2014) (index below and above 3, respectively). Columns (7) and (8) reestimate the models in Column (1) and (2) but use coarsened exact matching to account for potential heterogeneity in firm size, loss offset rules, type of owners and patent intensity (see also the definitions in Footnote 36).

Table 10
Individual ownership.

	Standard deviation of ROE			
	(1)	(2)	(3)	(4)
Corporate tax rate	−0.2270***	−0.1983***	−0.2112***	−0.1983***
	(0.0372)	(0.0583)	(0.0350)	(0.0583)
Observations	241,681	31,851	236,729	31,851
R-squared	0.2844	0.3280	0.3501	0.3280
Firm fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
Country controls	Yes	Yes	Yes	Yes
Corporate controls	Yes	Yes	Yes	Yes
Age and # of obs. controls	Yes	Yes	Yes	Yes
Individual Ownership	No	Yes	No	Yes
Matching	No	No	Yes	Yes

Note: Standard errors that account for two-way clustering at the country-year and firm level are reported in brackets (where 'year' refers to the affiliate's first year with non-missing ROE information). The table shows regression results from the cross-sectional baseline model specified in Section 5.2.1. In Columns (1) and (2), the sample is restricted to affiliates that belong to multinational groups, which are and are not majority-owned by individuals or families. Columns (3) and (4) reestimate the models in Columns (1) and (2) but use coarsened exact matching to balance the subsamples of firms that are and are not majority-owned by individuals/families on firm size, patent intensity, loss offset rules and transfer pricing rules (see also the definitions in Footnote 36).

true when we split the sample according to an index that approximates the strictness of transfer pricing regimes (Columns 5–6).[36] Finally, we use coarsened exact matching to ensure that the estimated heterogeneity by transfer pricing regimes does not pick up the effect of other transmission channels: when we reweigh observations to balance subsamples with and without formal transfer pricing rules on firm size, loss offset rules, type of owners and patent intensity (Columns 7–8), the results resemble the corresponding unweighted estimates in Columns 1–2.[37]

5.3.2. Risk aversion

Next, we test the theoretical prediction that risk averse shareholders, holding other factors constant, have an incentive to allocate more risk to high-tax countries to increase risk sharing with governments. We estimate the baseline model separately for multinational firms that are and are not majority owned by individuals or families (Table 10, Columns 1–2). The estimated coefficient on the tax variable is very similar across the two subsamples suggesting that the risk sharing motive is not a strong determinant of the risk allocation within multinational firms.[38] We find the same results when we use coarsened exact matching to reweigh observations to account for heterogeneity in firm size and patent intensity (defined as above) as well as heterogeneity with regard to other possible transmission channels (Columns 3–4).

[36] The index developed by Mescall and Klassen (2014) is based on multiple characteristics of the transfer pricing rules, including the existence of transfer price documentation requirements and the scrutiny of transfer price audits. The sample sizes drop somewhat (relative to Column 3–4) because the index is available for less country-year cells than information on the enactment of transfer pricing laws.

[37] We represent *firm size* with 10 dummies indicating the deciles of the distribution of total assets (where other binning strategies, including binning algorithms, yield similar results); *loss offset rules* with an indicator of whether firms may carry losses for at least 20 years (Langenmayr and Lester, 2018); *type of ownership* with an indicator of majority-ownership by individuals or families (a proxy for risk aversion); and *patent intensity* with an indicator of whether the group has successfully filed for at least one patent within our sample period.

[38] This is also consistent with our baseline results for the full sample, which suggests that the risk sharing motive - if it exists - is dominated by other motives that favor risk allocation to low-tax locations. Note, however, that the specifications in Table 11 do not fully exclude that risk aversion and risk sharing incentives exert some effect on risk allocation within the firm. Specifically, even if owners are well-diversified, managers have decision power within companies and might be risk averse, implying that risk aversion may shape the behaviour in both groups of firms.

Table 11
Loss offset provisions.

