Strategic Responses to Tax Policy: Insights on Wealth Transfers, Firm Behavior and the Environment

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Für Nelly und Dante.

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Chapter I

Introduction

Tax policy is a central tool of society to steer economic behavior, redistribute resources, and generate public revenue. Yet the effectiveness of tax policy depends critically on how economic actors respond to tax incentives. This dissertation empirically examines the interplay between tax policy design and the behavior of affected individuals and firms across four distinct but interconnected domains: taxation of (intergenerational) business transfers, inheritance tax regulation and firm performance, environmental taxation and commercial freight transport, and corporate transparency through mandatory reporting regimes against profit shifting. The central finding of this work is that tax policy can generate unintended behavioral responses which undermine the stated policy objectives. Relying on a broad variety of datasets and identification strategies, in this dissertation my co-authors and I show how businesses and individuals strategically adapt to tax regulations in ways that policymakers may not anticipate. These findings yield implications for tax policy design, suggesting that effective taxation requires careful consideration of behavioral responses and the institutional contexts in which these responses occur.

The second chapter investigates how business owners respond to anticipated changes in wealth transfer taxation, focusing on the strategic timing of inter-generational transfers. Taxes on wealth transfers represent important instruments to combat increasing wealth inequality, yet their effectiveness is often compromised by sophisticated avoidance strategies employed by wealthy business owners. The concentration of business assets at the top of the wealth distribution makes understanding these responses particularly important for an equitable tax policy design. Using comprehensive administrative data on the universe of German wealth transfers, this chapter exploits two anticipated policy changes that threatened to reduce the preferential tax treatment of business assets. The first event involved parliamentary debates about abolishing the "Cash-GmbH" scheme, which allowed individuals to transfer cash through (shell) companies to benefit from business asset exemptions. The second event centered on a Constitutional Court verdict that could have substantially altered the preferential treatment of business transfers. Employing a Difference-in-Bunching methodology that compares transfer patterns during event windows to counterfactual periods, the analysis reveals remarkably swift and substantial behavioral responses. When facing potential effective tax rate increases of up to 30 percent, business owners increased their transfer activity by up to nine times the normal rate. These responses occurred despite documented obstacles to timely wealth transfers and the short anticipation periods available to taxpayers. The findings reveal significant heterogeneity in responses, with high-value transfers showing nearly twice the responsiveness of average transfers. Analysis of transfer characteristics further reveals that transactions prior to the first event likely involved transfers of cash rather than actual business control, indicating the use of business structures primarily as tax avoidance vehicles. Quantifying the revenue implications of these behavioral responses through simulation exercises, we estimate foregone tax revenue of up to three times the total annual German gift and inheritance tax revenue. These findings demonstrate how anticipatory behavior by business owners can severely undermine the fiscal and redistributive objectives of wealth transfer taxation.

The third chapter shifts the focus to examine how conditional tax benefits affect firm behavior. Specifically, we investigate Germany's payroll sum requirement for firms in order to receive inheritance tax exemptions. While preferential treatment of business transfers aims to preserve employment and maintain firm liquidity during succession, the conditions attached to these benefits may create unintended distortions in firm decision-making. Since 2009, German inheritance tax law has required firms with more than 20 employees to maintain cumulative payroll above predetermined thresholds to qualify for generous tax exemptions. This requirement effectively increases layoff costs by linking employment decisions to potential retroactive tax obligations. The chapter exploits the discontinuous application of this requirement at the 20-employee threshold, focusing on death-related ownership transfers to ensure exogeneity. Combining firm-level data from Bureau van Dijk's Orbis database with death records compiled from newspaper obituaries and administrative employer-employee records, the analysis employs a Difference-in-Differences design comparing firms just above and below the threshold. This approach isolates the effect of the payroll sum requirement while controlling for succession-related and other potential confounding factors. The results reveal that firms subject to the payroll sum requirement experience significantly slower payroll growth, driven by both reduced wage increases and more cautious hiring practices. This finding is consistent with increased uncertainty about future tax obligations leading to more conservative employment strategies and a substitution of labor with capital investment. This suggests that the employment protection requirement paradoxically reduces employment growth while encouraging capital intensification. The results suggest that well-intended policies designed to protect employment may achieve the opposite effect when they increase uncertainty about future costs without regard for firms' economic circumstances.

The fourth chapter examines behavioral responses to environmental taxation in the commercial transportation sector. We assess how tax differentials across European borders affect truck routing decisions, and gauge the respective environmental consequences. This chapter proceeds through three complementary analyses to comprehensively assess trucking companies' responses to environmental tax differentials. First, using administrative toll data covering German border road sections, the analysis examines whether cross-border truck flows respond to changes in environmental taxes. An instrumental variable approach leverages tax differentials between Germany and neighboring countries to isolate the impact of environmental taxes from other price factors. The results demonstrate that commercial traffic responds significantly to environmental tax changes. A tax-induced increase in diesel prices of one euro cent per liter reduces monthly truck counts by 466 vehicles per border road segment, indicating substantial sensitivity to fuel cost differentials, most pronounced on highways with heavy commercial traffic. The second analysis employs the European Road Freight Transport survey database to investigate whether trucks strategically choose detours to avoid high-tax countries while taking advantage of low-tax jurisdictions. By comparing actual routes with optimal paths obtained through Google Maps, the analysis identifies systematic deviations from efficient routing patterns. More precisely, a one percentage-point increase in the diesel tax rate along a truck route increases the deviation probability by 0.2 percent. The third analysis quantifies the environmental consequences of these behavioral responses. Incorporating air pollution sensor data, the chapter demonstrates that tax-induced increases in cross-border truck flows generate measurable local emission peaks at border locations. Furthermore, calculations based on excess ton-kilometers driven suggest that strategic routing to avoid environmental taxes generates up to 1 million tons of additional CO_2 emissions. These findings reveal a fundamental tension in environmental tax policy: while higher taxes may reduce local demand for fossil fuels, they can simultaneously incentivize behaviors that increase overall emissions through longer routing patterns. The results highlight the importance of coordinated policy approaches when addressing mobile sources of environmental damage, as unilateral tax increases may simply displace rather than reduce harmful activities.

The fifth and final chapter investigates how mandatory private tax reporting requirements affect firms' voluntary public disclosure decisions. Specifically, we consider the introduction of Country-by-Country Reporting, which was part of the Base Erosion and Profit Shifting initiative of the Organisation for Economic Co-operation and Development (OECD), as a mandatory private tax reporting regime. Country-by-Country Reporting requires multinational corporations above specific revenue thresholds to file detailed country-level tax and financial information with fiscal authorities, who can share this information internationally. We build a comprehensive dataset of multinational firms that includes financial data and ownership information from Orbis, segment reporting information from Bloomberg, and textual analysis of annual reports from multiple databases. We then employ Difference-in-Differences and Regression Discontinuity designs, exploiting the revenue threshold for the applicability of Country-by-Country Reporting. The analysis reveals that firms significantly reduced voluntary disclosure of geographic information following the introduction of Country-by-Country Reporting. This reduction affects both quantitative segment reporting of sensitive geographic information and qualitative country-specific information in annual report narratives. The effect proves most pronounced for firms in jurisdictions with higher potential scrutiny from fiscal authorities and for more internationally diversified companies. Our findings suggest that mandatory private disclosure and voluntary public disclosure of geographic information act as substitutes rather than complements.

This dissertation makes significant methodological contributions. In each chapter, we employ innovative identification strategies and novel datasets to overcome traditional challenges in tax research. The Difference-in-Bunching approach for analyzing wealth transfer timing, the use of death records for identifying exogenous ownership changes, the instrumental variable strategy for isolating environmental tax effects, and the combination of quantitative and textual analysis for disclosure studies each represent methodological advances in their respective domains. Overall, this dissertation demonstrates the critical importance of anticipation effects and strategic behavior of individuals and firms in shaping tax policy outcomes.

Chapter II

Better Early than Never – The Effects of Anticipated Gift Tax Changes on Business Transfers

Status: Working Paper

Co-Author: Richard Winter

Abstract: Wealth transfer taxes can be important instruments to counter wealth inequality. Yet, preferential taxation regimes for intergenerational business transfers, an asset class that is particularly concentrated at the top, facilitate tax avoidance strategies by business owners. Using German administrative data at the individual-transfer level, we analyze how business transfers react to anticipated changes in such preferential tax treatment. We find strong and rapid timing responses, particularly for higher-valued transfers. We also find heterogeneity in transfer characteristics consistent with a tax avoidance motive. Our estimates suggest foregone gift tax revenue equals up to 2.8 times total wealth transfer tax revenues.

1 Introduction

Taxes on wealth transfers can be important instruments to counter increasing wealth inequality (Nekoei and Seim, 2022). A wealth class whose distribution is particularly concentrated at the top are business assets in the form of shares in partnerships and corporations (Kopczuk and Zwick, 2020; Saez and Zucman, 2016; Smith et al., 2023). The effective taxation of business wealth transfers, however, is prone to avoidance strategies by business owners (Henrekson and Waldenström, 2016). As a result, the effective tax rate structures for wealth transfers are often regressive in practice, which counteracts their intended purpose.[1] The measurement of business owners' avoidance responses to wealth transfer taxes is thus key in designing effective tax policies on wealth transfers.

The avoidance of wealth transfer taxes by business owners is facilitated by the existence of preferential tax regimes for business assets in many countries.[2] The intended purpose of these preferential taxation regimes is to secure employment and maintain firm liquidity by reducing the tax burden associated with inter-generational business succession. However, excessive privilege for a specific asset class, especially if it is more prominent at the top of the wealth distribution, undercuts the legitimacy of a tax mainly used as a re-distributive tool. As a political consequence, public pressure and judiciary decisions have led to reforms of inheritance and gift taxation in various countries in the past.[3] Business owners may anticipate such legislative changes and the adverse tax consequences for themselves and optimize the timing of their wealth transfers with respect to expected changes in the tax code.

In this study, we analyze how business owners respond to such anticipated changes in the preferential business transfer taxation, where re-timing responses may counteract policy intentions and reduce tax revenues. We exploit two anticipated events in the years 2012 and 2014 that threatened to negatively alter the preferential taxation of business transfers in Germany. We combine this institutional setting with a large administrative

[1] See e.g. OTS (2018) for the case of the UK.
[2] See OECD (2021) for an overview.
[3] Consider Henrekson and Waldenström (2016) for a description of the Swedish case, which led to the abolishment of the Swedish inheritance tax.

dataset containing the universe of German wealth transfers in the form of gifts and inheritances. We use a Difference-in-Bunching methodology to measure behavioral responses in the intra-year distribution of gifts on a weekly level preceding these event dates. As a counterfactual distribution, we use the years 2010 and 2011, where neither announcements nor legislative changes took place. This way, we can identify the excess mass of tax-motivated gift transfers of business assets. Furthermore, we explore the characteristics of transfers within the event windows to document heterogeneity consistent with differing motives underlying tax avoidance. Finally, we use the excess mass estimates from our bunching approach to provide back-of-the-envelope calculations of foregone gift tax revenue to the German State due to behavioral responses.

Our analysis begins with an investigation of the run-up period (Event Window I from hereon) to a debate in the German Parliament regarding the abolition of a well-known tax avoidance scheme called Cash-GmbH.[4] This scheme involved putting cash into a shell company prior to the transfer in order to benefit from the tax exemptions for business assets and allowed wealthy individuals to pass on basically unlimited amounts of wealth almost tax free. For instance, for an individual trying to pass-on a bank deposit of EUR 26 million, this scheme allowed unintended tax savings of up to EUR 8 million.[5]

Next, we consider the period leading up to the last major verdict of the German Constitutional Court in 2014 (Event Window II from here on), when it evaluated the conformity of the preferential treatment provisions with the German constitution. At the time, the provisions had been heavily criticized to be excessive and subject to no means-testing. They were thus argued to be in violation of the principle of equality granted by the German constitution. The precise tax consequences of the verdict were ex-ante unknown as there were several scenarios possible depending on the judgment of the court and the severity of subsequent legislative changes. However, the expectation of a significant increase of the tax burden on (large) businesses was predominant, due to which business owners were incentivized to conclude their succession before the verdict.

[4]The legal form *GmbH* (*Gesellschaft mit beschränkter Haftung*) is akin to a limited liability company (LLC), restricted to non-listed and privately-held companies.

[5]Assuming a 30% tax rate on the cash transfer and abstracting from the costs for setting up a corporation as well as fees for tax advisors and notaries.

We find that transfers of business assets in the form of gifts react very strongly and in an extremely timely manner to the risk of a future tax rate increase. For our first event, which threatened an increase in the effective tax rate (ETR) of up to 30%, we find that the excess number of transfers is more than 9 times higher than the average number of transfers in the counterfactual period. This observation is unexpected given the empirically documented obstacles to timely inter vivos transfers of ownership in the literature (Schmalbeck, 2001; Kopczuk, 2007) and the short period of opportunity for behavioral responses, as the event could only be anticipated four months in advance. For the verdict of the Constitutional Court, where the exact tax implications were not clear *ex ante*, we still find an excess mass of transfers five times higher than what we would expect absent the event. The observed pattern is particularly pronounced for high-value transfers, with individuals in the highest wealth quartile being almost twice as responsive as the average transfer. This might be due to higher tax literacy, better-informed tax consultancy, or fixed costs of avoidance coupled with higher amounts of wealth at stake compared to lower-value transfers.

Our heterogeneity results with respect to transfer characteristics suggest that transfers made within Event Window I are more likely to benefit a minor or a daughter of the donor and that effective tax rates are significantly lower for these transfers. We fail to detect such heterogeneity in Event Window II, which suggests that business transfers in the first event window are fundamentally different from transfers in the second event window. The observed pattern is consistent with a factual transfer of cash rather than control of an actual company.

We further quantify the extent of gift tax avoidance implied by the re-timing of business transfers. To this end, we perform the following thought experiment. Suppose that the excess transfers we identified were not taxed under the relevant schedule at that time, but under the provisions that were expected to be applicable after the respective point of the event windows. How much revenue did the German government lose in this hypothetical scenario due to re-timing responses? To provide a nuanced picture that takes into account the uncertainty individuals faced when forming their transfer decision, we simulate a variety of scenarios that differ in the tightness of applicable tax rules. We estimate the corresponding amount of foregone tax revenue to amount to up to EUR 12 billion, which exceeds the total tax revenue from gifts and inheritances of EUR 4.2 billion in the reference year 2011 by a factor of 2.8. Altogether, our findings suggest that gift tax policy design which disregards the behavior of business owners has adverse fiscal and distributional consequences.

We contribute to two related strands of the literature. Our main contribution lies in showing the timeliness with which wealthy business owners respond to threats of (adverse) tax changes. Early empirical evidence on the general responsiveness of wealth transfers to taxation was gathered by Bernheim et al. (2004) and Joulfaian (2004). Bernheim et al. (2004) use cross-sectional data from the Survey of Consumer Finances (SCF) to show that intergenerational wealth transfers in the US are responsive to estate and gift tax changes.[6] They find weak evidence that behavioral responses are stronger for higher-value transfers. By utilizing administrative gift tax assessment data, we are able to overcome the incomplete coverage of the wealthiest individuals inherent to surveys such as the SCF. From a macroeconomic perspective, Joulfaian (2004) uses aggregate time series to show large responses of overall gift volume in anticipation to tax changes in the US. His analysis supports the notion that inter vivos giving responds to anticipated tax changes through inter-temporal substitution. Closer to our institutional setting and by using survey data of German firms, Hines et al. (2019) also find that wealth transfer taxes significantly influence the timing of gift transfers. More precisely, they show that German family firms are more likely to conduct a succession after a tax reform in 2009 favorable for transfers of businesses. Mödinger and Kaiser (2018) find that the composition of overall gifts and bequests in Germany shifted towards business assets when their tax treatment became (expectedly) more favorable. This finding is consistent with work by Glogowsky (2021), who, using tax return data on German inheritances and gifts, documents that tax optimization patterns quickly adapt to the post-reform tax rates. Our approach builds

[6] Inheritance and gift taxes are levied at the level of the recipient of a wealth transfer whereas estate taxes target the decedent). When referring to wealth transfer taxes, we relate to all three tax types. The term bequest taxes comprises both estate and inheritance taxes.

on these insights by exploiting the high-frequency nature of the administrative tax data. This allows us to demonstrate the enormous speed in which inter-temporal shifting among the wealthy occurs. In particular, for both of our events we provide evidence of a trade-off between tax minimization and retaining control: business owners wait until the very last moment before locking in their transfer decision.

Second, we shed new light on the response channels of wealthy individuals to tax policy. Wealth (transfer) tax avoidance channels include deliberately under- or overvaluing assets (Montserrat, 2019; Poterba and Weisbenner, 2003), shifting housing assets between family members to reduce property taxes (Di Porto et al., 2021) or geographic relocation (Brülhart et al., 2022; Moretti and Wilson, 2023). As being wealthy often coincides with owning a business, a growing number of studies specifically examine the role of closely held businesses in their owners' tax avoidance strategies. Alvaredo and Saez (2009) and Duran-Cabré et al. (2019) demonstrate that business owners responded to the Spanish wealth tax by shifting non-business assets into tax-exempt business shells . More recently, Micó-Millán (2024) finds evidence of similar behavior for a Catalan inheritance tax reform, emphasizing that the tax-induced change in asset composition alone accounted for half of the post-reform tax revenue decrease from inheritances. The use of (closely held) firms as tax shelters is also documented in the context of income shifting between personal and corporate tax bases (Romanov, 2006; Alstadsæter et al., 2014) and the labeling of business owners' private consumption as tax-exempt business expenditures (Leite das Neves, 2024). We contribute to this emerging field within the literature by considering a setting in which transferring assets in the form of (closely held) business was essential to avoid high tax rates (Event Window I). Further, by exploiting differences in transfer characteristics between our two events, we can distinguish between mere tax-motivated asset transfers in business ownership (Event Window I), and transfers of actual business control (Event Window II).

In Section 2, we provide an overview about the preferential treatment of business assets under German inheritance and gift tax law. We also depict its development over time and define the two event windows that we use for our empirical approach. In Section 3, we describe our data, and in Section 4 we explain our methodology and provide our main results. We explore characteristics of the transfers within the bunching window in Section 5. The quantitative implications of our main results in terms of foregone tax revenue due to tax avoidance are discussed in Section 6, followed by a conclusion in Section 7.

2 Institutional Background

2.1 Taxation of Wealth Transfers in Germany

Tax Treatment of Wealth Transfers. Germany levies an inheritance tax on bequests at death, i.e., a tax on the enrichment of the heir. Gifts are treated in the same way as inheritances under German tax law. From a tax perspective, it should not matter whether wealth is transferred during the lifetime of the donor or only after his demise.[7] The starting point for the tax base is the gross wealth transferred to the recipient. In the case of a gift, the donor is free to choose the amount and the recipient of the transfer.[8] In principle, all types of wealth are subject to the transfer tax.

However, there is an exhaustive list of personal and objective exemptions depending on the relationship between the donor and the recipient as well as the type of asset transferred. The tax liability is based on the gross value of the assets received, after deducting the liabilities of the estate and the exemptions. The tax base is increased by transfers received by the same donor in the ten years preceding the taxable event, i.e., the date of death or the date of the gift. The inheritance and gift tax levied increases over seven tax brackets of taxable bequests. In general, tax rates are lower for close family members and increase as the degree of kinship decreases. Table II.A1 shows the tax schedules for the three tax regimes during our sample period. The highly progressive rates range from 7 % in tax class I up to 50% for transfers higher than EUR 13 million to unrelated persons.[9]

[7] Differential tax treatment of *inter vivos* gifts and inheritances would create incentives to exploit one form of transfer in order to avoid taxation of the unfavorable means of transfer.

[8] In case of an inheritance, there is a default line of succession with fixed proportions depending on the degree of kinship. This can be overridden to some extent by specifying a last will.

[9] As the inheritance and gift tax is designed as a stepwise proportional tax, the legislator grants a special

Preferentially treated asset classes. As in most EU countries, the German inheritance and gift tax law grants preferential treatment to certain asset classes, namely, agricultural assets, business assets and substantial shareholdings in corporations.[10] The preferential treatment of these asset classes is generally justified with the notion that the continuance of companies is in the public interest. As productive enterprises secure jobs and foster economic growth, they are argued to benefit society as a whole. However, the distinction between justified exemptions in the public interest and excessive privilege is not always clear cut.

Since 2009, the German legislation distinguishes between *productive business assets* and so-called *administrative assets* (*Verwaltungsvermögen*). Stemming from the rationale that only productive business assets should be taxed preferentially, these administrative assets are defined as assets which are not strictly necessary to successfully run the business.[11]

Crucially, the legal definition of administrative assets at the time did not include cash holdings, which was subsequently exploited by wealthy individuals to transfer their private wealth tax neutrally through use of a scheme called "Cash-GmbH". This tax avoidance scheme involved setting up a corporation and depositing cash into the company assets. As cash was not deemed to be harmful administrative assets, the cash within the corporation qualified for preferential treatment and could benefit from the generous exemptions for productive assets.[12] If tax subjects were willing and able to set up a corporation, they could pass-on basically unlimited cash holdings without being subject to the gift tax law, by making use of the provisions for productive assets detailed below.

provision (*Härteausgleich*) that prevents the average tax rate to increase substantially at the bracket cut-off points. Instead, the law allows for transition areas characterized by marginal tax rates of 50% if the statutory tax rate is lower than 30%, and 75% if the statutory rate is higher than 30%, until the average tax rate has caught up to the higher level of the next bracket.

[10]The definition of business assets comprises shares in partnerships and sole proprietorship. The definition of substantial shareholding refers to the donor of the wealth transfer possessing a minimum share of 25% in a corporation. This minimum share can be reached individually or through joint ownership, under the condition that joint ownership entails joint action inside the firm.

[11]E.g., properties granted for use by third parties, corporate shareholdings of 25% or less, art objects or financial asset shares.

[12]An additional benefit of usshing cash as productive assets was that this cash increased the share of productive assets relative to administrative assets in the company. As the exemption was granted on the overall company value as long as administrative assets were not higher than 50% of the total company value, cash injections could be used to cover for a larger share of non-productive business assets, such as rental property.

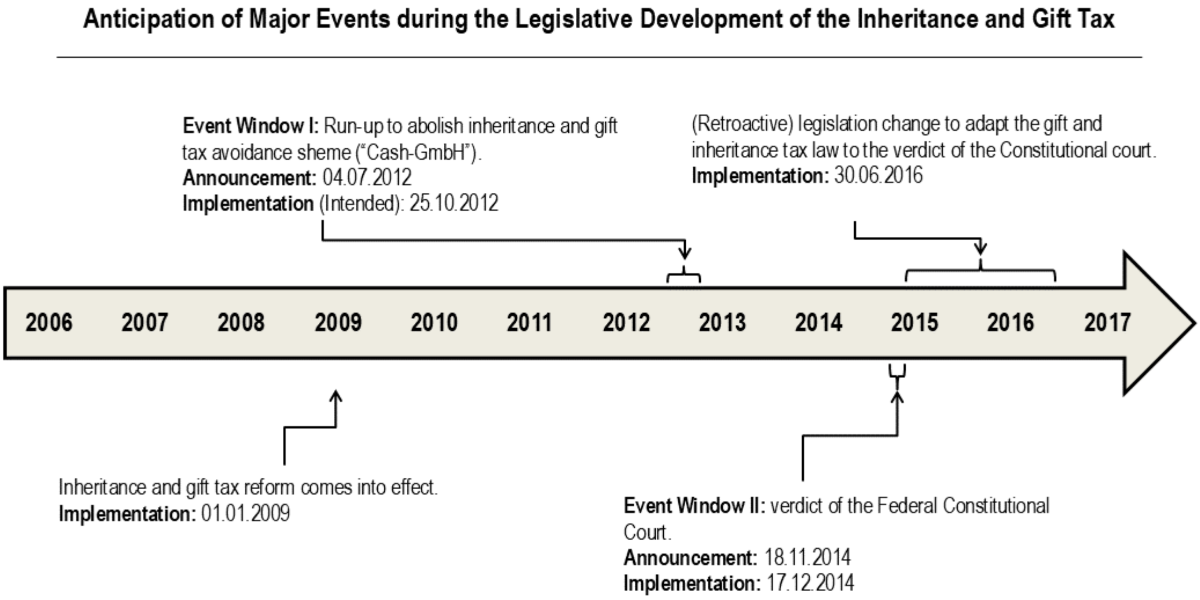
Exemptions for productive assets. Any agricultural assets, business assets and substantial corporate shareholdings that are not classified as administrative assets are in principle eligible for two possible modes of preferential taxation. First, the law allows for a regular exemption of 85% (*Regelverschonung*). This means that only 15 % of the taxable transfer of this asset type is considered in the tax base. The main requirements for the exemption to be applicable are that the transferred business could not be sold in the five years following the transfer and that the average sum of wages over this holding period could not be reduced by more than 20 %. This regular exemption could be replaced by a more generous but also more restrictive optional exemption of 100% (*Optionsverschonung*). In order to obtain a full exemption, the business must not be sold for a duration of seven years and the average sum of wages over the now seven year holding period must not be lowered. When filing her tax return, the recipient had to decide which exemption model should be applied. She was then locked into this decision, without the possibility to change to the less or more restrictive regime at a later point. If the requirements for the exemptions were violated at the end of the relevant period, the tax was proportionately re-levied. Importantly, the exemption was granted irrespectively of the amount of wealth transferred or the economic situation of the business in question.

2.2 Legislative Development and Leveraged Reforms

For our analysis, we exploit two events in the legislative development of the inheritance and gift tax law in Germany, which caused a substantial revision of the expectations of tax subjects with regard to their future tax liabilities. The respective windows for behavioral responses to these events had clearly defined end points, which were known to the public at the announcement date. This common feature allows us to cleanly identify transfer allocation within the event windows. Figure II.1 illustrates the two event windows we will focus on in our analysis and in the exposition below.

Event Window I: (Failed) ban of the Cash-GmbH. As noted in the previous section, an elementary flaw of the newly implemented provisions exempting business assets from inheritance and gift taxation was the administrative asset catalog. As cash

Figure II.1: Major Events during the Legislative Development of the Inheritance and Gift Tax



Notes: This figure shows the most important legislative events during our sample period. The last major reform which introduced the exemptions for business assets was implemented in 2009. Event Window I starts with the submission of the draft proposal from the German Federal Council regarding the effective abolition of the Cash-GmbH avoidance scheme, effectively banning masked cash transfers through shell corporations, and ends just before the parliament debate on 25 Oct 2012. Event Window II includes the time between the announcement of the verdict of the German Constitutional Court in November 2014 until the day of judgment on 17 December 2014. The court decided on whether the preferential treatment provisions in general were constitutional and had the power to set a retroactive implementation date.
Source: Troll/Gebel/Jülicher/Gottschalk: ErbStG, "XI. Entwicklung der ErbSt von 2009 bis 2016", 2021.

was not explicitly named in the definition of an administrative asset, paying wealth transfer taxes could be circumvented rather easily. In order to close this gaping loophole in the tax code, the Federal Council (*Bundesrat*) submitted a draft proposal on 6 July 2012 to the German Parliament (*Bundestag*), which included a respective amendment of the administrative asset catalog. The Parliament decided on 25 October 2012 on this provision change that would ban the transformation of cash into preferentially treated business assets. If the parliament had decided in favor of the legislative change on that day, the scheme would have been rendered impossible with immediate effect. This was also the expected outcome of the debate.

For individuals planning to make use of this tax saving vehicle, the abolition would entail the loss of a factual 100% exemption and in turn an increase in the effective tax rate from zero to about 30%.[13] Especially for wealthy individuals, this change in effective taxation would entail a massive loss of wealth to the family. For instance, a taxable amount of EUR 26 million passed on after the debate would be subject to an increase in the tax burden levied on the transfer by close to EUR 8 million. However, the Parliament could not produce the required majority and the current provision stayed in place until 7 June 2013, when the provision was eventually adjusted. The public discussion of the planned changes to the tax code started on 4 July 2012 after the submission of the draft proposal and culminated in the weeks imminent to 25 October 2012.[14] This is indicated by Figure II.2, which shows the monthly count of newspaper articles including the search term "Cash-GmbH" on the Dow Jones Factiva database. The figure shows a clear spike in media attention around the submission of the draft proposal in July 2012, with a surge just prior to the parliament debate in October of the same year and extended coverage afterwards until the loophole was finally closed in 2013.

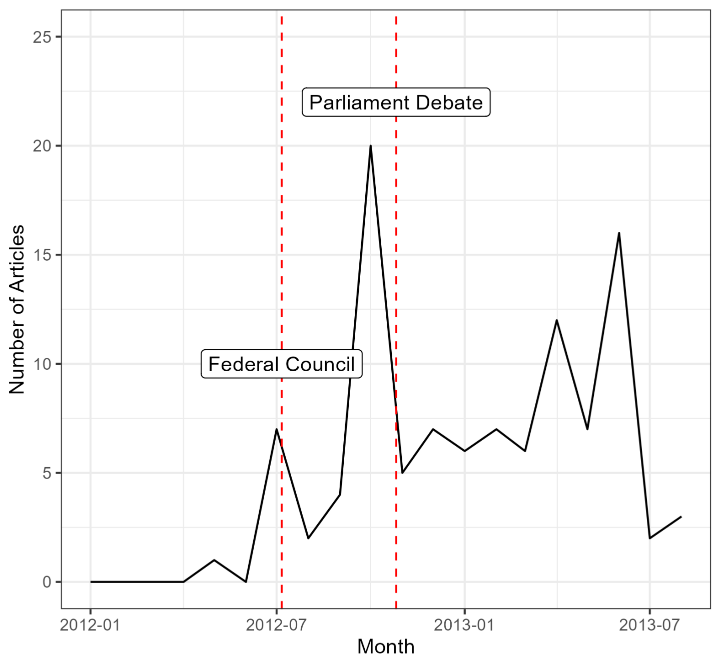
Event Window II: Verdict of the Federal Constitutional Court. In September 2012, the Federal Financial Court (*Bundesfinanzhof*) appealed to the Constitutional Court inquiring whether the preferential treatment of business assets was in violation of the constitution.[15] In its inquiry, the Financial Court argued that the far-reaching or even complete exemption of preferentially treated asset classes were excessive and unsubstantiated. Such an exemption would assume that the wealth transfer tax endangers business continuation. Yet, the actual exemption did not take into account the transferred value or the capacity of the recipient to bear the tax burden. For instance, there were no provisions to verify the existence of sufficient liquid funds to pay the tax, or whether such funds could be acquired in case that the tax would be deferred. It further stated that the notion of preserving jobs as an argument for exempting businesses was

[13] Assuming a transfer to a close family member in excess of EUR 26 million. Also for transfers of smaller wealth levels, the increase in effective tax rates was still substantially above 0%, see Table II.A1.

[14] The introduction of the new law failed because the law change involved some more controversial provision changes such as tax benefits for same sex partnerships. For more details see Bundesrat 6 July 2012, 302/12.

[15] Bundesfinanzhof, 27 September 2012, II R 9/11.

Figure II.2: Newspaper Articles Including the Term "Cash-GmbH"



Notes: This figure shows the monthly count of German newspaper articles containing the search term "Cash-GmbH" from January 2012 until August 2013. The vertical dashed lines indicate the date of the submission of the draft proposal by the German Federal Council on 6 July 2012 as well as the date of the parliament debate in the German Parliament on 25 October 2012.
Source: Dow Jones Factiva, accessed on 10 November 2022.

flimsy, as the vast majority of companies taxed had less then 20 employees, which automatically excluded them from the job preservation requirement. After the inquiry of the Financial Court, individuals had to expect that the generous exemption provisions were destined to change for the worse (Mödinger and Kaiser, 2018). Tax consultants publicly urged business owners to conclude their succession before the verdict of the Constitutional Court.

At this point it is instructive to consider the possible scenarios business owners could be confronted with, depending on the outcome of the court's decision. The three scenarios are summarized in Table II.A2. One possible albeit improbable outcome was that the Constitutional Court would dismiss the critique of the Financial Court and approve the existing rules. Second and similarly improbable was the outcome that the court would find all provisions of the wealth transfer tax law in its current form (or only the provisions in question) to be void and in need of a fundamental reform. In that case, the provisions deemed as void would not have been applicable for any transfer occurring after the verdict.

Note that the court has the power to declare certain provisions as void but cannot enact new legislation. In that case, the legislator would need to implement a new form of the law in accordance with the court's demands. This outcome would have had a similar effect as the abolition of the Cash-GmbH for companies, if only the provisions for preferential treatment of business assets was deemed to be void. In effect, this "worst case scenario" would have caused a substantial increase in effective tax rates as well. Finally, the court could reach a similar verdict as in 2006 and find that the law in its current form was incompatible with the constitution. This judgment would differ from the previous one in the sense that the law in its current form would remain applicable until the legislator has reformed the current provisions. However, even in that case the legislator could in principle backdate the reform to the day of judgment.

Hence, in order to hedge against Scenario 2 or 3, individuals would need to complete their transfers before the verdict. Despite some outcomes being more probable than others, each one was a possibility and remained so until judgment day.

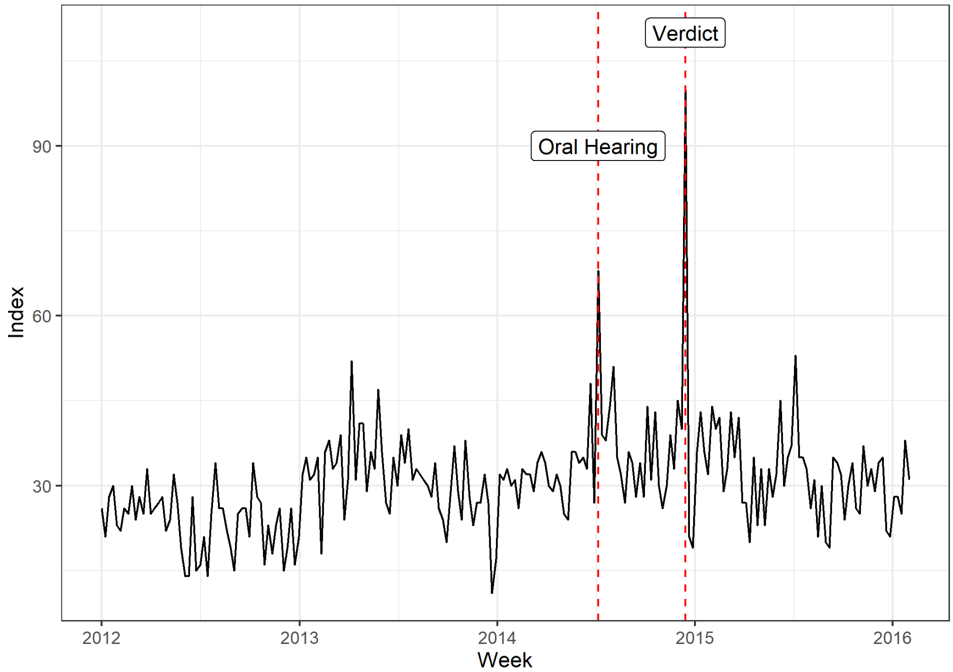
The Constitutional Court decided on the case in 2014, which was announced at the beginning of the same year. The oral hearing took place on 8 July 2014 and the passing of verdict was announced on 18 November and promulgated on 17 December.[16] Hence, the public knew that the court would decide on the case at some point during 2014 at the beginning of the year. The ruling of the Constitutional Court was salient in the media and public interest was high. Figure II.3 shows trends in the Google search index for the term inheritance tax (*Erbschaftsteuer*) during 2014.[17] The figure features two sizable spikes around the week of the oral hearing in July as well as the day of judgment in December. The first senate of the court declared the provisions granting preferential treatment to business assets to be incompatible with the constitution, i.e., scenario three was realized. In its verdict, the court deemed the exemptions to be excessive and for that reason unconstitutional and demanded an adjustment of the law until end of June

[16] See the corresponding press release no. 102/2014 from 18 November 2014.

[17] Interestingly, the Google trends index for the term "Cash-GmbH" did not show substantial variation during 2012. We view this as indication that Event Window I was less relevant for the general public but rather for a specific subgroup that was advised by professional tax consultants.

2016.[18]

Figure II.3: Google Trends Index for "Erbschaftsteuer" between 2012 and 2016



Notes: This figure shows a search index for the term "Erbschaftsteuer" (=*Inheritance Tax*) for the period between January 2012 and January 2016. The vertical dashed lines indicate points in time of public interest, namely the day of the oral hearing of the German Constitutional Court on 8 July 2014 as well as the day of verdict on 17 December 2014.
Source: Google Trends, accessed on 5 May 2022.

3 Description of Data

We use German inheritance and gift tax return data provided by the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States for the years from 2007 until 2019.[19] This dataset covers all wealth transfers whose tax determination dates fell into this period.[20] The data consist of repeated cross-sections, where the unit of

[18] After a lengthy legislative process, the provisions in question were adjusted on 4 November 2016 with retroactive application for taxable events after 1 July 2016. Instead of a fundamental reform of the law, the legislator adjusted the provisions selectively to comply with the demands of the court verdict.

[19] *Erbschaft- und Schenkungsteuer-Panel* (EVAS 73611).

[20] As inheritance and gift tax returns are usually filed and administered at least one year after the taxable event and with an average time lag of three years (see Figure II.A2), our dataset effectively covers earlier periods than 2007. Also, coverage of taxable events in the years 2018 and 2019 is likely incomplete, as a substantial share of same-year tax cases has not been assessed yet. Both years are (potentially) missing those gifts and inheritances that were filed late or took a long time to administer (for instance due to family conflicts).

observation is an individual tax assessment. As the records are anonymized, we can only track assessments of the same transfer. However, there is no identifier for individuals.

The data contain information about transferor and recipient characteristics (i.e. birth dates, sex, state, responsible financial office), their relational degree, tax base details and the tax rate as well as taxes paid. They further include three different variables relating to the relevant dates: the date of taxable event, the date of tax generation and the date of tax assessment. For our purposes, the date of taxable event is of main interest, as it allows to track the transmission of wealth at a daily frequency. It coincides with the date of tax generation, which constitutes the date of the legal recognition for tax purposes.[21] For our analysis, we always keep the most recent date of tax assessment, as deviations between initial and final tax assessments can be substantial. Apart from these time-related variables, our analysis uses different elements of the tax base. Primarily, these are the different asset classes provided for in the inheritance and gift tax returns, i.e. agricultural assets, business assets and company shares (see Section 2 for an elucidation).

Overall, the data provided by the RDC cover about 3 million assessments over the whole sample period from 2007 to 2019. Table II.A3 shows the sample selection process for our final sample. We first eliminate transfer types that are generally not of interest for our analysis, such as erroneously calculated tax amounts or special cases of inheritance taxation. Second, we eliminate transfers with missing birth dates. We then establish uniqueness of transfers by always keeping the latest tax assessment for a given transfer case, which ensures that our values correspond to the latest update to the values in the tax returns.[22] These initial selection steps leave us with roughly 2 million unique transfers. We further exclude negative asset transfers and transfers before 2009 and after 2017. Transfer values before 2009 where based on different valuation principles and the

[21]The date of tax assessment is important to understand the data structure and the different steps of the administrative process from initial to final tax determination. Moreover, it is essential to establish uniqueness of observations per transfer date and recipient.

[22]Unfortunately, the identifier for a given inheritance or gift case is not reliable as a panel identifier. The original tax return number is given by the responsible financial office, which may already be used by another financial office. Furthermore, the tax number is not kept when an individual moves and challenges a tax assessment later. As we are provided with an anonymized identifier based on the tax number, we are unable to distinguish these cases and produce our own identifier based on gender and birth dates of the donor and recipient, their relational degree and the responsible financial office. Our results are robust to relying on the tax return number as the initial identifier.

preferential treatment provisions were only introduced with the 2009 reform. We exclude observations after 2016 because of the lag between taxable event and tax assessment, which leads to these periods not being representative of overall transfers. The initial sample of unique transfers consists of 1.3 million receipts, the vast majority of which (79%) are inheritances. Our period of interest includes 281,545 unique gifts.

