Essays in Business Taxation

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Contents

1 Preface

The continuing trend towards globalization has become one of the most decisive forces shaping the environment in which firms operate. Rapid technological progress, the digitalization of production processes and the lifting of trade barriers allow firms to organize production in international value chains, sell products across borders and assign profits to various locations around the globe. This development has substantially changed the way in which firms are affected by corporate taxation. For instance, firms can avoid paying corporate income tax by setting up cross-border structures and shifting income to low-tax locations. These responses to international tax differences are well-documented by the existing literature (e.g. Hines & Rice, 1994; Huizinga *et al.*, 2008; Huizinga & Laeven, 2008; Dharmapala & Riedel, 2013; Dharmapala, 2014) and should in principle lead to lower tax burdens for multinational firms. On the one hand, lower effective tax payments reduce the sensitivity of corporate decisions with respect to statutory tax rate changes. On the other hand, however, the tax-sensitive organization of multinational groups distorts the corporate structure (Voget, 2011; Devereux *et al.*, 2015; Feld *et al.*, 2016a). Furthermore, multinational firms have been identified as important international transmitters of country-specific shocks (Cravino & Levchenko, 2017). The possibility of profit shifting means that tax changes in one jurisdiction may affect corporate investment decisions in another jurisdiction not only on the extensive (Devereux & Griffith, 1998) but also on the intensive margin. Finally, when establishing cross-border links or expanding within countries, firms do so not only through greenfield investments but increasingly also through mergers and acquisitions (M&As) which made up 49.7% of Foreign Direct Investment (FDI) around the world in 2016.[1] Fiscal policy that inhibits the efficient allocation of assets, such as the taxation of capital gains, may have adverse effects on the functioning of the market for corporate control.

To design an efficient corporate tax system it is crucial to understand the implications of tax policy in the context of a globalized economy. This thesis sheds light on two important issues. First, I study the impact of taxation on both the frequency

[1]Source: UNCTAD World Investment Report 2017.

and the outcome of M&As. Taxation is identified as an important driver of takeover dynamics and as a determinant of productivity gains in cross-border mergers. Second, I explore the cross-border effect of taxation on corporate R&D activity in the context of profit shifting. Tax cuts on income from intellectual property that do not require the establishment of nexus in the corresponding location benefit all firms of a multinational group with an affiliate in this location because income can eventually be shifted there. These tax cuts thus exert a positive cross-border effect on R&D activity.

Which fiscal policy emerges in a world where firms operate across borders? Previous studies have argued that an increase in capital mobility eventually leads to a so-called “race to the bottom” because countries compete for internationally mobile firms (Zodrow & Mieszkowski, 1986). Decreasing corporate income tax rates appear to support this line of argument (see Slemrod, 2004). However, not much is known about how such fiscal competition evolves in the context of growing public debt burdens which have become a relevant feature for many countries after the financial and economic crisis 2008-2009. I address this issue in a theoretical analysis in the final part of this thesis.

This thesis is organized in four self-contained chapters. I begin by analyzing the impact of capital gains taxation on corporate acquisition activity in Chapter 2 which is co-authored with Lars Feld, Martin Ruf, Ulrich Schreiber and Johannes Voget. In principle, shareholders demand to be compensated for the capital gains tax which comes due when they sell their shares. This price-increasing lock-in effect has been well-documented for M&A deals that are eventually completed (Ayers *et al.*, 2003). However, high capital gains tax payments may also increase premium demands above potential acquirers' reservation prices. In this case, sellers may prefer to retain their stock and the deal fails. Thus, capital gains taxation does not only affect deal prices but also the overall quantity of M&A deals and may thus constitute an important obstacle in the market for corporate control which should, in principle, assign assets to the owners that generate the highest value (Manne, 1965). We test this quantity effect of capital gains taxation on acquisition activity using a comprehensive dataset of corporate M&As around the globe. The lock-in effect is identified through substantial variation in corporate capital gains tax rates resulting from several reforms that have been implemented in different countries at different points in time and by contrasting deals with targets operating in industries with a high level of accumulated capital gains at the deal announcement with those that involve targets with low capital gains. We find that a one percentage point increase in the capital gains tax rate reduces acquisition activity by around 1% annually. Combining this estimate with information on deal premia realized in comparable deals, we compute the total cost to shareholders of capital gains taxation in the form of foregone synergy gains. It amounts to $9.3 billion each year for the United States.

In Chapter 3, which is co-authored with Johannes Voget, I turn to the effect of international taxation on the outcome of M&As. M&A deals are often succeeded by the reorganization of operations within the newly formed group. This involves the concentration of tasks in certain entities according to within-group productivity differences and constitutes an important source of productivity gains resulting from the acquisition. However, international tax differentials are likely to distort such reorganizations because they incentivize firms to establish nexus in low-tax locations by leaving some activities in potentially less productive affiliates. Thus, cross-border tax differences reduce the productivity gain in M&A deals similar to a mechanism described in Becker & Fuest (2011) and Devereux *et al.* (2015). We test this mechanism using a set of M&A deals in which we observe production factors and output of both the target and the acquiring firm before and after deal completion. We estimate total factor productivity applying the Levinsohn & Petrin (2003) method and relate its evolution before and after the deal completion to the tax differential between the target and acquirer location. We estimate that a one percentage point increase in the absolute tax differential between the locations of two merging firms reduces the subsequent total factor productivity gain by 4.5%. This effect is less pronounced when firms can use international profit shifting to attenuate effective differences in taxation.

Chapter 4 is co-authored with Thomas Schwab. We study the cross-border effect of tax cuts on R&D activity in the context of profit shifting. The direction of this effect is of high relevance in a world where countries use fiscal policy to compete for R&D investment and talents (Akcigit *et al.*, 2016; Moretti & Wilson, 2017). If a tax cut in one country requires firms to establish a nexus in this location to benefit from it, such policy is likely to draw away activity from other jurisdictions. However, in the absence of nexus requirements, firms can conduct R&D activity at the location of their choice and subsequently attribute the resulting profits to the low-tax location. Thus, the lower tax rate benefits the whole group and exerts a positive cross-border effect on R&D output. We test this mechanism by combining administrative data on corporate patent applications with firm-level information on ownership structure and economic activity in a difference-in-difference identification strategy. We estimate the response of a firm's patent output to a tax cut for income from intellectual property in one of its foreign affiliate locations. For firms with cross-border links, a tax cut in one country raises R&D output abroad by about 15%.

Finally, in Chapter 5 I analyze how differences in initial government debt levels affect fiscal competition. This chapter is co-authored with Eckhard Janeba. We set up a stylized two-period, two-jurisdiction framework in which countries compete for mobile firms using a source-based tax rate and long-run public infrastructure investments that require expenditure in the first period and make the jurisdiction more attractive in the second period. Jurisdictions differ in the initial debt repayment burden in period 1. If additional borrowing between the two periods is unrestricted, we find that initial debt levels do not affect fiscal policy. The more indebted jurisdiction redistributes the additional burden across the two periods by increasing public borrowing in period one. This result is overturned when public borrowing is restricted. In this case, the government in the more indebted region turns to public infrastructure investments as the second-best option to smooth consumption across periods. It reduces public infrastructure investments in the first period and partially compensates the resulting disadvantage in the second period by lowering tax rates. Through the interaction in the fiscal competition game, the less indebted jurisdiction raises tax rates but is still better off in terms of the number of investing firms. Thus, differences in initial debt levels induce a divergence in tax policy which in turn further deteriorates the fiscal position of the more indebted jurisdiction.

2 Taxing Away M&A: Capital Gains Taxation and Acquisition Activity

2.1 Introduction

Mergers and acquisitions (M&As) are an important component of the market for corporate control (e.g. Manne, 1965). In principle, corporate takeovers allocate assets to the owners that use them to generate the highest shareholder value. Any obstacle in the takeover market may thus be harmful to value creation and, potentially, the economy as a whole. Capital gains taxes are an important source of such a distortion as sellers demand compensation for the capital gains tax levied when they dispose of their shares which impedes the completion of deals. Some countries have recognized this problem and have repealed capital gains taxation for inter-corporate M&A deals. In the United States, the 2017 Tax Cuts and Jobs Act has abolished capital gains taxes at the corporate level as far as the selling of foreign subsidiaries is considered. However, the large majority of domestic affiliates held by U.S. corporations still face a substantial capital gains tax burden if sold in an M&A deal.

The price-increasing lock-in effect of capital gains taxation has been well documented for stock prices and acquisition premiums (Ayers *et al.*, 2003; Dai *et al.*, 2008). Less is known about whether these price distortions eventually lead to some deals not being completed at all. Are shareholders negatively affected by the lock-in effect of capital gains taxation as it inhibits value-creating M&As? In this paper, we address this question using a comprehensive dataset on domestic and international M&As. We provide empirical evidence on the impact of capital gains taxation on acquisition activity and estimate its effect on the location choice of an acquirer. After controlling for other determinants of location and target choice, the acquiring firm favors the location with the lower capital gains tax rate because it faces a lower seller reservation price there. We also take into account that capital gains taxation could affect the overall number of observed deals and estimate the impact of the capital gains tax rate on aggregate takeover dynamics. High capital gains tax payments may increase premium demands above potential acquirers' willingness to pay. In this case, sellers prefer to retain their stock and the deal fails.

Our estimations are based on micro-level data from 29,546 M&A deals in North America, Asia and Europe in the period from 2002 until 2013. M&As in the sample are dominated by transactions between incorporated entities (93.4%). Our international tax panel data exhibits many substantial changes in corporate capital gains tax rates by more than 10 percentage points. These take place in different countries at different points during the sample period, which allows us to control for unobserved factors.

We employ several empirical strategies to identify the quantity effect of capital gains taxation on acquisition activity via the lock-in of target shares. First, a number of large economies (e.g. United Kingdom, Germany, France, Italy) have implemented full or partial exemptions from corporate taxation for capital gains realized in M&As. Similar to an approach used by Lel & Miller (2015) and Dessaint *et al.* (2017), the staggered implementation of these reforms over the sample period serves as a quasi-experiment in our empirical analysis which allows us to control for potentially confounding factors (e.g. regulatory reforms) and unobserved firm- and location-specific effects. Second, we exploit variation in the capital gains tax exposure across targets operating in different industries to further ensure that the estimated association between capital gains taxation and acquisition activity is caused by the lock-in effect on target shares. Then the effect of capital gains taxation is present for targets with high capital gains, while it is absent for targets without capital gains. This additional variation allows us to filter out any unobserved factor that coincides with capital gains tax reforms. Finally, we note that changes in corporate capital gains tax rates should only affect M&A deals in which the selling party is incorporated. Contrasting the cases of corporate and non-corporate sellers, we find that deals with non-corporate sellers are not affected. This again points to capital gains tax reforms indeed driving our results rather than some omitted variable.

When estimating the quantity effect of capital gains taxation, we initially take the global number of M&As as given and focus on how capital gains taxation affects the location choice of acquirers and hence the distribution of M&A activity. A country with a high corporate capital gains tax rate exhibits a smaller number of M&As because acquirers choose other locations with a lower tax burden on capital gains and thus also a lower premium demanded by sellers. We employ a McFadden (1974) choice model to estimate how capital gains taxes affect the acquirers' choice of target location. We then back out the own-region elasticity of the number of deals with respect to the capital gains tax rate for each country. This allows us to determine the effect of capital gains taxation on the number of realized deals in a country.

The sensitivity to capital gains taxes is estimated at the deal level using conditional logit and mixed logit regressions. It also allows us to control for bilateral acquirer-target-country specific as well as firm-specific characteristics. We find that, if a country decreases its corporate capital gains tax by one percentage point, the likelihood that a target of this country is chosen increases by 0.7%. These estimates imply that the total volume of M&As in the United States would increase by 24% or $16.1 billion per year if U.S. corporate capital gains taxes on M&As were to be abolished. Using additional variation across target firms in the capital gains tax exposure at the deal announcement, we confirm that this effect is linked to the lock-in of target shares.

In a second step, we no longer take the overall number of M&A deals as given. For large capital markets like the United States it is reasonable to assume that acquirers do not always have a feasible acquisition option in another location. Therefore, a high level of capital gains taxation may decrease the number of M&As globally. To address this point, we also implement an alternative estimation approach which allows the total number of deals to decrease with rising capital gains tax rates. We employ a Poisson pseudo-maximum-likelihood (PPML) estimator to analyze aggregate measures of M&As in a panel fixed effects framework. Individual deals are aggregated at the country-level or, alternatively, the country-industry level to capture the industry-specific dynamics of acquisition activity such as regulatory reforms (e.g. Andrade *et al.*, 2001; Ovtchinnikov, 2013). We find that a one percentage point decrease in a country's corporate capital gains tax rate raises the number of M&As in that location by about 1 percent per year. This implies that a full tax exemption of capital gains in inter-corporate M&As in the United States would increase total M&A volume by $34.4 billion annually.

If capital gains taxation prevents the closing of deals, then shareholders would benefit less from the gains of industrial reorganization by means of M&As. These benefits have been shown to result from increased productivity (e.g. Devos *et al.*, 2009), increased innovation activity (e.g. Stiebale, 2016), knowledge spillovers (e.g. Bresman *et al.*, 1999; Bena & Li, 2014), enhanced corporate governance (e.g. Rossi & Volpin, 2004), as well as increased management efficiency (Manne, 1965; Wang & Xie, 2009) and management discipline (Scharfstein, 1988; Sapra *et al.*, 2014; Lel & Miller, 2015).[1] The price effect of capital gains taxes on acquisitions identified by

[1] Most of these benefits go to target shareholders. With respect to acquirer returns, empirical

the literature is, by itself, not sufficient to infer the implied losses to shareholders (Auerbach, 2006). For that, it is necessary to estimate the degree to which capital gains taxes inhibit the realization of M&As, which is the contribution of our study. We first estimate the quantity effect of capital gains taxation on M&As and then simulate the impact on M&A volume of a full tax exemption of capital gains realized in acquisition deals. This estimate is combined with observed acquisition premiums of realized deals to compute the potential shareholder gain of such an exemption which corresponds to the value loss of taxing these transactions.

Using our coefficient estimates we arrive at an estimate of the potential shareholder loss associated with corporate capital gains taxation. The corresponding foregone synergy gains of these unrealized M&As are proxied by premiums specific to target firms in particular industries. Using estimation results from the location choice model, this amounts to an estimated shareholder loss for the U.S. of $4.2 billion per year. Since in the choice model the total number of M&As is taken as given, this estimate does not reflect the possibility of acquirers withdrawing from the M&A market due to high capital gains taxation instead of merely switching their focus to more attractive locations. Our second estimation approach allows the global number of M&A deals to decrease with a higher level of capital gains taxation. The estimated shareholder loss is therefore higher. It amounts to $9.3 billion per year in the United States. The magnitude of this estimate reflects that for many potential M&A deals in the U.S. there may not exist a comparable outside option in another country. Then, capital gains taxation ultimately prevents some M&As which implies a considerable impact on value creation.

Our findings suggest capital gains taxes substantially reduce shareholder value by inhibiting the market for corporate control. By investigating the quantity effect of corporate-level capital gains taxation on acquisition activity, we expand the existing literature which examines the price effect of capital gains taxes in takeovers (Ayers *et al.*, 2003; Huizinga *et al.*, forthcoming). Furthermore, our paper relates to Edwards *et al.* (2004), who study the capital market effect of a corporate capital gains tax reform in Germany. Consistent with our findings, they report a positive market response to this particular reform in expectation of future efficiency gains. Our study shows that capital gains taxation is indeed an important determinant of M&A activity and thus complements prior studies by Rossi & Volpin (2004), Erel *et al.* (2012), John *et al.* (2015) and Dessaint *et al.* (2017) who show that economic and

evidence is mixed (e.g. Agrawal *et al.*, 1992; Loughran & Vijh, 1997; Fuller *et al.*, 2002; Savor & Lu, 2009).

institutional factors such as international trade integration, quality of accounting disclosure, shareholder protection and labor market regulations have a substantial influence on domestic and cross-border M&As. At the aggregate level, the estimation also allows for a comparison to Ayers *et al.* (2007), who found that time-series measures of acquisition activity on American stock exchanges are negatively related to changes in the U.S. federal capital gains tax rate on individual shareholders.[2]

The paper is structured as follows. In Section 2.2 we use a stylized theoretical framework to analyze the lock-in effect in the case of inter-corporate acquisitions and describe the institutional setting. Section 2.3 explains the empirical approach. We present the estimation results in Section 2.4 and quantify the shareholder loss in Section 2.5. Section 2.6 contains concluding remarks.

2.2 Capital Gains Taxes and Corporate M&As

2.2.1 A Stylized Framework

The following model serves to clarify the relationship between capital gains tax rates and inter-corporate acquisition activity via the lock-in effect on the seller's reservation price and demonstrates how the tax effect can be estimated either by a multinominal logit regression or, alternatively, by count regressions at the aggregate level.

We consider a corporation that has decided to acquire another firm and faces a choice between a set of potential target locations $i = 1, ..., l$. This is an assumption frequently used as a starting point in the empirical corporate finance literature. For instance, Harford (1999) argues that cash-rich firms are more likely to attempt acquisitions. Hanlon *et al.* (2015) and Edwards *et al.* (2016) show that foreign subsidiaries of U.S. multinationals engage in corporate acquisitions in order to make use of their locked-out cash due to repatriation tax costs. Both cases give plausible reasons why certain firms might exogenously become acquirers which then search for the best available option.

We first derive the acquisition prices for each potential target location i which we denote by p_i. Suppose that the acquirer is looking for a target with a discounted

[2] In contrast to acquisitions from individual shareholders, inter-corporate acquisitions often involve private targets and these deals have been shown to yield quite different outcomes (e.g. Fuller *et al.*, 2002). Furthermore, dispersed individual shareholders are likely to behave differently in M&A deals than concentrated corporate sellers (Shleifer & Vishny, 1986).

pre-tax cash flow of d per share. In the absence of an acquisition, a corporate seller[3] of such a target earns a discounted after-tax cash flow of $\left(1-\tau_i^{CIT}\right) d$ per share. τ_i^{CIT} is the effective profit tax rate from the seller's perspective where the subscript indicates that the seller is taxable in the target location.[4] If the seller decides to dispose of the target, it receives p_i and pays capital gains taxes on the realized gains at a rate τ_i^{CG}. For simplicity, we assume that the seller bought the target firm at a price normalized to zero, such that p_i is equal to the capital gain per share. The selling company accepts the deal offer only if p_i is above its reservation price $\tilde{p}_i$ which satisfies the following condition:

$$\left(1-\tau_i^{CG}\right) \tilde{p}_i = \left(1-\tau_i^{CIT}\right) d.$$

At $p_i = \tilde{p}_i$, the seller is indifferent between accepting or rejecting the offer as the net revenue from selling is equal to the net cash flow from holding. An implicit assumption underlying this condition is that the seller reinvests the revenue from selling the target into an asset which generates an identical after-tax cash flow.[5] Moreover, we assume an infinite life of the target and neglect any write-down of the target's shares. Though of simplifying nature, these assumptions allow us to isolate the lock-in effect. Assuming a reinvestment in shares, we abstract from any mode of payment effect that occurs if the deal triggers a change in the cash flow received by the seller which could potentially be related to a difference in tax treatment.

Since in our model the acquirer has the choice between targets in several locations it retains all the bargaining power and pays the reservation price of each seller.[6] The acquisition price is then given by

$$p_i = \tilde{p}_i = \frac{1-\tau_i^{CIT}}{1-\tau_i^{CG}} d,\ i = 1, ..., l. \tag{2.1}$$

[3]We focus on corporate sellers because they represent by far the largest share in M&A deals.

[4]The effective tax rate generally corresponds to the corporate income tax rate since inter-corporate dividends are usually exempt or credited in the domestic case and exempt by many countries (except for the United States) in the case of cross-border dividends.

[5]This is equivalent to assuming perfect capital markets.

[6]Assigning the full bargaining power to the acquirer makes the model simple. Note, that the results of the theoretical analysis only rely on the acquirer having some degree of bargaining power but are independent of its exact distribution between selling and acquiring firm. In practice, the distribution of bargaining power depends on various factors (e.g. target scarcity, see Ahern, 2012) and determines how the merger gain is divided between the deal participants (Bradley *et al.*, 1988) which is also relevant for the tax incidence in an M&A (Huizinga *et al.*, 2012).

p_i is equal to the expected discounted after-tax cash flow if and only if $\tau_i^{CG} = 0$. A positive capital gains tax rate raises the reservation price above the value of the after-tax cash flow of the target. More generally, the capital gains tax imposes an additional burden on the act of selling the target which *ceteris paribus* makes the deal less attractive from the seller's perspective.

Turning to the acquiring company, we assume that it has an ownership advantage (e.g. through better management or complementary technology) that enables it to increase the discounted cash flow from the target by Δ percent per share. One may also refer to Δ as the synergy gain. The discounted after-tax return per share of the target from the acquirer's perspective is then given by $r = \left(1 - \tau^A\right) d\,(1 + \Delta)$ where τ^A is defined as the effective tax rate faced by the acquiring firm and again is assumed to be identical across locations for simplicity.

The acquirer receives a payoff of $v_i = r - p_i$ if it makes an acquisition in location i. Assume for the moment that the acquirer can only make one acquisition. It will therefore only consider the optimal target firm within each location and then compare options across locations. It chooses i such that

$$v_i \geq v_j \forall j \in (1, ..., l)\,. \tag{2.2}$$

From this discrete choice model, we can derive the probability of the acquirer choosing a target in i which is given by

$$\Phi\left(v_i \geq v_j | \boldsymbol{x}, \boldsymbol{\tau^{CG}}\right) = \frac{\exp v_i\left(\boldsymbol{x}_i, \tau_i^{CG}\right)}{\sum_{j=1}^{l} \exp v_j\left(\boldsymbol{x}_j, \tau_j^{CG}\right)} \tag{2.3}$$

where $\boldsymbol{\tau^{CG}}$ is a vector of capital gains tax rates at all potential locations and $\boldsymbol{x}$ is a vector of other location-specific variables that may drive the location choice. *Ceteris paribus* an increase in τ_i^{CG} reduces the probability of a target location in i:

$$\frac{\partial \Phi}{\partial \tau_i^{CG}} = \frac{\left(\sum_{h \neq i} \exp v_h\left(\boldsymbol{x}_h, \tau_h^{CG}\right)\right) \exp v_i\left(\boldsymbol{x}_i, \tau_i^{CG}\right)}{\left(\sum_{j=1}^{l} \exp v_j\left(\boldsymbol{x}_j, \tau_j^{CG}\right)\right)^2} \frac{\partial v_i}{\partial \tau_i^{CG}} < 0. \tag{2.4}$$

Throughout our derivation, we have assumed for simplicity that target locations only differ with respect to the applicable tax rates τ_i^{CIT} and τ_i^{CG}. One could easily extend the model to account for other location-specific characteristics such as differences in the pre-tax cash-flow d. Such extensions would not alter the sign of (2.4) which is solely driven by the lock-in effect of the capital gains taxes. However, while the proposed mechanism is unaffected, location-specific variables would impact the magnitude of the effect.

Empirically, the effect in (2.4) can be tested and quantified using a multinominal logit model for the location choice of individual deals. Such a model can account for differences across locations or across acquiring firms. For example, acquirers may differ in their preference for certain target types d.

An important assumption underlying the choice model is that the overall number of acquisitions is fixed and not affected by tax changes in individual locations. This appears less realistic for large markets such as the United States. An acquirer may not have a potential acquisition target outside the United States available and a high level of capital gains tax payments may thus ultimately prevent the acquisition which reduces the overall number of M&As.

To address this, we relax the assumption of a fixed total number of acquisitions and move to a count model. We now assume that there is a multitude of acquisitions in each location by various firms. Conceptually, we describe the latter by a single representative acquirer which chooses between acquisition targets with different synergy gains Δ. The acquirer realizes all acquisition projects in location i with a positive return $v_i = r - p_i \geq 0$ where $r = \left(1 - \tau^A\right) d \left(1 + \Delta\right)$ and $p_i = \frac{1-\tau_i^{CIT}}{1-\tau_i^{CG}} d$. From this we can derive the cutoff level of synergy $\tilde{\Delta}_i$ such that any deal with $\Delta \geq \tilde{\Delta}_i$ is completed:

$$v_i \geq 0 \Longleftrightarrow \tilde{\Delta}_i \geq \frac{\phi_i}{1 - \tau_i^{CG}} - 1 \text{ with } \phi_i = \frac{1 - \tau_i^{CIT}}{1 - \tau^A} \tag{2.5}$$

It is apparent from (2.5) that without capital gains taxation and no differences in seller and acquirer taxation, we have $\tilde{\Delta}_i = 0$ such that all acquisitions with a positive economic gain are completed. In contrast, a positive capital gains tax rate requires strictly positive and sufficiently large synergy gains to compensate for the tax payment resulting from the deal.

In location i there exists a continuum of potential targets with synergy gains continuously distributed on the interval $\Delta \in \left(\underline{\Delta}_i, \bar{\Delta}_i\right)$. Δ follows a cumulative distribution function F and a corresponding probability function f. Under the assumption that $\tilde{\Delta}_i$ is interior, all deals with $\Delta \geq \tilde{\Delta}_i$ are completed. We can thus define the number of deals in i as

$$N_i = \int_{\tilde{\Delta}_i}^{\bar{\Delta}_i} \Delta' d\Delta = 1 - F\left(\tilde{\Delta}_i\right).$$

As long as F is continuously differentiable and strictly increasing, we can express the number of completed deals as a function of the corporate capital gains tax rate and a vector of covariates $\boldsymbol{x}$:

$$N_i = N_i\left(\tau_i^{CG}, \boldsymbol{x}_i\right) \tag{2.6}$$

Note that $\frac{\partial N_i\left(\tau_i^{CG}, \boldsymbol{x}_i\right)}{\partial \tau_i^{CG}} = -f\left(\tilde{\Delta}_i\right)\frac{\partial \tilde{\Delta}_i}{\partial \tau_i^{CG}} < 0$ implies that an increase in the capital gains tax rate decreases the number of acquisitions. This is commonly referred to as the lock-in effect of capital gains taxation on market activity (e.g. Feldstein & Yitzhaki, 1978). Intuitively, the capital gains tax imposes a transaction cost that prevents some inter-corporate acquisition deals.

Empirically, the effect of the capital gains tax on the number of acquisitions can be tested using a count model. One can also reformulate such a model so that N_i represents the total volume of all completed deals. As the economic impact of M&As may well depend on the size rather than the count of the deals this is useful when measuring the response of acquisition activity to changes in the corporate capital gains tax rate.

2.2.2 Capital Gains Taxation in Corporate M&As

At the center of our analysis lies the corporate-level tax rate on capital gains realized in M&A deals. Countries usually tax gains realized in the form of cash payments received in exchange for target shares. The relevant tax rate is often proportional to the general rate on corporate income and varies substantially across countries. Some apply the full corporate tax rate (e.g. Australia, Japan, United States) whereas others allow for partial exemption (e.g. Canada, Portugal) or fully exempt capital gains from taxation (e.g. New Zealand). Many countries provide preferential treatment in the form of a full exemption for gains realized from substantial holdings (e.g. Netherlands, Ireland) which is particularly relevant for firms holding controlling majorities in other companies. A small number of countries also exempt acquisitions executed

Table 2.1: Corporate Capital Gains Tax Reforms

This table summarizes the corporate capital gains tax reforms in our sample. $\Delta\tau^{CG}$ is the percentage point change in the corporate capital gains tax rate that resulted from the respective reform. Germany: From 2004 onward, 5% of the gains is added back to the taxable income. Sweden: Excluding non-substantial holdings on the stock market. Italy: 95% exemption from 2008 onward. France: 95% exemption for substantial holdings from 2007 onward. Turkey: In 2006, Turkey replaced its participation exemption with a new regime that required firms to keep capital gains in a reserve fund for at least 5 years in order not to be taxed. Iceland: Restricted to substantial holdings from 2011 onward. Source: IBFD.

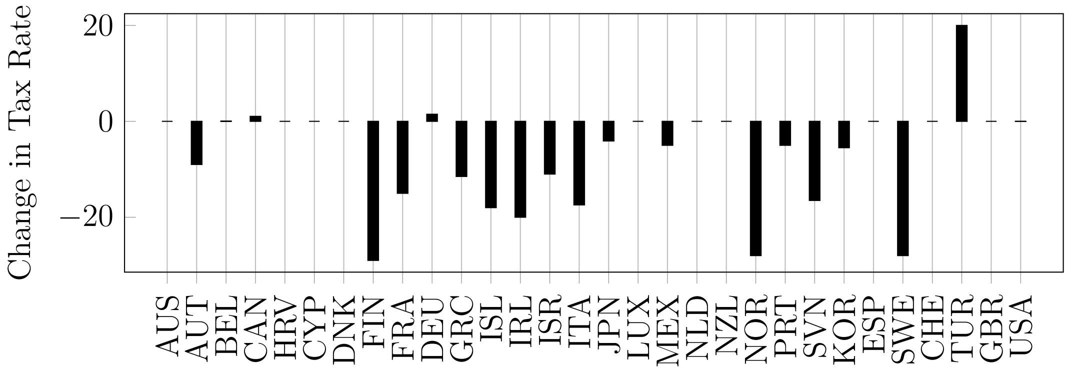
	Year	Type	$\Delta\tau^{CG}$
Germany	2002	General exemption	-38.9
Portugal	2002	50% exemption for substantial holdings	-18.7
United Kingdom	2002	Exemption for substantial holdings	-30.0
Sweden	2003	General exemption	-28.0
Italy	2004	General exemption	-19.0
Ireland	2004	Exemption for substantial holdings	-20.0
Finland	2004	Exemption for substantial holdings	-29.0
Slovenia	2007	50% Exemption for substantial holdings	-23.5
Norway	2004	Exemption for substantial holdings	-28.0
France	2006	Reduction of tax rate from 19% to 8%	-11.0
Turkey	2006	Exemption regime abolished	+30.0
Iceland	2009	General Exemption	-18.0

on the stock market from taxation (e.g. Malta, Cyprus). Deals involving the transfer of assets rather than shares and deals involving stock-for-stock exchange instead of a cash payment are usually treated differently. For instance, buyers can generate tax benefits through a step-up of the target's depreciable assets while these deals may lead to double taxation from the seller perspective. In line with previous studies, we focus on share deals which are less complex than and thus often preferred to asset deals. Stock-for-stock deals are often classified as tax-free deals since gains may be deferred until the stock is finally sold. These deals are included in our sample but they make up only a small fraction of our sample of non-listed targets. We account for their differential treatment with regard to capital gains taxation in a separate robustness check.

In our empirical estimation, we consider the tax rate applicable to capital gains realized by corporations when selling shares in substantial holdings not listed on the stock market to proxy for the taxation of corporate capital gains. Since the beginning of the century, many European countries have cut corporate capital gains tax rates for substantial holdings. Table 2.1 provides an overview of these tax reforms. Besides the United Kingdom and Germany, who abolished capital gains taxation for corporations in 2002, the group of reforming countries includes Italy and France as well as several Scandinavian countries. The timing and magnitude of the tax cuts differed across reforming countries. Figure 2.1 displays the changes in corporate capital gains tax rates for all countries in our sample.[7] The resulting tax rates in 2013 after these reforms are listed in Table 2.2 below.

Figure 2.1: Capital Gains Tax Reforms

This figure displays the accumulated corporate capital gains tax rate changes in the sample period 2002-2013. Changes in the corporate capital gains tax rate refer to changes in the rate charged on capital gains realized by corporations when selling shares in substantial holdings not listed on the stock market.



2.3 Empirical Identification

2.3.1 Micro-level Evidence

In the first part of our analysis, we identify the impact of corporate capital gains taxation on acquisition activity via the location choice of acquirers. We relate the empirical estimation to equation (2.3) and reformulate this expression in an empirical setting to obtain the probability that an acquirer f chooses target location i at time

[7] Note that for the United Kingdom, Germany and Portugal, the changes displayed refer to changes that occurred after the implementation of substantial capital gains tax exemption reforms in 2002.

t:

$$\Phi\left(v_{ift} \geq v_{jft}|\boldsymbol{x}_{1ft}, \tau_{1t}^{CG}, ..., \boldsymbol{x}_{lft}, \tau_{lt}^{CG}\right) = \frac{\exp\left(v_{ift}\right)}{\sum_{j=1}^{l}\exp\left(v_{jft}\right)}. \tag{2.7}$$

where v_{ift} is the value of this choice to the acquirer. We model v_{ift} as a function of the corporate capital gains tax rate in i as well as a large number of other variables that determine the location choice in M&A deals such as acquirer characteristics, target-location-specific variables and characteristics of the relation between acquirer and target location:

$$v_{ift} = \gamma\tau_{it}^{CG} + \boldsymbol{\beta}\boldsymbol{x}_{ift} + \boldsymbol{\phi_i} + \epsilon_{ift} \tag{2.8}$$

τ_{it}^{CG} is the tax rate applicable to capital gains realized by corporations when selling shares in substantial holdings. $\boldsymbol{x}_{ift}$ is a vector of time-varying control variables and $\boldsymbol{\phi_i}$ is a set of location-fixed effects that controls for level differences in the location choice. Following McFadden (1974), both the coefficient of interest γ and the other parameters, $\boldsymbol{\beta}$, can be estimated in a conditional logit regression on the sample of deals.

In this setting, identification of the lock-in effect of capital gains taxation relies on the exogenous variation in the capital gains tax rate that is driven by the staggered implementation of tax exemptions for M&As in various countries. In order to maintain causality, one needs to make sure that these reforms are not endogenous to M&A activity. Such endogeneity may, for example, result from an omitted variable bias. In our model specification, we control for a large range of factors that have been identified by the literature to affect takeover dynamics and may also be correlated with capital gains tax reforms. For instance, one needs to account for the fact that tax reforms may be associated with other regulatory changes that also affect M&A activity. Mitchell & Mulherin (1996) show that industry deregulation is an important driver of takeover dynamics and Dessaint *et al.* (2017) identify a negative impact of employment protection on the number of completed acquisitions. We account for this by including industry-specific indicators (3-digit SIC) for the strength of regulation that vary across time and locations as well as an indicator for the ease of laying off workers. Furthermore, we follow Rossi & Volpin (2004) and include annual GDP growth to account for macroeconomic conditions in the target country.

Economic growth may be correlated with tax rate changes (see Levine, 1991) and is thus crucial to control for in our regression. As pointed out by La Porta *et al.* (1999), changes in corporate taxation may coincide with changes in the quality of institutions. Rossi & Volpin (2004) and Erel *et al.* (2012) show that institutional features, such as the quality of accounting disclosure or investor protection, are crucial for a well-functioning market for corporate control. We use an annual index for audit and reporting quality to control for this feature. The index is based on a comprehensive survey among business executives in a large number of countries and is closely related in concept to the well-known legal indices developed by López de Silanes *et al.* (1998) and Djankov *et al.* (2008). An important advantage for the purpose of our study is that, in contrast to the legal indices, it varies both across countries and time. In addition, we also control for other determinants of institutional quality such as judicial independence and the restrictiveness of credit market regulation. Finally, a country's degree of integration with international product markets may put downward pressure on domestic tax rates due to increased competition from abroad and also raise the number of corporate takeovers. We control for the openness of countries using the logarithm of trade as a percentage of GDP where trade is defined as the sum of exports and imports.

After controlling for the full set of location-specific factors any remaining concern about identification would relate to an unobserved omitted factor. We note that this concern is somewhat alleviated because of the staggered implementation of the capital gains tax exemptions that drive the within-country variation of the corporate capital gains tax rate. For an omitted variable to cause endogeneity it must be systematically related to both corporate capital gains tax exemptions for M&As and takeover dynamics in different years and different countries. We address this remaining concern by exploiting additional variation in capital gains accumulation across target industry sectors over time. Griffin & Stulz (2001) and Bekaert *et al.* (2009) show that corporate stock returns are strongly correlated within industries and systematically vary across sectors. Sellers of targets operating in industries with a stronger increase in firm value prior to the deal are likely to realize a higher level of capital gains upon deal completion. They are thus more negatively affected by the capital gains tax rate than sellers of targets in industries with smaller gains. Such within-location variation in the impact of capital gains taxation allows us to single out any endogeneity resulting from unobserved events that coincide with changes in the corporate capital gains tax rate. We implement this strategy by including the interaction of sector-level capital gains with the corporate capital gains tax rate as a proxy for capital gains tax exposure of the target in our choice value model

$$v_{ift} = \gamma_1 \tau_{it}^{CG} + \gamma_2 \tau_{it}^{CG} \times CG_{ft} + \boldsymbol{\beta x}_{ift} + \boldsymbol{\phi_i} + \epsilon_{ift}. \tag{2.9}$$

CG_{ft} is the median capital gain at the deal announcement in the industry in which the target operates (2-digit SIC). We follow Ayers *et al.* (2003) and compute the 5-year and 3-year maximum gain. In this model, the coefficient of the interaction (γ_2) captures the lock-in effect of capital gains taxation as the size of the capital gains tax rate only becomes relevant if there exist locked-in capital gains. Hence, it is identified not only from variation in the capital gains tax rate but also from variation in both the capital gains tax rate and the accumulated capital gains of the target.

Besides the location-specific control variables mentioned above, we augment our model by a range of other factors that have been found to influence M&A activity. For instance, the corporate capital gains tax rate is usually related to the standard income tax rate (τ^{CIT}) for corporations. We thus include the latter in the estimation to capture any changes in location choices caused by corporate income tax changes. Furthermore, we include a set of control variables that may influence acquisition activity at the aggregate level, in particular if acquirers reside in the same location as the target. These include GDP (see Erel *et al.*, 2012; Rossi & Volpin, 2004), inflation, the size of the stock market, the amount of credit provided to firms (Di Giovanni, 2005), and the size of the service sector. In line with previous research, we lag the macroeconomic variables by one year to reflect that the decision makers' information set is based on completed rather than contemporaneous periods and to mitigate potential endogeneity problems. Finally, we include target-country fixed effects and thus account for any time-constant bias towards particular target locations.

While target-location-specific characteristics are a key factor in determining location choice, the relationship between the target and acquirer location may also be important. Following Feld *et al.* (2016a), we include a set of bilateral acquirer-target-country controls comprising the distance between the two location's capitals as well as dummies indicating a common language, a common border, a former colonial relationship, and whether the acquirer and the potential target location are or were the same country. The latter indicator captures the home bias in the location choice.

Target-country fixed effects in our model are a feasible way to avoid an unobserved variable bias by controlling for unobserved country characteristics that may drive location choice. However, the underlying assumption in such a model is that the preferences captured by these fixed effects are the same for each acquirer. This appears restrictive given that acquirers vary substantially in their acquisition objectives, capability and performance (e.g. Moeller *et al.*, 2004; Arikan & Stulz, 2016; Bird *et al.*, 2017). We thus exploit the detailed micro-level information in our M&A data to control for heterogeneity in the location choice with respect to acquirer-specific characteristics. For example, M&As usually constitute a high fixed cost investment (see Jovanovic & Rousseau, 2002), part of which is related to the administrative burden which differs across countries. While this would deter acquisitions by small firms, larger acquirers are likely to be less affected. We therefore allow the time-invariable preference towards individual locations to vary with the size of the acquirer. That is, we add the interactions between the target-country fixed effects and the logarithm of acquirer total assets in the last available year prior to the acquisition as an additional set of control variables.

Finally, acquirers may not only be heterogeneous with respect to their preferences for certain locations, but may also differ in their response to the capital gains tax rate itself, which would violate the independence of irrelevant alternatives (IIA) assumption. Most importantly, acquirers may differ in the level of synergy gains they expect from buying a particular firm. To account for this, we relax the assumption of a uniform response to capital gains tax rates and estimate a mixed logit model as described by Train (2009), which allows the estimates of γ in specification (2.7) as well as of γ_1 and γ_2 in specification (2.9) to vary across acquirers. Unlike the conditional logit model, results of a mixed logit model are also consistent when the IIA assumption does not hold.

2.3.2 Aggregate Acquisition Activity

Having identified the lock-in effect of capital gains taxation on the acquirer's location choice using deal-level data, we relax the assumption of a fixed number of overall acquisitions and turn to the effect of corporate capital gains tax rates on the level of M&A activity within a location. Guimaraes *et al.* (2003) show that a discrete choice model in the conditional logit framework of McFadden (1974) can be rewritten as a Poisson count model that relates the number of deals in a particular location to its characteristics. Applying this in the context of M&As, one would focus on the second perspective outlined in Section 2.2: A firm acquires all economically feasible targets instead of choosing between potential targets in a set of different locations $i = 1, ..., l$.

As the second step of our empirical analysis, we thus estimate a reduced form of expression (2.6), aggregating the number of deals first on the country and then alternatively on the country-industry level. We model the number and volume of acquisitions as a non-linear function of the corporate capital gains tax rate and a range of control variables:

$$N_{it} = exp\left(\mathbf{x'_{it}}\beta\right) \text{ with } \mathbf{x'_{it}}\beta \; = \gamma\tau_{it}^{CG} + \boldsymbol{\beta z_{it}} + \boldsymbol{\phi_i} + \boldsymbol{\phi_t} + \epsilon_{it} \tag{2.10}$$

where N_{it} denotes the number or total value of acquisitions in country i at time t, τ_{it}^{CG} is the corporate capital gains tax rate and $\boldsymbol{z}_{it}$ denotes the vector of location-specific control variables described for the choice model above. $\boldsymbol{\phi_i}$ and $\boldsymbol{\phi_t}$ are country- and year-fixed effects, respectively. The model is estimated using the Poisson pseudo-maximum-likelihood (PPML) estimator proposed by Silva & Tenreyro (2006). The PPML specification includes time and country fixed effects to account for time trends and unobserved variables that are constant over time but differ across countries.[8] As is shown in Guimaraes *et al.* (2003), this yields estimates that are equivalent to the results in the conditional logit model as long as the factors that determine the choice of target are purely location-specific. Note that the various corporate capital gains tax reforms presented in Table 2.1 provide the source of within-country variation necessary to identify γ in the aggregated model.

In a third step, we conduct an industry-level regression to account for the observation that a large part of acquisition activity is driven by shifts within specific industries (see Mitchell & Mulherin, 1996). The following disaggregated model is estimated using the PPML estimator[9]:

$$N_{ist} = exp\left(\mathbf{x'_{ist}}\beta\right) \text{ with } \mathbf{x'_{ist}}\beta \; = \gamma\tau_{it}^{CG} + \boldsymbol{\beta z_{it}} + \boldsymbol{\delta s_{ist}} + \boldsymbol{\phi_i} + \boldsymbol{\phi_s} + \boldsymbol{\phi_t} + \epsilon_{ist} \tag{2.11}$$

where the dependent variable N_{ist} is the number of M&As in country i, in industry s and in year t, where a corporate seller disposes of shares in a target firm. We

[8]See Fally (2015) for a feasible implementation of fixed effects in the PPML model.

[9]Silva & Tenreyro (2011) show that the PPML estimator is well suited for analyzing data with a disproportionate number of zeros. This is important for our industry sample which contains some country-industry-year observations with no M&A deals at all.

disaggregate the country-level deal count to 3-digit U.S. SIC code industry cells within each country. $\boldsymbol{z_{it}}$ are the same country-level controls described above.

An advantage of the industry-level regression is that we can explicitly control for various factors that drive takeover dynamics within sectors. To begin with, we augment the fixed-effects model above by including industry-fixed effects as well as U.S. SIC division specific year fixed effects to account for differential time trends within sectors. Furthermore, we include a vector $\boldsymbol{s_{ist}}$ of country-industry-year-specific controls which are available from the OECD: growth of unit labor costs, the respective industry's contribution to overall labor productivity, growth in employment and growth in employment compensation.[10]

Our final estimation approach exploits the fact that the corporate tax reforms providing the source of variation in our estimations should generally not affect acquisitions where the seller is not incorporated.[11] We test this using the number of deals that involve an unincorporated seller as a control group in a pooled regression. Using M&A deals with non-corporate sellers as a comparison group, we can test whether our results are driven by any unobserved events that coincide with corporate capital gains tax changes and affect M&A activity. These include regulatory measures that provide incentives for corporate investment or economic shocks that drive corporate consolidation.

We estimate a PPML model of the following form

$$\begin{aligned} N_{ikt} &= exp\left(\mathbf{x'_{ikt}}\beta\right) \\ \text{with } \mathbf{x'_{ikt}}\beta = &\gamma_1 \tau_{it}^{CG} + \gamma_2 \tau_{it}^{CG} \times CORPS_k + \gamma_3 CORPS_k \\ &+ \boldsymbol{\beta} \boldsymbol{z_{it}} + \boldsymbol{\alpha} \boldsymbol{z_{it}} \times CORPS_k + \boldsymbol{\phi_i} + \boldsymbol{\phi_t} + \boldsymbol{\phi_i} \times CORPS_k \\ &+ \boldsymbol{\phi_t} \times CORPS_k + \epsilon_{ikt} \end{aligned} \tag{2.12}$$

where N_{ikt} indicates the number of deals in country i at time t for seller type k. With regard to the seller type, we sort deals into two groups. $CORPS_k = 1$ indicates deals with sellers that are fully liable for corporate capital gains taxes (type-C deals). $CORPS_k = 0$ indicates those deals that are mainly affected by individual taxation (type-I deals), that is, the sellers include individuals or entities for whom corporate

[10] Since most of these sector-level variables are only available for OECD member countries, non-OECD countries are excluded from the analysis, when we include these controls.

[11] Non-corporate sellers such as sole proprietors and most partnerships formed by natural persons pay individual income but no corporate tax on realized gains from the sale of shares.

taxation is not applicable. $\boldsymbol{z_{it}}$, $\boldsymbol{\phi_t}$ and $\boldsymbol{\phi_i}$ are the same sets of controls and fixed effects as in the country-level regression above.

In equation (2.12), γ_1 captures the effect of changes in the corporate capital gains tax rate on M&As involving sellers that are not liable to pay corporate income tax. Since these deals are not subject to the lock-in effect of *corporate* capital gains taxation, γ_1 picks up indirect effects of reforms in corporate capital gains taxation on deals with non-corporate sellers as well as other events that coincided with the capital gains tax rate change and also influenced acquisition activity. γ_2 measures the effect of corporate capital gains tax changes on the number of deals involving only sellers which are directly affected. Consistent with a lock-in effect on acquisition activity, we expect γ_2 to be negative. Country-specific and time-specific differences in the level of acquisition activity are captured by the interaction of $CORPS_k$ with the corresponding fixed effects. Level differences across seller types are measured by γ_3.

2.3.3 Data

Data on corporate acquisitions is obtained from the Zephyr database provided by Bureau van Dijk. Zephyr contains detailed seller characteristics for each deal. Such information is critical to identify the deals associated with corporate capital gains tax payments and to exclude deals with individual shareholders as sellers.[12] The sample consists of acquisitions of shares in the period 2002-2013 where a corporation sold one of its domestic subsidiaries.[13] We use the seller's legal form and name to establish whether it is liable for a corporation tax according to the regulations of the country it is registered in.[14] As noted by Erel *et al.* (2015), the majority of deals (>95%) involve an unlisted target. Our study focuses on these deals because deals with listed targets often involve a substantial number of non-corporate sellers[15] for

[12]Moreover, as pointed out by Erel *et al.* (2015), Zephyr's coverage of acquisitions outside the stock market is superior to alternative databases. This is convenient as, for reasons explained below, we expect acquisitions of non-listed targets to be particularly affected by corporate capital gains taxes. See Bollaert & Delanghe (2015) for a detailed analysis of data quality in Zephyr.

[13]We do not consider sellers disposing of their holdings in foreign firms since these deals are taxed differently in some countries (e.g. Australia). In a robustness check we also include deals where seller and target reside in different countries and obtain qualitatively similar results. An overview of these deals can be found in Table A.1 in Appendix A.

[14]For some deals no seller information is available. It is reasonable to assume that in this case the sellers comprise mainly individual shareholders and we therefore exclude these deals.

[15]Deals involving listed targets are a more appropriate subject of study when investigating the role of shareholder-level taxation as in Ayers *et al.* (2003).

Table 2.2: Corporate M&As, 2002-2013

This table presents the number and volume of deals with corporate sellers per country from 2002-2013 as recorded in the Zephyr database. Listed targets and targets not residing in the country of the seller are excluded. Data is trimmed at the 1st and 99th percentile according to deal value. The deals are assigned to the country of residence of the seller company. The revealed deal volume is the sum of reported deal values. The total deal volume is obtained by multiplying the average revealed deal volume in each country with the number of deals observed in this country.

	Number of deals	Deal volume in bn US$		Corporate capital gains tax rate, 2013
		Revealed	Total	
Australia	1,093	45.69	67.58	30.00
Austria	329	8.83	54.84	25.00
Belgium	456	10.84	53.15	0.04
Canada	810	31.60	57.53	20.27
Croatia	67	0.32	0.52	20.00
Cyprus	55	2.88	3.60	20.00
Denmark	724	13.84	66.35	0.00
Finland	1,126	8.53	57.84	0.00
France	1,695	57.30	227.45	4.33
Germany	2,263	62.22	322.20	1.48
Greece	171	2.92	5.37	26.00
Iceland	48	0.88	3.26	0.00
Ireland	120	7.02	11.54	0.00
Israel	118	5.10	6.68	25.00
Italy	1,181	65.28	122.77	1.57
Japan	2,144	44.19	89.72	42.00
Luxembourg	31	2.88	7.44	0.00
Mexico	58	5.98	10.21	30.00
Netherlands	1,619	39.80	261.90	0.00
New Zealand	166	4.91	10.31	0.00
Norway	870	16.55	51.79	0.00
Portugal	218	11.03	22.69	12.50
Slovenia	39	0.60	1.80	8.50
South Korea	209	13.39	15.38	24.20
Spain	1,216	45.51	125.49	0.00
Sweden	1,507	25.13	92.58	0.00
Switzerland	633	11.81	108.33	0.00
Turkey	237	22.39	30.14	20.00
United Kingdom	4,458	162.55	306.80	0.00
United States	5,885	335.81	823.10	39.28
Total	29,546	1,066	3,018.35	

Table 2.3: Summary Statistics: Deals

	Obs.	Mean	Std. Dev.	Min	Max
τ^{CG}	886,380	13.110	13.775	0	42.1
τ^{CIT}	886,380	28.374	7.278	10	42.1
GDP	886,380	26.855	1.587	23.093	30.375
Growth	886,380	2.073	2.878	-9.132	11.113
Inflation	886,380	2.868	3.959	-5.205	52.851
Trade	886,380	4.310	0.502	3.009	5.853
Stock Market	886,380	0.737	0.495	0.080	3.264
Credit	860,160	1.018	0.471	0.002	3.122
Service Sector	843,120	67.911	14.125	0.561	87.470
Audit Quality	886,380	5.586	0.635	3.952	6.532
Industry Regulation	871,650	0.131	0.595	0.000	6.000
Start-up Time	886,380	19.207	19.793	0.500	138.000
Judicial Independence	856,834	7.246	1.818	2.333	9.597
Ease of Hiring	856,834	6.786	2.542	2.200	10.000
Credit Market Regulation	856,834	9.044	0.977	4.667	10.000
Contiguity	843,840	0.074	0.262	0	1
Language	843,840	0.128	0.334	0	1
Colony	843,840	0.075	0.263	0	1
Distance	843,840	8.045	1.184	2.951	9.885
Home	886,380	0.037	0.188	0	1
Total Assets	358,230	38.823	5.178	8.517	44.145

which the corporate capital gains tax rate is not relevant.[16]

For the analysis of corporate capital gains tax rates on total acquisition activity, we aggregate the number and total value of deals by industry, country and year according to the 3-digit U.S. SIC code of the target, residence of the selling firm and the completion date of the deal. Using the completion date avoids a bias of our estimate caused by timing issues when corporations anticipate tax changes and announce deals in advance. Where the completion date is not available in Zephyr, we compute it by taking the median number of days between announcement and completion across the deals with available data in the same year and country and adding this duration to the announcement date provided.[17]

[16] We have verified that the results are robust to including deals with listed targets.

[17] We conduct a robustness check by computing the time between announcement and completion using nearest neighbor matching. In particular, we take the power-distance weighted average over the five closest deals regarding announcement within the same country. Results are displayed in Table A.4.

Table 2.2 gives an overview of the deals included in our estimation. It reports the number and volume of deals by country of residence of the selling company. In total, we consider 29,546 acquisitions with a revealed volume of $1,066 billion. In most of these deals, the seller resided in one of the largest economies (i.e. the United States, the United Kingdom, Japan and Germany) but a substantial number and volume of deals are completed in several smaller countries such as Finland and Sweden, where corporate capital gains tax reforms may have spurred acquisition activity.

Information on the industry-level variation in capital gains accumulation which we exploit in our research design is obtained from CRSP. Consistent with Ayers *et al.* (2003), we compute for each firm contained in CRSP the maximum capital gain over 3 and 5 years as a share of the original price by dividing the difference between the current price and the 3-year or 5-year low price by the latter. We take the median within each industry (2-digit SIC code) and month and assign it to each target according to the announcement date of the deal and the corresponding target industry. In Table A.3 in Appendix A, we report median capital gains in our sample for individual SIC divisions. The majority of targets operate in an industry of the services and manufacturing division for which we estimate a median 3-year gain of 49.07% and 52.24%, respectively, which is within the range of figures obtained by Ayers *et al.* (2003).