	Standard deviation of ROE							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Corporate tax rate	−0.2475***	−0.2504***	−0.1407**	−0.1892***	−0.1790***	−0.1923***	−0.1542***	−0.1920***
	(0.0397)	(0.0398)	(0.0556)	(0.0478)	(0.0578)	(0.0471)	(0.0593)	(0.0471)
Loss offset years	0.0007**							
	(0.0003)							
Loss offset > 20 years		0.0071*						
		(0.0039)						
Observations	227,898	227,898	115,570	100,937	103,085	112,140	103,076	112,136
R-squared	0.2911	0.2910	0.3497	0.2771	0.3582	0.2781	0.3440	0.2781
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Corporate controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age & # of obs. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	All	All	Below 20	Above 20	Below 15	Above 15	Below 15	Above 15
Matching	No	No	No	No	No	No	Yes	Yes

Note: Standard errors that account for two-way clustering at the country-year and firm level are reported in brackets (where 'year' refers to the affiliate's first year with non-missing ROE information). The table shows regression results from the baseline cross-sectional model specified in Section 5.2.1. In Column (1) (Column (2)), the model is augmented by a continuous loss carry variable (a dummy indicating whether losses can be carried forward and backward for more than 20 years Langenmayr and Lester, 2018). In Columns (3)–(6), the baseline regression is rerun in subsets of affiliates in host countries where losses can be carried forward and backward for less/more than 20 and 15 years respectively. Columns (7) and (8) reestimate the models in Column (5) and (6) but use coarsened exact matching to balance the samples of affiliates in countries with generous and tight loss carry povisions on firm size, patent intensity, type of owners and transfer pricing rules (see also the definitions in Footnote 36).

5.3.3. *Loss offset provisions*

Finally, we assess empirically how loss offset rules shape the allocation of risk inside multinational firms and how these rules interact with tax rates.

We first augment the baseline model with a measure of the generosity of loss offset rules in the country where the affiliate is located. Following Langenmayr and Lester (2018), we employ both a continuous measure, defined as the number of years losses can be carried forward or backward (capped at 20 years) and a binary measure indicating whether losses can be carried forward or backward at least 20 years. Both measures yield results consistent with the theoretical predictions: more generous loss offset provisions are associated with more risk (Table 11, Columns 1–2). Quantitatively, the results imply that affiliates allowed to carry losses for more than 20 years exhibit a standard deviation of ROE that is around 0.007 percentage points larger than affiliates that are allowed to carry losses less than 20 years. This is the same magnitude as the effect of a decrease in the tax rate of around 3 percentage points.

We also test whether the generosity of loss offset rules affects the tax sensitivity of the risk allocation, as predicted in the theory model. We run the baseline model separately for affiliates that are and are not allowed to carry losses for at least 20 years and find statistically indistinguishable coefficient estimates (p-value: 0.511) on the tax variable in the two subsamples (Columns 3–4).[39] The same pattern emerges when we split the sample at 15 years, the median of the continuous loss carry variable (Columns 5–6). These findings also do not change when we use coarsened exact matching to account for heterogeneity in firm size and patent intensity as well as heterogeneity with regard to potential other transmission channels (Columns 7–8).

5.4. *Risk and profits*

Our empirical results so far indicate that multinational firms allocate more risk to low-tax countries and that the main transmission mechanism is the nexus between profit and risk created by transfer pricing rules. This suggests that risk shifting serves as a channel for profit shifting: since transfer pricing rules require that affiliates taking more risk are remunerated with higher expected returns, firms can reduce the global tax bill by jointly allocating risk and profits to low-tax countries. In this section, we attempt to quantify the importance of risk shifting as a profit shifting channel.

In a first step, we estimate the within-firm correlation between corporate tax rates and profitability while disregarding risk:

$$profits_{ijc} = \gamma_1 + \gamma_2 tax_c + \gamma_3' X_c + \rho_j + \phi_{ijc}$$

where $profits_{ijc}$ denotes the average ROE of affiliate i located in country c and belonging to multinational firm j over the sample period and tax_c is the first-year corporate tax rate. In the spirit of many

Table 12
Risk and profits.