Table II.1 provides an overview of the gift sample separated by the major asset class of the transfer.[23] The table illustrates several interesting features of the data. First, the preferentially treated asset classes (agricultural property, business assets, and company shares) are on average of higher overall transfer value compared to transfers of cash and real estate. The distributions of all asset classes are highly skewed to the right, with mean values being several orders of magnitude higher than the median. Second, recipients of preferentially treated assets are on average five to eight years younger when receiving a gift when compared to the recipients of real estate or cash and financial assets. Third, because of preferential treatment, effective tax rates are substantially lower for agricultural property, business assets and company shares, with an average effective tax rate of less than one percent. However, not all transfers of favored asset classes are fully exempt from taxation. Incomplete take-up of preferential taxation does not come as surprise. Especially for transfers of low-value assets, applying for preferential taxation came at a regulatory cost, while the amounts of assets transferred were below the generally high allowance values. This could incentivize owners of small businesses and especially agricultural asset owners to refrain from receiving preferential tax treatment. Fourth, gifts of preferentially treated assets are twice as likely to go to a son than to a daughter of the donor. In contrast, the gender distribution of receipts of cash and real estate is close to equality.

For our analysis, we restrict this initial sample to all transfers that include (non-negative) values for the sum of agricultural assets, business assets and company shares.[24]

[23] The major asset class is defined as the asset class that constitutes the largest share of the overall gift value. For instance, a gift transfer of EUR 10 million in business assets and EUR 5 million in real estate yields the major asset type of the transfer to be defined as a business asset. For comparison purposes, Table II.A4 provides the same measures for bequests.

[24] Tax law stipulates that the value sum across all three asset categories shall be considered for preferential taxation. Due to the application of the net principle, only positive sums are relevant for tax purposes.

This definition includes roughly 12,000 transfers in which none of the preferentially treated assets constitute the major asset type of the transfer. This final restriction reduces the sample size to 76,943 gift transfers over the period from 2009 to 2017.

Table II.1: Descriptive Statistics of Gift Sample

	Obs.	Mean	Std. Dev.	P01	P50	P99
Agricultural property						
Overall value of receipt	11,561	294.02	527.52	0	160	1,918
Age of Recipient at Transfer	11,558	40.70	11.71	19	39	75
Effective tax rate (p.p.)	11,561	0.44	1.98	0	0	11
Share of fav. assets (p.p.)	11,526	63.40	38.64	0	77	100
Above Allowance	11,561	0.32	0.46	0	0	1
Son	11,561	0.52	0.50	0	1	1
Daughter	11,561	0.14	0.34	0	0	1
Female Donor	11,561	0.35	0.48	0	0	1
Business assets						
Overall value of receipt	31,950	5,720.97	67,791.89	5	687	73,076
Age of Recipient at Transfer	31,884	40.02	13.38	8	40	78
Effective tax rate (p.p.)	31,938	0.46	2.28	0	0	13
Share of fav. assets (p.p.)	31,894	82.21	34.83	0	100	100
Above Allowance	31,950	0.71	0.45	0	1	1
Son	31,950	0.55	0.50	0	1	1
Daughter	31,950	0.26	0.44	0	0	1
Female Donor	31,950	0.31	0.46	0	0	1
Cash and financial assets						
Overall value of receipt	95,379	172.05	655.07	0	50	1,855
Age of Recipient at Transfer	94,575	48.68	17.62	4	49	87
Effective tax rate (p.p.)	95,304	4.36	7.23	0	0	29
Share of fav. assets (p.p.)	520	48.39	48.89	0	26	100
Above Allowance	95,379	0.62	0.49	0	1	1
Son	95,379	0.23	0.42	0	0	1
Daughter	95,379	0.20	0.40	0	0	1
Female Donor	95,379	0.50	0.50	0	1	1
Company shares						
Overall value of receipt	21,789	3,597.52	24,732.95	1	415	58,150
Age of Recipient at Transfer	21,716	40.65	14.37	7	40	79

Table II.1: Descriptive Statistics of Gift Sample Continued

Effective tax rate (p.p.)	21,784	0.72	3.03	0	0	18
Share of fav. assets (p.p.)	21,756	71.92	42.45	0	100	100
Above Allowance	21,789	0.65	0.48	0	1	1
Son	21,789	0.44	0.50	0	0	1
Daughter	21,789	0.22	0.42	0	0	1
Female Donor	21,789	0.32	0.47	0	0	1
Real estate						
Overall value of receipt	120,866	266.30	510.92	6	129	1,757
Age of Recipient at Transfer	120,820	45.47	15.07	13	45	81
Effective tax rate (p.p.)	120,850	3.47	5.64	0	0	24
Share of fav. assets (p.p.)	11,123	57.63	48.15	0	100	100
Above Allowance	120,866	0.42	0.49	0	0	1
Son	120,866	0.23	0.42	0	0	1
Daughter	120,866	0.19	0.39	0	0	1
Female Donor	120,866	0.51	0.50	0	1	1

Notes: This table shows descriptive statistics for the sample of gifts after our selection process detailed in Table II.A3. The overall value of receipt is expressed in Thousand Euros. Above Allowance is an indicator for a transfer above the personal allowance of the recipient. Son and Daughter are indicator variables indicating the recipient gender and relation of the recipient to the donor. Female Donor is an indicator equal to one if the donor is female. Summary statistics are given for each asset type separately. For comparison purposes we also show asset classes that are not the main focus of our analysis, namely, cash and financial assets as well as real estate.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

4 Excess Mass Estimation

4.1 Methodology

The shifts in expectations regarding effective tax rates for preferentially treated asset classes created large incentives for re-timing responses within the event windows described in Section 2. Individuals who expected their effective tax rate to change for the worse after the end point of the respective event window (25 Oct 2012 and 17 Dec 2014), were incentivized to conclude their wealth transfers of preferentially treated assets before these final deadlines.[25] Bunching in the distribution of transfers in the event windows over time allows us to estimate these short-term re-timing responses.

Bunching methods have been used extensively in the literature to estimate causal behavioral effects.[26] The basic idea of the bunching approach is to quantify the behavioral responses elicited by a discontinuity in incentives by estimating the excess mass in a distribution of interest. We derive adjustment responses by estimating the excess mass in the distribution of weekly wealth transfers around the event dates. In our particular case, we utilize an alternative to the classical polynomial based approach in which we use the unaffected 2010 to 2011 distribution as a counterfactual. This so-called Difference-in-Bunching approach has been applied in several recent studies, e.g. Brown (2013), Best and Kleven (2017) or Buhlmann et al. (2020). It relies on a suitable reference distribution as counterfactual to the distribution in the event window. The counterfactual distribution allows us to model how transfer behavior would have looked like absent the events. We can then attribute the excess mass of transfers to behavioral responses. The method relies on actual data rather than approximations based on polynomial extrapolation. This avoids some of the assumptions invoked, which we consider to be violated in our application.[27]

Figure II.4 illustrates our approach graphically. It depicts the annual distributions of transfers of preferentially taxed asset classes in weekly bins throughout our sample period. The figure distinguishes between inheritances and gifts and covers taxable event years from 2009 to 2017. Several patterns are worth emphasizing. First, inheritances are distributed almost uniformly across years. This suggests that the date of death is not strategically chosen for tax planning purposes in our sample. It is also suggestive that the patterns we observe for gifts are not artifacts of some underlying trends in transfer behavior. In stark contrast, the distribution of gifts features sizable spikes at specific

[25]From a tax planning perspective it would be optimal to set the transfer date as close to the deadline as possible. One reason for this is the potential of new information coming in, potentially rendering the re-timing no longer necessary. Another reason to delay the transfer for as long as possible was that transferring a business is a complex endeavor, which takes time to plan and execute correctly.

[26]The basic methodology was developed in the tax context by contributions of Saez (2010), Chetty et al. (2011) and Kleven and Waseem (2013) and has since then found many applications in the social sciences. See Kleven (2016) for a recent overview of methods and applications.

[27]For example, the polynomial approach generally assumes that observations farther away from the threshold are not affected by the discontinuity. In a robustness check, we also estimate the excess mass using the polynomial approach and find quantitatively similar results.

dates throughout the observed period.

Second, we observe substantial start- and end-of-year bunching as well as mid-year bunching, the latter albeit to a much smaller extent. These patterns can likely be explained by the end of the financial year. This is generally 31 December for most companies and 30 June for agricultural enterprises. The financial year may be relevant for a transfer decision, as valuation is generally based on the firms operating income.[28]

Third, there are irregularities in our event windows of interest, namely, in the third quarter of 2012, as well as in December 2014, as well as around mid-year of 2016, where we observe the highest mid-year spike of our sample period as well as a level-drop in the period afterwards. Finally, we detect a declining trend in inheritances starting in 2017, which we attribute to the administrative lag between taxable event and tax assessment, as well as the effect of the 2016 reform.

From our analysis of the legislative development and the graphical evidence just presented, we have identified the period from January 2010 until July 2012 as candidate for a "regular" transfer distribution without contamination from behavioral responses. By the onset of this period, enough time has passed since the 2009 reform for individuals to become familiar with the adjusted provisions. At this point, expectations for a stable legal framework could be formed. Importantly, the legislative discussions initiated in July 2012 could not be anticipated by the public beforehand. Hence, we have a stable legal framework during that time, and the gift transfer distribution only features the common start-, mid- and end-of-year spikes.

[28] In Germany, valuation of business assets for the purposes of the inheritance and gift tax is generally based on the market value. As this market value is commonly not available, alternative valuation methods such as the simplified income capitalization approach are common. Under this approach, average operating income over the last three financial years is multiplied with a capitalization factor to reflect future earnings prospects. Hence, valuation is easiest when the transfer occurs just after a financial year end.

Figure II.4: Evolution of Preferentially Treated Asset Transfers by Type

Notes: This figure depicts the evolution of assets transfers eligible for preferential treatment over time, split up between gifts and inheritances at the recipient-receipt level. Each point represents the number of transfers of transfers of preferentially treated assets (agricultural property, business assets and company shares) in a specific week.

Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

For illustration purposes and normalization, we consider the transfer distribution one year around the event date, i.e., 26 weeks before and after the respective end point of the event window (=normalization window). In order to be able to directly compare the distributions of transfers in our event windows with the counterfactual of the reference year, we have to account for level differences in transfers. Hence, we divide the weekly bin counts by the total sum of transfers in the normalization window. The normalized bin counts then represent the proportion of transfers in that week relative to the overall transfers occurring in that period.

More formally, let n_i denote the number of transfers in bin $i \in \{-26, \ldots, 26\}$ and $\tilde{n}_i \equiv n_i / \sum_{j=-26}^{26} n_i$ the normalized bin count. After visually identifying the bunching region, we calculate the excess mass $\hat{b}$ by the difference in bin counts between the transfer distribution in the event window and the counterfactual, normalized by the average bin count of the counterfactual distribution in the bunching region:

$$\hat{b} = \frac{\sum_{i=L}^{U} (\tilde{n}_i - \hat{\tilde{n}}_i)}{\sum_{i=L}^{U} \hat{\tilde{n}}_i / N_i} \tag{II.1}$$

where N_i is the number of bins in the bunching region and $\hat{\tilde{n}}_i$ is the normalized bin count for the counterfactual year. Hence, $\hat{b}$ estimates the excess number of transfers in the bunching region relative to the average height of the counterfactual. Multiplying the excess mass with the bin width yields an estimate of the average timing response. Following Buhlmann et al. (2020), we construct standard errors for our excess mass estimates using a non-parametric bootstrap procedure. We randomly sample individual transfers in our estimation sample with replacement and calculate a new sample of counts based on which we then re-estimate the excess mass. This process is repeated 1,000 times yielding a vector of excess mass estimates. We use the standard error of this vector as an estimate for the standard error of $\hat{b}$.

4.2 Difference-in-Bunching Estimates

We move on to quantify the observed behavioral responses using the Difference-in-Bunching framework. The results for our two main events of interest are presented in Figures II.5a and II.5b. Each graph shows weekly normalized bin counts centered around the deadline of interest and the corresponding date in the counterfactual period. The dashed lines at the zero mark indicate the deadline across all figures. The boxes next to the vertical lines display the estimated excess bunching with non-parametrically bootstrapped standard errors in parentheses. Outside the bunching regions, the distribution of the reference period and the counterfactual period appear to be remarkably similar. Our chosen reference period hence seems to constitute a suitable counterfactual for the event period.

Our chosen reference period seems to constitute a suitable counterfactual for the event period. Outside the bunching regions, the two distributions appear to be remarkably similar.

Event Window I. Our first window of interest is the period leading up to the debate about the abolition of the Cash-GmbH on 25 October 2012 in the Bundestag. Recall that the general expectation regarding the outcome of the event was that the Cash-GmbH avoidance scheme would be prohibited with immediate effect by extending the definition of administrative assets to include also excessive cash holdings. Even though the Bundestag surprisingly did not reach the expected conclusion, expectations had changed beforehand and the transfer decision was already locked in. Therefore, we observe a significant timing response within the event window which is depicted in Figure II.5a. The response to the threat of an effective tax rate increase that would entail an increase in tax burden in the millions is large in magnitude. The excess bunching detected constitutes 9.02 times the average size of the counterfactual normalized transfer distribution. As can be seen from the counterfactual distribution, the month of October is not a month where a lot of transfers of preferentially treated assets occur normally, indicating that most of the transfers we observe in that window are purely motivated by tax considerations.

This excess mass of transfer counts also translates in a substantial spike in volume. This is illustrated in Figure II.A3a, which provides the gross value of transfers of agricultural assets, business assets and company shares in the year of 2012. In less than a month, business owners transferred more than EUR 40 billion in anticipation of an adverse tax policy change.

Event Window II. A particularly interesting case provides Event Window II, the period leading up to the verdict of the Constitutional court on 17 December 2014. As the concrete tax implications of the verdict of the court where ex ante not known, it provides us with some insight into the beliefs of responding individuals regarding the outcome. As we have illustrated in Section 2, there were three potential outcomes and only some variations of two of them featured immediate detrimental consequences. The risk of retroactive application of any change or the potential voiding of the exemption provisions led a substantial amount of individuals to transfer their assets in the three weeks before the verdict. The results from our estimation are presented in Figure II.5b. Our excess mass indicates that the excess of normalized transfer counts is about 5.62 times the average size of the counterfactual in the bunching region and is strongly significant. When compared to the counterfactual distribution, it is apparent that the majority of the estimated excess mass comes from the start-of-year spike normally observed in the transfer distribution. Our results indicate that as a precautionary action to hedge against the possibility of an immediate law change, individuals planning to pass on their business at the beginning of 2015 pulled their transfer forward in time just before the verdict. Figure II.A3b shows that in terms of volume, the response in the second event window is much more moderate in comparison to the first event window. We see a spike in volume around the oral hearing of the Constitutional Court in July as well as a sharply increasing trend in the months leading up to the verdict, with a substantial spike in December. With an overall volume of business transfers of EUR 10 billion, the response size in December 2014 is equal to only about 25% of the October 2012 volume.

Overall, we detect sizable timing responses of transfers by business owners preceding expected tax changes. This speaks to the extreme tax literacy of this particular set of individuals, which supports findings by Houben and Maiterth (2013), Mödinger and

Kaiser (2018) and Glogowsky (2021) for the German context. Our evidence also shows that the responsiveness is extremely rapid. For our first event window, individuals had only four months to undertake all steps necessary to pass-on a fortune of wealth. In the following sections, we go a step further and investigate response heterogeneity, identify transfer characteristics to speak to the question who bunches, and provide a back-of-the-envelope calculation of the tax consequences.

4.3 Heterogeneous Effects

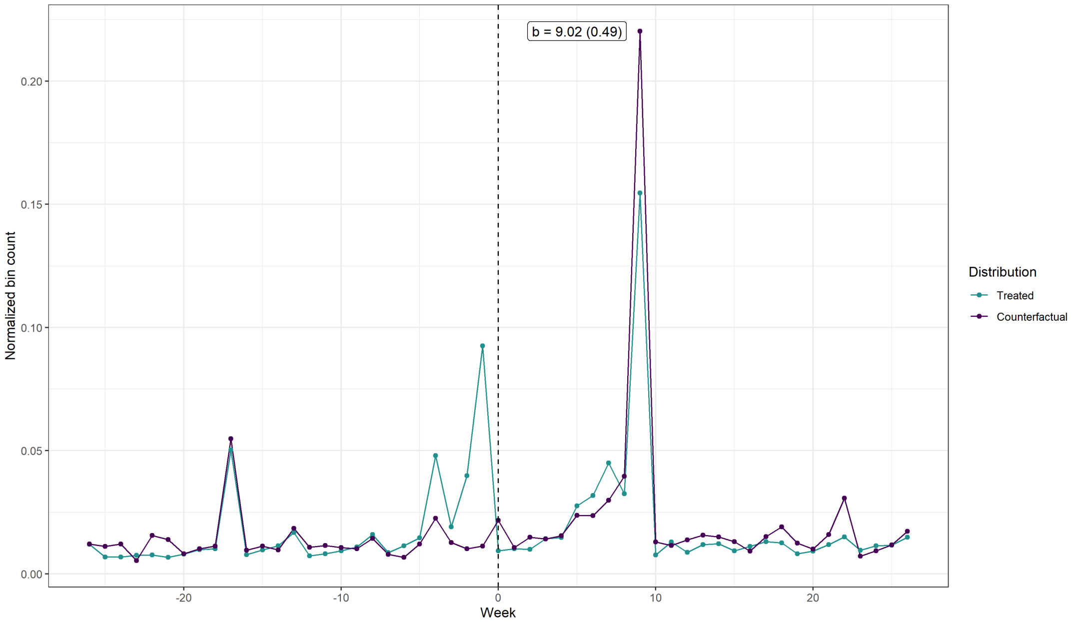
We repeat the analysis conducted on the main sample on two sets of sample splits to tease out response heterogeneity in our estimates. Of particular interest to us is first, whether the asset classes eligible for preferential treatment respond differently and second, whether wealthy individuals are more responsive than less wealthy ones and whether there are differences for these groups across the two event windows.

Asset Class. In a first step, we investigate whether the behavioral response differs across types of preferentially treated asset classes. We subset our data to the three types of transfers, i.e., transfer of agricultural assets, business assets, and company shares and re-estimate the excess mass for each sub-sample. We present the estimated normalized excess masses and two standard error confidence intervals in Figure II.6a.

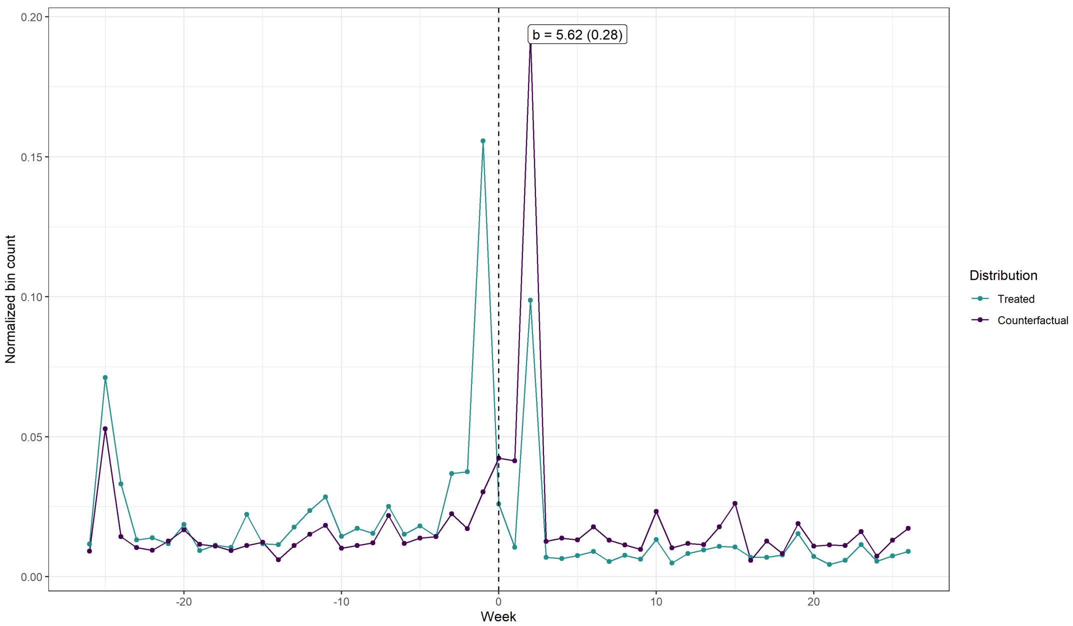
We find that for the first event window, business assets appear to be the most responsive asset class, closely followed by company shares. In comparison, agricultural assets seem to be unresponsive to the abolition of the Cash-GmbH. One contributor to this result might be the fact that transfers of agricultural assets tend to be much smaller in magnitude of wealth transferred, which diminishes the gains from tax planning compared to its cost. It might also more frequently be the case for these assets to fall under the personal exemption thresholds, which makes the provisions for preferential treatment irrelevant. We also detect differences in responses between the two event windows of interest. For the failed ban on the Cash-GmbH scheme, business assets and company shares responded similarly strong, whereas for the verdict of the German Constitutional Court, transfers of business assets are twice as responsive as transfers of company shares.

Figure II.5: Difference-in-Bunching Around Event I and II

(a) Event Window I: 2012 Failed ban of the Cash-GmbH



(b) Event II: 2014 Constitutional Court Verdict



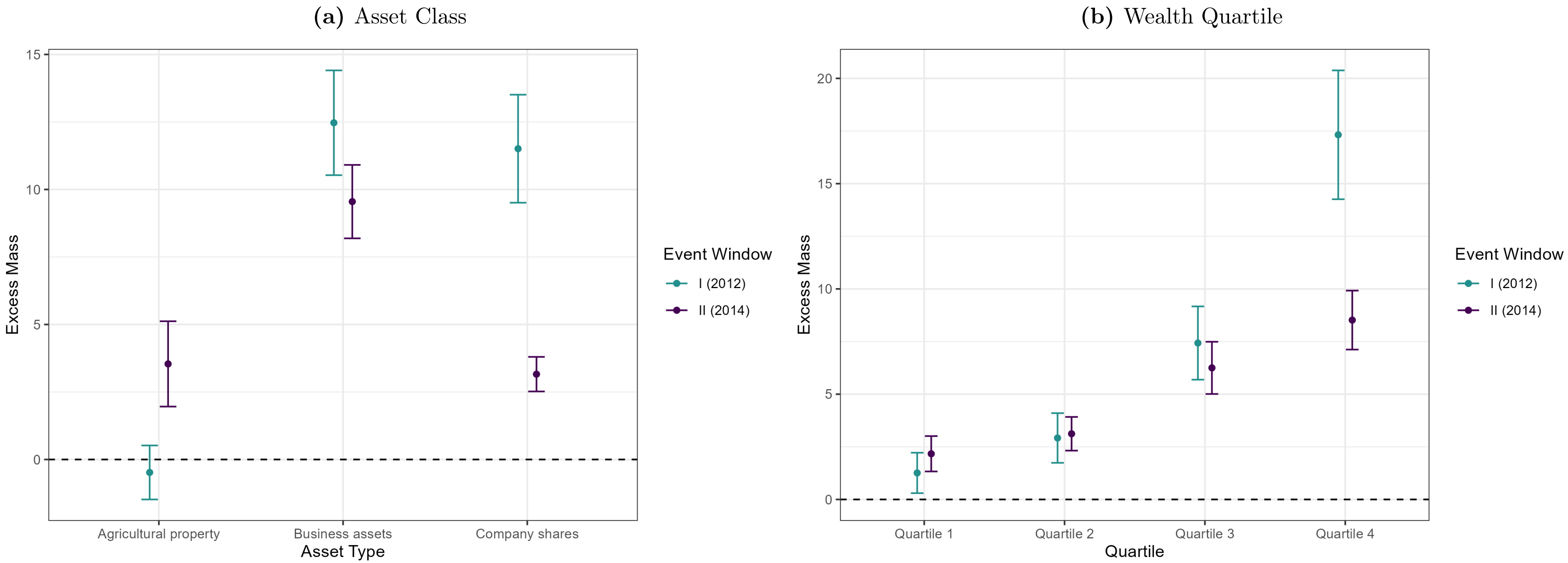
Notes: Figures II.5a and II.5b display normalized weekly transfer counts for Event Windows I and II detailed in Section 2. The bins for each distribution are expressed as shares of overall transfers occurring around a one-year window around the end point of the event window. Weeks are centered around the end of the event window, where week zero starts with the end point date and includes the six days thereafter. All details are described in Section 4.1. The treated distribution for Figure II.5a includes transfers in a one-year window around 25 October 2012 whereas the counterfactual distribution comprises transfers in the same window around 25 October 2011. The treated distribution for Figure II.5b includes transfers in a one-year window around 17 December 2014 whereas the counterfactual distribution comprises transfers in the same window around 17 December 2011. The boxed numbers indicate the excess mass estimate in the three weeks before Event I and II with bootstrapped standard errors in parentheses.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

Wealth Quartile. Second, we are interested in whether wealthy individuals were more responsive to the considered events compared to less wealthy individuals. Given the progressive nature of the tax schedule, more wealthy individuals had higher incentives to respond to the looming threats and given a fixed portion of the costs of avoidance, we expect them to gain more compared to less wealthy ones. To get at this question, we sort individual transfers into quartiles using data between 2009 and 2017.[29] By considering the overall distribution of wealth, wealth quartiles are comparable across events and not sensitive to the distribution of transfers in the respective event window.

We find that across both events, the responsiveness of individuals seems to increase in the amount of wealth transferred. Where the amount of bunching is relatively negligible in the lowest quartile, the excess mass estimates increase by up to 10 times as we move through the wealth distribution. We detect the largest response for the highest quartile for Event Window I, which amounts to almost two times the average effect. This result has intuitive appeal: as setting up a corporation for use as a tax saving vehicle only is costly, we expect the largest benefits of pulling forward the transfer for high net-worth individuals. Furthermore, the prospect of losing preferential treatment was more likely ex ante, increasing the incentives to transfer before the event date at all costs. The response heterogeneity by levels of wealth at stake has distributional consequences for the progressivity of announced tax changes, which is an important consideration for policymakers.

[29]We exclude the periods before 2009 for setting the wealth quartiles, as the determination of business value followed a different method before the 2009 reform, leading to apples to oranges comparisons.

Figure II.6: Bunching Heterogeneity



Notes: This figure shows excess mass estimates for different sample splits with two standard errors confidence bands. Figure II.6a illustrates excess mass estimates for the different preferentially treated asset classes (agricultural property, business assets and company shares), while Figure II.6b depicts excess mass estimates for each wealth quartile across the different event windows.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

5 Characteristics of Bunchers

After documenting significant behavioral responses to the legislative developments, we investigate whether transfers made inside the bunching windows identified in the previous section differ from transfers outside the bunching windows in terms of observable characteristics. The observed transfer characteristics might shed some light on the transfer motives and provide further indication of tax avoidance intent. Based on prior literature, we identify several characteristics which we expect do differ between transfers within the bunching windows and those outside of them.

First, we expect transfers within the bunching windows to be characterized by even lower effective tax rates and higher use of tax exemptions compared to the overall sample. As responding individuals show an acute awareness of legislative developments and threats, we expect them to be able to optimize the transfer from a tax perspective, making full use of any exemptions available.

Second, it is generally understood that family firm owners have difficulties relinquishing control, especially when they are the founder (Handler, 1994; Sharma, 2004). From this perspective, we would expect recipients of family businesses to be generally of a more mature age and ready to take over the business from their predecessor, even if inheritance tax planning is at play. As transfers of cash are less tied to a desire to retain factual control over the asset, we would, on average, expect more transfers to benefit a minor compared to regular business transfers. Consistent with this notion, Table II.1 shows that the share of minors is the highest for gift transfers of cash and financial assets. Finding a significantly higher share of minor recipients within our event windows would be consistent either with the threat of the legislative change to be perceived as so detrimental that it outweighs the desire to retain control, or with a masked cash transfer.

Finally, Bennedsen et al. (2007) among others show that male descendants are favored in obtaining control of the family business in a succession event. As pointed out by Kubíček and Machek (2019), this can be due to a multitude of reasons such as primogeniture, gender stereotypes, or willingness to join and lead on the recipient side.

Several studies show that male heirs are more likely to receive transfers of business assets in general (Ahrens et al., 2015; Kubíček and Machek, 2019; Tisch and Schechtl, 2023), which is consistent with the observed patterns in Table II.1. Based on these findings, we expect transfers in the first bunching window in particular to more likely benefit a female recipient compared to transfers outside. To the extent that these transfers constitute cash transfers masked as business successions, we should see a higher incidence of female ownership more akin to transfers of non-business assets.

To investigate differential transfer characteristics, we estimate Ordinary Least Squares (OLS) regressions using the following specification:

$$
\begin{aligned}
y_i = \alpha + \beta_1 \,\text{BW Event I}_i + \beta_2 \,\text{BW Event II}_i + \sum_{k=2}^{4} \gamma_k \,\mathbb{1}\left\{\text{Wealth Transfer Quartile}_i = k\right\} \\
+ \sum_{j=1}^{4} \delta_j \,\mathbb{1}\left\{\text{Age Quartile}_i = j\right\} + \eta_1 \,\text{Company Shares}_i + \eta_2 \,\text{Business Assets}_i + \varepsilon_i,
\end{aligned}
\tag{II.2}
$$

where *BW Event I* and *BW Event II* are indicators for transfers located in Bunching Window I and II respectively. We control for other determinants of transfer characteristics such as quartiles of the wealth transfer amount and donor age based on the distribution of the respective variables between 2009 and 2017, as well as for the major asset type transferred. As outcomes, we consider the ETR, the share of favorably treated assets, and a set of indicators equal to one if the recipient was of minor age, a son or daughter of the donor, and whether the gift donor was female. We show the result of this exercise in Table II.2. The table shows the coefficient estimates for the two indicator variables of interest with robust standard errors in parentheses.

We find that transfers in the bunching windows feature a significantly lower effective tax rate. In comparison to the sample average of 0.08%, taxes on transfers made during the first event window's bunching window were 50% lower, while transfers made during the second bunching window were about 13% lower on average. This suggests a higher level of tax expertise among individuals who choose to locate just before the event deadlines.

Additionally, we document that the proportion of transferred assets within the bunching windows that is taxed preferentially is higher than that outside of them, which accounts for the lower effective tax rates.

Next, we consider the characteristics of the recipients as outcomes. First, we find differing results regarding transfers to recipients of minor age between the two bunching windows. In case of the first bunching window, transfers are more likely to go to a minor recipient. Compared to the sample average of 2.8%, transfers to a minor occur 39% more frequently in the bunching window, holding wealth, the age of the donor, and the asset type constant. This finding is in line with evidence from Finland that transfers of firm ownership to minor children are a common method to avoid later inheritance and gift taxes (Paukkeri et al., 2023). However, for the second bunching window we find the opposite effect: transfers to a minor occur about 29% less frequently compared to the sample mean. This suggests that transfers immediately before the abolition of the Cash-GmbH avoidance scheme were driven more by pure tax avoidance motives than transfers prior to the verdict of the German Constitutional Court in 2014. If we consider the transfer of business assets that exploits a loophole in the administrative asset catalog as a mere transfer of liquid funds rather than the actual control of a business, these patterns become more intuitive.

Table II.2: Characteristics of Bunchers

	Dependent Variable:					
	ETR	Share Fav. Assets	Minor Rec.	Son	Daughter	Female Donor
BW Event I	-0.004^{***}	0.101^{***}	0.011^{***}	-0.025^{*}	0.041^{***}	0.02
	(0.001)	(0.008)	(0.006)	(0.013)	(0.012)	(0.013)
BW Event II	-0.001^{*}	0.016^{**}	-0.008^{**}	0.01	0.009	0.005
	(0.001)	(0.007)	(0.003)	(0.011)	(0.009)	(0.01)
Wealth Controls	X	X	X	X	X	X
Age Controls	X	X	X	X	X	X
Sample mean	.008	.728	.028	.483	.218	.339
$R^2 Adj.$	0.08	0.14	0.01	0.1	0.03	0.02
Observations	76,917	76,687	76,798	76,937	76,937	76,937

Notes: This table presents the results of estimating Equation II.2 using Ordinary Least Squares. The coefficients are displayed for regressing different outcome variables on indicators for transfers located within the bunching window of Event Windows I and II. All specifications control for wealth transfer quartile and age quartile as well as the major asset type. Robust standard errors are given in parentheses below the coefficient estimates. ***, **, and * denote significance at the 1%, 5%, and 10% significance level respectively. Results are robust to different specifications of the control variables. **Source:** Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

Second, our results suggest that transfers preceding the abolition of the Cash-GmbH are more likely to go to a daughter compared to transfers outside the bunching window. The coefficient estimate suggests that after controlling for other transfer characteristics, transfers in the first bunching window are about 19% more likely to benefit a daughter of the donor compared to the average over the whole sample. Interestingly, there is no significant difference in gender recipient patterns between transfers in the second bunching window compared to transfers outside of it. There are two main explanations for this pattern. On the one hand, this again could be indicative that the transfers during the first bunching window are more similar to a transfer of cash than a transfer of a company. Hence, viewing the first bunching window as an opportunity to pass on cash to the next generation could rationalize this result. Alternatively, it might also be the case that these quasi-cash transfers are more easily split among several descendants. In a succession case where the son receives the business and the daughter financial assets as compensation, we would not see the funds received by the daughter in our sample. However, if shares in a cash-holding corporation are transferred during the bunching window, this transfer will show up in our data and hence increase the share of female recipients in that period only.

Overall, these tests are consistent with the behavioral responses to the first legislative event being driven by individuals explicitly exploiting the tax loophole in the administrative asset catalog, whereas for the second event, responses are generally more similar to regular business transfers and would therefore be consistent with a hedging motive regarding detrimental future developments.

6 Revenue Implications and Discussion

Armed with an estimate of the normalized excess mass in the distribution of taxable transfers, we can quantify the extent of tax avoidance using a back-of-the-envelope calculation of the forgone tax revenue due to re-timed transfers. The quantification exercise is based on the following thought experiment. Suppose that the excess transfers we identified in the previous section were not taxed under the relevant schedule at that time, but under the provisions that were expected to be applicable after the respective end point of the event windows. How much revenue did the German government lose in this hypothetical scenario due to re-timing responses?

To answer this question, we back out the overall number of transfers that are due to tax planning in a first step. Let $\hat{b}_T$ be the estimated excess mass of the transfer count distribution for event window $T = 1, 2$. Based on the observed number of transfers in the bunching window $N_T = \sum_{t=L_T}^{U_T} n_t$, we can calculate the excess number of transfers using

$$N_T^E = N_T - \frac{N_T}{\hat{b}_T} = \frac{(\hat{b}_T - 1)}{\hat{b}_T} N_T. \tag{II.3}$$

Intuitively, we subtract the number of "regular" transfers $(1/\hat{b}_T \times N_T)$ from the overall number of transfers. The number of transfers left after this transformation can be interpreted as excess transfers in the sense that they would not have occurred in the absence of the events.

In a second step, we exploit the detailed information about taxable transfers in our data to recalculate the tax base and final tax burden of each transfer in the bunching window under the hypothetical scenario. In order to reflect the uncertainty taxpayers faced when deciding on pulling forward their transfer, we entertain a variety of hypothetical scenarios. For the baseline scenario, we simply add back the full amount of tax exemptions for preferentially treated assets to the actual gift tax base. Afterwards, we conduct the same calculation steps that lead from the tax base to the actual amount of determined tax. This implies applying the (progressive) tax rate schedules as stated in the respective version of the tax code.[30] Conceptually, this approach assumes that for both event windows, the extreme case scenario realizes, i.e., the exemptions for preferentially treated asset classes are void, meaning that companies are fully taxed on their assets.

As the complete voiding of the preferential treatment provisions was a rather unreal-

[30] This means that actual tax rates varied by transfer size, albeit they increased relative to the initially applicable tax rates (especially for large transfers of business assets and with little amounts of other transfers). The highest applicable tax rate was 30%.

istic outcome for the 2014 verdict of the Constitutional Court, we vary the negative tax consequences to provide a more nuanced picture. In our first set of alternative scenarios, we consider different exemption shares to be applied to the overall tax base. This would have been one way the legislator could have addressed concerns by the court that the privilege for business assets was excessive. Therefore, in addition to the complete voiding of the provision, which would correspond to an exemption share of 0, we calculate hypothetical scenarios based on an exemption share of 25, 50 and 75 percent.

Another possibility, which was proposed by researchers and politicians in the aftermath of the verdict, is a so-called flat tax.[31] A low, flat tax rate in combination with a broad tax base has the potential to raise equal if not more revenue while simultaneously curbing tax avoidance opportunities exploiting tax exemptions. For this alternative set of scenarios, we implement flat tax rates of 10, 12.5, and 15 percent while simultaneously reducing the exemption share for preferentially treated asset classes to zero. Note that we still allow for personal exemptions that would also apply to other types of assets, such as real estate or cash.

Figure II.A4 illustrates the tax consequences of the hypothetical scenarios in terms of the effective tax rate, based on the taxable acquisition of the transfer. The figure displays effective tax rates for an exemplary transfer to a spouse (tax class I), resulting from applying the tax schedule for different values of the exemption share. It is apparent that removing parts of the exemption share leads to substantial increases in effective tax rates across the wealth distribution. For very large inheritances, a flat tax of 15 percent would correspond to a decrease of the exemption share to 50 percent of the taxable acquisition.

By computing the difference between the recalculated hypothetical burden and the actual taxes paid and aggregating the individual changes over the bunching interval, we get a measure of the overall change in tax revenue if every transfer would have been subject to the hypothetical scenario tax schedule. We then compute the share of this revenue change due to tax planning by multiplying the overall revenue change with the

[31] See, for example, Bach and Thiemann, 2016, or the plenary protocol 18/180 of the Bundestag from 24 June 2016, available under `https://dserver.bundestag.de/btp/18/18180.pdf#P.17773`.

share of excess transfers in total transfers. Hence, our estimate of foregone tax revenue R^F can be expressed as:

$$
\begin{aligned}
R^F &= \sum_{i \in I_T} \left[TB_i^h - TB_i^r\right] \times \frac{N_T^E}{N_T} \\
&= \sum_{i \in I_T} \left[TB_i^h - TB_i^r\right] \times \frac{(\hat{b}_T - 1)}{\hat{b}_T},
\end{aligned}
\tag{II.4}
$$

where TB_i^h and TB_i^r denote the hypothetical and real tax burden of individual i and I_T denotes the set of individual transfers in the bunching window.

Figure II.7 shows the result of this exercise. For the two event windows, the foregone tax revenue is plotted for each of the seven hypothetical scenarios. The dashed horizontal lines depict the average foregone revenue across scenarios for each event, while the solid horizontal line corresponds to the overall revenue from inheritance and gift taxation in Germany in 2011 as a reference point.

For each scenario, the computed revenue loss constitutes a lower bound, as it is based on the assumption that behavioral responses only take place within the bunching windows. However, Cash-GmbHs were possible from 2010 until mid-2013, which means that the revenue loss is likely to be even higher. The different scenarios allow us to provide some bounds on the revenue effect.

The amounts of foregone tax revenue differ substantially across events, which is both due to very different estimated amounts of hypothetical tax revenues as well as a higher "share of bunchers".[32] A lower-bound estimate of the foregone tax revenue is provided by the least strict tightening of the preferential treatment provision, granting only a 75% exemption as opposed to a factual full exemption in most cases. In this case, the foregone revenue from tax avoidance of EUR 3.2 billion amounts to 76% of the total revenue from inheritance and gift taxation in Germany (from all transfers) in 2011. If these transfers had instead been taxed without preferential treatment exemption, the German government would have obtained additional revenues of EUR 12 billion, which constitutes 2.8 times the actual tax revenue from 2011. For Event Window I, this is a

[32]See Table II.A5.

reasonable scenario, as the excess mass is very likely to stem from tax planning vehicles only. This is because a major reason for the bunching right before the event date was to prevent administrative assets like cash and real estate from not being exempt from inheritance and gift taxes.[33] The average foregone revenue of roughly EUR 6 billion is still 1.5 times higher than the reference revenue, indicating substantial revenue losses due to tax planning. Note that while the initial purpose of the preferential treatment of certain assets was to alleviate concerns of overburdening firms with inheritance and gift taxes, the fiscal consequences of this tax avoidance scheme were enormous. This becomes evident when comparing the magnitude of our findings to evidence of tax expenditures for (family) businesses in other countries.[34]

For Event Window II, the foregone revenue estimates are much more moderate. The lower bound estimate of a reduced exemption of 75% would have implied a revenue gain of EUR 0.435 billion, which amounts to approximately 10% of the 2011 revenue. If the extreme scenario of a voiding of the preferential treatment provisions was realized, the additional revenue would have totaled EUR 2 billion or approximately 48% of the 2011 revenues. The average foregone revenue across the different scenarios amounts to EUR 1.093 billion, or 26% of the reference revenue.