Table 2.4: Summary Statistics: Industries

	Obs.	Mean	Std. Dev.	Min	Max
No. of Deals (dom. target, all payments)	160,680	0.197	1.145	0	77
No. of Deals (dom. target, cash payment)	160,680	0.190	1.108	0	73
No. of Deals (all targets, all payments)	160,680	0.019	0.226	0	28
Value of Deals in bn US$	160,680	0.007	0.077	0	5.557
Regulation	162,120	0.064	0.438	0	6
Prod. Growth Contribution	110,345	0.269	1.155	-5.545	7.099
Employment Growth	117,772	0.253	3.577	-33.872	28.632
Compensation Growth	114,947	2.749	4.338	-47.255	165.344
Unit Labor Cost Growth	114,947	1.780	6.896	-39.754	158.651

Summary statistics for the main variables are displayed in Table 2.3 and 2.4. Macroeconomic controls were obtained from the World Banks's World Development Indicators Database. The audit and reporting quality indicator is an index provided by the Global Competitiveness Report conducted by the World Economic Forum. Additional industry-level controls were obtained from the OECD which provides industry-level indicators on the level of regulation as well as sector-level macroeconomic variables. Table 2.4 presents summary statistics for these variables. A full list of variables used in the analysis is presented in Table A.2 in the A.

2.4 Empirical Results

2.4.1 Micro-level Evidence

Table 2.5 presents the results of the first step of our empirical analysis based on a multinominal choice model. Column (1) displays the results of a conditional logit regression. We consider a firm that has decided to acquire another firm and needs to choose between a set of potential target locations $i = 1, ..., l$. The dependent variable is equal to one if a location i is the actual location of the chosen target and equal to zero if a location is a counterfactual target location.

We find a significant and negative coefficient of -0.007 for the corporate capital gains tax rate, which translates into a semi-elasticity of -0.7% per percentage point change in the corporate capital gains tax rate. Thus, a one percentage point increase in the capital gains tax rate reduces the probability to observe a target there by 0.7%. Using derivations by Schmidheiny & Brülhart (2011) and Cameron & Trivedi (2005), this implies, for instance, that the abolition of capital gains taxation of inter-corporate acquisitions in the United States (39.28% in 2013[18]) would increase the number of acquisitions taking place there by 24%. To account for a potential correlation of the target choice within industries and acquirer locations, we report robust standard errors which are adjusted for clustering.[19]

In column (2), we add the interactions of the target location-fixed effects and the acquirer size as additional controls. Table A.5 in Appendix A lists the coefficients of the target-specific variables per acquirer location except for the United States which serves as the country of reference. The coefficient on the corporate capital gains tax rate remains significant and increases in magnitude to -0.01 (i.e. a semi-elasticity of -1.0%). This points to a potential omitted variable bias when not controlling for acquirer specific characteristics.

[18]Including state taxes.

[19]In particular, we allow for clustering on the location-industry level (double-digit SIC code) of the acquirer. Clustering on the country choice level is not a feasible option because this leads to inconsistent estimates of the corresponding variance-covariance matrix such that cluster-robust standard errors cannot be computed (Cameron & Miller, 2011). As suggested by Cameron & Miller (2015), we include country fixed effects to absorb within-alternative clustering while allowing for standard errors clustered on the acquirer-location-industry level.

Table 2.5: Multinominal Choice Model

This table reports the results of estimating a multinominal choice model where the dependent variable is equal to one if a location i is the actual location of the chosen target and equal to zero if a location is a counterfactual target location. $CG3Y$ and $CG5Y$ are the median maximum capital gains in the industry in which the target operates (2-digit SIC) at the deal announcement relative to the 3 and 5 years, respectively, prior to the deal announcement. Regressions (1) to (4) use a conditional logit model with target-country fixed effects (not reported). Regression (2) adds the interactions of target-country fixed effects with the logarithm of total assets in the acquirer as reported in the last available year prior to the acquisition as additional controls. Regressions (5) to (8) repeat regressions (1) to (4) using a mixed logit model where the coefficient for the capital gains tax rate is randomized. All regressions include country-fixed effects. Cluster-robust standard errors (clustered at the acquirer-location-industry level) are provided in parentheses. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)	(6)	(5)	(6)
	Conditional Logit	Conditional Logit: Interaction with Size	Conditional Logit	Conditional Logit	Mixed Logit	Mixed Logit: Interaction with Size	Mixed Logit	Mixed Logit
τ^{CG}	-0.007***	-0.010**	-0.003	-0.005	-0.007**	-0.013***	-0.003	-0.003
	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)
$\tau^{CG} \times CG3Y$			-0.005***				-0.006***	
			(0.002)				(0.002)	
$\tau^{CG} \times CG5Y$				-0.003*				-0.004**
				(0.001)				(0.002)
Audit Quality	0.315***	0.166	0.302***	0.308***	0.314***	0.179*	0.301***	0.305***
	(0.069)	(0.103)	(0.068)	(0.069)	(0.071)	(0.106)	(0.070)	(0.070)
Growth	0.003	-0.016	0.006	0.004	0.000	-0.019	0.004	0.003
	(0.012)	(0.017)	(0.011)	(0.011)	(0.012)	(0.017)	(0.012)	(0.012)
Trade	0.416	0.029	0.320	0.381	0.424	-0.003	0.315	0.371
	(0.301)	(0.434)	(0.301)	(0.301)	(0.305)	(0.441)	(0.307)	(0.305)
Credit	0.092	-0.092	0.087	0.099	0.090	-0.101	0.083	0.100
	(0.111)	(0.163)	(0.111)	(0.111)	(0.113)	(0.167)	(0.113)	(0.112)
GDP	-0.150	1.221*	-0.129	-0.099	-0.221	1.033	-0.196	-0.147
	(0.468)	(0.741)	(0.468)	(0.468)	(0.486)	(0.757)	(0.486)	(0.487)
Stock Market	-0.203**	-0.101	-0.202**	-0.202**	-0.206**	-0.094	-0.204**	-0.205**
	(0.092)	(0.139)	(0.092)	(0.092)	(0.096)	(0.143)	(0.096)	(0.096)
Inflation	-0.017**	-0.037***	-0.016**	-0.016**	-0.018***	-0.039***	-0.018***	-0.017**
	(0.007)	(0.012)	(0.007)	(0.007)	(0.007)	(0.012)	(0.007)	(0.007)
Service Sector	-0.000	-0.001	-0.000	-0.000	0.000	-0.001	-0.000	0.000
	(0.002)	(0.004)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)
τ^{CIT}	-0.009	-0.019**	-0.009	-0.010	-0.011	-0.021**	-0.011*	-0.012*
	(0.006)	(0.010)	(0.006)	(0.006)	(0.007)	(0.010)	(0.007)	(0.007)
Start-up Time	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Jud. Independence	0.113***	0.073*	0.109***	0.111***	0.115***	0.080**	0.112***	0.114***
	(0.027)	(0.039)	(0.027)	(0.027)	(0.028)	(0.040)	(0.028)	(0.028)
Ease of Hiring	0.023	0.014	0.020	0.022	0.020	0.015	0.017	0.018
	(0.020)	(0.029)	(0.020)	(0.020)	(0.021)	(0.030)	(0.021)	(0.021)
Credit Market Reg.	-0.040	-0.075*	-0.048*	-0.042	-0.051*	-0.081**	-0.060**	-0.054*
	(0.029)	(0.039)	(0.029)	(0.029)	(0.029)	(0.041)	(0.029)	(0.029)
Industry Regulation	-0.146**	-0.223***	-0.147**	-0.147**	-0.153**	-0.232***	-0.152**	-0.152**
	(0.070)	(0.079)	(0.070)	(0.070)	(0.073)	(0.081)	(0.073)	(0.073)
Contiguity	-0.496***	-0.203*	-0.491***	-0.492***	-0.417***	-0.150	-0.413***	-0.413***
	(0.103)	(0.111)	(0.102)	(0.102)	(0.100)	(0.104)	(0.100)	(0.100)
Language	0.491***	0.172	0.485***	0.485***	0.402***	0.157	0.397***	0.398***
	(0.101)	(0.138)	(0.101)	(0.101)	(0.100)	(0.132)	(0.100)	(0.100)
Colony	0.628***	0.536***	0.632***	0.632***	0.506***	0.416***	0.510***	0.509***
	(0.081)	(0.120)	(0.081)	(0.081)	(0.078)	(0.117)	(0.078)	(0.078)
Distance	-0.891***	-0.973***	-0.891***	-0.890***	-0.992***	-1.115***	-0.991***	-0.991***
	(0.036)	(0.044)	(0.036)	(0.036)	(0.039)	(0.048)	(0.039)	(0.039)
Home	2.461***	2.293***	2.462***	2.463***	2.457***	2.187***	2.459***	2.459***
	(0.076)	(0.073)	(0.076)	(0.076)	(0.078)	(0.075)	(0.077)	(0.077)
Observations	714,795	297,430	712,134	712,134	714,795	297,430	712,134	712,134
Pseudo LL	-26,012	-11,936	-25,927	-25,930	-25,907	-11,895	-25,820	-25,822

In columns (3) and (4) we add the interactions between the corporate capital gains tax rate and the 3-year and 5-year capital gain in the industry that the target operates in. In this specification, the coefficient for the interaction term captures the direct impact of capital gains taxation on the location choice via the lock-in effect on seller shares as the size of the capital gains tax rate only becomes relevant if there exist locked-in capital gains. The estimated coefficient for the interaction term is significantly negative, which implies that the association of capital gains taxation and takeover dynamics is indeed caused by a lock-in of seller shares in targets with high capital gains accumulation.

Besides the corporate capital gains tax rate, we find inflation, corporate taxation and distance to have a significant and negative effect on M&A activity. High inflation may deter M&A activity, since it is associated with greater uncertainty. The negative coefficient on the corporate tax rate expresses the well-known negative effect of corporate taxation on FDI. Distance increases transaction costs and thus decreases the likelihood to observe FDI. The indicators Home and Colony also proxy for transaction costs: Acquiring a target in the acquirer location facilitates the transfer of ownership for various reasons (legal, language, culture, etc.). To a lesser extent, the same argument applies to acquisitions in former colonies. Consistent with prior studies, industry regulation reduces the probability of locating in a particular country while an increase in institutional quality, as measured by the audit and reporting quality index and the judicial independence index, has a positive impact on takeover dynamics.

The conditional logit regressions may be inconsistent if the assumption of independence of irrelevant alternatives (IIA) is violated. In the mixed logit approach, in which the vector of coefficients for τ^{CG} is allowed to be random, one can relax this assumption. In column (5) to (8) of Table 2.5, we apply a mixed logit estimator following Train (2009, p. 138). We report the average coefficient obtained from simulating the maximum likelihood as a benchmark. Apart from the different estimation approach, the specifications in columns (5) to (8) are identical to the ones in columns (1) to (4), respectively, in terms of covariates and the computation of standard errors. The coefficient obtained in column (5) is similar to that for the conditional logit estimation and suggests that the average probability for an M&A deal to take place in a particular location increases by 0.7% per percentage point decrease in the corporate capital gains tax rate.

Switching to the mixed logit approach does not affect the results but it increases the coefficient from 0.010 to 0.013 (compare column (2) and (6)), when we include the interaction of acquirer characteristics and target location-fixed effects. The estimated average coefficient of -0.013 in column (6) implies a semi-elasticity of 1.29%. For specification (5), we also simulate specific values for each acquirer following Train (2009, p. 256). The density estimates for the latter are presented in Figure A.1 in Appendix A. The estimated standard deviation in each case is highly significant. This suggests that randomizing the coefficient of τ^{CG} is indeed a valid approach.

2.4.2 Country-level Aggregation

In Table 2.6, we present the results of the second step of our empirical analysis using the Poisson pseudo-maximum-likelihood (PPML) estimator and the number of M&A deals aggregated at the seller-country level as the dependent variable. We cluster standard errors at the country level. Column (1) presents the results of our main specification. We obtain a negative and significant coefficient for τ^{CG}. A 1 percentage point decrease in the corporate capital gains tax rate increases the number of M&As by about 1% per year. To demonstrate that our estimation result does not suffer from inappropriate clustering over a small number of clusters, we follow the suggestion of Cameron & Miller (2015) and also present an estimation using the score wild bootstrap method developed by Kline & Santos (2012) to obtain standard errors in column (3).

Audit and reporting quality, global economic integration and economic growth all increase the level of M&A activity. For instance, the results suggest that an increase in our index for audit quality by 1 point, which approximately resembles the institutional improvements in Turkey between 2006 and 2012, increases M&A activity by 85.52%.

In column (4) we verify that the results are not driven by countries that position themselves as a preferable location for holding companies. Potential candidates in our sample are Cyprus, Ireland, Luxembourg, Malta, the Netherlands and Switzerland because of their lack of substantial Controlled Foreign Company (CFC) rules and the dividend and capital gains tax exemption granted.[20] While these countries have low tax rates for corporate capital gains, the factors that actually raise acquisition activity there may be unrelated to taxation. This could induce a downward bias in our estimate. We thus re-estimate the model excluding the countries cited above. The coefficient for τ^{CG} remains significantly negative with very similar point estimates.

[20] Smith (2011) reviews the relevant rules in these countries in more detail.

Table 2.6: Corporate Capital Gains Tax and Acquisition Activity

Estimation with PPML. The dependent variable in columns (1)-(4) is the number of M&A deals per year and country in which a corporate seller disposes of shares in a target firm residing in the same country. Regression (3) repeats regression (2) sample and computes standard errors using the score wild bootstrap method proposed by Kline & Santos (2012). Wald test t-statistics for this approach are reported in parentheses. In regression (4) countries which are referred to as preferred holding locations are excluded. Regression (5) uses as dependent variable the sum of all values of M&A deals per year and country in which a corporate seller disposes of shares in a target firm residing in the same country. All regressions include target-country- and year-fixed effects. Cluster robust standard errors (clustered at the country level) are provided in parentheses for Regressions (1), (2), (4) and (5). Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)
	Full Sample	Full Sample	Bootstrap	w/o Holding Locations	Deal Value
τ^{CG}	-0.010***	-0.011***	-0.011***	-0.012***	-0.014***
	(0.003)	(0.004)	(-2.003)	(0.004)	(0.005)
Audit Quality	0.619***	0.443***	0.443***	0.390***	0.370**
	(0.163)	(0.113)	(2.793)	(0.129)	(0.148)
Growth	0.038***	0.040***	0.040**	0.040***	0.011
	(0.012)	(0.014)	(2.373)	(0.015)	(0.020)
Trade	1.427**	1.310**	1.310**	1.544***	0.436
	(0.621)	(0.591)	(1.353)	(0.568)	(1.141)
Credit	0.122	0.058	0.058	0.121	-0.803***
	(0.121)	(0.126)	(0.407)	(0.120)	(0.246)
GDP	-0.829	-0.889	-0.889	-0.601	3.136***
	(1.293)	(1.060)	(-0.774)	(0.996)	(1.116)
Stock Market	0.214	0.178	0.178	0.277*	0.456**
	(0.166)	(0.148)	(1.063)	(0.167)	(0.222)
Inflation	-0.020**	-0.021**	-0.021	-0.019**	-0.048***
	(0.009)	(0.008)	(-1.375)	(0.009)	(0.014)
Service Sector	0.008	0.006	0.006	0.011	0.060**
	(0.013)	(0.014)	(0.454)	(0.015)	(0.025)
τ^{CIT}	0.010	0.010	0.010	0.018*	0.005
	(0.013)	(0.011)	(0.778)	(0.011)	(0.023)
Start-up Time		-0.001	-0.001	-0.002	0.004
		(0.002)	(-0.498)	(0.001)	(0.003)
Jud. Independence		0.169***	0.169***	0.187***	0.074
		(0.056)	(2.444)	(0.055)	(0.073)
Ease of Hiring		-0.034	-0.034	-0.031	0.042
		(0.033)	(-0.946)	(0.038)	(0.059)
Credit Market Reg.		0.072**	0.072*	0.088***	-0.003
		(0.028)	(1.618)	(0.026)	(0.053)
Observations	333	313	313	266	313
No. of countries	30	29	29	24	29
Pseudo LL	-1,453	-1,310	-1,422	-1,137	-7.006e+07

If our results capture a quantity effect of corporate capital gains taxes, we should be able to observe this in both the count and volume of M&A deals. To verify that this is indeed the case, we re-estimate our results using aggregated deal values as the dependent variable. The results are presented in column (5). Again, the coefficient for the capital gains tax rate is significantly negative. With a magnitude of -0.014 in our main specification, it suggests that decreasing the corporate capital gains tax rate by one percentage point raises the total volume of acquisitions by 1.39% per year. As the effects on the number and the volume of M&As are similar, the quantity effect of corporate capital gains taxation appears to be homogeneous across size classes. Thus, the results regarding the quantity of the lock-in effect caused by corporate capital gains taxes cannot simply be explained by a change in the size of M&A deals.

2.4.3 Industry-level Aggregation

Table 2.7 presents the results of the third step of our empirical analysis based on an industry-level aggregation. Column (1) contains the basic fixed-effects estimation with target-location-specific controls. The coefficient for the corporate capital gains tax rate is significantly negative and similar in magnitude to those estimated using country-level aggregates. Again, a one percentage point decrease in the capital gains tax rate is expected to increase the number of M&As per industry by 1%. This finding is robust to adding further controls with respect to industry-specific policies and macroeconomic shocks in column (2). Consistent with previous findings, industry deregulation, indicated by a decrease in our regulation index, raises M&A activity in the respective industry. However, these industry-level developments cannot explain the decreasing effect of corporate capital gains taxation on M&A activity as the respective coefficient remains similar to the previous specification. The results are also not driven by holding locations which we exclude from the sample in the regression of column (3). In column (4), we again use the total deal volume in the industry-country-year cell as the dependent variable. The coefficient of interest remains negative and significant, and is similar in magnitude to estimates at the country-level.

2.4.4 Comparison Group Approach

Table 2.8 reports the results of the final step of our analysis. We compare the evolution of acquisition activity between individual and corporate sellers. While corporate sellers are affected by changes in the corporate capital gains tax rate, non-corporate sellers are not. However, all deals are affected by general macro-economic and policy shocks. This approach therefore allows us to separate the direct impact of capital gains tax changes on acquisition activity from the influence of other coinciding events. In column (1), we report the results of a regression including only the corporate capital gains tax rate and time and location specific fixed effects as well as their interactions with the seller-type indicators $CORPS$. As expected, the coefficient of $\tau^{CG} \times CORPS$ is negative and significant. This suggests that corporate capital gains taxation has a negative effect on the number of acquisitions involving corporate sellers relative to the number of acquisitions involving sellers which are

Table 2.7: Regression Results: Industry Level

Estimation with PPML. The dependent variable is the number of M&A deals per year, country and 3-digit U.S. SIC in which the seller disposes of shares in a target firm residing in the same country and receives a compensation that involves a cash payment. Regression (1) contains the main specification. Regression (2) adds industry-level controls. In regression (3) countries which are referred to as preferred holding locations are excluded. Regression (4) uses as dependent variable the sum of all values of M&A deals per year and country in which a corporate seller disposes of shares in a target firm residing in the same country. All regressions include target-country-, year- and industry-fixed effects, as well as U.S. SIC division-specific year fixed effects. Cluster robust standard (clustered at the country level) errors are provided in parentheses. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1) Benchmark	(2) Industry Controls	(3) w/o Holding Locations	(4) Deal Value
τ^{CG}	-0.010***	-0.009**	-0.011***	-0.013**
	(0.004)	(0.004)	(0.004)	(0.006)
Audit Quality	0.452***	0.414***	0.342***	0.481***
	(0.113)	(0.105)	(0.113)	(0.168)
Growth	0.038***	0.038***	0.035**	0.032
	(0.014)	(0.014)	(0.016)	(0.026)
Trade	1.214**	0.849*	0.969**	0.552
	(0.615)	(0.482)	(0.476)	(1.129)
Credit	0.062	-0.083	-0.036	-0.832***
	(0.134)	(0.110)	(0.120)	(0.245)
GDP	-0.946	0.165	0.359	4.000***
	(1.083)	(1.132)	(1.120)	(1.499)
Stock Market	0.188	0.235	0.310	0.499*
	(0.156)	(0.174)	(0.190)	(0.267)
Inflation	-0.023***	-0.031	-0.023	-0.049*
	(0.009)	(0.019)	(0.021)	(0.027)
Service Sector	-0.001	0.033	0.042**	0.069
	(0.002)	(0.021)	(0.020)	(0.044)
τ^{CIT}	0.011	0.009	0.013	0.013
	(0.011)	(0.012)	(0.013)	(0.024)
Start-up Time	-0.001	0.000	-0.001	0.004
	(0.002)	(0.001)	(0.001)	(0.003)
Jud. Independence	0.172***	0.178***	0.186***	0.099
	(0.057)	(0.055)	(0.055)	(0.077)
Ease of Hiring	-0.035	-0.026	-0.012	0.039
	(0.035)	(0.032)	(0.031)	(0.064)
Credit Market Regulations	0.070**	0.091***	0.101***	-0.002
	(0.029)	(0.025)	(0.023)	(0.068)
Regulation		-0.267**	-0.253*	-0.147
		(0.136)	(0.136)	(0.188)
Prod. Growth Contribution		0.046	0.044	0.068
		(0.036)	(0.037)	(0.059)
Employment Growth		0.018	0.019	0.003
		(0.014)	(0.015)	(0.022)
Compensation Growth		-0.001	-0.001	-0.013
		(0.010)	(0.010)	(0.012)
Unit Labor Cost Growth		0.004	0.005	-0.002
		(0.005)	(0.005)	(0.008)
Observations	118,030	76,543	71,871	75,037
No. of countries	30	24	21	24
Pseudo LL	-43497.586	-36671.113	-34119.912	-1.742e+09

not liable for corporate income taxation.

Our findings are robust to including the full set of control variables as well as their interaction with the seller-type indicator in column (2). The estimated semi-elasticity for inter-corporate acquisition activity with respect to a percentage point change in the corporate capital gains tax rate (i.e. $\gamma_1 + \gamma_2$ from specification (2.12)) is -0.011 (p-value 0.003), which is similar to our benchmark estimates reported in Table 2.6. In columns (3) and (4), we verify that this result is consistent across various sample specifications. We first exclude all stock-for-stock deals in column (3) thus reducing the sample to deals with cash payments which are directly affected by capital gains taxation. In column (4), we relax the sample restriction on sellers disposing their domestic subsidiaries and extend the sample to also include deals where a firm sells a foreign subsidiary. In both specifications the coefficient for $\tau^{CG} \times CORPS$ is significant and negative with an estimated semi-elasticity of -0.014 and -0.012 in regressions (3) and (4), respectively.

Table 2.8: Comparison Group Approach

Estimation with PPML. The dependent variable is the number of M&A deals per year, country and seller type. Column (1) and (2) only include deals in which the seller disposes of shares in a target firm residing in the same country. Regression (3) restricts the sample of regressions (1) and (2) to deals with cash payments. Column (4) presents the results of a regression including also deals with foreign sellers. All regressions include seller-type specific year fixed effects and seller-type specific country-fixed effects. Regressions (2) to (4) also include macro-level controls presented in Table A.6 in the Appendix. Cluster robust standard (clustered at the country-level) errors are provided in parentheses. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	Full Sample		Only Cash Payments	Including Foreign Sellers
	(1)	(2)	(3)	(4)
τ^{CG}	0.010	0.003	0.003	0.003
	(0.008)	(0.007)	(0.006)	(0.007)
$\tau^{CG} \times CORPS$	-0.018**	-0.013**	-0.014**	-0.012*
	(0.009)	(0.006)	(0.006)	(0.006)
$CORPS$	0.363	-40.356	-38.499	-55.223
	(0.321)	(51.025)	(54.019)	(56.827)
Control variables	No	Yes	Yes	Yes
Observations	780	626	626	626
No. of countries	30	29	29	29
Pseudo LL	-3,286	-2,311	-2,257	-2,326

Throughout the various specifications in Table 2.8, the estimated coefficient for τ^{CG}, which captures the effect of corporate capital gains taxation on deals involving primarily individual sellers, is small and not significant. This indicates that these deals are not affected by reductions in the corporate capital gains tax rate. Given that deals with individual sellers are affected by changes in the macro-economic environment as well as policy adjustments unrelated to corporate taxation, this finding reassures us of the causality in our empirical findings as it links the effect of cuts in the corporate capital gains tax rate directly to the behavior of corporate sellers.

Finally, the estimated coefficients for $CORPS$ in Table 2.8 capture general level differences between the number of deals with and without individual sellers. Since country-specific and time-specific level differences are already captured in the interaction with $CORPS$ and the corresponding fixed effects, it is not surprising that the estimated coefficient for $CORPS$ is insignificant or even negative when conditioning on macro-economic variables in columns (2) to (4).

2.4.5 Robustness

In this section, we present a range of tests to verify the robustness of our estimation results. Columns (1a-c) to (3a-c) of Table 2.9 contain several sample checks. In a first step, we note that our benchmark specification also includes deals that do not include some form of cash payment but are exclusively paid through stock-for-stock transfers. In many countries, these deals allow the seller company to defer the realization and thus also the taxation of capital gains until the shares received in compensation are eventually sold. As a consequence, such deals are generally less affected by capital gains taxation than deals that involve some sort of cash payment.

There are two important reasons for including these deals in the benchmark sample. On the one hand, this ensures that the results are not driven by a choice of payment effect, which has been reported for individual capital gains taxation by Ayers *et al.* (2004). It would imply that corporate capital gains tax reforms merely lead to different forms of payment, but do not affect the overall number of deals. On the other hand, sellers that agree to deals in order to unlock corporate equity may quickly sell shares received in stock-for-stock deals and may thus also be affected by corporate capital gains taxation. Nevertheless, even though it is helpful to include stock-for-stock deals in our main sample, the results should not be driven by such transactions. We thus exclude them in columns (1a-c) and re-estimate the choice and count models using our main specification. Again, we obtain negative and significant coefficients of a very similar magnitude.

In a second check, we add deals with foreign sellers: a corporate seller resident in country A sells shares in a subsidiary resident in country B. These transactions have been excluded since many countries - differing from the case where the seller and its subsidiary are resident in the same country - do not tax capital gains from these deals (e.g. Australia, Turkey). Furthermore, multinational enterprises generally have various possibilities to avoid taxation (e.g. through holding companies). Results from a robustness check including deals with foreign sellers are reported in columns (2a-c)

Table 2.9: Robustness Checks

This table reports robustness checks. Each group of regressions (1a-c), (2a-c) and (3a-c) repeats the benchmark regressions (4) in Table 2.5, (2) in Table 2.6 and (2) in Table 2.7. The first group of regressions (1a-c) excludes all deals whose payment was conducted exclusively in stock-for-stock transfers. The second group of regressions (2a-c) adds deals where corporate sellers sold a foreign target to the benchmark specification. Regressions (3a-c) include within-industry shocks and the interest rate as additional controls. Robust standard errors are provided in parentheses. All regressions include country-fixed effects. Cluster-robust standard errors (clustered at the acquirer-location-industry level for columns a and at the country level for columns b and c) are presented in parentheses. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	Only Cash Payments			Including Foreign Sellers			Additional Controls		
	(1a) Mixed Logit	(1b) Poisson (Country)	(1c) Poisson (Industry)	(2a) Mixed Logit	(2b) Poisson (Country)	(2c) Poisson (Industry)	(3a) Mixed Logit	(3b) Poisson (Country)	(3c) Poisson (Industry)
τ^{CG}	-0.014***	-0.011***	-0.009**	-0.009***	-0.009***	-0.009**	-0.010**	-0.011**	-0.011**
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)	(0.004)	(0.004)
Audit Quality	0.180*	0.422***	0.386***	0.137*	0.368***	0.307***	0.014	0.463***	0.377***
	(0.109)	(0.112)	(0.103)	(0.073)	(0.104)	(0.111)	(0.183)	(0.164)	(0.100)
Growth	-0.023	0.040***	0.038**	-0.016	0.023*	0.023	-0.004	0.034**	0.027
	(0.017)	(0.014)	(0.015)	(0.012)	(0.012)	(0.016)	(0.030)	(0.016)	(0.017)
Trade	-0.026	1.258**	0.818*	0.328	1.228**	0.810*	0.738	1.724***	1.510***
	(0.451)	(0.589)	(0.476)	(0.314)	(0.548)	(0.458)	(0.686)	(0.589)	(0.567)
Credit	-0.173	0.026	-0.092	0.001	0.050	-0.055	-0.253	-0.012	-0.050
	(0.175)	(0.118)	(0.109)	(0.117)	(0.115)	(0.126)	(0.323)	(0.197)	(0.187)
GDP	1.062	-0.850	0.191	1.262**	-0.350	0.554	2.349*	-2.364	-1.468
	(0.776)	(1.039)	(1.099)	(0.535)	(1.041)	(1.102)	(1.215)	(2.086)	(2.164)
Stock Market	-0.062	0.190	0.228	-0.035	0.083	0.296*	-0.231	0.314*	0.159
	(0.145)	(0.151)	(0.175)	(0.086)	(0.119)	(0.175)	(0.256)	(0.180)	(0.156)
Inflation	-0.043***	-0.022***	-0.031*	-0.017**	-0.015**	-0.021	-0.035**	-0.028*	-0.008
	(0.012)	(0.008)	(0.018)	(0.008)	(0.008)	(0.018)	(0.016)	(0.015)	(0.020)
Service Sector	-0.002	0.007	0.029	0.000	0.004	0.038**	-0.034	0.009	0.020
	(0.004)	(0.014)	(0.021)	(0.003)	(0.013)	(0.017)	(0.033)	(0.023)	(0.030)
τ^{CIT}	-0.023**	0.009	0.006	-0.014**	0.007	0.012	-0.006	0.002	-0.000
	(0.010)	(0.011)	(0.012)	(0.007)	(0.010)	(0.012)	(0.013)	(0.013)	(0.014)
Start-up Time	0.001	-0.001	0.000	0.000	-0.001	-0.001	-0.000	0.001	0.000
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.004)	(0.004)
Jud. Independence	0.095**	0.174***	0.181***	0.064**	0.135***	0.137***	0.116**	0.146***	0.139***
	(0.041)	(0.056)	(0.054)	(0.030)	(0.051)	(0.051)	(0.052)	(0.044)	(0.042)
Ease of Hiring	0.013	-0.032	-0.026	0.036	-0.026	-0.009	-0.052	-0.088*	-0.045
	(0.031)	(0.033)	(0.032)	(0.022)	(0.029)	(0.029)	(0.046)	(0.050)	(0.042)
Credit Market Reg.	-0.077*	0.071**	0.089***	-0.039	0.063**	0.092***	-0.127*	0.039	0.055**
	(0.042)	(0.028)	(0.026)	(0.029)	(0.027)	(0.024)	(0.071)	(0.033)	(0.025)
Industry Shock							-1.729	-1.279	0.077
							(1.282)	(1.084)	(0.052)
Interest Rate							0.031	0.096***	-1.210
							(0.059)	(0.034)	(0.752)
Contiguity	-0.154			-0.176**			-0.012		
	(0.106)			(0.077)			(0.111)		
Language	0.169			0.313***			-0.099		
	(0.133)			(0.094)			(0.154)		
Colony	0.413***			0.349***			0.672***		
	(0.119)			(0.078)			(0.132)		
Distance	-1.112***			-0.918***			-1.091***		
	(0.049)			(0.035)			(0.059)		
Home	2.179***			1.793***			2.268***		
	(0.075)			(0.064)			(0.077)		
Regulation	-0.214***		-0.266*	-0.188**		-0.262**	-0.282**		-0.244*
	(0.083)		(0.139)	(0.073)		(0.104)	(0.114)		(0.143)
Prod. Growth Contrib.			0.045			0.050			0.007
			(0.032)			(0.039)			(0.026)
Employment Growth			0.016			0.018			0.020
			(0.012)			(0.016)			(0.013)
Compensation Growth			-0.003			-0.005			0.002
			(0.009)			(0.010)			(0.011)
Unit Labor Cost Growth			0.005			0.006			0.000
			(0.005)			(0.006)			(0.005)
n	285,098	313	83,998	396,537	313	73,085	144,252	170	49,391
Countries	29	29	24	29	29	24	29	22	18
Pseudo LL	-11,491	-1,282	-36,491	-23,564	-1,348	-39,489	-7,197	-655	-24,664

of Table 2.9. The estimated coefficients remain negative and significant and decrease only slightly in magnitude. The latter observation may reflect that these deals are indeed less affected by corporate capital gains taxation.

In columns (3a-c) of Table 2.9, we add industry shocks and the long-term interest rate as further control variables which are only available for a limited number of countries in our sample. Following Ayers *et al.* (2007), industry shocks are defined as the standard deviation in value added growth across eight sectors within a country to account for sector specific shocks that may increase acquisition activity by triggering sector specific consolidation. Including both variables leaves the capital gains tax rate coefficient virtually unchanged.

2.5 Shareholder Loss

We use our coefficient estimates to determine the potential value loss for shareholders resulting from unrealized synergies due to the taxation of capital gains in inter-corporate M&As. This is obtained by calculating the potential increase in shareholder value resulting from a full exemption of inter-corporate M&As from capital gains taxation. Acquisition premia reported in Zephyr are employed as a market-based proxy of this gain. First, we compute the expected country-specific and industry-specific shareholder gain per deal using the information on M&As around the globe in the Zephyr database. Next, we derive the expected change in the number of deals within a country and sector following a reduction in the corporate income tax rate on gains realized in M&As using our elasticity estimates from the benchmark regressions above. Finally, these figures are used to calculate the annual shareholder gain from such a tax reform which corresponds to the shareholder loss of upholding capital gains taxation on corporate M&As.

The potential target shareholder gain of a deal f is derived from its acquisition price. The latter can be expressed in terms of the underlying market value of the target, m_f and the premium π_f (as a percentage of the market value) paid by the acquirer and is given by $p_f = (1 + \pi_f)\, m_f$. From this expression we back out the shareholder gain of a deal as $g_f = \pi_f m_f = \frac{\pi_f}{1+\pi_f} p_f$.

To compute the expected shareholder gain per deal, we use data on M&As from Zephyr. p is approximated by the average transaction size in US$ within a country and sector in our sample, $\bar{p}_{is}$. The acquisition premium π of a deal is defined as the deal value less the market price of the target one day prior to the announcement divided by the latter. As an estimate of the expected acquisition premium, we use the average within each country and sector, $\bar{\pi}_{is}$. The expected gain per deal in sector s of country i is thus given by

$$\bar{g}_{is} = \frac{\bar{\pi}_{is}}{1 + \bar{\pi}_{is}} \bar{p}_{is}. \tag{2.13}$$

Approximating gains of failed deals with those observed in realized deals is appropriate as long as the distribution of synergies is similar for both groups. In our analysis, we focus on deals that failed because of a high tax burden resulting from large capital gains accruing to the target. We thus require past gains of a firm to be unrelated to the synergy gains resulting from a potential M&A. Given that synergistic gains usually stem from structural complementarity between acquirer and target rather than existing financial wealth in the target firm (see Bradley *et al.*, 1988) and that retained gains in the target should generally be fully captured by the acquisition price, this appears to be a reasonable assumption in our setting.

In a second step, we simulate the impact of a full exemption of capital gains taxes on the number of deals within a country and sector using our elasticity estimates from the micro-level estimation. In doing so, we employ the most robust estimate obtained from the mixed logit estimation in column (5) of Table 2.5. As shown by Guimaraes *et al.* (2003) and Schmidheiny & Brülhart (2011), the change in the expected number of deals in a country i with respect to a one percentage point change in the capital gains tax rate for a particular deal f can be expressed as $\epsilon_{if} = \left(1 - \hat{\Phi}_{if}\right) \hat{\gamma}_f$ where $\hat{\Phi}_{if}$ is the predicted probability for the acquisition of a target in location i and $\hat{\gamma}_f$ is the estimated coefficient of τ_{it}^{CG} for deal f. $\hat{\Phi}_{if}$ and $\hat{\gamma}_f$ are obtained from the mixed logit estimation. The mean elasticity of location i is then given by $\bar{\epsilon}_i = \left(1 - \bar{\hat{\Phi}}_i\right) \bar{\hat{\gamma}}_i$ and the change in the number of deals following a capital gains tax exemption in sector s in location i is $\bar{N}_{is} \times \left(\exp\left(\bar{\epsilon}_i \times d\tau_i^{CG}\right) - 1\right)$ where $\bar{N}_{is}$ is the average number of deals per year in this sector and $d\tau_i^{CG}$ is the modeled tax cut. We consider a full exemption of capital gains from corporate taxation at the rates applied in 2013.

The yearly shareholder loss Γ_{is} in country i and sector s is then given by

$$\Gamma_{is} = \bar{N}_{is} \times \left(\exp\left(\bar{\epsilon}_i \times d\tau_i^{CG}\right) - 1\right) \times \bar{g}_{is}. \tag{2.14}$$

We group deals according to their target SIC code into four broad sectors: Mining

Table 2.10: Shareholder Loss (in million US$)

This table displays the yearly shareholder loss in million US$ caused by corporate capital gains taxation of the transfer of shares in inter-corporate M&A. The shareholder loss is defined as the foregone gain from all failed M&A deals.

(a) Shareholder Loss from Relocation of Deals

	Australia	Canada	Japan	United States
Corporate Capital Gains Tax Rate, 2013	30.00	20.27	42.00	39.28
Finance, Insurance and Real Estate	17.33	33.71	81.13	530.03
Manufacturing	37.45	38.12	196.82	1,238.80
Mining and Construction	44.05	22.64	4.42	147.48
Services	38.10	56.83	183.83	1,113.22
Other	35.04	28.46	79.48	1,198.79
Total	171.97	179.76	545.68	4,228.32

(b) Shareholder Loss from Failed of Deals

	Australia	Canada	Japan	United States
Corporate Capital Gains Tax Rate, 2013	30.00	20.27	42.00	39.28
Finance, Insurance and Real Estate	29.02	55.43	143.74	1,166.78
Manufacturing	62.70	62.67	348.73	2,727.06
Mining and Construction	73.75	37.22	7.84	324.66
Services	58.66	46.79	140.83	2,638.97
Other	63.79	93.42	325.70	2,450.61
Total	287.92	295.53	966.84	9,308.08

and Construction (1000-1799), Manufacturing (2000-3999), Finance, Insurance and Real Estate (6000-6799) and Services (7000-8999).

Panel (a) of Table 2.10 presents the computed annual shareholder loss related to capital gains taxation in inter-corporate M&A deals for Australia, Canada, Japan and the United States. All of these economies still levied capital gains taxes on corporate acquisitions in 2013. The computed shareholder losses are substantial, most notably in Japan and the United States where corporate sellers face particularly high tax rates. Our estimates suggest that a full exemption of capital gains from corporate M&A deals would generate a shareholder gain in the market for corporate control of $0.55 billion per year in Japan and $4.2 billion per year in the United States.

The underlying assumption of the elasticity obtained in the mixed logit estimation is that the overall number of M&As is constant and not affected by tax adjustments in individual locations. The results in Table 2.10 (a) thus represent the shareholder loss in a particular country that results from the location choice of the acquirers. However, acquirers often have a strong preference for a particular location. This is true especially for large capital markets such as the United States and leads to a more pronounced decrease in acquisition activity there because not pursuing a deal at all may be a more realistic outside option for acquirers than looking for a similar target in another country. The effect of capital gains taxation on the number of realized M&As in this setting is estimated in our PPML model in Table 2.6. The coefficient estimate from a Poisson regression can directly be interpreted as the semi-elasticity of the dependent variable with respect to the corresponding regressor. We thus re-estimate the shareholder loss under the assumption that the overall number of deals is not fixed by replacing $\bar{\epsilon}_i$ with the coefficient estimate from our benchmark regression presented in column (2) in Table 2.6.

The results of this exercise are presented in Panel (b) of Table 2.10. As expected, the computed shareholder loss is significantly larger when compared to the figures in Panel (a). The difference is especially pronounced for the United States which has a large domestic M&A market. When allowing for the overall number of deals to be affected by the capital gains tax rate, the resulting shareholder loss is $9.3 billion per year in the United States. The true value of the target shareholder loss is expected to be somewhere between the estimates in Panel (a) and (b). However, for a large economy such as the United States, it is more realistic to assume that it is closer to the figure in Panel (b).

There are several benefits from using realized deal premia as a proxy for forgone M&A gains from unrealized deals. First, the premium explicitly reflects the pre-tax financial gains of the selling shareholders (or the shareholders of the selling company). It thus measures the potential loss which the shareholders incur if the deal fails. Second, the deal premium is related to the synergy measure in our theoretical framework above (Δ). If investors behave rationally, the premium should partly contain the increase in the cash flow the acquirer is expecting to generate from the target (e.g. through synergy gains, see Bradley *et al.*, 1988). A higher level of expected synergies should thus be reflected in higher premiums.

A disadvantage of using deal premia is that it only fully captures the seller gain while the acquirer gain is not directly included. The degree to which the premium reflects the overall synergy gain from the deal effectively depends on the bargaining power of each participant. The premium is equal to the full synergy gain only when the seller has the full bargaining power. The premium thus constitutes a lower bound for the overall synergy gain of the deal. Another issue is directly related to capital gains taxation. As target shareholders may demand a higher premium to be compensated for capital gains taxes due upon deal completion (see Ayers *et al.*, 2003), the actual gains to the seller may be overstated by the premium. Note, however, that we are interested in the overall shareholder gain. Unless there exist substantial information asymmetries, this cannot be smaller than the realized premium. Thus, even if overestimating the seller gain, the premium remains a conservative lower bound for the overall shareholder gain.

2.6 Conclusion

In this study, we investigate whether and to what extent corporate capital gains taxes inhibit shareholder value creation by preventing M&A deals through the lock-in effect. The results suggest a significantly negative impact of capital gains taxes on the realization of M&As in a particular location. Presenting micro-level evidence based on a conditional or mixed logit approach, we find that a decrease in a country's corporate capital gains tax rate by one percentage point increases the likelihood to observe a target in that country by 0.7%. Our estimates of the magnitude of this effect are larger when we account for acquirer size. These results are robust to accounting for endogeneity due to unobserved confounding factors and heterogeneity in the effect across acquiring firms.

Presenting country and country-industry level evidence based on a panel-data PPML model, we arrive at a significantly negative coefficient for the corporate capital gains tax rate of -0.010. The estimate is slightly larger if we use the total deal value instead of the number of acquisitions as the dependent variable. Here, we obtain a coefficient of -0.014 which translates into an increase of acquisition activity by 1.4% as a reaction to a capital gains tax rate decrease by one percentage point.

Based on these results, we estimate the potential shareholder loss caused by corporate capital gains taxation in terms of foregone gains from M&A deals. For example, we consider a decrease of the United States tax rate on corporate capital gains

(39.28% in 2013[21]) to zero. Evaluated at the country mean for 2002-2013, this would imply an additional annual shareholder gain of $4.2 billion in the United States when only considering the effect of the capital gains taxation on the location choice of the acquirer. If we assume that capital gains taxation also affects the overall number of deals, which is more realistic in large capital markets, the estimated shareholder loss amounts to $9.3 billion per year in the United States.

These findings have several important implications. First, lowering the capital gains tax rate at the corporate level appears to be an effective instrument to foster acquisition activity. Tax cuts are thus worth considering, in particular in several large economies where capital gains tax rates are still high (e.g. United States, Australia, Canada, Japan) and the potential for M&As is substantial.

Second, using international data the results suggest a lock-in effect on inter-corporate acquisitions that is smaller than those previously estimated in time-series studies for individual shareholder taxation (e.g. Ayers *et al.*, 2007). This may partly reflect the use of different samples but also indicates that, on the global scale, corporations are less reactive to capital gains taxes in their acquisition behavior than individuals. One reason for this may be that capital gains taxation directly affects individual shareholders' income whereas managers who make decisions at the corporate level are only indirectly affected via the impact of annual firm yields on their reputation and can take a more long-term view on acquisitions. Nevertheless, the impact of corporate capital gains taxation on the M&A market is still substantial since inter-corporate acquisitions make up a much larger share of the overall acquisition activity.

Third, our results imply that corporate tax reforms which reduce capital gains taxes may be self-financing to a certain degree as has been previously suggested for the case of shareholder taxation (e.g. Feldstein *et al.*, 1980). Although the increase in acquisition activity may not fully compensate the revenue loss, in particular if capital gains are fully exempt, potential efficiency gains would still raise government revenue from taxing higher corporate profits and shareholder returns.

Our estimate of the efficiency loss of corporate capital gains taxation in M&As takes the shareholder perspective. The overall economic effect of increased M&A activity caused by lower corporate capital gains taxation depends on a range of factors not included in this measure. These encompass externalities such as the potentially inefficient use of production factors in transition periods and market distortion resulting from limited competition after mergers. Therefore, it remains an interesting

[21] Including state taxes.

question for future research whether and under what circumstances lower corporate capital gains taxation triggers acquisitions that improve corporate performance, for example with regard to productivity. Besides broadening the understanding of the market for corporate control, this would provide further insights into the distortive impact of corporate capital gains taxes.

3 International Taxation and Productivity Effects of M&As

3.1 Introduction

The international transmission of technologies and innovation is a major driver of global productivity growth. An important device in this process are corporate mergers and acquisitions (M&As) which provide direct inter-regional links between firms and open up channels for technology transfers (Jovanovic & Rousseau, 2008). However, whether or not the potential productivity gain in these transactions materializes strongly depends on the post-merger behavior of the combined firm.[1] In this paper, we investigate how firm-level adjustment after M&As is affected by differences in profit taxation between the target and the acquirer. These differences regularly occur in cross-border mergers and are thus likely to influence productivity improvements in the firms involved in these deals.

Our main finding is that tax differentials between the target and the acquirer location reduce post-merger productivity gains by distorting the reallocation of activity within the combined firm. Since the firm's objective is to maximize its net profit, it takes into account both the productivity and the corporate tax implications of a potential location choice. If the more productive unit resides in the location with the more favorable tax regime, the resulting allocation choice assigns production to the most productive units irrespective of the actual tax rate differential. However, if the more efficient unit happens to reside in a location with a higher tax burden, firms face a trade-off. Shifting activity to the high-tax location raises overall productivity but also increases the tax burden on the resulting profits. For large enough tax differences, the firm allocates activity to the less productive but more profitable unit. With regard to the overall productivity of the merged firm, this decision is inefficient

[1] Throughout the paper we use the terms merger, acquisition and M&A interchangeably. Even though the individual deal types certainly differ in their structure, they all result in a combination of two firms which is the key issue in our analysis.

and leads to a lower gain in productivity resulting from the M&A. This mechanism only occurs when firms cannot separate the location of productive activity from the location of its taxation. If firms were able to assign profits to the location of their preference (i.e. the location with the lowest tax rate), tax differences would not be relevant. In practice, such profit shifting activity is limited by domestic and international regulations and because firms usually incur some shifting cost. Nevertheless, the impact of tax differentials may be mitigated if firms engage in profit shifting activities such as transfer pricing.

The described effect is generally not unique to M&As but would be caused by any event that changes tax differentials within multinational groups (e.g. tax reforms). However, the reallocation of activity within existing groups of firms is usually associated with a high fixed cost and thus rarely observed. In contrast, while M&As themselves usually constitute a high fixed cost investment (Jovanovic & Rousseau, 2002), the subsequent reorganization after such a transaction provides an opportunity to exploit returns to scale at a relatively small cost and consolidate units operating in the merging firms that perform similar functions. As a consequence, substantial restructuring within the newly formed enterprise is common. In such an environment, the fixed cost of a reallocation of functions is weighted less heavily and firms are likely to react to tax differentials.

Below, we formulate a simple theoretical model to demonstrate this mechanism. We then investigate the impact of tax differentials on merger-induced productivity gains empirically. For this purpose we combine data on M&As from Bureau van Dijk's Zephyr database with firm-level information on inputs and outputs from the AMADEUS and ORBIS databases. An advantage of these databases is that they provide balance sheet data that is comparable across borders which makes them a prime data source for the study of firms in an international context (e.g. Cravino & Levchenko, 2017). First, we derive total factor productivity (TFP) for each individual firm within the sample of industry peers using the estimation method of Levinsohn & Petrin (2003). We then compute the TFP change resulting from an M&A deal and relate it to the absolute tax difference between the target and the acquirer. Our estimations, which include a large set of country-, deal-, and firm-specific controls, suggest that an increase in the absolute tax differential by 1 percentage point lowers the merger-induced productivity gain by 4.5%. We also show that this effect is mitigated when transfer pricing regulations are less strict. In a complementary analysis, we turn to the underlying mechanisms of this effect. Results of a fixed effects model and an event study suggest that the impact of the tax differential is asymmetric in the sense that the observed effect is mainly driven by deals where the level of taxation in the target location is lower than the one in the acquirer location. Following these transactions, the adjustment process in the target is hampered by the distorting tax incentive as firms make less reductions to employment and capital in the target firms involved. This finding is consistent with the notion that firms leave activity in the location with the lower tax burden which raises after-tax profit but also implies that some productivity gains from the M&A are not realized and the overall increase in productivity is smaller or even negative.

Our paper thus contributes novel insights to the growing literature on corporate M&As and taxation. Various studies have identified tax policy to be an important driver of M&A activity (e.g. Di Giovanni, 2005; Erel *et al.*, 2012; Feld *et al.*, 2016b,a).[2] Furthermore, taxes do not only influence whether but also how firms conduct M&As. For example, Ayers *et al.* (2004) and Faccio & Masulis (2005) show that capital gains taxation affects the method of payment in M&As. All of these studies investigate the role of tax rates as a determinant of the observed pattern of M&As and thus essentially focus on the effect of taxation *before* the M&A is completed. In contrast, our paper highlights the importance of the tax environment *after* the M&A completion. Existing studies with regard to this aspect have mainly examined the importance of taxation on financial variables. For instance, Ayers *et al.* (2003) and Huizinga *et al.* (2012) study realized deal values and show that shareholder-level taxation has a strong effect on deal premiums. In our analysis, we are interested in real outcomes of M&A. Huizinga & Voget (2009) and Voget (2011) show that taxes are an important determinant for the post-merger choice of headquarter location within the merged firm. However, while these allocation choices constitute real behavioral responses of firms, they have only minor effects on the structure of production within the firm. Our investigation focuses on taxation as a determinant of post-merger allocation of productive input factors and therefore reveals new insights into how tax differences affect the productive process and the evolution of productivity within the firm.

Thus, we also complement the large literature on productivity effects of M&As. Generally, M&As are perceived as an opportunity for productivity improvements. Results by Li (2013) suggest that this potential is indeed realized, mostly because the acquiring firm uses input factors of the target more efficiently. Other M&A

[2]In yet another study on M&A determinants, Rossi & Volpin (2004) do not include taxation in their estimations but acknowledge that taxes are a potential determinant of the deal volume which is, however, too complex an issue to deal with in the broad scope of their paper.

outcomes that may have a positive impact on firm productivity are an increased level of innovation (Stiebale, 2016), knowledge transfers (Bresman *et al.*, 1999; Bena & Li, 2014) and increased management efficiency (Wang & Xie, 2009). For cross-border takeovers, the positive effect of M&As on productivity is probably less pronounced. Foreign firms usually acquire the most productive firms in a country (Criscuolo & Martin, 2009) but the integration of these firms into the multinational group is more complex such that productivity improvements are realized only after a longer period of adjustment (Harris & Robinson, 2002). Indeed, a recent study by Wang & Wang (2015) finds no difference in the productivity effect of domestic and foreign acquisitions in a large sample of M&As in China. In contrast, Guadalupe *et al.* (2012) find substantial improvements of productivity and an increase of innovative activity following foreign acquisitions.[3] The impact of cross-border acquisitions on productivity probably depends on a large range of country-pair characteristics. In our analysis, we argue that international taxation is a relevant factor in this regard. We thus provide an important determinant of the realization of post-merger productivity gains which may help explain part of the ambiguity in previous studies on M&A and productivity.

Finally, our paper advances the debate on whether and how foreign profits should be taxed in the presence of international M&As. Becker & Fuest (2010) and Devereux *et al.* (2015) emphasize that the answer depends on the resource allocation mechanism within the firm after the merger. If adjustment in one part of the firm affects production in another part, tax differentials distort the allocation mechanism and lead to sub-optimal outcomes. Since a tax on foreign income may avoid these differentials, such a policy is superior to an exemption regime in this case. We argue that this situation occurs in the post-merger allocation of corporate activity and provide empirical evidence for the loss that arises in the form of foregone productivity gains from M&As when tax neutrality is not ensured.

The paper is structured as follows. In Section 3.2 we develop a theoretical model to formally analyze the relationship between merger-induced productivity changes and tax differentials. We explain our empirical strategy in Section 3.3 and describe the data in Section 3.4. Results are presented in Section 3.5. Section 3.6 concludes.

[3]Here we focus on productivity effects within the acquired firm. However, spillover effects of foreign activity on domestic firm productivity may also occur (e.g. Javorcik, 2004; Haskel *et al.*, 2007; Balsvik & Haller, 2010).

3.2 M&As, Taxation and Productivity Gains

3.2.1 Tax Differentials and Productivity Change Through Reallocation of Activity after M&As

In this section we develop a simple theoretical framework to analyze the impact of tax rate differences on the realization of productivity gains in M&As. We consider a merger or acquisition involving two firms, a and b. Each of these firms consists of a set of separable units that each perform a different function and also differ in their total factor productivity with respect to this function. Prior to the merger, a subset of functions is performed in both firms. An obvious example are cross-divisional functions such as distribution, promotion or research and development. Once the deal is completed, the management decides for each of these functions whether the respective task is performed by a unit in a or b. This reallocation of activity is a potential source of post-merger productivity gains if a particular function is assigned to the unit that is more productive with respect to this task. However, as managers maximize net profit rather than output, the allocation decision may also be affected by other factors such as taxes, which distort the allocation decision.[4] We show that tax differentials between the merged firms may lead to an allocation of functions that is inefficient with respect to productivity. As a consequence, tax differentials reduce or even revert productivity gains resulting from the merger.

We begin by deriving the profit of a unit performing function i in firm $s = a, b$. It is given by

$$\pi_s(i) = A_s(i)\, k_s(i)^{\alpha}\, l_s(i)^{\beta} - r_s k_s(i) - w_s l_s(i) \tag{3.1}$$

where $k_s(i)$ and $l_s(i)$ are capital and labor input of firm s in the unit performing function i, r_s and w_s are the respective input prices and $A_s(i)$ is the total factor productivity of the unit performing function i in firm s. Within the unit, we assume decreasing returns to scale, $\alpha + \beta < 1$.[5] For given input prices, the management of the firm chooses the level of productive inputs for each individual unit i so as to

[4]The analysis thus follows a notion that is similar to the one proposed for firm replacement by Foster *et al.* (2008).