	Mean ROE		
	(1)	(2)	(3)
Corporate tax rate	−0.1405***	−0.1176**	−0.1119*
	(0.0503)	(0.0494)	(0.0640)
Standard deviation of ROE		0.1012***	0.1071***
		(0.0091)	(0.0265)
Corporate tax rate X			−0.0191
Standard deviation of ROE			(0.0958)
Observations	276,314	276,314	276,314
R-squared	0.2797	0.2831	0.2831
Firm fixed effect	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes
Country controls	Yes	Yes	Yes
Corporate controls	Yes	Yes	Yes
Age and # of obs. controls	Yes	Yes	Yes

Note: Standard errors that account for two-way clustering at the country-year and firm level are reported in brackets (where 'year' refers to the affiliate's first year with non-missing ROE information). The table shows regression results from a cross-sectional model where the dependent variable is the mean of ROE taken over all years with non-missing values of ROE and the main explanatory variables are the standard deviation of ROE taken over all years with non-missing values of ROE and the corporate tax rate in the first year with non-missing values of ROE. All models include the full set of explanatory variables used in the baseline analysis (which take the value of the first year with a non-missing observation of ROE). See the notes to Table 4 for a description of the other control variables.

[39] The coefficient on the tax variable even turns out slightly larger in the subsample of affiliates that can carry losses at least 20 years, which contradicts the theoretical prediction.

earlier papers, γ_2 identifies the full extent of profit shifting, occurring through well-documented channels such as transfer mispricing and debt shifting as well as through risk shifting, as the difference in reported profitability across affiliates facing different tax rates (e.g. Huizinga and Laeven, 2008; Johannesen et al., 2016). The estimates suggest that an increase in the corporate tax rate of 10 percentage points lowers ROE by around 0.014 (Table 12, Column 1). At the sample mean, this is equivalent to a semi-elasticity of around 0.8, which is consistent with estimates reported in a recent meta-study (Heckemeyer and Overesch, 2017).

In a second step, we estimate the same equation but conditioning on risk:

$$profits_{ijc} = \delta_1 + \delta_2 tax_c + \delta_3' X_c + \delta_4 risk_{ijc} + \rho_j + \kappa_{ijc}$$

where $risk_{ijc}$ measures the standard deviation of ROE at the level of affiliate i located in country c belonging to multinational firm j. By comparing the reported profitability of affiliates facing different tax rates but with a comparable level of risk, δ_2 identifies profit shifting through other channels than risk shifting. The estimates suggest that an increase in the corporate tax rate of 10 percentage points lowers ROE by around 0.012 when holding risk constant (Column 2). A simple comparison of $\widehat{\gamma}_2$ and $\widehat{\delta}_2$ shows that differences in risk can account for around 16% of the intra-firm correlation between tax rates and reported profits suggesting that risk shifting is a quantitatively non-negligible channel for profit shifting.

We finally note that, under the relatively strong assumption that our risk measure is orthogonal to other determinants of reported profits (conditional on the controls), δ_4 can be interpreted as a measure of the within-firm "risk price": it captures the average compensation in terms of expected profits for taking on an additional unit of risk. We provide a simple test of "risk mispricing" by including the interaction between the corporate tax rate and the risk measure in the model. If multinational firms misprice risk to lower the global tax bill, we should expect affiliates in high-tax countries to receive less compensation for the same amount of risk than affiliates of the same firm in low-tax countries so that the coefficient on the risk term should be closer to zero when affiliates face relatively high tax rates. We find only weak evidence of such "risk mispricing": the interaction between the tax rate and the risk measure is quantitatively small and statistically insignificant (Column 3).

6. Concluding remarks

This paper studies the effect of taxes on the allocation of risk inside the multinational firm. Theoretically, we show that corporate taxes exert an ambiguous effect on the intra-firm risk allocation. Transfer pricing laws that establish a risk-profit nexus and loss offset limitations create incentives to distort the risk allocation within the firm towards low-tax countries; risk aversion of owners, in turn, creates incentives to allocate risk to high-tax countries. Empirically, we find that multinational firms disproportionately allocate risk to low-tax countries and that this effect is largely driven by the risk-profit nexus created by transfer pricing rules. Finally, we show that within-firm differences in risk can account for a significant part of the well-established correlation between profits and tax rates, suggesting that risk shifting is a quantitatively relevant channel for profit shifting.