Our quantification of foregone tax revenues is limited to the fiscal consequences of the extreme timeliness of tax planning responses. It thus only partially captures the impact on overall welfare. Two other sources of welfare loss are conceivable: administrative costs and the consequences of rushed company succession. First, the (short-term) use of tax advisors and lawyers to minimize the tax burden associated with a business succession can be substantial. Legal and advisory fees for a single tax-motivated business succession range from five-digit to small six-digit numbers.[35] Second, business successions ought

[33] In effect, administrative assets were excluded from gift tax exemptions after the reform, with two special cases depending on their value relative to the transferred amount of business assets. Above 90%, the entire amount of transferred business assets became fully ineligible for gift tax exemptions. Below 10%, their amount was considered negligible and therefore did not reduce gift tax exemptions.

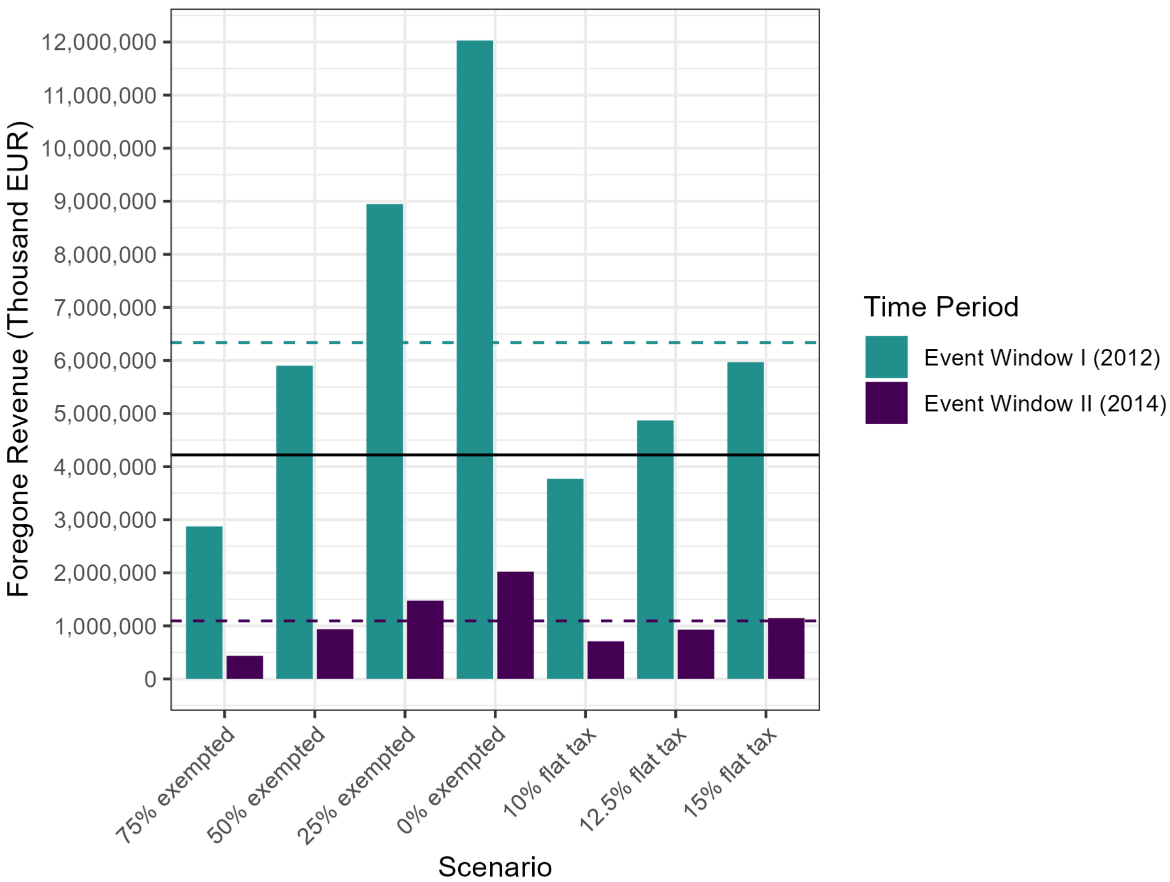
[34] See Figure 3.17 in OECD, 2021, where for Belgium 0.5% and for the Netherlands 8% of the actual tax base are foregone due to tax expenditures.

[35] In Germany, tax advisory cost comprises a time component for the preparatory tax advisory process, and a share of the transfer value when the actual tax declaration is prepared. Both cost components are subject to the German tax advisor fee regulation, although the latter component can be reduced by up to 90% on the tax advisor's discretion. Figure II.A5 depicts the value-based component.

to be carefully prepared in advance. Surveying all German chambers of industry and commerce reveals that the recommended time span for a business succession ranges from one to up to ten years, with the majority suggesting that a succession duration of five years is optimal.[36] Our results show that the motivation to avoid increases in wealth transfer taxes drastically shortens the succession period of businesses. Albeit we cannot directly observe the transfer of mere ownership versus actual company control, our identification of the characteristics of bunching business owners reveals that at least during Event Window II, actual company control was passed onto the next generation. We cannot observe whether such transfers had been planned long in advance, and are only executed at short notice due to tax reasons. If this is not the case, these firms could subsequently suffer from lower performance due to inferior successor choices or prolonged intra-family conflict.

[36]Figure II.A6 provides the distribution of recommended succession periods.

Figure II.7: Foregone Tax Revenue Across Hypothetical Scenarios



Notes: This figure illustrates the foregone tax revenue to the German state under the different hypothetical scenarios considered. Each bar represents the difference in tax revenue in the respective scenario net of the taxes actually paid. The first four scenarios show differences in taxes for lower shares of preferential treatment, ranging from 75% to 0%. The last three scenarios consider the revenue effects of a flat tax between 10 and 15% on the taxable transfer with no exemption for preferentially treated asset types. The dashed horizontal lines constitute the average foregone revenue across the different scenarios for each event window. The solid black line represents the overall revenue from the inheritance and gift tax for the reference year 2011 (EUR 4,221,122 Thousand).
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

7 Conclusion

Our findings show that the anticipation of tax changes substantially influences the timing of business transfers to the next generation. To our knowledge, we are the first to demonstrate the speed with at which business transfers react to anticipated changes in the tax environment. Event Window I most clearly allows to identify tax avoidance as the motive, given that bunching at the unusual mid-year date (25 October 2012) is hardly explainable by non-tax-planning reasons. Our results from Section 5 lend further support to this notion, as the characteristics of transfers during the bunching window differ from regular transfers in ways that are consistent with a tax avoidance motive. Prior literature suggests that successions within family businesses are prone to trigger conflicts within the family.[37] Against this background, we provide evidence that an external threat in the form of substantial increases in effective taxation leads to temporarily coordinated and timely family action. This has implications for the design and communication of tax policy changes, as anticipated tax changes may quickly yield large decreases in the potential tax base.

We also document heterogeneous behavior across asset classes and wealth levels. The muted response of agricultural assets transfers relative to those of businesses and company shares could be explained by missing awareness to the existence of these incentives, the deterrence effect that compliance with tax regulations would entail and low general tax planning activities (because transfer values are low). The latter factor would also help explain why business transfers in the highest quartile of the wealth transfer distribution are more responsive to the threat of taxation than business transfers in the lowest quartile by a factor between 4 (Event Window II) and 15 (Event Window I).

We further quantify the amount of foregone tax revenue to reach an upper bound of approximately EUR 12 billion. This is equivalent to 2.8-times the overall tax revenues from gifts and inheritances in 2011. Our results imply that the conventional argument which disregards the importance of wealth transfer taxes as fiscal instruments due to their low quantitative relevance (compared to taxes based on income or consumption) neglects the shifts in the underlying tax base due to avoidance behavior. In other words, effective wealth transfer taxation suffers from a high elasticity of the gift tax base.[38] Three policy instruments could mitigate the negative fiscal consequences: taxing wealth transfers at uniform rates, retroactive closure of loop holes in the tax code and the taxation of (net)

[37]See Kubíček and Machek (2020) for a recent overview.

[38]See also Escobar et al. (2019) for another example in the Swedish setting of how the elasticity of tax-favored gift transfers depleted the inheritance tax base.

wealth as a backstop to wealth transfer tax avoidance. The first instrument, essentially tax rate cut cum base broadening, enables policy makers to refrain from inherently difficult tax discrimination between business and non-business assets. By simulating the foregone tax revenues for both events, we show that levying uniform tax rates, in addition to the likely reduction in administrative costs, significantly reduces the negative fiscal consequences of tax avoidance. A second instrument, retroactive closure of loop holes, could also be implemented in the form of general anti-avoidance rules. However, this option increases the risk of undermining the legal certainty of the tax system. Third, (net) wealth taxation, while politically contentious and also subject to avoidance behavior, enjoys the advantage of being non-susceptible to the re-timing of wealth transfers. It may thus act as potential complementary backstop to the virtual non-taxation of wealth transfers through the exploitation of tax-advantaged business shells prior to legislative amendments.

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A Additional Tables and Figures

Table II.A1: Inheritance and Gift Tax Schedules under the Different Regimes

Taxable bequests (EUR 1,000)	before 2009			Taxable bequests (EUR 1,000)	in 2009			since 2010		
	Tax Class				Tax Class					
	I	II	III		I	II	III	I	II	III
52	7	12	17	75	7	30	30	7	15	30
256	11	17	23	300	11	30	30	11	20	30
512	15	22	29	600	15	30	30	15	25	30
5,113	19	27	35	6,000	19	30	30	19	30	30
12,783	23	32	41	13,000	23	50	50	23	35	50
25,565	27	37	47	26,000	27	50	50	27	40	50
$\geq$ 25,565	30	40	50	$\geq$ 26,000	30	50	50	30	43	50

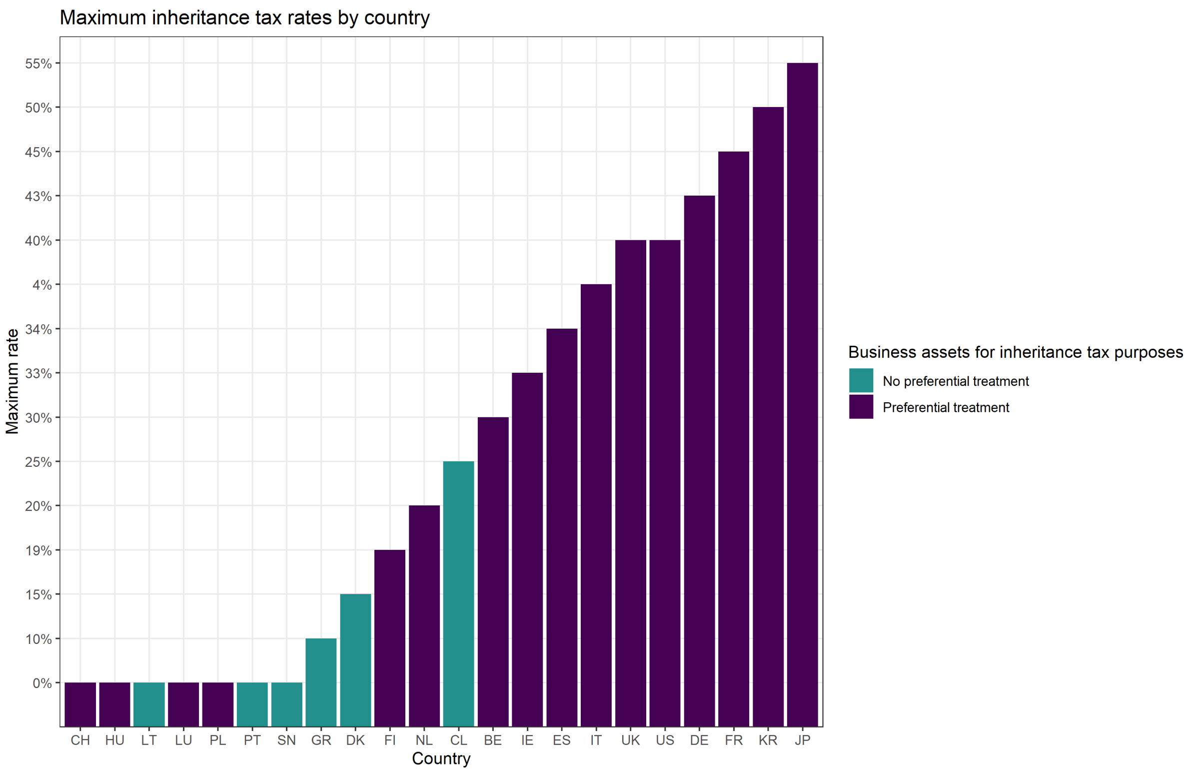
Notes: This table displays the (progressive) tax rate schedule for gifts and inheritances during three different periods of German Tax Law, out of which the tax rates after the onset of 2010 are most relevant to our empirical setting. Tax classes generally relate to the degree of kinship (with I denoting close family and III non-related recipients), albeit a receipt of assets that are treated preferentially (i.e. business assets, (closely held) company shares and agricultural assets) is by law tantamount to being a recipient within tax class I.
Source: Troll/Gebel/Jülicher/Gottschalk: ErbStG, "X. Reform der ErbSt 2009" and "XI. Entwicklung der ErbSt von 2009 bis 2016", 2021.

Table II.A2: Possible Decisions of the Constitutional Court and Implications

Decision	Meaning	Implication
Amnesty	Court finds provisions to be in line with the constitution	No change
Void	Inheritance and gift tax law (or just preferential treatment) is void	Day of judgment terminates preferential treatment immediately
Incompatible	Not void but incompatible with the constitution	For the time being, law remains applicable but provision change might be applied retroactively to transfers since judgment day.

Notes: This table shows the different decisions the German Constitutional Court could have reached in response to evaluating the preferential treatment provisions in 2014, together with the implications each decision would have had on the applicability of the law. The implications of an incompatibility decision were highly uncertain, as neither the degree nor precise timing of tightened provisions were known beforehand.

Figure II.A1: International Wealth Transfer Tax Regimes



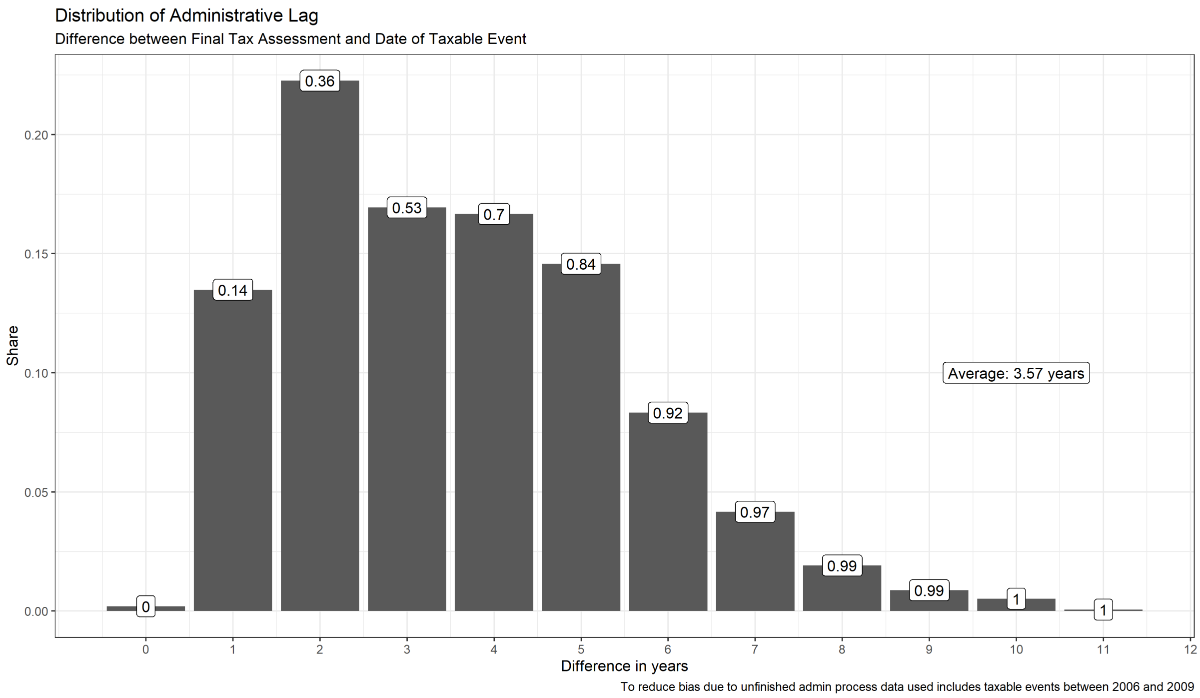
Notes: This figure displays the depicted maximum inheritance tax rates when recipients are close family members, with purple (green) color fill as an indication that business assets are (not) treated preferentially. Tax rates to third parties can be higher.
Source: OECD (2021).

Table II.A3: Sample Selection

Selection Step	Obs.	Δ Obs.
Overall transfers assessed between 2007 and 2019	3,025,788	
Regular transfer types	2,650,154	−375,634
No birth date nor age for nat. pers.	2,480,155	−169,999
Establish uniqueness	2,094,912	−385,243
Restricting to non-negative asset transfers	2,080,392	−14,520
Restricting to transfer years 2009 until 2017	1,324,195	−756,197
Restricting to gift transfers	281,545	−1,042,650

Notes: This table shows the selection steps taken for our final analysis. Before selection step four, the unit of observation is an individual tax assessment. Therefore, a specific inheritance or gift transfer can occur multiple times, with one observation for each tax re-assessment. Regular transfer types refers to the exclusion of special transfer types such as pre- and post-inheritances, cross-border cases, taxation of family foundations at fixed time intervals, cases with erroneously calculated tax amounts and intended use.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

Figure II.A2: Structure of Coverage Between First and Subsequent Tax Determination Dates



Notes: This figure displays the distribution of (yearly) tax assessment dates of gift and tax returns relative to the year of the taxable event.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

Table II.A4: Descriptive Statistics of Bequest Sample

	Obs.	Mean	Std. Dev.	P01	P50	P99
Agricultural property						
Overall value of receipt	10,389	186.06	653.35	3	78	1,389
Age of Recipient at Transfer	10,380	58.05	15.81	16	58	89
Effective tax rate (p.p.)	4,681	6.62	7.61	0	4	27
Share of fav. assets (p.p.)	4,543	41.29	39.04	0	33	100
Above Allowance	10,389	0.78	0.41	0	1	1
Son	10,389	0.07	0.26	0	0	1
Daughter	10,389	0.05	0.22	0	0	1
Female Decedent	10,389	0.27	0.45	0	0	1
Count of recipients per transfer	4,681	2.22	2.40	1	1	13
Business assets						
Overall value of receipt	14,212	2,726.53	22,511.47	14	689	35,385
Age of Recipient at Transfer	14,197	51.29	17.26	9	52	87
Effective tax rate (p.p.)	7,019	3.27	5.79	0	0	27
Share of fav. assets (p.p.)	6,538	59.84	44.00	0	85	100
Above Allowance	14,212	0.82	0.38	0	1	1
Son	14,212	0.29	0.45	0	0	1
Daughter	14,212	0.22	0.42	0	0	1
Female Decedent	14,212	0.28	0.45	0	0	1
Count of recipients per transfer	7,019	2.02	1.62	1	2	8
Cash and financial assets						
Overall value of receipt	650,438	252.10	2,090.02	7	70	2,417
Age of Recipient at Transfer	649,181	60.46	15.96	16	61	91
Effective tax rate (p.p.)	322,558	12.05	8.80	0	11	29
Share of fav. assets (p.p.)	43,241	31.40	44.15	0	0	100
Above Allowance	650,438	0.90	0.30	0	1	1
Son	650,438	0.06	0.23	0	0	1
Daughter	650,438	0.05	0.22	0	0	1
Female Decedent	650,438	0.59	0.49	0	1	1
Count of recipients per transfer	322,568	2.02	1.89	1	1	10
Company shares						
Overall value of receipt	3,688	4,919.16	49,672.84	10	891	43,916
Age of Recipient at Transfer	3,680	48.79	17.96	8	50	85

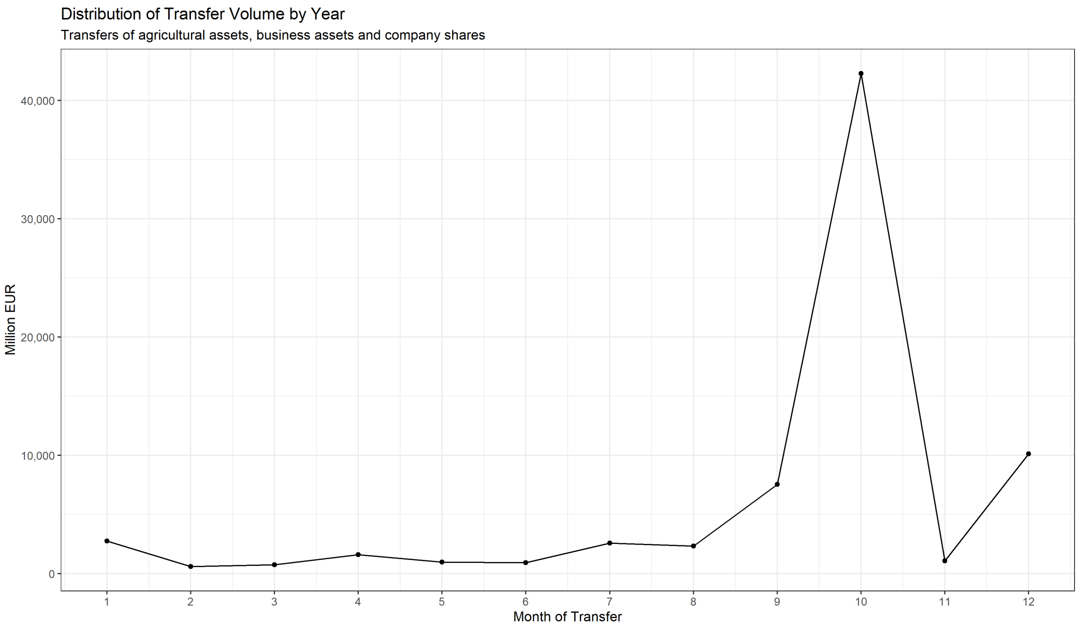
Table II.A4: Descriptive Statistics of Bequest Sample Continued

Effective tax rate (p.p.)	1,692	4.42	6.83	0	1	29
Share of fav. assets (p.p.)	1,576	52.65	44.35	0	74	100
Above Allowance	3,688	0.84	0.37	0	1	1
Son	3,688	0.28	0.45	0	0	1
Daughter	3,688	0.24	0.42	0	0	1
Female Decedent	3,688	0.25	0.43	0	0	1
Count of recipients per transfer	1,692	2.18	1.66	1	2	8
Real estate						
Overall value of receipt	333,020	254.78	1,252.19	6	94	2,052
Age of Recipient at Transfer	332,643	57.58	16.12	15	58	89
Effective tax rate (p.p.)	177,924	11.21	9.04	0	10	29
Share of fav. assets (p.p.)	37,474	34.14	45.59	0	0	100
Above Allowance	333,020	0.83	0.37	0	1	1
Son	333,020	0.09	0.28	0	0	1
Daughter	333,020	0.08	0.27	0	0	1
Female Decedent	333,020	0.53	0.50	0	1	1
Count of recipients per transfer	177,927	1.87	1.62	1	1	8

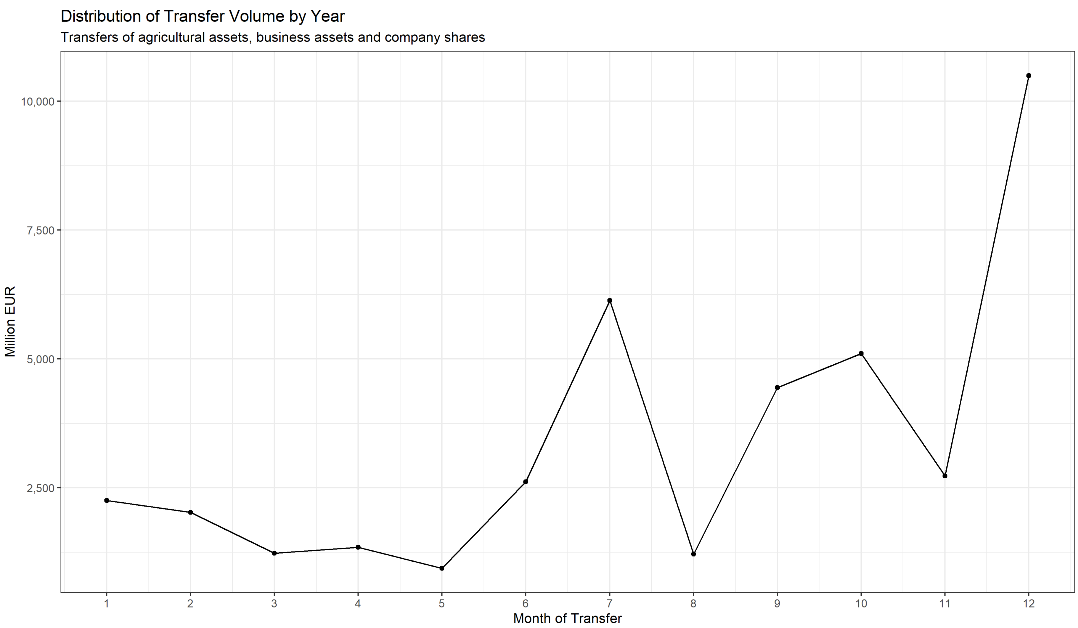
Notes: This table shows descriptive statistics for the sample of bequests after our selection process detailed in Table II.A3. Overall receipts are expressed in Thousand Euros. Above Allowance is an indicator for a transfer above the personal allowance of the recipient. Son and Daughter are indicator variables indicating the recipient gender and relation of the recipient to the donor. Female Decedent is an indicator equal to one if the bequeather is female. Summary statistics are given for each asset type separately. For comparison purposes we also show asset classes that are not the main focus of our analysis, namely, cash and financial assets as well as real estate.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

Figure II.A3: Monthly Gift Transfer Volumes

(a) Gift Transfer Volume 2012

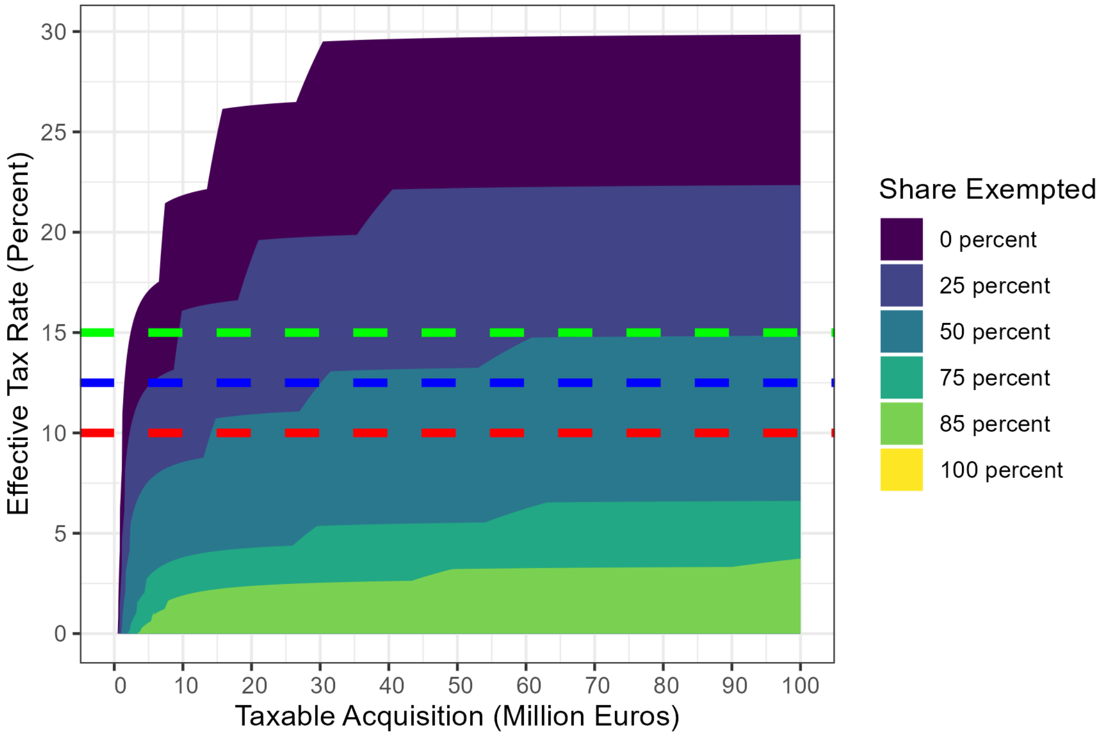


(b) Gift Transfer Volume 2014



Notes: Figures II.A3a and II.A3b display the monthly volumes of gift transfers for the years 2012 and 2014 respectively. Considered in the calculation are transfers that involve preferentially treated asset types, such as agricultural assets, business assets or shares in corporations.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

Figure II.A4: Effective Tax Rates in Hypothetical Scenarios



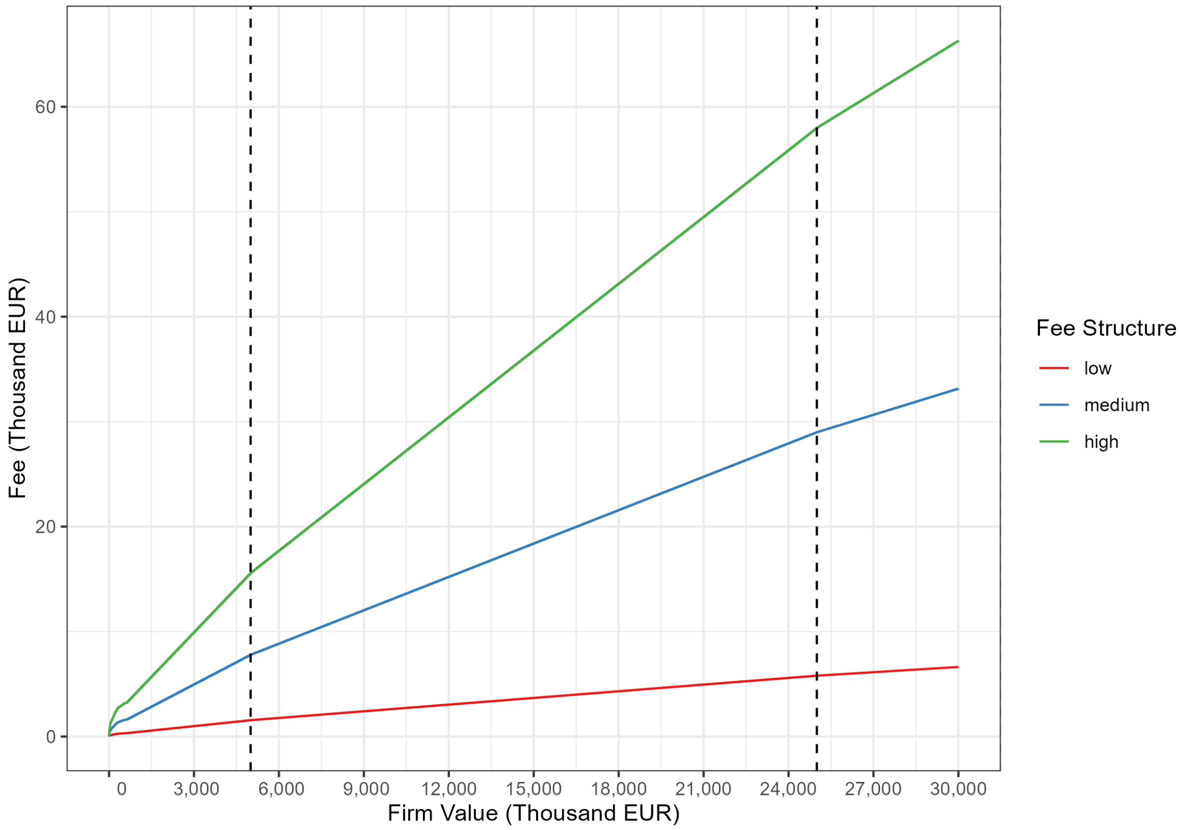
Notes: This figure shows the effective tax rates in the hypothetical scenarios we consider for our revenue loss calculations, exemplary shown for tax class I. The shaded areas visualize effective tax rate structures for different shares of exemption for qualifying asset types based on the value of taxable acquisition. The dashed lines on the other hand visualize the alternative flat tax rates of 10, 12.5 and 15 percent we employ. Effective tax rates are calculated assuming a transfer to a spouse, implying the maximum personal deduction of EUR 500,000 and tax class I. The calculated rates further accommodate the equitable compensation provided by the law in the region around an increase in the average statutory tax rate (*Härteausgleich*) as well as the deduction amount for low acquisitions (*Abzugsbetrag*).

Table II.A5: Calculation of Foregone Tax Revenue

Scenario	Actual tax	Counterfactual Scenario	Δ Revenue	Excess Mass	Share Avoiders	Foregone Revenue
Panel A: Event Window I (2012)						
75% exempted	93,031.99	3,322,189.30	3,229,089.10	9.02	0.89	2,873,889.30
50% exempted	93,031.99	6,723,778.00	6,630,579.60	9.02	0.89	5,901,215.84
25% exempted	93,031.99	10,145,452.00	10,052,155.00	9.02	0.89	8,946,417.95
0% exempted	93,031.99	13,609,604.00	13,516,209.00	9.02	0.89	12,029,426.01
10% flat tax	93,031.99	4,330,831.50	4,237,697.00	9.02	0.89	3,771,550.33
12.5% flat tax	93,031.99	5,564,546.10	5,471,339.20	9.02	0.89	4,869,491.89
15% flat tax	93,031.99	6,798,260.70	6,704,981.50	9.02	0.89	5,967,433.54
Panel B: Event Window II (2014)						
75% exempted	79,900.50	610,556.56	530,656.06	5.62	0.82	435,137.97
50% exempted	79,900.50	1,223,944.00	1,144,043.50	5.62	0.82	938,115.67
25% exempted	79,900.50	1,880,818.50	1,800,918.00	5.62	0.82	1,476,752.76
0% exempted	79,900.50	2,542,909.30	2,463,008.80	5.62	0.82	2,019,667.22
10% flat tax	79,900.50	945,278.86	865,378.37	5.62	0.82	709,610.26
12.5% flat tax	79,900.50	1,211,968.80	1,132,068.30	5.62	0.82	928,296.01
15% flat tax	79,900.50	1,478,658.70	1,398,758.20	5.62	0.82	1,146,981.72

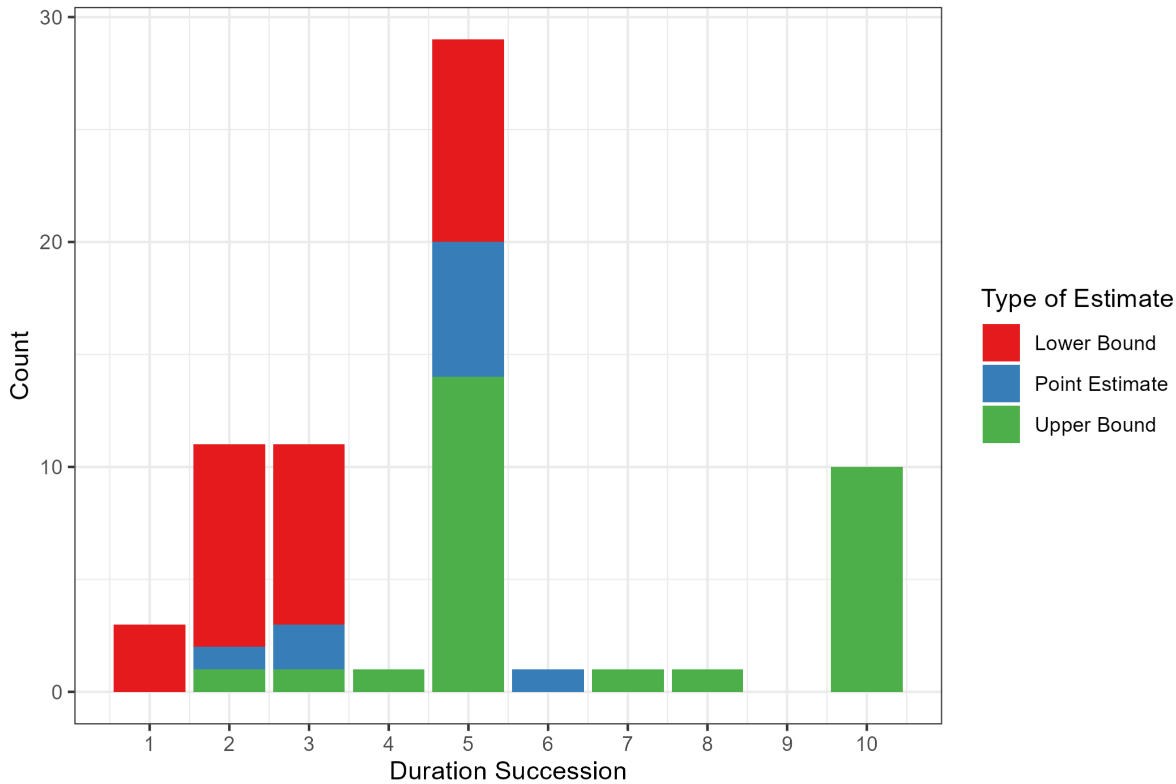
Notes: This table illustrates our calculations of foregone tax revenue for the different scenarios. Panel A displays the calculation steps for Event Window I, whereas Panel B displays the same for Event Window II. Each panel shows the overall taxes paid for the transfers within the respective bunching windows, which tax revenue would have been collected in the respective hypothetical scenario as well as the difference between counterfactual and actual revenue. Multiplying the difference in tax revenue with the share of avoiders, calculated as $(\hat{b}-1)/\hat{b}$, where $\hat{b}$ is the estimated excess mass of transfers in the bunching window, yields an estimate for the foregone tax revenue. To put the numbers into perspective, we relate the foregone revenue to the overall volume of collected inheritance and gift tax in 2011, which amounts to EUR 4,221,122 Thousand.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

Figure II.A5: Tax Advisory Fee Schedule Based on Transfer Values



Notes: This figure depicts the absolute amounts of tax advisory fee in EUR based on the cost of preparing a tax declaration for gifts or inheritances. The depicted amounts can be reduced by a factor of up to 90% on the discretion of the tax advisor.
Source: German tax advisor fee regulation (*Steuerberatervergütungsverordnung*), Annex 1, Table A.

Figure II.A6: Recommended Duration of Business Successions

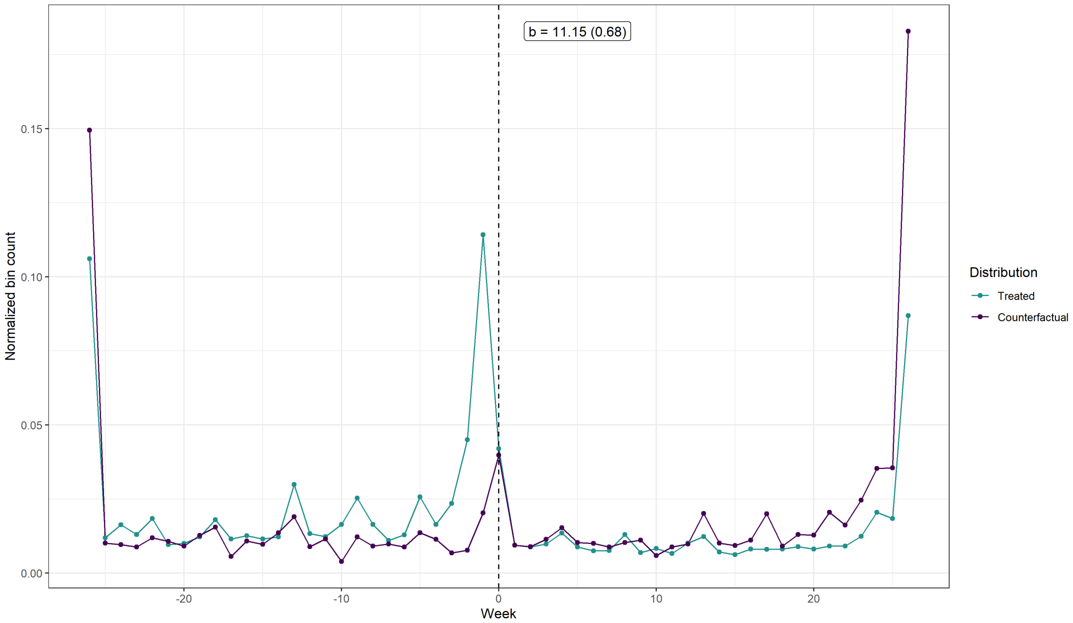


Notes: This figure shows the recommendation count for a specific duration period of inter-generational business succession by all German chambers of industry and commerce. Out of overall 79 chambers, 36 provided specific recommendations about the ideal succession duration period on their websites. Often, these recommendations relate to a time span, which means that multiple years are optimal from the viewpoint of the guidelines. Hence the sum of counts displayed in the figure can be larger than 36.
Source: Websites of all (regional) German chambers of industry and commerce (*Industrie- und Handelskammer*), accessed in early September 2024.