[5]Note that this does not preclude increasing returns to scale across the firm. For example, units may incur a fix cost f_i such that merging two units reduces the average fix cost and generates synergies through increasing returns to scale.

maximize the unit-specific profit $\pi_s(i)$. This yields the set of optimal input choices

$$l_s^*(i) = A_s(i)^\gamma \left(\frac{\beta}{w_s}\right)^{(1-\alpha)\gamma} \left(\frac{\alpha}{r_s}\right)^{\alpha\gamma}, \; k_s^*(i) = A_s(i)^\gamma \left(\frac{\beta}{w_s}\right)^{\beta\gamma} \left(\frac{\alpha}{r_s}\right)^{(1-\beta)\gamma} \tag{3.2}$$

where $\gamma = \frac{1}{1-\alpha-\beta}$. Substituting the input choices back into the profit function, we obtain the optimal profit

$$\pi_{i,s}^* = A_s(i)^\gamma \varphi_s \tag{3.3}$$

where

$$\varphi_s = \varphi_s(r_s, w_s) = \frac{1 - r_s^{(2-2\beta-\alpha)\gamma - \frac{1-\beta}{\alpha}} \alpha^{\frac{1-\beta}{\alpha}} - w_s^{(2-2\alpha-\beta)\gamma - \frac{1-\alpha}{\beta}} \beta^{\frac{1-\alpha}{\beta}}}{\left(w_s^\beta \beta^{-\beta} r_s^\alpha \alpha^{-\alpha}\right)^\gamma}$$

is a function of input prices and is decreasing in both r_s and w_s.

We first consider the post-merger production allocation decision without taxes. To simplify our derivation, we assume that factor prices are identical for both firms, such that $\varphi_a = \varphi_b$. This assumption is realistic, for example if capital input is purchased on the international capital market and wages reflect some form of quality-adjusted labor compensation. The latter can be assumed to be homogeneous across different locations if the labor market is sufficiently integrated. Abstracting from input price differentials allows us to clearly isolate the effect of tax differentials on post-merger productivity changes. We note, however, that frictions in the markets for labor or capital may preclude uniform input prices and we therefore relax this assumption in our empirical analysis below.

To simplify notation, we define the difference in total factor productivity between a and b for the unit performing function i by $\lambda(i) = A_a(i) - A_b(i)$ and normalize $A_b(i)$ to 1 such that $A_a(i) = 1 + \lambda(i)$. The objective function of the management is the overall profit of the firm which is the aggregate of the profits of the individual functions, $\Pi_s = \int_{i \in I} \pi_s(i)\, di$. Π_s is maximized by optimally allocating the individual functions to the most profitable unit, that is, the management allocates the function

i to a unit in a instead of b if

$$\pi_a^*(i) \geq \pi_b^*(i) \Longleftrightarrow \lambda(i) \geq 0. \tag{3.4}$$

and vice versa.[6] In this case, only the productivity differential $\lambda(i)$ determines where activity is located and the resulting post-merger productivity for the unit performing function i in the merged entity is given by

$$A(i) = \begin{cases} A_a(i) & \text{if } \lambda(i) \geq 0 \\ A_b(i) & \text{if } \lambda(i) < 0. \end{cases} \tag{3.5}$$

In order to derive the total productivity change in the combined firm, we aggregate the productivity of each individual unit. For analytical reasons, we assume that there is a large continuum of functions $i \in I$. The overall productivity of the merged firm is defined as the weighted aggregate of the productivity of all units, $A = \int_{i\in I} \omega(i) A(i)\, di$, where ω_i are the unit-specific weights with $\int_{i\in I} \omega(i)\, di = 1$ that depict the importance of each unit in the combined firm.[7]

We assume that in the merged entity, a subset of functions J is of the interchangeable sort described above while a subset of functions H are unique to each firm. The overall productivity prior to the merger is thus given by

$$A^{Pre} = \int_{i\in I} \omega(i) A(i)\, di = \int_{i\in H} \omega(i) A(i)\, di + \int_{i\in J} \omega(i) \left(zA_a(i) + (1-z) A_b(i)\right) di \tag{3.6}$$

The productivity of the units performing the interchangeable functions is again given by the weighted mean of the productivity in both firms where $0 < z < 1$ is the relative weight of firm a in the merging entity. After the merger, productivity in each of these units corresponds to the productivity of the respective units in one of

[6] Without loss of generality, we assume that the management has a slight bias towards a.

[7] This setup abstracts from complementarities between individual functions. Adding this feature to the model would probably make it more realistic but would also imply that allocation decisions are interdependent. This would lead to a high degree of complexity without adding new insights to or contradicting our main result.

the firms. The overall productivity is then given by

$$A^{Post} = \int_{i \in H} \omega(i) A(i) \, di + \int_{i \in J} \omega(i) \left(A_a(i) \mathbb{1}\{\lambda(i) \geq 0\} + A_b(i) \mathbb{1}\{\lambda(i) < 0\} \right) di \tag{3.7}$$

Eventually, we are interested in the productivity change after the merger or acquisition is completed. We define this change as the difference of overall productivity before and after the merger and denote it by Γ:

$$\begin{aligned} \Gamma =& A^{Post} - A^{Pre} \\ =& \int_{i \in H} \omega(i) \left(A_a(i) \mathbb{1}\{\lambda(i) \geq 0\} + A_b(i) \mathbb{1}\{\lambda(i) < 0\} \right. \\ & \left. - z A_a(i) - (1-z) A_b(i) \right) di. \end{aligned} \tag{3.8}$$

Let $\lambda(i)$ be distributed across some interval $\left[\underline{\lambda}, \bar{\lambda}\right]$. We can then rewrite expression (3.8) in the following way

$$\Gamma = (1-z) \int_0^{\bar{\lambda}} \omega(i) \lambda(i) \, d\lambda(i) + z \int_{\underline{\lambda}}^0 \omega(i) \left(-\lambda(i)\right) d\lambda_i \tag{3.9}$$

Expression (3.9) defines the productivity change as the weighted sum of productivity changes realized by allocating functions. Here, we abstract from taxes and potential factor price differentials such that the management allocates each function to the most productive location with respect to this function. As a consequence, the merger-induced productivity change is positive, $\Gamma \geq 0$. Note that expression (3.9) comprises both cases where each firm has a productivity advantage in some functions and cases where one firm is generally more productive than the other (e.g. $\lambda(i) > 0 \ \forall i$). The latter case often occurs in acquisitions when a large market leader takes over a smaller firm.

We now introduce tax differentials to our model. For simplicity, we assume that input costs are fully deductible such that the after-tax profit of the unit performing function i in firm s is given by $(1-\tau_s) \pi_s^*(i)$. When allocating functions between the two firms, the management now maximizes the overall after-tax profit of the merged firm such that it allocates function i to a instead of b if

$$(1-\tau_a)\,\pi_a^*(i) \geq (1-\tau_b)\,\pi_b^*(i) \Longleftrightarrow \lambda(i) \geq \tilde{\tau} = \left(\frac{1-\tau_b}{1-\tau_a}\right)^{\frac{1}{\gamma}} - 1 \tag{3.10}$$

When taxes are identical for both firms, $\tau_a = \tau_b$, we have $\tilde{\tau} = 0$ and the setting is identical to the case without taxes as no distortions are expected without tax differentials. However, if taxation differs between the two firms, $\tilde{\tau} \neq 0$, the management may allocate some activity to the firm with lower productivity but higher after-tax profit. The expression for the productivity change now reads

$$\hat{\Gamma} = \Gamma \underbrace{- \int_0^{\tilde{\tau}} \omega(i)\,\lambda(i)\,d\lambda(i)}_{\Lambda}. \tag{3.11}$$

The last term $\Lambda(\tilde{\tau})$ describes the unrealized productivity gains that are caused by the distorting effect of tax differentials with regard to the allocation of functions. It disappears if $\tau_a = \tau_b$ as $\lim_{\tilde{\tau}\to 0}\Lambda = 0$. Note that we have $\Lambda \leq 0$ irrespective of the direction of the tax differential. This implies that any tax difference between the target and acquirer location may lead to distorted allocations and thus reduces productivity gains resulting from the merger. Also, $\hat{\Gamma}$ does not need to be positive. For example, consider the case where firm a is more productive in all units, but is taxed substantially more such that $\tilde{\tau}$ is very large. In this extreme case, all functions are performed by the less productive location because of the tax difference and the productivity change is negative.

Furthermore, Λ is a decreasing function of the absolute tax differential. To illustrate this, consider the situation where $\tau_b > \tau_a$ such that $\tilde{\tau} > 0$ or $\tau_a > \tau_b$ such that $\tilde{\tau} < 0$. In both cases, an increase in the absolute tax differential $\Delta\tau = |\tau_a - \tau_b|$ raises $|\tilde{\tau}|$ and leads to more negative values of Λ. Thus, the merger-induced productivity change is a negative function of the absolute tax differential:

$$\frac{\partial\hat{\Gamma}}{\partial\Delta\tau} \leq 0. \tag{3.12}$$

3.2.2 Cross-Border Profit Shifting

So far, we have assumed that statutory tax rate differentials between merging firms correctly reflect the actual difference in taxation as perceived by the management.

This is the case if the profit generated in each subsidiary of the merged firm is correctly attributed to the location of activity. In an integrated company, this could, for example, be achieved through adequate transfer pricing. In practice, however, firms may be able to manipulate their effective tax burden through profit shifting (e.g. see Hines & Rice, 1994; Huizinga *et al.*, 2008). While previous studies have identified various forms of international profit shifting that use very different shifting vehicles[8], all of these approaches have in common that they reduce the tax payments in high tax locations of a multinational company by shifting part of the profit generated there to low-tax locations within the group. This leads to a convergence of effective tax rates in the various affiliate locations of the firm towards the lowest statutory rate in the multinational enterprise.

In the context of our framework above, this implies that the presence of profit shifting leads to a decrease in the absolute tax differential. We formalize this notion by assuming that a fixed proportion $0 < \phi < 1$ may be shifted between the two entities after the merger.[9] As the firm maximizes after-tax profit, shifting occurs only towards the location with a lower tax rate. The effective tax rate in location s is then given by

$$\tau_s = (1 - \phi)\,\tau_s + \phi \min(\tau_a, \tau_b)\,. \tag{3.13}$$

ϕ can be viewed as a function of the strictness of transfer pricing regulations and profit shifting opportunities between a and b. Substituting this into the absolute tax rate differential, we obtain $\Delta\tau = (1 - \phi)\,|\tau_a - \tau_b|$ where it is apparent that more profit shifting opportunities (i.e. higher ϕ) imply a smaller effective tax rate differential. Furthermore, we note that

$$\frac{\partial^2 \hat{\Gamma}}{\partial \Delta\tau \partial \phi} \geq 0 \tag{3.14}$$

such that an increase in the share of shifted profits mitigates the negative effect

[8]See Dharmapala (2014) for a comprehensive survey.

[9]Economic models usually assume that profit shifting induces some cost that is a convex function of the amount shifted (e.g. Hines & Rice, 1994). In our reduced-form expression, this would imply that ϕ is a function of the tax rate differential. However, since shifting is constrained to the realized profit, we still have $0 < \phi < 1$ and would thus obtain the same results with respect to the effect of the tax rate differential on the post-merger productivity change as described in our more simple model.

of statutory tax rate differentials on the productivity change after the merger. For example, we expect that the distorting effect of tax differentials in a cross-border merger is less severe if loose regulations regarding transfer pricing allow the management to manipulate profit allocation and thus narrow the difference in the effective tax burden between the two locations.

3.2.3 International Taxation

In the following, we briefly describe how tax differentials between different locations of a multinational enterprise may arise in the international tax system.[10] When analyzing the impact of tax rate differentials on the productivity change after an M&A deal, the relevant perspective is that of the management of the merged firm. Most M&A deals take the form of an acquisition and it is thus reasonable to assume that allocation decisions are taken from the perspective of the acquirer country. In the following we always refer to the tax rate faced by the acquiring firm when describing a tax rate as effective. The relevant tax rate differential is thus the difference between the tax rate on profits that the acquirer firm receives from the target in the form of dividends and the tax rate on profits realized at the acquirer location. The tax burden in each location depends on the statutory corporate income tax rate and the withholding tax rate (if applicable) for inter-corporate dividends.

The resulting difference depends strongly on the approach taken by the acquirer country to relieve firms of double taxation. The exemption method, which is applied by most European countries, fully or partially exempts foreign income from corporate taxation. The tax burden for profits received from the target is thus determined by the corporate income and withholding taxes in the target location, and the resulting tax rate differential is mainly driven by cross-border differences in these tax rates. Some countries, like the United States and, until 2009, Japan and the United Kingdom, apply the credit method instead. With this approach, foreign income is taxed at the domestic corporate tax rate but taxes paid abroad are credited against the domestic tax liability. This credit is usually limited to the amount of domestic tax payments due. As a consequence, tax differentials only arise when the effective tax rate of the acquirer country is below that of the target country. Credit regimes differ in the scope of the credit. A direct credit only considers the withholding tax paid abroad while indirect credits also include the underlying taxation of corporate

[10]See Huizinga & Voget (2009) for a comprehensive description of double-taxation of cross-border dividends.

profits.

Table 3.1: Tax Rate Differentials

This table summarizes the computation of the difference between the effective tax rate on profits that a firm in location a receives from a firm in location b in the form of dividends and the tax rate on profits realized in location a. τ_a^{CIT} and τ_b^{CIT} are the top statutory tax rates in location a and b, respectively. τ_{ba}^{w} is the final withholding tax rate on dividends paid from location b to location a. ψ is the exemption rate.

Double Tax Relief Method	Absolute Effective Tax Rate Difference $\Delta\tau$	
Exemption	$\left\lvert \tau_a^{CIT}\psi - \left(1-(1-\psi)\,\tau_a^{CIT}\right)\left(\tau_b^{CIT} + \left(1-\tau_b^{CIT}\right)\tau_{ba}^{w}\right)\right\rvert$	
Indirect Credit	$\left\lvert \tau_a^{CIT} - \tau_b^{CIT} - \left(1-\tau_b^{CIT}\right)\tau_{ba}^{w}\right\rvert$	if $\tau_b^{CIT} + \left(1-\tau_b^{CIT}\right)\tau_{ba}^{w} \geq \tau_a^{CIT}$
	0	if $\tau_b^{CIT} + \left(1-\tau_b^{CIT}\right)\tau_{ba}^{w} < \tau_a^{CIT}$
Direct Credit	$\left\lvert \tau_a^{CIT} - \tau_b^{CIT} - \left(1-\tau_b^{CIT}\right)\left(\tau_a^{CIT} - \tau_{ba}^{w}\right)\right\rvert$	if $\tau_{ba}^{w} < \tau_a^{CIT}$
	$\left\lvert \tau_a^{CIT} - \tau_b^{CIT} - \left(1-\tau_b^{CIT}\right)\tau_{ba}^{w}\right\rvert$	if $\tau_{ba}^{w} \geq \tau_a^{CIT}$

For our empirical analysis, we compute the effective tax rates on profits realized by the target and the acquirer, respectively, for each individual M&A deal from the perspective of the acquiring firm . We then use the absolute difference between these effective tax rates one year after the completion of the M&A deal as a proxy for the expected post-merger tax rate differential that determines the allocation within the merged firm. When determining the tax differential, we take into account international differences in statutory tax rates as well as the treatment of foreign profits for tax purposes in the acquirer country. Table 3.1 describes the computation of the absolute tax rate differential for the various double tax relief methods. The latter may either be based on unilateral approaches, bilateral tax treaties or multilateral agreements such as the Parent-subsidiary Directive which requires European Union (EU) and European Economic Area (EEA) members to exempt profits of substantial holdings in other member states from domestic taxation. Furthermore, we check whether final withholding taxes apply upon repatriation of foreign profits. Again, the level of these taxes depends on domestic legislation as well as the existence of bilateral or multilateral agreements.

3.3 Empirical Strategy

3.3.1 Identification

The objective of this paper is to analyze how tax differentials between the acquirer and the target firm affect the impact of the merger on the total factor productivity of the combined firm. For this purpose we estimate a reduced form of equation (3.11) by relating the merger-induced change in productivity to the absolute tax differential. Our empirical model takes the following form:

$$\hat{\Gamma}_{jlk} = \ln A_j^{Post} - \ln A_j^{Pre} = \alpha_0 + \alpha_1 \Delta\tau_{jlk} + \boldsymbol{\beta_1 X_j} + \boldsymbol{\beta_2 Z_{jlk}} + \boldsymbol{\psi} + \epsilon_j. \tag{3.15}$$

Our theoretical analysis suggests that the relationship between the productivity change and the tax rate differential is probably non-linear such that using the simple difference of TFP before and after the merger is not appropriate. Instead, we use the difference in the logarithms of TFP before and after the merger. This transformation mitigates the problem of outliers and turns out to be the most appropriate among a range of specifications (see Appendix B.2).

A_j^{Pre} and A_j^{Post} are the average estimated TFPs of the combined firm that emerges from deal j in the observable years before and after the completion of the M&A deal, respectively. Below, we explain in more detail how TFP is estimated. A major advantage of analyzing the TFP of the combined firm rather than focusing on the effect in the acquirer or target firm is that we avoid tax-driven measurement errors in the input variables. These may occur if firms engage in fictitious relocation of economic activity after the merger. For example, a firm may use transfer pricing to assign labor expenses to the high-tax location in the merged firm. This would raise labor input there without affecting the output in this location and thus would seemingly induce a decline in productivity of the high-tax affiliate while total factor productivity would appear to increase in the low-tax affiliate. However, since there was no actual reallocation of resources, this change in productivity would be misleading. More precisely, even though the perceived productivity change would certainly be a result of the tax differential between the two locations, it would not constitute the real productivity effect that we are interested in but would rather be a result of tax-optimizing financial accounting. Analyzing the TFP of the combined firm avoids this problem because artificial relocations of productive factors net out when consolidating acquirer and target firm.

The tax differential is defined as $\Delta\tau_{jlk} = |\tau_l - \tau_k|$ where τ_k is the top statutory tax rate on corporate profits realized in the acquirer location and τ_l is the effective tax rate one year after the completion of deal j from the perspective of the acquirer on profits realized by the target firm. The coefficient of interest is α_1 which measures the effect of one percentage point of absolute difference in target and acquirer tax rates on the productivity change resulting from the M&A deal. According to our theoretical model we expect α_1 to be negative.

We also check whether a certain type of tax differential drives our result by disaggregating $\Delta\tau_{jlk}$ into positive and negative differentials, $\Delta\tau^+_{jlk}$ and $\Delta\tau^-_{jlk}$ with

$$\Delta\tau^+_{jlk} = \begin{cases} |\tau_l - \tau_k| & \text{if } \tau_l > \tau_k \\ 0 & \text{else} \end{cases}$$

$$\Delta\tau^-_{jlk} = \begin{cases} |\tau_l - \tau_k| & \text{if } \tau_l < \tau_k \\ 0 & \text{else.} \end{cases}$$

In our estimation, we control for various deal-, firm- and location-specific variables that might affect the productivity change and post-merger performance more generally in line with the previous literature.[11] $\boldsymbol{X_j}$ is a vector of deal characteristics. Since most of the variation in $\Delta\tau_{lk}$ stems from cross-border deals which themselves might have a particular effect on firm productivity, we include a dummy that indicates whether a deal involves two firms located in different countries. Furthermore, we include dummies that are equal to one when the takeover resulted from a hostile bid, when target shareholders where paid in stocks rather than cash, when the deal included a capital increase and when the acquirer firm already had a toehold in the target firm before the acquisition was announced.

$\boldsymbol{Z_{jlk}}$ is a vector of characteristics of the target as well as the acquirer firm and their respective locations. On the firm level, these include the relative size of both firms measured by the acquirer to target ratio of total assets, leverage, which is defined as the ratio of current liabilities to current assets, firm age and an indicator for listed acquirers. We also account for relevant factors on the country level by controlling for wage differentials between target and acquirer location which are proxied by the logarithmic ratio of acquirer to target GDP per capita, as well as, the logarithm of GDP and GDP per capita growth. Since domestic taxes might also have direct

[11] See for example Harris & Robinson (2002), Herman & Lowenstein (1988), Fu *et al.* (2013), Fee & Thomas (2004), Stiebale (2016).

effects on firm productivity, we include the statutory corporate tax rate of the target in our regression.[12] Furthermore, we include the logarithm of the distance between the capitals of the acquirer and target country and a dummy that indicates if the merging firms are both located inside the European Union.

Each estimation contains a set of fixed effects $\boldsymbol{\psi}$ which comprise target and acquirer country-fixed effects, target and acquirer industry-fixed effects (2-digit US SIC code) and year-fixed effects. The variable of interest $\Delta\tau_{jlk}$ mainly varies across target and acquirer country pairs such that we cluster standard errors on the country pair level.[13]

Our theoretical model predicts that the effect of the tax differential is less pronounced when firms are able to easily allocate profits to the location with the more favorable tax rate. We test this notion in our empirical framework by interacting $\Delta\tau_{jlk}$ with an indicator for the looseness of transfer pricing regulations in the target and acquirer location for a deal, $LOOSE_{jlk}$. This variable thus exploits both variation across country pairs and within country pairs as transfer pricing legislation changes over time. It is equal to one whenever in both the target and the acquirer country the applicable transfer pricing regulations do not include a documentation requirement by law. We focus on the documentation requirement since the existence of transfer pricing regulations alone does not impose a sufficient constraint on corporate profit shifting if firms are not obliged to properly explain the assigned transfer prices to the tax authorities. Furthermore, previous studies suggest that documentation requirements indeed constrain international profit shifting (e.g. Beer & Loeprick, 2015; Beuselinck *et al.*, 2015).[14] Our empirical model is defined as follows:

$$\hat{\Gamma}_{jlk} = \alpha_0 + \alpha_1 \Delta\tau_{jlk} + \alpha_2 \Delta\tau_{jlk} \times LOOSE_{jlk} + \alpha_3 LOOSE_{jlk} + \boldsymbol{\beta_1 X_j} + \boldsymbol{\beta_2 Z_{jlk}} + \boldsymbol{\psi} + \epsilon_j. \tag{3.16}$$

As above, we expect α_1 to be negative while α_2 should be positive and capture the

[12]We note that this may be correlated with the absolute tax rate differential and also run regressions without the statutory tax rate in the target location as control variable to check whether collinearity drives our findings. In these estimations we obtain very similar results.

[13]To verify the robustness of our results, we have also conducted a regression analysis with a two-way clustering of standard errors as suggested by Cameron *et al.* (2012) and again obtained significant coefficient estimates.

[14]A comprehensive overview of the legislation regarding transfer pricing documentation in a large number of countries is provided by Zinn *et al.* (2014).

mitigating effect of loose transfer pricing rules on the impact of the tax differential. More precisely, $\alpha_1 \geq \alpha_2$ with $\alpha_1 = \alpha_2$ indicating that the effect of the tax differential on the productivity change may be completely eliminated if transfer pricing rules are sufficiently loose.

Transfer pricing regulation in the two locations of the merging firms may not be equally important for the productivity change. For example, it may be more relevant for the acquirer location if most of the transfer pricing adjustments are taken in the headquarter. Furthermore, the strictness of transfer pricing regulations may be more important in the location with the higher effective tax rate from which profit is shifted away. We investigate this asymmetry by interacting the absolute tax rate differential $\Delta\tau_{jlk}$ with a set of dummies $LOOSE_{jlk}^{Acq}$ and $LOOSE_{jlk}^{Tgt}$ that indicate whether the transfer pricing regulations do not require documentation in the acquirer or target country, respectively, and another set of dummies $LOOSE_{jlk}^{High}$ and $LOOSE_{jlk}^{Low}$, which indicate the same for the location with the higher and the lower effective tax rate, respectively. When computing the latter set of dummies, we set $LOOSE_{jlk}^{High} = LOOSE_{jlk}^{Acq}$ and $LOOSE_{jlk}^{Low} = LOOSE_{jlk}^{Tgt}$ whenever the tax rate differential is zero.

Having explored the relationship between tax differentials and productivity changes on the deal level, we conduct a further inquiry to investigate the mechanisms underlying our result. Our theoretical model makes no assertion to what extent tax differentials affect productivity gains in the acquirer or the target firm. Assuming a merger between similar firms, the effect is expected to be symmetric. However, in practice, this may not necessarily be the case: Acquirer firms are often much larger (e.g. Moeller *et al.*, 2004) and also more productive (e.g. Schoar, 2002). It is thus likely that the inefficient relocation described above, which results in lower overall productivity gains, occurs more often with respect to the target, that is, merged firms do not efficiently relocate to the more productive acquirer if the target location has a lower tax rate. Furthermore, the management of the merged firm often originates from the acquiring company and therefore may be less reactive towards tax differentials that induce a (inefficient) relocation away from the acquirer location. From a methodological perspective, an explanation for such a finding may be that the acquiring entity is so much larger than the target that a productivity change induced by the M&A deal and the following relocation of resources between the two is hard to observe in the data of the acquiring firm.

We are thus interested in whether the productivity effects of the tax differential are more pronounced in the target or the acquirer firm. Bearing in mind the potential measurement errors described above, we estimate a regression model that relates acquirer and target firm TFP to the absolute tax differential. To capture the evolution of total factor productivity more precisely, we use a panel regression for this purpose. The respective empirical model is specified as follows:

$$\ln\left(A_{j,t}\right) = \alpha_0 POST_{j,t} + \alpha_1 \Delta\tau_{jlk} \times POST_{j,t} + \boldsymbol{\beta_1 X_j} \times \boldsymbol{POST_{j,t}} + \boldsymbol{\beta_2 Z_{jlk,t}} + \boldsymbol{\psi} + \epsilon_{j,t} \tag{3.17}$$

where A_{jt} is the estimated total factor productivity in year t of a firm related to merger j, that is either the combined, the target or the acquirer firm. $POST_{j,t}$ switches to one in the year after the merger is completed. α_0 thus captures the general impact of the merger on the total factor productivity while α_1 again is the heterogeneity in this effect that is attributed to the tax differential. $\boldsymbol{X_j}$ and $\boldsymbol{Z_{lk,t}}$ are the same vectors of deal, target and acquirer specific variables as defined above. The effect of the time invariant variables is fully captured by firm fixed effects and we thus interact $\boldsymbol{X_j}$ with a vector of indicators for the post-merger period. Finally, $\boldsymbol{\psi}$ comprises firm- and year-industry-fixed effects. The latter capture industry-specific time trends of productivity.

We also check whether we can observe the expected pattern of allocation of productive factors after the merger. This is done by replacing the dependent variable in equation (3.17) with the logarithms of the employment and tangible fixed assets in the target and the acquirer firm. In this estimation, the effect of the absolute tax differential may not be symmetric. We check this by disaggregating $\Delta\tau_{jlk}$ into positive and negative differentials, $\Delta\tau^+_{jlk}$ and $\Delta\tau^-_{jlk}$ as described above. Alternatively, one could use the simple tax differential instead of the absolute one. However, the underlying assumption for such an estimation is that tax rate differentials have a symmetric effect on the productivity change which is not necessarily the case as explained above. Using $\Delta\tau^+_{jlk}$ and $\Delta\tau^-_{jlk}$ imposes a less restrictive framework.

In a final analysis, we verify our results using an event study design. This methodology was originally developed for the finance and accounting literature by Fama *et al.* (1969) but has since been adjusted and is now widely applied in economic studies (Corrado, 2011).[15] In general, an event study tracks the behavior of observed individuals around an event which is defined as the M&A deal completion for

[15] More recent applications of event studies in economics include Almond *et al.* (2011), Chetty *et al.* (2014) and Hoynes *et al.* (2016).

our purposes. It has two important benefits. First, it allows us to explore the timing of distortions in the post-merger adjustment process more systematically. This provides further insights with regard to the underlying mechanism and also informs us about the persistence of these distortions. Second, this method allows us to check whether pre-merger trends in TFP and factor input cause spurious findings. Ruling out such trends would strengthen the causal inference from our regression results.

For the event study, we adjust the specification of Sandler & Sandler (2014) for our purposes such that the empirical model looks as follows:

$$\begin{aligned}\ln y_{j,t} =& \alpha_{-3} \sum_{n=3}^{M-t} D_{j,t-n} \times \Delta\tau_{jlk} + \sum_{n=-2}^{3} \alpha_n D_{j,t-n} \times \Delta\tau_{jlk} + \alpha_4 \sum_{n=4}^{t-N} D_{j,t-n} \times \Delta\tau_{jlk} \\ &+ \gamma_{-3} \sum_{n=3}^{M-t} D_{j,t-n} + \sum_{i=-2}^{3} \gamma_n D_{j,t-n} + \gamma_4 \sum_{i=4}^{t-N} D_{j,t-n} \\ &+ \boldsymbol{\beta_1 X_j} \times \boldsymbol{POST_{j,t}} + \boldsymbol{\beta_2 Z_{jlk,t}} + \boldsymbol{\psi} + \epsilon_{j,t}. \end{aligned} \tag{3.18}$$

The dependent variable $y_{j,t}$ is TFP, labor or capital input of the acquiring, target or the combined firm as described above for the panel regression. It is regressed on a range of dummies $D_{j,t-n}$ which indicate whether the deal in which entity j is involved has been completed in period $t-n$. Within the first and last data year, M and N, we define our event window to 3 years before until 4 years after the merger completion.[16] The end points of this window are open brackets, that is, they indicate whether the merger has been completed 4 or more years before (for the upper window limit) and 3 or more years after a given period (for the lower window limit). This mitigates collinearity with the year-fixed effects. The regressor for the period before the merger completion is omitted and normalized to zero such that remaining coefficients have to be interpreted relative to the pre-merger year. Our event study specification is augmented by the same set of fixed effects and control variables as the panel regression model.

While the coefficients of the individual dummies γ_n capture the direct effect of the merger on the outcome variables, we are interested in the distortive impact of tax differentials on this effect. We thus interact the dummies with the absolute tax rate differential $\Delta\tau_{jlk}$ and add this set of interactions to the regression model to obtain our coefficients of interest α_i. The latter measure how a tax differential of one percentage point changes the impact of the merger on the outcome variable n

[16] We experimented with alternative window definitions and obtained similar results.

years after (if $n < 0$) or before (if $n > 0$) the merger completion relative to the year before the M&A is executed. If tax differentials only affect the adjustment process after the two firms have merged, one should not find an effect for pre-merger years, that is, we should obtain $\alpha_n = 0 \; \forall n < 0$.

3.3.2 Productivity Estimation

An important prerequisite for analyzing the effect of within-firm tax differentials on productivity changes after M&As is a precise estimate of total factor productivity in the involved firms. A common approach is to estimate the parameters of a Cobb-Douglas production function by regressing firm output on the main input factors labor and capital, compute the predicted values and back out total factor productivity as the residual. However, the latter contains both the total factor productivity of the entity and a potential productivity shock which is not observed by the researcher but known to the firm. Since the latter also affects the input choices of the firm, a simultaneity problem arises. Previous studies have addressed this issue by either using investments (Olley & Pakes, 1996) or intermediate inputs (Levinsohn & Petrin, 2003; Wooldridge, 2009) as proxies for the firm expectation regarding future productivity changes.

In this paper, we estimate total factor productivity using firm level data on inputs and outputs from Bureau van Dijk's AMADEUS and ORBIS databases. In doing so, we closely follow Fons-Rosen *et al.* (2013) who also use ORBIS and apply the Levinsohn & Petrin (2003) procedure. Output is measured as firm value added while inputs are labor, which is the total cost of employees, and capital, which is defined as the total assets of the firm. Following Levinsohn & Petrin (2003), firm expectations about future productivity shocks are proxied by intermediate inputs which are measured as the cost of materials.

This approach yields consistent estimates of total factor productivity but is also very demanding in terms of required data. Missing firm level data are imputed as described by Gal (2013) in order to ensure a sufficient sample size. Before conducting the productivity estimation, we also check the balance sheet data obtained from Bureau van Dijk for consistency errors. The relevant steps for constructing the productivity estimation sample are described in detail in Appendix B.1.

We conduct our productivity estimation using the universe of available firms in ORBIS and AMADEUS that reside in either an OECD or an EU member country and contain sufficient observations with reliable information on the relevant variables. This sample of 1,366,343 firms with annual data between 2000 and 2013 also contains the acquirer and target firms of interest. We estimate total factor productivity using the Levinsohn & Petrin (2003) method within each 2-digit US SIC code industry. The firm- and year-specific total factor productivities for the firms involved in an M&A during the observation period are then used in the main analysis.

3.4 Data

We collect M&A deals from the Zephyr database. An important feature of Zephyr is that target and acquirer firms are each assigned a unique Bureau van Dijk ID which allows us to match balance sheet data from ORBIS and AMADEUS to the deal-level data and compute total factor productivity before and after the merger. A major advantage of these databases is that they provide internationally comparable data for individual firms in various locations and can thus be used to investigate the behavior of companies in an international context (e.g. Cravino & Levchenko, 2017). Only deals with firms for which we obtain sufficient data to estimate total factor productivity for the year before and the year after the deal completion are used in the estimation. We also exclude financial and insurance firms[17] and privatizations of state-owned enterprises.

We restrict our sample to M&A deals which constitute a full acquisition or a merger to make sure that after the completion of the deal, the management of the combined firm has full control over the target and acquirer assets and thus possesses the means to reallocate the resources. The resulting sample consists of 9,649 firm-year observations for combined firms which are involved in 896 M&A deals. For 885 deals we observe TFP before and after the merger for both the acquirer and the target firm. These deals form the estimation sample for our main analysis. Their distribution across acquirer and target countries is summarized in Table 3.2. 18% of them are cross-border deals and thus provide the source of variation in the tax rate differential. Table 3.3 displays summary statistics for the other deal-specific variables. Most of the deals are paid in cash with only 1.2% of stock-for-stock deals in our sample. Only 10.1% of acquirers are listed on the stock market. In our sample, the absolute tax differential ranges up to 20.8% with an average of 1.0%. Given that a substantial number of M&As in our sample are domestic deals with no tax difference, this points to significant tax differentials among cross-border deals. Indeed, for this

[17]These are defined as firms with US SIC codes 60-67.

Table 3.2: M&A Deal Sample

Acquirer country	Code	Target Country																			
		BE	BG	CZ	DE	EE	ES	FI	FR	GB	HR	HU	IT	NL	NO	PL	PT	RO	SE	SI	SK	Total
Austria	AT	.	.	.	.	.	.	1	1	.	1	1	.	.	.	.	.	.	.	.	.	4
Belgium	BE	36	.	1	1	.	2	.	1	.	.	.	1	.	.	.	.	1	.	.	.	43
Bulgaria	BG	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8
Czechia	CZ	.	.	21	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	1	24
Germany	DE	4	.	2	19	.	3	1	4	3	.	1	.	.	.	2	.	3	2	.	.	44
Estonia	EE	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Spain	ES	.	.	2	1	.	192	.	3	2	.	.	6	.	.	.	5	.	.	.	.	211
Finland	FI	.	.	.	1	2	.	106	.	.	.	.	.	.	1	1	.	.	6	.	.	117
France	FR	7	.	.	.	.	4	.	77	2	.	.	5	1	.	.	.	.	2	.	.	98
UK	GB	.	.	.	.	.	4	.	4	38	.	.	.	.	.	.	.	.	1	.	.	47
Croatia	HR	.	.	.	.	.	.	.	.	.	15	.	.	.	.	.	.	.	.	3	.	18
Hungary	HU	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	5
Italy	IT	3	.	1	1	.	8	1	4	2	2	.	76	.	.	.	.	.	3	1	.	102
Norway	NO	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	.	2	.	.	11
Poland	PL	.	.	.	1	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	6
Portugal	PT	.	.	.	1	.	5	.	.	.	1	.	.	.	.	.	11	.	.	.	.	18
Romania	RO	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Sweden	SE	1	.	.	1	.	1	7	.	1	.	.	.	.	3	1	.	.	93	.	.	108
Slovenia	SI	.	.	.	.	.	1	.	.	.	2	.	1	.	.	.	.	.	.	8	.	12
Slovakia	SK	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	6
Total		51	8	28	26	4	220	116	95	48	21	8	90	1	13	9	16	4	109	12	6	885

sub-group, the average tax differential is 4.3%. 41% of deals in our sample comprise an acquirer and target location in both of which transfer pricing documentation is not required at the completion of the deal. This figure is also high among cross-border deals with a share of 35.2% involving locations with loose transfer pricing regulations and neither differs much between target and acquirer locations nor between high and low tax locations.

The deal sample is then combined with balance sheet data from the financial databases of Bureau van Dijk as well as the estimated TFP. Table 3.4 provides summary statistics for these variables. On average, acquirer firms are slightly more productive than target firms before the merger. This relation reverses after the M&A is completed, possibly pointing at some within-firm reorganization after the merger. As is commonly observed, acquirer and target firms differ substantially in size. In our sample, acquirers are on average about 18 times larger than the target firm in terms of total assets. They are also older and more leveraged. A positive average of the wage difference suggests that acquirers generally invest in countries with a lower level of labor compensation than in their home location.

Table 3.3: Summary Statistics: Deals

Variable	Observations	Mean	Standard deviation	Min	Max
Cross-border	885	0.180	0.384	0	1
$\Delta\tau$	885	1.043	2.260	0	20.75
$\Delta\tau^{+}$	885	0.626	1.586892	0	18.43
$\Delta\tau^{-}$	885	0.417	1.764	0	20.75
$LOOSE$	885	0.410	0.492	0	1
$LOOSE^{Acq}$	885	0.437	0.496	0	1
$LOOSE^{Tgt}$	885	0.429	0.495	0	1
$LOOSE^{High}$	885	0.446	0.497	0	1
$LOOSE^{Low}$	885	0.421	0.494	0	1
Hostile	885	0.001	0.034	0	1
Stock-for-Stock	885	0.012	0.111	0	1
Capital Increase	885	0.014	0.116	0	1
Horizontal	885	0.409	0.492	0	1
Toe	885	0.045	0.208	0	1
Acquirer Listed	885	0.101	0.301	0	1
EU Member	885	0.932	0.252	0	1
Log Distance	885	5.553	0.679	3.980	7.862

3.5 Results

3.5.1 Tax Differentials and Changes in Total Factor Productivity

Before turning to the results of our econometric analysis, we first investigate the sample graphically. Figure 3.1 plots the evolution of TFP of the combined firm before and after the merger. For each particular period it presents the average logarithm of TFP in our sample of merged firms. We differentiate between mergers with an absolute tax differential of zero (the blue, solid line) and deals with a positive absolute tax differential between the acquirer and target location (red, dash-dotted line). Combinations of firms with no difference in taxation between the two locations are generally more productive. However, this difference becomes more pronounced after the M&A deal is completed as TFP increases for firms with zero tax differentials

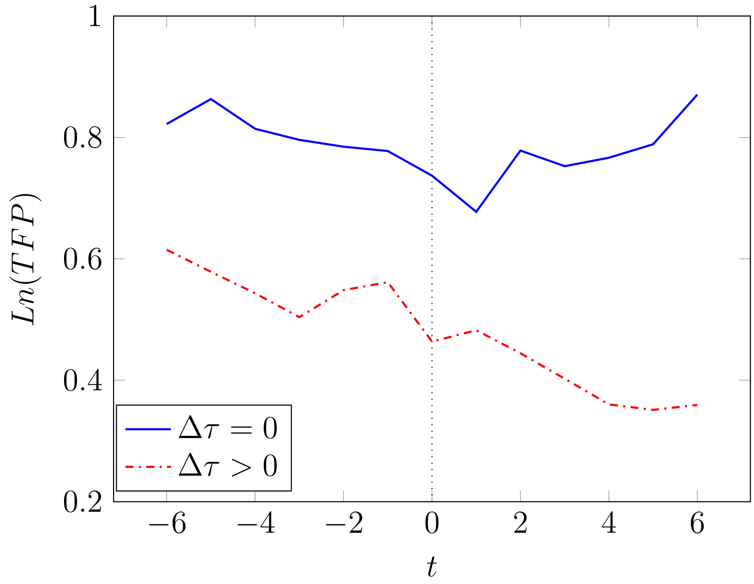
Table 3.4: Summary Statistics: Firms

Variable	Observations	Mean	Standard Deviation	Min	Max
Log TFP (combined firm)	7,379	0.652	0.951	-4.906	5.777
Log TFP (Acq.)	8,815	0.642	1.004	-6.369	7.120
Log TFP (Acq., before the merger)	4,691	0.653	0.943	-5.005	6.375
Log TFP (Tgt.)	9,672	0.586	0.976	-5.024	6.375
Log TFP (Tgt., before the merger)	4,512	0.640	0.962	-6.369	7.120
Relative Size	7,388	17.686	54.001	0.007	995.950
Leverage (Acq.)	9,262	1.762	56.786	0	4933.701
Leverage (Tgt.)	9,621	1.006	3.939	0	224.5
Log Age (Acq.)	9,493	2.972	0.870	0	5.298
Log Age (Tgt.)	9,841	2.774	0.854	0	4.942
CIT (Acq.)	14,681	0.302	0.056	0.1	0.52
CIT (Tgt.)	14,681	0.299	0.056	0.1	0.52
GDP p.c. Growth (Acq.)	11,844	0.014	0.043	-0.190	0.220
GDP p.c. Growth (Tgt.)	11,844	0.015	0.044	-0.190	0.220
Log GDP (Acq.)	13,716	27.258	1.156	23.020	28.803
Log GDP (Tgt.)	13,716	27.180	1.171	23.020	28.803
Wage Difference	13,716	0.027	0.252	-2.295	2.331

while it declines for firms with positive tax differential. Consistent with our theoretical model, this indicates that M&A deals with positive tax differentials have lower productivity gains than those without distortive differences in target and acquirer taxation. Of course Figure 3.1 may also capture the impact on TFP of other deal characteristics that are correlated with the induced tax differential. For example, cross-border deals are more prevalent when the tax differential is positive but probably also generate lower productivity gains because integrating two firms that are located in different countries may be very costly.[18]

[18] Note, however, that a tax differential of zero does not necessarily imply that the deal is domestic. Some countries have identical tax rates for some time (e.g. Norway and Sweden) while others applied the credit regime with respect to foreign dividends (e.g. the United Kingdom) which, assuming zero withholding taxes, also leads to a zero tax differential in the case of cross-border acquisitions of targets with lower tax rates relative to the acquirer location.

Figure 3.1: Evolution of TFP before and after the M&A



In our regression analysis, we control for these confounding effects. Table 3.5 presents the main findings. Column (1) displays results for a parsimonious regression with a set of fixed effects as described above but no control variables. The resulting coefficient is significantly negative, suggesting that an increase in the absolute tax differential reduces the productivity gain after the merger.

We augment the regression by including control variables in columns (2) and (3). Only coefficients for the firm- and deal-level variables are displayed while results for the location specific characteristics are relegated to Appendix B.3. The estimation results suggest that hostile M&As (i.e. deals that go ahead without the approval of the target firm's management) generate significantly lower productivity gains. This may reflect that the acquiring firm often faces substantial resistance by executives of the target firm when integrating it after the merger. Furthermore, deals which are financed via a capital increase also yield lower productivity gains which may be related to the observation that these deals often involve a large number of participants on the acquirer side. Such a consortium may find it more difficult to make decisions regarding the firm reorganization after the M&A completion.

In column (3), we account for industry-level variation. M&A often coincide with shifts in specific industries (see Mitchell & Mulherin, 1996). These may, for example, be caused by substantial deregulation within certain industries or an increase in competition that leads to a consolidation in particular production sectors. Any of these events may both be related to changes in productivity and increased foreign acquisition activity within the specific industry, the latter being generally associated

Table 3.5: Benchmark

OLS regression. The dependent variable in columns (1), (2), (4) and (5) is the difference in the logarithm of average productivity before and after the merger. In columns (3) and (6) the dependent variable is the difference in the logarithm of average productivity before and after the merger relative to the industry mean (SIC 2 digit code). Columns (2), (3), (5) and (6) contain regression results with country-level controls for which estimated coefficients are reported in Table B.1 in Appendix B. All regressions include target and acquirer country fixed effects, target and acquirer industry fixed effects and year fixed effects. Cluster robust standard errors (clustered at the acquirer-target country-pair level) are provided in parentheses. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\tau$	-0.030***	-0.045**	-0.038***			
	(0.010)	(0.018)	(0.014)			
$\Delta\tau^-$				-0.047**	-0.051*	-0.055**
				(0.019)	(0.026)	(0.026)
$\Delta\tau^+$				-0.018	-0.040	-0.022
				(0.011)	(0.024)	(0.017)
Cross-border		0.028	0.021		0.029	0.025
		(0.146)	(0.132)		(0.146)	(0.131)
Hostile		-0.930**	-0.171		-0.931**	-0.178
		(0.397)	(0.324)		(0.394)	(0.319)
Stock-for-Stock		0.249	0.239		0.253	0.251
		(0.172)	(0.196)		(0.172)	(0.196)
Capital Increase		-0.311***	-0.355***		-0.313***	-0.362***
		(0.098)	(0.085)		(0.098)	(0.086)
Horizontal		-0.041	-0.022		-0.040	-0.019
		(0.034)	(0.026)		(0.034)	(0.026)
Toe		0.044	0.118		0.042	0.111
		(0.093)	(0.095)		(0.092)	(0.094)
Relative Size		-0.000	-0.000		-0.000	-0.000
		(0.000)	(0.000)		(0.000)	(0.000)
Leverage (Acq.)		0.026	0.000		0.026	-0.000
		(0.040)	(0.039)		(0.041)	(0.039)
Acquirer Listed		-0.081*	-0.058		-0.080	-0.054
		(0.048)	(0.045)		(0.048)	(0.045)
Log Age (Acq.)		-0.012	-0.003		-0.012	-0.003
		(0.016)	(0.020)		(0.016)	(0.021)
Intercept	-0.605*	19.329	0.960	-0.669*	19.104	0.365
	(0.337)	(29.693)	(25.995)	(0.344)	(29.610)	(25.783)
Country-level controls	No	Yes	Yes	No	Yes	Yes
N	885	785	782	885	785	782
R^2	0.244	0.288	0.285	0.245	0.288	0.286

with higher tax rate differentials. For instance, a slow-down in productivity growth of an industry in a particular country makes firms in this industry potential takeover targets for foreign, more competitive firms. This implies larger tax rate differentials for acquisitions in this industry but also lower productivity gains if the foreign acquisition cannot completely reverse the downward trend in productivity growth.

Ignoring within-industry developments may thus induce a spurious correlation between merger-induced TFP changes and tax rate differentials that is unrelated to the mechanism suggested in our theoretical model above. We account for this effect by conducting an additional estimation in which we scale the dependent variable by the industry average. In particular, we use the difference in the logarithm of average productivity before and after the merger relative to the industry mean (SIC 2 digit code). Results are presented in column (3) of Table 3.5 which otherwise repeats the specifications of column (2). The effect of the tax differential on the change in TFP is still significantly negative. These findings suggest that our results are robust to accounting for industry trends in productivity and are thus not driven by industry-specific shifts.

In all of the augmented regressions, the coefficient for the absolute tax differential remains significantly negative. Using regression (2) with the full set of controls and a straight-forward interpretation of the observed effect as a conservative benchmark, we find that an increase in the absolute tax differential between acquirer and target location by 1 percentage point drives down the merger-induced productivity gain by about 4.5%.

We complement our analysis in columns (4) to (6) by allowing for different coefficients for positive and negative tax differentials. Again, column (4) presents the results for regressing the tax differentials on the variables of interest and a set of fixed effects. The coefficient for negative tax differentials (i.e. tax differences where the effective tax rate of the target location is below that of the acquirer location) is significantly negative while the coefficient for positive tax differences is insignificant. This suggests that deals with targets in low-tax jurisdictions drive our main result. When adding control variables in column (5) or controlling for industry-specific trends in column (6), we again obtain the result that deals involving low-tax targets have a particularly negative impact on the post-merger productivity change.

One explanation for this finding is that the potential for productivity improvement is probably higher in the target firm. Thus, negative tax differences, that induce the management to continue the operation of some less productive units in the target have a more negative impact on overall productivity than positive tax differences. The latter would only reduce the post-merger productivity gain by a substantial amount if there is a sufficient number of units in the acquirer location whose productivity is inferior to that of the corresponding units in the target firm. If generally most of the adjustment takes place in the target firm, one may also refer to asymmetric adjustment costs in factor demand (Hamermesh & Pfann, 1996) as a complementary explanation. Jaramillo *et al.* (1993) show that the cost for lowering labor demand is much higher than for increasing it and the persistent nature of capital investment implies that downward adjustment is also more expensive for this factor (Pindyck, 1988). The excessive reduction in resources in the target firm that would be induced by positive tax differentials is thus likely to be more costly than the relative increase of resources resulting from negative tax differences, especially if this means that resources remain where they are and no net adjustment takes place. In this setting, negative tax differences are more likely to have an impact on management decisions and thus affect productivity changes more strongly.

Table 3.6: Transfer Pricing Regulation

OLS regression. The dependent variable in columns (1), (2), (4) and (5) is the difference in the logarithm of average productivity before and after the merger. In column (3) the dependent variable is the difference in the logarithm of average productivity before and after the merger relative to the industry mean (SIC 2 digit code). Columns (2)-(5) contain regression results with control variables for which estimated coefficients are reported in Table B.2 in Appendix B. All regressions include target and acquirer country fixed effects, target and acquirer industry fixed effects and year fixed effects. Cluster robust standard errors (clustered at the acquirer-target country-pair level) are provided in parentheses. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)
$\Delta\tau$	-0.041***	-0.062***	-0.048***	-0.072***	-0.071**
	(0.013)	(0.020)	(0.016)	(0.027)	(0.028)
$\Delta\tau \times LOOSE$	0.042*	0.058**	0.035*		
	(0.021)	(0.022)	(0.019)		
$LOOSE$	-0.010	-0.052	0.021		
	(0.060)	(0.082)	(0.071)		
$\Delta\tau \times LOOSE^{Acq}$				0.059***	
				(0.021)	
$\Delta\tau \times LOOSE^{Tgt}$				-0.005	
				(0.021)	
$LOOSE^{Acq}$				-0.196	
				(0.157)	
$LOOSE^{Tgt}$				0.176	
				(0.177)	
$\Delta\tau \times LOOSE^{High}$					0.048**
					(0.024)
$\Delta\tau \times LOOSE^{Low}$					0.006
					(0.024)
$LOOSE^{High}$					-0.085
					(0.125)
$LOOSE^{Low}$					0.061
					(0.139)
Intercept	-0.669*	28.887	6.007	23.562	25.153
	(0.349)	(31.473)	(26.900)	(31.612)	(31.327)
Country-level controls	No	Yes	Yes	Yes	Yes
N	885	785	782	785	785
R^2	0.249	0.296	0.290	0.296	0.295

In the next set of regressions, which is presented in Table 3.6, we analyze how transfer pricing regulation affects our results. In the regression in column (1) of Table 3.6 we add the interaction of the tax rate differential and $LOOSE$, our indicator for the strictness of transfer pricing regulation, to the benchmark specification displayed in columns (1) to (3) in Table 3.5. As before, the coefficient of the absolute tax differential $\Delta\tau$ is significantly negative. The coefficient of the interaction between $\Delta\tau$ and an indicator for loose transfer pricing regulations is significantly positive. This suggests that the impact of the tax differential on the productivity change is mitigated if transfer pricing regulation is not very strict and firms are able to reduce the effective tax rate difference between the locations by engaging in profit shifting activities. Furthermore, our results suggest that if the tax law in the acquirer and the target country either does not contain transfer pricing regulations or does not require firms to provide a written documentation of their transfer pricing system, this may neutralize the effect of the tax differential. In particular, we cannot reject the hypothesis that $\alpha_1 + \alpha_2 = 0$ in our sample.[19] This finding is robust to adding control

[19] Conducting a simple Wald test, we obtain F-Statistics of 0.00, 0.13 and 0.62 for the regressions

variables and controlling for industry trends in columns (2) and (3), respectively.

Does transfer pricing legislation matter more in the target or in the acquirer location? We answer this question by disaggregating $LOOSE$ into two indicators for the strictness of transfer pricing regulation in the acquirer and the target country, $LOOSE^{Acq}$ and $LOOSE^{Tgt}$. Results presented in column (4) suggest that legislation in the acquirer location is much more important than in the target location. Given our findings above, this is not surprising. Our estimation results in Table 3.5 indicate that the results are mainly driven by negative tax differences, that is, when profits of the target are taxed at a lower rate than profits of the acquirer. In this case firms would like to shift profits away from the acquirer location to the target firm. This is what stricter transfer pricing legislation in the former would be implemented to inhibit. On the contrary, raising transfer pricing documentation requirements in the low-tax target location might increase overall transparency but is probably not designed to prevent profit shifting to this location (Bucovetsky & Haufler, 2008) and is therefore less relevant.

An alternative disaggregation would be to differentiate between the strictness of transfer pricing legislation in the location with the higher and the lower effective tax rate, $LOOSE^{High}$ and $LOOSE^{Low}$. Results for this approach are presented in column (5) of Table 3.6. Consistent with the idea described above that legislation to curb profit shifting via transfer pricing is more important in the high-tax location, we find that the estimated coefficient for $LOOSE^{High}$ is much bigger than the one for $LOOSE^{Low}$. The latter is not significantly different from zero.

3.5.2 Allocation of Productive Factors

We now extend our analysis to explore the mechanisms that underlie our main result. Inefficient reallocation after M&As can take various forms. The management can either allocate too many or too few resources to either the acquirer or the target depending on the sign of the tax difference between the locations of the two firms. Our theoretical model is not conditional on such biases which has the advantage of very general results but also precludes us from forming any expectations about how the effect evolves in practice. Instead, we rely on empirical evidence to identify particular channels.

For this purpose, we turn to a panel analysis in order to follow the evolution of important determinants of total factor productivity over time. This allows us to

in columns (1), (2) and (3) of Table 3.6, respectively.