The results highlight an important limitation of the arm's length principle at the heart of the international tax system. While arm's length rules are designed to curb multinational profit shifting and mitigate its negative consequences in the form of base erosion and tax competition (see e.g. Keen and Konrad, 2013; Beer et al., 2018), they actually *create* a profit shifting channel when it comes to risk. Specifically, the risk pricing implied by arm's length rules induces multinational firms to distort their intra-firm risk allocation, potentially at the cost of organizational efficiency, in order to justify the allocation of more profits to low-tax countries. Risk-related profit transfers to low-tax entities are fully consistent with the arm's length rules; so instead of limiting profit shifting, arm's length rules to some extent also facilitate it. By pointing to this important conceptual weakness of the international tax system, our findings inform current policy discussions about reforms that would move the system away from the arm's length standard.[40]

Appendix A. Theory

A.1. Proof of Prop. 2

Proof. Assume that Eq. (7) holds with equality (interior solution). An increase in $t_H - t_L$ affects α according to

$$\frac{d\alpha}{d\left(t_H - t_L\right)} = -\frac{\bar{\theta}'(\alpha)}{\Psi}$$

where Ψ denotes the derivative of the left hand side of Eq. (7) with respect to α. With Eq. (7) representing the profit-maximizing choice of α, the second-order condition, Ψ, is strictly negative. Thus, $\frac{d\alpha}{d(t_H - t_L)} > 0$, from which follows the Proposition. ■

[40] The existing critique of the system mainly relates to the fact that profit allocation at arm's length is an inappropriate concept for modern intangible rich multinational firms as immaterial assets are by definition firm-specific in nature and no third party reference price exists (see e.g. Beer and Loeprick, 2015). Additionally, the literature has pointed to the many economic differences between multinational and national firms, which make national firms' price choices a poor reference for pricing within multinational firms (see e.g. Bauer and Langenmayr, 2013).

A.2. Proof of Prop. 3

Proof. Based on Eq. (8), an increase in the tax gap affects *a* as follows:

$$\frac{d\alpha}{d\left(t_H - t_L\right)} = -\frac{\frac{E[u'(\pi(\varepsilon))\cdot\varepsilon]}{E[u'(\pi(\varepsilon))]} + \left(t_H - t_L\right)\frac{E[u''(\pi(\varepsilon))\cdot q(\varepsilon)\cdot\varepsilon]}{E[u'(\pi(\varepsilon))]} - \left(t_H - t_L\right)\frac{E[u'(\pi(\varepsilon))\cdot\varepsilon]E[u''(\pi(\varepsilon))\cdot q(\varepsilon)]}{\left(E[u'(\pi(\varepsilon))]\right)^2}}{\Psi}$$

where $\Psi < 0$ denotes the derivative of the left hand side of Eq. (8) with respect to α. The first term in the numerator is negative, as explained in the main text above. The second and the third term are negative if $E\left[u''\left(\pi(\varepsilon)\right)\cdot\varepsilon\right] < 0$ which is the case if $u'''(.) > 0$ – the defining feature of decreasing absolute risk aversion (DARA). Then, $\frac{d\alpha}{d(t_H - t_L)}$ is unambiguously negative. ■

A.3. Proof of Prop. 4

Proof. With $B_H = \int_{\varepsilon-\infty}^{\varepsilon^H} b_H f(\varepsilon)d\varepsilon + \int_{\varepsilon^H}^{\varepsilon\infty}\left(p(\varepsilon) - q(\varepsilon)\right)f(\varepsilon)d\varepsilon$ and $\int_{\varepsilon-\infty}^{\varepsilon^L} b_L f(\varepsilon)d\varepsilon + \int_{\varepsilon^L}^{\varepsilon\infty} q(\varepsilon)f(\varepsilon)d\varepsilon$, the first order condition with respect to α is given by Eq. (10) where we used the fact that a change of ε^H and ε^L in response to a change in α does not affect the tax base. An increase in t_H and t_L affect the optimal choice of α as follows:

$$\frac{d\alpha}{dt_H} = \frac{\int_{\varepsilon^-}^{\varepsilon^H}\varepsilon f(\varepsilon)d\varepsilon}{\Psi} > 0$$

$$\frac{d\alpha}{dt_L} = -\frac{\int_{\varepsilon^-}^{\varepsilon^L}\varepsilon f(\varepsilon)d\varepsilon}{\Psi} < 0$$

where Ψ denotes the second derivative of Eq. (10) with respect to α (which is negative if Eq. (10) represents a profit maximum). This proves part (i) of the Proposition.

Differentiating Eq. (10) with respect to α and b_H as well as with respect to α and b_L gives the response of α to a change in the loss offset limits b_H and b_L:

$$\frac{d\alpha}{db_H} = \frac{t_H\frac{\varepsilon^H}{1-\alpha}f\left(\varepsilon^H\right)}{\Psi} > 0$$

$$\frac{d\alpha}{db_L} = -\frac{t_L\frac{\varepsilon^L}{\alpha}f\left(\varepsilon^L\right)}{\Psi} < 0$$

where we used $\frac{\partial\varepsilon^H}{\partial b_H} = \frac{1}{1-\alpha}$ and $\frac{\partial\varepsilon^L}{\partial b_L} = \frac{1}{\alpha}$. This proves part (ii) of the Proposition. ■

A.4. Deductible transaction costs

We now introduce tax deductibility while assuming that the share of transaction costs that is deductible in a location equals the share of the risk that allocated to that location: α in L and $1 - \alpha$ in H. These assumptions imply that the after-tax transaction costs are given by:

$$c(\alpha)[(1-\alpha)\left(1 - t^H\right) + \alpha\left(1 - t_L\right)]$$

Tax deductibility of transaction costs creates an incentive for the firm to allocate more risk to an affiliate the higher the tax rate it is facing because the tax value of deductions is increasing in the tax rate. For instance, in the model version with profit motive, the first order condition is now given by

$$\left(t_H - t_L\right)\left(\bar{\theta}'(\alpha) - c(\alpha)\right) - c'(\alpha)\left(1 - t\right) = 0$$

where $1 - t = (1-\alpha)\left(1 - t^H\right) + \alpha\left(1 - t_L\right)$.

As it turns out, the effect of deductibility is ambiguous. On the one hand, tax deductibility makes risk allocation in the high tax country more attractive. On the other hand, it reduces the tax inclusive transaction cost which increases the relative gain from profit shifting (via risk shifting) to L.

A.5. More than two locations

We now extend the model with profit-risk nexus to more than two locations. We assume that the MNE consists of n entities with index i which, in total, have an expected profit of $\bar{p}$ which is subject to a shock ε. All kinds of bilateral intra-firm trade and contractual links are used to allocate both expected profit and risk within the firm such that $\sum_i \bar{q}_i = \bar{p}$ and $\sum_i \alpha_i = 1$. As in the main model, risk and profit allocation in a given location i is subject to a cost $c_{\alpha_i}(\alpha_i)$ and $c_{\bar{q}_i}(\bar{q}_i)$. Again, minimizing these cost functions gives rise to an allocation of risk $(\alpha_1, \alpha_2, \ldots \alpha_n)$ and an allocation of expected profit $(\bar{q}_1, \bar{q}_2, \ldots \bar{q}_n)$ that is optimal in the absence of taxes (or with equal tax rates everywhere).

Transfer pricing rules create a profit-risk nexus for each location, i.e. $\bar{q}_i = \bar{\theta}_i(\alpha_i)$. The functions $\bar{\theta}_i(\alpha_i)$ are constructed such that $\sum_i \bar{\theta}_i(\alpha_i) = \bar{p}$ for any risk allocation, i.e. the expected profit of $\bar{p}$ needs to be allocated *somewhere*.