B Additional Event Analysis

Event Window III: The 2016 reform. As a final exercise we estimate the excess mass for the retroactive reform implementation date on 1 July 2016 which is illustrated in Figure II.B1. Also the third event window features sizable bunching in the distribution immediately before the reform date. Interesting in that case is that there seems to be excess mass in the entire region on the left of the event window endpoint with missing mass in the distribution for the entire region to the right. As the distribution of transfers appears to be increased almost for the entire left-hand side, determination of the bunching window is rather difficult. We provide a lower-bound estimate by considering the excess mass within three weeks before the reform implementation. That way, we probably underestimate the true reaction as increasing the bunching window only increases the estimated excess mass. Nevertheless, we find strong and significant bunching even in the direct vicinity of the event date.

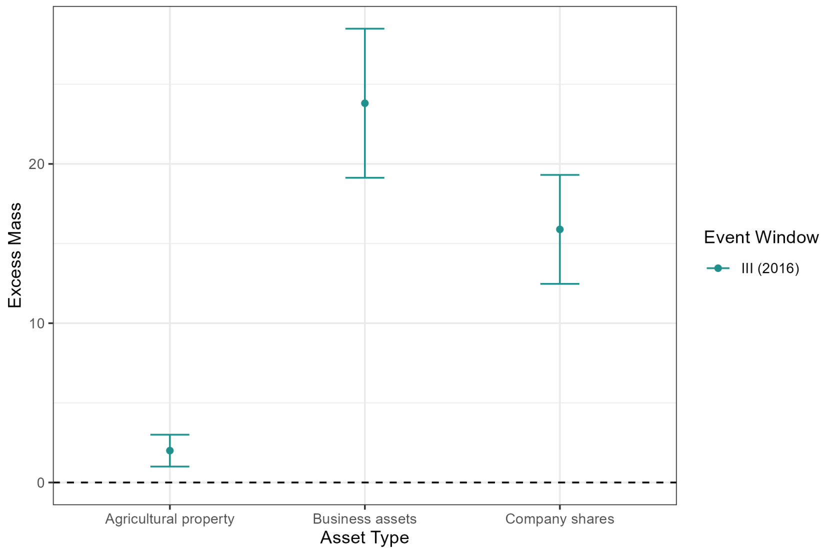
Figure II.B1: Difference-in-Bunching Around 2016 Reform



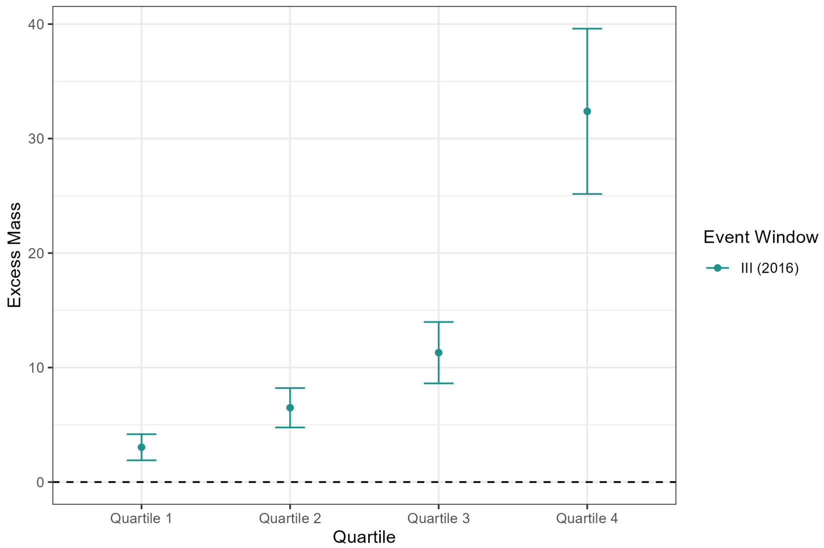
Notes: Figure II.B1 displays normalized weekly transfer counts for the year surrounding 30 June 2016, the retroactive implementation date of the last major reform of the German Inheritance and Gift Tax Law. The bins for each distribution is expressed as a share of overall transfers occurring around a one-year window around the event window endpoint. Weeks are centered around the end point, where week zero starts with the event date and includes the six days thereafter. All details are described in Section 4. The treated distribution for Figure II.B1 includes transfers in a one-year window around 1 July 2016 whereas the counterfactual distribution comprises transfers in the same window around 1 January 2010 and 2011. The boxed number indicated the excess mass estimate in the three weeks before the event window deadline with bootstrapped standard errors in parentheses.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

Figure II.B2: Heterogeneity Excess Mass 2016 Reform

(a) Asset Class



(b) Wealth Quartile



Notes: This figure shows excess mass estimates and two standard error confidence bounds for different sample splits for the mid-2016 reform. Figure II.B2a shows excess mass estimates for the different preferentially treated asset classes (agricultural property, business assets and company shares) whereas Figure II.B2b shows excess mass estimates for the different wealth quartiles.
Source: Authors' calculations based on data from the RDC of the Federal Statistical Office and the Statistical Offices of the Federal States.

Chapter III

The Real Effects of Job Protection Legislation on Firm Performance – Evidence from German Inheritance Tax

Status: Working Paper

Co-Authors: Philipp Doerrenberg, Richard Winter

Abstract: This paper examines the real effects of employment protection measures on firm performance by leveraging a unique feature of German inheritance and gift tax law. Specifically, we exploit the preferential tax treatment granted to gratuitous business transfers, which is contingent on meeting minimum holding periods and payroll sum requirements. To study these effects, we identify firm ownership changes triggered by the death of the owner, utilizing Orbis ownership data and publicly available death records. We merge this data with administrative employment data and employ a stacked Difference-in-Differences design, exploiting a size-dependent applicability threshold. By comparing firms subject to payroll sum requirements to those exempted, we isolate the causal impact of these provisions, as both treatment and control group undergo an exogenous succession event. Our findings indicate that the payroll sum requirements significantly reduce employment growth, with affected firms experiencing up to 20% slower growth relative to the control group.

1 Introduction

Taxes on wealth transfers can be important instruments to combat increasing wealth inequality (Nekoei and Seim, 2022). In this context, the tax treatment of business assets is the cause of heated public debate in many countries. Almost all developed countries treat business assets preferentially, for example, through lower rates or exemptions (OECD, 2021). This preferential tax treatment is granted on grounds of the notion that productive businesses provide employment and growth, which benefits society as a whole. Therefore, it is argued that it is essential not to overburden these companies during firm succession. Paying wealth transfer taxes may lead to a lack of liquidity in transferred businesses and, in the worst case, could induce company liquidation and threaten employment.

Tax policies designed to shield transferred businesses from harmful taxation should ensure that preferential treatment achieves its intended purpose. In many countries, this requires recipients to meet specific conditions to qualify for tax benefits. Such conditions may include restrictions on selling the business within a set period or mandates to preserve jobs (OECD, 2021). Ideally, these requirements incentivize companies to continue generating positive externalities. However, they could also negatively impact firm performance for two main reasons. First, these conditions may hinder the efficient allocation of labor and capital within and between firms (Akcigit et al., 2023). In such cases, well-meaning restrictions on restructuring decisions could inadvertently exacerbate crises. Firms with declining employment trends face a difficult trade-off between complying with the requirements on the one hand and optimizing their resource allocation on the other. Second, conditional exemptions introduce uncertainty about future tax obligations, which could affect risk taking (Astrachan and Tutterow, 1996). Inexperienced heirs in particular may respond to this uncertainty by adopting a risk-averse, "business-as-usual" approach to avoid potential retroactive tax liabilities. Given these risks, it is worth exploring whether tying tax benefits to constraints on factor inputs could lead to unintended consequences.

We provide an empirical answer to this question by examining the case of Germany.

Since 2009, German inheritance tax legislation has required firms to meet input factor requirements to qualify for generous tax exemptions on the transfer of business assets. Specifically, firms must maintain their cumulative payroll above a pre-defined threshold and are prohibited from selling operationally essential parts of the business during a designated holding period. During this time, neither capital nor labor inputs can be significantly reduced without risking a retroactive revocation of the tax exemption. This requirement effectively increases the layoff costs incurred by the firm by the proportional withdrawal of the tax exemption. Between 2010 and 2016, the cumulative payroll requirement applied only to firms with more than 20 employees at the time of transfer. Firms with 20 or fewer employees could benefit from the exemptions without the requirement.[1] We exploit this policy variation by focusing on firms that experienced exogenous, death-related ownership transfers. Using a stacked Difference-in-Differences design, we compare firms that underwent a succession while being subject to the payroll sum requirement with comparable firms that experienced the same event at the same point in time, but without the requirement. Our approach allows us to eliminate a variety of potential confounders (such as the succession itself) and is robust to treatment effect heterogeneity (Cengiz et al., 2019; Baker et al., 2022), thus isolating the impact of the labor protection element of the provision.

We combine three data sources to conduct our analysis. First, we use the company database Orbis from the commercial data provider Bureau van Dijk (BvD) to identify all German firms that underwent ownership changes between 2010 and 2015.[2] Second, we link these ownership changes to publicly available individual-level death data to identify death-related successions. This data mainly consist of two databases sourced from newspaper death notices and tombstones, hosted by CompGen, a German non-profit association for Computer Genealogy. We enrich this information by scraping obituary sections from regional newspaper websites. In order to ensure that we are capturing ownership changes subject to inheritance taxation, we restrict our sample to unique matches

[1] These firms only had to adhere to the capital requirement.

[2] We focus on this period because the requirements were adjusted in 2009 and mid-2016, without retroactive application.

within our database and focus on family firms where the incoming owner has the same family name compared to the outgoing owner. Third, we merge the firm-level data with administrative employer-employee records, which provide us with a rich set of labor market outcomes. To further limit differences between our treatment and control group, we require firms to be in a window of 10 employees above or below the threshold.

Our findings show that the payroll sum requirement reduces growth of the firm-level payroll among affected firms facing uncertainty about their future tax obligations. This decline is driven by both lower increases in nominal wages and reduced expansion of employment, consistent with more cautious employment strategies imposed by incoming heirs. Our results are robust to zooming in close to the threshold. Moreover, using this more-fine grained identification approach, we find a significant positive positive effect on investment during the holding period, indicating that firms substitute labor with capital. We further validate our design with a placebo test that assumes that the treatment takes effect at ten employees. Both tests suggest that size differences are unlikely to explain our findings. Finally, we detect a muted impact of the requirement on highly leveraged firms, suggesting that the responsiveness to the treatment hinges on the financial situation of the firm.

We contribute to several strands of literature. First, our work relates to an established literature on the effects of wealth transfer taxes on firms. Utilizing German firm survey data, Hines et al. (2019) show that inter vivos gift transfers occur more often during economically viable circumstances, which speaks to the importance of liquidity concerns when liable to wealth transfer taxation. Using data from Greek firms and an instrumental variable approach, Tsoutsoura (2015) finds that inheritance taxation has a negative effect on firm investment. In a similar vein, Ellul et al. (2010) find that inheritance law as such can already have a negative effect on firm investment by dispersing ownership within families. In the German setting, Glogowsky (2021) finds that tax incentives are actively exploited, particularly for testaments, which is a conventional way to organize firm succession in an anticipatory manner. Franke et al. (2016) evaluate the payroll sum policy using cross-sectional data from the inheritance and gift tax statistic and simulations. Their findings suggest that the requirements for preferential treatment are likely to exert only negligible effects on firms. We add to this literature by showing the distortionary effects of tying inheritance tax exemptions to real economic outcomes.

Second, we add to the literature on the effects of labor market regulation on firm outcomes. In particular, we provide evidence on the role of firing costs and employment targets on firm-level employment. Theory predicts that employment protection in the form of increased lay-off costs has a stabilizing effect on employment by reducing job turnover through reduced hiring and firing (Bentolila and Bertola, 1990; Lazear, 1990). There is some empirical support for this prediction. Autor et al. (2007) exploit state-level variation in wrongful-discharge legislation in the US to provide evidence on the link between dismissal costs and productivity. They find that wrongful-discharge protection reduces employment flows and firm entry rates. Adhvaryu et al. (2013) use fluctuations in rainfall in rural India to instrument local labor demand, finding that industrial employment is more sensitive to shocks where labor regulation is less restrictive. Related to Autor et al. (2007), Kugler and Pica (2008) examine the effects of an Italian reform that lead to an increased cost of unjust dismissals. The authors find that this increased cost decreased new hires as well as separations of workers in affected relative to unaffected firms. Additional evidence from the Italian setting is provided by Sestito and Viviano (2018), who leverage an Italian reform lowering firing costs for newly signed open-ended job contracts. Utilizing differential exposure to the reform, the authors show modest hiring responses to a reduction in dismissal costs. We complement these findings by showing that these effects also materialize in a setting with uncertainty with respect to dismissal costs. In a closely related setting Akcigit et al. (2023) investigate the effects of binding employment maintenance commitments in the context of the privatization of East German firms in the aftermath of the fall of the Iron Curtain. They find that firms with binding employment commitments experienced a 22 percentage point higher annual employment growth rate but also had a 3.6 percentage point higher probability of exit. We complement their findings by showing how targets imposed without regard for the economic situation of the firm can reverse the well-intended effects of the regulation in the context of firm ownership successions.

Third, we offer new insights to the literature on the impact of uncertainty on firm performance. It is long recognized that firms experiencing a temporary increase in uncertainty with respect to their business environment become more cautious in their hiring and firing decisions.[3] This prediction is based on the notion that hiring and firing costs increase the option value of waiting (Bloom, 2014; Bamieh et al., 2025). Another explanation for this result could be that the mere act of hiring new personnel could itself entail additional business risk, which a firm in an especially uncertain business environment might be reluctant to take on (Bamieh et al., 2025). The empirical literature in this field mostly focuses on the impact of macroeconomic shocks to uncertainty that affect entire countries or industries, see Bloom (2014) for a review. A clear limitation of relying on this type of variation is that it is difficult to isolate the impact of changes in a firm's own belief about uncertainty from the behavior of others or the realizations of these uncertainty shocks (Berger et al., 2020). To the best of our knowledge, the only other study using firm-level variation in uncertainty to investigate the effects of uncertainty on firm outcomes is Bamieh et al. (2025), who leverage quasi-experimental variation in business uncertainty induced by variation in trial duration for wrongful dismissal litigation in Italy. The authors find that uncertainty has a curbing effect on job turnover, hiring, and separations during the period of uncertainty, which vanishes as soon as the source of uncertainty is removed. We find similar employment effects in our setting.

Finally, we relate to a literature that utilizes death events as exogenous variation for identification. This approach was pioneered by Jones and Olken (2005), who use deaths of national leaders while in office to investigate whether changes in country leadership have effects on economic growth. Similarly, Fadlon and Nielsen (2021) use Danish administrative data on fatal health shocks to provide evidence on their impact on households' short- and medium-run labor supply. Finally, Jäger and Heining (2022) use exogenous, death-related worker exits to examine how these exits affect firms' demand for incumbent workers and new hires. Studies on the effects of wealth transfer taxes typically face

[3]For a leading seminal paper in this regard, see e.g. Bernanke (1983).

challenges due to the endogeneity of the transfer decision. A few papers implemented Instrumental Variable (IV) approaches to isolate exogeneous variation in transfers, e.g., Bennedsen et al. (2007) or Tsoutsoura (2015), who both use the gender of the donor's first-born child as an instrument for within-family firm succession. We leverage surprising deaths as exogenous changes in firm ownership to identify the causal effect of the payroll sum requirement on affected family firms.

2 Institutional Background and Hypotheses Development

2.1 Institutional Background

Gratuitous Business transfers that involve a German recipient, donor or firm are subject to German wealth transfer taxes. The German transfer tax system is organized as an inheritance tax, which taxes the recipient of a wealth transfer rather than the total estate.[4] Inter vivos giving is integrated into the inheritance tax law in order to harmonize the two means of gratuitous wealth transfers. Hence, gifts and bequests *a priori* yield the same tax consequences. The tax base is the net wealth transferred to the recipient, defined as gross wealth received net of liabilities associated to the receipt. It encompasses all transfers that the recipient has received by the same donor within a ten-year period prior to the gift or bequest. Applicable rates increase in wealth transfer amount and decrease in the degree of kinship to the donor (see Table III.B1a in Appendix B). Importantly for our setting, business assets are always treated as transfers within the most favorable tax class I. Additionally, the amount of tax allowances also decreases in the degree of kinship (see Table III.B1b in Appendix B). In case of bequests of business assets, the inheritance tax due may be deferred up to seven years with zero-rated interest.

In principle, all types of wealth are subject to the transfer tax. However, various personal and objective exemptions exist. Most prominently, certain types of assets are taxed

[4]This is in contrast to the estate taxes levied for example in the United States or the United Kingdom.

at reduced rates, such as housing or business assets. Business assets in this definition comprise closely-held shares in limited liability companies, shares in partnerships and assets of sole proprietors as well as agricultural assets. These asset classes are eligible to the exemptions elucidated below, provided they contain predominantly productive and not so-called administrative assets. The latter category includes cash, other financial assets and rented housing. This owes to the notion that only economically productive values such as machines and production buildings should benefit from the tax exemptions. During the considered time period, administrative assets within an asset transfer are considered not eligible for the business asset exemptions, if their share in the total transferred business asset exceeds 50%.

When an individual firm owner transfers her assets gratuitously, the recipient may choose between two alternative exemption models: the regular exemption (*Regelverschonung*) or the optional exemption (*Optionsverschonung*). Both schemes differ in the generosity of the exemption granted and the requirements that must be met by the recipient of the business in the years after the transfer.

Under the regular exemption, the recipient benefits from an 85% exemption of the taxable bequest. This exemption is tied to two requirements. First, the recipient may not sell or liquidate the business over a period of five years. Second, if the company has more than 20 employees at the date of the taxable event, it must adhere to the payroll sum requirement. This requirement compares the initial payroll sum, defined as the average payroll sum over the five years prior to the transfer, with the cumulative payroll sum over the holding period. The cumulative payroll must at least equal 400% of the initial payroll, which allows for an overall reduction in labor of 20%. If either of the requirements is violated at the end of the holding period, the exemption is proportionally re-levied depending on the degree of violation. For instance, if the cumulative payroll after five years only reaches 200% of the initial payroll sum, the exemption of 85% is reduced by 50% to 42.5%.

Under certain conditions the heir may choose the optional exemption, which increases the exemption to 100%, i.e., the tax base is fully exempt. This more generous exemption mode is however also tied to stricter requirements.[5] The period during which the business cannot be sold nor liquidated increases to seven years, and the cumulative payroll sum over this period may not fall below 700% of the initial payroll. This would require the annual payroll sum to stay at least at the level of the initial payroll sum on average. A violation of either requirement leads to the same tax consequences as for the regular exemption.

Figure III.1 illustrates the tax consequences from violating either the holding or the payroll sum requirement for the two exemption models. Both examples are based on a company value of EUR 6.5 million and assume a transfer to a child of the donor subject to a EUR 400 thousand personal allowance. Figure III.0a shows the total tax liability for the recipient if she sells or forecloses the business at specific points in time after the receipt. Figure III.0b below shows the total tax liability based on the cumulative payroll sum at the end of the respective holding period relative to the initial payroll sum. What becomes apparent when comparing the tax consequences across the two requirements is that violating the holding requirement has a lot more bite compared to the payroll sum restriction. For example, falling short of the holding requirement by one year (20%) entails an increase in the overall tax burden of 200% for the regular exemption, whereas decreasing the payroll sum by an average of 20% entails no tax consequences at all, and only by reducing the payroll sum by an average of 40% do the same tax consequences arise.

Both holding and payroll sum requirements have been in place since 2009. The take-up rates of these exemptions for bequests across the years 2010 until 2015 varies between 71% and 75%, implying a strong attractiveness of the tax exemptions.[6] Despite adjustments in both 2009 and 2016, their basic functioning has remained the same since then. Since reductions in employment have a larger relative impact on the payroll sum for smaller firms, the payroll sum requirement was imposed only on firms with more than 20 employees in the year of transfer, whereas firms with 20 employees or less only had to

[5]In addition to a stricter eligibility criterion of administrative assets not exceeding 10% of the overall company value.

[6]Source: own calculations based on the inheritance and gift tax statistics.

comply with the holding requirement.[7]

Severe sector-specific economic downturns do not generally lead to a relaxation of the payroll sum requirements.[8] Further, various loopholes to the regulation exist.[9] However, these are only relevant for active tax planning of wealth transfers through *inter vivos* gifts. Given our focus on surprising inheritances of small and medium-sized firms with remunerated employees, such exceptions to the policy applicability do not interfere with our later analysis.

More relevant in our setting is the question whether family firms could try to manage the payroll by paying themselves or employed family members higher wages on paper to fulfill the requirement while reducing the number of employees at the same time. This concern is alleviated by strict monitoring and safeguards in place. First, compensation of managers of closely-held corporations is closely monitored by the financial offices. Once the manager holds more than 25% of shares, the compensation has to withstand an arms-length comparison with the earnings of other managing directors in comparable positions. If this test fails, the manager is at risk to be liable to a back taxes, as the excess compensation is deemed as a hidden profit distribution, which is subject to corporate income tax and local business tax. Second, similar safeguards are in place for employment of close family members. Employment contracts have to fulfill certain requirements in order to qualify as dependent employment (instead of co-entrepreneurship). Among other things, these contracts also have to satisfy an arms-length principle. If this test fails and the illegitimate arrangement is detected, any accrued entitlement to social security benefits is revoked and potentially back taxes are levied. Hence, trying to circumvent the

[7] This headcount requirement was softened after the last major reform in 2016, where a payroll sum requirement was imposed also for firms between five to 20 employees.

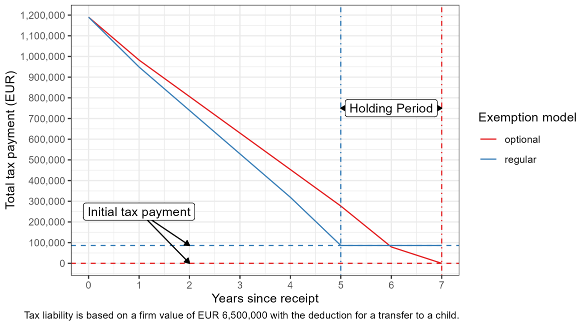
[8] An exception occurred during the COVID-19-pandemic, when a government program partially replaced the wage bill of firms in sectors of the economy that were hit particularly by mandatory measures, such as store closings. Subsequently, concerns were voiced about the harsh consequences concerning the payroll sum requirement regulation, as total payroll sums paid by firms substantially decreased during this period. As a result, the payroll sum requirement was relaxed from 1.3.2020 until 30.6.2022.

[9] First, firms without any employees can still fully benefit from tax exemptions, without any need to contribute to the positive externalities of providing employment. Second, until 2013 (larger) firms with more than one dependency could avoid the payroll sum requirements through holding companies. Due to a lack of legal clarification, payroll sum requirements only targeted the employees in the holding company itself. The payroll sum in the subsidiaries was disregarded. Third, temporary workers are excluded from the payroll sum definition, creating incentives for maintaining flexible shares of non-permanent labor force under the constraint of labor laws.

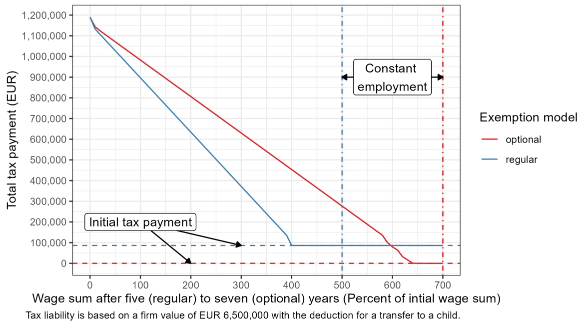
payroll sum requirement through family employment arrangements is subject to hefty financial penalties and therefore not an attractive option.

Figure III.1: Exemplary Tax Consequences

(a) Violation of Holding Requirement



(b) Violation of Payroll Sum Requirement



Notes: For the calculation of effective tax rates, we assume transferred business assets to have a value of EUR 6.5 million. The personal deduction for a child of the donor is EUR 400,000. The tax liability calculation abstracts from additional personal circumstances of the recipient and assumes that the overall transfer is fully eligible for the regular and optional tax exemption.

2.2 Hypotheses Development

In this section, we develop our hypotheses on how the payroll sum might affect firm outcomes. Firms that fail to meet the payroll sum thresholds face significant financial penalties proportional to the reduction in labor input when the inheritance tax is reapplied, effectively increasing costs of layoffs, wage cuts, and voluntary separations. The extent to which these adjustment costs actually impact firms depends on their development during the holding period and the uncertainty associated with employment expectations. If the firm subject to the requirement is on a positive employment trend prior to the succession, the requirement is likely to be immaterial for two reasons. First, the initial average payroll, based on which the cumulative payroll is evaluated, is lower than the current payroll, which gives the company some leeway in adjusting employment downward. Second, to the extent that the positive growth continues after succession, the firm would actually increase its labor input, which is not affected by a downward restriction.

In contrast, for firms with a declining trend in employment (e.g., during a recession), the payroll sum requirement is likely to be binding. Such firms may want to *reduce* employment without the requirement. Under these circumstances, firms subject to the payroll sum requirement are expected to maintain higher payroll sums during the holding period than comparable firms not required to maintain a certain level of employment. This artificial stabilization is expected to vanish once the holding period ends, as treated firms are then free to optimize labor input.

We visualize the outcome trajectory for treated and control units in the recession scenario in Figure III.2a. The graph shows the actual and counterfactual outcome evolution of treated and control firms around the succession event under the assumption that the optional exemption was chosen. In this case, the average payroll sum over seven years is not allowed to drop below the initial payroll sum. When the firm is on a declining trend, that means that it actually has to increase employment relative to the year before the succession during the holding period to fulfill the requirement. After the holding period, the firm is then free to adjust its labor input to the optimal level, which would entail a substantial decrease in employment. As the descriptive results of Section 5 will show, it is unlikely that during our period of study any firm in the sample was facing such circumstances. During the period 2010 to 2015, economic growth was generally positive in Germany and therefore declining employment trends such as during the COVID-19 pandemic were not prevalent.

However, in addition to these direct effects, the payroll sum requirement may influence firms even in the absence of a recession. Incoming owners, particularly those with limited experience, may adopt conservative labor strategies due to the requirement, as firing costs increase the option value of waiting (Bloom, 2014; Bamieh et al., 2025). In addition, the mere act of hiring new personnel could itself entail additional business risk, which a firm in an especially uncertain business environment might be reluctant to take on (Bamieh et al., 2025). Thus, this tendency is likely to be more pronounced in cases of unexpected ownership transitions, such as those resulting from the sudden death of a predecessor. In such scenarios, inexperienced owners might avoid taking risks in order to avoid potential tax penalties, leading to slower employment growth. This mechanism would give rise to the dynamic effects illustrated in Figure III.2b. We formalize this mechanism in the following hypothesis.

Hypothesis III.1: *The payroll in firms that experience a surprising ownership transition due to an early death of the previous owner grows slower when subject to the payroll sum requirement.*

To the extent that labor and capital are substitutes, we expect the free resources not used for an expansion of labor to be used for capital investment instead. This is due to the expected tax penalty increasing the cost of labor relative to the user cost of capital, which gives rise to substitution effects (Caballero and Hammour, 1998). This prediction would also be in line with empirical evidence on the effects of employment protection on capital investment (Autor et al., 2007; Cingano et al., 2016). Furthermore, unlike labor, which represents an ongoing expense and commitment, capital investments (e.g., machinery, equipment, or real estate) are tangible assets that can be resold if the firm is liquidated. If the heir is uncertain about their long-term commitment to the business, they may see capital investments as a way to preserve or even enhance the firm's liquidation value. Based on these considerations, we formulate the following prediction regarding the effect of the payroll sum requirement on investment.

Hypothesis III.2: *Capital investment in firms that experience a surprising ownership transition due to an early death of the previous owner increases during the holding period when subject to the payroll sum requirement.*

These opposite effects of the payroll sum regulation on adjustment of capital and labor are driven by the elasticity of substitution between capital and labor. The more easily a firm can invest into new machinery to replace labor (higher elasticity of substitution), the stronger the positive effect on investment and the stronger the negative effect on employment growth following an increase in labor adjustment costs.

However, financially constrained firms, whose ability to acquire capital instead of labor is limited, might exhibit a lower effective elasticity of substitution. This would result in more attenuated responses to such regulations - these firms neither reduce employment nor increase capital investment as strongly as their financially healthy counterparts. Against this background, we consider heterogeneity in responses due to differing financial conditions as a potential explanation why identical labor market policies can have varying effects across firms and sectors. Our third hypothesis hence becomes:

Hypothesis III.3: *Capital investment (employment) in treated firms with limited access to external financial funds prior to ownership transition increases (decreases) less than capital investment (employment) in treated firms without financial constraints.*

3 Data and Descriptive Statistics

3.1 Data Sources

Our analysis builds on information from a variety of data sources, which we describe in the following. Our starting point is firm ownership information from BvD's Orbis data base. We focus on changes in the global ultimate owner (GUO), defined as an individual with a controlling influence of more than 25%, to identify changes of firm ownership during the period 2007 to 2022. In addition, we gather information on firm characteristics and financial data.

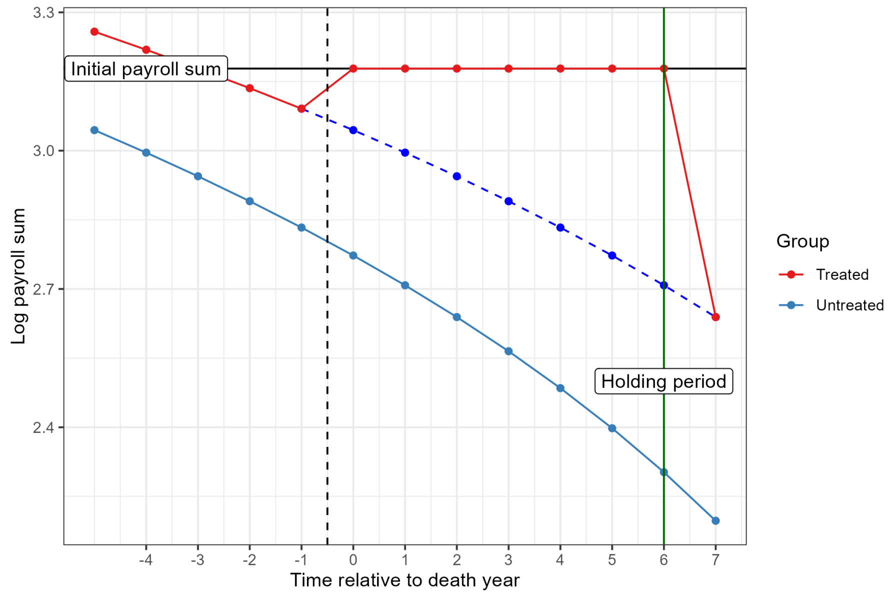
In order to identify changes in firm ownership that are due to an inheritance, we retrieve death information from three different data sources.[10] First, we use death notice data provided by the CompGen family announcements project.[11] CompGen is a non-profit and non-governmental association for computer genealogy, which hosts several projects related to researching ancestors and family history. The data for the death notice project is collected by volunteers browsing through the obituaries sections of local newspapers and digitalizing the information on the deceased in a comprehensive database. Figure III.3a illustrates the spatial coverage of this data and indicates that most of Germany is well covered in the database, with a higher concentration of observations in the

[10] More extensive detail on data collection and preparation is provided in Appendix C

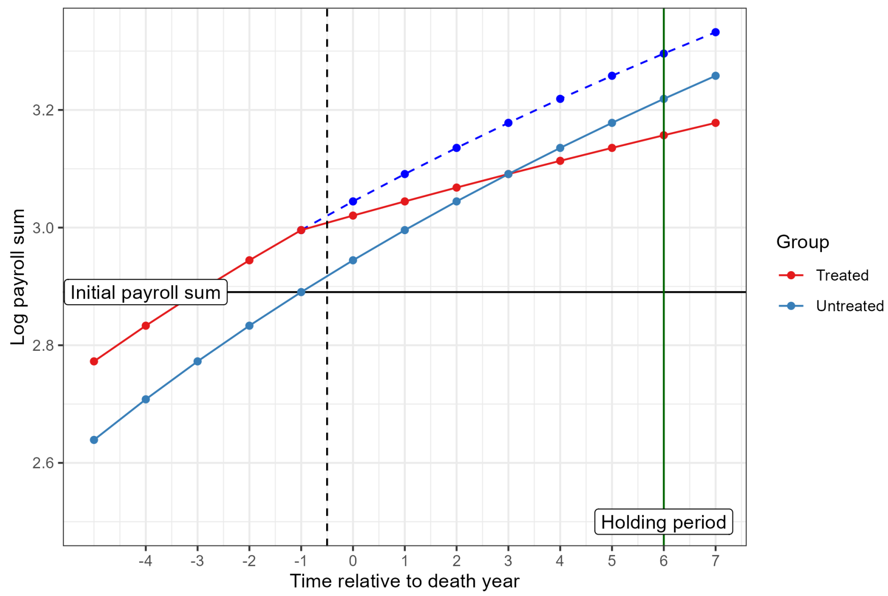
[11] Data by the *CompGen-Projekt Familienanzeigen in Tageszeitungen* available at `http://familienanzeigen.genealogy.net/`

Figure III.2: Illustration of Hypothesized Effects.

(a) Recession Scenario



(b) Uncertainty Scenario



Notes: Figure III.2 shows the potential development of treatment and control firms in two distinct scenarios. In the first scenario (Figure III.2a), both firms are on declining employment trends before the succession, but one firm needs to maintain a sub-optimally high payroll sum. In the second scenario (Figure III.2b), both firms are on the same positive employment growth path prior to succession, but the firm facing the restriction becomes more conservative in its employment strategy during the holding period.

West and South. Figure III.3c shows the time coverage of the death notice database from 2000 to 2022. Over our period of interest, the coverage is on a declining trend, starting from about 110 thousand observations in 2010 to about 65 thousand in 2015. Overall, the data holds death records for about 556 thousand individuals in that time window.

Second, we employ digitalized tombstone data provided by the CompGen tombstone project. In order to preserve the information on the deceased, voluntary contributors take pictures of all tombstones on a given graveyard and digitalize the inscriptions in a database. The included information generally comprises the full name as well as the date of birth and death. Figure III.3b shows the distribution of inscriptions aggregated on the zip code level. As is apparent from the figure, the spatial distribution of the tombstone database is less dispersed than the death notice database. Its coverage is particularly high in the north and east of Germany, whereas it is only sporadic in the southeast. Our period of interest covers recorded deaths of 595,977 individuals. Similarly to the death notice database, the number of observations decreases during our period of interest, albeit to a smaller extent. The number of deaths steadily decreases from a total of 105 thousand in 2010 to about 95 thousand in 2015.

Third, we augment the obituary information of the death notice data base by web scraping the obituaries sections of a total of 46 regional newspapers.[12] Using optical character recognition trained on German texts, we recover a total of 1,321,583 obituaries. Figure III.3c shows the number of obituaries by death year over time, illustrating that coverage improves for our scraped newspapers as we move closer to the present, which counteracts the declining trend in the other two sources. The upward trend starts to pick up with the onset of our period of interest, where we observe about 10 thousand recorded deaths. At the end of our sample period in 2015, coverage increased to more than 60,000, surpassing the CompGen death notice database by the next year.

Figure III.3d compares the inter-temporal coverage of our data to the official data on recorded deaths by the German Federal Statistical Office. Due to the opposing trends in coverage between our different data sources, we attain a relatively constant set of about 200 thousand death records per year, which constitutes roughly a quarter of the overall number of deaths in Germany. Given the nature of our data sources, we expect business owners to be over-represented in the available death records. For the death notice data,

[12] List of newspapers available upon request from the authors.

we deem it more likely that a departed business owner receives an obituary posted by either his or her family or the company. For the tombstone data on the other hand, large graveyards in bigger cities are better covered, which is where most economic activity takes place.

Finally, to enable the analysis of labor outcomes of the inheritance tax policy, we require reliable and detailed firm-level data on wages and employees. Firm databases containing firms' financial accounts cannot reliably provide such information reliably, as especially small and medium-sized firms in Germany are not required to report these numbers in their external accounting. To overcome this challenge, we complement our firm-level dataset with administrative information on establishment-level employment and wages provided by the Research Institute of the Federal Employment Agency (*Institut für Arbeitsmarkt- und Berufsforschung, IAB*). We use a project-specific sample based on a link of the Mannheim Enterprise Panel to the Establishment History Panel.[13] These data include the number of full-time and part-time employees and their compensation at the level of the establishment.[14]. This excludes temporary and seasonal workers, which coincides with the tax policy definition we consider. Employee compensation is measured as the (imputed) sum of all wages.[15]

3.2 Sample Selection

The sample selection process is summarized in Table III.1. Our starting point is the set of first-level ownership links between a German company and another entity covered by Orbis, augmented by information on the global ultimate owners with at least 25% total ownership share. From 2007 until 2023, these data include about 65 million links involving 5 million unique firms and 6 million owners. From this initial sample, we keep

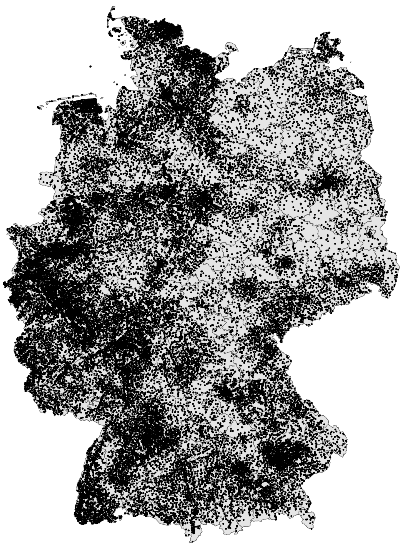
[13]The resulting data product is called *Projektspezifische Stichprobe aus dem Mannheimer Unternehmenspanel verknüpft mit administrativen Daten des IAB.*. For more details on the linkage process underlying the administrative data see Diegmann et al. (2024).

[14]A business number, centrally assigned by the federal employment agency, defines an establishment. This definition moves the level of observation down, from the firm-level to the actual place of production. However, multiple places of production may share a common business number if, for instance, they perform a similar task within the company and are located within the same municipality.

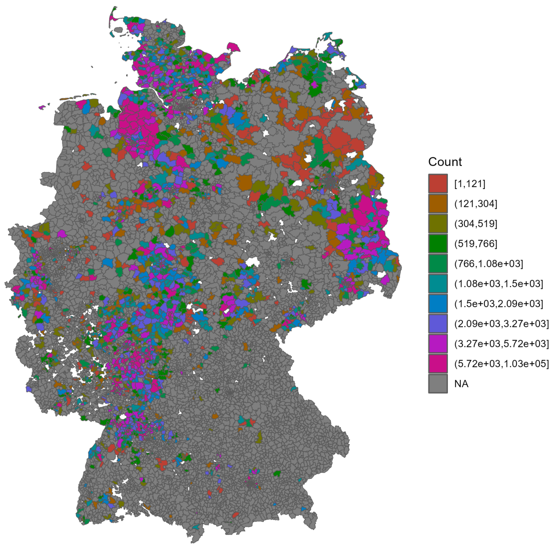
[15]The underlying database originated from reports of social security contributions, which are capped at approximately 160% of the average gross wage. The imputation procedure is described by Drechsler et al. (2023).