Table 3.7: Panel Regression: Total Factor Productivity

OLS regression. The dependent variable is the logarithm of total factor productivity of the combined firm in columns (1)-(2), of the target firm in columns (3)-(4) and the acquirer firm in columns (5)-(6). All regressions include country-level controls for which estimated coefficients are reported in Table B.3 in Appendix B. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm and industry-year fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1) Combined Firm	(2) Combined Firm	(3) Target Firm	(4) Target Firm	(5) Acquirer Firm	(6) Acquirer Firm
$POST$	-0.805*** (0.217)	-0.809*** (0.212)	-0.851*** (0.315)	-0.847*** (0.312)	-0.667** (0.281)	-0.664** (0.275)
$POST \times \Delta\tau$	-0.035*** (0.011)		-0.042*** (0.015)		-0.020* (0.011)	
$POST \times \Delta\tau^-$		-0.035*** (0.012)		-0.046** (0.020)		-0.017 (0.011)
$POST \times \Delta\tau^+$		-0.034** (0.016)		-0.036* (0.020)		-0.025 (0.017)
$POST\times$Cross-border	-0.040 (0.086)	-0.045 (0.086)	-0.017 (0.122)	-0.050 (0.121)	-0.061 (0.103)	-0.057 (0.104)
$POST\times$Hostile	-0.294 (0.188)	-0.301 (0.187)	-0.292 (0.338)	-0.311 (0.343)	-0.223** (0.098)	-0.228** (0.098)
$POST\times$Stock-for-Stock	-0.097 (0.159)	-0.095 (0.160)	-0.706*** (0.196)	-0.707*** (0.199)	0.252 (0.179)	0.243 (0.182)
$POST\times$Capital Increase	0.010 (0.102)	0.010 (0.102)	0.638*** (0.169)	0.653*** (0.170)	-0.371*** (0.108)	-0.369*** (0.109)
$POST\times$Horizontal	0.025 (0.033)	0.023 (0.033)	-0.053 (0.054)	-0.062 (0.054)	0.041 (0.036)	0.040 (0.036)
$POST\times$Toehold	0.142* (0.078)	0.140* (0.079)	0.087 (0.119)	0.080 (0.118)	0.108 (0.081)	0.109 (0.081)
$POST\times$Acquirer Listed	-0.036 (0.059)	-0.037 (0.060)	-0.190* (0.099)	-0.192* (0.101)	0.055 (0.064)	0.052 (0.065)
Relative Size	-0.001** (0.000)	-0.001** (0.000)	0.001 (0.001)	0.001 (0.001)	-0.001* (0.000)	-0.001** (0.000)
Leverage (Acq.)	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.003*** (0.000)	0.003*** (0.000)
Leverage (Tgt.)	0.001 (0.020)	0.002 (0.020)	-0.016 (0.034)	-0.016 (0.034)	0.007 (0.011)	0.007 (0.011)
Log Age (Acq.)	0.005 (0.054)	0.006 (0.054)	0.047 (0.079)	0.043 (0.078)	0.030 (0.063)	0.032 (0.062)
Log Age (Tgt.)	0.032 (0.042)	0.028 (0.042)	0.094 (0.069)	0.089 (0.069)	-0.039 (0.044)	-0.041 (0.044)
Country-level controls	Yes	Yes	Yes	Yes	Yes	Yes
N	5,075	5,102	5,072	5,099	5,072	5,099
R^2	0.239	0.236	0.191	0.187	0.295	0.293

control for co-moving variables and general time trends. In columns (1) and (2) of Table 3.7 we repeat our main analysis in a panel regression framework to demonstrate that this approach also captures the negative effect of the tax differential on TFP. The coefficient of the interaction between the absolute tax difference and the post-merger dummy is significantly negative. This is the case both for positive and for negative tax differences although we note that negative tax differences appear to be somewhat more important with a slightly larger magnitude for the corresponding coefficient.

Next, we turn to the target firm, that is, instead of the TFP of the combined firm we relate the tax differential to the estimated TFP of the target firm only. Our results in column (3) suggest, that the productivity gain on the target level is substantially lower when the absolute tax differential is positive.[20] In particular, we find that a one percentage point increase in the absolute tax difference lowers the merged-induced change in target productivity by 4.2%. We also explore whether this result is rather driven by negative or positive tax differentials, that is, whether lower productivity gains are a result of the target being located in a low-tax or high-tax country with respect to the acquirer location. The results for the corresponding estimation are presented in column (4). The coefficient for the interaction of the post-merger dummy with the absolute magnitude of the negative tax differential, $\Delta\tau^-$, is negative and highly significant. In contrast, the coefficient for the related interaction with the positive tax differential, $\Delta\tau^+$, is only marginally significant and much smaller in magnitude. This finding suggests that the negative effect of tax differentials on the post-merger productivity change in the target in our sample is mainly driven by deals where profits received from the target are taxed at a lower rate than those generated in the acquirer country.

We then conduct a similar analysis for the acquiring firm in columns (5) and (6). Our results indicate that tax differentials have a much smaller impact on acquirer productivity. With a coefficient of -0.02 the estimated effect is less than half the magnitude found for target firms and only marginally significant. When relating the TFP of the acquirer to negative and positive tax differentials separately, we do not obtain precise results. The respective coefficients are negative but insignificant.

These findings point to the target firm as the entity within the merged firm where tax differentials are most harmful for productivity gains. Although the estimated impact of the tax differential is a novel effect with regard to M&A outcomes, it is not surprising that the main impact relates to the target firm as this is the place where probably most of the reorganization occurs after the merger. How the tax differential affects this process should also be visible in the data. In our next estimation we therefore trace the evolution of the input factors labor and capital before and after the M&A completion and analyze how their use is affected by tax differentials.

We begin this analysis with employment and present our findings in Table 3.8. The first two columns show results with respect to the target firm. A negative, albeit insignificant coefficient for the post-merger dummy in column (1) suggests that firms reduce employment in the target firm after the merger. However, this reduction is

[20]The results presented here are estimated including the full set of controls. We also estimated the corresponding models without firm-, country- and deal-level controls and obtained very similar results.

mitigated when there is a positive absolute tax differential. The estimation suggests that the post-merger employment cut is reduced by 2% per percentage point of absolute tax difference. As we focus on the target firm in this estimation, it is again useful to separate the absolute tax differential into positive and negative tax differences. We do this in column (2). Consistent with our theoretical explanations above, target employment is mainly affected by negative rather than positive tax differences.

Table 3.8: Panel Regression: Employment

OLS regression. The dependent variable is the logarithm of the total number of employees of the target firm in columns (1)-(2) and the acquirer firm in columns (3)-(4). All regression results contain country-level controls for which estimated coefficients are reported in Table B.4 in Appendix B. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm and industry-year fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1) Target Firm	(2) Target Firm	(3) Acquirer Firm	(4) Acquirer Firm
$POST$	-0.402	-0.166	-0.126	-0.127
	(0.288)	(0.278)	(0.206)	(0.204)
$POST \times \Delta$	0.021*		-0.019*	
	(0.012)		(0.010)	
$POST \times \Delta\tau^-$		0.033***		-0.019*
		(0.011)		(0.010)
$POST \times \Delta\tau^+$		0.005		-0.019
		(0.018)		(0.014)
$POST \times$Cross-border	-0.083	-0.006	0.024	0.032
	(0.102)	(0.098)	(0.079)	(0.078)
$POST \times$Hostile	-0.473***	-0.242	-0.449**	-0.443**
	(0.101)	(0.167)	(0.210)	(0.210)
$POST \times$Stock-for-Stock	-0.435**	-0.519***	0.949***	0.948***
	(0.186)	(0.187)	(0.190)	(0.192)
$POST \times$Capital Increase	0.037	0.014	-1.004***	-1.007***
	(0.131)	(0.127)	(0.112)	(0.113)
$POST \times$Horizontal	-0.009	-0.004	-0.004	-0.002
	(0.051)	(0.049)	(0.040)	(0.040)
$POST \times$Toehold	0.172	0.185	-0.103	-0.101
	(0.118)	(0.117)	(0.112)	(0.112)
$POST \times$Acquirer Listed	0.138*	0.155**	0.094	0.098
	(0.075)	(0.071)	(0.081)	(0.083)
Leverage (Acq.)	0.000**	0.000***	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Leverage (Tgt.)	-0.065***	-0.059***	0.017	0.015
	(0.018)	(0.019)	(0.013)	(0.014)
Log Age (Acq.)	0.000	0.040	0.265***	0.263***
	(0.071)	(0.048)	(0.067)	(0.067)
Log Age (Tgt.)	0.250***	0.242***	0.034	0.039
	(0.082)	(0.061)	(0.050)	(0.050)
Country-level controls	Yes	Yes	Yes	Yes
N	5,096	5,123	5,096	5,123
R^2	0.209	0.185	0.317	0.314

The opposite effect is observed with regard to the acquiring firm for which we present results in columns (3) and (4). Higher absolute tax differentials enhance the post-merger employment cut in the acquirer by 1.9% points for each percentage point in tax difference. Again, separating the tax differential in positive and negative differences suggests that this result is driven by M&As where a firm in a high-tax country takes over a firm located in a low-tax country.

We repeat this analysis for the other input factor capital which is measured as the logarithm of tangible fixed assets. Results are shown in Table 3.9 where the first two columns refer to the target firm. Similar to the effect on labor input, the estimation suggests that an increase in the absolute tax differential has a positive effect on the use of capital in the target after the merger. Furthermore, the significantly positive coefficient of the interaction between the post-merger dummy and $\Delta\tau^{-}$ in column (2) indicates that this is mainly driven by negative tax differences. An increase in the magnitude of the negative tax difference between target and acquirer raises merger-induced change in capital employed in the target by 4.6% per percentage point. In contrast, we do not find a significant effect of positive tax differences on the post-merger level of capital in the target which mirrors the asymmetry observed for labor input. Firms only adjust the post-merger use of input factors in the target to tax rate differentials if the target is located in a country with an effective tax rate below that of the acquirer location. If the acquirer resides in a country with a more favorable tax regime, no reaction occurs.

Turning to capital employment in the acquirer firm we cannot identify a significant effect of the absolute tax differential. The corresponding coefficient in column (3) is negative but relatively small and not significant. We also do not find a significant impact if we differentiate between positive and negative differences. Thus, acquirer firms in our sample do not adjust their post-merger investment policies to tax differences. On the one hand, this may reflect that firms find it easier to adjust labor input than to decrease or increase capital. On the other hand, acquirer firms are usually much bigger than target firms, especially in terms of assets, and may adjust their capital stock because of various factors unrelated to taxation. Such noise in the data would prevent us from precisely measuring the effect of the tax difference on changes in the capital employment of the acquirer following the M&A.

The main channel through which tax differentials affect the realization of productivity changes in M&As thus appears to be that they reduce the scale of adjustment in the target firm when the tax burden for profits is lower there. Previous empirical studies have already shown that target firms often undergo a period of substantial restructuring after the completion of an M&A (e.g. Maksimovic *et al.*, 2011; Li, 2013). However, our results suggest that differences in taxation are relevant with regard to the magnitude and the speed of such adjustments. For instance, our results suggest that firms reallocate less activity away from targets that are located in low-tax locations. This distortion hampers the realization of productivity gains in these firms and thus has a negative impact on the overall productivity gain in the merged enterprise.

Table 3.9: Panel Regression: Capital

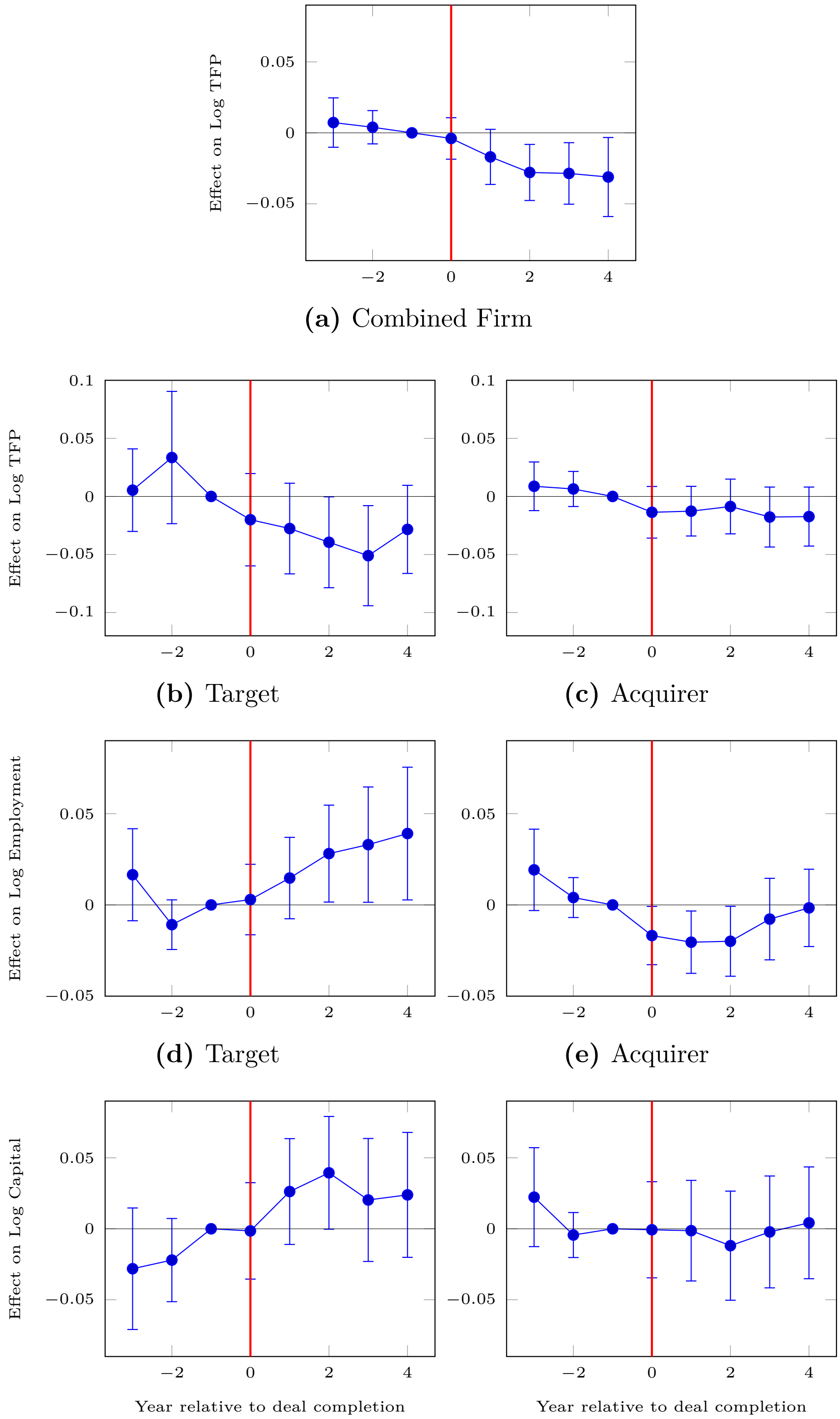
OLS regression. The dependent variable is the logarithm of tangible fixed assets of the target firm in columns (1)-(2) and the acquirer firm in columns (3)-(4). All regression results contain country-level controls for which estimated coefficients are reported in Table B.4 in Appendix B. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm and industry-year fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	Assets			
	(1)	(2)	(3)	(4)
	Target	Target	Acquirer	Acquirer
$POST$	-0.065 (0.440)	-0.083 (0.436)	-0.009 (0.348)	-0.049 (0.344)
$POST \times \Delta\tau$	0.031* (0.017)		-0.005 (0.018)	
$POST \times \Delta\tau^{-}$		0.040** (0.018)		-0.014 (0.021)
$POST \times \Delta\tau^{+}$		0.023 (0.026)		0.011 (0.021)
$POST \times$Cross-border	0.118 (0.193)	0.113 (0.188)	-0.135 (0.153)	-0.137 (0.150)
$POST \times$Hostile	-0.274 (0.290)	-0.275 (0.290)	-0.227 (0.139)	-0.220 (0.140)
$POST \times$Stock-for-Stock	-0.169 (0.351)	-0.190 (0.356)	2.061*** (0.313)	2.093*** (0.315)
$POST \times$Capital Increase	0.040 (0.244)	0.039 (0.245)	-2.315*** (0.185)	-2.333*** (0.184)
$POST \times$Horizontal	0.089 (0.092)	0.090 (0.092)	-0.081 (0.068)	-0.077 (0.067)
$POST \times$Toehold	-0.033 (0.174)	-0.029 (0.173)	0.139 (0.183)	0.142 (0.183)
$POST \times$Acquirer Listed	0.198 (0.178)	0.195 (0.180)	0.224 (0.143)	0.235 (0.143)
Leverage (Acq.)	0.000 (0.000)	0.000 (0.000)	0.036 (0.055)	0.037 (0.055)
Leverage (Tgt.)	0.081*** (0.030)	0.081*** (0.030)	0.038** (0.018)	0.037** (0.018)
Log Age (Acq.)	-0.220* (0.132)	-0.209 (0.131)	0.250** (0.109)	0.249** (0.108)
Log Age (Tgt.)	0.205 (0.139)	0.204 (0.139)	0.181* (0.104)	0.187* (0.103)
Country-level controls	Yes	Yes	Yes	Yes
N	5,075	5,102	5,084	5,111
R^2	0.199	0.198	0.307	0.307

We complement our analysis using the event study design described above. Results are displayed in Figure 3.2 which plots the coefficients of the interactions between the event dummies and the tax rate differential against the number of years relative to the merger completion. In panel (a), the dependent variable is the TFP of the combined firm. After an M&A is completed, TFP declines relative to one year prior to the merger. This decrease is persistent over time and even increases in later periods. Panels (b) and (c) present results for acquirer and target firms separately. For the latter, we observe a significant decrease in TFP two and three years after the merger. This suggests that the effect of tax rate differentials on merger-induced productivity continues at least over the medium run. In contrast, there is no effect of tax rate differentials on TFP of the acquirer neither before nor after the merger.

Turning to the effect of the tax differential on employment, we observe in panels

Figure 3.2: Event Study



(a) Combined Firm

(b) Target **(c)** Acquirer

(d) Target **(e)** Acquirer

(f) Target **(g)** Acquirer

Standard errors are clustered on firm level. 95% confidence intervals are reported. Estimations include firm-fixed and industry-year-fixed effects.

(d) and (e) that it has opposite directions for the target and the acquirer. Relative to the year before the merger, employment significantly increases in the target from

2 years after the M&A completion onward. The effect increases over time. For the acquirer, the effect is negative, albeit of much smaller magnitude. It only persists in the short-run but is zero in year 4 after the merger. The impact of tax differences on capital is less clear-cut. There is a marginally significant positive effect on target capital two years after the M&A is executed but this quickly reverses. For the acquirer, we find no significant change in capital in any post-merger year. These results point to employment as the factor whose adjustment is affected most strongly by tax differences between target and acquirer firm. At least for the acquirer, these responses are not quickly reversed but continue over a substantial period of time. For capital, the effect is less pronounced which probably reflects that adjustment cost is higher for this factor as indicated, for example, by Hall (2004).

In none of the event study analyses we observe a significant response of the outcome variable prior to the merger.[21] This rules out that pre-merger trends in the outcome variable drive our results and strongly points to the M&A completion as the event that triggers the effect of the tax differential which strengthens the causal interpretation of our results.

3.6 Conclusion

In this paper, we investigate how the productivity change after corporate M&As is affected by differences in profit taxation between the target and the acquirer location. In our theoretical model, tax differentials between the locations of firms involved in an M&A distort the post-merger reallocation of productive activity. If tax differences are large enough, firms assign some activity to units that are less productive but more profitable due to a lower tax burden. With respect to overall productivity in the combined firm, this choice is inefficient and reduces the productivity gain after the M&A.

We then employ firm-level data to test this notion empirically. First, we derive firm-level estimates of TFP using the Levinsohn & Petrin (2003) method. We then compute the merger-induced change in TFP in the combined firm and relate it to the absolute value of the difference between the effective tax rate on profits received from the target in the form of inter-corporate dividends and the tax rate applied to profits generated by the acquirer. Our results suggest that an increase in the absolute tax differential by one percentage point reduces the merger-induced productivity gains

[21] The graphical observation is confirmed using a Wald test for the joint insignificance of the interaction of the pre-merger dummies with the absolute tax rate differential.

by 4.5%. Consistent with our expectation that tax differentials are less distortive if firms are able to reattribute part of their profit from high-tax to low-tax locations, we find that the impact of the tax differential is mitigated when transfer pricing regulations are less strict such that firms can more easily engage in profit shifting. In a complementary analysis, we explore the mechanisms that drive the impact of tax differences on overall firm productivity. Our findings indicate that the effect is asymmetric. It is mainly driven by M&A deals where firms located in high-tax countries acquire a firm in a low-tax country and fail to efficiently adjust the input factors of production in the target to fully realize the productivity gain. In contrast, tax differentials that would induce a relocation of activity to the acquirer location have no significant impact on overall firm productivity. This probably reflects the observation that post-merger adjustment relative to firm size is usually much larger in the target entity.

An important limitation of our analysis, which is inherent to many empirical studies of corporate M&A, is that we only observe completed deals. Both potential productivity gains and the tax differential affect the expected benefit from an M&A deal in terms of future profits. These factors may thus influence whether or not a deal is completed. In particular, we may be less likely to observe M&As with low productivity gains and small tax differentials because these deals lack two important sources of future benefits. Due to the large number of domestic deals, this is, however, not observed in practice. Alternatively, productivity gains and tax rates may interact in their potential to increase post-merger returns. However, they do so only with respect to the *level* of tax rates in the individual locations. An increase in production is more valuable if the resulting profit is taxed at a lower rate. However, there is no obvious interaction in this regard between productivity gains and the tax rate *difference*. Thus, even though our estimations are exposed to biases similar to those of other M&A studies, this is unlikely to drive our empirical results. In particular, the results of an event study analysis reject the presence of pre-merger trends which strengthens the causal inference from our estimations.

The findings of this paper have several important implications. First, they point to a potential advantage of tax regimes that are neutral with respect to the location of investment. These are mainly regimes with high domestic corporate tax rates that avoid international double taxation through a credit on foreign tax payments such as the United States. In contrast, systems that exempt foreign profits from domestic taxation usually imply effective international tax differences. Devereux *et al.* (2015) suggest higher tax administration costs as a potential motive for switching from a credit to an exemption regime despite the distortive impact of the latter. In the light of our findings, these benefits should, however, be carefully weighted against negative effects on the efficiency of international factor allocation.

Second, tax differentials turn out to be an additional impediment to cross-border knowledge flows that has so far been largely ignored. Given that a large fraction of conventional trade barriers has been eliminated in comprehensive bilateral and multilateral agreements, substantial differences in tax policy across countries are likely to emerge as an important obstacle to the international transmission of technology.

Finally, while the analysis of firm reactions to international tax competition has so far mostly focused on its relevance for financial accounting (see Hines Jr, 1999), our results highlight that differences in taxation are also harmful in real terms by reducing productivity growth. We show that firms make real adjustments not only with respect to the level of domestic tax rates but also with regard to the international tax system. Furthermore, in contrast to financial effects such as profit shifting for which tax competition between developed countries and so-called tax havens is an important driver, the real effect that we identify in this paper mainly refers to tax differentials between developed economies. These are more likely to be linked by real cross-border investments and are thus more exposed to the negative impact of distortive tax rate differences.

4 Thinking Outside the Box: The Cross-border Effect of Tax Cuts on R&D

4.1 Introduction

Research and development (R&D) activity is an important determinant of economic growth and technological progress. Not surprisingly, governments regularly use fiscal policy to attract R&D investment and top inventors (Akcigit *et al.*, 2016; Moretti & Wilson, 2017). With integrated economies, the implementation of such policies is likely to exert effects on other locations. The direction of these cross-border effects is of high relevance in a world where jurisdictions use tax policy to compete for internationally mobile capital and talent. If nexus is required to benefit from tax cuts such that income must be collocated with the underlying real activity, a lower average tax rate in one location draws away operations from other locations. Hence, the cross-border effect of a tax cut is negative (Barrios *et al.*, 2012). However, this is not necessarily true if income and real activity can be separated via profit shifting. For instance, it is possible to assign the generation and ownership of output from R&D to different locations via patent transfers. In this case an entity can attribute profits to a low-tax affiliate but leave the actual operations in the high-tax location. As profit shifting strategies become more sophisticated, the cross-border impact of tax policy is thus getting more complex. Despite the intuitive relevance of this issue, not much is known about the international effect of unilateral tax reductions on innovative activity in the context of profit shifting. In this paper, we close this gap by estimating the cross-border effect of tax cuts on R&D output. We explicitly account for the possibility of profit shifting.

Our focus on R&D activity allows us to base our analysis on two important features. First, the source of income and the underlying real activity are easily separated for R&D because the ownership rights of intellectual property are usually assigned via tradable patents. Thus, profit shifting is a particularly relevant phenomenon which allows us to study the cross-border effect of tax cuts in its full complexity. Second, there have been a large number of tax cuts specifically for corporate income from intangible assets at different points in time in different locations. These tax regimes are often termed "patent boxes" because they are exclusively targeted at returns to intellectual property. Patent box regimes exempt a large share of profits related to intangible assets (mainly patents)[1] from taxation and, thus, reduce the effective tax rate on these profits. Furthermore, patent boxes differ substantially in their design, in particular with regard to the extent of real activity (i.e. nexus) which is required to become eligible for the lower tax rate. This makes them an interesting policy feature for our analysis. Since the R&D activity of individual firms outside of a jurisdiction is unlikely to affect this jurisdiction's fiscal policy, these reforms can be exploited as an exogenous variation for the identification of the cross-border impact of tax cuts on R&D output.[2]

We analyze the cross-border effect of tax cuts on corporate R&D activity using a difference-in-differences design which exploits firm-level variation in the exposure to foreign patent box regimes within a multinational group. The cross-border effect is identified by estimating the response of a firm in one location to the exogenous patent box implementation in another location where one of its foreign affiliates resides.[3] Following previous studies (e.g. Blundell *et al.*, 1995; Stiebale, 2016), we measure R&D output by granted patent applications. We address the potential endogeneity of firm structure in an instrumental variable research design following the approach by Gumpert *et al.* (2016). Furthermore, we provide additional evidence for R&D inputs using confidential data on R&D expenditure for German firms. For the analysis, ownership information for more than 26,000 firms is linked to administrative data on patent applications. Cross-border links are established via multinational companies which have been identified as important transmitters of macroeconomic and policy shocks (Cravino & Levchenko, 2017). Using micro-level data also allows us to avoid problems of spatial effects that arise when using aggregated data (Montmartin & Herrera, 2015).

Importantly, in our analysis we differentiate between patent box reforms with and without nexus requirement. Patent boxes *without* nexus requirement also tax patents

[1]Some patent boxes also allow for the inclusion of trademarks or other intellectual property.
[2]We verify this by testing for common trends in our empirical analysis.
[3]See Figure C.3 in Appendix C for a graphical illustration of this concept.

at the favorable rate that have been generated elsewhere. This is usually done by including existing and acquired patents in the patent box which provides firms with the following profit shifting opportunity: They conduct R&D in the location of their choice and then transfer the resulting patent to a patent box location without nexus requirement in order to benefit from the lower tax rate there.[4] This lowers the user cost of capital for R&D activity in the group as a whole through a mechanism that is very similar to the one described in Hong & Smart (2010) for tax havens. In fact, this similarity is not surprising. Countries that implement patent boxes without nexus requirement effectively become tax havens for a particularly important asset. Below, we thus refer to these regimes as *patent havens*. Because patent havens provide an output-related tax incentive beyond the location where they are implemented, we expect them to generate a positive cross-border effect on R&D activity.

Nexus patent boxes only apply the reduced tax rate if at least part of the research activity has been carried out in the respective country (i.e. there is some nexus in this country). These regimes make it hard to separate R&D profits from underlying operations. Thus, we do not expect this incentive to raise R&D activity beyond the jurisdiction where it is implemented. The cross-border effect would be negative, if the tax cut leads to the relocation of R&D activity. One could, however, still observe some positive repercussions on domestic investment from increases in R&D activity in the foreign affiliate. A similar effect has been identified for FDI of U.S. multinationals by Desai *et al.* (2009). This is likely to mitigate or compensate a negative cross-border effect of nexus patent boxes.

Our estimation results suggest that the implementation of a foreign patent haven (no nexus requirement) raises R&D activity in the form of patent output by about 15% on average. We capture the treatment intensity by interacting the implementation indicator with the change in the tax rate difference between firm and affiliate location and find that the patent haven implementation leads to an increase of patent output by 1.1% per percentage point of change in the tax rate differential. The cross-border effect of tax cuts on R&D output is thus about one third of the effect estimated by Karkinsky & Riedel (2012) for domestic tax changes. Similar results are obtained when using confidential data on R&D expenditures of German firms. For patent boxes with nexus requirement, we find a cross-border effect that is close to zero and possibly negative. Furthermore, we find that nexus patent boxes

[4]The extent to which such a profit shifting strategy is feasible depends on the design of both the patent box regime and the tax system in the high-tax country. We discuss institutional issues in more detail below.

reduce the average patent quality in related firms abroad. The cross-border effect of nexus boxes thus occurs with respect to the intensive rather than with respect to the extensive margin of corporate R&D location decisions. This result can be explained by the spatial sorting of patents according to their profitability: Nexus patent boxes probably lead to the relocation of the most profitable patents.

These findings are robust to controlling for domestic tax-related input incentives such as super-deductions and credits. They also pertain when we adjust the patent count for heterogeneity in the patent quality. We further ensure robustness by replicating our results using different estimation methods such as propensity score matching as well as an event study design and by conducting a number of sample checks with regard to the structure and activity of the corporate group.

Our analysis expands the large literature on tax policy and R&D activity. We explore the cross-border impact of tax cuts as a novel effect of tax policy on R&D and highlight the importance of nexus conditions in these policies. Previous studies have established a link between taxation and investment in R&D (Mamuneas & Nadiri, 1996; Bloom *et al.*, 2002; Wilson, 2009), the location choice of intangible assets (Dischinger & Riedel, 2011; Karkinsky & Riedel, 2012; Griffith *et al.*, 2014) and the quality of patents (Ernst *et al.*, 2014) within the borders of a particular location. The literature on international effects of tax policy on R&D is scarce and relies on macro data. For example, Wilson (2009) uses aggregate data on R&D spending from US states to show that a large part of the increasing effect of tax credits on R&D *inputs* is due to a reallocation of research activity between states. In contrast, we study the cross-border effect of *output*-related tax incentives in the form of tax cuts for intellectual property. This allows us to directly account for the differences in nexus requirements that drive the cross-border impact of these reforms.

More generally, we contribute to the literature on the cross-border impact of taxation on economic activity which is centered around multinational firms (e.g. Dharmapala, 2008; Slemrod & Wilson, 2009; Hong & Smart, 2010; Desai *et al.*, 2006). Our results provide important insights into the role of tax policy in determining the geographical distribution of economic activity. We show that tax incentives in one location only attract real activity from another location if they are combined with an effective nexus requirement. In contrast, if tax benefits are available without nexus, tax cuts raise economic activity across borders. Such differences in the cross-border effect of tax policy are especially relevant for high-growth industries. For instance, the sustainability of nexus rules is particularly questionable in the case of highly valued R&D activity which is associated with extremely mobile intellectual property and top scientists. Moreover, the fast-growing digital economy challenges conventional concepts of the economic nexus of a taxable activity. Our results suggest that tax policy is less likely to determine the location choice of real activity for these growing sectors. However, it remains relevant for the allocation of mobile income and tax revenue.

In addition, we enrich the growing literature on patent box regimes. In this field, more normative analyses (e.g. Evers *et al.*, 2015) have recently been complemented by empirical studies (e.g. Bradley *et al.*, 2015; Koethenbuerger *et al.*, 2016; Alstadsæter *et al.*, 2018). Even though most governments claim to implement patent boxes mainly to facilitate *domestic* R&D activity, the emergence of these regimes has raised concerns. Not surprisingly, the cross-border effect that we investigate in this paper is at the heart of several of these issues. For instance, it is not certain that patent boxes actually boost new R&D projects and, thus, increase the overall level of corporate innovation. In response to the implementation of a more favorable tax regime in one location, firms could merely relocate existing research projects. Such a beggar-thy-neighbor effect is well-known for tax credits (Wilson, 2009). In addition, the economic role of patent boxes is heavily debated. In the best case, these regimes eliminate a market failure by increasing the net return of R&D to a level that better reflects its positive externalities on knowledge generation within the economy. In the worst case, patent boxes distort the location decisions of R&D investments. To the best of our knowledge, our paper is the first to empirically analyze the cross-border effect of patent boxes on R&D activity. Our results suggest that the institutional design of patent boxes is decisive for the direction and magnitude of their international impact.

The remainder of this paper is structured as follows. Section 4.2 develops a stylized theoretical framework for our analysis. We explain the empirical strategy in Section 4.3 and describe the data collection in Section 4.4. Results are presented in Section 4.5 while Section 4.6 concludes.

4.2 The Cross-border Effect of Tax Cuts

In this section we develop a stylized theoretical framework to characterize the response of a firm's R&D activity to a tax cut in one of its foreign affiliate locations (e.g. the implementation of a patent box). From this framework we derive testable hypotheses for our empirical analysis. We consider a multinational enterprise (MNE)

i that is located in country h and has an affiliate in country p. We are interested in the cross-border effect of a tax cut for patent income. Thus, our focus is on the number of successfully realized research projects (measured as patents) in h rather than the overall research activity in the MNE. The firm makes three decisions: (i) it chooses whether or not to realize projects (patents) from a given set of potential undertakings indicated by $s = 1, ..., n_i$, (ii) it decides on the location of R&D activity and (iii) it chooses the location of patent ownership. The two location decisions do not necessarily coincide and depend on the characteristics of h and p such as R&D related fixed costs and tax rates for patent income. All three choices jointly determine the number of realized research projects in h denoted by P_i.

Let us define the return to a research project s by

$$r_s = (1 - t)\, \pi_s - c \tag{4.1}$$

where $(1 - t)\, \pi_s$ is the net profit (i.e. revenue less deductible cost after taxes) and c is some non-deductible fixed cost. The effective tax rate t and the fixed cost c may differ between location h and p and are thus functions of the ownership and activity location choices of the firm. For simplicity, we normalize tax rates to be equal initially, $t_h = t_p$. The tax cut in p lowers t_p such that $t_h > t_p$. The fixed cost c comprises items that are hard to price and usually not considered as deductible expenses such as the cost of risk-taking in R&D investments in a particular location, the cost of becoming acquainted with local patenting institutions or the cost to identify suitable researchers in different regions. To simplify the derivation, we assume that firm i incurs higher fixed costs if it relocates its research activity to country p (i.e. $c_p > c_h$). Besides the specific characteristics of the fixed costs described above, this reflects potential relocation costs which include the establishment of new organizational R&D structures in p and the effort for convincing researchers to move.

The firm either co-locates or geographically separates R&D activity and ownership. There are various ways to achieve the latter, including the direct transfer of patent rights, contract R&D and cost sharing agreements between the two affiliates (Griffith *et al.*, 2014). Effectively, all of these arrangements result in part of the profit from the research project being taxed in a location different from the one where the R&D activity was carried out and, thus, have qualitatively similar consequences. The organizational form of the geographical location of patent rights is, however, an important feature for the empirical identification of the cross-border effect of tax cuts. We discuss this in more detail below.

Depending on the location choices of the firm, the profit of a research project s is given by

$$
\begin{aligned}
r_s^{h,h} &= (1 - t_h)\,\pi_s - c_h && \text{if R\&D activity and ownership in } h, \\
r_s^{h,p} &= (1 - t_h + \alpha\Delta t)\,\pi_s - c_h && \text{if R\&D activity in } h \text{ and ownership in } p, \\
r_s^{p,p} &= (1 - t_p)\,\pi_s - c_p && \text{if R\&D activity and ownership in } p
\end{aligned}
$$

where $\Delta t = t_h - t_p \geq 0$. Locating R&D activity in p and ownership in h is not optimal because $c_p > c_h$. α denotes the profit share of a research project conducted in h that is taxed at t_p as a consequence of the relocation of the ownership right to p. The parameter α captures the extent to which a reduction in the tax burden is inhibited both by regulations in location h (e.g. CFC rules or exit taxes) and in location p. Regulations in location h are likely to be orthogonal to the patent box implementation while regulations in location p are directly linked to the setup of the exploited patent box. For example, α is small if the patent box in p excludes R&D profits for projects conducted outside of p (nexus patent box). In contrast, α is close to 1 if the patent box regime in p includes existing and acquired patents (patent haven).

To compute the number of realized research projects, we assume the following sequence of decisions: The firm first decides on whether or not to realize a particular project s and then simultaneously determines where to optimally locate R&D activity and legal ownership. Solving this problem backwards, we begin with the location decision. If $\Delta t > 0$, legal ownership is assigned to p because there are no fixed costs for separating ownership and R&D activity[5] and hence $r_s^{h,h} < r_s^{h,p},\ r_s^{p,p}$. To simplify notation, we assume that the ownership rights are also assigned to p if $\Delta t = 0$. The ownership location does not affect the return of a project if tax rates are equal. R&D activity is located according to the cut-off profit

$$
\tilde{\pi} = \frac{c_p - c_h}{(1 - \alpha)\,\Delta t}
$$

[5]To make the framework more realistic, one could introduce some fixed costs to separating ownership and activity which would result in the ownership of some research projects being located in h even if $t_h > t_p$. This would make our model slightly more complicated without adding further insights with regard to the main effect of interest.

Activity for all projects with $\pi_s < \tilde{\pi}$ is located to h because in this case $r_s^{h,p} \geq r_s^{p,p}$, while R&D activity for the remaining projects (for which $r_s^{h,p} < r_s^{p,p}$) is located to p. Next, we turn to the decision of whether or not a research project is realized. Only research projects with a positive return are completed. This implies that any project s with

$$\pi_s > \tilde{\pi}^* = \frac{c_h}{1 - t_h + \alpha \Delta t}$$

is realized. We sort the gross profits of all available projects along the interval $(\underline{\pi}_i, \bar{\pi}_i)$ and define the corresponding cumulative distribution function F. Let us assume for illustrative purposes that $\tilde{\pi}^* < \tilde{\pi}$.[6] The overall number of finished projects is then given by $n_i\left(1 - F\left(\tilde{\pi}^*\right)\right)$ with $n_i\left(1 - F\left(\tilde{\pi}\right)\right)$ projects realized in p and the number of realized R&D projects of firm i in location h given by

$$P_i = n_i\left(F\left(\tilde{\pi}\right) - F\left(\tilde{\pi}^*\right)\right). \tag{4.2}$$

Note that $F\left(\tilde{\pi}\right) \to 1$ as $\Delta t \to 0$, that is, P_i converges to the overall number of realized projects as the tax differential shrinks.

How is P_i affected by a tax cut in p? Such a reform lowers t_p and, thus, increases the tax differential Δt. The change in the number of realized R&D projects in h as a result of an increase in the tax differential of $d\Delta t$ is given by

$$dP_i = n_i\left(-\left(1-\alpha\right)\frac{f\left(\tilde{\pi}\right)\left(c_p - c_h\right)}{\left(\left(1-\alpha\right)\Delta t\right)^2} + \alpha\frac{f\left(\tilde{\pi}^*\right)c_h}{\left(1 - t_h + \alpha\Delta t\right)^2}\right)d\Delta t. \tag{4.3}$$

The sign of the effect depends on how much the separation of ownership and real activity for tax purposes is inhibited by regulations. For example, if the patent box requires full nexus in location p, that is $\alpha = 0$, dP_i is negative. In this case, cross-border relocation of ownership (and, thus, profits) from h to p is not an option and the tax reduction in p does not affect the cost of capital in h. Rather, activity for sufficiently profitable projects is located to p, reducing the overall number of realized projects in h.[7] In contrast, a patent haven (no nexus requirement) has a positive

[6] Various orders of the threshold profits are possible but yield the less interesting case where all research activity is located to p irrespective of the change in the tax rate differential.

[7] Note that this does not necessarily imply that overall research activity of the multinational

effect on research output in h. Abstracting from inhibiting factors in the transferor location, we have $\alpha = 1$ in this case and, thus, $dP_i > 0$. As the firm is able to relocate the ownership of some projects realized in h to p, the tax cut there also reduces the user cost of R&D capital in h and increases research output.[8]

Finally, we observe that the average profit of realized projects in h decreases with the tax cut in p. A formal analysis of this result is presented in Appendix C.1. For nexus boxes (small α), the intuition for this result is that only R&D activity for the most profitable projects is relocated to p. This is consistent with an analysis by Haufler & Stähler (2013) who show in a tax competition model, that more profitable projects sort into low-tax jurisdictions. Empirical evidence by Becker *et al.* (2012) suggests that this effect contributes significantly to the overall tax base location effect of corporate taxes. In principal, the negative effect on average R&D quality can also occur when a patent haven is established in p because this allows R&D projects with lower profitability to be realized in h. In practice, this effect can, however, be compensated or even overturned by an increase in R&D profitability due to an agglomeration effect that is likely to be observed if patent havens generate a positive cross-border effect on R&D quantity.

Thus, the theoretical framework suggests two types of cross-border effects that are tested in the empirical analysis. First, the cross-border effect of a tax cut for patent income on the quantity of R&D output is positive if profit shifting is possible and absent or negative if profit shifting is limited. Second, we expect a negative cross-border effect of tax cuts on the quality of R&D output, especially if firms can only benefit from the tax cut if they establish sufficient nexus in the relevant patent box country.

4.3 Empirical Identification

4.3.1 Patent Output

The goal of this paper is to assess the cross-border impact of tax cuts on R&D activity. Following previous studies (e.g. Blundell *et al.*, 1995; Stiebale, 2016), R&D activity of a firm is measured by its annual registered output of granted patents.[9]

company decreases. If the tax benefits in p are large enough, the total number of patents would even increase. This occurs, however, only because the increase in research activity in p more than compensates for the decrease in h. Research activity in h always decreases.

[8] A graphical illustration of this formal analysis can be found in Appendix C.2.

[9] Granted applications are commonly used in the literature (e.g. Aghion *et al.*, 2013; Seru, 2014; Stiebale, 2016; Bena & Li, 2014) because they better capture actual research activity rather

We model the number of granted patent applications P_{ijct} in year t of firm i which is member of multinational group j and is located in country c as a function of foreign tax cuts on patent income and several control variables.

We begin our analysis using an event study design.[10] The general idea of the event study is to regress the number of patents on individual dummies indicating periods before and after the implementation of a foreign patent box. This approach is helpful in two ways. First, it allows us to verify the validity of our research design, which compares the response of firms with and without affiliates in particular countries to exogenous tax cuts in these locations, by establishing common pre-trends of R&D activity for the treatment and control firms. Second, since in an event study we observe the cross-border effect of foreign patent box implementations for individual periods, we are able to explore the dynamics of this effect. The setup of the event study closely follows Fuest *et al.* (2018) and is described in detail in Appendix C.5.

In order to estimate the average cross-border effect of a tax cut, we use a difference-in-differences strategy in a Poisson fixed effects model[11] (see Hausman *et al.*, 1984; Wooldridge, 1999; Cameron & Trivedi, 2015) of the following form:

$$\begin{aligned}
&E\left(P_{ijct}\right) = exp\left(\mathbf{x}'_{\mathbf{ijct}}\beta\right) \\
&\text{with } \mathbf{x}'_{\mathbf{ijct}}\beta = \alpha \cdot BOX_{jt}^{Haven} + \eta \cdot BOX_{jt}^{Nexus} + \boldsymbol{\beta X_{it}} + \boldsymbol{\gamma Z_{jt}} + \boldsymbol{\delta C_{ct}} + \boldsymbol{\phi_t} + \boldsymbol{\phi_i}
\end{aligned} \tag{4.4}$$

BOX_{jt}^{Haven} and BOX_{jt}^{Nexus} are binary variables that are equal to 1 if a patent box of a particular type is implemented in the country of residence of at least one of the foreign affiliates of firm i and zero otherwise. $\boldsymbol{X_{it}}$, $\boldsymbol{Z_{jt}}$ and $\boldsymbol{C_{ct}}$ are firm-, group- and location-specific characteristics. $\boldsymbol{\phi_t}$ and $\boldsymbol{\phi_i}$ capture time- and firm-specific effects. In the estimation, we differentiate between nexus patent boxes (some nexus requirement, indicated by BOX_{jt}^{Nexus}) and patent havens (no nexus requirement, indicated by BOX_{jt}^{Haven}). Patent havens are defined as patent boxes that include both acquired and existing patents and, thus, allow firms to realize tax benefits

than strategic patent filing.

[10] See Hoynes *et al.* (2011), Kline (2012) and Chetty *et al.* (2014) for recent applications of event studies in public economics. Furthermore, Alpert *et al.* (forthcoming) use an event study design in a count model that closely resembles our approach.

[11] This model is equivalent to the Poisson Pseudo Maximum Likelihood estimator proposed by Silva & Tenreyro (2006). As demonstrated by Wooldridge (1999), it is the most robust choice among nonlinear count models. To verify whether over-dispersion drives our result, we have also estimated a negative binomial regression and obtained very similar results.

through the post-generation cross-border transfer of patent rights (see Table 4.2). In contrast, the nexus patent boxes apply the favorable rate mainly to profits from R&D activity conducted in the respective location.

To identify the cross-border effect of tax cuts on a particular firm, we exploit the exogenous implementation of a patent box regime in the location of a foreign affiliate of this firm. The identification relies on the assumption that, prior to the implementation of a patent box, firms with affiliates in the implementing countries are not systematically different with respect to the evolution of their R&D activity from those that do not have affiliates in these locations. We test this assumption using the event study design. A further potential source of endogeneity is the structure of the multinational group. On the one hand, MNEs that comprise firms which expect an increase in their research activity have an incentive to set up a new affiliate in a patent box location. On the other hand, firms may establish affiliates in patent box locations once they accumulated a significant stock of patents and R&D activity subsequently slows down. There are two ways in which we account for these issues and ensure that our results are not driven by firms endogenously establishing affiliates in patent box locations: We employ an instrumental variables strategy and we conduct an additional sample check where we consider only firms with no changes in their group structure.

The instrumental variable approach follows a strategy proposed by Gumpert *et al.* (2016) to account for the potential endogeneity of firm location. In this estimation, we fix the organizational structure of each firm at the beginning of our sample period and then redefine the variables that indicate the occurrence of foreign tax cuts (e.g. BOX_{jt}^{Haven}, BOX_{jt}^{Nexus}) according to this fixed structure. We use these hypothetical realizations as instruments for the actual variables. The instruments only capture foreign tax cuts on patent income that result from the exogenous implementation of patent boxes and are unrelated to the location choice of the firm during our sample period. Such an instrumental variable strategy is valid if the initial structure of the firm is not affected by the subsequent response of innovation output to foreign tax cuts. This is a plausible assumption given that both the tax changes implemented through the patent box regimes and the success of R&D activity are highly unpredictable. In an additional robustness check, we exclude all groups that changed their structure with respect to a patent box location and reestimate our benchmark specification. In this setting, the foreign tax cuts are again the ones exclusively caused by the exogenous implementation of patent box regimes.

The macroeconomic and institutional control variables include the log of GDP per capita, GDP growth, general research activity measured by R&D expenditures as a percentage of GDP and the corporate income tax rate. One concern with regard to our analysis is that those countries without a patent box have instead turned to input-related tax incentives in order to remain competitive R&D locations. If these alternative incentives are the main drivers of the observed rise in domestic patenting activity, this would still hint to a cross-border effect of patent boxes. Instead of a direct impact on the user cost of capital, the effect would then be a result of policy interactions in a fiscal competition game. To avoid capturing such spurious effects, we include the user cost of capital for R&D in our estimation which is a composite measure that includes input-related tax incentives such as tax credits and super-deductions for R&D activity.[12] We also control for several items that have been suggested to affect R&D activity on the firm level such as the number of affiliates, the age of a firm as well as the firm size measured in total assets, the working capital and the capital intensity of a firm (see Stiebale, 2016). Finally, we include firm- and time-fixed effects to capture cross-sectional differences in the level of R&D output, as well as general time trends.

We restrict our analysis to firms located in countries without a patent box implementation during our sample period. As the focus of this study is the cross-border effect of tax cuts through patent box regimes, patent box locations must be excluded to avoid distorting effects of the implementation of domestic regimes that may or may not coincide with the implementation of patent boxes abroad. However, we verified that our results also hold when we include these locations.

The number of patents is primarily measured as the count of annual granted patents per firm. To capture the intensity of domestic R&D activity, we also conduct our analysis using the quality-weighted number of new patents. Frequently cited patents registered at multiple patent offices and classified to contribute to many patenting classes are potentially more valuable (see Harhoff *et al.*, 1999). We construct patent quality using the composite quality indicator proposed by Lanjouw & Schankerman (2004) which is commonly employed in this strand of literature (see, e.g., Hall *et al.*, 2007 and Ernst *et al.*, 2014). The composite quality indicator is derived through a multiple-indicator model relying on the number of forward citations, the patent family size and the number of patent classifications resulting in a relative measure for patent quality. The procedure to derive it is described in Appendix C.3.

[12]See Appendix C.4 for a detailed derivation.

4.3.2 Patent Quality

We also estimate the cross-border effect of a patent box implementation on the average quality of new patents to test our theoretical predictions with regard to the cross-border effect of patent boxes on the quality of R&D output. The latter is computed by dividing the quality-weighted patent count by the number of patents, $q_{ijct} = \frac{P^{qual.}_{ijct}}{P_{ijct}}$. To account for general quality shifts within the same industry as well as level differences across industries and countries, we then scale this measure by its 2-digit SIC industry, country- and year-specific mean $\bar{q}_{sct}$ and obtain $\tilde{q}_{ijct} = \frac{q_{ijct}}{\bar{q}_{sct}}$. We relate the logarithm of this relative measure to foreign patent box implementations in the following fixed effects regression:

$$\begin{aligned} \log\left(\tilde{q}_{ijct}\right) &= \iota + \alpha \cdot BOX^{Haven}_{jt} + \eta \cdot BOX^{Nexus}_{jt} \\ &\quad + \boldsymbol{\beta X_{it}} + \boldsymbol{\gamma Z_{jt}} + \boldsymbol{\delta C_{ct}} + \boldsymbol{\phi_t} + \boldsymbol{\phi_i} + \epsilon_{it} \end{aligned} \tag{4.5}$$

The specification of variables is the same as for equation (4.4).

4.4 Data

4.4.1 Patent Data

The analysis is based on a rich panel dataset built by combining multiple data sources on administrative patent data, firm information and patent box characteristics. Patent data is taken from the PATSTAT database operated by the European Patent Office (EPO). PATSTAT is a comprehensive data source covering patent data for over 80 countries in a harmonized way (Jacob, 2013). For the econometric analysis we count the number of granted patents per firm for each year.[13]

In our analysis we focus on domestically developed patents. In principal, the country of residence of the firm applying for a patent does not necessarily constitute the place of development of the patent. As is common in the literature, we identify whether or not a patent was developed at the location of the firm using address information of the inventors (Guellec & de la Potterie, 2001). A patent is classified as domestic if the majority of its inventors reside in the same country as the applicant firm.[14] We remove outliers by trimming the sample at the 99 percentile of annual

[13]Since it can take multiple years between application and approval of a patent, we account for this time lag between generating an innovation and acceptance of the patent application using the date of first patenting application instead of the patent publication date.

[14]For those patents with no inventor information provided by PATSTAT, it is assumed that the

Table 4.1: New Patents, 2000-2012

	Number of firms in sample	Number of granted patent applications	Avg. new dom. patents per firm-year	Share of firms with affiliate in patent box location	
				Patent Haven	Nexus Patent Box
AT	1,086	6,162	0.50	0.25	0.26
BG	72	175	0.23	0.11	0.08
CH	1,337	8,604	0.55	0.40	0.39
CZ	808	2559	0.27	0.12	0.11
DE	11,849	67,250	0.48	0.19	0.22
DK	561	2,135	0.36	0.25	0.30
EE	46	97	0.21	0.03	0.06
FI	591	3,457	0.51	0.29	0.32
GB	4,035	17,541	0.38	0.29	0.34
GR	15	55	0.29	0.27	0.13
HR	21	32	0.13	0.14	0.14
IS	9	17	0.16	0.06	0.18
IT	3,288	13,101	0.34	0.11	0.12
LT	21	46	0.17	0.13	0.15
LV	44	87	0.20	0.06	0.06
NO	552	1,828	0.32	0.18	0.23
PL	489	1,743	0.31	0.16	0.18
PT	135	300	0.19	0.27	0.36
RO	157	403	0.22	0.06	0.06
SE	997	5,086	0.44	0.35	0.36
SI	172	621	0.31	0.09	0.09
TR	401	1,173	0.25	0.02	0.05
Total	26,686	132,472	0.43	0.21	0.24

domestic patent output.

Table 4.1 displays descriptive statistics of the firm locations we include in our sample.[15] Research activity is particularly strong in Switzerland, Austria, Finland and Germany with average annual domestically developed patents per firm of between 0.55 and 0.48. Fewer patent applications are observed in smaller locations like Croatia and Lithuania.

patent was developed domestically. As a robustness check, it is also assumed that all patents without inventor information provided are non-domestic ones. The results still hold implying that these patents are not systematically different from those with inventor information.

[15] An overview of the sample selection process is displayed in Table C.2 in Appendix C.

As pointed out above, an institutional feature that is crucial to identify the cross-border effect of a tax cut on R&D output is the way MNEs separate patent ownership and R&D activity. Previous studies that estimate the elasticity of legal ownership of a patent in a particular jurisdiction with respect to the applicable tax rate have argued that, if the separation of R&D activity and ownership occurs, this is done mainly through contract R&D and cost sharing arrangements whereby the patent applicant would also be the final owner (Karkinsky & Riedel, 2012; Griffith *et al.*, 2014). In contrast, actual transfers of patents via intra-company sales are less attractive because of their adverse tax effects. This assumption appears sensible given that these studies cover periods when many countries applied CFC rules that should substantially diminish potential tax benefits of cross-border patent transfers.[16] Under these circumstances, contract R&D or cost sharing are probably more attractive modes of cross-border ownership allocations.