The firm chooses the risk allocation $(\alpha_1, \ldots, \alpha_n)$ to maximize the following Lagrangian:

$$\sum_{i=1}^{n} \left[(1-t_i) \left(\bar{\theta}_i(\alpha_i) + \alpha_i \varepsilon \right) - c_{\alpha_i}(\alpha_i) - c_{\bar{q}_i}(\bar{q}_i) \right] + \lambda \left(1 - \sum_i \alpha_i \right)$$

The n first order conditions are:

$$\bar{\theta}_i'(\alpha_i) \left[(1-t_i) - c_{\bar{q}_i}(\bar{q}_i) \right] - c'_{\alpha_i}(\alpha_i) = \lambda \quad \text{for all } i$$

With λ being equal in all n conditions, the profit maximizing risk allocation equates the net benefit of allocating risk (and, via the nexus $\bar{\theta}_i(\alpha_i)$, profit) to a given location. This implies that a tax rate change in one location affects the whole risk allocation (not just the risk allocated to the jurisdiction with the lowest tax rate). This result is due to the assumption of locational non-tax cost of risk and profit allocation (see Huizinga/Laeven (2008) for a similar modelling approach, especially the optimum condition in their equation (2)). Without these cost, the above set of first order conditions imply a corner solution in which all risk and profit is allocated to the location with the lowest tax rate. In such a setting, tax rate changes only change the allocation of risk and profit if they change the identity of the lowest-tax location.

Appendix B. Empirics

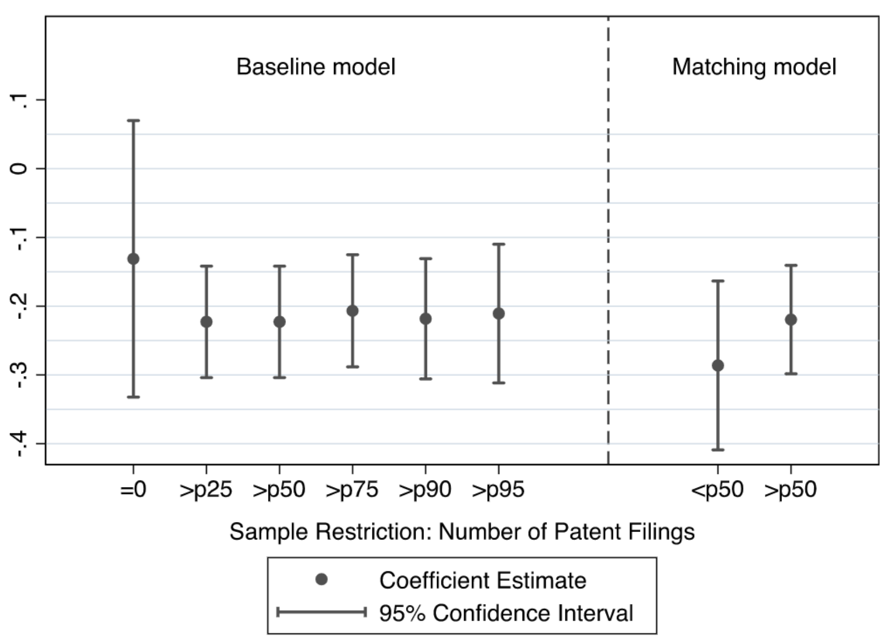


Fig. A.1. Effect heterogeneity - IP intensity (as measured by patent applications and immaterial assets on balance sheet). The figure depicts coefficient estimates and 95% confidence intervals for the baseline model (Specification (9) of Table 4) estimated in subsamples of multinational firms with no granted patent application within our sample period and no immaterial assets on the balance sheet (= 0); multinational firms whose number of granted patent applications or balance sheet immaterial assets relative to total assets is above the 25th/50th/75th/90th/95th percentile of the sample distribution (>p25/>p50/>p75/>p90/>p95). The matching models account for heterogeneity in group size and host countries when estimating the tax effect on risk for groups of firm with a number of aggregate patent applications and a balance sheet ratio of intangibles to total assets below/above the sample median.

Table A1
Robustness.