Figure III.3: Spatial and Inter-temporal Coverage of Death Data

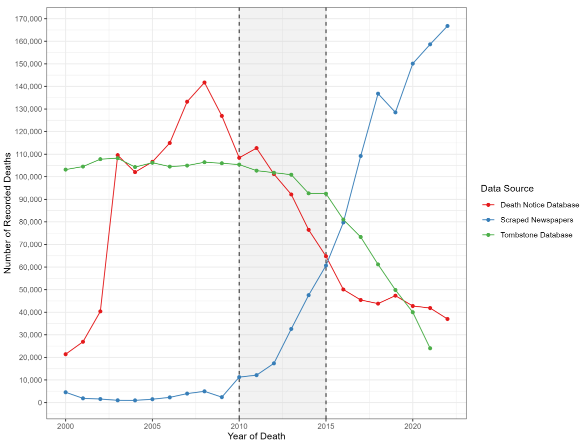
(a) Spatial Coverage of Death Notice Data.



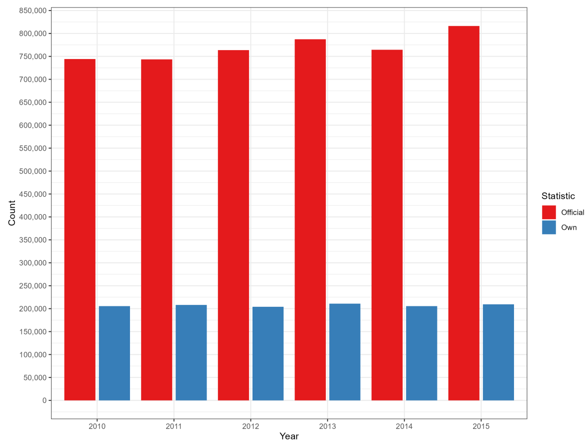
(b) Spatial Coverage of Tombstone Data.



(c) Coverage over Time.



(d) Comparison with Official Statistics.



Notes: Figure III.3 shows the spatial and absolute coverage of our different death data sources. Figure III.3a shows the spatial coverage of recorded newspaper obituaries across Germany. Figure III.3b shows the spatial coverage of the Tombstone data. As we only have information about the zip code a graveyard is located in, observations are aggregated on the zip code level. Figure III.3c shows the intertemporal coverage of each data source. Figure III.3d compares the count of death events in our three databases to the official death statistics provided by the German Federal Statistical Office.
Source: Orbis, CompGen archives, regional newspapers and Destatis.

firms with less than five owners at a time, reducing the number of firms and individuals slightly. Next, we only retain firms with at least one substantial ownership change over the observed period. That is, we retain firms with a first-level shareholding change of at least 25% or a change in the GUO. After these pre-selection steps we are left with 817 thousand firms belonging to 1.04 million individuals between 2007 and 2022.

At this point, an observed exit of an individual GUO could be due to a variety of reasons. For instance, the owner could have sold their share in the company, or transfer their share via a gift or inheritance to another individual. In order to isolate exogenous changes in firm ownership due to an inheritance, we match the ownership data against the death data sources introduced in Section 3.1. A death record observed in the death data is matched with a GUO exit if the records share the same first name and last name. Additionally, we allow for a lag of up to one year between the recorded death and the observed change in ownership in Orbis.[16]

During the period between 2007 and 2022, we match a total of 38 thousand individuals based on their last name, first name, and year of death, owning a total of 47 thousand firms. We subsequently merge this data to the establishment-level administrative employment data of the IAB. We are able to match about 67% of Orbis firms with a death record to the IAB data. While this reduces the number of firms to 31 thousand, we now observe a total of 41 thousand establishments of these firms.

We implement several steps to ensure that we correctly identify an ownership transition that is due to an inheritance and minimize any potential attenuation bias due to false positive matches.[17] As metrics for our baseline restriction, we use the number of matches as well as the headquarter location of the firm and the coverage area of our death sources. For the CompGen death notice data, which stems from newspaper archives, we geo-reference any location we find in the death record for each distinct newspaper.[18] Sub-

[16] In the Orbis ownership data, an individual is identified as a GUO in that year, if the information provider confirmed the ownership relation within the year of observation. Hence, it could be that a GUO was confirmed in that year and died in the same year, but the new incoming GUO was only confirmed in the following year.

[17] As we rely on a combination of last name, first name, and the year of ownership change vis-a-vis a death year, a chance match where these margins correspond for two different persons by coincidence could occur.

[18] This most frequently refers to the place of death. Alternatively, it includes place of last residence,

Table III.1: Sample Selection

Description	Observations	Establishments	Firms	Individuals
All first-level shareholder links of German firms	64,867,881		5,238,125	6,303,703
Less than 5 owners in a year	53,177,761		5,077,543	5,539,569
Collapse to firm-year panel	37,031,115		5,077,543	3,799,643
At least one substantial ownership change	10,043,190		817,074	1,044,849
Add financial Years 2005 and 2006	10,506,534		817,074	1,044,849
Matched with death records	696,477		47,147	38,853
Merged to yearly establishment-level IAB data	602,317	41,219	31,418	29,024
Keep unique or local name matches during 2010-2015	152,063	13,779	10,495	9,826
Keep firm when incoming/outgoing owner share family name	60,963	5,393	4,208	3,949
Keep non-exiting establishments	40,122	3,455	2,945	2,792
Single-owner-firm-establishments with 10-30 pre-death employees	7,237	611	611	611
Owner is younger than 70 at death	1,733	165	165	165

Notes: Table III.1 shows the sample selection process from the Orbis ownership data until our match with the IAB data. We start with all ownership links from a German individual to a company during the available period from 2007 until 2022.

sequently, we calculate the centroid of the mentioned locations and create a buffer zone based on the 80th percentile of the distance between each location and the centroid. This way, we obtain a coverage area for each newspaper, which is not sensitive to outliers. As we do not directly observe the location of an obituary in our scraped newspaper data, we use the coverage area for the newspapers identified from the CompGen death notice data also for our scraped death records. For the tombstone data on the other hand, we calculate the coverage area of a graveyard based on the zip code of the grave yard combined with a fixed buffer zone of 300 km around the graveyard location.

Figure III.4 provides an illustration of the match quality in the data and our first validation of match quality based on the number of matches and coverage area of our death records. The figure shows the number of individuals with the same combination of last name, first name, and death year, that are matched to a GUO exit in Orbis on the x-axis, and the number of occurrences on the y-axis. For the vast majority of cases, we either have a unique match within a given database or find at least one match that is in the coverage area of the respective death source.[19] As our baseline restriction, we omit all ownership transitions with a duplicate match or where neither of the matches is inside the coverage area of the newspaper or graveyard.

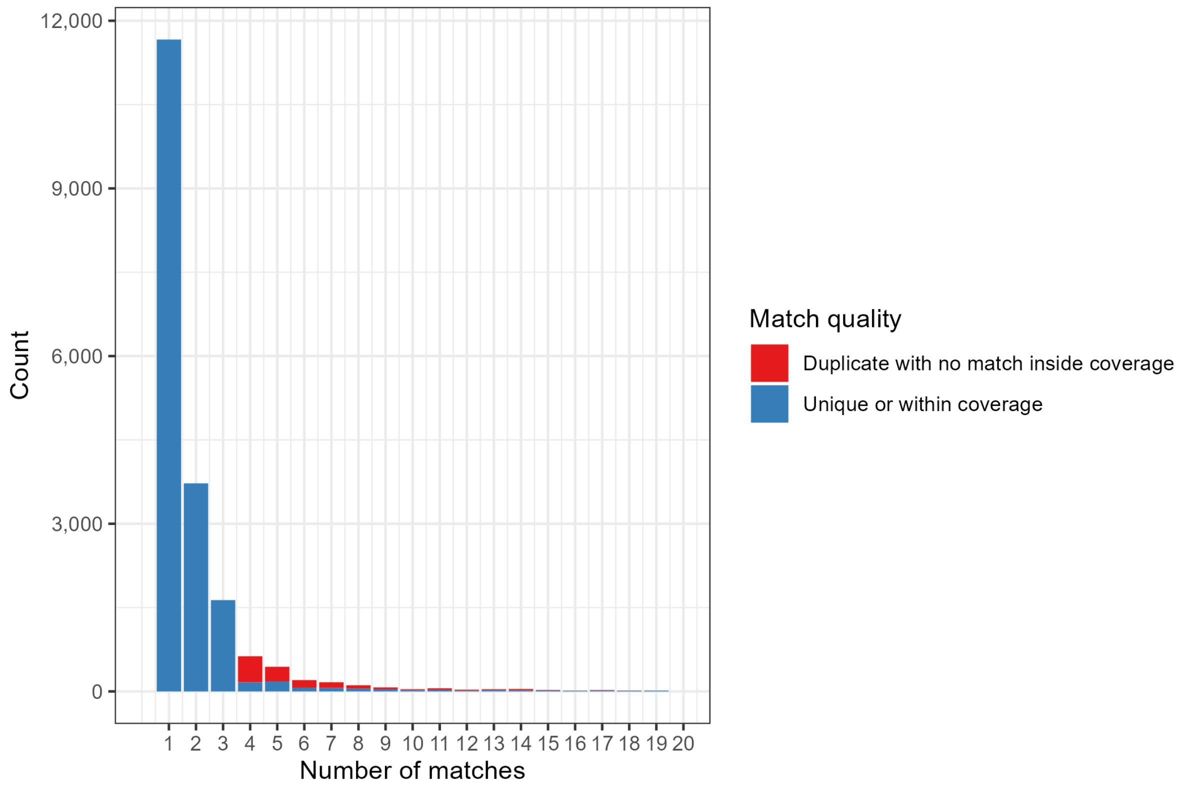
After restricting the sample further to our period of interest between 2010 and 2015, we are left with 14 thousand establishments of 10.5 thousand firms belonging to 9.8 thousand individuals. In order to further sharpen the identification, we implement several additional restrictions to isolate unexpected inheritances. First, we require the new incoming GUO to share the same last name as the deceased GUO, which is true for about half of the remaining sample (4,208 firms).[20] Second, we focus on non-exiting establishments, which leaves us with 3,455 establishments of 2,945 firms. Third, we consider single-owner-establishment firms with more than 10 and less than 30 employees in the

place of funeral, place service, or place of birth.

[19]Note that in principle, a given death could be recorded multiple times. We might have a death notice from the CompGen death notice database, which was also retrieved from our scraper of the newspapers website. Additionally, we might have an observation for this individual from the tombstone data, when she was buried on a graveyard covered by the CompGen tombstone database.

[20]This restriction effectively trades off more credible identification of inheritances, as most inheritances occur within family, for coverage of female heirs, who are more likely to change their last name after marriage.

Figure III.4: Number of Matches



Notes: Figure III.4 illustrates the number of matches between an individual shareholder exiting the sample with a deceased individual from our death data. The horizontal axis shows the number of matches with the cumulative proportion of observations in parentheses. Counts colored in blue indicate that the match was either unique across all data or unique within one database, whereas red counts indicate duplicate matches within a data base.
Source: Orbis, CompGen archives and regional newspapers.

year before the succession, which includes 611 firms. Finally, we only retain cases where the departed was less than 70 years old at the time of death.[21] This leaves us with a final sample of 165 firms.

3.3 Descriptive Statistics

Table III.2 shows descriptive statistics for our regression sample. The table compares key firm characteristics for treatment and control firms in the year prior to succession. Firms above and below the relevant size threshold of 20 employees are similar in most aspects

[21] This restriction enables us to focus on surprising changes in ownership and control. At 70 years, a German male can expect to live for another 14 years, while the life expectancy of a German female is even 17 years, which is considerably longer than the expected time to pass on a business to the next generation. The figures are taken from the mortality tables published by the German Federal Statistical Office (Destatis) for the years 2010 to 2015.

but not identical. We (naturally) see differences in employee count and the payroll sum, as group assignment depends on these variables. On average, control firms employ 14 employees and have a payroll sum of EUR 864 thousand, compared to an average of 25 employees and a payroll sum of EUR 1.6 million among treated firms. Apart from these differences, treatment and control firms are remarkably similar. At death, the previous owners are on average 60 years old and the firm existed for 30 years in both treatment and control group. Total assets are with an average of EUR 1.3 million and EUR 1.9 million not identical but also not significantly different from each other.

Table III.2: Descriptive Statistics and Difference-in-Means Test

	Control Group (10-20)		Treated Group (21-30)		Mean Difference	
	Mean	Count	Mean	Count	Difference	t-Statistic
Age at death	60.44	128	60.78	37	-0.346	-0.25
Firm age	30.97	122	29.22	36	1.745	0.41
Total assets	1237.90	104	1856.58	31	-618.677	-1.55
Leverage	0.70	104	0.75	31	-0.049	-0.83
Investment	0.08	102	0.05	28	0.025	0.37
Cash Share	0.17	102	0.16	31	0.009	0.26
Employees	14.09	128	25.03	37	-10.933***	-19.61
Payroll sum	864.46	128	1647.11	37	-782.654***	-9.02
Median wage	81.17	125	79.09	37	2.081	0.56
Mean wage	83.59	125	83.45	37	0.148	0.04

Notes: Table III.2 shows descriptive statistics of our final dataset. The depicted averages and observation counts of firms are split up by employee-size class (10-20 employees for the control group and 21-30 for the treated group) and measured in the year before ownership succession. The two rightmost columns show differences in means between the two groups for the respective variables as well as t-statistics for the differences. Imbalances for the number of employees and payroll are by construction, as the assignment to the treatment and control group depends on these variables.
Source: MUP-ADIAB-PSS.

4 Empirical Strategy

Our identification strategy centers on the feature of the inheritance tax code that ownership transfers of establishments with more than 20 employees are subject to the payroll sum regulation, while ownership transfers of firms with less than 20 employees are not. We estimate the effect of the payroll sum restriction on affected firms using a cohort-based Difference-in-Differences design. Thereby, we compare two companies that experienced an inheritance event in the same year (cohort), where one of these companies has more than 20 employees and is therefore liable to the payroll sum requirement, and the other has less than 20 employees and is therefore out of scope.[22] Using this approach, our estimand is the intended treatment effect on the treated, as we cannot be certain whether the preferential treatment provisions were actually invoked, i.e., whether the firm actually took up the policy, and if yes, which mode of exemption was utilized.

In order to estimate treatment effects based on valid comparisons only, we employ a stacked regression approach. This approach addresses concerns related to staggered-adoption Difference-in-Differences designs that were raised by recent literature (Goodman-Bacon, 2021; Callaway and Sant'Anna, 2021; Sun and Abraham, 2021; Baker et al., 2022). The stacked regression approach involves setting up separate datasets for each clean 2×2 treatment-comparison group. In our case, this boils down to a separate dataset for each event year cohort, that is, for transfers of ownership in each year from 2010 to 2015. The data is then stacked on top of each other and treatment effects are estimated from this stacked dataset with dataset-specific unit and time fixed effects using the following OLS regression (Cengiz et al., 2019; Baker et al., 2022):

$$y_{ijte} = \alpha + \beta_1 \text{Treatment}_{ie} \times \text{Post}_{te} + \gamma_{jt} + \mu_i + \delta_{te} + \varepsilon_{ite}, \qquad \text{(III.1)}$$

where i refers to the individual firm, j to the industry, t to the year of observation and

[22] An obvious concern would be that the applicable employee size threshold underlying the payroll sum requirements also coincides with other relevant size-varying employment regulations. To the best of our knowledge, this is not the case in our setting. For instance, German protection against dismissals becomes mandatory with firms above 10 employees. Similarly, the implementation of work councils takes place for firms with at least 5 employees.

e to the event cohort. As outcome variables, we consider the (logarithm of the) payroll sum, the (logarithm of the) number of employees, the logarithm of the median and mean wage, and the percentage change in fixed assets. In our baseline specification, we allow for industry-specific trends γ_{jt} and include unit-cohort fixed effects (which reduce to unit fixed effects) μ_i as well as time-cohort fixed effects δ_{te}. To investigate differential effects during and after the required holding period, we adjust Equation III.1 by splitting the post indicator into a short-run (up to five years after the taxable event) and a long-run (at least 6 years after the taxable event).

We accommodate the non-negative nature of our outcomes and the fact that the number of employees is a count variable by also estimating the equivalent specifications using a PPML model:

$$E[y_{ijte}|X] = \exp\left\{\alpha + \beta_1 \text{Treatment}_{ie} \times \text{Post}_{te} + \gamma_{jt} + \mu_i + \delta_{te}\right\}, \tag{III.2}$$

where X denotes the set of control variables. Since our outcome variables are likely non-linear, PPML regressions are particularly well suited in this setting (see e.g., Wooldridge, 2023) and serve as a robustness check for functional form assumptions.

We check for pre-trends and dynamic effects by estimating an event study specification that includes leads and lags of the treatment indicator:

$$y_{ijte} = \alpha + \sum_{l=-4, l\neq -1}^{7} \beta_l \; D_{ie,t-l} + \gamma_{jt} + \mu_i + \delta_{te} + \varepsilon_{ite} \tag{III.3}$$

Again, we estimate this specification using OLS and the PPML equivalent:

$$E[y_{ijte}|X] = \exp\left\{\alpha + \sum_{l=-4, l\neq -1}^{7} \beta_l \; D_{ie,t-l} + \gamma_{jt} + \mu_i + \delta_{te}\right\}. \tag{III.4}$$

Significant coefficient estimates for the lead terms, $l = -4, \ldots, -2$ would cast doubt on the parallel trends assumption, whereas the coefficients on treatment lags, $l \geq 0$ allow us to gauge the dynamic effect of the payroll sum.

5 Results

5.1 Labor and Investment Effects

We begin by investigating the effect of the payroll sum requirement on the payroll sum itself. Column (1) of Table III.3 shows the results of estimating Equation III.1 with the natural logarithm of the payroll sum as the dependent variable, while Column (2) depicts the results when using a Poisson model instead. We report the transformed coefficient estimates $\tilde{\beta} = \exp(\hat{\beta}) - 1$, with robust standard errors in parentheses such that the effects have a percentage change interpretation. We find that over a period of up to 8 years after the ownership transition, the payroll sum requirement has a negative effect on the overall payroll sum. On average, the payroll sum decreases by 11 to 14% in the treatment group relative to the control group.

We dissect this result by looking at whether this overall effect on the payroll is driven by the number of employees or wage setting. Columns (3) and (4) of Table III.3 show results of estimating Equation III.1 and the Poisson equivalent of III.2 when the dependent variable is the (log of) number of employees, whereas Columns (5) and (6) show treatment effects for the log specification for median and mean wages. We find negative effects in most specifications, suggesting that both hiring and firing as well as wage-setting decisions are affected by the requirement.

As our hypotheses postulate dynamic effects that differ in the short- and long-run, we estimate a variation of our static baseline specification where we split the post dummy into a short-term (1-5 years after the event) and a long-term effect (6-8 years). The results are shown in Table III.4 and suggest that the treatment effect increases dynamically over time, from a short-term effect of seven to 10% during the first five years of the requirement reaching 19 to 22% after eight years. This pattern is present both for the number of employees and median wages, however, the negative effect is much more substantial for the number of employees.

In order to speak to the nature of the effect, i.e., whether we see an actual decrease in

Table III.3: Effect of the Payroll Sum Requirement

	Payroll		Employment		Wages		Invest.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treat x Post	-0.111	-0.142**	-0.121**	-0.09	-0.06**	-0.052**	0.07
	(0.076)	(0.068)	(0.052)	(0.057)	(0.027)	(0.025)	(0.233)
Ind.-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-years	1,733	1,733	1,733	1,733	1,696	1,696	1,296
Adj. R2	0.821	0.853	0.316	0.671	0.869	0.874	0.747

Notes: Table III.3 shows results for regressions of our dependent variables on our main treatment indicator. For the payroll sum and employment we present estimations from OLS estimations of the logged outcome in (1) and (3), and Poisson regressions in (2) and (4). For wages we consider the log of the median (5) and mean (6) wage for a given establishment. The investment regression in (7) considers the log of fixed assets. All specifications include the full set of fixed effects. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: MUP-ADIAB-PSS.

the level of our outcomes or rather a hampered growth of treated firms, we investigate the raw outcome evolution for both treated and control firms. Figure III.5 shows the average development of treated and control firms across the four outcome variables of interest around the event. We show differences in outcomes with respect to the year prior to the event. As the raw averages are not taking the fixed effects structure into account, slight deviations in trends are to be expected. For example, the industry composition is likely different between the treatment and control group. Nevertheless, the raw trends indicate that before the succession event, both treatment and control firms are on a positive growth path. After the succession, however, growth in the treatment group seems to decline relative to the control group, which is noticeable both in the evolution of the payroll as well as the number of employees, where the treatment group actually starts to reduce employment slightly over the medium term, whereas the control group continues its positive growth after about five years.

We check the validity of our parallel trends assumption and investigate dynamic effects using the event study design of Equation III.3. The results of this approach are shown in Figure III.6. The flat pre-trends in the four years prior to the succession suggest that, conditional on our fixed effects structure, there is no significant difference in the outcome

Table III.4: Short-term and Long-term Effects

	Payroll		Employment		Wages		Invest.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treat x Post(1-5)	-0.069	-0.1*	-0.08*	-0.055	-0.05**	-0.041*	0.105
	(0.062)	(0.056)	(0.042)	(0.047)	(0.025)	(0.022)	(0.221)
Treat x Post(6-8)	-0.189*	-0.215**	-0.197**	-0.153*	-0.08**	-0.073**	0.006
	(0.114)	(0.1)	(0.083)	(0.09)	(0.034)	(0.032)	(0.326)
Ind.-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-years	1,733	1,733	1,733	1,733	1,696	1,696	1,296
Adj. R2	0.822	0.854	0.317	0.673	0.869	0.875	0.747

Notes: Table III.4 shows results for regressions of our dependent variables on separate indicators for the first five years and following three years of treatment. For the payroll sum and employment we present estimations from OLS estimations of the logged outcome in (1) and (3), and Poisson regressions in (2) and (4). For wages we consider the median (5) and mean (6) for a given establishment. The investment regression in (7) considers the log of fixed assets. All specifications include the full set of fixed effects. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: MUP-ADIAB-PSS.

evolution of our treated and control units prior to succession. In particular, we do not find evidence for managing the headcount in anticipation of an ownership transfer in order to either fall below the required 20 employees (leading to the firm not being subject to the requirement at all) or easing the requirement due to a lower initial payroll sum.[23] However, we observe a dynamically building negative treatment effect in the years after the payroll sum requirement becomes active. The pattern is similar for the payroll sum itself as well as the number of employees, with a rather muted response of median wages. We find no evidence for a substantial effect on investment, suggesting that labor is not substituted for capital in our main sample. This suggests that the saved labor costs are either kept as reserves or are paid out instead.

The pre-succession outcome trajectories suggest that, on average, our sample firms are on positive employment trends prior to succession. Since the payroll sum requirement was not necessarily binding, we are unable to assess potential crisis-exacerbating effects. However, we find evidence supporting Hypothesis III.1 suggesting that uncertainty regarding future tax obligations inhibits employment growth. This effect is particularly

[23] Figure III.A1 in Appendix A shows that there is no evidence for firms bunching at the threshold of 20 employees in the data.

pronounced in our preferred specification of surprising ownership transitions.[24] Concerning Hypothesis III.2, i.e. the effect of the payroll sum regulation on investment, we do not identify a significant effect in our main specification. The point estimates suggest a slightly positive effect, which is concentrated during the holding period as indicated by Column (7) of Table III.4. When we zoom in closer to the threshold of 20 employees by considering control firms in the range of 15 to 20 employees (cf. Section 5.2 below and Figure III.A3 in Appendix A), we find that the policy had a temporary positive investment effect. Due to the limited sample size for this particular subset, we cannot conclusively say whether this finding is due to statistical outliers or improved comparability of the control group with respect to investment trends. Therefore, we interpret this result with caution.

Our findings are consistent with prior literature that examines the role of dismissal costs and uncertainty on employment, which generally finds that after an increase in dismissal costs, firms tend to hire fewer new workers due to the anticipated costs of downward adjustment (Autor et al., 2007; Kugler and Pica, 2008; Sestito and Viviano, 2018) and potential increase in business risk by hiring new staff (Bamieh et al., 2025). As a failure to maintain employment levels above the pre-succession average effectively raises the cost of employee separation, we document similar effects in our setting. Unfortunately, the time period covered by our panel does not allow us to investigate long-run effects. Therefore, we cannot conclusively speak to whether treated firms catch up in the long run. We find suggestive evidence that the treatment effect indeed vanishes over time, as the dynamic treatment effect is no longer significantly different from zero by the last relative period, which corresponds to the first year after the holding period of the optional exemption.

In a closely related study, Akcigit et al. (2023) examine the effects of employment maintenance requirements on firm growth, but they find markedly different outcomes. Their analysis focuses on a policy implemented during the privatization of East German

[24]In untabulated tests, we repeated the analysis for the full sample of identified death cases without restricting the age of the deceased owner at death. The effect is considerably weaker in the overall sample.

firms after reunification, which mandated that new owners commit to employment targets, with penalties for non-compliance. Unlike our findings, they document a 22 percentage point higher annual employment growth rate for firms subject to binding requirements, alongside a 3.6 percentage point increase in the likelihood of firm exit.

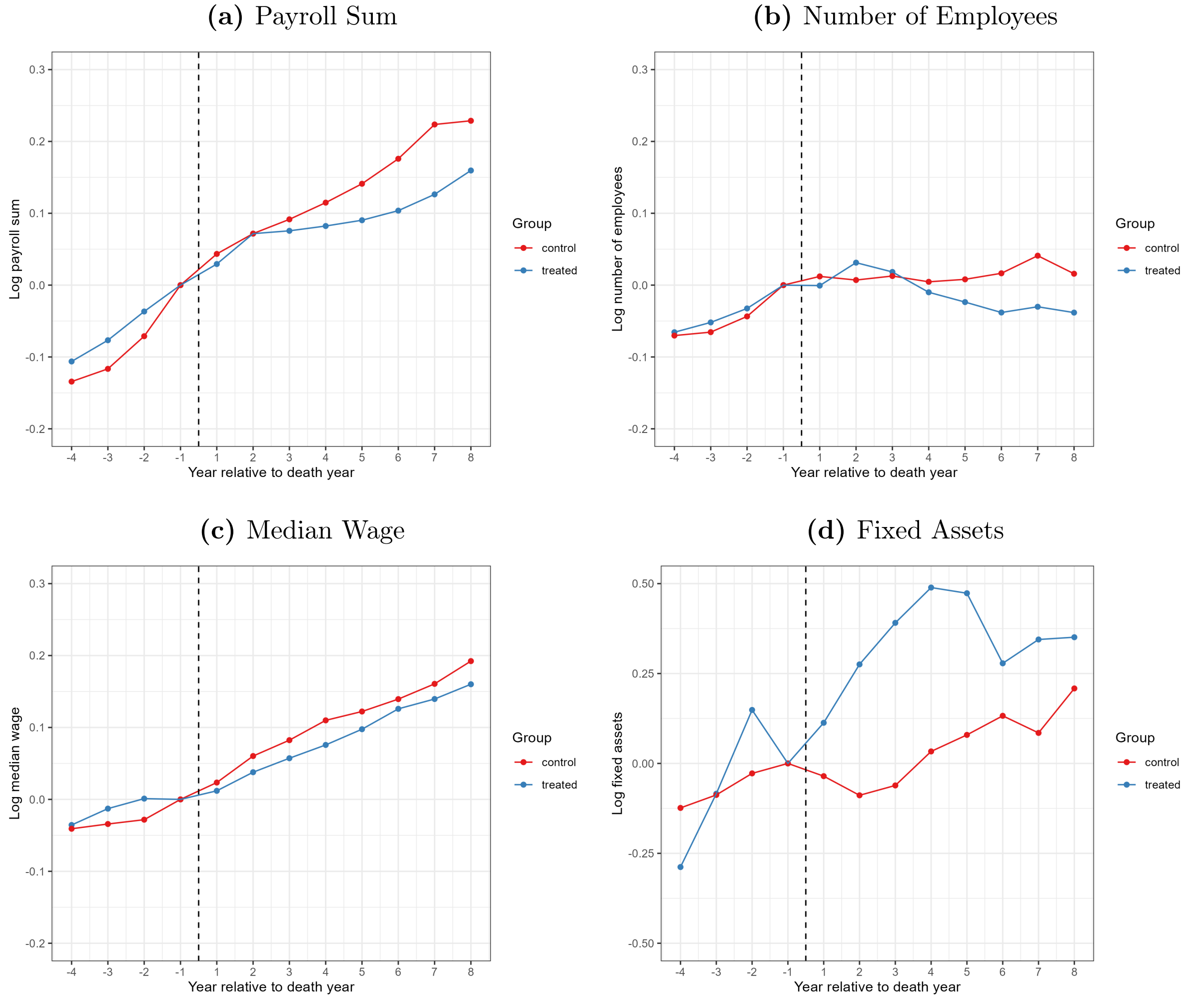
These contrasting results likely stem from differences in policy design and implementation. In our setting, firms and their heirs were assigned to the policy exogenously, whereas in the East German case, individuals self-selected into the policy, and employment targets were negotiated individually at the firm level. Furthermore, in our setting, most firms were not directly constrained by the policy, which may further explain the divergence in outcomes.

5.2 Robustness Tests

The biggest threat to our identification strategy is arguably the size-dependent threshold of the policy. By construction, this threshold leads to imbalances between our treatment and control group, which could induce bias driven by size-specific trends post treatment. Even though there is early empirical evidence that smaller firms create more jobs compared to larger firms, thereby violating Gibrat's law (Birch, 1981; Birch, 1987), more recent studies have shown that these differences vanish once the age of the firm is controlled for (Haltiwanger et al., 2013; Criscuolo et al., 2014; Franke et al., 2016). As the firms in both our treatment and control group tend to be mature companies with an average age of 30 years, differential size trends violating Gibrat's law are unlikely to be present in our setting. However, in spite of this evidence and even though we restrict our treatment and control group to a narrow range of 10 employees above and below the threshold in the year prior to the taxable event, the possibility of this form of bias remains. Thus, we implement two tests that address this concern.

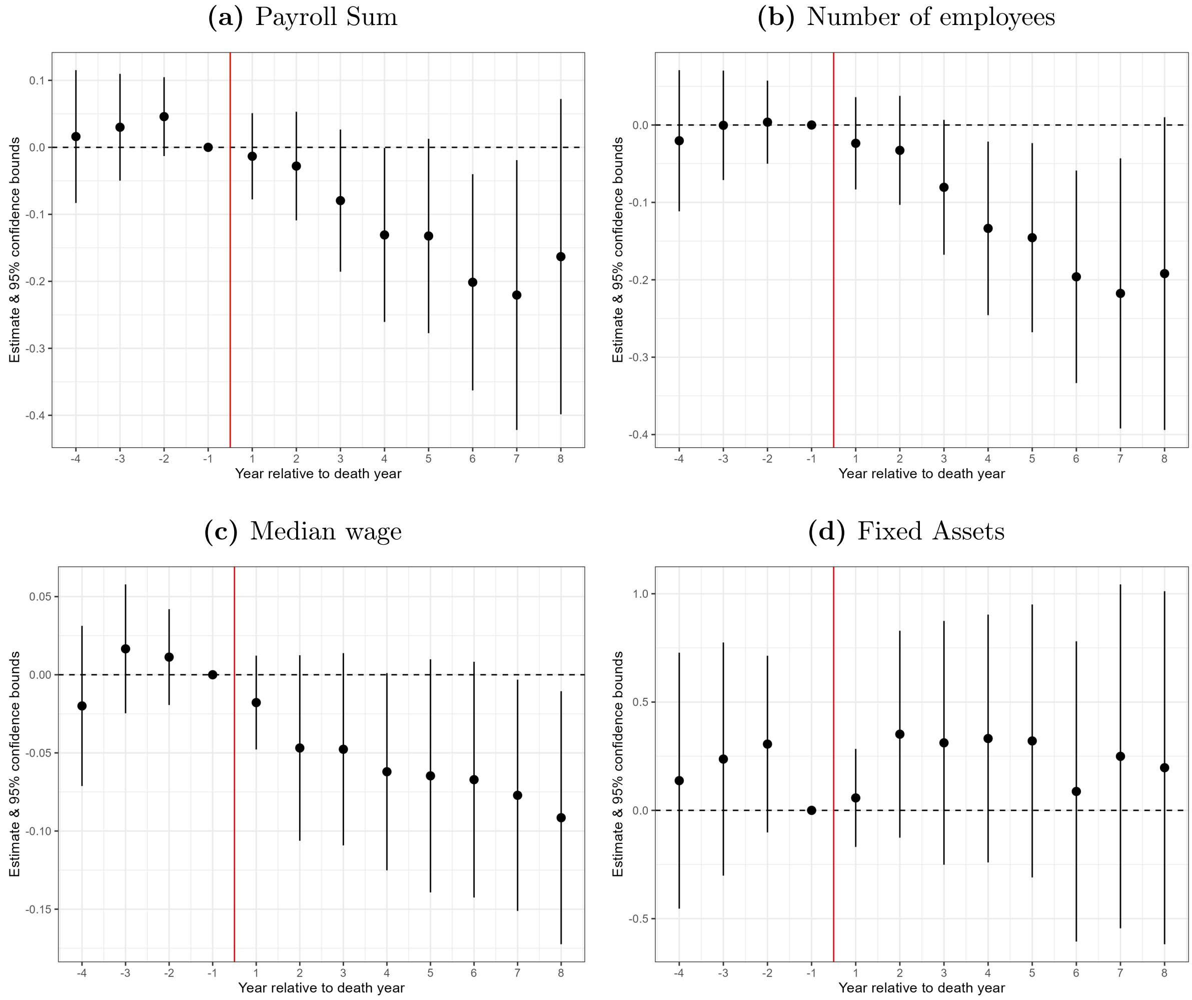
In our first test, we re-estimate the event study specification for a stricter size requirement on our control firms. As the firm size distribution provides for a larger mass of potential control firms, we restrict the comparison group to firms with at least 15 but less than 20 employees in the year before the death of the owner. That way, our

Figure III.5: Raw Trends of Main Outcomes of Interest



Notes: Figure III.5 shows raw averages of our main outcomes of interest for the treated and control group separately. Averages are taken over relative time to treatment across all cohorts with no adjustment for fixed effects.
Source: MUP-ADIAB-PSS.

Figure III.6: Dynamic Effects of the Payroll Sum Requirement



Notes: Figure III.6 shows the results of our event study specification Equation III.3 for our four main outcomes. In each figure, we plot the coefficient estimates on the relative-time treatment dummy as well as the 95% confidence interval around the estimate. Standard errors are clustered on the individual firm level. The coefficients for the payroll sum and the number of employees are based on the PPML specification in Equation III.4, while the estimates for median wage and fixed assets are from the OLS specification in Equation III.3.
Source: MUP-ADIAB-PSS.

control firms are even closer in terms of observable characteristics. Figure III.A3 shows the results for this alternative specification. Our employment findings remain virtually unchanged in terms of magnitude and significance, suggesting that size is not a relevant factor driving our results. Moreover, zooming into a more comparable size range reveals a significant positive effect of the payroll sum requirement on investment during the first years of the holding period. The effect materializes with a delay of about one year and begins to flatten out in the fifth year after the succession. Hence, we find evidence for the substitution of labor for capital using the more comparable control group, supporting Hypothesis III.2.

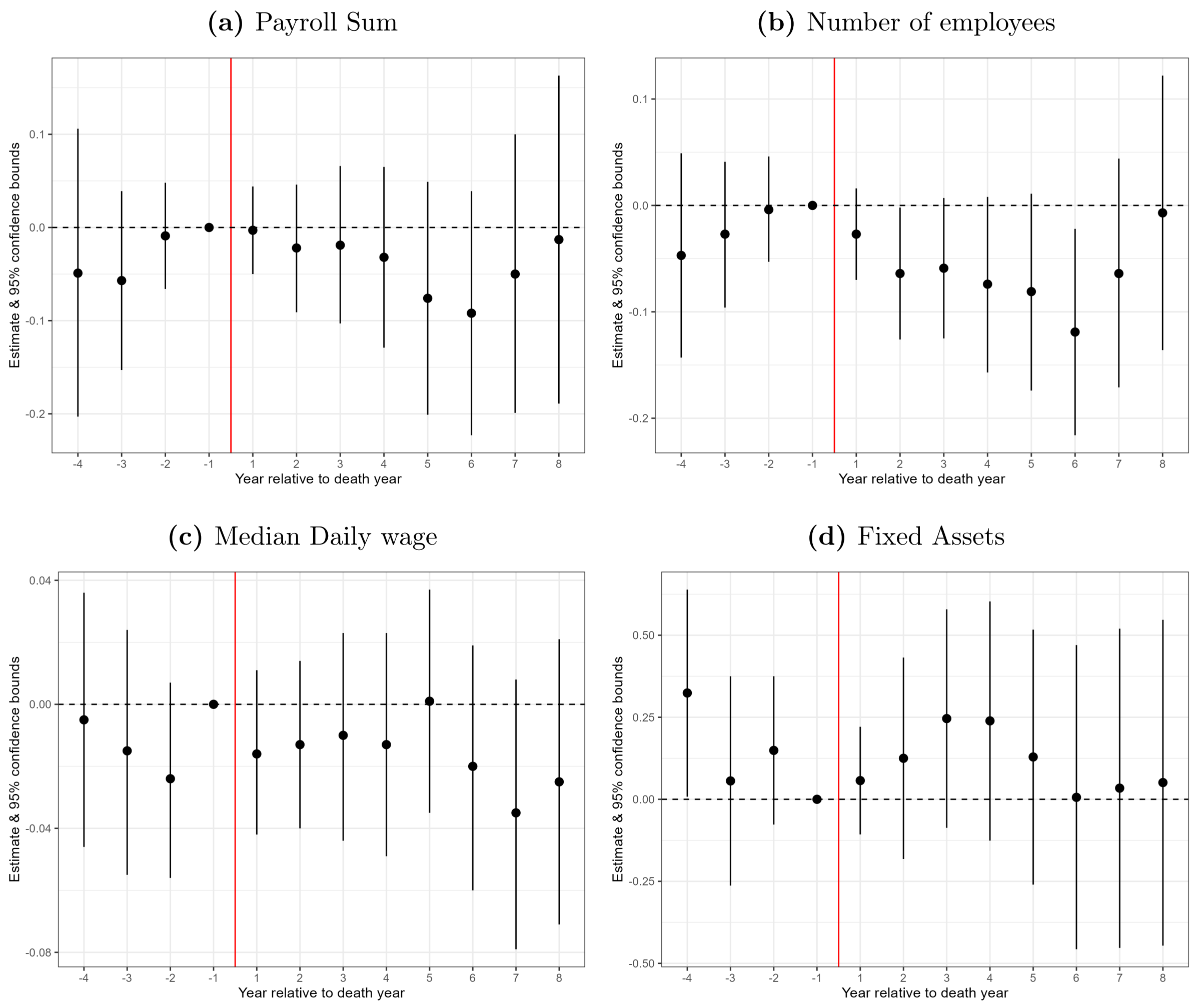
For our second test, we implement a placebo treatment, which assumes that the payroll sum requirement was applicable for firms exceeding a size threshold of 10 employees. If our approach was to capture only size effects, we would expect to find similar differences between treatment and control firms for this placebo treatment. The results of this exercise are shown in Figure III.A4. We find no significant pre- or post-trends for employment outcomes, strengthening our confidence that the documented effects are indeed not driven by differences in size between our treatment and control group. This echoes previous findings of Franke et al. (2016), which also document that firms in different size groups in Germany do not show differential employment growth rates over time.

5.3 Effects on Highly Leveraged Firms

In order to test Hypothesis III.3, we slightly alter our sample to focus on highly-leveraged firms with restricted access to external funding. As the small sample size of our main specification does not allow us to explore further heterogeneity, we ease the requirements of our preferred identification approach by lifting the restriction on the age at death of the outgoing owner. In this way, we retain a larger set of firms in exchange for a potential loss in the exogeneity of the transfer. Table III.A1 shows descriptive statistics for this alternative sample. As for our main sample, apart from size-related differences in employment and capital, the firms in the two samples are similar.

We explore the effects of the payroll requirement on highly leveraged firms by estimating our event study specification of Equation III.3 on the subset of firms with above median current leverage prior to succession. Figure III.7 shows the results of this exercise. We document that the payroll sum requirement has no significant negative impact on the overall payroll sum and only a weak negative effect on the number of employees at the end of the holding period of the regular exemption. Neither median daily wages nor investment seem to be significantly affected by the requirement as well, consistent with Hypothesis III.3.