However, in its seminal 2006 Cadbury-Schweppes ruling the European Court of Justice (ECJ) has effectively limited the applicability of CFC rules and the majority of countries has amended their regimes (Bräutigam *et al.*, 2017). Further ECJ rulings have mitigated the threat of exit taxes on the capital gains realized in these cross-border transfers.[17] In fact, a recent anonymized survey conducted by Heckemeyer *et al.* (2015) reveals that MNEs consider the selling of patents to foreign affiliates a feasible way to transfer ownership rights across borders.[18] A possible reason for this observation is that it is particularly difficult for tax authorities to examine the true value of recently granted patents with no revenues attached which makes it easy to set transfer prices in such a way that MNEs can realize tax benefits from cross-border transfers. At the same time, direct patent transfers avoid communication costs and uncertainty arising from cost sharing or contract R&D arrangements. Furthermore, many input-related incentives for R&D (e.g. direct subsidies, tax credits) usually do not apply to contract arrangements.

In line with Dischinger & Riedel (2011), we conclude that the post-generation transfer of intangible assets such as patents is a viable mode of ownership relocation

[16] Griffith *et al.* (2014) study patent applications from 1985 to 2005, Karkinsky & Riedel (2012) observe annual patent applications of European firms from 1995 to 2003. According to Bräutigam *et al.* (2017), Germany, Denmark, Finland, France, the United Kingdom, Hungary, Norway, Portugal and Sweden had CFC rules with respect to other European countries in 2003.

[17] E.g. National Grid Indus BV v Inspecteur van de Belastingdienst Rijnmond C-371/10 (NGI) and C-657/13 Verder LabTec GmbH & Co. KG v Finanzamt Hilden

[18] The survey also finds that cost sharing agreements are much less important, which probably reflects that they are primarily a phenomenon in MNEs with US parents due to institutional reasons (Dischinger & Riedel, 2011).

for tax purposes. Recent findings suggest that such transfers are a relevant phenomenon. For instance, Gaessler *et al.* (2017) estimate that the implementation of patent boxes in the recipient country that include acquired and existing patents (i.e. no nexus requirement) significantly increases the number of annual bilateral patent transfers. It follows that it is feasible to identify the cross-border effect of patent boxes using patent application data. We further ascertain that the initial applicant is likely to be the entity that was actively involved in the research project by using information on inventor residence to isolate patents for which the underlying R&D activity has been conducted elsewhere. If anything, the measurement error induced by R&D contract arrangements would exert a downward bias on our estimates of the cross-border effect. While the patent box implementation in one affiliate actually raises R&D output in another non-patent box affiliate of an MNE, this would in some cases not be observed in the patent application data since the final applicant would be the patent box affiliate as the internal buyer of R&D services. Our estimate would then have to be interpreted as a lower bound of the true effect.

4.4.2 Tax Cuts for Income from Intellectual Property

Before testing the empirical relevance of our analytical results, it is useful to describe the patent boxes that exist in practice. Evers *et al.* (2015) and Alstadsæter *et al.* (2018) provide a comprehensive overview of the various regimes that have been established since 2000. In Table 4.2, we summarize key elements of existing patent box regimes in our sample. In general, firms enjoy substantial reductions in effective tax payments when opting for these regimes but significant differences remain. Patent boxes differ in the treatment of expenses as well as in the types of intangible assets they are applied to beyond patents (e.g. trademarks, brands). The magnitude of the tax exemption varies significantly across locations. For instance, while the tax rate on profits from patents is reduced by 35 percentage points in Cyprus, firms enjoy only a 50% exemption in Portugal which implies a decrease in the statutory tax rate of 11.25 percentage points.

For the cross-border effect of a patent box, it is relevant whether or not the regime has a nexus requirement. In the sense of our analytical framework, a nexus requirement is a regulation that restricts the lower tax rate to income from patents for which the underlying R&D activity has also been carried out in the respective country. This is done by either excluding previously existing or acquired patents from the benefits of the lower patent box tax rate (Spain, Portugal) or by requiring acquired

Table 4.2: Patent Box Regimes in European countries

Country	Year of implementation	Corporate income tax rate (2015)	Patent box tax rate (2015)	Acquired Patents	Existing Patents
France	2000	34.0	16.8	Yes	Yes
Hungary	2003	19.0	9.5	Yes	Yes
Netherlands	2007	25.0	5.0	No	No
Spain	2008	30.0	12.0	No	Yes
Belgium	2008	34.0	6.8	No	No
Luxembourg	2008	29.2	5.8	No	No
Malta	2010	35.0	0.0	Yes	Yes
Cyprus	2012	10.0	2.5	Yes	Yes
United Kingdom	2013	20.0	12.0	No	Yes
Portugal	2014	22.5	11.3	No	No
Italy	2015	31.4	22.0	No	No
Turkey	2015	20.0	10.0	No	No
Ireland	2016	12.5	6.3	No	No

Source: IBFD; Alstadsæter *et al.* (2018); Evers *et al.* (2015). Note: Ireland initially introduced a patent box regime in 1973 but abolished it in 2010. It was reintroduced in 2016.

patents to either have been further developed to a substantial degree at the patent box location (Belgium, Ireland[19], Netherlands, United Kingdom) or to have been purchased from a non-related entity (Luxembourg). Effectively, all of these patent boxes require that a substantial part of the research activity must be conducted in the respective country for the lower patent box rate to apply. As a consequence, profit shifting opportunities are limited and these regimes are thus unlikely to generate a positive cross-border effect on R&D activity.

Several patent box regimes include acquired and existing patents (France, Hungary, Malta, Cyprus) without effective restrictions.[20] Since this allows firms to conduct the actual development of the patent elsewhere and then transfer the resulting

[19] In 2008, Ireland extended the scope of its patent box to patent income resulting from R&D conducted in a EEA member state. However, the reform also imposed an upper limit of EUR 5 million for the income to which the exemption is applied. This prohibits the setup of effective profit shifting structures through holding entities.

[20] In France, the only limitation is that acquired patents must be held for at least 2 years by the acquiring company for the resulting profits to be taxed under the patent box regime.

patent right to the patent box location, these regimes correspond to the patent *havens* in the theoretical analysis.

4.4.3 Ownership and Firm Data

We obtain PATSTAT patent data through Bureau van Dijk's Orbis database. This allows us to link patents of the applying firms to the comprehensive ownership information contained in Bureau van Dijk's Amadeus database via common identifiers. The firm level databases by Bureau van Dijk are unique in two important ways. First, they provide information on the organizational structure of multinational firms around the globe. Second, they contain firm-level balance sheet data in an internationally comparable format. Both features are crucial for the analysis of the cross-border effect within MNEs and have also been exploited to identify other types of international transmissions (e.g. Cravino & Levchenko, 2017).

Using the ownership information, we are able to identify the ultimate owner for each firm in the sample. We construct multinational groups by assigning firms with a common ultimate owner to the same group. This approach is complemented using data on firm establishment and acquisitions in order to record changes in the ownership structure over time. More precisely, we check whether the firm existed throughout the whole observation period and combine the ownership information with data on mergers and acquisitions (M&A) from Bureau van Dijk's Zephyr database to capture ownership changes. In line with previous studies (e.g. Stiebale, 2016), we restrict our sample to industries where patenting is actually relevant. We include firms active in the manufacturing sector as well as several knowledge-intensive service sectors such as information technology, telecommunications, transport, or business-related services.[21] Table 4.1 provides information on the geographical distribution of firm observations over the 22 locations that remain after excluding patent box locations.

We also obtain balance sheet items as well as firm age from Amadeus. Working capital is computed by scaling the difference between current assets and current liabilities with total assets, while capital intensity is defined as the ratio of tangible fixed assets and sales.[22]

Macroeconomic control variables are obtained from the World Bank's World Development Indicators (WDI) and the OECD. Tax policy indicators are collected

[21] This excludes financial services. We identify relevant sectors via 2-digit NACE Rev. 2 codes and include firms with codes 10-32, 51-53, 58-63, 69-74 and 77-82.

[22] Missing entries for the necessary variables are replaced by annual industry (2-digit US SIC code) means.

from the IBFD tax database. When computing the user cost of capital, we follow Bloom *et al.* (2002) and incorporate the input incentives, the applicable tax rate and the fixed depreciation rate into a measure for the user cost of a domestic R&D investment. In order to isolate the effect of tax policy on R&D activity, we calculate the user cost with a fixed interest rate of 5%.[23]

Firm-level ownership and balance sheet information is available from 2000 onward. We analyze data until 2012 because for more recent years the patent data is not reliable. The process of granting patents usually takes several years, such that for more recent periods we do not yet observe the full amount of R&D output.[24]

4.4.4 Descriptive Statistics

Table 4.3 provides summary statistics for all variables used in the empirical analysis. As mentioned above, for the cross-border effect of patent boxes to be identified, we require firms with affiliates in patent box locations (treated) and those that do not have affiliates in these countries (non-treated) to be comparable. We thus complement the descriptive statistics with various characteristics of the two types of firms. In Table 4.4 we display the distribution across industries (NACE Rev. 2 divisions) of the two groups (Panel A) and state the within-group averages for key variables (Panel B). Treated and non-treated firms have a similar distribution across industries, with the majority of patenting firms in the manufacturing and services sectors. They differ with respect to location-specific variables such as the user cost of R&D capital, the statutory corporate income tax rate and GDP per capita. However, these differences are very small in magnitude. This implies that firms with affiliates in patent box countries are not clustered in certain locations and, therefore, our results are not driven by such a clustering. The two groups differ more substantially with respect to size (measured in total assets), age and the number of affiliates within their corporate group. Firms with foreign affiliates in patent box locations are larger, older and more often part of large multinationals. This difference in levels is not surprising since a large part of the non-treated firms operates domestically. We control for this by including the respective variables in our regression model. Furthermore, we further ensure the robustness of our results using a matching analysis.

[23]See Appendix C.4 for a detailed description of the calculation of user cost of capital.

[24]In a robustness check, we extended the sample to 2015 (see Table C.3). The results remain highly significant with coefficients of similar size.

Table 4.3: Summary Statistics

	Number of Observations	Mean	Standard Deviation	Min	Max
New patent appl.	310,852	0.426	1.114	0	10
New patent appl. (qual. adj.)	310,852	0.242	0.693	0	9.570
BOX_{Haven}	310,852	0.198	0.399	0	1
BOX_{Nexus}	310,852	0.144	0.351	0	1
Δt (Haven)	310,852	0.134	1.398	-13.1	31.20
Δt (Nexus)	310,852	0.776	3.401	-8.850	40.25
Number of affiliates	310,852	20.028	66.850	1	2,566
Log Age	303,054	2.705	1.042	0.000	6.592
Log Total Assets	310,817	9.388	2.464	-8.151	19.842
Working Capital	310,817	-6.740	1,921.617	-769,074	344,886
Log Capital Intensity	300,446	-2.690	2.189	-24.089	10.901
Corporate income tax rate	310,852	31.856	6.925	10	52
User cost of R&D capital	310,852	0.344	0.024	0.115	0.364
Real Interest Rate	301,420	0.056	0.020	-0.014	0.265
R&D expenditures (% of GDP)	308,611	2.140	0.721	0.323	3.914
Log GDP p.c.	310,852	10.427	0.421	7.920	11.143
GDP Growth	310,852	1.455	2.655	-14.814	11.902

4.5 Results

4.5.1 R&D Quantity

In a first step, we present results from an event study design. Figure 4.1 plots the results of the event-study analysis for the implementation of patent havens and nexus boxes separately.[25] The effect is normalized to zero in the year before the patent box implementation and the coefficients have to be interpreted as the cross-border effect of a patent box on patent output relative to the year prior to the reform. Here, we present the benchmark results using a Poisson count model and report very similar results for a linear model in the Appendix. For foreign tax cuts that allow for profit shifting (patent havens), we observe a positive cross-border effect on patent income. It is strongest in year two after the reform with a significant increase of about 21.2% relative to the pre-reform. In contrast, the impact of tax cuts that require real activity in the relevant location for a firm to become eligible to the lower tax rate (nexus patent box) is initially negative. However, this trend reverses in later

[25] Although both effects are estimated jointly.

Table 4.4: Treated vs. Non-treated Firms

Panel A: Distribution Across Industries (Share of firms in industry)

	Manufacturing	Transportation and Storage	Information & Communication	Professional, Scientific & Technical Activities	Administrative & Support Service Activities
Treated	0.7255	0.0042	0.0403	0.2023	0.0277
Non-treated	0.7622	0.0052	0.0486	0.1498	0.0342

Panel B: Means of Key Variables

	User Cost of R&D Capital	CIT	Log GDP per Capita	Total Assets (th. USD)	Age	No. of Affiliates
Treated	0.337	31.523	10.447	160,967.3	24.333	36.160
Non-treated	0.352	32.212	10.406	120,298.9	22.949	2.740
Difference	0.015	0.689	-0.040	-40,668.4	-1.384	-33.421
	(0.000)	(0.025)	(0.002)	(1403.082)	(0.096)	(0.232)

This table reports summary statistics for treated and non-treated firms. Treated firms are all firms that have an affiliate in a patent box country during the sample period. Non-treated firms are all other firms. The third line in Panel B reports the difference in means for the indicated variables, standard deviations are reported in parentheses.

periods and is close to zero in period five.

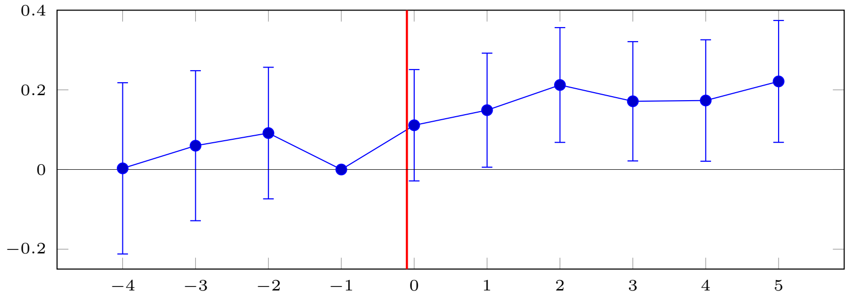
Interestingly, neither the cross-border effect of nexus patent boxes nor the one of a patent haven implementation materializes immediately. Rather, the response is significantly pronounced only about two years after the foreign tax cut became effective. This is consistent with the observation that it takes some time for R&D activity to result in patent applications. Furthermore, we note that pre-trends are flat which implies that our difference-in-differences design is a valid approach.[26] Thus, our econometric approach identifies the cross-border effect of patent boxes correctly if it exists.

Having established the validity of our research design, we turn to the benchmark difference-in-differences setup to estimate the average cross-border effect of tax cuts on R&D activity. Table 4.5 contains the main estimation results. Heteroscedasticity robust standard errors adjusted for firm clusters are presented in parentheses.[27]

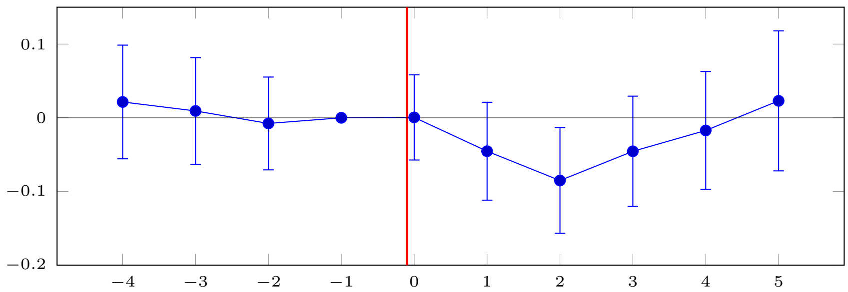
[26] More precisely, we cannot reject the hypothesis of common trends, that is, all coefficients of the pre-implementation periods are jointly equal to zero (χ^2-test statistic 2.99 for patent havens, 1.10 for nexus boxes).

[27] We also ran the regression with standard errors clustered in the group level and found the results to be robust to this adjustment. However, clustering on a level that nests the firm-fixed effects is computationally demanding and the model did not converge when we included the full set

Figure 4.1: Event-study Design



(a) Patent Havens



(b) Nexus Boxes

This figure plots the event study estimates and corresponding 95% confidence bands. The model specification is explained in Appendix C.5. The plotted coefficients correspond to $\alpha_n, n \in [-4, 5]$. Standard errors are clustered at the firm level. The event variables are indicators for the implementation of a patent haven or a nexus patent box in a foreign affiliate location of the firm.

In column (1), the cross-border effect of patent havens is captured by a dummy BOX_{Haven} that indicates a relevant patent box implementation in the residence country of a foreign affiliate of a firm. We estimate a positive cross-border effect for patent havens. The foreign tax cut for patent income leads to a significant increase of domestic patenting activity by 14 log points. This translates into a rise of annual patent output by approximately 15%.

We are also interested in the cross-border effect of nexus patent boxes on R&D activity. In columns (2) of Table 4.5 we present results of an estimation that relates the patent count to a dummy BOX_{Nexus} that switches to one when the residence country of one of the foreign affiliates of the firm implements a patent box with nexus requirement. The coefficient of interest is insignificant and very small. Thus, we cannot identify a significantly positive cross-border effect for nexus patent boxes. This is consistent with the notion that tax cuts for patent income only reduce the user cost of R&D capital in other countries if they do not inhibit profit shifting (e.g. by requiring nexus). We note from the results of the event study design, that

of controls.

Table 4.5: Benchmark

Estimation of a Poisson fixed effects model except for columns (9) to (12) where a linear fixed effects model is estimated using an inverse hyperbolic sine transformation. The dependent variable is the (quality-weighted) number of new domestic patents per year and firm. Columns (11) and (12) report results for an instrumental variable regression. Kleibergen-Paap rk Wald F-statistics for exclusion of the instruments in the first-stage are reported. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	No. of new Patents						No. of New Patents (quality-weighted)		No. of New Patents OLS		No. of New Patents IV	
BOX_{Haven}	0.140***		0.140***				0.165***		0.042***		0.069*	
	(0.054)		(0.054)				(0.058)		(0.016)		(0.039)	
BOX_{Nexus}		0.005	0.003				-0.022		-0.018**		-0.019**	
		(0.024)	(0.024)				(0.025)		(0.007)		(0.009)	
$BOX_{Haven} \times \Delta t$				0.011***		0.011***		0.012**		0.003**		0.007*
				(0.004)		(0.004)		(0.005)		(0.001)		(0.004)
$BOX_{Nexus} \times \Delta t$					-0.002	-0.002		-0.004*		-0.002***		-0.002**
					(0.002)	(0.002)		(0.002)		(0.001)		(0.001)
R&D Exp.	0.366***	0.368***	0.366***	0.368***	0.367***	0.366***	0.450***	0.446***	0.080***	0.079***	0.075***	0.073***
	(0.058)	(0.058)	(0.058)	(0.058)	(0.058)	(0.058)	(0.063)	(0.063)	(0.011)	(0.011)	(0.011)	(0.011)
Log GDP p.c.	-0.581***	-0.578***	-0.581***	-0.580***	-0.579***	-0.581***	0.517**	0.513**	-0.155***	-0.155***	-0.183***	-0.184***
	(0.208)	(0.208)	(0.208)	(0.208)	(0.208)	(0.208)	(0.218)	(0.218)	(0.033)	(0.033)	(0.033)	(0.033)
CIT	-0.000	-0.000	-0.000	-0.000	0.000	0.000	-0.003	-0.003	-0.000	-0.000	0.000	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.000)	(0.000)	(0.001)	(0.001)
GDP Growth	-0.001	-0.001	-0.002	-0.001	-0.001	-0.001	-0.012**	-0.012**	-0.000	-0.000	-0.001	-0.001
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.001)	(0.001)	(0.001)	(0.001)
User Cost of R&D	-4.608***	-4.618***	-4.613***	-4.596***	-4.589***	-4.574***	-3.282***	-3.257***	-0.900***	-0.903***	-0.950***	-0.948***
	(0.505)	(0.505)	(0.505)	(0.504)	(0.504)	(0.504)	(0.538)	(0.538)	(0.077)	(0.077)	(0.078)	(0.078)
Real Interest Rate	-1.149**	-1.146**	-1.150**	-1.146**	-1.144**	-1.145**	-1.524***	-1.525***	-0.220***	-0.222***	-0.230***	-0.233***
	(0.459)	(0.459)	(0.459)	(0.459)	(0.459)	(0.459)	(0.474)	(0.473)	(0.081)	(0.081)	(0.081)	(0.081)
No. of affiliates	0.060**	0.077***	0.060**	0.062**	0.082***	0.066**	0.038	0.048	0.016**	0.018**	0.006	0.006
	(0.029)	(0.028)	(0.030)	(0.030)	(0.028)	(0.029)	(0.032)	(0.032)	(0.007)	(0.007)	(0.009)	(0.009)
Log Age	0.074***	0.074***	0.074***	0.074***	0.073***	0.073***	0.069***	0.069***	0.019***	0.020***	0.017***	0.017***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.021)	(0.021)	(0.004)	(0.004)	(0.004)	(0.004)
Log Total Assets	0.045***	0.045***	0.045***	0.045***	0.045***	0.045***	0.034***	0.034***	0.007***	0.007***	0.006***	0.006***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.001)	(0.001)	(0.001)	(0.001)
Working Capital	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.016***	0.016***	0.016***	0.016***	0.016***	0.017***	0.015***	0.016***	0.002***	0.002***	0.002***	0.002***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.001)	(0.001)	(0.001)	(0.001)
N	276,048	276,048	276,048	276,048	276,048	276,048	268,427	268,427	315,532	315,532	297,480	297,480
No. of firms	24,346	24,346	24,346	24,346	24,346	24,346	23,642	23,642	29,666	29,666	28,915	28,915
Pseudo LL	-154,176	-154,184	-154,176	-154,178	-154,183	-154,176	-93,473	-93,472	-171,683	-171,686	-158,221	-158,234
F-statistics	–	–	–	–	–	–	–	–	–	–	988.752	291.046

the cross-border impact of nexus patent boxes is initially negative. This probably reflects that, consistent with the theoretical prediction, some research projects are relocated away from the observed firm to the corresponding patent box location to satisfy the nexus requirement and benefit from the tax cut. However, we also observe a reversal of this trend in later periods leading to an insignificant cross-border effect of nexus patent boxes in the long-run. We attribute this to positive repercussions on domestic investment from increased activity in the foreign affiliate. This is consistent with previous studies that have found positive effects of FDI on domestic activity (e.g. Desai *et al.*, 2009).

In column (3) we include both implementation dummies BOX_{Haven} and BOX_{Nexus} into one regression. Again, we estimate a significantly positive coefficient for BOX_{Haven} which is similar to the previous results while the coefficient for BOX_{Nexus} is insignificant and small in magnitude.

Firm-level patent output is also driven by other macroeconomic factors and policies. R&D expenditures as a share of GDP increases patent output of firms. On the contrary, an increase in the financing cost measured by the real interest rate or a higher statutory corporate income tax rate is expected to induce a decline in innovative activity. Consistent with related studies (e.g. Bloom *et al.*, 2002; Wilson, 2009), our estimates suggest that an increase in the user cost of R&D capital leads to a decline in corporate R&D investment. The fact that the coefficient for the patent box dummy is significant despite the inclusion of the user cost of R&D capital indicates that our estimates are not the result of the fiscal competition game described above.[28] The significantly positive coefficients of total assets and the firm age indicate that, consistent with previous findings, larger and also older firms conduct more R&D.

In columns (4) to (6) of Table 4.5 we account for treatment intensity, that is, we allow patent boxes with different magnitudes of tax exemption for patent income to have a different cross-border impact. Instead of an implementation dummy, we use the change in the tax rate difference between the location of the firm and the patent box country that is induced by the patent box implementation. More specifically, we take the change in the difference between the corporate income tax rate in the residence country of the firm and the applicable tax rate for patent profits in the relevant affiliate country upon implementation of the patent box and interact

[28] We also ran regressions restricting the set of control variables to macro-economic factors first and then excluding all control variables (keeping year-fixed and firm-fixed effects in both cases). The resulting coefficient estimates were qualitatively similar albeit somewhat larger in magnitude.

it with our implementation dummies, BOX_{Haven} and BOX_{Nexus}. We then repeat regressions (1) to (3) using our more sophisticated indicator. Again, the estimated coefficient of interest is significantly positive for the patent haven indicator. Our results suggest that a patent haven that increases the tax rate differential by 1 percentage point raises the number of patents by 1.1%. This cross-border effect of taxation on patent output is thus about one third of the effect estimated by Karkinsky & Riedel (2012) for domestic tax changes.[29] The coefficient for the nexus box indicator is insignificant and small.

In the next step, we account for the fact that patents vary strongly with regard to their quality, usefulness and applicability (see Hall *et al.*, 2010) and repeat our analysis using the quality-weighted patent count as dependent variable. Columns (7) and (8) of Table 4.5 present the results from replicating regressions (3) and (6) with this alternative dependent variable. Throughout the specifications, the coefficients of the patent haven implementation dummy as well as the one for the more sophisticated measure of the corresponding patent-box-induced tax difference remain significantly positive. We note that the coefficients for the nexus box indicator is slightly negative and marginally significant when interacted with the reduction in the tax rate differential. This suggests a negative cross-border effect of nexus patent boxes on R&D quality. We analyze this phenomenon in more detail below.

In addition, we check whether the direction of our estimated effect is driven by the model choice and use a linear fixed-effects model in columns (9) and (10). In this specification, the dependent variable is the inverse hyperbolic sine transformation[30] of the patent count. This transformation is often employed to account for the non-linearity of the relationship while not generating missing observations for firm-years without patent applications (e.g. Burbidge *et al.*, 1988). Again, the estimated coefficient for the patent haven indicator is significantly positive. Consistent with the notion that patent boxes with nexus requirement lead to relocations of R&D activity, we estimate a negative coefficient for the nexus patent box indicator. However, for our benchmark results we prefer to rely on the Poisson model as it correctly adjusts for the count nature of the patent data.

Finally, we employ an instrumental variable strategy to verify that our results are

[29] Karkinsky & Riedel (2012) estimate a semi-elasticity between 3.5% and 3.8%. A comparison to Griffith *et al.* (2014) is more difficult because they allow the own-region semi-elasticity of patent applications with respect to the tax rate to vary by location. The estimated own tax semi-elasticity ranges from 0.52% in Germany to 3.9% in Luxembourg.

[30] The inverse hyperbolic sine transformation of the patent count takes the following form: $\ln\left(P_{ijct} + \sqrt{P_{ijct}^2 + 1}\right)$.

Table 4.6: Patent Quality

Estimation of an OLS fixed effects model. The dependent variable is the logarithm of average patent quality per year and firm for domestic patents. The full sample is used in the regressions presented in columns (1)-(3), while the sample is restricted to firms which have patent applications before and after the implementation of a foreign patent box in regressions presented in columns (4)-(6). Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	Patent Quality					
		Full Sample			Restricted Sample	
	(1)	(2)	(3)	(4)	(5)	(6)
BOX_{Haven}	0.036		0.025	0.034		0.025
	(0.027)		(0.028)	(0.027)		(0.028)
BOX_{Nexus}		-0.038***	-0.034***		-0.034***	-0.034***
		(0.010)	(0.010)		(0.010)	(0.010)
R&D exp.	0.079***	0.080***	0.090***	0.079***	0.083***	0.090***
	(0.028)	(0.028)	(0.031)	(0.028)	(0.031)	(0.031)
Log GDP p.c.	-0.132	-0.133	-0.131	-0.123	-0.129	-0.131
	(0.091)	(0.091)	(0.099)	(0.092)	(0.099)	(0.099)
CIT	0.001	0.001	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDP Growth	0.001	0.001	-0.001	0.001	-0.001	-0.001
	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)
User Cost of R&D	-1.240***	-1.179***	-0.408	-1.242***	-0.401	-0.408
	(0.278)	(0.279)	(0.344)	(0.281)	(0.340)	(0.344)
Real Interest Rate	-0.494*	-0.482*	-0.281	-0.512*	-0.284	-0.281
	(0.265)	(0.265)	(0.293)	(0.269)	(0.288)	(0.293)
Log no. of affiliates	-0.030**	-0.019	-0.025*	-0.028**	-0.023*	-0.025*
	(0.012)	(0.012)	(0.013)	(0.012)	(0.012)	(0.013)
Log Age	-0.004	-0.005	-0.010	-0.004	-0.010	-0.010
	(0.011)	(0.011)	(0.012)	(0.011)	(0.012)	(0.012)
Log Total Assets	-0.024***	-0.023***	-0.025***	-0.024***	-0.024***	-0.025***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)
Working Capital	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.001	0.001	-0.001	0.000	-0.000	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
N	62,323	62,323	47,151	61,131	47,786	47,151
No. of firms	23,840	23,840	16,160	23,294	16,369	16,160
R^2	0.014	0.014	0.014	0.014	0.014	0.014

not driven by firms endogenously establishing affiliates in patent box locations. In this specification, the actual realizations of foreign tax cuts are instrumented by the hypothetical realization that we obtain when fixing the firm structure in 2000. To ensure exogeneity of the instrument we begin our estimation in 2001. Results are presented in columns (11) and (12). The size of the F-test statistic for the exclusion of the instruments in the first-stage regression is large which indicates that our instrumental variable strategy is a valid approach. Again, we find a positive cross-border effect of tax cuts if profit shifting is possible while tax cuts that require nexus exhibit negative cross-border effects. Comparing the coefficients obtained from the instrumental variable specification to the results of the linear model in columns (9) and (10), we observe that the estimated cross-border effect is slightly larger for patent havens and very similar for nexus patent boxes. This points to a slight underestimation in our benchmark model due to endogenous location choices of the treated firms. Our benchmark results can thus be interpreted as lower bounds of the actual effect.

4.5.2 R&D Quality

In Table 4.6, we present estimates of the cross-border effect of a patent box implementation on the average quality of patents. Column (1) contains the regression result relying on a dummy indicating that one of the affiliate countries of a firm turned into a patent haven as well as the set of control variables and fixed effects described above. We find no significant cross-border effects of this type of patent box on average R&D quality. In contrast, we find significantly negative cross-border effects for nexus patent boxes in column (2). Having an affiliate in a country with a nexus patent box significantly reduces the average quality of domestic patents. We estimate similar coefficients when including both dummies in the regression presented in column (3). Taking into account our results for the cross-border effects on the number of patents (i.e. R&D quantity), this implies that cross-border effects of nexus boxes occur with respect to the intensive rather than with respect to the extensive margin of corporate R&D location decisions.

We are only able to compute the average quality of patents for firm-year observations where the firm successfully applied for a patent. In order to not distort our estimation by potentially confounding effects of the R&D quantity decision of a firm, we restrict the sample to firms that apply for patents before and after a foreign patent box was implemented. Regression results are presented in columns (3) to (6) where we obtain similar results as in the benchmark analysis.

While it is possible in theory, that both patent havens and nexus patent boxes generate negative cross-border effects on patent quality, these effects are in practice only observed for nexus boxes. If a sufficiently large number of high-quality R&D projects is available, a decrease in the user cost of R&D does not necessarily lead to a significant decrease in R&D quality. One reason for this is that the increase in R&D quantity that results from the positive cross-border effect of patent havens is likely to lead to agglomeration effects which increase R&D quality rather than decreasing it. This compensates negative cross-border effects on the quality of R&D projects chosen for realization. In contrast, nexus patent boxes directly affect R&D related decisions of the firm on the intensive margin by providing an incentive to relocate profitable R&D projects. This observation is consistent with previous findings by Ernst *et al.* (2014).

4.5.3 Further Robustness Checks

The validity of our results is reassured when exposing them to various robustness checks. We discuss the three most important tests here and relegate the corresponding results to the Appendix. First, one concern is that the firms in our sample are not sufficiently comparable since we include both domestic and multinational firms. We verify that this is not the case by re-estimating our benchmark results with a sample restricted to MNEs. Results are presented in Table C.4. Reassuringly, the coefficient estimates are similar to those in our benchmark regression.

Second, the structure of an MNE may be affected by the implementation of patent box regimes which may induce an endogeneity bias to our results. For instance, if firms can foresee increases in patent output and are more likely to establish an affiliate in a patent box location if they expect such an increase, our coefficient estimate for the foreign patent box indicators in the benchmark regression would be upward biased due to reverse causality. We check empirically whether this is an issue in our data by reestimating the benchmark regressions using a restricted sample. In this specification we exclude all multinational groups that had an ownership change with respect to a patent box location after the relevant regime had been implemented there. For this specification, the foreign patent box implementation is exogenous as long as the level of patent output in particular firms does not affect the implementation of such a reform in another country. If there was an upward bias, we would expect to estimate a smaller coefficient for the patent box indicators than we do in the benchmark estimation presented in Table 4.5. However, this is not the case. The coefficient estimate, which is presented in Table C.6, is larger rather than smaller when we use the restricted sample. From this we infer that our estimation does not suffer from an endogeneity bias that would drive estimates upwards. If anything, our estimates are biased downwards. In principal, a downward bias in the benchmark sample is possible, e.g. firms may first pile up their patent stock and then acquire a firm in a patent box location to shift the property rights and benefit from the lower tax rate but at the same time do not further accelerate R&D activity. The results in Table C.6 are also likely to reflect that by excluding firms with ownership structure changes, we exclude many large MNEs from the sample. Since these firms often have additional opportunities to shift profits and lower their effective tax burden (e.g. through tax havens), they react much less to foreign patent box implementations. Thus, we obtain a smaller coefficient in the benchmark estimate that includes these firms.

Third, the differences in average assets, age and group size between treated and untreated firms (see Table 4.4) could be indicators for endogenous sorting causing a self-selection bias (Wooldridge, 2010). For example, a member of a large group is more likely to be assigned to the treatment group because of having more foreign affiliates and, thus, having a higher probability that one of these foreign affiliates obtains access to a patent box. However, if affiliates of large groups exhibit a different evolution of patent output during the sample period, comparability of treatment and control group is limited. To verify the preclusion of such a selection bias, we reestimate our benchmark model using propensity score matching to account for structural differences between treatment and control group. More precisely, we employ nearest neighbor matching on initial firm characteristics in 2000, the first year of our sample period, to find for each firm of the treatment group its most similar counterpart in the control group. The nearest neighbor for a firm is found by estimating a Probit model for being in the treatment group. This is conducted by regressing a dummy for having access to a foreign patent box at some time during our sample period on our usual firm- and group-specific characteristics. Based on this Probit regression result, a propensity score is calculated for each firm. The propensity score statistic enables comparisons in terms of similarity of firms. Single nearest neighbor matching is then conducted by assigning each firm of the treatment group to the firm in the control group with the most similar propensity score. Our benchmark regression results in Table 4.5 are then reestimated on the sub-sample of treatment group firms and firms of the control group which are most similar to the treatment group. The estimated average treatment effect on the treated (ATT) in various specifications as reported in Table C.8 is similar to our benchmark regression results. Therefore, we rule out endogenous sorting of firms into the treatment group.

Further untabulated robustness checks include re-estimations of the benchmark model including industry-specific and location-specific time trends as well as separate time trends for MNEs and domestic firms. We obtain virtually the same results in all specifications.

4.5.4 Additional Analysis

In this section, we consider several extensions to our benchmark analysis. First, we examine heterogeneity across industry sectors to further verify the plausibility of our results. Second, we compute the elasticity of R&D output to various measures of the effective tax burden within company groups. This exercise highlights more general aspects of our results. Finally, we complement our analysis of patent output using additional information on R&D expenditures of German firms to check whether the impact of the foreign, output-related tax incentives we study is also reflected in domestic R&D spending.

Industry Heterogeneity

Previous studies have shown that the responsiveness of corporate R&D activity to domestic tax incentives varies across industry sectors (Griffith *et al.*, 2014). This is likely to be the case for cross-border effects of taxation as well. Moreover, firms in different industries probably react differently to foreign patent boxes with and without nexus requirement. To explore these heterogeneities, we focus specifically on two sectors with different types of R&D activity: the Information and Communications Technology (ICT) sector and the manufacturing sector. The ICT sector is characterized by low relocation costs, in particular for software development which, for instance, does not require specific hardware. In contrast, R&D activity in the manufacturing sector, which includes large pharmaceutical and chemical companies, is usually concentrated in one place and not easily relocated to another country because of the immobility of invested R&D capital. Researchers in this sector are often highly specialized and not easily replaceable at a new location while laboratories are hard to move across long distances.

In Table C.5 in the Appendix, we analyze how firms in these two sectors respond to foreign tax incentives. Columns (1) to (4) report the results for the sub-sample of ICT firms. We find a significantly negative cross-border effect of nexus patent boxes on patent output. This is consistent with the notion that these tax regimes generally incentivize firms to relocate R&D activity away from locations with relatively higher taxation of patent income. ICT firms are more responsive to this incentive than the overall sample because the relocation cost for R&D in this sector is lower. We do not find a significant cross-border response to the implementation of patent havens. While the ICT sector experiences strong growth in patenting (e.g. Fink *et al.*, 2016), these patents are also more likely to be held together in one location as this strengthens the position of the owner in patent litigation that frequently occurs in this sector.[31] This inhibits the relocation of patents for profit shifting and, thus, also mitigates the response to foreign tax cuts on patent income without nexus

[31] These cases regularly result in so-called "patent wars" with large costs. For instance, in a recent case Samsung was ordered to pay US$ 120 million to Apple for patent infringements in October 2016. This case had been open since 2012.

requirements (i.e. patent havens).

Results for manufacturing firms are reported in columns (5) to (8) of Table C.5. We find no significant response to foreign nexus patent boxes which is consistent with the observation that the cost to relocate R&D activity is relatively high in this sector and firms are thus less reactive to foreign tax cuts that incentivize the relocation of R&D. However, innovation in the manufacturing sector usually occurs in the form of well-specified technologies and is easily patented. The ownership rights can then be transferred to other locations to benefit from tax cuts that do not require nexus (i.e. patent havens). This explains the significantly positive coefficient for foreign patent haven indicators.

The Effective Tax Burden of R&D

We now turn to implications of our findings for the measurement of the tax burden on corporate R&D investment in the presence of cross-border effects of tax cuts. An important issue raised by the literature on tax havens and investment of MNEs (e.g. Hong & Smart, 2010) is that the domestic tax rate of a jurisdiction is not very informative with respect to the tax environment faced by such firms for investing in this jurisdiction. Since internationally operating firms are able to shift part of their profit from one location to another, their effective tax burden in one location is likely to depend on the applicable tax rates in the whole group. With sufficiently low costs of profit shifting (e.g. when locating intellectual property rights to patent havens), it is the location with the lowest tax rate in the group that determines the effective tax burden of its members.

We test this notion by replacing the main variable of interest BOX in equation (4.4) by several measures for the effective tax rate for profits faced by a firm. We are interested in how R&D activity reacts to each of these measures. They include the statutory corporate income tax rate and the minimum tax rate on patent profits within the whole group. For the latter, we again distinguish between nexus patent boxes and patent havens. Effectively, we extend our analysis beyond the particular incidence of a foreign patent box implementation and exploit the full variance of tax rates on patent profits in a multinational group to identify cross-border effects on patent output.

Following Hong & Smart (2010) and Slemrod & Wilson (2009), the statutory tax rate should be most relevant for firms without foreign affiliates. If we take into account tax rate reductions of patent boxes without nexus requirement (patent havens), the minimum tax rate within a group should be more informative for the whole sample. Table 4.7 displays the results of this exercise. In column (1), the vari-

Table 4.7: R&D Activity and Corporate Taxation

Estimation of a Poisson fixed effects model. The dependent variable is the number of new domestic patents per year and firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects and the firm-, location- and group-specific controls of the benchmark model (results are reported in Table C.7). Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	No. of New Patents			
	(1) Full Sample	(2) Domestic Firms	(3) Full Sample	(4) Full Sample
CIT	-0.000 (0.002)	-0.007** (0.003)		
Minimum Tax Rate (Patent Havens)			-0.003** (0.002)	
Minimum Tax Rate (Nexus Boxes)				-0.001 (0.001)
N	276,048	179,162	276,048	276,048
No. of firms	24,346	16,202	24,346	24,346
Pseudo LL	-154,184	-81,597	-154,180	-154,183

able of interest is the statutory corporate income tax rate. The respective coefficient is negative but small and insignificant. This implies that the statutory tax rate is not very informative with respect to the tax environment of a firm in our sample that also includes large MNEs. In column (2), we restrict the sample to firms without foreign affiliates. The coefficient for the statutory corporate income tax rate is now larger and significantly negative. Our results suggest that for domestically operating firms a one percentage point decrease in the corporate income tax rate would raise R&D activity by about 0.7%. Next, we use the minimum tax rate on patent profits within the group of affiliates of a firm as a measure of the tax burden in column (3). In doing so, we take into account tax reductions resulting from the implementation of patent havens. In contrast to the regression in column (1), the coefficient for this adjusted tax rate measure is significantly negative and implies that an effective tax rate decrease by one percentage point leads to an increase of patent output by 0.3%.

Thus, our results indicate that the effective tax burden of a firm with respect to R&D investment is better described by also taking into account tax rate changes in the whole group. The statutory corporate income tax rate is, however, informative for firms that operate in one country only. Consistent with our expectation that cross-border effects only result from the implementation of patent haven regimes that allow for profit shifting, we do not find a significant effect of the minimum group tax rate when we account for tax cuts induced by foreign nexus patent boxes. The corresponding coefficient in column (4) is negative but insignificant.

R&D Expenditures

Our analysis focuses on R&D output measured by patent applications because this captures the firm response that directly corresponds to the output-related tax incentive we study. In the following extension, we investigate how this response transmits to R&D inputs. The level of innovation in a firm is not necessarily proportional to its R&D expenditure (Hausman *et al.*, 1984). However, if the change in corporate patent output that we measure in our benchmark analysis reflects an increase in innovative activity, we are likely to observe a similar cross-border effect of tax cuts on R&D expenditure.

Table 4.8: R&D Expenditures

Estimation of a fixed effects model. The dependent variable is the logarithm of R&D expenditure in the indicated area per year and firm. In columns (1) and (4), we use the total R&D expenditure of a firm while we focus expenditure for personnel in columns (2) and (5) and on equipment expenditure in columns (3) and (6). Columns (1) to (3) use the full sample. We restrict the sample to MNEs in columns (4) to (6). Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%. Data source R&D expenditures: SV Wissenschaftsstatistik GmbH, RDC, R&D Surveys 2001-2011, own calculations.

	(1)	(2)	(3)	(4)	(5)	(6)
	R&D Expenditures (all firms)			R&D Expenditures (MNE only)		
	Total	Personnel	Equipment	Total	Personnel	Equipment
BOX_{Haven}	0.184*	0.173**	0.144	0.213**	0.186*	0.245*
	(0.096)	(0.086)	(0.158)	(0.107)	(0.104)	(0.149)
BOX_{Nexus}	0.031	-0.001	0.082	0.020	0.021	0.064
	(0.036)	(0.043)	(0.055)	(0.040)	(0.052)	(0.064)
No. of affiliates	0.043	0.078*	0.054	0.086	0.163	0.103
	(0.038)	(0.041)	(0.056)	(0.099)	(0.102)	(0.134)
Log Age	0.0304	0.057	-0.020	-0.010	0.051	-0.023
	(0.047)	(0.055)	(0.078)	(0.061)	(0.075)	(0.105)
Log Total Assets	0.024***	0.027**	0.015	0.029*	0.036	0.025
	(0.009)	(0.013)	(0.016)	(0.017)	(0.031)	(0.034)
Working Capital	0.002	0.004	0.000	-0.003	-0.009	0.049
	(0.005)	(0.011)	(0.008)	(0.043)	(0.065)	(0.067)
Log Capital Intensity	0.015	0.027*	0.037**	0.025*	0.076*	0.095**
	(0.008)	(0.015)	(0.016)	(0.015)	(0.045)	(0.045)
N	13,006	13,006	13,006	6,156	6,156	6,156
No. of firms	3,762	3,762	3,762	1,712	1,712	1,712
R^2	0.034	0.035	0.008	0.042	0.040	0.017

Unfortunately, detailed information on R&D inputs is scarce. Firms are usually not required to report them and are generally reluctant to publish related data because of the strategic information contained in these figures. In the following analysis we use confidential survey data for German firms.[32] The data is collected on a biannual basis and feeds into the Eurostat database on corporate R&D. In this confidential database, total annual R&D expenditures together with R&D expenditure for R&D personnel and R&D equipment of German firms are reported. The identifier used by the Stifterverband is identical to the one in the Bureau van Dijk databases such that we can directly link our ownership and tax policy information as well as the relevant balance sheet items to the R&D expenditure data. In total, we obtain R&D expen-

[32] We use the R&D survey of the Wissenschaftsstatistik of the Stifterverband.

diture information from 2001 to 2011 on a biannual basis for 3,762 German firms of our main sample (13,006 firm-year observations). Aligning the R&D expenditure information with the benchmark estimation sample ensures consistency across data sets. Furthermore, we focus on firms that file patent applications throughout the sample period such that the R&D expenditure we observe is closely linked to the firm's innovative output which the foreign tax cuts relate to. Descriptive statistics for the R&D expenditures are reported in Table C.9 in the Appendix.

We estimate a linear model that follows the specification defined in equation (4.4) but replace the patent count with the logarithm of firm-level R&D expenditure.[33] Results are presented in Table 4.8. In column (1), we use total R&D expenditures as the dependent variable. We obtain a significantly positive coefficient for the patent haven indicator which suggests a positive cross-border effect on R&D inputs of a tax cut that allows for profit shifting. This is consistent with our benchmark findings for R&D output. According to our estimates, the patent haven implementation in a foreign affiliate of a German firm increases its overall R&D expenditure by about 18.4%. We find no cross-border effect for nexus patent boxes and attribute this result to the fact that in order to benefit from this type of foreign tax cut the firm is required to relocate R&D activity. This is costly in practice and, thus, rarely observed. In a next step, we disaggregate R&D expenditure into expenditure for personnel and expenditure for equipment and report results separately in columns (2) and (3). We estimate a significantly positive response of personnel expenditure. In our sample of German firms, it increases by 17.3% once a foreign patent haven is implemented. We also estimate a positive response for equipment expenditure which is, however, not significant. In columns (4) to (6), we repeat a robustness check from the benchmark analysis, by excluding all domestic firms from the estimation sample. In these regressions, we thus compare MNEs with and without affiliates in patent box locations. Our results with regard to the cross-border effect of tax cuts which allow for profit shifting are robust to this restriction. If anything, the estimated effect is larger.

[33]Since the analysis is restricted to firms residing in Germany, we capture macro-economic shifts by including year-fixed effects as in the benchmark specification and drop macro-economic control variables due to collinearity.

4.6 Conclusion

In this paper, we combine information on firm ownership, administrative patent data and output-related R&D tax incentives to identify the cross-border effect of tax cuts within multinational groups. Our results indicate that, within MNEs, the patent box implementation in one location also affects R&D output at other locations of the group. It increases the research activity there by 1.1% per percentage point of change in the cross-border tax rate differential. Consistent with our theoretical analysis, we find this effect only for patent boxes *without* nexus requirement (patent havens). In contrast, patent boxes *with* nexus requirement effectively preclude tax benefits from the transfer of intangibles and, thus, do not lower the effective tax burden on R&D investment across borders. However, for these nexus patent boxes we estimate a negative cross-border effect on patent quality. This implies that the cross-border effect of nexus boxes occurs with respect to the intensive rather than with respect to the extensive margin of corporate R&D location decisions.

These results have several important implications. First, they provide empirical evidence with regard to previous theoretical analyses (e.g. Desai *et al.*, 2006; Hong & Smart, 2010), who argue that the presence of low-tax countries reduces the user cost of capital for investment in high-tax countries. It is questionable whether tax havens are beneficial from an overall welfare perspective (see Slemrod & Wilson, 2009), but our analysis shows that the proposed mechanism is a relevant phenomenon for investments in intangible assets which are particularly mobile with regard to the location of related profits.

Second, these findings inform the ongoing debate on patent boxes and tax cuts on mobile types of income in general. Some countries have argued that patent boxes are not effective in fostering domestic research activity but merely constitute an instrument for harmful tax competition. Indeed, existing empirical studies have not yet robustly identified a direct effect of patent boxes on domestic innovation. The risk that these tax regimes merely provide an opportunity for profit shifting by transferring patents is arguably high and, thus, a negative cross-border effect on tax revenue is likely. However, our results show that the possibility of profit shifting implies that the real activity underlying these profits is not necessarily relocated as well. In contrast, it may even increase because tax benefits are realized across borders. In the context of intellectual property, this means that R&D remains in the location with the relatively higher tax burden. As a consequence, this location continues to benefit from R&D industry spillovers and other effects that have been cited as positive externalities of research activity (e.g. Jones & Williams, 1998). More generally, the insight that foreign tax cuts do not necessarily draw away real activity applies to all sectors where profit generation and the underlying activity can be easily separated. For instance, profits in the fast growing digital economy are often difficult to tax.[34] At the same time, a large part of the real activity of this sector is clustered in high-tax locations such as the United States. Profit shifting allows these firms to effectively separate profits and real activity. As more firms develop sophisticated profit shifting strategies, the relevance of profit shifting for the cross-border impact on corporate activity is likely to become more relevant over time. However, we caution against interpreting our findings as a positive cross-border effect of tax cuts on welfare. A first-best solution would always be to design a tax system in which the location of both the ownership and creation of an asset are independent of corporate taxation.

We note that our empirical analysis does not address all aspects of the preceding theoretical consideration. In particular, there are two consecutive firm responses to the creation of a foreign patent haven. Companies first raise R&D output and then locate the resulting patent rights to the patent box location. In our empirical estimation we have verified the first step, which is relevant for the cross-border implications of patent boxes on real R&D activity, and have left the analysis of the second step for future research. More generally, we are interested in the impact of patent boxes on corporate innovation rather than on the resulting profit allocation. As it is the case for many corporate investment decisions, the former effect depends on the *expected* tax rate on future profits. Thus, the change of *prospective* taxation induced by the patent box, which we capture in our empirical specification, is decisive. Even though we do not identify the second step, we note that recent findings by Ciaramella (2017) and Gaessler *et al.* (2017) on patent relocation and the implementation of patent boxes strongly point to the relevance of this effect. Furthermore, we note that empirical findings of previous studies suggest that profit shifting via the transfer of patent rights is a very relevant phenomenon (see Dischinger & Riedel, 2011; Karkinsky & Riedel, 2012). In fact, a recent empirical analysis by Koethenbuerger *et al.* (2016) on the effect of patent boxes on cross-border profit shifting suggests that the introduction of these regimes leads to a substantial transfer of profits to the affiliates that are located in the implementing countries.[35] Consistent with our analysis, this

[34]For example, see the Base Erosion and Profit Shifting (BEPS) Action 1 of the OECD.
[35]On the reverse effect, Chen *et al.* (2016) show that patent boxes reduce outward profit shifting in the countries where they are implemented.

effect is confined to patent boxes without sufficient nexus requirements.

5 Fiscal Competition and Public Debt

5.1 Introduction

The recent economic and financial crisis has led to substantial increases in government debt levels in many countries, which has raised concerns about the sustainability of government finances in general and fears about default in some countries (IMF, 2015). In the short-run, governments may need to increase taxes or cut spending to counter high indebtedness. At the same time, fiscal policy also needs to stabilize output and must not become pro-cyclical. While academic research has extensively covered the effect of fiscal policy on economic stabilization and solvency (see DeLong & Summers, 2012; Auerbach & Gorodnichenko, 2012), the implications of high indebtedness for tax policy and strategic tax setting in internationally integrated capital markets have found much less attention.

In this paper, we propose a novel channel through which changes in initial debt levels, like the major pile up of debt during the recent economic and financial crisis, affect the policy and economic outcome. In particular, we show in a two-country model that in case of a binding constraint on public borrowing in one country, a rise in this country's initial debt level induces it to spend less on investment in public infrastructure and to set a lower business tax, while in the other country the opposite occurs. Thus, public policy diverges. On net, the borrowing constrained country who experiences a debt shock becomes an unambiguously less attractive location for firms.

The result is driven by a government's limited ability to shift resources across time: A higher level of legacy debt reduces *ceteris paribus* a government's spending on public goods in the present. If taking on new public debt is not constrained by possible default, the optimal policy response is to increase public borrowing to smooth consumption across periods without affecting investment in public infrastructure. However, when default on new debt is an issue, the government's second best response is to partially reduce public infrastructure spending relative to the no default case. This affects the region's attractiveness for firms in the long-run due to the durable goods nature of public infrastructure. In addition, the government responds with a cut in its business tax to partially make up for the loss in competitiveness. Conceptually, our analysis is in the spirit of Cai & Treisman (2005) who argue that asymmetries in certain jurisdictional characteristics may have a substantial effect on how these jurisdictions behave in fiscal competition and how they react to an increase in tax base mobility. In this regard, initial debt levels may constitute an important but so far largely neglected factor.

Our mechanism assumes a direct link between the choice of government borrowing and adjustment of public investment in infrastructure. One might think that the government could respond to the problem of constrained borrowing by adjusting alternative instruments, in particular taxes. We show that this intuition is not correct because the alternative revenue source is optimally chosen even before the debt shock occurs. This finding is in line with Trabandt & Uhlig (2013) who report that shortly after the start of the economic and financial crisis in 2010 many industrialized countries were near the peaks of the Laffer curve regarding their labor income tax.[1] In addition, Servén (2007) shows evidence for fiscal rules that limit government borrowing or debt to reduce spending on public infrastructure, a finding that is in line with a political economy explanation: Politicians reduce spending on durable goods like public infrastructure that has strong long-term consequences in order to please voters.