Standard deviation of ROE, First year values on RHS								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Corporate tax rate	−0.2262***	−0.2753***	−0.1959***	−0.2091***	−0.2295***	−0.2157***	−0.1189**	−0.1450***
	(0.0366)	(0.0451)	(0.0388)	(0.0611)	(0.0382)	(0.0371)	(0.0520)	(0.0355)
log GDP	0.0073***	0.0085***	0.0097***	−0.0008	0.0063***	0.0071***	−0.0049**	0.0064***
	(0.0017)	(0.0018)	(0.0017)	(0.0038)	(0.0018)	(0.0018)	(0.0022)	(0.0019)
log GDPpC	0.0239***	0.0322***	0.0110*	0.0312***	0.0290***	0.0265***	0.0133**	0.0200***
	(0.0059)	(0.0064)	(0.0057)	(0.0071)	(0.0054)	(0.0059)	(0.0066)	(0.0069)
Unemployment rate	0.0002	0.0010*	−0.0008*	0.0022	0.0002	0.0001	0.0005	−0.0001
	(0.0004)	(0.0006)	(0.0004)	(0.0014)	(0.0004)	(0.0004)	(0.0006)	(0.0005)
Stock market volatility	0.0000	−0.0000	−0.0003	0.0002	0.0002	0.0002	0.0010***	0.0003*
	(0.0002)	(0.0003)	(0.0003)	(0.0004)	(0.0002)	(0.0002)	(0.0004)	(0.0002)
Corruption control	−0.0159***	−0.0231***	−0.0140***	−0.0291***	−0.0175***	−0.0167***	0.0107**	−0.0064
	(0.0040)	(0.0041)	(0.0043)	(0.0067)	(0.0040)	(0.0041)	(0.0052)	(0.0048)
Exchange rate volatility		0.0069***						
		(0.0015)						
Observations	276,314	208,084	247,577	25,842	240,747	245,411	36,632	193,188
R-squared	0.2861	0.2933	0.2695	0.4049	0.2888	0.2680	0.1940	0.3365
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Corporate controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age and # of obs. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	All	All	EU	Non-EU	Core Ind.	Subs.	Parent	>5 obs

Note: The table shows regression results from the cross-sectional model specified in Section 5.2.1. Columns (1) depicts Specification (9) of Table 4, Column (2) reestimates this baseline specification but additionally controls for exchange rate risk. Columns (3) and (4) reestimate the baseline model in the subsample of affiliates located in European and non-European countries (where Europe is defined as the EU 28 countries plus Norway and Switzerland). Column (5) excludes firms in the financial and government sector. Columns (6) and (7) reestimate the baseline model in the subsamples of subsidiary and parent firms. Specification (8) restricts the sample to firm observations where the risk measure is calculated based on five observations or more. See the notes to Table 4 for a description of the explanatory variables. All explanatory variables take the value of the first year with non-missing ROE.

Table A2
Ex ante risk measure and effect heterogeneity (IP intensity).

	Industry risk (4-digit level)				
	(1)	(2)	(3)	(4)	(5)
Corporate tax rate	−0.0382***	−0.0604***	−0.0596***	−0.0593***	−0.0533**
	(0.0113)	(0.0110)	(0.0113)	(0.0160)	(0.0226)
Observations	215,026	95,887	86,053	34,787	17,611
Firm fixed effect	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Country controls	Yes	Yes	Yes	Yes	Yes
Corporate controls	Yes	Yes	Yes	Yes	Yes
Age and # of obs. controls	Yes	Yes	Yes	Yes	Yes
Sample	Zero	Non-zero	>p75	>p90	>p95

Note: The table shows regression results from the cross-sectional baseline model specified in Section 5.2.1. The dependent variable is the 'baseline' *ex ante* industry risk measure defined in Column (1) of Table 8 (see the notes to Table 8). The sample is restricted to affiliates that belong to multinational groups that do and do not successfully file for patent applications within our sample period respectively (Columns (1) and (2)) and affiliates that belong to multinational firms with patent applications above the 75th/90th/95th percentile of the distribution respectively. See the notes to Table 4 for further variable definitions. All explanatory variables take the value of the first year with non-missing values of ROE.

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