Figure III.7: Heterogeneous Effects of the Payroll Sum Requirement for Firms in Financial Distress



Notes: Figure III.7 shows the results of our event study specification for firms with an above-median current leverage. In each figure, we plot the coefficient estimates on the relative-time treatment dummy as well as the 95% confidence interval around the estimate. Standard errors are clustered on the individual firm level. The coefficients for the payroll sum and the number of employees are based on the PPML specification in Equation III.4, while the estimates for median wage and fixed assets are from the OLS specification in Equation III.3.
Source: MUP-ADIAB-PSS.

6 Conclusion

In this paper, we exploit the setting of the German inheritance tax tying tax exemptions to payroll requirements to analyze the effects of such requirements on firm outcomes. We combine ownership information, publicly available information on death cases, and administrative employment data to estimate the causal impact of these requirements on employment, wages, and investment. By comparing firms that undergo an inheritance while being subject to a payroll target with unrestricted firms experiencing the same event, we are able to isolate the effect of the payroll sum requirement.

We document that the growth of employment and daily wages in treated firms is up to 20% smaller than in their untreated counterparts. This finding is contingent on surprise ownership successions, where heirs are arguably less prepared to assume the responsibilities of running a business. Zooming in close to the treatment threshold, we further find some evidence for a substitution from labor to capital in the form of a (short-term) increase in investment.

Our results highlight the unintended consequences of tying tax relief to rigid input factor conditions. This suggests that such policies, while aimed at preserving employment, may affect firm adaptability and growth. These findings raise important questions about the trade-off between safeguarding jobs in the short term and promoting efficient resource allocation in the long term. One possibility to reduce the distortions we document in the context of inheritance taxation could be to broaden the tax base by terminating preferential treatment of specific asset classes with a simultaneous reduction of the high statutory tax rates, possibly with extended options for tax deferral based on the companies' economic condition. This would eliminate the need to impose conditions on these exemptions to align differential treatment with constitutional and fairness considerations.

An important caveat of our analysis is that we provide evidence for a selected subset of all firms liable for these provisions. As a substantial share of firms are passed on already during the lifetime of its owner through inter vivos gifts, careful tax planning and preparation of incoming heirs for their new responsibilities can circumvent much of the potentially harmful effects of the policy.

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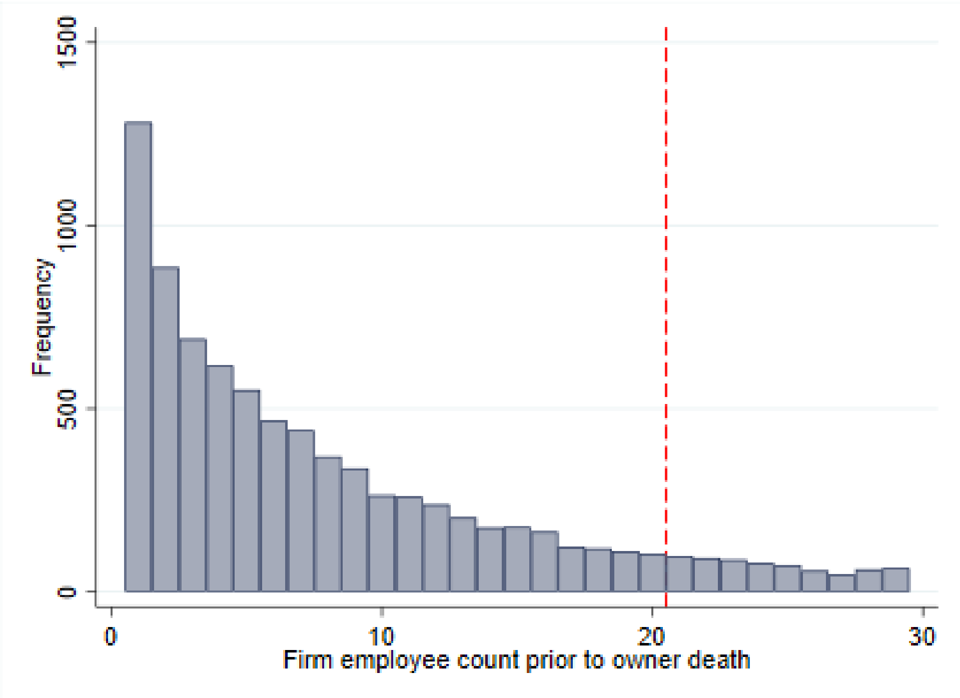
Wooldridge, J. M. (2023). "Simple Approaches to Nonlinear Difference-in-Differences with Panel Data." *The Econometrics Journal* 26.3, pp. 31–66.

A Descriptive Statistics and Results

Figure III.A1: Visual Verification of Threshold Manipulation



Notes: Figure III.A1 shows the distribution of firm counts in the year prior to death before restricting on non-exiting single-owner-firms with a shared name between successor and predecessor. The red dotted line marks the employee threshold above which the payroll sum regulation became binding.
Source: MUP-ADIAB-PSS.

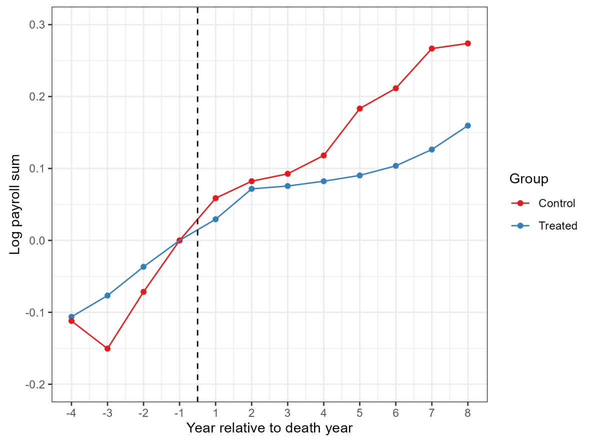
Table III.A1: Difference-in-Means Test for Full Sample

	Control Group		Treated Group		Mean Difference	
	Mean	Count	Mean	Count	Difference	t-Statistic
Age at death	75.48	447	76.36	148	-0.879	-0.80
Firm age	33.83	444	31.36	149	2.466	1.21
Total assets	1101.90	370	1649.72	120	-547.821***	-3.37
Leverage	0.36	327	0.43	109	-0.045	-1.65
Investment	0.07	364	0.07	116	-0.002	-0.06
Cash Share	0.18	367	0.17	120	0.005	0.24
Employees	14.07	459	24.70	152	-10.639***	-39.16
Payroll sum	856.26	459	1557.49	152	-701.229***	-13.13
Median wage	80.58	455	78.97	151	1.613	0.76
Mean wage	83.05	455	82.32	151	0.724	0.33

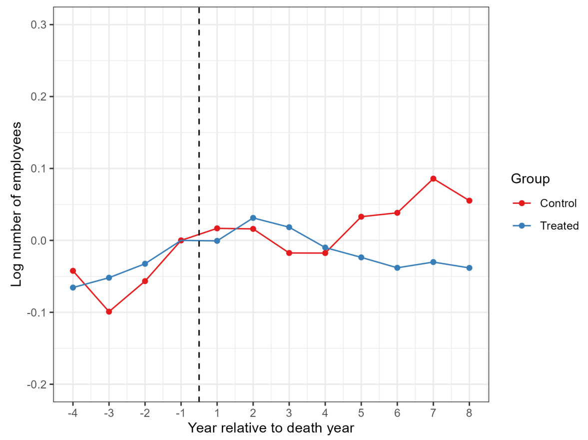
Notes: Table III.A1 shows descriptive statistics of our final dataset of firms irrespective of owner age at death. The depicted averages and observation counts are split up by employee-size class (10-20 employees for the control group and 21-30 for the treatment group) and measured in the year before the succession. The two rightmost columns show differences in means between the two groups for the respective variables as well as t-statistics for the differences. Imbalances for the number of employees and payroll are by construction, as the assignment to the treatment and control group depends on these variables. Leverage is defined as current liabilities over total assets. Investment is equal to the percentage increase in the share of fixed assets over total assets per period. Median wage refers to the median daily wage earned at firms.
Source: MUP-ADIAB-PSS.

Figure III.A2: Raw Trends of Main Outcomes of Interest for Full Sample

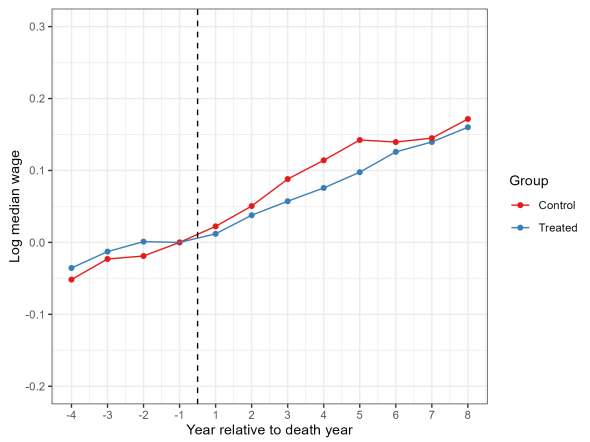
(a) Log Payroll Sum



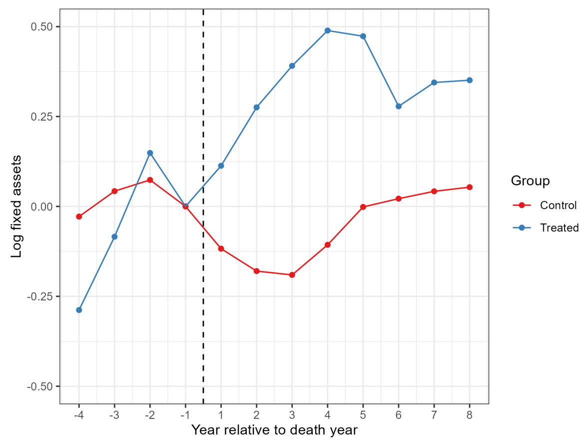
(b) Log Number of Employees



(c) Log Median Daily Wage



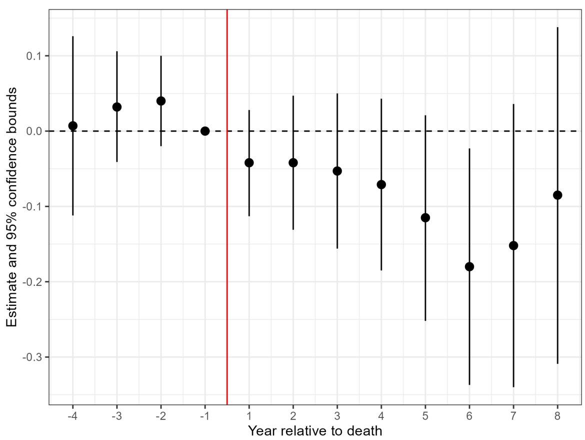
(d) Log Fixed Assets



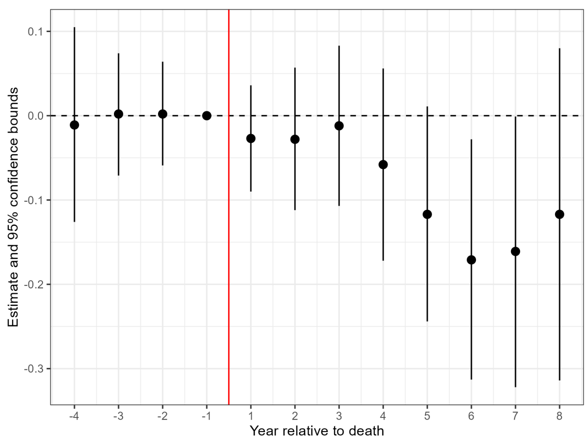
Notes: Figure III.A2 shows raw averages of our main outcomes of interest for the treated and control group separately. The natural logarithm of the outcomes is normalized to the year prior to owner death. The control group consists of firms with a total number of employees between 15 and 20 in the year before the inheritance. Averages are taken over relative time to treatment across all cohorts with no adjustment for fixed effects.
Source: MUP-ADIAB-PSS.

Figure III.A3: Robustness Test: Dynamic Effects of the Payroll Sum Requirement for Larger Control Firms

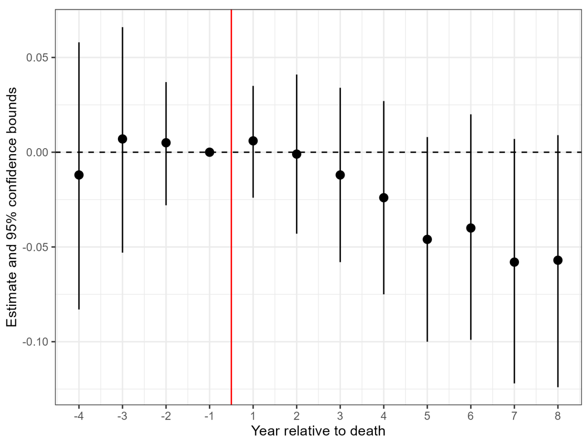
(a) Payroll Sum



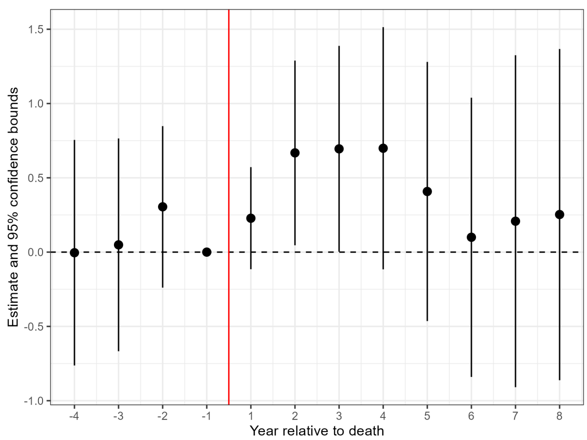
(b) Number of Employees



(c) Median Daily Wage



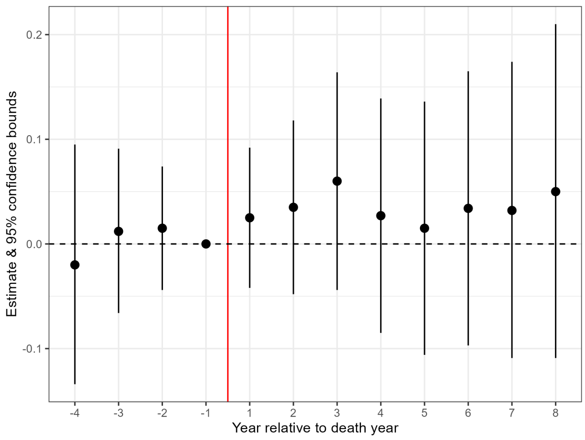
(d) Fixed Assets



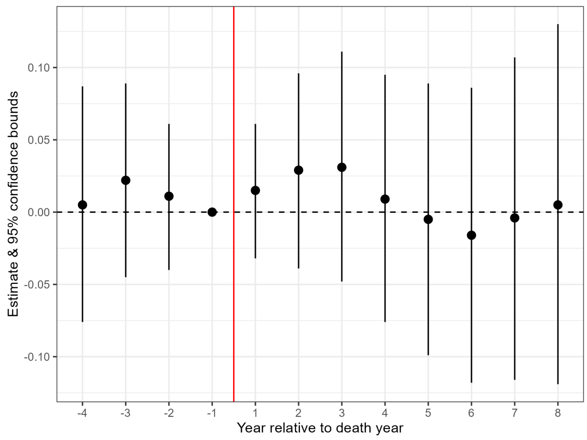
Notes: Figure III.A3 shows the results of our event study specification Equation III.3 for our four main outcomes, where we restricted the control group to consist of establishments with at least 15 employees in the year before the inheritance. In each figure, we plot the coefficient estimates on the relative-time treatment dummy as well as the 95% confidence interval around the estimate. Standard errors are clustered on the individual firm level.
Source: MUP-ADIAB-PSS.

Figure III.A4: Robustness Test: Placebo Treatment at 10 Employees in the Year of Death.

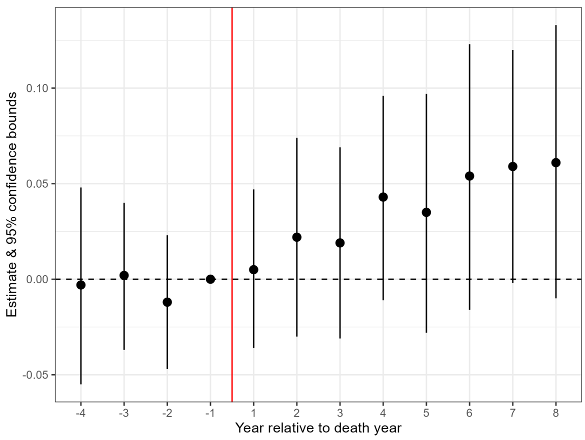
(a) Payroll Sum



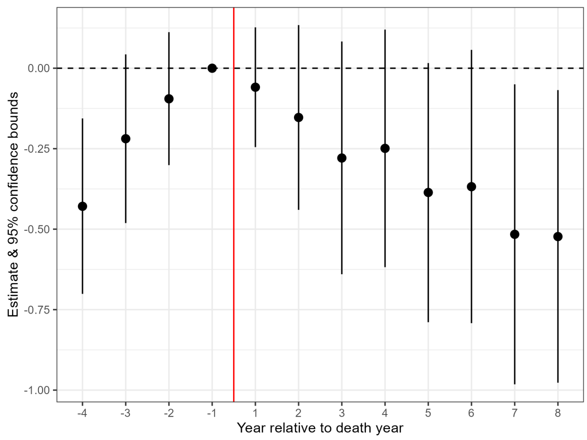
(b) Number of Employees



(c) Median Daily Wage



(d) Fixed Assets



Notes: Figure III.A4 shows the results of our event study specification Equation III.3 for our four main outcomes, where we falsely assume that the payroll sum requirement was to be applicable for firms with more than 10 employees. Our placebo treatment group hence comprises of firms with more than 10 and less than 20 employees in the year before the inheritance, and our control group is formed by firms with less than 10 employees in the year before the succession. In each figure, we plot the coefficient estimates on the relative-time treatment dummy as well as the 95% confidence interval around the estimate. Standard errors are clustered on the individual firm level.
Source: MUP-ADIAB-PSS.

B Further Information on Institutional Background

Table III.B1: Current Inheritance and Gift Taxation Overview

(a) Tax Rate Schedule

Taxable bequests (in EUR 1,000)	Tax Class I	Tax Class II	Tax Class III
75	7	15	30
300	11	20	30
600	15	25	30
6,000	19	30	30
13,000	23	35	50
26,000	27	40	50
$\geq$ 26,000	30	43	50

(b) Tax Allowances

Relational Degree	Tax Class	Value (in EUR 1,000)
Spouses	I	500
Children	I	400
Grandchildren	I	200
Parents & Grandparents	I	100
Siblings, Divorcées	II	20
Unrelated	III	20

Notes: Table III.B1a depicts the tax rate structure for gifts and inheritances applicable since 2011. Table III.B1b provides the tax allowances that are deductible from wealth transfer values within a ten-year period since the last transaction.

Table III.B2: Overview of International Preferential Tax Treatment of Business Assets

Country	**Preferential Treatment**	**Minimum Ownership Duration**	**Requirements regarding capital and labor**
Belgium	Reduced tax rates	3 years (heir)	Local management; maintain capital; rate depends on beneficiary type
Finland	Preferential valuation (40% of tax value); 10-year interest-free deferral	5 years (heir)	Management; minimum ownership 10%
France	75% exemption	4 years (heir)	Management; signed commitment to conserve shares
Germany	85% or 100% exemption; abatement assets over EUR 26 million	5 to 7 years (heir)	Local management; maintain wage bill; minimum ownership 25%
Ireland	90% exemption	2 years (donor) or 6 years (heir)	Minimum ownership 25%; management or employment required
Italy	100% exemption	5 years (heir)	Specified heirs; local management; maintain employees
Japan	Payment deferral	5 years (heir)	Local management; maintain employees and wage bill; SMEs only
South Korea	100% exemption, capped; taxable value capped at KRW 20 to 50 billion	5 to 7 years (heir); 10 years (donor)	Maintain 80% ownership; maintain employees and wage bill; SMEs only
Spain	95% exemption	10 years (heir)	Carry out economic activity; exempt from wealth tax; minimum ownership share 5% (individual) or 20% (family)
Switzerland	Preferential valuation; 80% reduction of tax liability	10 years (heir)	Local management; minimum ownership 51%
UK	50% or 100% exemption; payment in interest-free installments over 10 years	2 years (donor)	Exemption for privately held / unlisted companies (100%); management required
United States	Preferential valuation, capped at USD 1.18 million	5 years (donor); 10 years (heir)	Business is minimum share of donor's estate; specified heirs

Source: OECD (2021)

Table III.B3: Size-dependent Firm Regulation of Labor

Employee count	Event
5	Works council with one member in simplified vote
9	Establishment of executive committee of the work council
10	Application of Employment Dismissal Act
16	Legal requirement to offer part-time work
21	Work council of three members needs to approve staff hires/transfers.
50	Work council of five members

Source: German Chamber of Industry & Commerce (IHK)

C Data Collection

C1 Orbis

We source financial and ownership information on German firms from Bureau van Dijk's Orbis data base. Orbis offers company financial statement data as well as descriptive information, such as legal form, status of operations, and date of incorporation. Furthermore, the Orbis database includes time varying information on company ownership since 2007, including direct and total control as well as information on the global ultimate owner (GUO) of an entity. The ownership data contains the name of a specific shareholder of a company as a text string. Unfortunately, these strings are not in a consistent format. Hence, in order to identify the last name and first name of a shareholder, we rely on a dictionary approach.[25]

From the financial data we collect information on balance sheet items such as total assets and leverage, defined as current and non-current liabilities and long-term debt over total assets. Unfortunately, coverage of financial information is rather poor for our companies of interest, especially in regards to the number of employees and cost of employment (payroll sum), which is why we rely on administrative linked employee-establishment data for these variables instead.

C2 Death Notice Data

The CompGen family announcements project records family announcements, such as death, birth and marriage notices from regional and supra-regional newspapers. For a recorded death, the available information may include the last name, first name, birth name, occupation, date of birth and death, place of birth and death, place and date of

[25]Specifically, we use the comprehensive first name database provided by Matthias Winkelmann available at `https://github.com/MatthiasWinkelmann/firstname-database`. After identifying all unique name parts of every name string of natural person owners of German firms in Orbis and removing all titles and abbreviations, we identify first names using the dictionary. The remaining name parts constitute last names, which we collect in a second dictionary. Based on the first name and last name dictionaries we are able to identify the last name and first first name for every name string regardless of the format.

burial and service, place of last residence as well as information on the newspaper or newspapers where the obituary was published. In total, the database provides death information for 2,178,776 individuals, with recorded death reaching back until before the two world wars.

C3 Scraped Newspapers

We selected the set of newspapers by visiting each website and assessing how extensive the provided obituary archive is and hence how many obituaries could be recovered. Most newspapers provide the last name, first name, date of birth and date of death directly in the HTML code of their website and in the majority of cases a picture of the published obituary as well. Using the pictures of the obituaries, we are able to recover the obituary text using optical character recognition trained on German texts. Naturally, the coverage of the online archives is better for more recent periods. However, many newspapers have extensive archives that reach back into our period of interest.

C4 Tombstone Data

The CompGen tombstone project has been initialized in 2007 by a small group of genealogists. In Germany, gravesides have a usual lay time of about 25 years, after which tombstones are either given to interested relatives or destroyed and used for road construction. In order to preserve the information on the deceased, voluntary contributors take pictures of all tombstones on a given graveyard and digitalize the inscriptions in a database. The included information generally comprises the full name as well as the date of birth and death. The death years of deceased individuals range from 1408 until 2021. Overall, this reflects 5,728,734 inscriptions of deceased individuals. Furthermore, the postal code of the graveyard as well as its name is provided. In total, the project includes data from 7,927 distinct graveyards covering 2,278 zip codes.

Chapter IV

The Impact of Environmental Taxes on Commercial Traffic and Its Environmental Consequences

Status: Working Paper

Co-Author: Alina Pfrang

Abstract: This paper examines how commercial trucks respond to differences in environmental taxes on diesel fuel across European borders. By analyzing truck flows at German borders using administrative toll data we study the impact of environmental taxes on truck traffic. Next, we investigate if trucks choose longer routes to avoid high environmental taxes by studying individual journeys across Europe. We find that commercial transport responds to changes in environmental taxes. An increase in a country's tax rate reduces truck traffic through that country. However, these tax changes also cause more trucks to take detours leading to unintended environmental consequences. Using air pollution data, we observe that pollution at the border increases as a result of tax-induced increases in cross-border truck flows. In addition, we estimate an additional 1 million tons of carbon emissions due to the detours taken.

1 Introduction

The need to address the global climate crisis has sparked considerable interest in exploring effective policy instruments that can mitigate its consequences (IPCC, 2021). As the transportation sector accounts for a significant portion of greenhouse gas emissions worldwide (European Environment Agency, 2022), finding strategies to reduce emissions from commercial trucks has become a critical objective for policymakers and researchers alike (see e.g., European Commission, 2023b; OECD, 2021; World Bank, 2014). Environmental taxes on diesel fuel have emerged as a potential instrument to incentivize more sustainable transportation practices and discourage high-emission activities (International Energy Agency, 2022).[1] However, understanding how commercial traffic responds to environmental taxes, particularly when they vary across national borders, is a complex and so far understudied area. In this study, we aim to fill this gap.

The transportation sector is a significant contributor to global greenhouse gas emissions, accounting for 20% of the total emissions. Within this sector, road transport is responsible for the majority of this burden, accounting for three-quarters of emissions, which equals to 15% of the overall global emissions (International Energy Agency, 2022). Trucks, in particular, heavily rely on diesel fuel, notable for its substantially higher carbon dioxide (CO_2) emissions compared to the majority of passenger cars fueled by gasoline. Fuel costs, constituting roughly 20% of a truck's total operating expenses, play a crucial role in companies' strategic route planning. Taxes, which account for nearly half of the gross fuel price, wield a decisive influence over where transport companies choose to refuel. This influence becomes particularly pronounced when tax rates vary across countries, as observed in the EU (Transport and Environment, 2021), or across states, such as in the U.S., incentivizing commercial trucks to strategically plan their refueling locations. Environmental taxes on fuel are designed to curb its demand, thereby aiming to reduce emissions and encourage a transition to cleaner alternatives. However, the existence of tax differentials across borders can lead to unintended consequences, such as

[1] An alternative instrument is the implementation of a cap-and-trade system. So far, no cap-and-trade system has been implemented in the road transport sector.

trucks taking detours to access cheaper fuel in neighboring countries.

In this paper, we investigate how commercial trucks respond to differences in environmental taxes on diesel fuel across European borders. Our analysis proceeds in three steps to comprehensively assess the behavioral responses of truck operators to changes in tax rates and the resulting environmental consequences of such tax-induced responses. First, we use administrative toll data to examine whether cross-border truck traffic responds to changes in environmental taxes across countries. Next, we examine whether differences in tax rates between countries induce trucks to take detours to avoid high environmental taxes on fuel. Finally, we examine the environmental consequences of these actions by incorporating air pollution data and emissions.

We start our analysis by examining cross-border truck flows at the German borders. We obtain comprehensive administrative data containing monthly truck counts from mid-2018 to the end of 2022 on detailed road segments in Germany, which allows us to measure the responsiveness of cross-border truck flows between Germany and its neighboring countries to differences in environmental taxes on fuel. To overcome the challenge of isolating the impact of environmental taxes on the gross price of diesel, we use an instrumental variable (IV) approach. We leverage the environmental tax differential between Germany's neighboring countries and Germany as an instrument to predict tax-induced changes in the gross price differential of diesel. These predicted price changes resulting from changes in environmental taxes on diesel allow us to estimate the tax-induced effects on cross-border transport.

We find that commercial traffic responds to changes in environmental taxes. An increase in the tax rate of a neighboring country leads to a decrease in truck traffic through that country. Specifically, we observe that a tax-induced increase in the average gross price of diesel fuel by one euro cent per liter of fuel results in 466 fewer trucks per road segment at the border per month, suggesting a shift in truck traffic patterns away from more expensive cross-border routes. This finding implies that trucking companies prioritize fuel cost-optimized routes and underscores the influence of environmental taxes on their decision-making processes. Moreover, we show that this effect is more pronounced on highways that are heavily used by commercial traffic. The effect is consistently observed within the first six road-sections close to the border, but gradually diminishes as one moves away from the border region and more inland traffic intersects, underscoring the robustness of our results.

Subsequently, we focus on individual truck routes across Europe. We leverage an administrative survey dataset spanning from 2011 to 2020 to investigate whether trucks strategically choose detours to to avoid countries with high environmental taxes while taking advantage of low environmental taxes in other countries. The European Road Freight Transport (ERFT) database allows us to track individual truck journeys from their starting point to their end point, while recording the countries crossed in between. To determine whether trucks intentionally detour to avoid high fuel taxes, we compare the actual route observed in our data with the fastest and shortest route obtained from Google Maps (GMAP) via web scraping. Our survey dataset then includes the actual distance traveled per trip, the optimal distance, and the deviation between the two.

Leveraging environmental taxes on diesel fuel, averaged for each journey, we incorporate a linear probability model into our IV approach to examine whether an increase in the average environmental tax rate on diesel fuel for a journey affects the probability that a truck deviates from the fastest and shortest route available. Our results indicate that an increase in the average environmental tax on diesel significantly increases the probability that a truck deviates from the optimal route for the trip, suggesting that commercial trucking companies are indeed driving detours to save on fuel costs. Furthermore, we find that this behavior leads to an increase in total mileage, which includes both excess kilometers and excess ton-kilometers, taking into account the size and environmental impact of the truck involved in the trip.

To further validate these findings, we take a closer look at the countries where detours are most common. Descriptively, we find that Luxembourg, along with Romania and Slovakia, are the main destinations for truck detours. Notably, these countries consistently have the lowest environmental tax rates on diesel on average in our dataset. To provide empirical support for this observation, we focus on a subset of cross-border trips that involve detours. We regress the number of divergent truck journeys per country and quarter on the average environmental tax rate for that country and quarter. We include country and year-quarter fixed effects to account for the size of a country and general time trends. Our results show a negative relationship, meaning that the lower the environmental tax rate on diesel, the more trucks pass through a country. This supports the notion that environmental taxes on diesel have a significant impact on commercial trucking by influencing route planning decisions to minimize diesel costs.

Finally, we assess the environmental consequences of tax-induced responses in the context of cross-border truck traffic. Expanding on our initial study of truck flows at German borders, we incorporate sensor stations that measure local air pollution to investigate whether increased cross-border truck flows resulting from environmental tax differentials contribute to local increases in air pollution. The sensor data we collect provide information on short-lived climate pollutants (SLCPs), with a particular focus on particulate matter (PM) emissions. PM is an important pollutant emitted during the combustion of fossil fuels that has adverse effects on both the environment and human health. Using an event study approach, we find that tax-induced increases in cross-border truck flows lead to local emission peaks at these border road-sections.

In addition, we use the results of our second analysis to quantify the environmental externalities resulting from the deviation of trucks to minimize fuel taxes. To do so, we establish a correlation between the excess ton-kilometers driven by trucks and the resulting emissions. Building on our earlier results, we employ a linear prediction model to estimate the cumulative excess ton-kilometers resulting from tax-induced deviations. We then calculate the associated CO_2 emissions by multiplying the total surplus by its emission factor. We find an increase in emissions of up to 1 million tons of CO_2 due to trucks taking detours to avoid high environmental taxes on diesel fuel.

Our study provides evidence on the effects of environmental taxes on commercial transport and the resulting environmental impacts. Such evidence is scarce but policy-relevant as policymakers seek to promote sustainable practices in the transport sector.[2]

[2]Alternative fuel options for the road transport sector will not be available in the foreseeable future, primarily because freight transportation typically involves heavy loads, making electricity, for example,

We uncover unintended consequences arising from unharmonized tax rates within the EU, particularly in a sector that is crucial to the EU's climate change (European Commission, 2020). While our initial findings suggest that higher environmental taxes on diesel fuel lead to a reduction in commercial transport, in line with the objective of environmental taxes to reduce emissions from transport, we find in a subsequent analysis that trucks resort to deviations to avoid these higher taxes. As a result, they refuel in countries with lower tax rates, leading to increased mileage, fuel burned and thus higher overall emissions.

We contribute to the literature studying behavioral responses to environmental taxes in the transportation sector. The existing literature is relatively limited, with a notable absence of studies focusing on commercial transportation. Most research on environmental taxes in the transport sector has focused on non-commercial drivers, examining aspects such as fuel consumption and consumer responses to tax and price changes (Rietveld et al., 2001; Banfi et al., 2005; Davis and Kilian, 2011; Rivers and Schaufele, 2015; Jansen and Jonker, 2018; Bonnet et al., 2024). Notably, studies like Marion and Muehlegger (2011) and Li et al. (2014) utilizing fuel consumption data, find that consumers tend to react more strongly to tax changes than to price changes. Gimenez-Nadal and Molina (2019) use variation in gasoline tax rates across US (United States) states and finds that higher taxes lead to a greater number of people choosing public transportation instead of private cars for their commutes. Andersson (2019) examines the effect of a carbon tax on emissions in the Swedish transport sector and finds a reduction in pollution. Our study fills a critical gap in research by addressing how commercial truck traffic reacts to cross-border changes in environmental taxes across borders.[3] We examine the mechanism that primarily affects fuel demand, namely driving behavior, using comprehensive data on traffic across Europe. This approach further distinguishes our study from previous literature that finds a net reduction in emissions in response to environmental

impractical. Additionally, shifting transportation to railways is not feasible due to the lack of sufficient freight rail infrastructure in most European countries.

[3]A related study by Luechinger and Roth (2016) differs from our study in that it examines how trucking in Switzerland responds to the introduction of a mileage tax that differs from environmental taxes on diesel fuel.

taxes on fuel (e.g., Andersson, 2019; Runst and Höhle, 2022), thereby overlooking shifts in driving behavior and emissions when only examining demand and emissions at the implementation location of the tax.[4]

Prior literature examining firms' responses to environmental taxes in different settings finds that firms generally reduce their own emissions in response to taxes and cap-and-trade systems (Martin et al., 2014; Dussaux, 2020; Erbertseder et al., 2023; Martinsson et al., 2024). However, consistent with our study, firms reallocate resources to avoid paying or bearing environmental taxes and regulations without necessarily reducing emissions (Itzhak et al., 2021; Dechezleprêtre et al., 2022; Ecker and Keeve, 2023; Kaenzig et al., 2023; Colmer et al., 2024). We add to this literature by documenting evidence of this relationship for commercial trucking companies. Using extensive but unexplored traffic data combined with emissions data, we quantify the impact on truck traffic and the excess kilometers driven by trucking companies to avoid high environmental taxes on fuel. We further estimate the incremental emissions caused by this shift in driving behavior.

Furthermore, our study adds to the broader literature on the effects of taxes on mobility, drawing insights from works by Kleven et al. (2013), Schmidheiny and Slotwinski (2018), and Akcigit et al. (2016). This body of research has demonstrated that tax differentials and the mobility of the tax base can trigger various behavioral responses by individuals, including tax avoidance strategies. Our study builds upon this literature by showing that commercial truck drivers adjust their routes in response to cross-border tax differences, particularly within the context of environmental taxes.

2 Setting

2.1 Road Freight Transport in the EU

Road freight transportation plays a significant role within the transport sector, accounting for a substantial share of 76.3% of total freight transportation in the EU as of 2019 (Euro-

[4]Santos (2017) examines fuel taxes in Europe and calculates corrective fuel taxes aimed at internalizing externalities from road transport.

pean Commission, 2021). Emissions stemming from road transport make a considerable contribution, comprising approximately 15% of global CO_2 emissions (International Energy Agency, 2022; European Environment Agency, 2022). Trucks, in particular, heavily rely on diesel fuel, which is associated with higher levels of emittants compared to other fuels. Diesel engines emit a complex mixture of air pollutants, including CO_2, diesel particulate matter and nitrogen oxide (NO_x), which contribute to both adverse health effects and climate change (OECD, 2019).

A single truck tank filling can hold between 1,000 to 1,500 liters of diesel, allowing trucks to cover distances of up to 1,600 km.[5] On average, a truck filling in Europe costs between EUR 1,400 and EUR 2,100. Thus, fuel costs represent a substantial portion, approximately 20%, of a truck's overall operating expenses, making it a critical factor in optimizing cost-efficient truck route planning (Trego and Murray, 2010; Hooper and Murray, 2018). Importantly, environmental taxes on fuel make a significant contribution to the total fuel price, accounting for up to half of it (see Appendix Figure IV.A1.1 and Figure IV.A1.2). As these taxes are a function of the gross fuel price, they exert a substantial influence on the refueling decisions made by transportation companies (Izadi et al., 2020).

Refueling given its substantial cost is typically not left to the discretion of individual truck drivers in commercial trucking businesses. Instead, it is planned and managed by the company itself. Truck transport companies aim to strategically minimize fuel expenses by employing commercial transportation management systems. These systems plan truck journeys on the go, considering factors like saving fuel costs along with truck driver working hours, the average speed of the truck as well as road congestions. Anecdotal evidence further supports this notion, with several business models advertising diesel price tools designed to plan fuel-optimal routes across Europe and highlight the lowest diesel prices available (see, e.g. DKV Mobility[6] and Transport Topics).

Conversely, while road tolls are present in most EU countries, they are not among

[5] A distance of approximately 1,600 km can cover journeys such as traveling from Warsaw to Paris, from Amsterdam to Barcelona or from Hamburg to Rome.
[6] Appendix Figure IV.A1.3.

the cost factors that transport companies can easily avoid.[7] These tolls apply to both highways and federal roads, making it difficult for trucking companies to consistently navigate around them. To operate profitably, transport companies must select routes on well-developed roads. Choosing alternative routes on less-developed roads typically incurs a time surcharge that is more expensive than the toll costs. Additionally, toll charges remained stable throughout the EU during our sample period.

2.2 Environmental Taxes on Fuel

Environmental taxes on fuel are at the core of taxation within the transportation sector (OECD, 2019). These taxes typically serve a dual purpose. Firstly, they are primarily designed to address the environmental externalities associated with fuel consumption. Secondly, they generate revenue for the government. Taxes on fuel typically encompass both value-added tax (VAT) and excise taxes reflecting the environmental impact associated with fuel usage. At the pump excise taxes are added to the net fuel price, with the resulting sum being multiplied by the applicable VAT rate.[8] It is important to note here that VAT is not relevant in the context of freight transport, as companies can reclaim the VAT paid. As a result, we focus on excise taxes on fuel. In practice, different tax rates apply to the most commonly used fuels, diesel and gasoline. While diesel is predominantly used by trucks, gasoline is more common with private cars.

The landscape of environmental taxes on fuel (both diesel and gasoline) differs across nations. For instance, certain countries label their excise tax on fuel as mineral oil tax (e.g. Switzerland or Ireland), others include them in their energy tax (e.g. Germany). Either are applied per liter of fuel. Additionally, some countries impose a carbon tax based on the amount of CO_2 emissions produced during fuel combustion.[9] We combine all these taxes as environmental taxes on fuel (European Commission, 2023a). The

[7] Two different toll systems exist in the EU. Tolls are levied according to the distance travelled and the type of vehicle, while vignettes are scaled according to the duration of the use of the infrastructure.

[8] Gross price fuel = (Net price fuel + Environmental tax fuel) x (1 + VAT).

[9] An illustration involves the introduction of a carbon tax on fuels in Luxembourg and Germany in 2021, followed by Austria in September 2022. Notably, Switzerland excludes fuel usage from its carbon tax, while Slovenia places the liability for the carbon tax on fuel producers rather than fuel consumers. Meanwhile, France and Finland embed an explicit carbon component within their fuel excise tax.

revenue generated from these environmental fuel taxes typically flows into the state's general budget, contributing to the financial resources of the government.[10] In 2021, tax revenue from environmental taxes on fuel within the EU amounted to EUR 60 billion, representing 18% of overall tax revenue from environmental taxes (European Commission, 2023b).[11]

As we narrow our focus to commercial traffic, our attention centers on environmental taxes concerning diesel fuel. Notably, environmental tax rates on diesel vary significantly between EU member states, with certain countries imposing lower taxes compared to others. These differences present opportunities for commercial truck companies to strategically plan their journeys, opting to refuel in countries with lower diesel tax rates, thereby minimizing their operational costs. In some EU countries, including Belgium, France, Hungary, Ireland, Italy, Romania, Slovenia, and Spain, commercial trucking businesses can partially recover the diesel taxes they pay through state-issued tax rebates.[12]

We use these variations in environmental taxes and the availability of tax rebates to investigate the responsiveness of commercial trucks to differences in these tax regimes. Our analysis begins by examining cross-border traffic in Germany. Germany serves as an ideal setting due to its prominent role in intra-European land transport. Its geographical location at the heart of Europe coupled with a well-developed transportation infrastructure including highways and federal roads results in a constant flow of goods between Germany and its neighbors. Moreover, Germany's environmental tax on diesel remained stable throughout our sample period, making it an ideal choice as our baseline country.[13] Figure IV.1 illustrates the monthly evolution of environmental taxes on diesel fuel in euro cent per liter across Germany and its neighboring countries from 2011 to 2022. Notably, Germany imposes rather high taxes on diesel, while Poland and Luxembourg consistently maintain lower rates. Additionally, Belgium and France have comparatively higher taxes

[10] In contrast, the money generated by road tolls is used to maintain the road infrastructure.