Two further results show when the link between initial debt and fiscal competition is further strengthened and when it is overturned. The main mechanism is reinforced when firm location choices become more flexible. An increase in capital mobility (by loosening firm attachment) does not only drive down tax rates on firms, a direct effect that is well known in the literature, but also tends to reinforce the impact of initial debt on fiscal competition. The latter represents a novel indirect effect. Higher initial debt levels are therefore more problematic when international capital markets are more integrated. The mechanism can be reversed, however, if higher initial debt is correlated with or even caused by higher initial public infrastructure. In that case, the affected region gains an advantage in fiscal competition early on when debt increases, which makes its government less rather than more constrained in its subsequent borrowing. The opposite holds when higher initial debt is correlated with

[1] Furthermore, quantitative results by Mendoza *et al.* (2014) suggest that capital tax increases would not have been sufficient to restore solvency in Europe after the financial crisis.

more government consumption spending and thus less public infrastructure. Our finding thus complements the literature on the composition of public expenditure (e.g. Keen & Marchand, 1997).

In an empirical analysis using data from about 11,000 municipalities in Germany over the period of 1998 until 2013 we show evidence in line with the base model's theoretical predictions. We make use of an event study design and capture the change in initial debt by a well above average increase in the net repayment burden of a municipality. In line with the theoretical model, the municipality lowers its contemporaneous spending on public infrastructure by nearly 27%, which recovers within 5 years. In addition, the municipality decreases its local business tax by a small, but significant amount. The opposite behavior is found in localities who do not have a neighbor with a debt repayment shock and who increase slightly their tax rates.

Our analysis contributes to the debate on fiscal decentralization (Besley & Coate, 2003; Oates, 2005; Janeba & Wilson, 2011; Agrawal, 2012; Asatryan *et al.*, 2015). Many countries consider or have recently devolved powers from higher to lower levels of government, including the right to tax mobile tax bases like capital (Dziobek *et al.*, 2011). In Germany, for instance, federal states (Länder) may be granted the right to supplement the federal income tax with a state specific surcharge. Critics often fear that devolving taxation power leads to "unfair" fiscal competition and may aggravate existing spatial economic inequalities if regions differ economically and fiscally. We provide a rigorous framework to analyze this concern and show that it is justified if the default constraint on government borrowing is binding, for example due to a large initial debt levels.

It is perhaps surprising that despite the large body of research on inter-jurisdictional competition in taxes (see Keen & Konrad, 2013) and public infrastructure investment (e.g. Noiset, 1995; Bucovetsky, 2005), the theoretical literature in this field has mostly ignored public debt levels as a factor in inter-jurisdictional competition for business investment. One possible reason is that, in the absence of government default, there is no obvious reason why governments cannot separately optimize public borrowing and fiscal incentives for private investment, thus precluding any interaction between the initial debt level and business taxes. This notion also underlies the results of more comprehensive general equilibrium models such as in Mendoza & Tesar (2005).[2] However, in the light of public defaults and a surge in

[2]Mendoza & Tesar (2005) show in a setting without borrowing constraints that legacy debt provides an incentive for large economies to use capital taxes to manipulate interest rates but

policy measures, such as fiscal rules designed to limit deficits and government debt, unconstrained public borrowing is an unrealistic assumption for some jurisdictions.[3]

We note two exceptions. Arcalean (2017) analyzes the effects of financial liberalization on capital and labor taxes as well as budget deficits in a multi-country world linked by capital mobility. In contrast to our analysis, he focuses on endogenous budget deficits that are affected by financial liberalization because permanently lower tax rates on capital due to more intensive tax competition lead to higher capital accumulation. This in turn makes it attractive for the median voter, who is a worker by assumption, to bring forward the higher benefits of capital taxation through government debt. The mechanism works at the early stages of financial liberalization when capital taxes are relatively high.

Jensen & Toma (1991) show in a two-period, two-jurisdiction model that a higher level of first-period debt leads to an increase in taxation in the following period and a lower level of public good provision in that jurisdiction. In the other jurisdiction, either a higher or a lower tax rate is set depending on whether tax rates are strategic complements or substitutes.[4] The present paper differs from this setting in three important aspects: First, we allow for a default on government debt which endogenously limits the maximum level of public debt. Second, we introduce public infrastructure investment, which is shown to play a key role. Finally, we assume a linear within-period utility function, which allows us to abstract from the intra-period transmission mechanism identified by Jensen & Toma (1991).

The paper is structured as follows. In Section 5.2, we describe the model framework. We then proceed to the equilibrium analysis in Section 5.3, which contains the main results for the situation with symmetric initial public infrastructure but possible differences in the public borrowing constraint. In Section 5.4, we consider a number of extensions, including an asymmetry that is due to differences in initial public infrastructure. In Section 5.5 we present our empirical analysis based on German municipal data. Section 5.6 provides the conclusion.

does not directly affect tax competition.

[3]By "unconstrained" we mean that the government can borrow as much as it wants at the current interest rate assuming no default.

[4]An interesting empirical application for this model in the case of interactions in borrowing decisions can be found in Borck *et al.* (2015). Krogstrup (2002) also analyzes the role of government debt in an otherwise standard ZMW (Zodrow & Mieszkowski, 1986; Wilson, 1986) model of tax competition. Higher interest payments on exogenous public debt lead to lower spending on public goods and higher taxes, similar to Jensen & Toma (1991).

5.2 The Model

We start with a brief overview of the model. The world consists of two jurisdictions, $i = 1, 2$, linked through the mobility of a tax base. The tax base is the outcome of the location decisions of a continuum of firms and generates private benefits and tax revenues that are used by the government for spending on a public consumption good, a public infrastructure good, and debt repayment. Better infrastructure makes a jurisdiction more attractive, while taxes work in the opposite direction. The economy lasts for two periods. Both jurisdictions start with an initial (legacy) debt level b_{i0} and issue new debt in the first period in an international credit market at a given interest rate r. We pay particular attention to a government's willingness to repay its debt in period 2, which endogenously limits the maximum available credit in period 1.

The government is assumed to maximize a linear combination of the number of firms in its jurisdiction and the level of the public consumption good. There are two inter-temporal decisions for a government to be made in period 1: the level of borrowing and the spending on public infrastructure. The latter is modeled as a long-term decision to capture the durable good nature of infrastructure projects. Public investment is costly in period 1, but carries benefits only in period 2.

Fiscal competition has two dimensions: tax rate competition in periods 1 and 2, where governments set a tax on each firm in their jurisdiction, and competition in infrastructure spending. We consider a fiscal policy game between the two governments without commitment, that is, governments choose fiscal policy in each period non-cooperatively and cannot commit in period 1 to fiscal policy choices in period 2.

5.2.1 Firms

We begin the description of the model with the location of the tax base, which follows a simple Hotelling (1929) approach.[5] There is a continuum of firms with the total number of firms normalized to 1. Each firm chooses a jurisdiction to locate in and can switch its location between periods at no cost. Firms are heterogeneous in terms of their exogenous bias towards one of the two jurisdictions, which is captured by the firm-specific parameter $\alpha \in [0, 1]$. α comprises firm-specific characteristics

[5] Our model shares some features with classical models of tax competition as, for example, Zodrow & Mieszkowski (1986), Wilson (1986) and Kanbur & Keen (1993). Our approach is analytically simpler to handle, which is crucial in the presence of many government instruments and possible default on government debt.

that make it more attractive to locate in one or the other region such as existing production facilities or requirements for natural resources. Omitting the time index for the moment, a firm of type α receives a net benefit $\varphi_i(\alpha)$ in jurisdiction i given by

$$\varphi_i(\alpha) = \begin{cases} \psi + \alpha\nu + \rho q_i - \tau_i & \text{for } i = 1 \\ \psi + (1-\alpha)\nu + \rho q_i - \tau_i & \text{for } i = 2. \end{cases} \tag{5.1}$$

The terms $\psi + \alpha\nu$ and $\psi + (1-\alpha)\nu$ represent the exogenous returns. The general return ψ is assumed to be sufficiently positive so that overall return φ_i is non-negative and the firm always prefers locating in one of the two jurisdictions rather than not operating at all. The second component of the private return is the firm-specific return in each jurisdiction weighted by $\nu > 0$. The parameter ν allows us to capture the strength of the exogenous component relative to the policy-induced one. Variation in ν changes the degree of fiscal competition, which we analyze below. The overall return to investment in a jurisdiction i further increases when the jurisdiction has a stock of public infrastructure in place at level $q_i \geq 0$. The effectiveness of public infrastructure is captured by the parameter $\rho \geq 0$ and is not firm-specific.[6] Finally, the uniform tax τ_i reduces the return. We assume that the tax is not firm-specific, perhaps because the government cannot determine a firm's type or cannot choose a more sophisticated tax function for administrative reasons.

Let $\alpha \in [0,1]$ be uniformly distributed on the unit interval. There exists a marginal firm of type $\tilde{\alpha}$ that is indifferent between the two locations for the given policy parameters, that is $\varphi_1(\tilde{\alpha}) = \varphi_2(\tilde{\alpha})$. Under the assumption that the marginal firm is interior, $\tilde{\alpha} \in (0,1)$,[7] the number of firms in each jurisdiction is then given by $N_1 = 1 - \tilde{\alpha}$ and $N_2 = \tilde{\alpha}$ or, more generally,

$$N_i(\tau_i, \tau_{-i}, q_i, q_{-i}) = \frac{1}{2} + \frac{\rho\Delta q_i - \Delta\tau_i}{2\nu}, \tag{5.2}$$

where $\Delta q_i = q_i - q_{-i}$ and $\Delta\tau_i = \tau_i - \tau_{-i}$. The number of firms in a jurisdiction is a linear function of the tax and public infrastructure differentials. Firms split evenly

[6] We could let the firm-specific component and the effectiveness of public infrastructure interact. This would lead to a less tractable framework without providing additional insights.

[7] Similarly to Hindriks *et al.* (2008), we make this assumption to avoid the less interesting case of a concentration of all firms in one of the two jurisdictions.

between the two jurisdictions when both policies are symmetric across jurisdictions, that is $\Delta q_i = \Delta \tau_i = 0$. The sensitivity of a firm's location choice with respect to tax rates and infrastructure spending depends on the parameter ν. Higher values of ν represent less sensitivity.

5.2.2 Governments

Government i takes several decisions in each period. In both periods, it sets a uniform tax τ_{it} and provides a public consumption good g_{it}, which can be produced by transforming one unit of the private good into one unit of the public good. In the first period, the government pays back initial debt b_{i0} (no default by assumption), and decides on public infrastructure investment m_{it} as well as the level of newly issued debt b_{i1}. If the government honors the debt contract, b_{i1} is repaid in period 2. We denote the government's default decision with the binary variable $\kappa_i = \{0, 1\}$, where 0 stands for no default and 1 for default.

Public investment raises the existing stock of public infrastructure q_{it}. In each period, a share $\delta \in [0, 1]$ of q_{it} depreciates so that the law of motion for q_{it} is denoted by

$$q_{it} = (1 - \delta)\, q_{it-1} + m_{it-1}. \tag{5.3}$$

In period 1 jurisdictions are endowed with an exogenous level of public infrastructure $q_{i0} = \bar{q}_i$.[8] The cost for public infrastructure investment is denoted by $c(m_i)$, which is an increasing, strictly convex function: $c'(m_i) > 0$, $c''(m_i) > 0$. To simplify notation, we suppress the time subscript in m_i, since it is effectively only chosen in period 1.

The period-specific budget constraints for the government in $i = 1, 2$ can be stated as follows:

$$g_{i1} = \tau_{i1} N_{i1} - c(m_i) - (1 + r)\, b_{i0} + b_{i1} \tag{5.4}$$

$$g_{i2} = \tau_{i2} N_{i2} - (1 - \kappa_i)(1 + r)\, b_{i1}. \tag{5.5}$$

In these expressions, the set of available revenue-generating instruments is limited to the business tax. In practice, governments may use a wide range of taxes, including levies on consumption and labor. In the base version we consider only the taxation

[8] A jurisdiction's level of public infrastructure may be correlated with its initial level of government debt. We consider this aspect in Section 5.4.2.

of firms. In Appendix D.5 we demonstrate that the main insights of the base model are qualitatively not affected by introducing a second tax instrument.

Government borrowing takes place on the international credit market at the constant interest rate r. We assume for the time being that government debt is repaid. In our subsequent analysis we pay attention to the possibility of default in period 2.[9]

Each government is assumed to maximize the discounted benefit arising from attracting firms and government spending on a public consumption good according to the following specification:

$$U^i = h_1 (u_{i1}) + \beta h_2(u_{i2}) = h_1 (N_{i1} + \gamma g_{i1}) + \beta h_2 (N_{i2} + \gamma g_{i2}) . \tag{5.6}$$

We think of (5.6) as the utility function of a representative citizen who benefits from attracting firms because this generates private benefits such as income and employment. Here, we simply use the number of firms in jurisdiction i, N_i, as an indicator of this benefit. In addition, attracting firms increases the tax base and generates higher tax revenues.[10] The marginal benefit of the public good, $\gamma > 1$, implicitly determines the relative weight attached to the private benefit and public consumption. The linear structure of the within-period utility function is in line with earlier literature (e.g. Brueckner, 1998) in order to solve for Nash tax rates explicitly. This assumption makes the model different from Jensen & Toma (1991) who assume a strictly concave function for the benefit of the public good (within the function h_2). As mentioned earlier, our approach is more tractable in the context of multiple government instruments and possible default on debt, and allows us to demonstrate the novel mechanism at work. β is the discount factor which we set equal to $\frac{1}{1+r}$. The inter-temporal structure of the utility function assumes that the functions h_1 and h_2 are concave, and at least one of them is strictly concave. We assume this for h_1, such that $h_1' > 0$, $h_2' > 0$, $h_1'' < 0$, $h_2'' \leq 0$.

So far, we assumed that public debt is repaid in both periods, such that creditors have no reason to restrict lending to the government. We now consider default on debt in period 2 through a willingness-to-pay constraint. A government honors the

[9] We ignore the possibility of bailouts, which have been relevant in the financial crisis in some cases, but go beyond the scope of this paper.

[10] Our utility function is qualitatively similar to standard models of tax competition. In Section 5.4.4 we argue that a micro-founded model in the spirit of Hindriks *et al.* (2008) generates also very similar results.

debt contract when the net benefit of defaulting is smaller than the net benefit of paying back the debt. While the former is related to the size of the existing debt level, the latter involves a loss of access to the international credit market and possibly other disturbances. The two-period time horizon allows us, similar to Acharya & Rajan (2013), to take a shortcut for modeling such disturbances. Default in period 2 causes a utility loss of size z in that period, representing the discounted value from being unable to borrow in the future among other possible disadvantages. The period 2 utility in jurisdiction i is given by

$$u_{i2} = N_{i2} + \gamma g_{i2} - \kappa_i z.$$

Two comments are in order. First, we do not model the default decision on government debt regarding initial (legacy) debt b_{i0} in period 1. Legacy debt levels may accumulate due to unforeseen shocks as in the recent European financial and economic crisis, or may play a role when switching to a more decentralized tax system (as is considered in the reform debate on fiscal federalism in Germany).[11]

In a second comment we like to highlight a particular modeling choice. In our model, the fixed interest rate and the binary government default decision are separated. Alternatively, one could assume that the interest rate on debt depends positively on the size of debt b_{i1} due to default risk. In that case the government would face an increasing marginal cost of borrowing. By contrast, in our model default prohibits any borrowing beyond a certain level. This approach has certain advantages in terms of tractability and captures explicitly that the rising cost of borrowing originate from the possibility of default. We return to the role of this assumption in Section 5.4.4.

5.2.3 Equilibrium

The equilibrium definition has two components. The economic equilibrium is straightforward, as this refers only to the location decision of firms. There is no linkage across periods because relocation costs for firms are zero. An economic equilibrium in period $t = 1, 2$ is fully characterized in Section 5.2.1 as a profit-maximizing location

[11] Our assumption of repayment of legacy debt is reasonable if its size is small enough so that default in period 1 is not attractive. Even if a government default was attractive in period 1, it would not occur in equilibrium, since creditors would not have given any loans in the first place. We checked that there exists a set of sufficiently small initial debt levels that does not lead to default in period 1 but still influences the subsequent choice of fiscal instruments.

choice of each firm for given levels of taxes and infrastructure in that period.

The second component comprises the policy game between governments. We assume the following timing of events. In period 1, governments simultaneously decide on how much to invest (i.e. set m_i), set new debt b_{i1}, choose the tax rate τ_{i1} and the public good g_{i1}, assuming that they pay back the legacy debt b_{i0}. Then firms decide where to invest. In period 2, governments simultaneously choose tax rate τ_{i2}, as well as the public good g_{i2}, and decide on the default of existing debt b_{i1}. Subsequently, firms again make their location choices. Governments observe previous decisions and no commitment is possible. We consider a sub-game perfect Nash equilibrium and solve the model by backward induction.

5.3 Results

5.3.1 Period 2

We begin with analyzing the government decision making in period 2. At that stage, a government decides on its tax rate, the public consumption good level and default, taking as given the policy choices of period 1, that is, the debt levels b_{i1} and the public infrastructure q_{i2} in both jurisdictions $i = 1, 2$. A period 2 Nash equilibrium is a vector of tax rates, public good levels and default decisions such that each government maximizes its period 2 sub-utility, taking the other government's fiscal policy decisions in that period as given, and anticipating correctly the subsequent locational equilibrium.

Government i maximizes period 2 utility as given by equation (5.6). We analyze the tax and default decisions sequentially, making sure that in the end a global maximum is reached. We start with the choice of the tax rate, which affects the number of firms N_{i2}, given by (5.2) adding time subscripts. The first-order conditions are given by

$$U^i_{\tau_{i2}} := \frac{\partial U^i}{\partial \tau_{i2}} = h_2' \frac{\partial \left(N_{i2} \left(1 + \gamma \tau_{i2}\right)\right)}{\partial \tau_{i2}} = 0, \ i = 1, 2 \tag{5.7}$$

For the period 2 decision the outer utility function h_2 can be ignored as long as $h_2' > 0$, which we assume. Solving the system of two equations (one for each jurisdiction) with two unknowns, we obtain τ_{12} and τ_{22}.[12]

[12]The second-order condition is fulfilled because N_{i2} is a linear function of tax rates and depends

Next, we analyze the default decision in period 2, holding tax rates in both jurisdictions constant for the moment. For this purpose, we need to compare the utilities under default and under no default, which defines a willingness-to-pay threshold b^{wtp} at which the government is indifferent:

$$\begin{aligned} u_{i2}(\kappa_i = 1) = u_{i2}(\kappa_i = 0) \Leftrightarrow & N_{i2} + \gamma N_{i2}\tau_{i2} - z = N_{i2} + \gamma \left(N_{i2}\tau_{i2} - b^{wtp}(1+r) \right) \\ \Leftrightarrow & b^{wtp} = \frac{z}{\gamma(1+r)}. \end{aligned}$$

If $b_{i1} > b^{wtp}$, a jurisdiction does not repay its debt as the benefits from default outweigh the related costs, and vice versa.[13]

The additive structure of the within period 2 utility allows us to separate the tax and default decisions. The government could choose a different tax rate in case of default than when honoring debt contracts. There is no incentive to do so, however, as tax rate choices are best responses that do not depend on default, as long as the level of public good provision is strictly positive, that is, tax revenue exceeds the repayment burden resulting from debt in period 1. The latter holds as long as the willingness-to-pay threshold is sufficiently strict, which is fulfilled for a sufficiently small z.[14]

Taken together, the first-order conditions (5.7) and the willingness-to-pay condition define the government's optimal decision in period 2. Inserting these candidate tax rates into (5.2), we find the marginal firm to be of type $\tilde{\alpha} = \frac{1}{2} - \frac{\rho \Delta q_{i2}}{6\nu}$, from which we can derive the number of firms $N_{i2} = \frac{1}{2} + \frac{\rho \Delta q_{i2}}{6\nu}$. Note that $\Delta q_{i2} = \Delta q_{i2}(m_i, m_{-i}) = \Delta \bar{q}_i (1-\delta) + \Delta m_i$ is a linear function of the inter-jurisdictional differences in existing public infrastructure $\Delta \bar{q}_i = \bar{q}_i - \bar{q}_{-i}$ and additional investment in public infrastructure $\Delta m_i = m_i - m_{-i}$. We summarize the results for period 2 in the following Proposition.

Proposition 1. *Let $\gamma\nu > 1$. For given public infrastructure investment levels (m_1, m_2) and borrowing in period 1 (b_{11}, b_{21}), there exists a unique Nash equilibrium for the period 2 fiscal policy game with*

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negatively on the own tax rate.

[13] b^{wtp} is identical across jurisdictions because they face the same z. This assumption simplifies the derivation but is not crucial for our results. In fact, heterogeneous utility losses in case of default are one of the reasons why the Willingness-to-pay Condition that we derive below may be binding in one jurisdiction and not the other. We describe this situation as Case II below.

[14] When inserting b^{wtp} as the maximum debt level for b_{i1} into (5.5), it becomes obvious that $g^*_{i0} > 0 \iff \frac{z}{\gamma} < \tau^*_{i2} N^*_{i2}$.

$$\tilde{\tau}_{i2}\left(m_i, m_{-i}\right) = \nu + \frac{\rho \Delta q_{i2}}{3} - \frac{1}{\gamma},$$

$$\tilde{\kappa}_i\left(b_{i1}\right) = \begin{cases} 0 & \textit{if } b_{i1} \leq b^{wtp} \\ 1 & \textit{if } b_{i1} > b^{wtp} \end{cases}$$

$$\tilde{g}_{i2}\left(m_i, m_{-i}, b_{i1}\right) = \tilde{\tau}_{i2}\tilde{N}_{i2} - (1 - \tilde{\kappa}_i)(1 + r)b_{i1},$$

and the number of firms in $i = 1, 2$ *given by* $\tilde{N}_{i2}\left(m_i, m_{-i}\right) = \frac{1}{2} + \frac{\rho \Delta q_{i2}}{6\nu}$.

Proposition 1 carries several implications. First, the equilibrium tax rate of jurisdiction i increases with the value of the gross location benefit ν, the own investment in infrastructure m_i, and the marginal benefit of the public good γ, while the tax rate decreases with infrastructure spending by the other government m_{-i}. Better infrastructure provides more benefits to firms that are partially taxed. The tax rate is positive if ν and γ are sufficiently large ($\gamma\nu > 1$). Moreover, any divergence in tax rates stems solely from differences in public infrastructure, Δq_{i2}. Second, the average tax rate across jurisdictions $\bar{\tau}_2 = \frac{\tau_{12}^* + \tau_{22}^*}{2} = \nu - \frac{1}{\gamma}$ is independent of public infrastructure levels, as the terms involving public infrastructure offset each other, but decreases when the general location benefit ν declines, making firms more sensitive to policy differences.

5.3.2 Period 1

We first abstract from any confounding asymmetries and let initial levels of public infrastructure be the same ($\bar{q}_1 = \bar{q}_2$). We relax this assumption below. Beginning with the second stage of period 1, firms choose their location in the same way as in period 2 because location decisions are reversible between periods at no cost. In the first stage of period 1 fiscal policy is determined. Recall that default on debt from period 0 is not considered. However, new borrowing in period 1 is constrained by default in period 2. Proposition 1 shows that a government defaults when its debt level exceeds b^{wtp}. Therefore, no lender gives loans above this threshold. We thus have an upper limit on borrowing in the form of a willingness-to-pay condition which is defined as follows.

Condition 1 (Willingness-to-pay Condition)**.** $b_{i1} \leq b^{wtp} = \frac{z}{\gamma(1+r)}$.

The advantage of Condition 1 is its simplicity, as it does not depend on public investment and legacy debt levels.

We denote by b_{i1}^{des} the desired level of borrowing in period 1 if the default problem in period 2 is ignored. If utility is strictly concave in b_{i1}, and assuming an interior level of the public consumption good, the optimal period 1 debt is given by

$$b_{i1}^{*} = \min\left\{b_{i1}^{des}, b^{wtp}\right\}.$$

We now consider two separate cases. First, we assume that the willingness-to-pay condition is not binding in either of the jurisdictions. The assumption is correct if, for example, the default cost z and thus b^{wtp} are very large, so that $b_{i1}^{*} = b_{i1}^{des} < b^{wtp}$. In this case we can derive and use the first-order conditions for all fiscal variables in period 1, taking into account the variables' impact on period 2 equilibrium values. In a second step, we turn to the case where Condition 1 is binding in jurisdiction 1 only, that is $b_{11}^{*} = b^{wtp}$. The set of first-order conditions of the government in jurisdiction 1 is reduced by one because it is constrained in its borrowing (or more precisely, the first-order condition for b_{11} does not hold with equality).[15]

Case I: The Willingness-to-pay Condition is not binding in both jurisdictions

After inserting budget constraints, both governments $i = 1, 2$ solve the following maximization problem

$$\begin{aligned}\max_{\tau_{i1}, m_i, b_{i1}} U^i = {} & h_1\left(N_{i1} + \gamma\left(\tau_{i1}N_{i1} - c - (1+r)\,b_{i0} + b_{i1}\right)\right) \\ & + \beta h_2\left(\tilde{N}_{i2} + \gamma\left(\tilde{\tau}_{i2}\tilde{N}_{i2} - (1+r)\,b_{i1}\right)\right) \text{ s.t. } g_{i1} \geq 0,\, m_i \geq 0.\end{aligned} \tag{5.8}$$

This maximization problem is similar to the one discussed by the tax-smoothing literature that also considers inter-temporal aspects of fiscal policy (e.g. Barro, 1979). As before, we assume a positive level of public good provision $g_{i1} \geq 0$.[16] The values for period 2 ($\tilde{\tau}_{i2}$, $\tilde{\kappa}_i$, $\tilde{N}_{i2}$), as given in Proposition 1, are correctly anticipated. Condition 1 ensures that debt contracts are always honored, as shown in expression (5.8). The first-order conditions for $i = 1, 2$ are

[15] We have checked the consistency of all assumptions and the working of the model using a numerical example with quasi-linear utility. We let $h_{i1}(u_{i1}) = \ln(u_{i1})$, $h_{i2}(u_{i2}) = u_{i2}$, $c(m_i) = m_i^2$, $\bar{q}_i = \bar{q}_j$ and set parameter values $\rho = 1.4$, $\nu = 1.4$, $\gamma = 1.3$, $\delta = 1$, $z = 0.25$, $r = 0.01$ such that $\beta = 0.99$ and $b^{wtp} = 0.19$. We solve the example using a simple iterative algorithm and obtain results that are consistent with our general analysis.

[16] The relevant parameter restriction depends on the functional form of U^i. For example, if U^i is quasi-linear, that is $h_2'' = 0$, one obtains a positive public good level $g_{i1}^{*} = \frac{1}{2\gamma} > 0$ in equilibrium.

$$\frac{\partial U^i}{\partial \tau_{i1}} = h'_{i1} \frac{\partial \left(N_{i1} \left(1 + \gamma \tau_{i1} \right) \right)}{\partial \tau_{i1}} = 0, \tag{5.9}$$

$$\frac{\partial U^i}{\partial m_{i1}} = -h'_{i1} \gamma c' + \beta h'_{i2} \frac{\partial \left(\tilde{N}_{i2} \left(1 + \gamma \tilde{\tau}_{i2} \right) \right)}{\partial m_i} = 0, \tag{5.10}$$

$$\frac{\partial U^i}{\partial b_{i1}} = \gamma h'_{i1} - \beta \gamma (1+r) h'_{i2} = h'_{i1} - h'_{i2} = 0. \tag{5.11}$$

In the first-order condition (5.11), we make use of the assumption $\beta = \frac{1}{1+r}$. We derive the full set of second-order conditions in Appendix D.1.[17] Note that U^i is strictly concave in b_{i1}, as long as at least one of the two functions h_{i1} or h_{i2} is strictly concave.

We solve the system of six first-order conditions (three for each jurisdiction) as follows: Assuming that public consumption good levels are strictly positive, the first-order conditions for tax rates (5.9) for both jurisdictions are independent of infrastructure investment as well as debt levels, and can be solved in a similar way as above in period 1, yielding

$$\tau^*_{i1} = \nu - \frac{1}{\gamma}, \; N^*_{i1} = \frac{1}{2}, \; i = 1, 2 \tag{5.12}$$

Since by assumption the public infrastructure differential is zero in period 1, the tax base is split in half between the two jurisdictions. As in period 2, the more footloose firms are (i.e. the lower ν is), the lower are equilibrium tax rates. This corresponds to the standard result that increasing capital mobility drives down equilibrium tax rates.

Using the condition for period 1 borrowing (5.11), $h'_{i1} = h'_{i2}$, we can simplify the condition for optimal infrastructure investment (5.10) to $\beta \frac{\partial \left(\tilde{N}_{i2}(1+\gamma\tilde{\tau}_{i2}) \right)}{\partial m_i} = \gamma c'(m_i)$. We use the period 2 equilibrium values to obtain

$$c'(m_i) = \frac{\beta \rho}{3} \left(1 + \frac{\rho \Delta m_i}{3\nu} \right), \; i = 1, 2. \tag{5.13}$$

A symmetric equilibrium, $m_1 = m_2 = m^*$, always exists. It is unique if the cost function for public infrastructure c is quadratic because then the first-order conditions

[17] The second-order conditions are always satisfied if the cost function for infrastructure investment is sufficiently convex.

are linear. Asymmetric equilibria may exist though.[18] The combined results from the first-order conditions for taxes and infrastructure spending can now be used to determine the optimal borrowing level, as all other variables entering the arguments of h_{i1} and h_{i2} are determined via (5.10) and (5.11).

An interesting property of (5.13) is that it is independent of the initial debt level, which leads to a neutrality result: The choice of m_i is not affected by b_{i0} if the willingness-to-pay condition is not binding. We summarize our insights from the equilibrium under non-binding debt constraints in the Proposition below.

Proposition 2. *Let $\gamma\nu > 1$. Assume Condition 1 is not binding in both jurisdictions and initial public infrastructure levels are symmetric $\bar{q}_1 = \bar{q}_2$.*

a) A subgame perfect Nash equilibrium with symmetric infrastructure spending exists, in which first-period tax rates are $\tau_{i1}^* = \nu - \frac{1}{\gamma}$ and infrastructure spending and first period borrowing are implicitly given by $c'(m^*) = \frac{\beta\rho}{3}$ and condition (5.11).

b) Changes in a jurisdiction's legacy debt (b_{i0}) affect its period 1 borrowing and its period 2 public consumption good, but do not affect fiscal competition (tax rates and public infrastructure). The firms' location decisions in both periods are unaffected.

c) Lower ν (i.e. firms are more footloose) implies lower tax rates in both jurisdictions in both periods.

Underlying the debt neutrality result is the following intuition: When governments can choose their desired borrowing level, the unconstrained decision on period 1 debt leads to the equalization of marginal utilities across periods. This frees the infrastructure spending decision from doing this. Infrastructure spending serves to equalize the marginal benefit of an improved economic outcome in period 2 (number of firms and public consumption good) and the marginal cost from spending in period 1 that implies forgone public good consumption in that period. The neutrality result with respect to inter-temporal aspects of fiscal competition may explain why the existing literature has not much addressed the link between fiscal competition and public legacy debt.[19] However, endogenous constraints on borrowing change this

[18] For example, a corner solution with one jurisdiction not investing at all exists if $c(m_i) = \frac{m_i^2}{2}$ and $2\beta\rho^2 > 9\nu > \beta\rho^2$. The first inequality ensures that one jurisdiction cannot benefit from infrastructure investment, while the second inequality makes sure that the jurisdiction finds a positive level of infrastructure $m_i^* = \frac{3\beta\rho\nu}{9\nu - \beta\rho^2}$ optimal.

[19] We abstract from inefficiencies in public good provision and thus ignore the intra-period transmission channel highlighted by Jensen & Toma (1991) to focus on the inter-temporal effect of initial public debt.

conclusion.

Case II: The Willingness-to-pay Condition is binding in one jurisdiction

We now turn to the case where Condition 1 is binding in jurisdiction 1, but not in the other jurisdiction. In this scenario, jurisdiction 1 would like to run a higher debt level than lenders are willing to provide, as the latter correctly anticipate the default problem in period 2, that is $b_{11}^{des} > b^{wtp}$. In equilibrium, the first-order condition for period 1 debt, (5.11), does not hold with equality. Instead the optimal borrowing level equals the maximum feasible level given by b^{wtp} due to the strict concavity of U^1 with respect to b_{11}. First-order condition (5.9) still holds and together for both jurisdictions the two conditions determine the Nash tax rates in period 1, which are identical to Case I. As before, we make the appropriate assumption that the level of the public consumption good is positive and thus an interior solution is obtained.[20] In this case, legacy debt does not affect period 1 taxes.

We are left with the two jurisdictions' first-order conditions for public infrastructure investment, (5.10). The absence of condition (5.11), however, now implies that the marginal utilities in periods 1 and 2 are typically not equalized for jurisdiction 1, $h'_{11} \neq h'_{12}$. In particular, h'_{11} in (5.10) depends on the level of infrastructure investment. This is the key difference to Case I.

We are interested in the effect of legacy debt on fiscal competition, that is period 2 taxes and public infrastructure. We cannot solve explicitly for public investment levels, as the two conditions are nonlinear functions of m_1 and m_2. We can undertake comparative statics, however, by totally differentiating the first-order conditions for public infrastructure, assuming an interior solution for the public consumption good and making sure that tax rates for period 1 are determined in isolation from the other relevant first-order conditions.

The sign of the comparative static effects can be partially determined when we assume that the Nash equilibrium is stable, as suggested by Dixit (1986). In this case, the sign of the own second-order derivative regarding infrastructure spending is negative, $\frac{\partial^2 U^i}{\partial m_i^2} < 0,\ i = 1, 2$, and importantly, the own effects dominate the cross effects, that is $\frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^{-i}}{\partial m_{-i}^2} > \frac{\partial^2 U^{-i}}{\partial m_{-i} \partial m_i} \frac{\partial^2 U^i}{\partial m_i \partial m_{-i}}$. A detailed derivation of the comparative static analysis is relegated to Appendix D.2. Making use of the Dixit (1986) stability assumptions, we obtain

[20] Using the numerical example described in footnote 15 we verify that such an equilibrium may indeed be obtained.

$$\frac{\mathrm{d}m_1}{\mathrm{d}b_{10}} = -\frac{1}{\phi}\frac{\partial^2 U^2}{\partial m_2^2}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0, \tag{5.14}$$

$$\frac{\mathrm{d}m_2}{\mathrm{d}b_{10}} = \frac{1}{\phi}\frac{\partial^2 U^2}{\partial m_2 \partial m_1}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} > 0, \tag{5.15}$$

with $\phi = \frac{\partial^2 U^1}{\partial m_1^2}\frac{\partial^2 U^2}{\partial m_2^2} - \frac{\partial^2 U^2}{\partial m_2 \partial m_1}\frac{\partial^2 U^1}{\partial m_1 \partial m_2} > 0$ and $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} = h''_{11}\frac{\gamma^2}{\beta}c' < 0$. The latter inequality means that the incentive to invest in infrastructure declines with higher legacy debt, as the marginal utility of consumption rises when $h''_1 < 0$. Thus, solution (5.14) contains our second important result: If a jurisdiction is constrained in its borrowing, an increase in legacy debt leads unambiguously to a decline in its infrastructure investment. The cross effect of an increase in legacy debt on the infrastructure investment in the other jurisdiction is positive. Furthermore, since $\frac{\partial^2 U^i}{\partial m_i \partial b_{i0}}$ depends on ν, capital mobility clearly affects the size of the effect of legacy debt on public infrastructure investments. We summarize these results in the following proposition and discuss them in detail below.

Proposition 3. *Let $\gamma\nu > 1$. Assume that jurisdiction 1 is constrained in its borrowing decision in period 1 and initial public infrastructure levels are symmetric $\bar{q}_1 = \bar{q}_2$.*

a) If the Nash equilibrium in infrastructure spending is stable, an increase in the legacy debt of jurisdiction 1 (b_{10}) leads to a decline in infrastructure investment (m_1) and also reduces i's period 2 tax rate (τ_{12}). In jurisdiction 2, it raises the tax rate (τ_{22}) and infrastructure spending (m_2). As a consequence, the number of firms decreases in jurisdiction 1 and increases in jurisdiction 2.

b) Lower ν (i.e. firms are more footloose) implies lower tax rates in both jurisdictions in both periods. In addition, if $h'''_1 > 0$, the effect of legacy debt on the public investment level and period 2 tax rates is the stronger in magnitude the larger is ν.

The interaction of public infrastructure investment and tax setting both within jurisdictions and over time, as well as, between competing governments implies that an increase in legacy debt in one jurisdiction affects various fiscal policy instruments. Table 5.1 summarizes these effects for unrestricted (Case I) and restricted (Case II) public borrowing in period 1.

The main reason for the negative effect of legacy debt b_{10} on public investment m_1 is that borrowing cannot be increased to smooth consumption if the willingness-to-

Table 5.1: Change in Legacy Debt (b_{10}), Impact on Fiscal Policy

Willingness-to-pay Condition	Jurisdiction 1 ($db_{10} > 0$)				Jurisdiction 2 ($db_{20} = 0$)			
	Period 1		Period 2		Period 1		Period 2	
	m_1	b_{11}	τ_{12}	N_{12}	m_2	b_{21}	τ_{22}	N_{22}
Case I (non-binding)	-	↑	-	-	-	-	-	-
Case II (binding in 1)	↓	-	↓	↓	↑	↑	↑	↑

pay condition is binding. The burden from higher legacy debt falls *ceteris paribus* on period 1 and raises the marginal utility of consumption in period 1, thus making a transfer of resources from period 2 to period 1 more desirable. Because higher government debt is impossible, a second best government response is to reduce investment in public infrastructure in that jurisdiction. This in turn lowers government spending in period 1 and increases the space for public good consumption. At the same time, the constrained government makes up for reduced competitiveness in period 2 by lowering its tax rate in the long run.

The increase in b_{10} also affects public investment policy in jurisdiction 2. The decrease in m_1 provides an incentive for jurisdiction 2 to increase public investment because of the strategic advantage arising from this situation.[21] As a consequence, jurisdiction 2 becomes more attractive in period 2.

A policy divergence occurs also in the period 2 tax equilibrium. Starting from a stable equilibrium, an increase in a jurisdiction's initial debt leads to a lower tax rate for this jurisdiction in period 2, while the opposite holds in the other jurisdiction. The latter can afford a higher tax because the better relative standing in public infrastructure partially offsets higher taxes. Overall, we conclude that an exogenous increase in government debt leads to policy divergence across jurisdictions regarding fiscal competition instruments.

The second part of Proposition 3 refers to the impact of capital mobility. As in the case with no restriction on public borrowing, higher capital mobility, captured by a decrease in ν, puts downward pressure on equilibrium tax rates. However, in addition to this direct effect, an additional indirect effect from capital mobility arises when public borrowing in period 1 is restricted. Intuitively, higher capital mobility reduces the government's revenue from taxing firms in period 1. This makes

[21] Since jurisdiction 2 is not constrained in its borrowing, the increase in m_2 is financed by an increase in b_{21}, see Appendix D.2.

the government even more sensitive in period 1 to increases in legacy debt. It becomes even less attractive to shift resources to the future by investing in public infrastructure. Consequently, a government sets an even lower tax rate in period 2. Analytically, by affecting the level of tax rates in period 1, ν changes $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}$. In particular, $\frac{d}{d\nu}\left(\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\right) = h_{11}'''\,(1+r)\,\gamma^3 c'$ is positive if and only if $h_{11}''' > 0$, which holds for many strictly concave functions such as natural logarithm and square root.

It is interesting to put our main results in the context of the scarce literature on tax competition and public debt. As noted in the introduction, Arcalean (2017) is close to but different from our work. In his model, government debt is always repaid. Financial liberalization puts pressure on tax rates which in turn leads to more capital accumulation. The gains from an increase in future tax bases can be brought forward through higher initial budget deficits. This incentive works because the median voter, who has labor income only, redistributes through capital taxation to herself intratemporally and through debt intertemporally. In our paper, we emphasize the role of initial (legacy) debt and focus on a different inter-temporal mechanism through investment in public infrastructure. Our results can also be related to Jensen & Toma (1991), who show that period 1 debt affects period 2 capital tax rates even in the absence of default. While the models are different in some other aspects, the nonlinear within-period utility function in Jensen & Toma (1991) drives this difference. In contrast, our simplifying assumption is useful in order to clearly identify the role of default which we obtain by comparing the results from Case I and Case II, respectively.

5.4 Robustness and Extensions

We have made several simplifying assumptions to ease presentation and direct attention to the main insights and underlying mechanisms. In this section we discuss other settings. For example, we consider the case where both competing jurisdictions are unable to borrow at their desired level. Furthermore, we analyze the effect of structural differences in initial infrastructure across competing jurisdictions which are a frequent phenomenon and may be correlated with the legacy debt level. Finally, we consider a tax on an immobile tax base. We also discuss more general modeling choices including the exogenous interest rate. We summarize the main findings and relegate a more formal derivation to Appendix D.

5.4.1 Constrained Borrowing in Both Jurisdictions

We begin by considering an alternative case where the Willingness-to-pay Condition is binding in both jurisdictions. In this case, the set of first-order conditions in period 1 is reduced to (5.9) and (5.10) (see Appendix D.3). The first-order condition with respect to b_{i1} does not hold with equality for both jurisdictions. Thus, the maximization problem of each jurisdiction is identical to the constrained jurisdiction in Case II (see derivation in Appendix D.2). It follows that the direction of the response to a marginal increase in b_{i0} is also the same: Jurisdiction i lowers public infrastructure investment in period 1 and also reduces its period 2 tax rate to mitigate the resulting loss in attractiveness.

The effect of a change in legacy debt in one jurisdiction on the infrastructure investment in the other jurisdiction is less clear cut and depends on the strategic interaction of public infrastructure investment. If public investments are strategic substitutes[22] jurisdiction 2 reacts to jurisdiction 1's decrease in m_1 with an increase in m_2. Such an unambiguous result is, for example, obtained if we assume that the inter-temporal utility function is of the quasi-linear type ($h_2'' = 0$). In this case $\frac{\partial^2 U^2}{\partial m_2 \partial m_1}$, which is the change in the net benefit of public infrastructure investment in one jurisdiction if the government in the other jurisdiction invests more (or less), is negative and $\frac{\mathrm{d}m_2}{\mathrm{d}b_{10}} > 0$.

With regard to tax policy, the increase in initial debt in jurisdiction 1 leads to a divergence in the period 2 tax equilibrium similar to Case II. The tax rate of jurisdiction 1 decreases relative to the tax rate in jurisdiction 2. This effect is independent of the infrastructure spending response in region 2 because in the fiscal competition game the best response of jurisdiction 2 when deviating from the initial Nash equilibrium is to adjust fiscal policy instruments in such a way that its attractiveness increases relative to jurisdiction 1. Thus, even if it lowers m_2, it will do so only to the extent that it still turns out to be more attractive than jurisdiction 1. As a consequence, jurisdiction 2 can afford a higher tax rate without reducing its mobile tax base.

[22] This a standard feature in fiscal competition models (e.g. Hindriks *et al.*, 2008). For a discussion on the role of public inputs in fiscal competition, see Matsumoto (1998).

5.4.2 Interaction Between Initial Public Infrastructure and Initial Public Debt

A potential feed-back mechanism of legacy debt differentials may occur if these are related to differences in initial infrastructure levels, $\bar{q}_1 \neq \bar{q}_2$. Public debt that results from large public infrastructure investments in the past has a different impact on the subsequent fiscal competition game than one that has mostly been caused by public consumption.

To understand the mechanism at work, note that an asymmetric level of initial public infrastructure has two implications. First, *ceteris paribus* it causes the better endowed and thus generally more attractive jurisdiction to set higher taxes because its better infrastructure offsets weaker tax conditions. This effect takes place in period 1, and also in period 2 if public infrastructure does not fully depreciate ($\delta < 1$). Second, asymmetric equilibria in the tax competition game feed into the inter-temporal fiscal variables. A higher level of public infrastructure attracts more firms, which in turn raises the incentive for additional public infrastructure spending as long as public investment is a strategic substitute.[23] More public infrastructure investment also raises the level of desired public borrowing in period 1, b_{i1}^{des}, both in order to compensate for an otherwise lower public good provision in that period, and because the better endowed jurisdiction intertemporally shifts part of the benefits from a higher level of period 2 tax revenues to period 1. A higher level of existing public infrastructure thus improves a jurisdiction's position in the subsequent fiscal competition game. This relates to the polarization effect described by Cai & Treisman (2005).

We consider an asymmetry in initial infrastructure ($\bar{q}_1 \neq \bar{q}_2$) that is caused by legacy debt differentials. In particular, suppose that the initial level of public infrastructure is a function of legacy debt, $\bar{q}_i = f(b_{i0})$. Intuitively, there are two forms in which such a relation appears reasonable. For example, Poterba (1995) points out that debt financing of public infrastructure spending can make it easier to obtain support for government investment projects as they appear less costly to the public. Thus, if higher legacy debt levels are an indicator of more public infrastructure spending in the past, the relationship is positive, that is, $f' > 0$. High legacy debt levels may, however, also be caused by public consumption spending. In this case, the level of existing infrastructure may be negatively related to the observed legacy debt, and therefore $f' < 0$.

[23] In our model this is generally the case for quasi-linear inter-temporal utility functions.

In Appendix D.4, we insert $\bar{q}_i = f(b_{i0})$ into our model and analyze the equilibria for Cases I and II. In both scenarios, the negative effect of an increase in initial public debt on infrastructure investment in period 1 is reinforced when there is a negative relation between legacy debt and initial public infrastructure ($f' < 0$). A positive relation between b_{i0} and $\bar{q}_i$ ($f' > 0$) leads to more nuanced results. If legacy debt has no effect on inter-temporal redistribution (Case I), only the polarization effect of public infrastructure spending is present. This additional mechanism generates a link between b_{i0} and m_i even in the case of unrestricted public borrowing. Higher b_{i0} leads to more infrastructure spending in period 1 if higher legacy debt is associated with more public investment in the past ($f' > 0$).[24]

Inter-temporal considerations are relevant, if public borrowing is restricted (Case II). The benchmark result in Proposition 3 remains relevant as the government's desire to smooth utility across periods induces it to lower public investment when the legacy debt burden is higher. At the same time, the polarization effect that results from the (potentially positive) relation between b_{i0} and $\bar{q}_i$ works in the opposite direction if public investment is a strategic substitute. The effect described in Proposition 3 is thus mitigated. In extreme scenarios, the results may even be reversed. This is, however, only the case if public infrastructure spending is indeed a strategic substitute and the polarization effect dominates the coinciding mechanism of Proposition 3.

5.4.3 A Tax on Domestic Income

In the base model we restrict tax policy to the taxation of capital at source. In reality, governments have various revenue sources, which may include a tax on a less mobile base such as labor income. Would the introduction of such a tax affect the results with regard to the role of legacy debt in our fiscal competition model? The short answer is basically no. In Appendix D.5, we prove this result in a model with an additional tax on domestic income: the government can tax a share of the local benefit of foreign investment, which can be interpreted as a wage tax on labor income that citizens receive from the firms that locate in their jurisdiction. The tax is distortive by assuming that the government incurs a convex administrative cost when collecting revenue from this source.

We repeat our analysis and show that the results with regard to legacy debt prevail. An additional tax raises government revenue in both periods but does not

[24] This result is formalized in condition (D.17) in Appendix D.

affect the nature of inter-temporal redistribution that induces governments to react to an increase in the initial debt repayment burden with a cut in public investment spending and a subsequent reduction in the tax rate on the mobile income. The result is obtained precisely because the additional tax instrument relates to the immobile, local tax base and thus has no effect for the fiscal competition game that drives our main results. The tax is optimized separately in any case. We note, however, that the additional revenue from a labor tax can make it less likely that governments face binding constraints with regard to their borrowing.

5.4.4 Model Robustness

Two further modeling choices are worth being discussed in more detail. In the base model the number of firms in a region enters directly into the region's utility function. In comparison to a standard micro-founded model, this simplifies notation while still keeping the main idea: firms generate private benefits in form of wages and employment. As discussed above, introducing an additional immobile income source does not alter the results of our analysis, even if it is related to the level of firm investment. Furthermore, we are able to confirm our results in a micro-founded model similar to Hindriks *et al.* (2008).[25] More generally, our results hold for any form of economy for which a jurisdiction's within-period utility is a concave function of its own tax rate.

The other important modeling choice refers to the market for government bonds. Public borrowing is assumed to take place on an international debt market with an exogenous interest rate. Both assumptions may not hold in reality. For example, governments may largely borrow domestically. In this case, the repayment burden in period 1 is a simple transfer between the government and its citizens. We note, however, that $\gamma > 1$ ensures that an increase in the debt repayment burden affects the marginal utility of public infrastructure investment and thus triggers the mechanism described above. Finally, private borrowing may serve as a substitute for inter-temporal redistribution by the government. This appears feasible with regard to the consumption of the private good. Public goods are, however, generally provided more efficiently by the government[26] such that private borrowing is, at best, an imperfect substitute for public redistribution across periods.[27] Thus, inter-temporal

[25] Results are available from the authors upon request.

[26] In this regard, the simplifying assumption of a representative citizen in our model constitutes an exemption which would need to be relaxed to determine the optimal way of public goods provision.

[27] An additional requirement for private borrowing to completely compensate for the public bor-

adjustments via reductions in public infrastructure spending remain relevant. Furthermore, some citizens are likely to borrow at a higher cost, this cannot completely compensate for the public borrowing restriction.

Another important assumption we made is that the interest rate is exogenous. Alternatively, one could allow for a positive, possibly convex relation between the interest rate and the level of public borrowing in the current or the previous period. The case of a contemporaneous relationship turns out to be a simple extension to our model in which the marginal increase in the initial public debt burden is reinforced by its effect on the interest paid.[28] The case with a lagged relationship introduces a cost on the inter-temporal redistribution via public borrowing. If the relation between past borrowing and the current interest rate is non-linear (e.g. convex), this precludes the friction-less reallocation of resources between periods through additional borrowing. As a consequence, more borrowing is not necessarily the best option for inter-temporal redistribution since the corresponding costs must be compared to the cost of redistribution between periods via an adjustment in long-run public infrastructure investment. Our results thus rely on the assumption that public borrowing is generally used as the best option for inter-temporal utility-smoothing in the sense of Barro (1979).

5.5 Empirical Evidence

We test the main implications of our theoretical analysis using administrative data from German municipalities. We do not aim at fully identifying the causal relationships suggested in the model as this would require further information which is hard to obtain. For example, we do not know whether and to what extent jurisdictions are constrained in their public borrowing. Still, the empirical analysis is an important first step towards verifying the mechanism proposed in our theoretical model.

The case of Germany is a good testing ground as the constitution provides municipalities with substantial discretion in fiscal policy. Each municipality approves its own budget, which includes decisions on public borrowing and public investment expenditure. Furthermore, several tax rates are set at the municipal level such as the taxation of business profits ("Gewerbesteuer"). Most importantly, fiscal policy in German municipalities varies substantially both with respect to the tax rates

rowing restriction is that, on average, citizens do not borrow at a cost above the one faced by the government.

[28]Formally, $\frac{\partial^2 U^i}{\partial m_i \partial b_{i0}} = h''_{i1}\gamma^2 \left(1 + r + \frac{\partial r}{\partial b_{i0}} b_{i0}\right) c' < h''_{i1}\gamma^2 (1+r)\, c' < 0.$

applied and in terms of the debt ratio.

5.5.1 Empirical Specification

To test the main results of our theoretical analysis, we apply an event study design. Originally developed by Fama *et al.* (1969) for the analysis of stock market responses, this methodology is now also widely used in the area of public economics (e.g. Hoynes & Schanzenbach, 2012; Chetty *et al.*, 2014; Fuest *et al.*, 2018). In our context, we measure the responses of jurisdictions within a pre-defined time window around a particular event of interest. In this way, event studies allow for a precise analysis of the timing of responses which is crucial for our purposes as we test an inter-temporal model with policy responses that are not necessarily contemporaneous.

We estimate the response of two fiscal policy instruments to shocks in the debt-repayment burden of individual municipalities. The latter are defined as years in which the level of net redemption payments of a municipality is extraordinarily high. Net redemption payments are defined as the difference between the total debt redemption payment and additional revenue obtained from issuing new debt in the same period. The value of net redemption payments is set to zero whenever newly issued credit exceeds redemption payments.[29] We then compute the share of net redemption payments in the net expenditure of a municipality for each individual year and also the average of this share within a municipality across the observation period. A shock is defined as a municipal-year observation in which the share is at least three times as high as its average within the municipality. Therefore a shock constitutes a substantial increase in the debt repayment burden of a municipality and corresponds to an increase in the initial debt burden, b_{i0}, in our theoretical model, which in turn results in a net repayment burden in period 1 of $b_{i1} - (1+r)b_{i0}$.

An alternative specification would be to regress the fiscal policy variables of interest on the lagged level of public debt. Instead, we analyze debt-repayment shocks for three reasons. First, by focusing on unit-specific events we avoid a number of endogeneity issues related to the inter-temporal correlation of fiscal variables and other equilibrium effects that would arise in a framework with lagged variables. Second, within a region public debt levels of neighboring municipalities are likely to be correlated (e.g. see Borck *et al.*, 2015). This aspect makes it difficult to identify fiscal competition effects, which only occur when initial debt levels diverge. In contrast,

[29]This avoids classifying temporary reductions of municipal borrowing with a continuing increase in public debt as debt repayment shocks.

the debt repayment shocks that we observe are confined to individual municipalities and thus constitute an asymmetry in a competitive environment. Finally, in order to apply an event study design with its various econometric and conceptual advantages, we need to define changes in the initial debt repayment burden as events. A feasible way to do this is to look at debt repayment shocks.

Our empirical model takes the following form:

$$y_{i,t} = \alpha_{-4} \sum_{n=4}^{t-1998} s_{i,t+n} + \sum_{n=-3}^{-2} \alpha_n s_{i,t-n} + \sum_{n=0}^{4} \alpha_n s_{i,t-n} + \alpha_5 \sum_{n=5}^{2012-t} s_{i,t-n} + \boldsymbol{\beta_2 x_{i,t}} + \boldsymbol{\psi} + \epsilon_{i,t}. \quad (5.16)$$

$y_{i,t}$ is the fiscal policy variable of interest in municipality i at year t, and $s_{i,t}$ is a dummy that indicates whether in year t municipality i experienced a debt repayment shock as described above. Within the first and last year in our sample, 1998 and 2012, we define an event window of 10 years, that is, we observe 4 years before and 5 years after the repayment shock as well as the shock year itself.[30] In each year, we thus compare the treated municipalities to those that did not experience a debt repayment shock in this particular period. Following Kline (2012), we adjust the end points of the event window to indicate whether a debt repayment shock has occurred 4 or more years before (upper window limit) and 5 or more years after a given year (lower window limit) in order to mitigate collinearity with the year-fixed effects. The resulting coefficients, however, do not assign the same weights to municipalities with events early and late in our observation period since the sample is generally unbalanced in event time. As in Kline (2012), the interpretation of the results thus focuses on the coefficients for indicators within the event window. To avoid perfect collinearity among the shock indicators, the regressor in the year before the repayment shock is dropped and normalized to zero. As a consequence, the remaining coefficients α_t are interpreted as the effect of the shock on $y_{i,t}$ relative to the pre-shock year.

We test the theoretical predictions by analyzing the response of local business tax rates and local public investment expenditure to the debt repayment shocks. Both measures are decided by the municipal council and may be adjusted each year. Local public investment is measured as the logarithm of investment expenditure of the municipality.

[30] Expanding or contracting the event window leads to virtually the same results.

We complement our model by a vector of lagged control variables, $\boldsymbol{x}_{i,t}$, including the logarithm of total population and the logarithm of GDP per capita in the district of the municipality. Furthermore, we intend to capture unobserved confounding factors by including a set of fixed effects which comprises municipality-fixed effects, year-fixed effects and state-year-fixed effects. The latter take into account that time trends may vary across states (*Länder*).

Since our fiscal competition model relies on the interaction between competing jurisdictions, we are not only interested in the response of the municipality that experiences the debt repayment shock but also in the response of its competing neighbors. We therefore rerun the model described above replacing the variables $y_{i,t}$ and $\boldsymbol{x}_{i,t}$ with the weighted average of the respective variables across the neighboring municipalities that are within 10 kilometers of municipality i. Using inverse distance weights in terms of the difference in total population between the municipality and its neighbor[31], we observe how fiscal policy evolves in the neighboring jurisdictions of a municipality when it experiences a debt repayment shock.

The effect is identified by comparing the neighbors of treated and untreated municipalities in each year. Note that the control group includes the whole sample in both regressions. Following our theoretical analysis, fiscal competition implies that the neighboring localities are affected by the debt repayment shock as well and are thus analyzed in a separate regression.

5.5.2 Data

The data set contains information on fiscal variables, including local tax rates, of all municipalities in Germany from 1998 to 2013. In total, there are 11,064 municipalities in our sample. The effective business tax rates are obtained by multiplying the base rate ("Steuermesszahl") of 3.5% (5% until 2007) with the local tax rate ("Hebesatz"), which is determined each year by the municipal council. The base rates are determined at the federal level and are therefore not a local choice variable. The effective business tax rates in our sample range from 0% to 45% with an average of 14.9%. About 17.2% of municipalities change their local business tax rate within the sample period. 57.5% of the municipalities in our sample experience a debt repayment shock in the sample period. Only 3.5% of municipalities have more than two shocks. The empirical framework described above accounts for the occurrence

[31] In a robustness check we have used distance weights in terms of geographical distance in kilometers and obtained very similar outcomes. Results are available from the authors upon request.

of more than one event within a unit. The full set of descriptive statistics can be found in Appendix D.6.

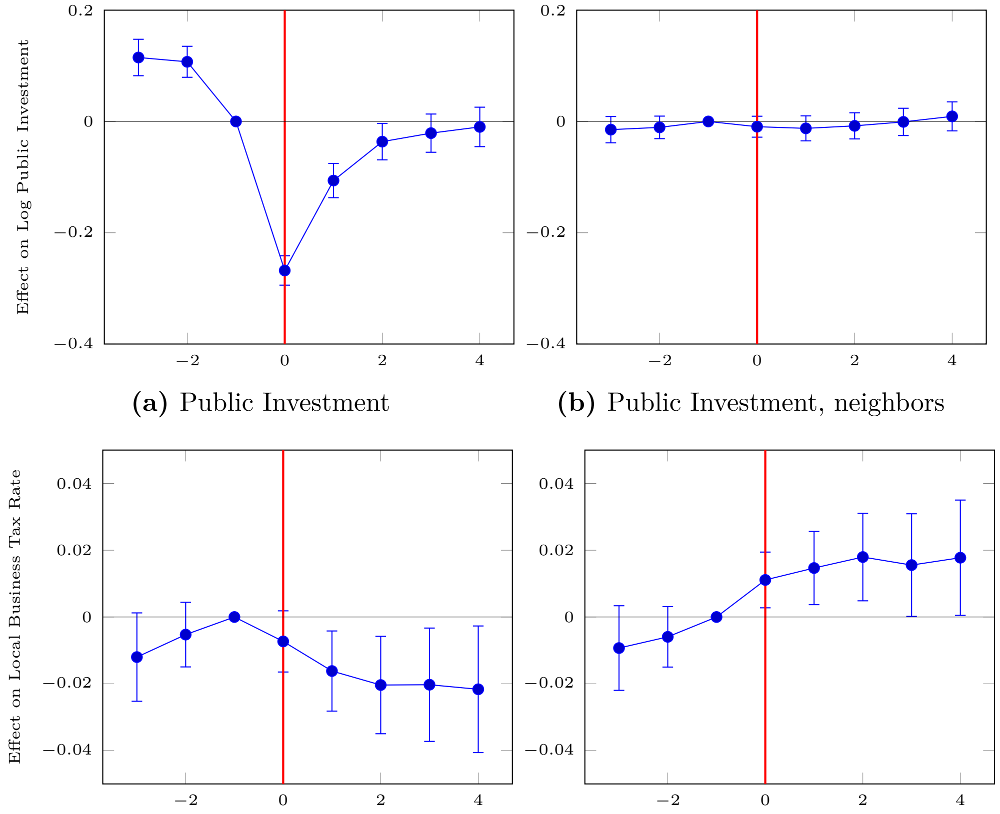
5.5.3 Results

We present our results in the form of event-study graphs. Figure 5.1 displays graphs for the response of both the municipality itself (panels a and c) and the neighboring municipalities (panels b and d). We first explore the response of municipalities that experience a debt repayment shock. Results displayed in panel (a) of Figure 5.1 show that, relative to the pre-shock year, the treated jurisdictions substantially reduce their investment expenditure in the year of the shock and also in the years immediately after the shock.[32] The main effect occurs instantly, with a decrease of public investment expenditure of 26.8% in the year of the shock. The negative effect is smaller in later years and diminishes to an insignificant decrease of 0.1% five years after the shock. This is consistent with our theoretical analysis. Note that the level of public investment is also higher prior to the shock. This positive effect does not match the negative effect after the repayment shock. Yet the finding suggests that at least part of the increase in initial debt burden may be related to an earlier increase in public infrastructure investment. We have considered this aspect in our theoretical model in Section 5.4.2.

We now turn to the response of municipal tax rates. Panel (c) depicts the impact of the repayment shock on the local business tax rate. We find no effect in the year of the shock but the tax rate is about 0.02 percentage points lower in each of the following four years. The delayed response mirrors the dynamics in the theoretical analysis. While the reduction in investment expenditure is immediate, the tax rate cut - that is aimed at restoring the jurisdiction's attractiveness - only occurs in later periods when a lower level of past investment and thus less public infrastructure becomes effective. The estimated tax cut is significant but relatively small in absolute size. We attribute this finding to a generally low level of tax competition among German municipalities. The lack of fiscal competition among German municipalities

[32]Since several highly indebted municipalities in Germany have eliminated their debt burden by selling municipal assets such as real estate to repay outstanding debt, one might be concerned that these events drive our results. In particular, the reduction in the stock of public capital induced by the assets sales might have also triggered the subsequent decrease in public investment. We ensure that this is not the case by repeating the analysis excluding all municipalities involved in substantial real estate privatizations during the observation period. Information for this exercise has been provided by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). We obtain virtually the same results when excluding these municipalities.

Figure 5.1: Event Study



(a) Public Investment **(b)** Public Investment, neighbors

(c) Local Business Tax Rate **(d)** Local Business Tax Rate, neighbors

Standard errors are clustered on firm level. 95% confidence intervals are reported. Estimations include municipality-fixed, year-fixed and state-year-fixed effects.

has mainly been explained by the existence of equalization grants for municipalities in many German states (Baretti *et al.*, 2002; Buettner, 2006; Egger *et al.*, 2010). Furthermore, previous studies have found only small cross-border effects of local tax rates in Germany (e.g. Buettner, 2003).

How do competing municipalities react to debt repayment shocks affecting their neighbors? As described above, we approach this issue in an additional estimation involving the weighted average of a municipality's neighbors. Results are presented in panels (b) and (d) of Figure 5.1. Again, we begin with the response of public infrastructure investment. Our results suggest that competing neighbors of municipalities that experience a strong increase in the debt repayment burden do not alter their level of public investment expenditure. This implies that in our sample the strategic interaction in infrastructure expenditure is not very strong. One explanation is that an upward adjustment in infrastructure, as indicated by our theoretical model, is not easily achieved in practice as new investment opportunities have to be developed first. In contrast, municipalities can easily reduce current investment expenditure by postponing or canceling planned investment projects.

With respect to local taxation, our results suggest that neighboring governments increase their tax rates for local business profits. This finding is consistent with our theoretical model and is an indicator of tax competition. The decrease in public investment in the municipality experiencing a debt repayment shock induces its neighbor to increase business taxes. Neighboring municipalities thus exploit the relative decrease in the attractiveness of the treated municipality to increase local revenue from business taxes without reducing the local tax base. Again, the absolute effect is relatively small.

5.6 Conclusion

In this paper, we have used a two-jurisdiction, two-period model to analyze a fiscal competition game with asymmetric initial public debt levels. We first show that in the absence of government default the level of legacy public debt does not affect the fiscal competition game. Governments merely shift the repayment burden to future generations by increasing additional borrowing one by one. We then allow for government default which endogenously imposes an upper bound on public debt. This restricts inter-temporal redistribution of governments and provides an important theoretical link between legacy debt and fiscal competition.

In the presence of restricted public borrowing the government's decision on long-term infrastructure investment is shaped by its desire to optimally allocate resources between periods. A higher level of legacy debt causes the government to decrease public investment in the first period, making the jurisdiction a less attractive location for private investment in the following period. Governments partly compensate this disadvantage by setting lower tax rates in the second period. In our two-jurisdiction model, the jurisdiction experiencing an increase in legacy debt therefore invests less and sets a lower tax on capital, while the opposite occurs in the other (unconstrained) jurisdiction. Under mild assumptions, this mechanism is the stronger the higher is the level of capital mobility. Capital mobility, therefore, leads not only to downward pressure on tax rates, as is well known, but tends to reinforce the effect of initial debt.

We show that the fiscal behavior of municipalities in Germany is broadly in line with the theoretical model predictions. Tax rates diverge when a municipality experiences a debt repayment shock. While the response is statistically significant, it is relatively small in value, which may be explained by the strong fiscal equalization scheme and the large number of interacting municipalities. We also find a strong negative public investment response by the municipality experiencing the shock. Neighboring regions, however, do not adjust in a significant way their public investment, as our benchmark result predicts, perhaps because increases in investment take more time compared to cuts.

Our results provide insights into current policy debates. For example, in Germany the federal states (Länder) have little tax autonomy. Some policy makers and many academics support more tax autonomy for states such as a state income and business tax. Given that states differ widely in existing debt levels, it is not clear whether and how existing debt would influence the competitiveness in a subsequent fiscal competition game. Our model suggests that default on government debt plays a crucial role and would disadvantage highly indebted regions. Among German states per capita debt levels differ significantly, including a few with very high levels. Opponents of more tax autonomy may therefore find support for their view in our model. So far, however, German states do not appear to be substantially constrained in their borrowing, as an implicit bail-out guarantee by the German federal government and the collection of all states is provided in the German constitution.

Our model sheds also light on the efforts to harmonize taxes in the European Union, which in the area of business taxation have proven to be difficult. The economic and financial crisis has led to a substantial increase in debt levels, which in some countries still prevail while others have reduced them back to near pre-crisis levels. Attempts to harmonize tax rates may have become more difficult now. Countries with a high debt repayment burden may have very different fiscal policy strategies than governments with a low level of consolidation requirement.

A Appendix to Chapter 2

A.1 Additional Descriptive Statistics

Table A.1: Corporate M&As, 2002-2013, Additional Data

This table presents the number and volume of deals with cash payment and corporate sellers per country from 2002-2013 as recorded in the Zephyr database. Listed targets are excluded. Data is trimmed at the 1st and 99th percentile according to deal value. The deals are assigned to the country of residence of the seller company. The revealed deal volume is the sum of reported deal values.

	Only cash payments, domestic targets		All payments, all targets	
	Number of deals	Revealed deal volume in bn US$	Number of deals	Revealed deal volume in bn US$
Australia	1,006	41.55	1,372	66.23
Austria	318	7.17	489	11.13
Belgium	446	9.80	668	24.50
Canada	704	27.08	1,289	56.32
Croatia	67	0.32	75	0.43
Cyprus	50	2.79	345	14.91
Denmark	702	13.53	913	20.69
Finland	1,091	8.47	1,371	14.17
France	1,660	55.93	2,258	93.21
Germany	2,209	60.71	3,088	96.87
Greece	167	2.83	225	5.76
Iceland	45	0.71	95	1.77
Ireland	119	7.02	265	13.89
Israel	108	4.61	154	6.97
Italy	1,130	60.87	1,434	81.04
Japan	2,043	37.97	2,489	52.57
Luxembourg	30	2.64	259	23.77
Mexico	57	5.98	64	6.52
Netherlands	1,608	39.05	2,368	98.03
New Zealand	158	4.73	197	6.17
Norway	822	15.63	1,090	22.60
Portugal	212	10.86	255	12.75
Slovenia	38	0.60	50	0.62
South Korea	203	13.16	254	15.52
Spain	1,188	43.55	1,429	65.26
Sweden	1,445	22.63	1,924	44.02
Switzerland	621	11.80	999	27.19
Turkey	237	22.39	258	24.11
United Kingdom	4,327	157.94	5,908	261.67
United States	5,681	326.36	7,634	465.86
Total	28,492	1,019	39,219	1,635

Table A.2: Variables

Variable	Description	Source
GDP	Lagged logarithm of GDP in constant (2005) US$	WDI
Growth	Lagged annual GDP growth in %	WDI
Credit	Lagged domestic credit to private sector as a share of GDP	WDI
Stock Market	Lagged market capitalization of listed firms as a share of GDP	WDI
τ^{CIT}	Top statutory corporate income tax rate	IBFD
Trade	Lagged logarithm of the trade ratio	WDI
Audit Quality	Strength of auditing and reporting standards index (1-7, best)	Global Competitiveness Report
Inflation	Lagged inflation	WDI
Service Sector	Value added of services in % of GDP	WDI
Start-up Time	Number of days needed to start a business	World Bank
Judicial Independence	Indicator for judicial independence (0-10, highly independent)	Index of Economic Freedom
Ease of Hiring	Ease of hiring index (0-10, very easy)	Index of Economic Freedom
Credit Market Regulation	Indicator for credit market regulation (0-10, strongly deregulated)	Index of Economic Freedom
Interest Rate	Interest rate on national government securities	OECD
Industry Shock	Standard deviation in value added growth across 8 sectors	WDI
Total Assets	Logarithm of total assets of the acquirer in the last available year prior to the deal, th US$	Bureau van Dijk
Contiguity	Dummy indicating whether the acquirer and the target location share a common border	CEPII GeoDist Database
Language	Dummy indicating whether the acquirer and the target location share a common official language	CEPII GeoDist Database
Colony	Dummy indicating whether the acquirer and the target location have ever been in a colonial relationship	CEPII GeoDist Database
Distance	Logarithm of the simple distance between the capitals of the acquirer and the target location, km	CEPII GeoDist Database
Home	Dummy indicating whether the acquirer and the target location are or have been the same country	CEPII GeoDist Database
Regulation	Indicator for regulation (0-6, strongly regulated)	OECD
Prod. Growth Contribution	Industry contribution to growth in business sector labor productivity, employment based	OECD
Employment Growth	Annual growth in total number of employees in the sector	OECD
Compensation	Annual growth in the compensation per employee in the sector	OECD
Unit Labor Cost Growth	Annual growth in unit labor costs in the sector, employment based	OECD

Table A.3: Capital Gains Across Industries

This table reports the number of deals and the median capital gains for individual SIC divisions over the sample period. The capital gain in any period is the current stock price minus the low stock price in the 3 or 5 preceding years divided by the low stock price in the 3 or 5 preceding years.

SIC Division	Number of Deals	Median capital gain over 3 years	Median capital gain over 5 years
Mining	587	49.32%	65.27%
Construction	707	48.59%	63.78%
Manufacturing	7,937	49.07%	64.71%
Transportation, Communications, Electric, Gas, And Sanitary Services	3,491	39.58%	51.82%
Wholesale Trade	1,669	47.04%	61.09%
Retail Trade	1,852	47.62%	63.18%
Finance, Insurance, And Real Estate	3,632	24.99%	33.44%
Services	9,158	52.24%	66.67%
Public Administration	166	22.44%	25.13%

A.2 Additional Estimation Results

Table A.4: Robustness: Nearest-Neighbor Matching

This table replicates Table 2.6 using weighted nearest neighbor interpolation to compute the time between deal announcement and completion. Distance d_{ij} is measured in absolute number of days between the announcement dates of two deals i and j. We include the five nearest neighbors, use power distance weights with an exponent $\alpha = 3$ and row-normalize weights so that the weight for observation j within the 5 nearest neighbors is given by $w_{ij} = d_{ij}^{-\alpha} / \sum_{j=1}^{5} d_{ij}^{-\alpha}$. Estimation with PPML. The dependent variable is the number of M&A deals per year and country in which a corporate seller disposes of shares in a target firm residing in the same country. Regression (1), (2), (3) and (4) replicate regressions (2), (3), (4) and (5) of Table 2.6, respectively. All regressions include country- and year-fixed effects. Cluster robust standard errors (clustered at the country level) are provided in parentheses, except for column (2) where the parentheses contain Wald test t-statistics obtained from the score wild bootstrap method proposed by Kline & Santos (2012). Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)
	Full Sample	Full Sample	Bootstrap	w/o Holding Locations	Deal Value
τ^{CG}	-0.009**	-0.010**	-0.010*	-0.011***	-0.013**
	(0.004)	(0.004)	(-1.592)	(0.004)	(0.006)
Audit Quality	0.568***	0.392***	0.392***	0.346**	0.428***
	(0.171)	(0.118)	(2.423)	(0.136)	(0.163)
Growth	0.035***	0.038***	0.038***	0.038***	0.006
	(0.011)	(0.012)	(2.572)	(0.013)	(0.020)
Trade	1.200**	1.077*	1.077*	1.326**	0.355
	(0.610)	(0.572)	(1.190)	(0.537)	(1.122)
Credit	0.011	-0.046	-0.046	0.022	-0.832***
	(0.127)	(0.131)	(-0.314)	(0.121)	(0.258)
GDP	-0.739	-0.851	-0.851	-0.594	2.989**
	(1.357)	(1.128)	(-0.692)	(1.081)	(1.194)
Stock Market	0.228	0.196	0.196	0.295*	0.424*
	(0.158)	(0.137)	(1.250)	(0.155)	(0.229)
Inflation	-0.018*	-0.020**	-0.020**	-0.018*	-0.052***
	(0.010)	(0.009)	(-1.319)	(0.009)	(0.015)
Service Sector	0.009	0.007	0.007	0.012	0.059**
	(0.013)	(0.013)	(0.563)	(0.014)	(0.023)
τ^{CIT}	0.007	0.007	0.007	0.016	0.009
	(0.014)	(0.012)	(0.535)	(0.012)	(0.021)
Start-up Time		-0.001	-0.001	-0.001	0.004
		(0.002)	(-0.447)	(0.001)	(0.003)
Jud. Independence		0.167***	0.167***	0.184***	0.064
		(0.055)	(2.419)	(0.055)	(0.071)
Ease of Hiring		-0.035	-0.035	-0.027	0.034
		(0.033)	(-1.009)	(0.038)	(0.058)
Credit Market Reg.		0.080***	0.080**	0.098***	-0.025
		(0.029)	(1.749)	(0.026)	(0.059)
Observations	333	313	313	266	313
No. of countries	30	29	29	24	29
Pseudo LL	-1,501	-1,360	-1,473	-1,190	-7.539e+07

Table A.5: Interaction with location choice fixed effect and acquirer-specific variables

This table contains the estimated or simulated coefficients for the country-fixed effects and their interaction with the logarithm of total assets from specifications (2) and (4) in Table 2.5. The United States is the base category.

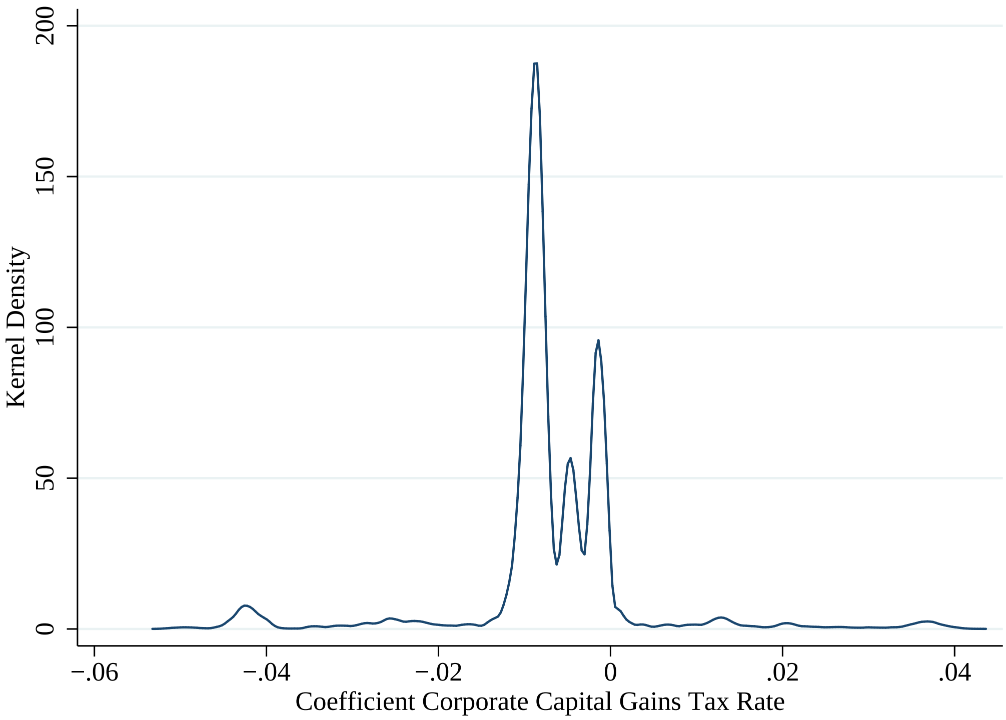
	Conditional Logit		Mixed Logit	
	Coefficient	SE	Coefficient	SE
$AU \times \ln TotalAssets$	-0.037	0.028	-0.021	0.031
$AT \times \ln TotalAssets$	-0.021	0.052	-0.005	0.059
$BE \times \ln TotalAssets$	-0.084***	0.021	-0.045*	0.023
$CA \times \ln TotalAssets$	0.005	0.014	0.044***	0.016
$HR \times \ln TotalAssets$	0.015	0.068	0.039	0.069
$CY \times \ln TotalAssets$	0.136	0.136	0.180	0.149
$DK \times \ln TotalAssets$	-0.065***	0.019	-0.022	0.021
$FI \times \ln TotalAssets$	-0.011	0.041	0.028	0.042
$FR \times \ln TotalAssets$	-0.052***	0.017	-0.024	0.020
$DE \times \ln TotalAssets$	-0.096***	0.013	-0.054***	0.016
$GR \times \ln TotalAssets$	-0.032	0.032	-0.019	0.036
$IS \times \ln TotalAssets$	0.267**	0.108	0.324***	0.114
$IE \times \ln TotalAssets$	-0.087**	0.035	-0.046	0.038
$IL \times \ln TotalAssets$	-0.118***	0.033	-0.108***	0.035
$IT \times \ln TotalAssets$	-0.032	0.022	0.005	0.024
$JP \times \ln TotalAssets$	-0.040*	0.022	-0.033	0.023
$LU \times \ln TotalAssets$	0.147	0.148	0.182	0.158
$MX \times \ln TotalAssets$	-0.039	0.037	-0.016	0.038
$NL \times \ln TotalAssets$	-0.107***	0.020	-0.067***	0.024
$NZ \times \ln TotalAssets$	0.017	0.061	0.052	0.066
$NO \times \ln TotalAssets$	-0.038	0.027	-0.001	0.030
$PT \times \ln TotalAssets$	0.087***	0.031	0.124***	0.036
$SI \times \ln TotalAssets$	0.012	0.097	0.041	0.104
$ES \times \ln TotalAssets$	0.006	0.023	0.048*	0.025
$SE \times \ln TotalAssets$	-0.059***	0.018	-0.018	0.021
$CH \times \ln TotalAssets$	-0.039	0.036	0.004	0.039
$TR \times \ln TotalAssets$	-0.016	0.031	0.014	0.034
$UK \times \ln TotalAssets$	-0.076***	0.022	-0.039	0.025
AU	3.459	2.367	2.725	2.458
AT	1.899	3.245	0.738	3.439
BE	3.780	2.745	1.807	2.828
CA	0.764	1.790	-0.749	1.842
HR	1.585	4.420	-0.004	4.506
CY	-2.326	7.346	-4.956	7.789
DK	4.320	2.927	2.136	3.003
FI	2.814	3.622	0.756	3.665
FR	2.314	1.487	1.187	1.582
DE	3.603***	1.269	1.948	1.350
EL	2.969	3.155	1.842	3.325
IS	-6.956	7.061	-10.323	7.294
IE	3.759	3.294	1.598	3.390
IL	5.647	3.512	4.747	3.607
IT	1.895	1.563	0.396	1.631
JP	1.148	1.071	0.888	1.137
LU	-5.715	7.501	-7.888	7.950
MX	1.920	2.388	0.864	2.444
NL	4.777**	2.386	2.855	2.483
NZ	1.483	3.978	-0.623	4.127
NO	3.444	2.793	1.568	2.894
PT	-1.510	3.241	-3.428	3.375
SI	0.959	5.791	-0.975	6.051
ES	1.136	1.934	-0.639	2.016
SE	4.320	2.714	2.310	2.802
CH	1.892	2.905	-0.223	3.011
TR	2.134	2.643	0.730	2.772
UK	3.284**	1.636	1.710	1.746

Table A.6: Comparison Group Approach: Control Variables

This table reports coefficient estimates for the control variables and their interactions with the seller-type indicator used in the regressions of columns (2) to (4) in Table 2.8. Cluster robust standard errors (clustered at the country-level) are provided in parentheses. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	Full Sample (2)	Only Cash Payments (3)	Including Foreign sellers (4)
Audit Quality	-0.042	-0.147	-0.157
	(0.218)	(0.228)	(0.216)
Audit Quality × $CORPS$	0.485**	0.569**	0.512**
	(0.215)	(0.224)	(0.213)
Growth	0.046*	0.044*	0.038
	(0.023)	(0.026)	(0.025)
Growth × $CORPS$	-0.006	-0.005	-0.014
	(0.025)	(0.028)	(0.027)
Trade	0.018	-0.117	0.013
	(0.889)	(0.957)	(0.900)
Trade × $CORPS$	1.292*	1.375*	1.201*
	(0.670)	(0.726)	(0.725)
Credit	-0.707**	-0.781**	-0.689*
	(0.330)	(0.312)	(0.354)
Credit × $CORPS$	0.765***	0.807***	0.725**
	(0.274)	(0.263)	(0.314)
GDP	-1.927	-1.805	-1.937
	(1.886)	(2.002)	(2.031)
GDP × $CORPS$	1.038	0.956	1.588
	(1.597)	(1.688)	(1.788)
Stock Market	0.439	0.508*	0.507*
	(0.270)	(0.297)	(0.281)
Stock Market × $CORPS$	-0.260	-0.318	-0.415
	(0.307)	(0.333)	(0.318)
Inflation	-0.017	-0.019	-0.017
	(0.015)	(0.014)	(0.014)
Inflation × $CORPS$	-0.004	-0.003	0.001
	(0.013)	(0.013)	(0.012)
Service Sector	-0.002	0.006	0.011
	(0.022)	(0.024)	(0.023)
Service Sector × $CORPS$	0.009	0.001	-0.006
	(0.017)	(0.018)	(0.018)
τ^{CIT}	0.028**	0.022	0.024*
	(0.014)	(0.014)	(0.013)
τ^{CIT} × $CORPS$	-0.017	-0.013	-0.018
	(0.014)	(0.015)	(0.013)
Start-up Time	0.007	0.007	0.007
	(0.004)	(0.004)	(0.004)
Start-up Time×$CORPS$	-0.008**	-0.007**	-0.007**
	(0.004)	(0.004)	(0.003)
Jud. Independence	0.073	0.064	0.059
	(0.072)	(0.075)	(0.067)
Jud. Independence×$CORPS$	0.097**	0.110**	0.077
	(0.049)	(0.051)	(0.051)
Ease of Hiring	-0.105	-0.145	-0.128
	(0.103)	(0.106)	(0.102)
Hiring Restrictiveness×$CORPS$	0.071	0.113	0.103
	(0.092)	(0.094)	(0.092)
Credit Market Reg.	-0.036	-0.034	-0.016
	(0.083)	(0.082)	(0.077)
Credit Market Reg.×$CORPS$	0.108	0.105	0.077
	(0.068)	(0.068)	(0.065)

Figure A.1: Kernel Density



This figure plots the kernel density of the simulated coefficients for τ^{CG} obtained in regression (5) of Table 2.5 following the method of Train (2009). The estimated coefficients have a mean of -0.007 and a standard deviation of 0.037.

B Appendix to Chapter 3

B.1 Productivity Estimation Data Sample

We obtain unconsolidated balance sheet data for the productivity estimation from Bureau van Dijk's ORBIS and AMADEUS databases. In a first step, missing values are imputed as described in Gal (2013). In particular, firm value added is replaced by the sum of operating revenue and material cost if missing. Conversely, material cost is replaced by the difference between operating revenue and value added if both items are available.

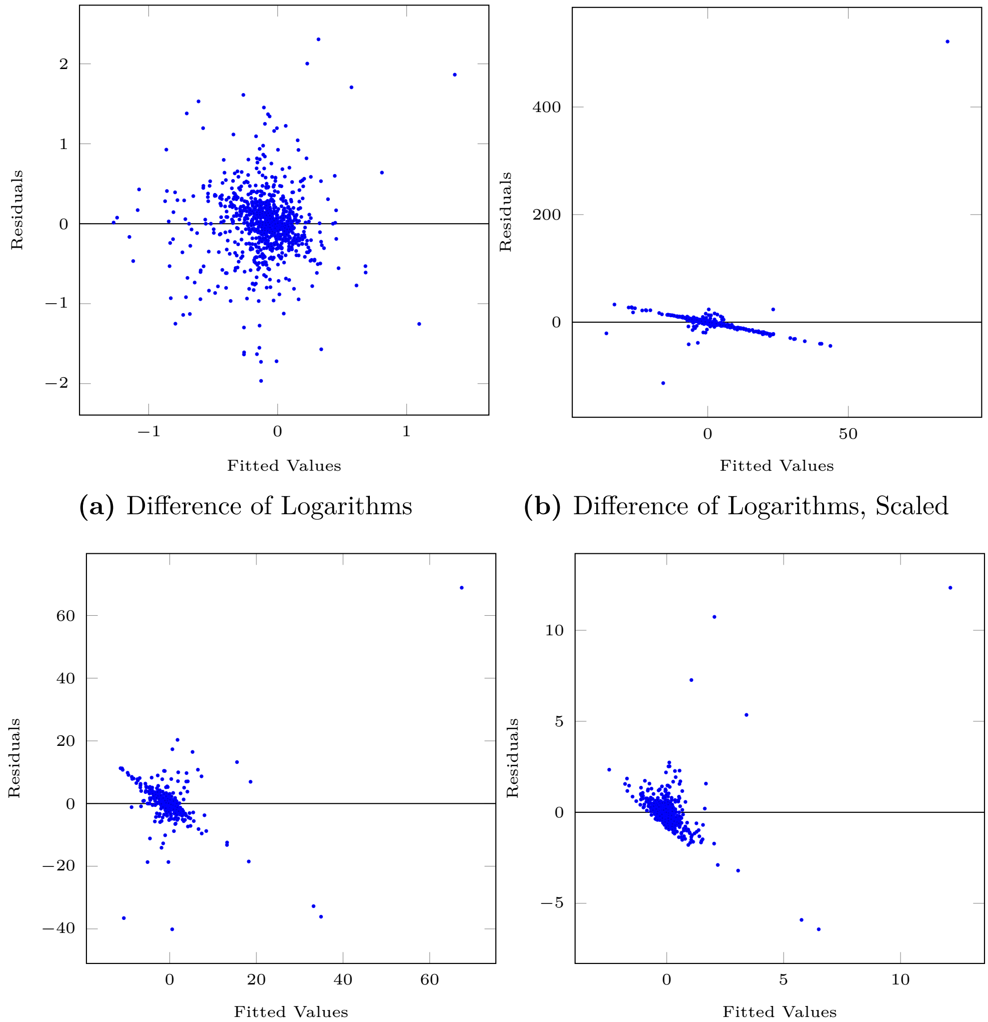
The second step is to eliminate inconsistent data points from the sample. We drop all firm-year observations with a sum of EBIT and cost of employees that is not strictly positive. Furthermore, we drop observations with negative operating revenue or material cost as well as those with total assets below 1,000 USD. Further potential mistakes in the accounts are captured by deleting extreme outliers. We drop observations for which any of the following ratios lies below the 0.1% or above the 99.9% quantile of the sample within a year: operating revenue to total assets, number of employees to total assets, number of employees to operating revenue, operating revenue less material cost to operating revenue, operating revenue less material cost to number of employees. We also drop observations where the sum of fixed intangible assets, fixed tangible assets and other fixed assets does not add up to a figure that is close to the entry for total fixed assets ($\pm 5\%$).

Finally, we adjust the balance sheet items for inflation and cross-border differences in purchasing power to obtain the evolution of productive factors and output in real terms. For this purpose we apply the GDP deflator and the Purchasing Power Parity conversion factor for the GDP for 2005 prices to the nominal balance sheet items.

B.2 Choice of Specification

There are several ways to transform the dependent variable in the deal-level regression model. Here, we consider four alternatives: the simple difference of TFP before

Figure B.1: Transformations of Dependent Variable



(a) Difference of Logarithms **(b)** Difference of Logarithms, Scaled

(c) Simple Difference **(d)** Simple Difference, Scaled

and after the merger, $\hat{\Gamma}_{jlk} = A_j^{Post} - A_j^{Pre}$, the simple difference scaled by TFP before the merger, $\hat{\Gamma}_{jlk} = \frac{A_j^{Post} - A_j^{Pre}}{A_j^{Pre}}$, the difference in logarithms, $\hat{\Gamma}_{jlk} = \ln A_j^{Post} - \ln A_j^{Pre}$ and the difference in logarithms scaled by the logarithm of TFP before the merger, $\hat{\Gamma}_{jlk} = \frac{\ln A_j^{Post} - \ln A_j^{Pre}}{\ln A_j^{Pre}}$. We regress each of these measures on the absolute tax differential $\Delta\tau_{jlk}$ and a set of fixed effects which corresponds to the model estimated in column (1) of Table D.2 and plot the fitted values against the residuals. These plots are presented in Figure B.1. Among the suggested transformations, only the difference in logarithms, depicted in the upper left panel, generates a random pattern that is required to assume a linear relationship after transforming the dependent variable. All other transformations generate a non-random pattern of residuals which implies that heteroscedasticity of the error terms is inherent in these models.

B.3 Additional Control Variables

Table B.1: Results for Country-level Controls of Regression Table 4.5

This table contains the coefficients for the OLS regressions of columns (2), (3), (5) and (6) of Table 4.5. Cluster robust standard errors (clustered at the acquirer-target country-pair level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	Change in Total Factor Productivity			
	(2)	(3)	(5)	(6)
CIT (Tgt.)	-0.575 (2.072)	-0.108 (2.082)	-0.659 (2.142)	-0.366 (2.143)
Wage Difference	3.315 (2.576)	1.925 (2.509)	3.135 (2.561)	1.373 (2.509)
GDP p.c. Growth (Acq.)	-3.857* (2.201)	-3.351 (2.115)	-3.806* (2.170)	-3.202 (2.053)
GDP p.c. Growth (Tgt.)	4.150* (2.366)	3.052 (2.091)	4.095* (2.350)	2.888 (2.054)
Log GDP (Acq.)	-2.910 (2.233)	-1.303 (2.137)	-2.716 (2.240)	-0.711 (2.159)
Log GDP (Tgt.)	2.143 (2.195)	1.247 (2.110)	1.959 (2.208)	0.684 (2.107)
EU Member	0.017 (0.366)	-0.101 (0.390)	0.012 (0.368)	-0.115 (0.391)
Log Distance	0.019 (0.080)	0.013 (0.067)	0.018 (0.081)	0.009 (0.067)

Table B.2: Results for Country-level Controls of Regression Table 3.6

This table contains the coefficients for the control variables in the OLS regressions of columns (2), (3), (5) and (6) of Table 3.6. Cluster robust standard errors (clustered at the acquirer-target country-pair level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	Change in Total Factor Productivity			
	(2)	(3)	(5)	(6)
Cross-border	0.086 (0.147)	0.060 (0.131)	0.101 (0.148)	0.083 (0.147)
Hostile	-1.001** (0.403)	-0.226 (0.327)	-0.972** (0.408)	-0.968** (0.409)
Stock-for-Stock	0.292* (0.171)	0.266 (0.192)	0.264 (0.179)	0.276 (0.175)
Capital Increase	-0.344*** (0.096)	-0.368*** (0.083)	-0.331*** (0.095)	-0.327*** (0.096)
Horizontal	-0.040 (0.034)	-0.021 (0.026)	-0.041 (0.034)	-0.041 (0.034)
Toe	0.052 (0.094)	0.120 (0.095)	0.054 (0.093)	0.054 (0.093)
Relative Size	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Leverage (Acq.)	0.029 (0.041)	0.003 (0.039)	0.034 (0.042)	0.031 (0.042)
Acquirer Listed	-0.067 (0.046)	-0.051 (0.043)	-0.071 (0.046)	-0.074 (0.048)
Log Age (Acq.)	-0.009 (0.016)	0.000 (0.020)	-0.011 (0.016)	-0.012 (0.016)
CIT (Tgt.)	-0.918 (1.899)	-0.292 (1.919)	-0.823 (1.904)	-0.806 (1.936)
Wage Difference	3.089 (2.443)	1.745 (2.407)	2.958 (2.748)	2.828 (2.467)
GDP p.c. Growth (Acq.)	-4.167* (2.171)	-3.731* (2.037)	-3.884* (2.144)	-4.023* (2.139)
GDP p.c. Growth (Tgt)	4.702** (2.344)	3.477 (2.097)	4.417* (2.334)	4.510* (2.282)
Log GDP (Acq.)	-2.866 (2.104)	-1.193 (2.035)	-3.042 (2.417)	-2.704 (2.195)
Log GDP (Tgt.)	1.752 (2.090)	0.953 (2.021)	2.124 (2.438)	1.726 (2.152)
EU Member	0.010 (0.360)	-0.114 (0.394)	-0.004 (0.374)	0.020 (0.366)
Log Distance	-0.032 (0.080)	-0.018 (0.067)	-0.031 (0.078)	-0.023 (0.075)

Table B.3: Results for Country-level Controls of Regression Table 3.7

This table contains the coefficients for the OLS regressions of Table 3.7. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm and industry-year fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1) Combined Firm	(2) Combined Firm	(3) Target Firm	(4) Target Firm	(5) Acquirer Firm	(6) Acquirer Firm
CIT (Tgt.)	1.049*	1.134**	0.105	0.063		
	(0.568)	(0.567)	(0.831)	(0.829)		
CIT (Acq.)					1.963***	2.024***
					(0.599)	(0.598)
Wage Difference	1.274	1.176	3.343**	3.057**	0.614	0.739
	(1.213)	(1.190)	(1.392)	(1.373)	(1.395)	(1.363)
GDP p.c. Growth (Acq.)	0.869	0.896	1.334	1.307	0.493	0.502
	(0.568)	(0.560)	(0.823)	(0.798)	(0.619)	(0.614)
GDP p.c. Growth (Tgt.)	-0.414	-0.385	-2.037***	-2.012***	0.384	0.455
	(0.501)	(0.488)	(0.788)	(0.747)	(0.606)	(0.595)
Log GDP (Acq.)	-1.416	-1.354	-2.878*	-2.779*	-1.309	-1.329
	(1.087)	(1.069)	(1.516)	(1.483)	(1.298)	(1.279)
Log GDP (Tgt.)	1.099	1.091	1.506	1.526	1.278	1.308
	(1.091)	(1.078)	(1.434)	(1.406)	(1.318)	(1.307)
$POST \times$EU Member	0.193	0.183	0.069	-0.016	0.153	0.157
	(0.124)	(0.113)	(0.175)	(0.179)	(0.111)	(0.103)
$POST \times$Log Distance	0.107***	0.109***	0.151***	0.166***	0.082	0.081
	(0.040)	(0.040)	(0.057)	(0.058)	(0.053)	(0.052)

Table B.4: Results for Country-level Controls of Regression Tables 3.8 and 3.9

This table contains the coefficients for the OLS regressions of Table 3.8 in columns (1a)-(4a) of Table 3.9 in columns (1b)-(4b). Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm and industry-year fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	Employment				Assets			
	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
	Target	Target	Acquirer	Acquirer	Target	Target	Acquirer	Acquirer
CIT (Tgt.)	0.949	0.899			-1.794	-1.617		
	(0.736)	(0.717)			(1.247)	(1.238)		
CIT (Acq.)			0.230	0.151			-0.864	-0.941
			(0.592)	(0.591)			(1.068)	(1.062)
Wage Difference	1.706	0.949***	-0.547	-0.467	0.498	1.052	2.160	1.712
	(1.349)	(0.213)	(1.186)	(1.174)	(2.266)	(2.298)	(2.062)	(2.036)
GDP p.c. Growth (Acq.)	1.045	1.156*	0.303	0.327	0.584	0.461	-0.045	0.119
	(0.755)	(0.696)	(0.526)	(0.526)	(1.062)	(1.045)	(0.979)	(0.938)
GDP p.c. Growth (Tgt.)	-0.698	-0.529	0.160	0.177	-0.383	-0.260	0.144	-0.033
	(0.758)	(0.709)	(0.480)	(0.475)	(1.038)	(1.013)	(0.934)	(0.881)
Log GDP (Acq.)	-1.494	-0.094	-0.006	-0.018	-0.273	-0.491	-2.670	-2.494
	(1.419)	(0.088)	(1.114)	(1.110)	(2.525)	(2.536)	(2.010)	(1.991)
Log GDP (Tgt.)	1.970	0.195**	0.243	0.237	1.001	1.083	2.010	1.885
	(1.364)	(0.095)	(1.090)	(1.089)	(2.438)	(2.438)	(1.976)	(1.966)
$POST \times$EU Member	0.090	0.085	-0.037	-0.021	0.088	0.132	-0.227*	-0.190
	(0.166)	(0.145)	(0.091)	(0.084)	(0.217)	(0.197)	(0.130)	(0.125)
$POST \times$Log Distance	0.045	0.004	0.035	0.032	-0.052	-0.056	0.053	0.052
	(0.049)	(0.048)	(0.039)	(0.038)	(0.090)	(0.089)	(0.068)	(0.067)

C Appendix to Chapter 4

C.1 Patent Boxes and Average Patent Quality

The average profits are given by

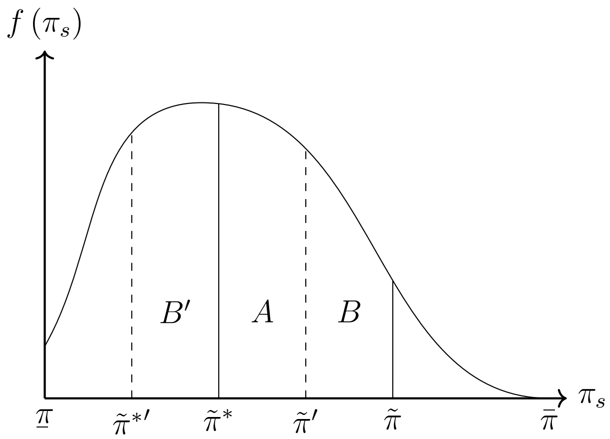
$$\Pi = \int_{\tilde{\pi}^*}^{\tilde{\pi}} \pi_s f(\pi_s)\, d\pi_s.$$

The change in Π with respect to the tax differential is given by

$$d\Pi = -\left((1-\alpha) \frac{(c_p - c_h)\, \tilde{\pi} f(\tilde{\pi})}{((1-\alpha)\,\Delta t)^2} + \alpha \frac{c_h \tilde{\pi}^* f(\tilde{\pi}^*)}{(1 - t_h + \alpha\Delta t)^2} \right) d\Delta t < 0.$$

C.2 Graphical Illustration of the Theoretical Framework

Figure C.1: Profit distribution and realized R&D projects



In Figure C.1 we display the effect of the patent box introduction graphically. We plot the density function of the profits of available research projects and mark the relevant cut-off profits. Initially, the firm realizes projects with profits greater than $\tilde{\pi}^*$ but locates R&D activity of projects with profits greater than $\tilde{\pi}$ to p. The overall share of projects realized in h is thus given by $A + B$. The introduction of a patent box in p shifts $\tilde{\pi}$ and $\tilde{\pi}^*$ to $\tilde{\pi}'$ and $\tilde{\pi}^{*'}$, respectively, such that the share of realized projects is given by $A + B'$. The overall effect relies on a comparison of B and B' which in turn depends on the setup of the patent box. B' refers to the increase of realized R&D projects in h because of the reduction in the user cost of R&D capital captured in the second term of equation (4.3). B describes the R&D activity which is shifted to p because of the foreign tax cut that reduces the number of projects realized in h and is reflected in the first term of expression (4.3). For a patent haven, α is close to 1 and $B = 0$ such that we obtain an increase in the share of R&D projects realized in h by B'. In contrast, when a nexus patent box is implemented, B and B' may neutralize each other leaving the number of research projects in h unchanged. Eventually, the direction of the effect is an empirical question and our analysis points out that it is important to take into account the precise incentive structure of the investigated patent box.

C.3 Composite Patent Quality Indicator

Patent quality is a latent variable which is not directly observable in the data. To approximate it, we follow the approach proposed by Lanjouw & Schankerman (2004) and employ a multiple-indicator model with one unobserved common factor. We use three different indicators, namely forward citations, patent family size and number of patent classifications codes (IPC classes). Therefore, the underlying equations for the multiple-indicator model are

$$y_{k,s} = \lambda_k v_s + \boldsymbol{\beta X} + e_{k,s}, \;\; k \in \{1, 2, 3\}$$

where $y_{k,s}$ is the value of quality indicator k for patent s, v_s indicates the common factor, λ_k represents the factor loading, $\boldsymbol{X}$ contains common controls and $e_{k,s} \sim N(0, \sigma^2)$ is the idiosyncratic component with $Cov(e_{k,s}, e_{k,r}) = 0$, $s \neq r$. Since the term $\lambda_k v_s$ is latent, we estimate the reduced form of the equations:

$$y_{k,s} = \boldsymbol{\beta X} + u_{k,s},\ k \in \{1, 2, 3\}$$

where $u_{k,s} = \lambda_k v_s + e_{k,s}$ combines a common component $\lambda_k v_s$ and an idiosyncratic component $e_{k,s}$. We estimate these equations using 3SLS where $\boldsymbol{X}$ contains the year of application and the main technology class of the patent. To gather λ_k and v_s, we conduct a factor analysis using maximum likelihood to decompose $u_{k,s}$. The estimated factor loadings are presented in Table C.1.

Table C.1: Factor loadings

Factor analysis of the residuals from regressing each indicator on year and industry class dummies. Factor loadings represent both weighting of the indicator and correlation between indicator and patent quality.

Indicator	Factor loading
Forward citations	0.6201
Patent family size	0.3593
Patent classification codes	0.1229

We use the estimated factor loadings to calculate the composite quality indicator for each patent. The composite quality indicator is a relative measure to determine the quality of patents and is normally distributed with mean zero. To construct the quality-weighted annual patent count, we transform the distribution by adding the value of the patent with lowest patent quality so that all composite quality indicators turn positive. After this transformation the composite quality indicator for each patent has a positive value and can be used as weight for summing up patent output. The implied relative ordering of the quality of patents is unaffected by this transformation.

C.4 User Cost of R&D Investment

The computation of the user cost follows the derivation of Bloom *et al.* (2002) who extend its standard expression as presented by Hall & Jorgenson (1967) to R&D investment. The user cost is defined as the pre-tax financial return ρ for a marginal R&D investment project (i.e. a project with zero economic rent). The economic rent of an R&D project is given by

$$
\begin{aligned}
R &= (1+i)\, dV_t = dD_t + dV_{t+1} \\
&= \frac{(\rho+\delta)\left(1-\tau^{CIT}\right) + (1-\delta)\, A}{1+r} - (1-A)
\end{aligned}
$$

where dV_t is the change in the market value of the firm and dD_t is the change in dividends paid out by the firm that results from the investment. i denotes the nominal and r the real market interest rate and δ is the economic rate of depreciation. A is the net present value of allowances. Following Thomson (2013) and Warda (2002), we assume the R&D investment to consist of an investment in labor (60%), machinery and equipment (5%), buildings (5%) and other current expenditures (30%). A accounts for additional deductions, tax credits and accelerated depreciation. To obtain the user cost, we set $R = 0$ and solve for ρ. This yields

$$
\rho = \frac{1-\left(A^D + A^C\right)}{1-\tau^{CIT}}\,(r+\delta)
$$

We compute ρ_{ct} for every country and year and follow Bloom *et al.* (2002) in setting $\delta = 0.3$ and $r = 0.05$. Tax policy variables are obtained from the IBFD database.

C.5 Event-study design

The event-study design follows the setup of Fuest *et al.* (2018) and is specified as:

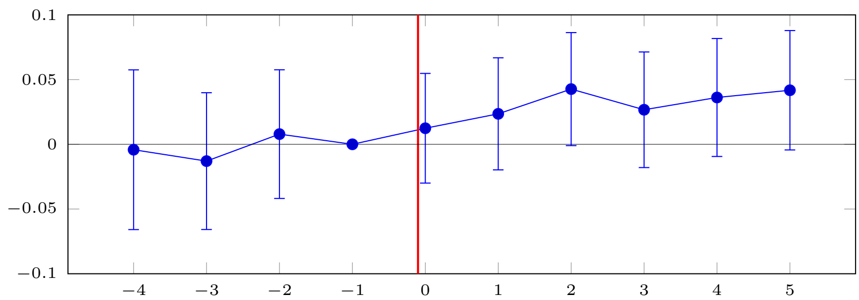
$$
\begin{aligned}
P_{ijct} = {} & \alpha_{-5} \sum_{n=5}^{t-2000} b_{j,t-n}^{Haven} + \sum_{n=-4}^{-2} \alpha_n b_{j,t+n}^{Haven} + \sum_{n=0}^{5} \alpha_n b_{j,t+n}^{Haven} + \alpha_6 \sum_{n=6}^{2012-t} b_{j,t+n}^{Haven} \\
& + \eta_{-5} \sum_{n=5}^{t-2000} b_{j,t-n}^{Nexus} + \sum_{n=-4}^{-2} \eta_n b_{j,t+n}^{Nexus} + \sum_{n=0}^{5} \eta_n b_{j,t+n}^{Nexus} + \eta_6 \sum_{n=6}^{2012-t} b_{j,t+n}^{Nexus} \\
& + \boldsymbol{\beta X_{it}} + \boldsymbol{\gamma Z_{jt}} + \boldsymbol{\delta C_{ct}} + \boldsymbol{\phi_t} + \boldsymbol{\phi_i} \qquad \text{(C.1)}
\end{aligned}
$$

P_{ijct} is the number of newly granted patent applications of firm i which is member of multinational group j and is located in country c in period t, and $b_{j,t}^{Haven}$ ($b_{j,t}^{Nexus}$) is a dummy that indicates whether in year t group j has an affiliate in a country where a patent box with(out) nexus requirement is implemented and zero otherwise. Within the first and last year in our sample, 2000 and 2012, we define an event window of

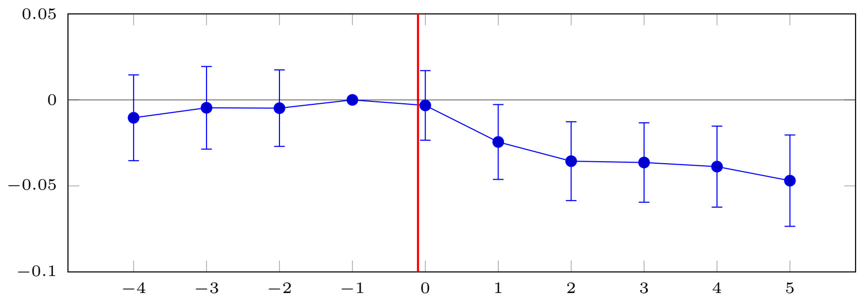
12 years, that is, we observe 5 years before and 6 years after the implementation of the patent box as well as the implementation year itself. In each year, we thus compare the treated firms to those that do not have a foreign patent box affiliate. Following Kline (2012), we adjust the end points of the event window to indicate whether a foreign patent box has been implemented 5 or more years before (upper window limit) and 6 or more years after a given year (lower window limit) in order to mitigate collinearity with the year-fixed effects. To avoid perfect collinearity among the patent box indicators, the regressor in the year before the implementation is dropped and thereby normalized to zero. As a consequence, the remaining coefficients α_t are interpreted as the effect of the patent box implementation on P_{ijct} relative to the pre-reform year. The regression is complemented by a set of control variables which are identical to the main specification (4.4) as well as a set of firm-fixed and year-fixed effects.