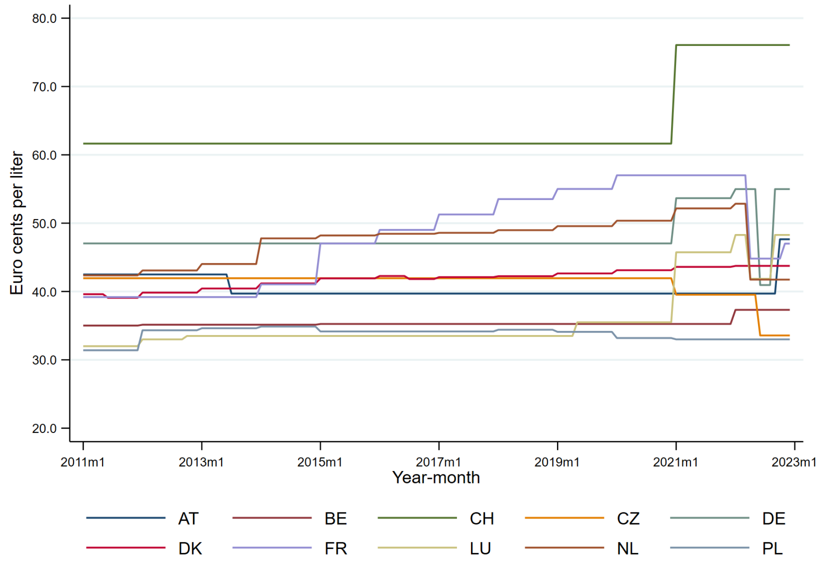
[11] Other environmental taxes besides taxes on fuel are energy taxes, pollution taxes and resource taxes.

[12] In 2018, the total amount of truck diesel tax rebates paid by these EU countries amounted to approximately EUR 4 billion. Currently, trucks in the EU pay an average diesel tax of EUR 0.43 per liter, which is EUR 0.07 below the rate imposed on cars (Transport and Environment, 2021).

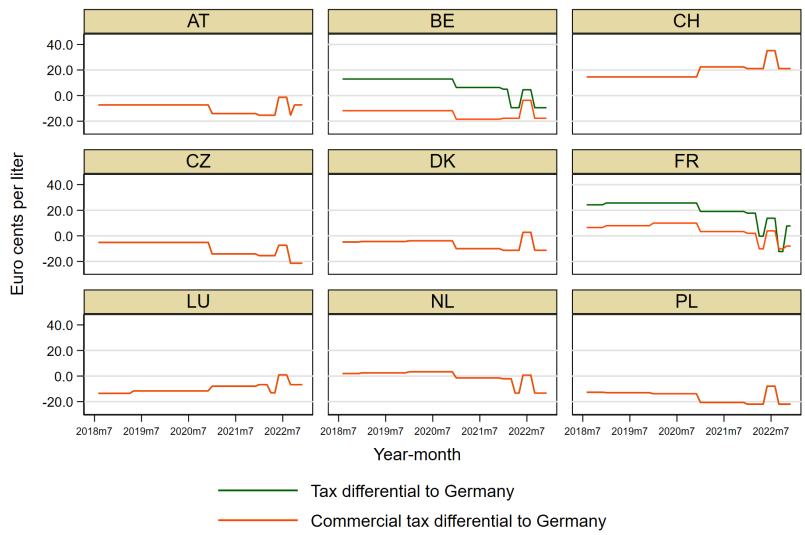
[13] Germany adjusted its environmental taxes on fuel only in 2022, a response prompted by the events surrounding the Ukraine war.

Figure IV.1: Development of Environmental Taxes on Diesel

(a) In Germany and neighboring countries



(b) Neighboring countries relative to Germany



Notes: The figures plot the development of environmental taxes on diesel in Germany and its neighboring countries. Panel (a) plots the countries' monthly tax rates in euro cent per liter over the period 2011 to 2022. Panel (b) plots the countries' tax differentials relative to Germany (tax in neighboring country - tax in Germany) in euro cent per liter of diesel fuel over the period mid-2018 to 2022. For Belgium and France that apply different tax rates on commerical vs. private use the green line is the tax differential excluding commercial tax rebates and the orange line is the tax differential including commercial tax rebates.

on diesel fuel for cars but offer tax rebates, as depicted by the dashed line, for commercial trucks.[14]

[14]The drops observed in 2022 were implemented as a response to the Ukraine war, during which several

Table IV.1: Summary Statistics of Environmental Taxes on Diesel by Country

	Obs.	Mean	St. Dev.	Min.	Max.	Median
Austria (AT)	144	40.45	1.55	39.70	47.65	39.70
Belgium (BE)	144	35.38	0.59	35.02	37.32	35.25
Bulgaria (BG)	144	32.75	0.49	31.44	33.01	33.01
Switzerland (CH)	144	64.05	5.39	61.65	76.07	61.65
Czech Republic (CZ)	144	41.26	1.91	33.57	41.95	41.95
Germany (DE)	144	47.96	2.75	40.95	54.99	47.04
Denmark (DK)	144	41.85	1.37	39.08	43.75	42.11
Estonia (EE)	144	41.54	4.82	37.20	49.30	39.29
Spain (ES)	144	31.29	1.28	30.39	35.19	30.39
Finland (FI)	144	47.18	3.90	36.28	51.25	46.28
France (FR)	144	48.06	6.87	39.19	57.01	49.02
Greece (GR)	144	38.20	3.86	33.00	41.20	41.00
Croatia (HR)	114	39.47	2.18	34.03	40.67	40.67
Hungary (HU)	144	34.36	3.50	22.05	38.88	35.54
Italy (IT)	144	40.13	0.72	37.51	40.32	40.32
Lithuania (LT)	96	35.01	1.83	33.02	37.20	34.70
Luxemburg (LU)	144	35.65	4.67	32.00	48.28	33.50
Latvia (LV)	108	37.04	3.39	33.29	41.40	37.20
Netherlands (NL)	144	47.34	3.29	41.75	52.85	48.45
Poland (PL)	144	33.78	0.93	31.40	34.87	34.16
Portugal (PT)	144	42.22	7.21	27.84	51.33	45.59
Romania (RO)	144	34.67	2.63	30.44	38.45	33.79
Sweden (SE)	144	47.27	7.87	30.29	58.66	46.22
Slovenia (SI)	144	33.00	0.00	33.00	33.00	33.00
Slovakia (SK)	144	37.89	0.91	36.80	38.64	38.64
Total	3486	40.43	8.00	22.05	76.07	39.29

Notes: The table reports summary statistics of (commercial) diesel tax rates (in euro cent per liter) by country during the period 2011 to 2022. The statistics include the number of observations, mean, standard deviation, minimum, maximum and median diesel tax rates by country.

Our first analysis leverages the variations in environmental taxes on diesel fuel relative to the German diesel tax rate. We subtract the environmental tax of Germany from that of each of its neighboring countries per month (tax in neighboring country - tax in Germany). Figure IV.1 presents the development of diesel taxes compared to Germany,

nations reduced their taxes on fuel as a countermeasure against rising oil prices.

encompassing Germany's neighboring countries and the time period mid-2018 to 2022 for which we possess traffic data from German roads. These relative differences in environmental tax rates on diesel serve as the main explanatory variable in the initial part of our empirical analysis, aiming to investigate the response of commercial traffic to changes in environmental taxes.

In our subsequent analysis, we delve into whether truck drivers take detours to circumvent high environmental taxes. For this purpose, we once again employ the diesel tax rates, now encompassing all continental European countries, and extending the time frame from 2011 to 2022. Table IV.1 shows summary statistics of (commercial) diesel tax rates by all European countries included in our sample. This expanded dataset on environmental tax rates on diesel allows us to examine truck routes throughout Europe and explore potential deviations undertaken by drivers to avoid regions with high environmental taxes.

3 Data and Descriptives

3.1 Traffic: Toll Data

To assess the impact of environmental tax rate differences on cross-border truck traffic flows between Germany and its neighboring countries, we utilize administrative toll data for Germany. The data provide us with monthly information on all trucks passing through Germany at a highly detailed spatial level, covering both highways and federal roads.[15] By observing the monthly count of trucks traveling on each road-section per month, we can assess how sensitive truck traffic flow is to changes in environmental taxes on fuel. Specifically, we observe the number of trucks traversing a given road-section for each direction independently resulting in two monthly observations per road-section. The data available spans from mid-2018 to the end of 2022.[16] Given that the data include

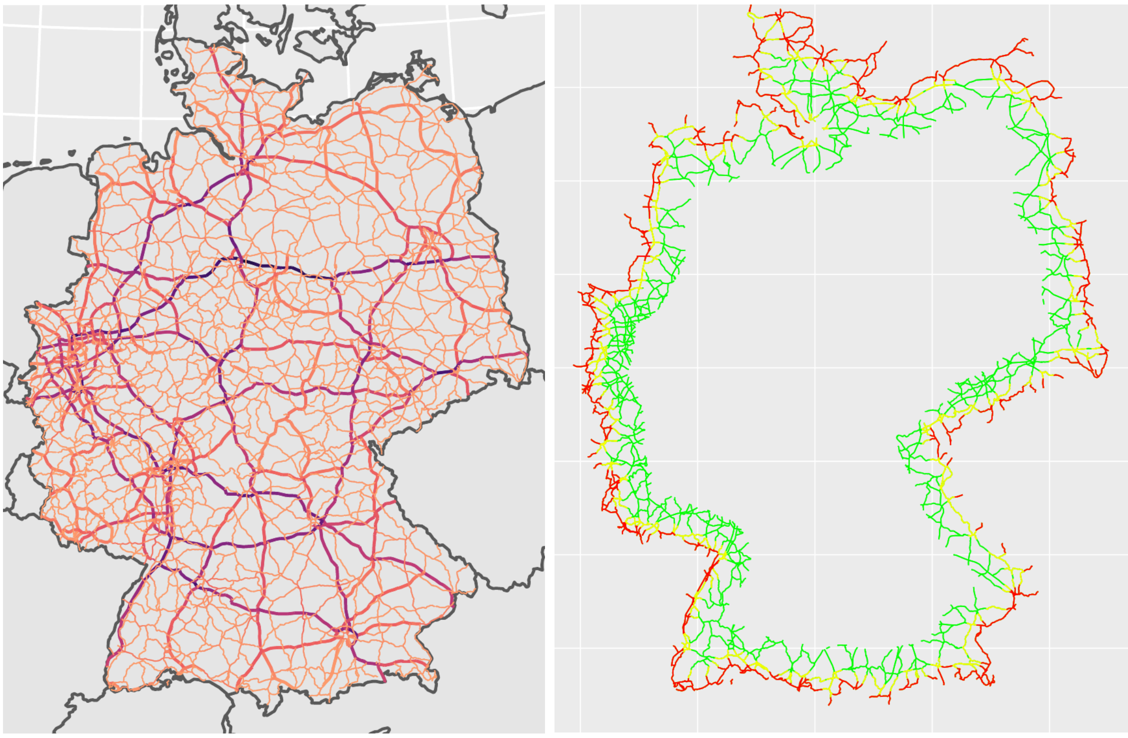
[15] In our study, we use the term highway to refer to the German "Autobahnen" while federal roads are German "Bundesstraßen".

[16] Data availability is limited to mid 2018 until the end of 2022 as the German toll system for trucks was implemented incrementally. The implementation started in April 2017 on highways, and was extended to federal roads by July 2018. As a result, data for the period before July 2018 is not available for

information on the number of axes (i.e. truck size), we restrict our analyses to trucks with more than four axes, representing about 80% of the truck count in our sample (see Appendix Figure IV.A2.1). Road freight transportation heavily relies on trucks equipped with four or more axes, which are also the predominant vehicles commonly observed on highways.[17] Our data further includes the road type driven (i.e. highway vs. federal roads). This enables us to analyze heterogeneity in tax sensitivity between road types, with highways possibly being the preferred choice for truck drivers in terms of delivery speed and infrastructure.

Figure IV.2: Geographic Coverage of Road-sections by Toll Data

(a) Highways and federal roads in Germany **(b)** Highways and federal roads at borders



Notes: The figures plot the toll data geographically. Panel (a) shows all highway and federal road road-sections present in the dataset. The thick lines represent highways, and the thin lines represent federal highways. The darker the color, the more traffic a road-section has on average. Panel (b) shows only highways and federal roads around borders. Red lines are all road-sections within 5 kilometers of the border, yellow are all between 5 and 10 kilometers, and green are within 10 to 15 kilometers of the border.

analysis.

[17] Trucks featuring three axes, such as car cranes, and those with two axes, like tractors or combined harvesters, serve different specialized purposes.

Figure IV.2 displays all highways and federal roads in Germany included in our dataset, while Table IV.2 provides descriptive statistics such as the total number of observations, which amounts to 690,792, and the average length of a road-section, which stands at 731 meters. Notably, 96% of the road-sections in our dataset are composed of federal roads, while the remaining 4% pertain to highways. Road-sections on highways are, however, on average ten times longer than those on federal roads. Moreover, monthly truck count statistics underline the significance of German "Autobahnen" (highways), with a monthly average of 79,273 trucks passing through each highway section, in contrast to an average of 4,856 trucks on federal roads.

Given our focus on cross-border flows, Figure IV.2 (b) identifies the border corridors we use to examine the impact of environmental taxes on cross-border truck traffic. We analyze road-sections that directly cross the border, as well as those within 5 km, 10 km, and 15 km of the border. A total of 135 highways and federal roads intersect the German border, connecting to neighboring countries. These roads serve as crucial transportation links, facilitating cross-border movement and trade between Germany and its neighboring countries. Appendix Table IV.A2.1 presents the average monthly truck traffic flow by distance to the border, while also differentiating traffic intensity by country of destination.

3.2 Traffic: Survey Data

In our second analysis we utilize a large sample of administrative route survey data to track truck drivers on their journeys across Europe. The ERFT database provided by EUROSTAT enables us to trace individual truck drivers from their starting point to their final destination while capturing the countries they cross in between.[18] This second dataset allows us to observe the actual routes commercial trucks drive through Europe. For anonymity purposes the starting and end point of each journey is reported in NUTS-2 (Nomenclature of Territorial Units for Statistics) format, which corresponds to district-

[18] According to a regulation by the European Commission, each member state is required to collect data on the carriage of goods by road. This data is obtained by surveying owners of road vehicles registered within their respective member states. It includes the journeys made by the vehicles, including the start and end points, as well as the countries crossed. Countries are required to report quarterly surveyed micro-data on selected vehicles. See Article 1 of Regulation (EC) 70/2012, as of 18 January 2012 (European Commission, 2012).

Table IV.2: Summary Statistics of Toll Data

	Obs	Mean	SD	P1	P50	P99
Road-section length						
Overall	691,098	731	1,272	100	300	6,800
Highway	25,478	5,050	3,493	300	4,300	16,400
Federal road	665,620	565	687	100	300	3,300
Truck count						
Overall	691,098	7,599	17,841	49	2,320	108,671
Highway	25,478	79,273	43,794	4,881	75,079	171,241
Federal road	665,620	4,855	7,273	48	2,182	38,018
Cross-border truck count						
Overall	13,094	17,728	32,222	2	2,786	145,806
Highway	2,550	69,578	40,841	7,898	68,524	161,426
Federal road	10,544	5,188	8,865	2	1,653	46,952

Notes: The table reports summary statistics for the toll data. Displayed are monthly averages spanning the time period mid-2018 till the end of 2022. Road-section length is measured in meters. Truck count is measured in the number of trucks passing the road-section each month. Cross-border truck count restricts the sample to road-sections crossing the border. The number of observations is presented in road-section-months.

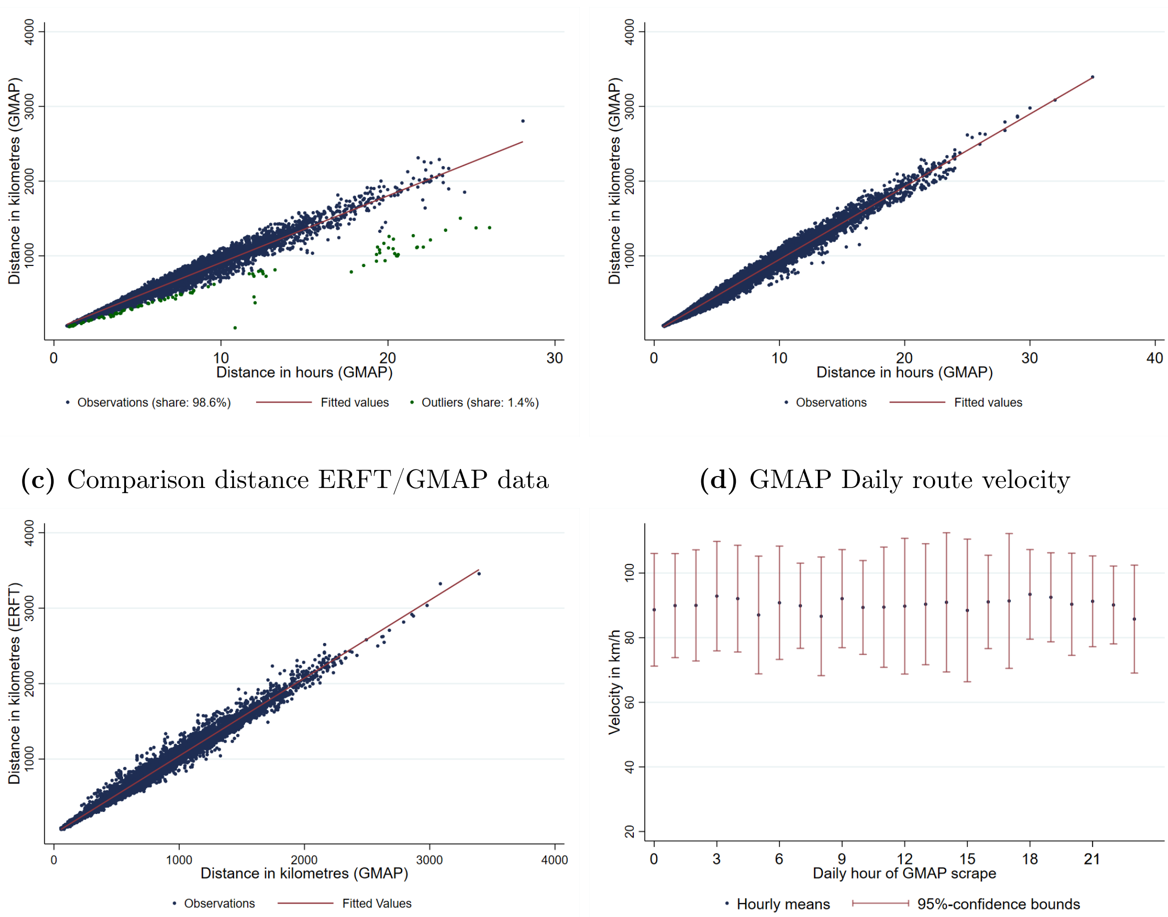
sized geographical regions.[19] Moreover, the ERFT database contains information on the actual distance traveled per journey (in kilometers), the type of journey (whether the truck is laden or unladen), and the type of transport (whether the journey was for hire or on own account). In total, we observe more than 46 million journeys from 426.115 unique vehicles during the time period from 2011 to 2020.[20] As we are interested in journeys that drive through continental Europe, we filter the data and find 1,182,339 cross-border journeys provided by 307,241 unique respondents.

Using this second dataset we investigate whether trucks deliberately take detours to avoid high environmental taxes. For this, we compare the actual route taken by each truck driver with the fastest and shortest route possible. The detour is quantified by measuring the difference between these two distances while also noting the specific countries trucks deviate to. Given that the ERFT dataset originally only provides information on the actual route taken for each journey, we employ a web scraping technique to extract

[19]The NUTS format classifies Europe's territory in a hierarchical order, where NUTS-1 corresponds to larger regions such as federal states, while areas covered by NUTS-2 and NUTS-3 are more granular.

[20]Release date: 10 November 2021, version 1.

Figure IV.3: Visualization of GMAP and ERFT data



(a) GMAP data before cleaning

(b) GMAP data after cleaning

(c) Comparison distance ERFT/GMAP data

(d) GMAP Daily route velocity

Notes: The figures show properties of the actual ERFT data and the scraped GMAP data. Panels (a) and (b) depict the scraped GMAPs data before and after cleaning. Plotted observations are aggregated at the NUTS2-pair level for the start and end points of each route, provided suchs pairs contain at least 10 observations per route (approx. 95 percent of all routes). Panel (c) provides a comparison of distance lengths between ERFT and GMAP, again aggregated at the level of the NUTS2-start-end-pairs. Panel (d) visualizes the influence of daily scrape hours on average route velocity.

the fastest and shortest route from GMAP for every journey. Our web scraper utilizes the journey's start and end points from the data, searching for the most direct route in GMAP. Since the start and end points are classified under the NUTS-2 system, we execute this search using the centroids of each NUTS-2 district. Additionally, we ensure that GMAP identifies a suitable location near these centroids, ensuring that simulated routes commence from areas suitable for road traffic. Simultaneously, we collect information on the countries traversed during each journey. This allows us to determine the potential detours taken for the specific journeys.

Table IV.3: Summary Statistics of Survey Data

	Obs	Mean	SD	P1	P50	P99
Actual distance (ERFT)						
Overall	1,185,176	624.05	468.91	87	491	2,106
Deviating	71,793	511.22	488.22	69	286	2,108
Optimal distance (GMAP)						
Overall	1,185,176	448.24	368.87	72	323	1,770
Deviating	71,793	473.10	457.95	66	272	1,946
Deviation distance						
Overall	1,185,176	24.39	86.27	-143	10	341
Deviating	71,793	38.12	102.63	-167	22	432
Hired journey						
Overall	1,185,176	0.88	0.32	0	1	1
Deviating	71,793	0.85	0.36	0	1	1
Single-trip						
Overall	1,185,176	0.71	0.45	0	1	1
Deviating	71,793	0.64	0.48	0	1	1
Laden journey						
Overall	1,185,176	0.81	0.39	0	1	1
Deviating	71,793	0.80	0.40	0	1	1
Laden weight						
Overall	1,185,176	136.76	102.33	0	150	313
Deviating	71,793	124.77	103.79	0	114	352

Notes: The table reports summary statistics for the survey data. Displayed are journey averages spanning the time period 2011 till the end of 2020. Overall refers to all cross-border journeys in the dataset, with deviating being those that deviate from the optimal route by crossing another or a different country. Distances are measured in kilometers. The actual distance per journey refers to the ERFT survey data. Optimal distance per journey refers to the fastest route according to GMAP. Deviation is the measured deviation between actual and optimal journey in kilometers. Hired, laden and Single-trip journeys are displayed in percentage points. Laden weight is displayed in 100 kg and corresponds to the weight of the laden goods.

To validate the accuracy of our web scraping approach we show the properties of the actual ERFT data, including the actual distances driven, and the scraped GMAP data, including the fastest and shortest route feasible, in Figure IV.3. As Panel (a) depicts, we identify 1.4% of journeys as outliers, classifying them as such due to their significantly longer duration relative to the distance driven.[21] We exclude these outliers from our sample, enhancing the reliability of our analysis (see Panel (b)). Figure IV.3

[21] These deviations are typically triggered by extraordinary events such as extensive traffic congestion, road closures, or truck breakdowns.

Panel (c) further illustrates a comparison of the distances of journeys between the ERFT and GMAP data. The alignment of these distances provides additional validation for our scraping approach. To address concerns regarding potential temporal biases in the GMAP data due to the time of scraping, Panel (d) displays the hourly averages of the scraped data. Notably, these averages remain consistent across different times of the day, mitigating any potential time-related influences on our results.

We present summary statistics for our refined survey dataset in Table IV.3, providing insights into both all cross-border journeys and those that involve deviations. On average, each journey covers a distance of 624.05 kilometers, while the optimal journey distance is 448.24 kilometers, resulting in an average deviation distance of 24.39 kilometers. Among the cross-border routes in our sample 71,793 deviate by traversing different or additional countries compared to the optimal route. The majority of journeys involve laden and hired trucks. The countries crossed most frequently are Germany, the Netherlands, and Belgium (see Appendix Table IV.A3.3).

3.3 Emissions: Sensor Data

In the second part of the paper we aim to estimate the environmental consequences of trucking businesses' tax-induced reactions. To link the tax-induced increases in truck traffic to local increases in environmental emissions, we rely on two data sources: first, we use administrative air pollution data provided by the German Federal Environment Agency (henceforth, we use the abbreviation of its German name "Umweltbundesamt", i.e. UBA). Second, we employ publicly available, open source (OS) air pollution data provided by the Sensor Community.[22] Both databases collect sensor data on short-lived climate pollutants (SLCPs), with particulate matter (PM) being the key pollutant collected. PM is emitted when fossil fuel is combusted. Road traffic is the main source of PM (World Health Organization, 2005). PM is classified in different categories of fine-

[22] The Sensor Community project originated from Luftdaten.info, an open knowledge initiative located in Stuttgart, Germany. It began as a regional project in 2015 but has grown significantly in recent years and now covers air pollution sensors across the world. Citizens install sensors that measure air pollutants, and the Sensor Community generates a constantly updating particulate matter map from the transmitted data.

ness (i.e. PM2.5, PM10) and is measured in particles (in g/m^3). In our analyses we focus on PM10 as it is the most consistently measured air pollutant in both datasets and combined with our traffic data. SLCPs such as PM have serious consequences for health and climate change. Black carbon, a component of fine particulate matter, is one of the largest contributors to global warming. It warms the earth's atmosphere by absorbing sunlight, thereby accelerating the melting of snow and ice (Ramanathan and Carmichael, 2008). Moreover, PM can cause harm to human health. PM can be carried deep into the lungs where it can cause inflammation and worsen the condition of people with heart and lung diseases (European Environment Agency, 2023).

To investigate the impact of increased truck traffic on environmental emissions, we combine our traffic data and emissions data. Leveraging our toll dataset, we link sensors to corresponding road-sections based on geographical coordinates. We hereby focus on road-sections located closer to the border (i.e. up to a road-order of 60 inside Germany). The advantage of the UBA data lies in its complete time coverage and measurement reliability, implying no outlier observations in any direction and a fully balanced panel. Conversely, the measurement data provided by OS is significantly larger, allowing us to identify emission responses to taxation at a very granular, local level. However, station coverage changes over time and the share of outliers for PM10 is substantial. We thus restrict our initial sample as follows: first, to reduce excessive imbalance over time, we require each OS emission station to have at least 40 year-month observations (equal to the sample median). Second, we winsorize the year-month values of PM10 at the level of both lower and upper 5%. This yields a similar tail distribution of PM10 as the UBA data. In order to balance the advantages and limitations of both emission data sources, for our further analysis we require that PM10 is measured at the closest UBA or OS emission sensor station.

Table IV.4 shows the summary statistics for the distance of a road-section to a sensor station and the monthly PM10 emissions for highways and federal roads. The median distance between a sensor and the nearest cross-border road-section is equal to 500 meters for the full sample, but increases to 6.4 kilometers when considering only cross-border road-sections. Given that PM can be reliably monitored within a range of up to 1,000 meters, this setup still allows us to evaluate environmental emissions for subsets of emission stations located closely to road-sections at highways and federal roads in Germany.

Table IV.4: Summary Statistics of Emission Data

	Obs	Mean	SD	P1	P50	P99
Distance to emission station						
Full sample						
Overall	401,435	1,554	2	23	547	9,839
Highway	25,209	1,962	1	640	1,452	6,154
Federal road	376,226	1,526	2	23	429	9,839
Cross-border road-sections						
Overall	10,226	8,915	7	251	6,375	28,050
Highway	2,550	7,631	6	668	5,062	26,017
Federal road	7,676	9,341	8	232	6,593	28,481
Monthly emissions (PM10)						
Full sample						
Overall	339,798	12.505	6.6	3.277	11.085	33.127
Highway	21,377	13.221	6.7	3.539	11.928	32.653
Federal road	318,421	12.457	6.6	3.276	11.044	33.138
Cross-border road-sections						
Overall	8,865	12.530	6.8	3.216	11.074	33.180
Highway	2,190	12.873	7.0	3.256	11.116	33.726
Federal road	6,675	12.417	6.7	3.201	11.051	32.653

Notes: The table reports summary statistics for the emission data for the full sample and the cross-border road-sections by road type. The upper half of the table displays distances between the road-sections and the emission sensor stations. The lower half of the table depicts the measured values for PM10. Observations span the time period from mid-2018 until September 2022. Distance between road-sections and emission sensor stations is measured in meters. Monthly PM10 is measured in $\mu g/m^3$. The number of observations is presented in road-section-months.

4 Effect of Environmental Taxes on Commercial Traffic

4.1 Toll Data

Empirical Strategy. To investigate the effect of environmental taxes on cross-border truck traffic, we examine changes in the environmental tax differential between Germany and its neighboring countries. Environmental taxes on diesel fuel influence a trucking company's refueling choices by being part of the gross price of diesel. Diesel prices are endogenously determined by market dynamics, which involve both supply and demand factors. Consequently, the gross price of diesel is influenced not only by the environmental tax rate but also by variables such as oil prices and decisions made by local fuel station owners. To address endogeneity issues due to simultaneity or imperfect pass-through and to isolate the variation in the diesel gross price attributable to environmental taxes, we employ an instrumental variable strategy. We instrument the gross price differential with the environmental tax differential (see a similar approach e.g. in, Bonnet et al., 2024). This enables us to isolate the tax-induced impact of gross diesel price differences on cross-border truck traffic.

An effective instrument must satisfy two key criteria. First, the instrument must be correlated with the endogenous variable (*relevance condition*). In our context, this means that environmental taxes on diesel must be correlated with the gross price of diesel. Our first stage regression (see Table IV.5 Panel A) confirms this correlation. Second, the *exclusion restriction* necessitates that, conditional on covariates, the instrument influences the outcome only through the endogenous variable. In our case, environmental taxes on diesel exclusively affect cross-border truck traffic through their influence on the gross price of diesel. Given that environmental taxes are integrated into the gross price and that truck drivers ultimately consider the gross price when making decisions, this assumption appears reasonable. Moreover, as environmental tax revenues are not used to maintain road infrastructure, we can mitigate concerns that road quality is a correlated omitted variable.

One remaining identification challenge is the potential policy endogeneity and omitted variable bias that arise from using policies as sources of variation. To address this, we provide evidence that our tax variable is plausibly exogenous. Figure IV.A1.4 shows that the average monthly net and gross price of diesel in Germany and its neighboring countries follows a similar pattern during our sample period. This suggests that the net price of diesel is primarily influenced by the oil price, while gross price differences between countries are driven by changes in tax rates. We further conduct an additional robustness check excluding the months following the outbreak of the Ukraine war (February 2022). In response to the war, many countries significantly lowered their taxes on diesel, potentially leading to confounding. Our results remain consistent (see Table IV.A2.4).

We implement the IV estimator using two-stage least squares (2SLS). In the first stage, we regress the gross price differential of diesel on our instrument, the environmental tax differential. The gross price and tax differentials are computed as the difference between the gross price or environmental tax in the neighboring country and the corresponding values in Germany. Germany is selected as our baseline country as we are examining traffic at German borders. Moreover its location, infrastructure, and relatively stable environmental tax on diesel fuel make it a suitable reference point. In the second stage, we regress our outcome variable of interest, commercial cross-border traffic, on the predicted gross price differential.

To estimate the first stage regression, we set up the following equation:

$$\textit{Gross price differential}_{icm} = \alpha_i + \beta_m + \gamma \times \textit{Env. tax differential}_{icm} + \epsilon_{icm}. \tag{IV.1}$$

$\textit{Gross price differential}_{icm}$ represents the diesel gross price difference between country c and Germany on road-section i during a particular year and month m. Our instrument $\textit{Env. tax differential}_{icm}$ captures the variation in environmental taxes on diesel. Using the predicted values of the first stage regression, we estimate the following second stage equation:

$$\textit{Cross-border traffic}_{icm} = \alpha_i + \beta_m + \delta \times \textit{Gross } \widehat{\textit{price differential}}_{icm} + \epsilon_{icm}. \tag{IV.2}$$

$\textit{Cross-border traffic}_{icm}$ represents the number of trucks driving on a specific cross-border road-section i during a particular year and month m.[23] Our variable of interest is the instrumented diesel tax rate differential $\textit{Gross } \widehat{\textit{price differential}}_{icm}$ that captures the tax-induced variation in diesel gross price between a neighboring country and Germany. By

[23]We refrain from using a Poisson specification because the second stage of our 2SLS analysis cannot be non-linear, even though our outcome variable is a count variable.

construction Equation IV.2 estimates the Local Average Treatment Effect (LATE). The coefficient of interest δ examines how a tax-induced change in the gross price differential of diesel affects commercial traffic flow at the border. Put differently, it estimates the effect on cross-border truck traffic for price changes that are caused by environmental tax changes on diesel. In all our specifications, we include road-section fixed effects (α_i) to account for factors that remain constant over time and are specific to a road-section. We also include year-month fixed effects (β_m) to control for variations in time and cluster standard errors by road-section.

Finally, to examine the direct effect of the environmental tax differential on cross-border traffic, we specify the following reduced form equation:

$$\textit{Cross-border traffic}_{icm} = \alpha_i + \beta_m + \lambda \times \textit{Env. tax differential}_{icm} + \epsilon_{icm}. \tag{IV.3}$$

Since truck traffic predominantly occurs on highways (see Table IV.2), we conduct our regression analyses separately for two groups. First, we examine the entire set of cross-border road-sections on highways and federal roads, which includes our full sample. Second, we narrow our focus to cross-border road-sections situated on highways, reflecting the most prominent roads for truck traffic. To broaden our perspective and provide a more comprehensive understanding of the effects, we further expand our analysis to include road-sections located at different distances from the border. To mitigate concerns that our results are confounded by the Covid-19 pandemic, we exclude affected months (March and April 2020) in a robustness test.[24]

Results. Table IV.5 Panel A presents the results of the first stage regression, exploring the relation between the environmental tax differential on diesel and the gross price differential. Column (1) displays the results for the full sample, while Column (2) focuses on highways. In both specifications, we observe a significant positive effect of the tax differential on the gross price differential. This suggests that our instrument, the

[24] To control for pandemic factors that equally affected cross-border traffic between countries during the same period, we include year-month effects. Thus, in this additional robustness test, we specifically test for the possibility that, for example, border closures affecting only a subset of neighboring countries could affect our results.

environmental tax differential, accurately predicts the gross price differential. The high F-statistics support this notion and suggests that our instrument is not weak.

In Table IV.5 Panel B, we explore the reduced form directly regressing cross-border truck traffic on the environmental tax differential on diesel. Again, Column (1) presents results for the full sample, while Column (2) narrows the focus to highway traffic. The estimated coefficients are statistically significant showing that commercial cross-border traffic reacts negatively to an increase in the tax differential. An increase in the tax differential by one euro cent per liter of fuel (referring to an environmental tax increase in the neighboring country) is associated with an average decrease of 47 trucks per month on a cross-border road-section in the full sample, with this reduction increasing to 327 trucks per month on highways.

Table IV.5 Panel C presents results for the OLS specification, regressing cross-border traffic on the gross price differential for the full sample and highways. For the full sample, we find a positive coefficient that is statistically insignificant. In contrast, for the highway sample, we observe a significantly negative coefficient. Under our preferred IV specification in Panel D, both 2SLS coefficients are negative and statistically significant. We find that an increase in the environmental tax rate on diesel in a neighboring country leads to a substantial reduction in cross-border traffic toward and away from that country. More precisely, a tax-induced increase in the price differential by one euro cent per liter of fuel (i.e., the neighboring country experiences an environmental tax-induced increase in diesel price by one euro cent relative to Germany) is associated with an average monthly decrease of 53 trucks on all cross-border roads and a significant decrease of 466 trucks on highways. These findings align with our initial expectations, demonstrating that truck traffic responds to changes in environmental tax rates on fuel. An increase in the environmental tax rate on diesel in one country decreases truck traffic flow through that country, while a decrease in the tax rate leads to an increase in traffic flow. This result is stronger on highways, highlighting the importance of highways for trucking companies.

To calculate the overall increase in truck traffic caused by tax differences, we consider the mean environmental tax rate difference of -6.5 euro cent per liter of fuel between

Table IV.5: Toll Data: Effect of Environmental Taxes on Commercial Traffic

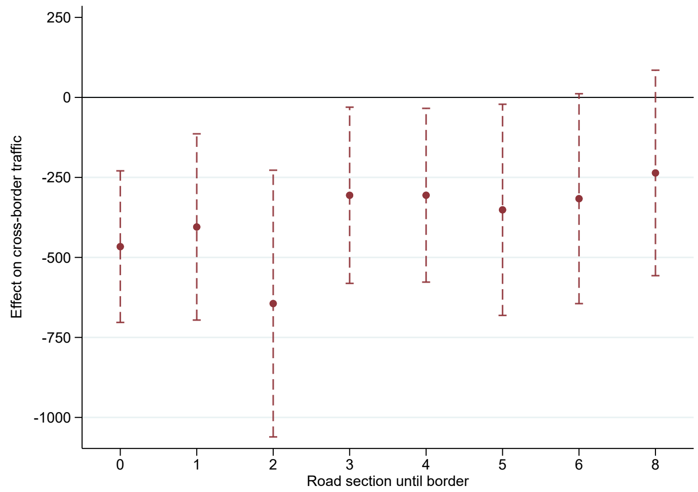
	Panel A: First stage Diesel gross price differential		**Panel B: Reduced form** Cross-border traffic	
	Full sample (1)	*Highway* (2)	*Full sample* (1)	*Highway* (2)
Env. tax differential	0.932***	0.591***	-46.737**	-327.138***
	(0.080)	(0.141)	(18.091)	(87.593)
Year-month FE	X	X	X	X
Road-section FE	X	X	X	X
Observations	13,094	2,550	13,094	2,550
F-statistic	135.66	17.58	-	-
	Panel C: OLS Cross-border traffic		**Panel D: Second stage** Cross-border traffic	
	Full sample (1)	*Highway* (2)	*Full sample* (1)	*Highway* (2)
Gross price differential	7.134	-181.164***	-53.930**	-466.317***
	(11.804)	(49.050)	(21.828)	(117.849)
Year-month FE	X	X	X	X
Road-section FE	X	X	X	X
Observations	13,094	2,550	13,094	2,550

Notes: The table presents the main results of our toll data analysis. Panel A reports first stage results regressing the environmental tax differential on the gross price differential. Panel B reports estimates of the reduced form equation. The dependent variable is the monthly truck count on a cross-border road-section. The independent variable is the diesel tax differential between Germany and its neighboring countries. Panel C reports results from a OLS specification and Panel D results from the second stage. The dependent variable is the monthly truck count on a cross-border road-section. The independent variable is the (instrumented) gross price differential. The environmental tax differential and the gross price differential are calculated relative to Germany (tax/price in neighboring country - tax/price in Germany) and measured in euro cent per liter of diesel fuel. In all specifications we include road-section and year-month fixed effects. Columns (1) display the results for the full sample, Columns (2) for the highways Standard errors are clustered on the road-section level and shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

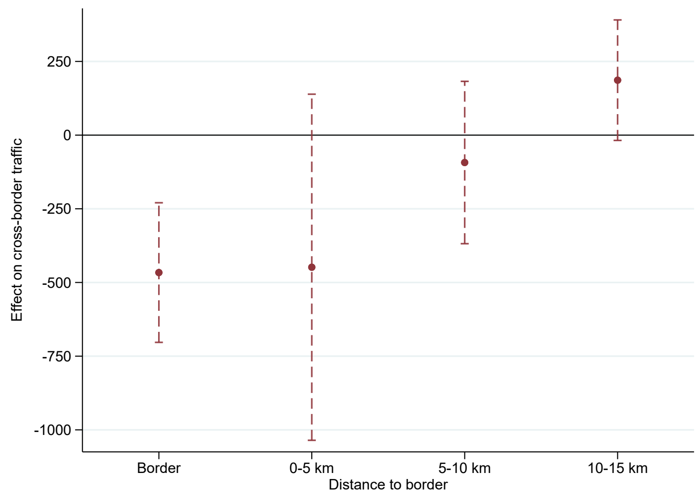
two neighboring countries and multiply it by our estimated coefficient. We predict approximately 1,177 additional trucks per month per cross-border road-section and 3,029 additional trucks per month on highway road-sections. For Germany as a whole, this amounts to an annual excess of approximately 1,177 trucks x 12 months x 2 incoming and outgoing road-section x 133 cross-border roads, which results in an increase of

Figure IV.4: Toll Data: Effect by Distance to Border

(a) By road-section until border



(b) By distance to border



Notes: The figure plots the effect of environmental taxes on commercial highway traffic by road-section and distance to the border.The points plotted are the 2SLS estimates regressing the monthly truck count on the instrumented gross price differential. The gross price differential is calculated relative to Germany (price in neighboring country - price in Germany) and measured in euro cent per liter of diesel fuel. Panel (a) presents the effects by road-section until border. Panel (b) presents the estimates by grouping road-section by their distance to the border. 95% confidence intervals are represented by the dashed red lines lines and based on standard errors clustered on the road-section level.

around 4 million truck commutes per year. This highlights the substantial impact that even small shifts in environmental tax rates on diesel in neighboring countries can exert on the volume of cross-border truck traffic in Germany.