In our benchmark estimate, we estimate a Poisson model to obtain the coefficients of the event study. Below, we also plot the results for a linear estimation. In this case, P_{ijct} is the inverse hyperbolic sine transformation of the number of newly granted patent applications.

Figure C.2: Event-study Design (Linear Model)



(a) Patent Havens



(b) Nexus Boxes

This figure plots the event study estimates and corresponding 95% confidence bands. The model specification is explained in Appendix Event-study design. The plotted coefficients correspond to $\alpha_n, n \in [-4, 5]$. Standard errors are clustered at the firm level. The event variables are indicators for the implementation of a patent haven or a nexus patent box in a foreign affiliate location of the firm.

C.6 Additional Tables and Figures

Figure C.3: Graphical Illustration of the Conceptual Framework

This figure illustrates the concept of this paper. The focus of the analysis is R&D activity of firm 1, located in country A with an affiliate in country B. We investigate the response of R&D activity of firm 1 to the patent box implementation in country B. Empirically, this is done by comparing firm 1 to another firm 2 which may have a a foreign affiliate in a country C but is not linked via an affiliate to the patent box country B.

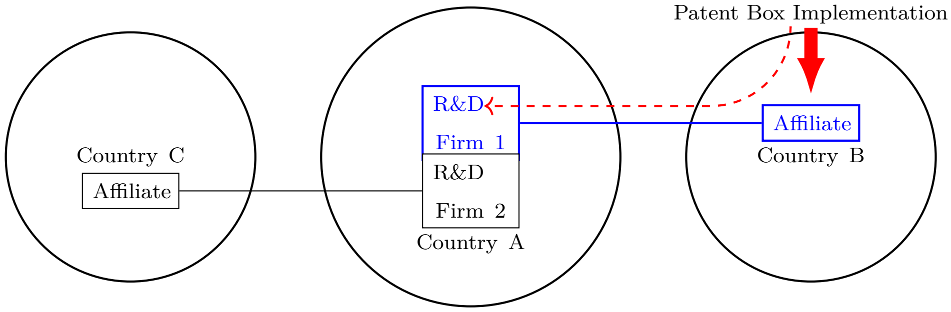


Table C.2: Sample Selection

This table displays the sample selection. Patenting sectors are defined by 2-digit NACE Rev. 2 codes 10-32, 51-53, 58-63, 69-74 and 77-82. Firms that conduct R&D are defined as firms included in the PATSTAT database that have successfully filed a patent application at any point in time.

	Number of Firms in the Sample
Firms in patenting sectors that conduct R&D with data for 2000-2012	38,844
Excluding firms located in patent box countries	31,023
Trimming at the 99% quantile of the patent count	30,927
Excluding firms with no patent application in the observation period	26,686

Table C.3: Extended Sample (2000-2015)

Estimation of a Poisson fixed effects model except for columns (9) and (10) where a linear fixed effects model is estimated using an inverse hyperbolic sine transformation. The dependent variable is the (quality-weighted) number of new domestic patents per year and firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. The sample uses the same observations as the benchmark regression and adds observations for the years 2013-15. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	No. of New Patents						No. of New Patents (quality-weighted)		No. of New Patents Linear Model	
BOX_{Haven}	0.135**		0.135**				0.171***		0.037**	
	(0.054)		(0.054)				(0.059)		(0.015)	
BOX_{Nexus}		-0.001	-0.004				-0.036		-0.015**	
		(0.023)	(0.023)				(0.024)		(0.006)	
$BOX_{Haven} \times \Delta t$				0.010**		0.010**		0.011**		0.002*
				(0.004)		(0.004)		(0.005)		(0.001)
$BOX_{Nexus} \times \Delta t$					-0.002	-0.002		-0.005**		-0.001***
					(0.002)	(0.002)		(0.002)		(0.000)
R&D Exp.	0.447***	0.449***	0.447***	0.448***	0.446***	0.445***	0.540***	0.536***	0.086***	0.086***
	(0.054)	(0.054)	(0.054)	(0.054)	(0.055)	(0.055)	(0.060)	(0.060)	(0.010)	(0.010)
Log GDP p.c.	-0.461**	-0.458**	-0.461**	-0.459**	-0.460**	-0.461**	0.604***	0.597***	-0.153***	-0.153***
	(0.187)	(0.187)	(0.187)	(0.187)	(0.187)	(0.187)	(0.201)	(0.201)	(0.028)	(0.028)
CIT	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.003	-0.003	-0.000	-0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.000)	(0.000)
GDP Growth	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.014***	-0.014***	-0.000	-0.000
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.001)	(0.001)
User Cost of R&D	-5.030***	-5.033***	-5.025***	-5.025***	-5.014***	-5.001***	-3.870***	-3.865***	-0.911***	-0.913***
	(0.451)	(0.451)	(0.451)	(0.450)	(0.450)	(0.450)	(0.467)	(0.467)	(0.070)	(0.070)
Real interest rate	-1.202***	-1.198***	-1.201***	-1.198***	-1.200***	-1.200***	-1.677***	-1.681***	-0.270***	-0.271***
	(0.453)	(0.454)	(0.453)	(0.453)	(0.453)	(0.453)	(0.467)	(0.467)	(0.078)	(0.078)
No. of affiliates	0.065**	0.083***	0.066**	0.068**	0.088***	0.073***	0.043	0.055*	0.011	0.013*
	(0.027)	(0.026)	(0.027)	(0.027)	(0.026)	(0.027)	(0.029)	(0.029)	(0.007)	(0.007)
Log Age	0.067***	0.067***	0.067***	0.067***	0.067***	0.067***	0.064***	0.063***	0.020***	0.020***
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.020)	(0.020)	(0.003)	(0.003)
Log Total Assets	0.043***	0.043***	0.043***	0.043***	0.044***	0.044***	0.033***	0.033***	0.006***	0.006***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.001)	(0.001)
Working Capital	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.016***	0.016***	0.016***	0.016***	0.016***	0.016***	0.016***	0.016***	0.002***	0.002***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.001)	(0.001)
N	307,434	307,434	307,434	307,434	307,434	307,434	298,870	298,870	343,903	343,903
No. of firms	25,307	25,307	25,307	25,307	25,307	25,307	24,568	24,568	30,205	30,205
Pseudo LL	-165,431	-165,440	-165,431	-165,434	-165,438	-165,432	-100,202	-100,202	-184,491	-184,493

Table C.4: MNEs

Estimation of a Poisson fixed effects model except for columns (9) and (10) where a linear fixed effects model is estimated using an inverse hyperbolic sine transformation. The dependent variable is the (quality-weighted) number of new domestic patents per year and firm. The sample only contains MNEs. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(7)	(8)
	No. of New Patents						No. of New Patents (quality-weighted)		No. of New Patents Linear Model	
BOX_{Haven}	0.115*		0.114*				0.155**		0.036*	
	(0.061)		(0.061)				(0.065)		(0.019)	
BOX_{Nexus}		0.027	0.027				0.011		-0.004	
		(0.028)	(0.028)				(0.029)		(0.009)	
$BOX_{Haven} \times \Delta t$				0.016***		0.016***		0.019***		0.004**
				(0.006)		(0.006)		(0.006)		(0.002)
$BOX_{Nexus} \times \Delta t$					0.000	-0.000		-0.002		-0.001
					(0.002)	(0.002)		(0.002)		(0.001)
R&D Exp.	0.371***	0.373***	0.371***	0.373***	0.373***	0.373***	0.411***	0.411***	0.111***	0.110***
	(0.076)	(0.076)	(0.076)	(0.076)	(0.076)	(0.076)	(0.082)	(0.082)	(0.019)	(0.019)
Log GDP p.c.	-0.971***	-0.963***	-0.972***	-0.973***	-0.962***	-0.974***	-0.130	-0.135	-0.295***	-0.299***
	(0.357)	(0.357)	(0.357)	(0.356)	(0.358)	(0.357)	(0.377)	(0.377)	(0.077)	(0.077)
CIT	0.005	0.005*	0.005	0.005	0.005*	0.005	-0.000	0.000	0.001	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)
GDP Growth	-0.000	-0.001	-0.001	-0.000	-0.000	-0.000	-0.004	-0.004	-0.001	-0.001
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.002)	(0.002)
User Cost of R&D	-1.482*	-1.499*	-1.492*	-1.440	-1.489*	-1.440	-1.475	-1.439	-0.414**	-0.410**
	(0.888)	(0.888)	(0.888)	(0.885)	(0.887)	(0.885)	(0.940)	(0.939)	(0.190)	(0.190)
Real interest rate	-0.028	-0.035	-0.032	-0.019	-0.031	-0.019	-0.732	-0.725	-0.141	-0.141
	(0.642)	(0.642)	(0.642)	(0.642)	(0.642)	(0.642)	(0.654)	(0.653)	(0.156)	(0.155)
No. of affiliates	0.065	0.080*	0.061	0.069	0.084*	0.069	0.035	0.049	0.027*	0.030*
	(0.047)	(0.045)	(0.047)	(0.046)	(0.045)	(0.047)	(0.048)	(0.047)	(0.016)	(0.016)
Log Age	0.066**	0.066**	0.066**	0.066**	0.066**	0.066**	0.052	0.052	0.028***	0.028***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.033)	(0.033)	(0.009)	(0.009)
Log Total Assets	0.066***	0.066***	0.066***	0.066***	0.066***	0.066***	0.057***	0.057***	0.015***	0.015***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.011)	(0.011)	(0.002)	(0.002)
Working Capital	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.021**	0.021**	0.021**	0.021**	0.021**	0.021**	0.022**	0.022**	0.003	0.003
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.002)	(0.002)
N	94,112	94,112	94,112	94,112	94,112	94,112	92,716	92,716	107,908	107,908
No. of firms	8,494	8,494	8,494	8,494	8,494	8,494	8,363	8,363	10,397	10,397
Pseudo LL	-70,788	-70,791	-70,786	-70,786	-70,793	-70,786	-47,047	-47,046	-74,886	-74,884

Table C.5: Heterogeneity Across Industries

Estimation of a Poisson fixed effects model. The dependent variable is the number of new patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. Columns (1)-(4) present estimations on the sample of ICT firms, columns (5)-(8) refer to results on the sample of manufacturing firms other than ICT. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ICT				Manufacturing			
BOX_{Haven}	0.158		0.165		0.140**		0.143**	
	(0.123)		(0.123)		(0.061)		(0.061)	
BOX_{Nexus}		-0.143*	-0.145*			-0.016	-0.019	
		(0.076)	(0.076)			(0.028)	(0.028)	
$BOX_{Haven} \times \Delta t$				0.010				0.011**
				(0.011)				(0.005)
$BOX_{Nexus} \times \Delta t$				-0.017**				-0.002
				(0.007)				(0.002)
R&D Exp.	0.155	0.159	0.160	0.141	0.353***	0.355***	0.354***	0.353***
	(0.175)	(0.175)	(0.175)	(0.177)	(0.068)	(0.068)	(0.068)	(0.069)
Log GDP p.c.	-0.311	-0.322	-0.328	-0.375	-0.738***	-0.732***	-0.735***	-0.735***
	(0.794)	(0.781)	(0.783)	(0.784)	(0.229)	(0.228)	(0.229)	(0.228)
CIT	0.004	0.005	0.005	0.007	-0.002	-0.001	-0.002	-0.001
	(0.006)	(0.006)	(0.006)	(0.006)	(0.002)	(0.002)	(0.002)	(0.002)
GDP Growth	-0.003	-0.002	-0.002	-0.003	-0.002	-0.001	-0.001	-0.001
	(0.016)	(0.016)	(0.016)	(0.016)	(0.006)	(0.006)	(0.006)	(0.006)
User Cost of R&D	-4.238**	-4.103**	-4.070*	-4.122**	-4.518***	-4.490***	-4.486***	-4.484***
	(2.108)	(2.092)	(2.094)	(2.090)	(0.553)	(0.553)	(0.554)	(0.552)
Real interest rate	-1.632	-1.650	-1.643	-1.629	-1.465***	-1.451**	-1.459***	-1.461***
	(1.612)	(1.601)	(1.602)	(1.598)	(0.566)	(0.566)	(0.565)	(0.565)
No. of affiliates	0.142	0.183**	0.156*	0.184**	0.028	0.045	0.030	0.033
	(0.089)	(0.081)	(0.088)	(0.092)	(0.039)	(0.037)	(0.039)	(0.038)
Log Age	0.016	0.006	0.005	0.006	0.072***	0.072***	0.072***	0.072***
	(0.056)	(0.056)	(0.056)	(0.056)	(0.025)	(0.025)	(0.025)	(0.025)
Log Total Assets	0.050***	0.054***	0.054***	0.054***	0.044***	0.045***	0.044***	0.045***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.007)	(0.007)	(0.007)	(0.007)
Working Capital	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.034***	0.034***	0.034***	0.034***	0.015**	0.015**	0.015**	0.015**
	(0.013)	(0.013)	(0.013)	(0.012)	(0.006)	(0.006)	(0.006)	(0.006)
N	28,581	28,581	28,581	28,581	193,114	193,114	193,114	193,114
No. of firms	2,563	2,563	2,563	2,563	16,498	16,498	16,498	16,498
Pseudo LL	-15,441	-15,437	-15,435	-15,430	-109,018	-109,023	-109,017	-109,018

Table C.6: Excluding Firms with Patent Box specific Ownership Changes

Estimation of a Poisson fixed effects model except for columns (9) and (10) where a linear fixed effects model is estimated using an inverse hyperbolic sine transformation. The dependent variable is the (quality-weighted) number of new domestic patents per year and firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	No. of New Patents						No. of New Patents (quality-weighted)		No. of New Patents Linear Model	
BOX_{Haven}	0.598***		0.596***				0.574***		0.180***	
	(0.157)		(0.157)				(0.172)		(0.045)	
BOX_{Nexus}		0.011	0.006				-0.034		-0.013	
		(0.031)	(0.031)				(0.033)		(0.010)	
$BOX_{Haven} \times \Delta t$				0.055***		0.055***		0.054***		0.014***
				(0.014)		(0.014)		(0.013)		(0.005)
$BOX_{Nexus} \times \Delta t$					0.002	0.002		-0.002		-0.000
					(0.003)	(0.003)		(0.003)		(0.001)
R&D Exp.	0.323***	0.331***	0.323***	0.326***	0.332***	0.326***	0.429***	0.429***	0.063***	0.063***
	(0.065)	(0.065)	(0.065)	(0.065)	(0.065)	(0.065)	(0.072)	(0.072)	(0.011)	(0.011)
Log GDP p.c.	-0.360	-0.373*	-0.361	-0.363	-0.372*	-0.362	0.916***	0.912***	-0.122***	-0.123***
	(0.224)	(0.224)	(0.224)	(0.224)	(0.224)	(0.224)	(0.234)	(0.234)	(0.033)	(0.033)
CIT	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.006**	-0.006**	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.000)	(0.000)
GDP Growth	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.016***	-0.016***	-0.000	-0.000
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.001)	(0.001)
User Cost of R&D	-5.257***	-5.284***	-5.266***	-5.274***	-5.294***	-5.298***	-3.930***	-3.977***	-0.943***	-0.951***
	(0.553)	(0.555)	(0.554)	(0.553)	(0.555)	(0.555)	(0.582)	(0.583)	(0.078)	(0.079)
Real interest rate	-1.279**	-1.273**	-1.281**	-1.287**	-1.273**	-1.288**	-1.741***	-1.756***	-0.232***	-0.234***
	(0.536)	(0.537)	(0.536)	(0.536)	(0.537)	(0.537)	(0.557)	(0.557)	(0.086)	(0.086)
No. of affiliates	0.098***	0.122***	0.097***	0.122***	0.122***	0.121***	0.088**	0.111***	0.021***	0.024***
	(0.034)	(0.033)	(0.034)	(0.033)	(0.033)	(0.033)	(0.036)	(0.034)	(0.008)	(0.008)
Log Age	0.082***	0.080***	0.082***	0.081***	0.081***	0.081***	0.077***	0.077***	0.017***	0.018***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.022)	(0.022)	(0.004)	(0.004)
Log Total Assets	0.038***	0.038***	0.038***	0.038***	0.037***	0.037***	0.026***	0.025***	0.005***	0.005***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.001)	(0.001)
Working Capital	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.015***	0.016***	0.015***	0.016***	0.016***	0.016***	0.015***	0.015***	0.002***	0.002***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.001)	(0.001)
N	234,113	234,113	234,113	234,113	234,113	234,113	227,037	227,037	268,435	268,435
No. of firms	20,790	20,790	20,790	20,790	20,790	20,790	20,132	20,132	25,570	25,570
Pseudo LL	-119760.804	-119773.336	-119760.744	-119763.501	-119772.873	-119762.897	-70545.726	-70547.510	-133995.500	-134004.975

Table C.7: R&D Activity and Corporate Taxation: Controls

This table reports the coefficients of the control variables for the estimations reported in Table 4.7. Estimation of a Poisson fixed effects model. The dependent variable is the number of new domestic patents per year and firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	No. of New Patents			
	(1)	(2)	(3)	(4)
	Full Sample	Domestic Firms	Full Sample	Full Sample
R&D exp.	0.373***	0.308***	0.360***	0.365***
	(0.076)	(0.087)	(0.057)	(0.057)
Log GDP p.c.	-0.963***	-0.306	-0.574***	-0.575***
	(0.357)	(0.255)	(0.208)	(0.208)
GDP Growth	-0.000	-0.003	-0.003	-0.002
	(0.007)	(0.007)	(0.005)	(0.005)
User Cost of R&D	-1.489*	-6.291***	-4.551***	-4.607***
	(0.887)	(0.610)	(0.503)	(0.504)
Real interest rate	-0.031	-1.898***	-1.215***	-1.165***
	(0.642)	(0.662)	(0.445)	(0.445)
Log no. of affiliates	0.084*	0.111**	0.069**	0.073***
	(0.045)	(0.047)	(0.028)	(0.028)
Log Age	0.066**	0.078***	0.073***	0.074***
	(0.030)	(0.025)	(0.020)	(0.020)
Log Total Assets	0.066***	0.034***	0.046***	0.045***
	(0.010)	(0.006)	(0.005)	(0.005)
Working Capital	-0.000	0.000*	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.021**	0.015***	0.016***	0.016***
	(0.009)	(0.005)	(0.005)	(0.005)

Table C.8: Average Treatment Effect on the Treated Using Matching

Results from propensity score matching based on firm characteristics in year 2000 (single nearest neighbor matching). ATT denotes 'average treatment effect of the treated' and is calculated using a Poisson model. The calculation of the ATT includes firm-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	(1)	(2)	(3)	(4)	(5)	(6)
	No. of New Patents			No. of New Patents (quality-weighted)		
ATT BOX_{Haven}	0.192***		0.174***	0.222***		0.178***
	(0.055)		(0.062)	(0.059)		(0.067)
ATT BOX_{Nexus}		-0.006	0.000 (0.034)		-0.019	-0.018
		(0.035)			(0.036)	(0.035)
N	55,328	54,191	57,060	54,587	53,658	56,501
Number of firms	4,378	4,281	4,503	4,321	4,240	4,460
Pseudo R^2 (Matching)	0.592	0.561	0.556	0.592	0.561	0.556
Pseudo LL	-43,698	-43,882	-45,675	-29,378	-28,943	-30,054

Table C.9: Summary Statistics: R&D Expenditures

Data source R&D expenditures: SV Wissenschaftsstatistik GmbH, RDC, R&D Surveys 2001-2011, own calculations. Minimum and maximum values are not reported because of data confidentiality. All R&D expenditures in 1000 EUR.

	Number of Observations	Mean (logged)	Standard Deviation (logged)	Mean	Standard Deviation
R&D Expenditure, Total	13,633	7.772	1.633	2,373.213	3,946.653
R&D Expenditure, Equipment	13,633	5.442	2.426	230.904	560.171
R&D Expenditure, Employment	13,633	6.527	2.535	683.345	1,732.280

D Appendix to Chapter 5

D.1 Second-Order Conditions for Case I

The Hessian for the system of first-order conditions (5.9) to (5.11) for jurisdiction i is given by

$$\boldsymbol{H} = \begin{pmatrix} \frac{\partial^2 U^i}{\partial m_i^2} & \frac{\partial^2 U^i}{\partial \tau_{i1} \partial m_i} & \frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} \\ \frac{\partial^2 U^i}{\partial m_i \partial \tau_i} & \frac{\partial^2 U^i}{\partial \tau_{i1}^2} & \frac{\partial^2 U^i}{\partial b_{i1} \partial \tau_i} \\ \frac{\partial^2 U^i}{\partial m_i \partial b_{i1}} & \frac{\partial^2 U^i}{\partial \tau_{i1} \partial b_{i1}} & \frac{\partial^2 U^i}{\partial b_{i1}^2} \end{pmatrix} = \begin{pmatrix} \frac{\partial^2 U^i}{\partial m_i^2} & 0 & \frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} \\ 0 & \frac{\partial^2 U^i}{\partial \tau_{i1}^2} & 0 \\ \frac{\partial^2 U^i}{\partial m_i \partial b_{i1}} & 0 & \frac{\partial^2 U^i}{\partial b_{i1}^2} \end{pmatrix}$$

In the second term, we insert the first-order condition for taxes (5.9) to verify that $\frac{\partial^2 U^i}{\partial m_i \partial \tau_i} = -h''_{i1} \frac{\partial (N_{i1}(1+\gamma \tau_{i1}))}{\partial \tau_{i1}} \gamma c' = 0$ and $\frac{\partial^2 U^i}{\partial b_{i1} \partial \tau_i} = \gamma h''_{i1} \frac{\partial (N_{i1}(1+\gamma \tau_{i1}))}{\partial \tau_{i1}} = 0$. For (5.9)-(5.11) to yield a maximum, $\boldsymbol{H}$ must be negative definite which is the case if and only if

$$\frac{\partial^2 U^i}{\partial m_i^2} = h''_{i1} \left(\gamma c'\right)^2 - h'_{i1} \gamma c'' + \beta h''_{i2} \left(\frac{\partial \tilde{N}_{i2} \left(1 + \gamma \tilde{\tau}_{i2}\right)}{\partial m_i} \right)^2 + \beta h'_{i2} \frac{\gamma \rho^2}{9\nu} < 0, \tag{D.1}$$

$$\frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^i}{\partial \tau_{i1}^2} > 0, \tag{D.2}$$

$$\frac{\partial^2 U^i}{\partial \tau_{i1}^2} \left(\frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^i}{\partial b_{i1}^2} - \left(\frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} \right)^2 \right) < 0. \tag{D.3}$$

Condition (D.1) is fulfilled for any sufficiently convex public investment cost function $c\left(m_i\right)$. In particular, noting from (5.11) that $h'_{i2} = h'_{i1}$, we know that $c''\left(m_i\right) > \frac{\beta \gamma \rho^2}{9\nu}$ is a sufficient condition for (D.1) to be satisfied. This relation holds for a wide range of parameters and functional forms. Since $\frac{\partial^2 U^i}{\partial \tau_{i1}^2} = -h'_{i1} \frac{\gamma}{\nu} < 0$, (D.2) must hold whenever (D.1) holds. Furthermore, note that $\frac{\partial^2 U^i}{\partial b_{i1}^2} = \left(h''_{i1} + \frac{1}{\beta} h''_{i2} \right) \gamma < 0$ and $\frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} = -\gamma^2 h''_{i1} c' - \gamma h''_{i2} \left(\frac{\partial \tilde{N}_{i2}(1+\gamma \tilde{\tau}_{i2})}{\partial m_i} \right) > 0$ such that for (D.3) to hold, we must have $\frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^i}{\partial b_{i1}^2} > \left(\frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} \right)^2$. Inserting the first-order conditions (5.10) and (5.11), it is straightforward to show that this condition is satisfied if $c''(m_i) > \frac{\beta\gamma\rho^2}{9\nu}$ (i.e. the cost function must be sufficiently convex) such that condition (D.3) holds whenever (D.1) is fulfilled.

D.2 Comparative Statics for Case II

If Condition 1 is binding in jurisdiction 1, the system of first-order conditions is given by

$$\frac{\partial U^i}{\partial \tau_{i1}} = h'_{i1}\frac{\partial\left(N_{i1}\left(1+\gamma\tau_{i1}\right)\right)}{\partial \tau_{i1}} = 0,\ i=1,2 \tag{D.4}$$

$$\frac{\partial U^1}{\partial m_1} = -h'_{11}\gamma c' + \beta h'_{12}\frac{\partial\left(\tilde{N}_{12}\left(1+\gamma\tilde{\tau}_{12}\right)\right)}{\partial m_1} = 0 \tag{D.5}$$

$$\frac{\partial U^2}{\partial m_2} = -\gamma c' + \beta\frac{\partial\left(\tilde{N}_{22}\left(1+\gamma\tilde{\tau}_{22}\right)\right)}{\partial m_2} = 0 \tag{D.6}$$

Condition (D.6) is obtained by inserting the first-order condition for b_{21}, (5.11), into the first order condition for m_2, (5.10), as in Case I. The Hessian for the system of first-order conditions for jurisdiction 1 (D.4), and (D.5) is given by

$$\boldsymbol{H} = \begin{pmatrix} \frac{\partial^2 U^1}{\partial m_1^2} & \frac{\partial^2 U^1}{\partial \tau_{11}\partial m_1} \\ \frac{\partial^2 U^1}{\partial m_1 \partial \tau_{11}} & \frac{\partial^2 U^1}{\partial \tau_{11}^2} \end{pmatrix} = \begin{pmatrix} \frac{\partial^2 U^1}{\partial m_1^2} & 0 \\ 0 & \frac{\partial^2 U^1}{\partial \tau_{11}^2} \end{pmatrix}$$

In the second term, we insert the first-order condition for taxes (D.4) to verify that $\frac{\partial^2 U^1}{\partial m_1 \partial \tau_{11}} = 0$. For (D.4) and (D.5) to yield a maximum, $\boldsymbol{H}$ must be negative definite which is the case if and only if

$$\frac{\partial^2 U^1}{\partial m_1^2} = h''_{11}\left(\gamma c'\right)^2 - h'_{11}\gamma c'' + \beta h''_{12}\left(\frac{\partial \tilde{N}_{12}\left(1+\gamma\tilde{\tau}_{12}\right)}{\partial m_1}\right)^2 + \beta h'_{12}\frac{\gamma\rho^2}{9\nu} < 0, \tag{D.7}$$

$$\frac{\partial^2 U^1}{\partial m_1^2}\frac{\partial^2 U^1}{\partial \tau_{11}^2} > 0, \tag{D.8}$$

Condition (D.7) holds if $-\frac{\partial\left(\tilde{N}_{12}(1+\gamma\tilde{\tau}_{12})\right)}{\partial m_1}\frac{c''}{c'} < \frac{\gamma\rho^2}{9\nu}$ which is true for any convex function c. Since $\frac{\partial^2 U^1}{\partial \tau_{11}^2} < 0$, (D.8) must hold whenever (D.7) holds. The first-order conditions for taxes (D.4) yield again (5.12). The Dixit (1986) stability conditions are

$$\frac{\partial^2 U^i}{\partial m_i^2} < 0, \ \frac{\partial^2 U^{-i}}{\partial m_{-i}^2} < 0, \ \frac{\partial^2 U^i}{\partial m_i^2}\frac{\partial^2 U^{-i}}{\partial m_{-i}^2} > \frac{\partial^2 U^{-i}}{\partial m_{-i}\partial m_i}\frac{\partial^2 U^i}{\partial m_i \partial m_{-i}}. \tag{D.9}$$

Taking the total differential of the first-order conditions with respect to b_{10} we arrive at the following system of equations

$$\begin{pmatrix} \frac{\partial^2 U^1}{\partial m_1^2} & \frac{\partial^2 U^1}{\partial m_1 \partial m_2} \\ \frac{\partial^2 U^2}{\partial m_2 \partial m_1} & \frac{\partial^2 U^2}{\partial m_2^2} \end{pmatrix} \begin{pmatrix} \mathrm{d}m_1 \\ \mathrm{d}m_2 \end{pmatrix} + \begin{pmatrix} \frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} \\ 0 \end{pmatrix} \mathrm{d}b_{10} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \tag{D.10}$$

which can be rearranged to yield

$$\frac{\mathrm{d}m_1}{\mathrm{d}b_{10}} = -\frac{1}{\phi}\frac{\partial^2 U^2}{\partial m_2^2}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0, \ \frac{\mathrm{d}m_2}{\mathrm{d}b_{10}} = \frac{1}{\phi}\frac{\partial^2 U^2}{\partial m_2 \partial m_1}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} > 0 \tag{D.11}$$

with $\phi = \frac{\partial^2 U^1}{\partial m_1^2}\frac{\partial^2 U^2}{\partial m_2^2} - \frac{\partial^2 U^2}{\partial m_2 \partial m_1}\frac{\partial^2 U^1}{\partial m_1 \partial m_2} > 0$. The first effect is obtained because of the Dixit (1986) stability conditions and since $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0$. The second effect results from $\frac{\partial^2 U^2}{\partial m_2 \partial m_1} = -\frac{\gamma \rho^2}{9\nu} < 0$. From Proposition 1 we know that the effect of a change in b_{i0} on τ_{i2}^* and N_{i2}^* is given by

$$\frac{d\tau_{i2}^*}{db_{i0}} = \frac{\rho}{3}\frac{d\Delta q_{i2}}{db_{i0}} = \frac{\rho}{3}\left(\frac{dm_i}{db_{i0}} - \frac{dm_{-i}}{db_{i0}}\right), \ \frac{dN_{i2}^*}{db_{i0}} = \frac{\rho}{6\nu}\frac{d\Delta q_{i2}}{db_{i0}} = \frac{\rho}{6\nu}\left(\frac{dm_i}{db_{i0}} - \frac{dm_{-i}}{db_{i0}}\right) \tag{D.12}$$

where $\Delta q_{i2} = m_i - m_{-i}$ (assuming that $\bar{q}_1 = \bar{q}_2$). It follows from (D.11) that $\frac{d\tau_{12}^*}{db_{10}} < 0$, $\frac{dN_{12}^*}{db_{10}} < 0$, $\frac{d\tau_{22}^*}{db_{20}} > 0$ and $\frac{dN_{22}^*}{db_{20}} > 0$.

Adjustment in period 1 borrowing only occurs in jurisdiction 2 as jurisdiction 1 is constrained. We derive jurisdiction 2's borrowing response by totally differentiating the corresponding first order condition for b_{12} (5.11) with respect to m_1, m_2 and b_{12} which yields

$$\frac{\partial^2 U^2}{\partial b_{21}^2}db_{21} + \frac{\partial U^2}{\partial b_{21}\partial m_2}dm_2 + \frac{\partial U^2}{\partial b_{21}\partial m_1}dm_1 = 0. \tag{D.13}$$

Substituting (5.14) and (5.15) for dm_1 and dm_2 we solve for

$$\frac{db_{21}}{\mathrm{d}b_{10}} = \frac{1}{\phi}\left(\frac{\partial U^2}{\partial b_{21}\partial m_1}\frac{\partial^2 U^2}{\partial m_2^2} - \frac{\partial U^2}{\partial b_{21}\partial m_2}\frac{\partial^2 U^2}{\partial m_2 \partial m_1}\right)\frac{\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}}{\frac{\partial^2 U^2}{\partial b_{21}^2}} > 0 \tag{D.14}$$

where the inequality follows because $\frac{\partial U^2}{\partial b_{21}\partial m_2} > 0$, $\frac{\partial^2 U^2}{\partial m_2 \partial m_1} < 0$, $\frac{\partial^2 U^2}{\partial m_2^2} < 0$, $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0$, $\frac{\partial^2 U^2}{\partial b_{21}^2} < 0$ (see Section D.1) and $\frac{\partial U^2}{\partial b_{21}\partial m_1} = -\gamma h''_{i2}\left(\frac{\partial \tilde{N}_{22}(1+\gamma\tilde{\tau}_{22})}{\partial m_1}\right) < 0$.

D.3 Comparative Statics for Constrained Borrowing in Both Jurisdictions

Taking the total differential of the first-order conditions we arrive at the same system of equations as in (D.10) which can be rearranged to yield expressions for $\frac{\mathrm{d}m_2}{\mathrm{d}b_{10}}$ and $\frac{\mathrm{d}m_1}{\mathrm{d}b_{10}}$ as in (D.11). Since $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0$, the Dixit (1986) stability conditions (D.9) again imply $\frac{\mathrm{d}m_1}{\mathrm{d}b_{10}} < 0$. However, since the first-order condition for b_{20} does not necessarily hold, it cannot be substituted to yield $\frac{\partial^2 U^2}{\partial m_2 \partial m_1} < 0$ which leads to the unambiguous result obtained for jurisdiction 2 in (D.11). If $h''_2 = 0$ such that U^2 is quasi-linear, we can show that $\frac{\mathrm{d}m_2}{\mathrm{d}b_{20}} < 0$ by verifying that in this case

$$\frac{\partial^2 U^2}{\partial m_2 \partial m_1} = -\beta h''_{22}\left(\frac{\rho}{6\nu} + \frac{\gamma\rho}{3}\left(\frac{1}{2\nu}\tau_{12} + N_{12}\right)\right)^2 - \frac{\gamma\rho^2}{9\nu}\beta h'_{22} = -\frac{\gamma\rho^2}{9\nu}\beta h'_{22} < 0.$$

The effect of a marginal increase in b_{10} on tax rates and the number of firms is again given by (D.12). Substituting from (5.14) and (5.15) and noting that

$$\begin{aligned}
\frac{\partial^2 U^2}{\partial m_2 \partial m_1} &= -\beta h'_{22}\frac{\gamma\rho^2}{9\nu} - \beta h''_{22}\left(\frac{\rho}{6\nu}\left(1+\gamma\tau_{22}\right) + \frac{\rho}{3}N_{22}\right)^2, \\
\frac{\partial^2 U^2}{\partial m_2^2} &= h''_{21}\left(\gamma c'\right)^2 - h'_{21}\gamma c'' - \frac{\partial^2 U^2}{\partial m_2 \partial m_1}
\end{aligned}$$

allows us to rewrite the effect of a marginal increase in legacy debt on taxes and the number of firms in period 2 as

$$\begin{aligned}
\frac{d\tau_{12}^*}{db_{10}} &= -\frac{1}{\phi}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\frac{\rho}{3}\left(h_{21}''\left(\gamma c'\right)^2 - h_{21}'\gamma c''\right) < 0,\\
\frac{dN_{12}^*}{db_{10}} &= -\frac{1}{\phi}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\frac{\rho}{6\nu}\left(h_{21}''\left(\gamma c'\right)^2 - h_{21}'\gamma c''\right) < 0,\\
\frac{d\tau_{22}^*}{db_{10}} &= \frac{1}{\phi}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\frac{\rho}{3}\left(h_{21}''\left(\gamma c'\right)^2 - h_{21}'\gamma c''\right) > 0,\\
\frac{dN_{22}^*}{db_{10}} &= \frac{1}{\phi}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\frac{\rho}{6\nu}\left(h_{21}''\left(\gamma c'\right)^2 - h_{21}'\gamma c''\right) > 0.
\end{aligned}$$

The inequality is a result of the convexity of c and the strict concavity of h_1. Note that in the derivation above, the indices for jurisdiction 1 and 2 are interchangeable because, with both jurisdictions constrained in their borrowing, it is irrelevant where the marginal increase in initial public debt that we investigate in the comparative static analysis occurs.

D.4 Interaction Between Initial Public Infrastructure and Initial Public Debt

Unrestricted Borrowing Let $\bar{q}_i = \bar{q}_i\left(b_{i0}\right),\ i = 1, 2$. Condition (5.13) must be modified and reads

$$c'\left(m_i\right) = \frac{\beta\rho}{3}\left(1 + \frac{\rho}{3\nu}\Delta m_i + \frac{\rho}{3\nu}\Delta\bar{q}_i\left(1-\delta\right)\right),\ i = 1, 2. \tag{D.15}$$

Taking the total differential of (D.15) with respect to m_i and b_{i0} we obtain

$$\frac{dm_i}{db_{i0}} = \frac{\frac{\beta\rho^2}{9\nu}\left(1-\delta\right)}{c''\left(m_i\right) - \frac{\beta\rho^2}{9\nu}}\bar{q}_i',\ i = 1, 2 \tag{D.16}$$

where $\bar{q}_i' = \frac{\partial\bar{q}_i'}{\partial b_{i0}}$. Again, we assume that the cost function is sufficiently convex, $c''\left(m_i\right) > \frac{\beta\gamma\rho^2}{9\nu}$, such that the second-order conditions are fulfilled. Then (D.16) implies

$$\frac{dm_i}{db_{i0}} \lesseqgtr 0 \Longleftrightarrow \bar{q}_i' \lesseqgtr 0. \tag{D.17}$$

Restricted Borrowing in Jurisdiction 1 The sign of (5.14) depends on $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}$. Let $\bar{q}_1 = \bar{q}_1(b_{10})$ and differentiate (D.5) w.r.t b_{10} to obtain

$$\begin{aligned} \tfrac{\partial^2 U^1}{\partial m_1 \partial b_{10}} &= h''_{11}\tfrac{\gamma^2}{\beta}c' + \left(\beta\left(1-\delta\right)\eta_{12} + \eta_{11}\right)\bar{q}'_1, \\ \eta_{11} = -h''_{11}\gamma c'\tfrac{\partial(N_{11}(1+\gamma\tau_{11}))}{\partial \bar{q}_1} &> 0,\ \eta_{12} = h''_{12}\left(\tfrac{\partial(N_{12}(1+\gamma\tau_{12}))}{\partial m_1}\right)^2 + h'_{12}\tfrac{\gamma\rho^2}{9\nu}. \end{aligned} \tag{D.18}$$

The first term in (D.18) captures the effect of b_{10} on the marginal utility of public infrastructure investment ($\frac{\partial U^1}{\partial m_1}$) that results from its impact on the incentives for inter-temporal redistribution as described in Proposition 3. The second term $\left(\beta\left(1-\delta\right)\eta_{12} + \eta_{11}\right)\bar{q}'_1$ represents the change in $\frac{\partial U^1}{\partial m_1}$ caused by a change in $\bar{q}_1 = \bar{q}_1(b_{10})$ that is due to the variation in the marginal utility of public infrastructure investment in period 1, η_{11}, and period 2, η_{12}. In order to obtain a reversal of the result in Proposition 3, such that a rise in jurisdiction i's legacy debt (b_{i0}) leads to an increase in i's infrastructure investment (m_i) and period 2 tax rate (τ_{i2}), the following assumption must hold.

Assumption 1. *An increase in initial public infrastructure $\bar{q}_i$ raises the marginal utility of public infrastructure investment in period 1. It does so at a rate greater in magnitude than the coinciding marginal change in the repayment burden.*

The first part of Assumption 1 ensures that a higher level of initial public infrastructure incentivizes governments to raise infrastructure investment in period 1. This holds if public investments are strategic substitutes. In the reverse case, any positive relation between initial infrastructure and initial debt would merely reinforce the effect described in Proposition 2 as an increase in b_{i0} would unambiguously reduce the marginal utility of public infrastructure investment in period 1. The second part of Assumption 1 states that the positive effect of $\bar{q}_i$ on the marginal utility of public infrastructure investment dominates the overall effect.

The effect of initial infrastructure investment depends on the sign of the second term in (D.18), $\left(\beta\left(1-\delta\right)\eta_{12} + \eta_{11}\right)\bar{q}'_1$. It is assumed to be positive (first part of Assumption 1). The assumption is satisfied in the quasi-linear case with $h''_{12} = 0$, because then $\eta_{12} = h'_{12}\frac{\gamma\rho^2}{9\nu} > 0$. If $\left(\beta\left(1-\delta\right)\eta_{12} + \eta_{11}\right)\bar{q}'_1 > 0$, and $\left|h''_{11}\frac{\gamma^2}{\beta}c'\right| < \left|\left(\beta\left(1-\delta\right)\eta_{12} + \eta_{11}\right)\bar{q}'_1\right|$, as stated in the second part of Assumption 1, we have

$$\frac{dm_1}{db_{10}} \lesseqgtr 0 \Longleftrightarrow \bar{q}'_1 \lesseqgtr 0. \tag{D.19}$$

Under Assumption 1 the negative effect of an increase in initial public debt on infrastructure investment in period 1 is reinforced when there is a negative relationship between legacy debt and initial public infrastructure ($f' < 0 \Longrightarrow \bar{q}_1' < 0$).

D.5 A Tax on Domestic Income

We consider an additional tax on an immobile tax base. We assume that a fraction $0 \leq \omega \leq 1$ of the local benefit of firm investment N_{it} is taxed at τ_{i1}^{w}. One may think of ωN_{it} as a wage which is taxed with a labor tax. We also introduce a welfare loss from taxation by assuming that the corresponding tax revenue is reduced by administrative costs which are a convex function of τ_{i1}^{w}.[1] The budget constraints thus read

$$g_{i1} = \tau_{i1} N_{i1} + \left(\tau_{i1}^{w} - \xi \frac{\left(\tau_{i1}^{w}\right)^2}{2}\right) \omega N_{i1} - c(m_i) - (1+r)\, b_{i0} + b_{i1} \tag{D.20}$$

$$g_{i2} = \tau_{i2} N_{i2} + \left(\tau_{i2}^{w} - \xi \frac{\left(\tau_{i2}^{w}\right)^2}{2}\right) \omega N_{i2} - (1+r)\, b_{i1}, \tag{D.21}$$

and governments maximize

$$\begin{aligned} U^i = h_1\left(u_{i1}\right) + \beta h_2(u_{i2}) =& h_1\left(\left(1-\omega\right) N_{i1} + \left(1-\tau_{i1}^{w}\right) \omega N_{i1} + \gamma g_{i1}\right) \\ &+ \beta h_2\left(\left(1-\omega\right) N_{i2} + \left(1-\tau_{i2}^{w}\right) \omega N_{i2} + \gamma g_{i2}\right). \end{aligned} \tag{D.22}$$

Solving by backward induction, the set of first-order conditions in period 2 - given by (5.7) - is extended by the optimal choice of τ_{i2}^{w}:

$$U_{\tau_{i2}^{w}}^{i} := \frac{\partial U^i}{\partial \tau_{i2}^{w}} = h_2' \frac{\partial u_{i2}}{\partial \tau_{i2}^{w}} = 0. \tag{D.23}$$

The optimal labor tax equals $\tau_{i2}^{w*} = \frac{\gamma-1}{\gamma\xi}$. Substituting into (5.7), we can determine capital tax rates and the number of firms in a similar way as stated in Proposition 1:

[1] Ignoring administrative costs yields an equilibrium where $\tau_{i1}^{w} = 1$ since $\gamma > 1$ and the results of the main analysis are immediately obtained.

$$\tilde{\tau}_{i2}\left(m_i, m_{-i}\right) = \nu - \frac{1}{\gamma} + \frac{\rho\Delta q_i}{3} - \frac{\left(\gamma-1\right)^2}{2\gamma^2\xi}\omega \tag{D.24}$$

$$\tilde{N}_{i2}\left(m_i, m_{-i}\right) = \frac{1}{2} + \frac{\rho\Delta q_i}{6\nu} \tag{D.25}$$

$$\tau_{i2}^{w*} = \frac{\gamma-1}{\gamma\xi} \tag{D.26}$$

$$\tilde{\kappa}_i\left(b_{i1}\right) = \begin{cases} 0 & \text{if } b_{i1} \leq b^{wtp} \\ 1 & \text{if } b_{i1} > b^{wtp} \end{cases} \tag{D.27}$$

$$\tilde{g}_{i2}\left(m_i, m_{-i}, b_{i1}\right) = \tilde{\tau}_{i2}\tilde{N}_{i2} - (1-\tilde{\kappa}_i)(1+r)b_{i1}, \tag{D.28}$$

Solving period 2, we begin with the case where the Willingness-to-pay Condition is not binding in both jurisdictions. The maximization problem of jurisdiction i is given by

$$\begin{aligned} \max_{\tau_{i1}, m_i, b_{i1}, \tau_{i1}^{w}} U^i = & h_1\left(\left(1-\omega\right)N_{i1} + \left(1-\tau_{i1}^{w}\right)\omega N_{i1} + \gamma g_{i1}\right) \\ & + \beta h_2\left(\left(1-\omega\right)\tilde{N}_{i2} + \left(1-\tau_{i2}^{w*}\right)\omega\tilde{N}_{i2} + \gamma\tilde{g}_{i2}\right) \end{aligned} \tag{D.29}$$

which leads to the first-order conditions

$$\frac{\partial U^i}{\partial \tau_{i1}} = h_1' \frac{\partial u_{i1}}{\partial \tau_{i1}} = 0, \tag{D.30}$$

$$\frac{\partial U^i}{\partial m_{i1}} = -h_1'\gamma c' + \beta h_2' \frac{\partial \tilde{u}_{i2}}{\partial m_i} = 0, \tag{D.31}$$

$$\frac{\partial U^i}{\partial b_{i1}} = \gamma h_1' - \beta\gamma(1+r)h_2' = h_1' - h_2' = 0, \tag{D.32}$$

$$\frac{\partial U^i}{\partial \tau_{i1}^{w}} = h_2' \frac{\partial u_{i1}}{\partial \tau_{i1}^{w}} = 0. \tag{D.33}$$

The Hessian for the system of first-order conditions (D.30) to (D.33) for jurisdiction i is given by

$$
\boldsymbol{H} = \begin{pmatrix} \frac{\partial^2 U^i}{\partial m_i^2} & \frac{\partial^2 U^i}{\partial \tau_{i1} \partial m_i} & \frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} & \frac{\partial^2 U^i}{\partial \tau_{i1}^w \partial m_i} \\ \frac{\partial^2 U^i}{\partial m_i \partial \tau_{i1}} & \frac{\partial^2 U^i}{\partial \tau_{i1}^2} & \frac{\partial^2 U^i}{\partial b_{i1} \partial \tau_i} & \frac{\partial^2 U^i}{\partial \tau_{i1}^w \partial \tau_i} \\ \frac{\partial^2 U^i}{\partial m_i \partial b_{i1}} & \frac{\partial^2 U^i}{\partial \tau_{i1} \partial b_{i1}} & \frac{\partial^2 U^i}{\partial b_{i1}^2} & \frac{\partial^2 U^i}{\partial \tau_{i1}^w \partial b_{i1}} \\ \frac{\partial^2 U^i}{\partial m_i \partial \tau_{i1}^w} & \frac{\partial^2 U^i}{\partial \tau_{i1} \partial \tau_{i1}^w} & \frac{\partial^2 U^i}{\partial \tau_{i1}^w} & \frac{\partial^2 U^i}{\partial \left(\tau_{i1}^w\right)^2} \end{pmatrix} = \begin{pmatrix} \frac{\partial^2 U^i}{\partial m_i^2} & 0 & \frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} & 0 \\ 0 & \frac{\partial^2 U^i}{\partial \tau_{i1}^2} & 0 & 0 \\ \frac{\partial^2 U^i}{\partial m_i \partial b_{i1}} & 0 & \frac{\partial^2 U^i}{\partial b_{i1}^2} & 0 \\ 0 & 0 & 0 & \frac{\partial^2 U^i}{\partial \left(\tau_{i1}^w\right)^2} \end{pmatrix}
$$

In the second term, we insert the first-order condition for taxes (D.30) to verify that $\frac{\partial^2 U^i}{\partial m_i \partial \tau_i} = -h_{i1}'' \frac{\partial (N_{i1}(1+\gamma \tau_{i1}))}{\partial \tau_{i1}} \gamma c' = 0$ and $\frac{\partial^2 U^i}{\partial b_{i1} \partial \tau_i} = \gamma h_{i1}'' \frac{\partial (N_{i1}(1+\gamma \tau_{i1}))}{\partial \tau_{i1}} = 0$. For (D.30)-(D.33) to yield a maximum, $\boldsymbol{H}$ must be negative definite which is the case if and only if

$$
\frac{\partial^2 U^i}{\partial m_i^2} < 0, \tag{D.34}
$$

$$
\frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^i}{\partial \tau_{i1}^2} > 0, \tag{D.35}
$$

$$
\frac{\partial^2 U^i}{\partial \tau_{i1}^2} \left(\frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^i}{\partial b_{i1}^2} - \left(\frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} \right)^2 \right) < 0. \tag{D.36}
$$

$$
\frac{\partial^2 U^i}{\partial \tau_{i1}^2} \frac{\partial^2 U^i}{\partial \left(\tau_{i1}^w\right)^2} \left(\frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^i}{\partial b_{i1}^2} - \left(\frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} \right)^2 \right) > 0. \tag{D.37}
$$

Conditions (D.34), (D.35), and (D.36) are identical to the benchmark model (see Section D.1). Condition (D.37) holds whenever (D.36) holds because $\frac{\partial^2 U^i}{\partial \tau_{i1}^2} < 0$ and $\frac{\partial^2 U^i}{\partial \left(\tau_{i1}^w\right)^2} = -\gamma \xi < 0$.

The system of first-order conditions (D.30)-(D.33) can be solved to obtain equilibrium tax rates and the number of investments in period 1:

$$
\tau_{i1}^* = \nu - \frac{1}{\gamma} - \frac{(\gamma - 1)^2}{2\gamma^2 \xi} \phi, \; \tau_{i1}^{w*} = \frac{\gamma - 1}{\gamma \xi}, \; N_{i1}^* = \frac{1}{2}. \tag{D.38}
$$

Noting that $\frac{\partial \tilde{u}_{i2}}{\partial m_i} = \frac{\gamma \rho}{3} \left(1 + \frac{\rho \Delta m_i}{3\nu}\right)$, we can substitute (D.32) into (D.31) to obtain the modified first-order condition for infrastructure investment $c'(m_i) = \frac{\beta \rho}{3} \left(1 + \frac{\rho \Delta m_i}{3\nu}\right)$ which is identical to (5.13) such that the results stated in Proposition 2 prevail.

Turning to the case where borrowing is constrained in jurisdiction 2, we note that the comparative static analysis is unaffected by the introduction of the additional tax instrument because $\frac{\partial \tilde{u}_{i2}}{\partial m_i}$ is independent of the choice of τ^w_{i1}. As a consequence, the results stated in Proposition 3 are also valid with a tax on the immobile tax base.

D.6 Empirical Evidence: Additional Tables

Table D.1: Summary Statistics

Variable	Observations	Mean	Standard Deviation	Min	Max
Business Tax Rate	165,873	14.880	2.698	0	45
Property Tax Rate	165,878	1.451	0.670	0	4.55
Log Local Public Investment Expenditure	151,360	12.819	2.071	1.138	20.416
Shock ($s_{i,t}$)	165,880	0.054	0.225	0	1
Log GDP p.c.	121,985	10.075	0.227	9.484	11.580
Log Population	165,880	7.568	1.491	1.099	15.073

Table D.2: Event Study: Regression Results

This table contains the regression results of the event study design. All regressions contain year, municipality and state-year fixed effects. The dependent variable is the logarithm of public investment expenditure in columns (1)-(2) and the local business tax rate in columns (3)-(4). In columns (2) and (4), the dependent variable and the control variables refer to the corresponding inverse distance weighted average (weighted according to difference in population) of all neighboring municipalities of municipality within 10km. Cluster robust standard errors (clustered at the municipality level) are provided in parentheses. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

	Public Investment Expenditure		Business Tax Rate	
	(1)	(2)	(3)	(4)
	Treated	Neighbor	Treated	Neighbor
$s_{i,t+4}$	0.031** (0.015)	-0.016 (0.011)	-0.023** (0.010)	0.005 (0.008)
$s_{i,t+3}$	0.115*** (0.017)	-0.015 (0.012)	-0.012* (0.007)	-0.009 (0.006)
$s_{i,t+2}$	0.107*** (0.014)	-0.011 (0.010)	-0.005 (0.005)	-0.006 (0.005)
$s_{i,t}$	-0.268*** (0.013)	-0.009 (0.010)	-0.007 (0.005)	0.011*** (0.004)
$s_{i,t-1}$	-0.106*** (0.016)	-0.012 (0.011)	-0.016*** (0.006)	0.015*** (0.006)
$s_{i,t-2}$	-0.036** (0.017)	-0.008 (0.012)	-0.020*** (0.007)	0.018*** (0.007)
$s_{i,t-3}$	-0.021 (0.017)	-0.001 (0.012)	-0.020** (0.009)	0.016** (0.008)
$s_{i,t-4}$	-0.010 (0.018)	0.009 (0.013)	-0.022** (0.010)	0.018** (0.009)
$s_{i,t-5}$	-0.022 (0.015)	-0.015 (0.011)	-0.039*** (0.011)	0.011 (0.010)
Log GDP p.c.	0.404*** (0.091)	0.269*** (0.083)	-0.123* (0.072)	-0.141*** (0.044)
Log Population	0.106 (0.133)	1.107*** (0.071)	-0.206** (0.102)	0.144 (0.118)
Observations	116,463	103,103	121,985	104,666
Municipalities	8,132	6,979	8,137.	6,981
R^2	0.110	0.206	0.957	0.972

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Invited Seminars

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2016	University of Economics and Business (WU) Vienna

Presentations at Conferences and Workshops

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