Next, we broaden our perspective by including road-sections located further away from the border. Figure IV.4 illustrates the 2SLS estimates on the tax-induced price differential by the distance to the border. Figure IV.4 (a) estimates Equation IV.2 separately by road-section. Road-section 0 is the section directly located at the border, while road-section 1 is one section away from the border. Notably, the coefficients for the first six sections are all negative and statistically significant. However, the magnitude of the coefficient diminishes as we move farther from the border. We attribute this trend to an increasing presence of inland traffic on road-sections located at a greater distance to the border. As more domestic traffic intersects with these roads, the impact of tax differentials on cross-border truck traffic gradually diminishes. In Figure IV.4 (b) we separately estimate point estimates for road-sections directly at the border, 0 to 5 km, 5 to 10 km, and 10 to 15 km from the border. We confirm that the negative effect gradually decreases the farther we move away from the border and add it is most pronounced within the first 5 kilometers to the border.

We acknowledge that our results could be contaminated by the impact of concurring events. Our results are unlikely to be biased by the COVID-19 pandemic and associated border closures in March and April 2020. While borders were closed for private travelers, they remained open for transport vehicles. Additionally, some countries relaxed Sunday driving bans for trucks, opened green lanes for faster truck passage at borders, and eased driving and rest requirements. Therefore, we believe that the pandemic did not have a significant impact on transport operations due to these special measures. If trucks were unable to respond to environmental tax differences due to border closures during this period, our results would be biased toward zero. To address this concern, we exclude the first two months of the pandemic (March and April 2020) from our sample. We document in Appendix Table IV.A2.3 that our estimated coefficients remain consistent.

Another potential confounding event is the outbreak of the war in Ukraine, which caused fuel prices to spike throughout 2022. At the same time, European governments responded by lowering environmental taxes on fuel across the board. To ensure that our results are not affected by this confounding event in February 2022, we test whether our results hold when excluding all months after January 2022. We expect to find even stronger results for this shortened sample period, as tax changes that occurred due to the

Ukraine are more closely aligned across countries. Indeed, in Appendix Table IV.A2.4 we observe even stronger responses when we exclude the period of the Ukraine war.

4.2 Survey Data

Empirical Strategy. Next, we investigate whether differences in tax rates across countries induce trucking companies to take detours. To this end, we examine individual truck journeys across continental Europe. We begin by observing the actual distance traveled by a truck during its trip and the countries it crosses, as recorded in the survey data. By leveraging data scraped from GMAP, which includes the fastest and shortest routes along with the associated countries, we can compare these two routes to determine whether a truck deviates from the optimal route and assess if this deviation is driven by fuel tax differences.

First, we assess whether the likelihood of deviation increases with higher environmental taxes on diesel along the journey We begin by creating a binary variable that indicates whether a truck's journey deviates from the fastest and shortest route available. A journey is classified as deviating if it involves driving a longer distance and traveling through an additional or different country compared to the optimal route. Subsequently, we regress this deviation indicator on the average gross price of diesel along the journey. To account for potential endogeneity, we instrument the gross price with the average environmental tax on diesel to isolate the tax-induced component of the gross diesel price. We then apply a linear probability model[25] to estimate the following 2SLS regression:

$$Deviation_{jnq} = \alpha_n + \beta_q + \delta \times Gross\ \widehat{price\ average}_{jnq} + \epsilon_{jnq} \tag{IV.4}$$

The dependent variable $Deviation_{jnq}$ is coded as one if the truck journey j deviates from the optimal route in quarter q by passing through an additional or different country, and zero otherwise. We define the $Gross\ price\ average_{jnq}$ as the average gross price of

[25]We choose a linear probability model over a logit or probit specification to avoid the incidental parameter problem, which would pose challenges in including fixed effects (Greene, 2002). For robustness, we provide the results using a probit specification without fixed effects in Appendix Table IV.A3.2, where our results remain consistent.

diesel along journey j in quarter q, instrumented by the average environmental diesel tax in the first stage. We expect a positive coefficient ($\delta > 0$) for our coefficient of interest δ, supporting the hypothesis that trucks are more likely to deviate when the average tax rate along the route increases. Our model incorporates robust standard errors. Additionally, we introduce year-quarter fixed effects (β_q) to capture time-specific variations and NUTS2-start-end-point pair fixed effects (α_n) to account for factors specific to a journey from one region to another. This addresses concerns that our estimated effect might be influenced by factors other than taxes, such as geographic characteristics or tolls, that could determine the optimal route. With this demanding fixed-effect structure, we account for variation in tax rates over time while holding the specific journey in NUTS2 classification constant. However, recognizing that fixing our results on NUTS2-start-end-point pairs leads to a loss of variation, we also present the results without any fixed effects.

Next, we quantify the additional distance traveled by trucks due to variations in environmental taxes. To achieve this, we replace the deviation indicator variable with the journey's deviation distance, measured both in kilometers and ton-kilometers to account for the size and environmental impact of the truck involved in a journey. On the right-hand side of Equation IV.4 we introduce an interaction term, which incorporates the deviation indicator. This adjustment allows us to quantify how far truck companies deviate when faced with an increase in environmental taxes on diesel. As before, we employ 2SLS to isolate the tax-induced changes in the gross price of diesel.

Subsequently, we seek to gain a more profound understanding of the countries through which trucks deviate from their optimal routes. Initially, we conduct a descriptive analysis to identify countries where detours are most prevalent. In this step, we compile our data into a country-quarter panel, capturing the number of journeys passing through a country and the number of deviations within that country. By computing the share of these two metrics, we gain insights into the countries most frequently deviated through by controlling for the overall number of trucks passing that country. We empirically assess whether these deviations are influenced by tax considerations. We regress the number of deviating truck journeys per country and quarter on the tax-induced average gross price of diesel for that specific country and quarter using our 2SLS model. Our specification incorporates county and year-quarter FEs accounting for variations in a country's size and across time.

Results. We initiate the analysis of the survey data using a linear probability model to assess whether differences in the environmental taxes on diesel influence the likelihood of truck companies deviating from the fastest and shortest route. The results are detailed in Table IV.6. Panel A displays the outcomes of the first stage, regressing the average diesel gross price on the average environmental tax on diesel. Panel B presents the results of the reduced form, regressing the deviation indicator on the average environmental tax on diesel. We perform an OLS specification, directly regressing the deviation indicator on the gross price average of diesel, in Panel C. Finally, we present the second stage results, where the deviation indicator is regressed on the tax-induced average gross price of diesel, in Panel D. Columns (1) do not include fixed effects, and Columns (2) incorporate both year-quarter and NUTS2-start-end-point fixed effects.

To validate the relevance condition, Table IV.6 Panel A displays the results of the first stage regression. The positive and significant coefficients confirm the existence of a correlation and, consequently, thereby affirming the relevance of the instrument. Additionally, the sufficiently high F-statistics support this notion, confirming that our instrument is not weakly identified.

The results from the reduced form in Table IV.6 Panel B reveal a positive and significant relation between the probability of deviating from the shortest and fastest feasible route and the average environmental tax rate on diesel. This suggests that truck drivers are more inclined to deviate from the optimal journey when faced with higher average tax rates on that route. To be precise, a one euro cent per liter of fuel increase in the average environmental tax corresponds to a 0.43% (0.18%) increase in the probability of a truck deviating from its optimal route, without (with) the inclusion of fixed effects.

Finally, the results of the second stage regression in Table IV.6 Panel D validate the positive relationship highlighted by the reduced form. We observe that a tax-induced

Table IV.6: Survey Data: Effect of Environmental Taxes on Commercial Traffic

	Panel A: First stage		**Panel B: Reduced form**	
	Average diesel gross price		Deviation	
	(1)	(2)	(1)	(2)
Env. tax average	0.43870***	1.40913***	0.00429***	0.00177***
	(0.04465)	(0.05370)	(0.00086)	(0.00048)
Year-quarter FE		X		X
NUTS2-start-end FE		X		X
Observations	1,182,316	1,177,246	1,182,339	1,177,269
F-statistic	123.17	649.84	-	-
	Panel C: OLS		**Panel D: Second stage**	
	Devation		Deviation	
	(1)	(2)	(1)	(2)
Gross price average	0.00019	0.00041***	0.00974***	0.00126**
	(0.00025)	(0.00013)	(0.00286)	(0.00039)
Year-quarter FE		X		X
NUTS2-start-end FE		X		X
Observations	1,185,153	1,180,083	1,182,316	1,177,246

Notes: The table presents the results of our survey data analysis estimating a linear probability model. Panel A reports first stage results regressing the average diesel gross price on the average environmental tax on diesel. Panel B reports estimates of the reduced form equation. The dependent variable is the deviation indicator and the independent variable is the average environmental tax on diesel on the journey. Panel C reports results from a OLS specification and Panel D results from the second stage. The dependent variable is the deviation indicator and the independent variable is the (instrumented) average diesel gross price on the journey. Columns (2) include year-quarter and NUTS2-start-end FEs. Robust standard errors are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

increase in the average gross diesel price by one euro cent per liter of fuel corresponds to a 0.97% (0.13%) increase in the probability of a detour, without (with) the inclusion of fixed effects. Initially, in our toll data analysis, we established that truck drivers respond to changes in environmental taxes by reducing traffic when taxes are raised. This second part demonstrates that our first results, a reduction in traffic causing less cross-border traffic, does not mean trucks are driving less overall. Instead, the probability of transport companies deviating to refuel in a country with lower environmental taxes on fuel increases when differences in environmental taxes exist.

Table IV.7: Survey Data: Deviation Distance

	Panel A: Deviation distance Excess kilometers		
	2SLS (1)	*2SLS* (2)	*RF* (3)
Env. tax average			0.169
			(0.196)
Env. tax average x Deviation			0.398***
			(0.031)
Gross price average	-2.148***	0.140	
	(0.532)	(0.137)	
Gross price average x Deviation	0.128***	0.132***	
	(0.024)	(0.010)	
Year-quarter FE		X	X
NUTS2-start-end FE		X	X
Observations	1,182,316	1,177,246	1,177,269
	Panel B: Deviation ton-kilometers Excess ton-kilometers		
	2SLS (1)	*2SLS* (2)	*RF* (3)
Env. tax average			5.078
			(3.052)
Env. tax average x Deviation			6.155***
			(0.540)
Gross price average	-37.845***	3.916*	
	(9.437)	(2.106)	
Gross price average x Deviation	1.594***	2.041***	
	(0.416)	(0.180)	
Year-quarter FE		X	X
NUTS2-start-end FE		X	X
Observations	1,182,316	1,177,246	1,177,269

Notes: The table presents results from our survey dataset estimating the effect of environmental taxes on deviation distance. Panel A reports the results using the deviation distance in kilometers as outcome variable. Panel B reports estimates using deviation in ton-kilometers as outcome variable. The independent variables are the average environmental tax on diesel on the journey and its interaction with the deviation indicator for the reduced form in Columns (3) and the (instrumented) diesel gross price on the journey and its interaction with the deviation indicator for the 2SLS approach in Columns (1) and (2). In Columns (2) and (3) we include year-quarter and NUTS2-start-end FEs. Robust standard errors are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

We delve deeper into the implications of these findings by quantifying the extent of the detour. To achieve this, we replace the deviation indicator variable with a variable containing the deviation distance and re-estimate our 2SLS IV regression, as illustrated in Table IV.7. Panel A shows the deviation distance in kilometers as the dependent variable, while Panel B measures deviation in ton-kilometers, accounting for the size and freight a truck is transporting. For the deviating journeys, we find that a tax-induced increase in the average gross diesel price by one euro cent per liter increases the deviation distance by 132 meters in the 2SLS specification and by 398 meters in the reduced form. Looking at excess ton-kilometers, we confirm a positive relationship, observing that a one euro cent per liter increase in the tax-induced average gross diesel price leads to an increase of 2.04 ton-kilometers.

Next, our focus shifts to identifying countries where detours are most prevalent. Initially, we descriptively examine the number of trucks deviating through a country, scaled by the overall number of trucks passing through that country. Our observations highlight Luxembourg, along with Romania and Slovakia, as primary destinations for truck detours (see Appendix Table IV.A3.3). These countries exhibit the lowest environmental tax rates on diesel on average in our dataset.

Table IV.8: Survey Data: Country Effects

	No. deviations	**Log(No. deviations)**	**Share deviations**
	2SLS	*2SLS*	*2SLS*
	(1)	(2)	(3)
Gross price average	-2.179	-0.028	-0.007
	(1.732)	(0.022)	(0.006)
Year-quarter FE	X	X	X
Country FE	X	X	X
Observations	920	757	920

Notes: The table presents the effects of environmental taxes on deviations by country. The dependent variable is the number of deviations in Column (1), the log(number of deviations) in Column (2) and the share of deviating journeys per country and year-quarter in Column (4). The independent variable is the (instrumented) average diesel gross price per country and year-quarter. All specifications include year-quarter and country FEs. Standard errors clustered on country level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

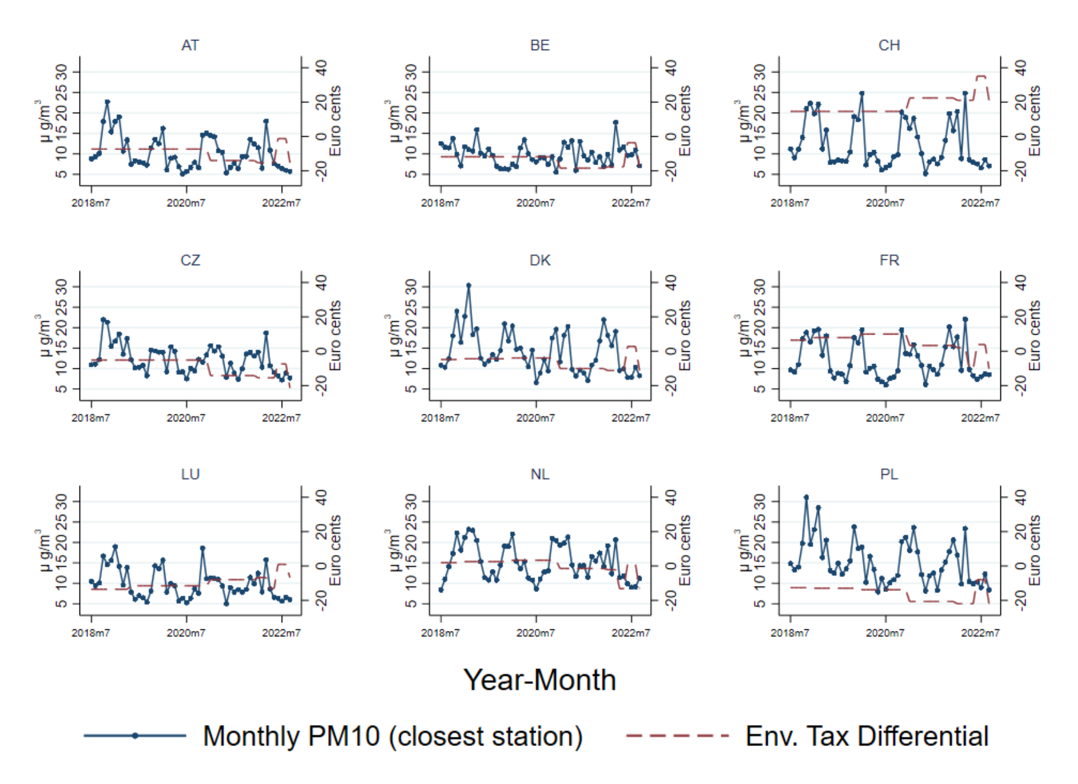
To empirically confirm this observation, we focus on a subset of cross-border journeys involving deviations. We regress the number of deviating truck journeys per country and quarter on the average tax-induced gross diesel price for that country and quarter. Our model incorporates controls for the total number of journeys passing through each country per quarter, as well as the country's population, to account for variations in size and traffic. The results in Table IV.8 reveal negative coefficient estimates, indicating that the volume of trucks deviating through a country increases as the environmental tax in that country decreases. This finding substantiates the notion that environmental taxes on diesel significantly impact commercial trucking operations, influencing route planning decisions to minimize diesel costs.

5 Environmental Consequences

5.1 Combining Toll and Emission Data

To assess the environmental implications of tax-induced shifts in truck traffic, we link our toll dataset to emissions data collected by sensor stations near specific road-sections. Focusing on the German cross-border setting, we examine emissions from roads leaving and entering Germany. To gain a first understanding of the relationship between environmental taxes and emissions, we plot the tax differentials between Germany and its neighboring countries against the average emissions on cross-border roads over our study period (mid-2018 to 2022) in Figure IV.5. The figure suggests that PM10 emissions generally increase on average when the tax in the neighboring country decreases, particularly evident when the tax differential becomes more negative, favoring lower environmental taxes in neighboring countries (e.g., Austria, AT; Belgium, BE; Czech Republic, CZ; Denmark, DK; Netherlands, NL; Poland, PL). Conversely, we observe a decrease in average emissions during periods where the environmental tax differential increases, indicating that neighboring countries have raised their environmental taxes on fuel compared to Germany (e.g., Austria, AT; Belgium, BE; Switzerland, CH; Denmark, DK; Luxembourg, LU; Netherlands, NL; Poland, PL). We observe a shifting effect of emissions towards the country with lower tax rates.

Figure IV.5: Emission Data: Environmental Tax Differentials and Emissions



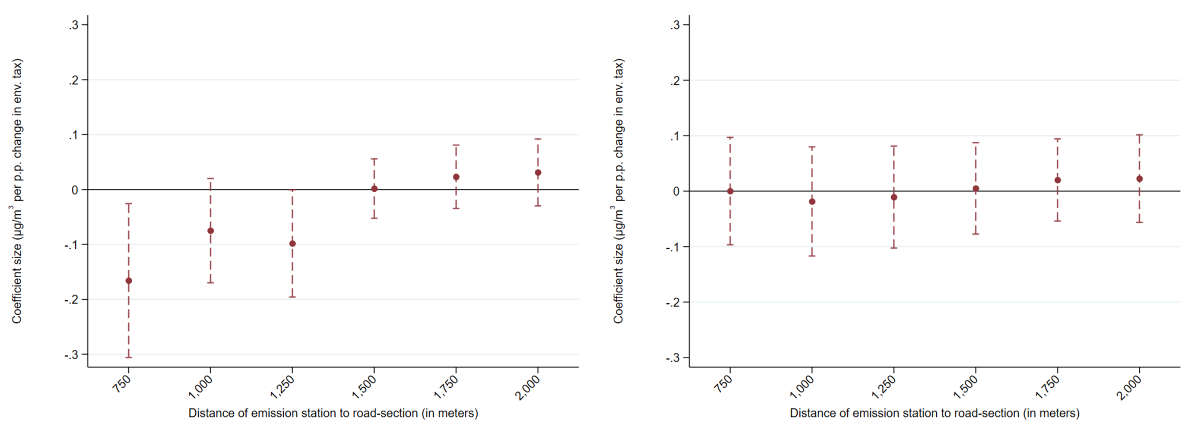
Notes: The figure plots average environmental emissions on cross-border roads and the corresponding environmental tax differential between Germany and its neighboring countries over the time period from July 2018 until September 2022. Monthly PM10 is measured in $\mu g/m^3$ for the closest emission station. The environmental tax differential is calculated relative to Germany (tax in neighboring country - tax in Germany) and measured in Euro cents per liter of diesel fuel.

To analyze how local emission pollution reacts to tax-induced variations in cross-border truck traffic, we again employ the reduced form approach already utilized in Equation IV.3, with PM10, measured at the closest emission sensor station, being the dependent variable. Our analysis is limited by the requirement that PM10 must be measured at a close distance, i.e. in a radius of not more than one kilometer. As Table IV.4 shows, however, this is only the case for a small share of our road-sections. We thus estimate our reduced form empirical model for subsets of our overall cross-border road-sections in a stepwise procedure: we start with including only values for PM10 that come from emission stations within a 750 metre perimeter. We subsequently increase this perimeter by 250 metres for each following regression until a perimeter of two kilometres. The further away from the threshold of one kilometer, we cannot expect the value of PM10 being measured precisely. Our empirical specification thus addresses the trade-off between obtaining a sufficiently large sample for a reliable estimation of our coefficient of interest on the one hand, and measuring our outcome variable PM10 reliably on the other hand. The first factor moreover limits our ability to conduct two-way clustering of standard errors, as our individual road-sections reduce to less than fifty individual clusters. We thus use one-way clustered standard errors at the year-month level.

Figure IV.6, Panel A depicts our regression result visually for cross-border road-sections (cf. also Table IV.A4.1 in the appendix). We observe that for small perimeters, the limited number of observations yields a negative and (partially) significant coefficient until a perimeter of 1.5 kilometers, above which the coefficient becomes insignificantly positive. This is in line with our concern that measurement precision of PM10 decreases increasingly for perimeters larger than one kilometer. Concerning the interpretation, our findings imply that a decrease in the environmental tax differential relative to a neighboring country by one percentage point increases local PM10 emissions at the respective cross-border road-section by between 0.09 and 0.16 $\mu g/m^3$. This effect is significant at the 95%-level.

Figure IV.6: Emission Data: Effect of Tax Differentials on Emissions

(a) On cross-border road-sections **(b)** On inland road-sections



Notes: The figure plots the effect of environmental taxes on emissions by distance of emission station to road-section. The points plotted are coefficient estimates of a reduced form regression of local PM10 on the environmental tax differential between Germany and its neighboring countries. Panel (a) presents the reduced form estimates for stepwise increases in perimeter size around the cross-border road-sections. Panel (b) repeats the same analysis with a focus on inland road-sections, i.e. those with a road order between 10 and 40. 95% confidence intervals are represented by the dashed red lines lines and based on standard errors clustered at the year-month level.

As a placebo test, we also estimate the identical regression for a subset of road-sections located further inside Germany, i.e. at a larger distance from the border. To this end, we choose a set of road orders between 10 and 40, because the road-sections below 10 provide a risk that the associated emission sensor stations are identical to the cross-border road sections. Figure IV.6, Panel B depicts our placebo regression result visually. There is no discernible effect in any direction of cross-border tax differentials on local PM10 emissions. We thus conclude that environmental tax differentials lead to higher local pollution due to divergence in truck routes, in line with our findings from the prior section.

5.2 Predicting Emissions with Survey Data

The findings from our second analysis, utilizing the Europe-wide survey data, enable us to quantify the environmental externalities arising from trucks deviating to minimize fuel taxes. We start by considering the excess ton-kilometers driven, as estimated in Table IV.7. Expanding on our previous findings, we employ a linear prediction model to estimate the cumulative surplus ton-kilometers resulting from tax-induced adjustments within the cross-border trucking sector in Europe. We use the 2SLS point estimate from Table IV.7 Panel B, along with a lower and upper bound derived from the 95%-confidence interval. We predict the deviation excess-ton kilometers using our sample of journeys throughout Europe. In the subsequent step, we adjust the result based on the sampling rate of the survey data. Finally, we calculate the predicted excess ton-kilometers by multiplying them by the associated tons of CO_2 emissions per ton-kilometer, considering varying levels of CO_2 emission intensity.

The results are displayed in Table IV.9, showing a range of excess emissions from 426,000 tons to 1,070,000 tons CO_2 emissions caused by tax-induced deviations in truck transport. These additional emissions result from trucks driving longer routes to save on fuel, highlighting an unintended consequence of non-harmonized environmental tax rates on diesel fuel. To contextualize these findings, it's notable that the total yearly CO_2 emissions caused by road transport in the EU amount to 199 million tons (European

Environment Agency, 2024). Thus, tax-induced deviation contributes approximately 0.54% of these emissions. Overall, the differences in environmental tax rates on diesel thus lead to an increase in emissions.

Table IV.9: Survey Data: Excess Emissions from Deviations

	Low CO2-Intensity	Medium CO2-Intensity	High CO2-Intensity
Lower Bound	426,540.7	785,732.8	1,046,147.1
Point estimate	431,679.1	795,198,4	1,058,749.8
Upper Bound	436,817.5	804,663.9	1,071,352.5

Notes: The table presents the additional emissions resulting from tax-induced differences in diesel prices across the EU. The estimates are derived from the point estimates and 95%-confidence interval obtained from Table IV.7, Panel B, using a linear prediction model. The values are then scaled up by the sampling rate and multiplied by the excess ton-kilometers, along with their corresponding tons of CO_2 emissions. We include a low, medium and high CO_2 emissions multiplier.

6 Discussion and Conclusion

This study quantifies the impact of environmental taxes on commercial truck traffic and its environmental consequences. We use administrative toll data to analyze cross-border truck flows at German borders and assess the response of truck traffic to changes in environmental taxes. Second, we examine individual truck trips across Europe using administrative survey data to investigate whether trucks take detours to avoid high environmental taxes. In both analyses, we use an IV approach to isolate the effect of environmental taxes on the gross price of diesel. Specifically, we instrument the gross price of diesel with the environmental tax to disentangle the changes in the price of diesel induced by environmental taxes. In the second part, we assess the environmental consequences of these tax-induced responses by incorporating data on air pollution and CO_2 emissions.

We find that trucking companies respond significantly to environmental taxes on diesel. While we initially observe a decrease in cross-border truck traffic, especially on heavily congested highways near borders, we do not witness an overall reduction in traffic. Instead, trucking companies drive detours to refuel in countries with lower fuel taxes, leading to increased mileage and exacerbating environmental externalities. Moreover, our investigation into the environmental consequences reveals spikes in air pollution in response to tax-induced changes in commercial traffic at borders. We quantify that the increased truck mileage lead to additional emissions of up to 1 million tons of CO_2.

Our comprehensive investigation into the effects of environmental taxes on commercial truck traffic makes a unique contribution to the existing literature. Responding to the timely and highly relevant call for more research on the impacts of environmental taxes (Lester and Olbert, 2024), our study enhances the understanding of how such taxes influence commercial traffic and provides valuable insights into potential policy solutions to mitigate environmental consequences. The evidence we present suggests that harmonizing tax rates across the EU could be a viable strategy to prevent commercial trucks from deviating to other countries. Such cross-border harmonization could potentially decrease traffic and foster more sustainable practices in the transportation sector.

Our findings extend beyond Europe and the specific environmental taxes on fuel. Similar variations in fuel taxes exist across US states (Davis and Kilian, 2011; Li et al., 2014), and the broader implications of our results can be generalized to scenarios with non-harmonized tax rates on different mobile tax bases. The key takeaway from our study is that when the tax base is mobile and opportunities for tax avoidance exist, there is a risk of shifting behavior. This issue is particularly critical in the context of environmental regulations aimed at reducing emissions to mitigate climate change, as it can lead to leakage and an overall increase in emissions.

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Appendices

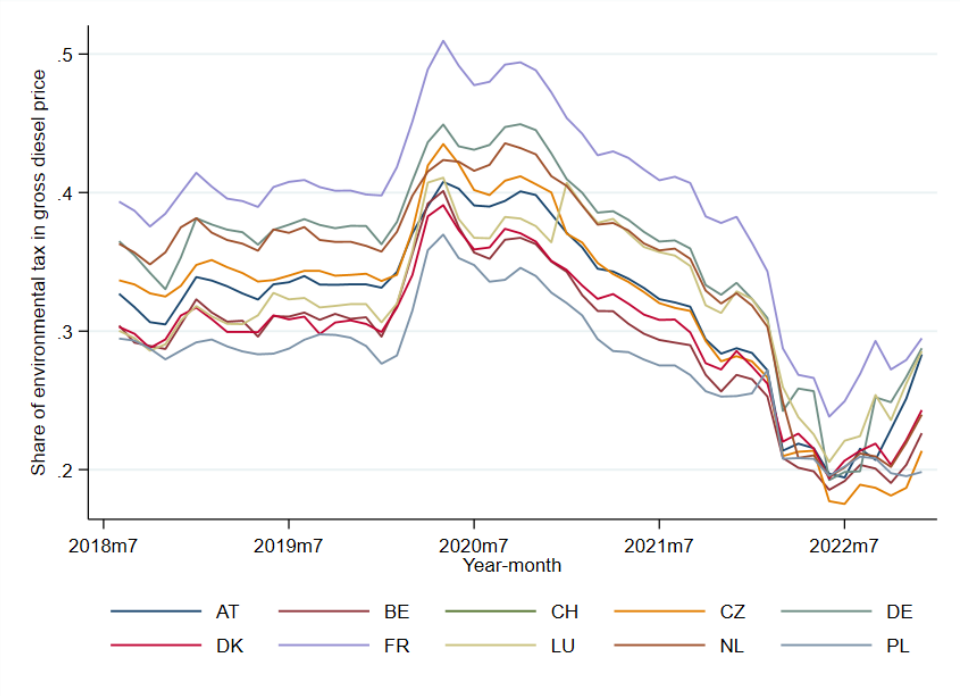
The next pages include the following appendices:

- Environmental Taxes and Diesel Price (Appendix A1)
- Toll Data (Appendix A2)
- Survey Data (Appendix A3)
- Emission Data (Appendix A4)
- Variable Definitions (Appendix B).

A Further Descriptive Information and Results

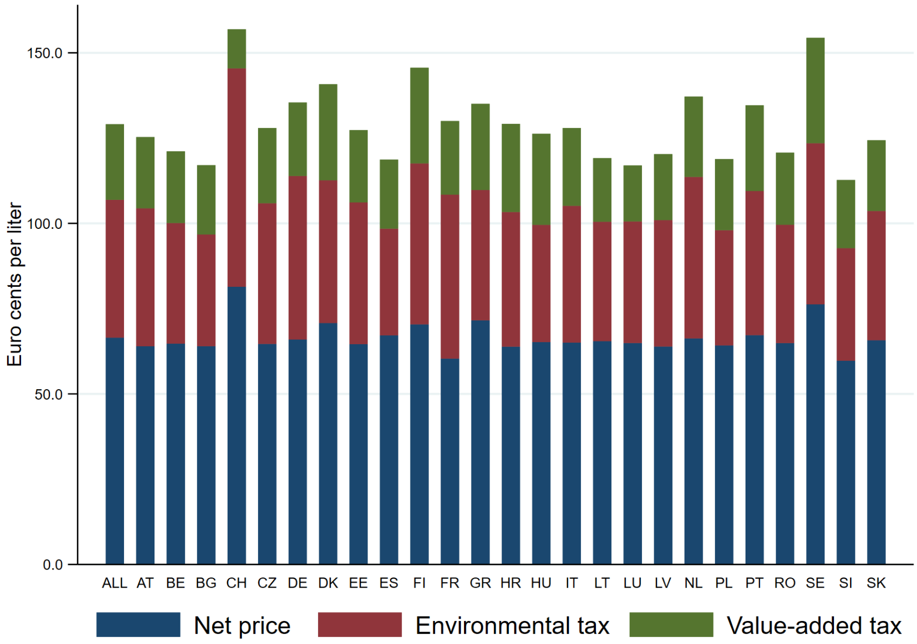
A1 Environmental Taxes and Diesel Prices

Figure IV.A1.1: Share of Environmental Taxes in Gross Diesel Price



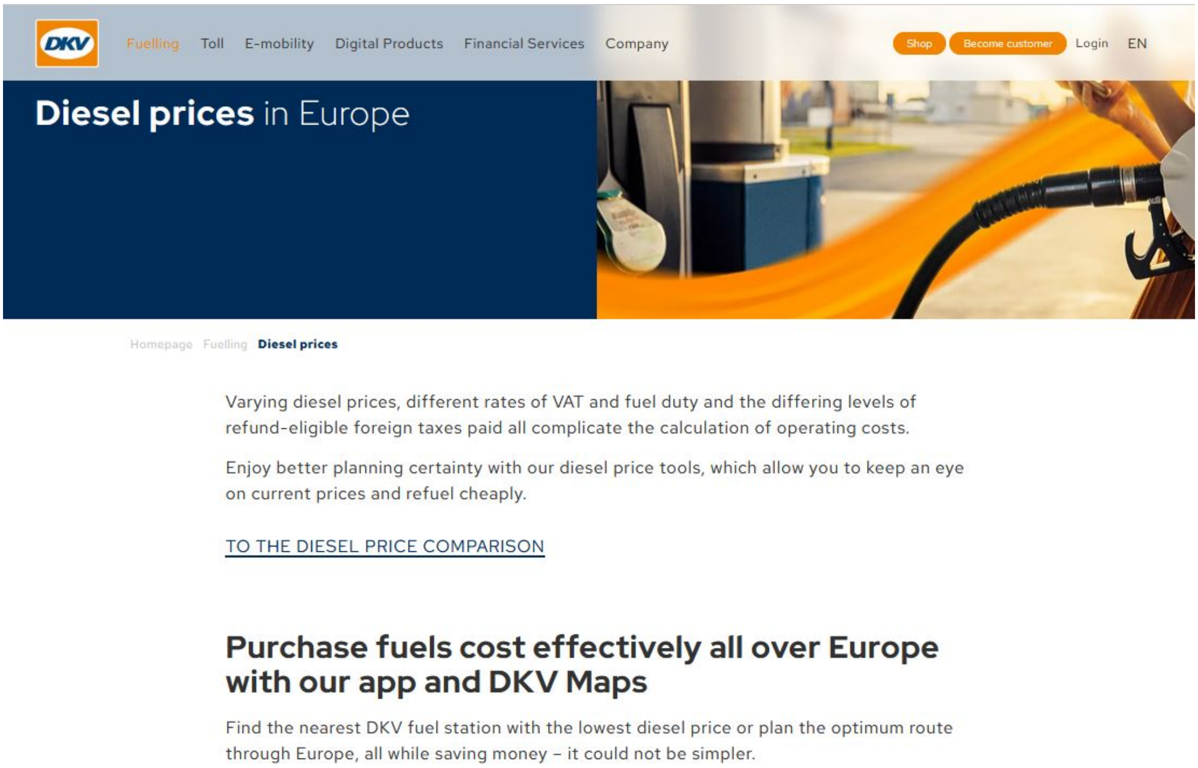
Notes: The figure illustrates the share of environmental taxes in the total gross price of diesel in Germany and its neighboring countries during the period spanning from mid-2018 to 2022.

Figure IV.A1.2: Diesel Price Components by Country



Notes: The figure illustrates the components of the total gross price of diesel by continental European countries. The numbers displayed are averages over the time period 2011 to 2022. The components are the net price of diesel, the environmental tax on diesel and the value-added tax. The price components are displayed in euro cents per liter of diesel.

Figure IV.A1.3: Advertising Diesel Price Tools for Trucking Companies

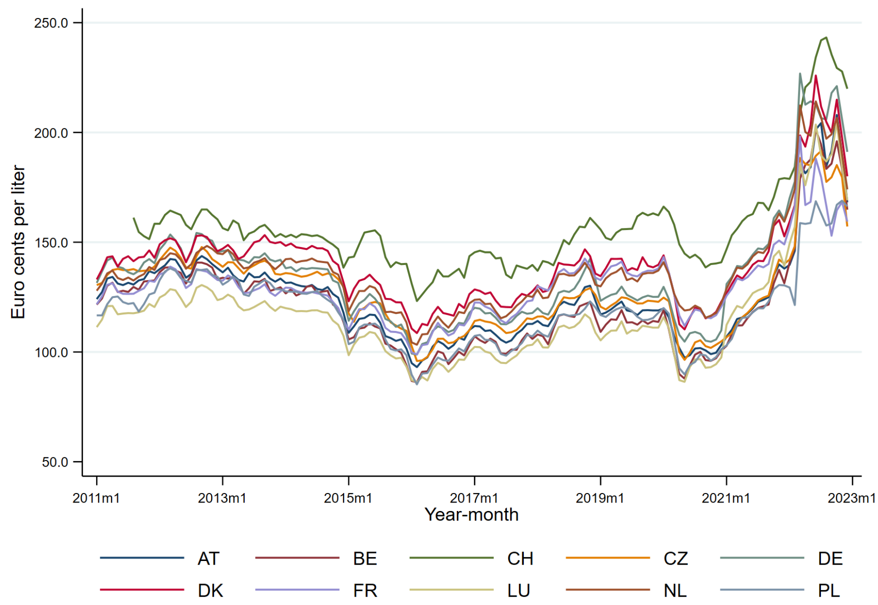


Notes: The figure shows anecdotal evidence how the company DKV Mobility advertises diesel price tools for trucking companies.

Figure IV.A1.4: Net and Gross Diesel Price by Country

(a) Net price diesel

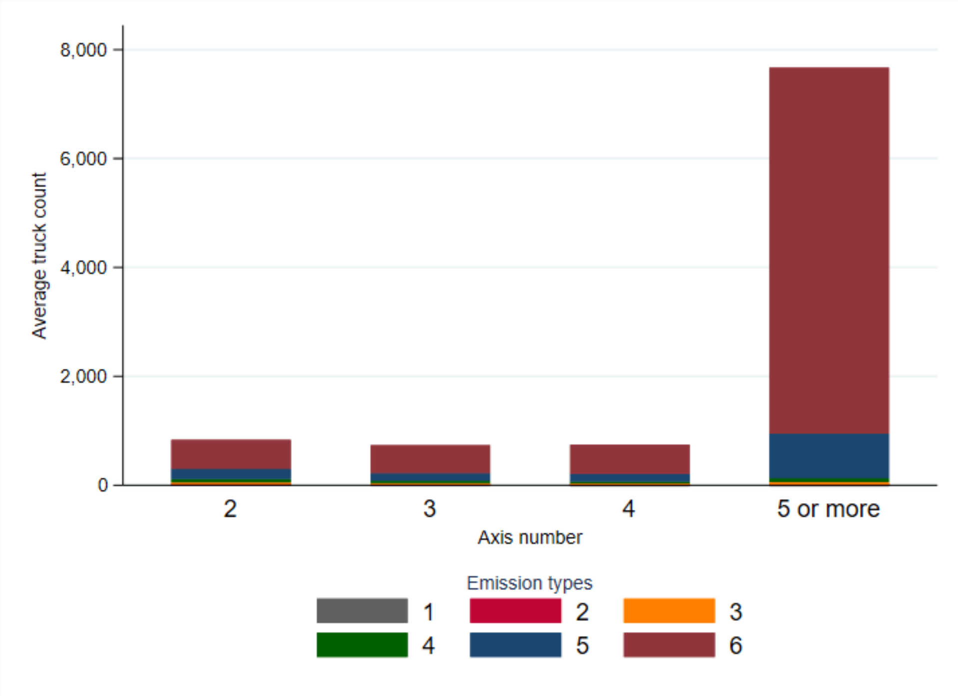
(b) Gross price diesel



Notes: The figure plots the average monthly diesel price in Germany and its neighboring countries for our sample period 2011 to 2022. Panel (a) shows the average monthly net price by country. Panel (b) displays the average monthly gross price including VAT and environmental taxes by country. Prices are displayed in euro cents per liter of diesel.

A2 Traffic: Toll

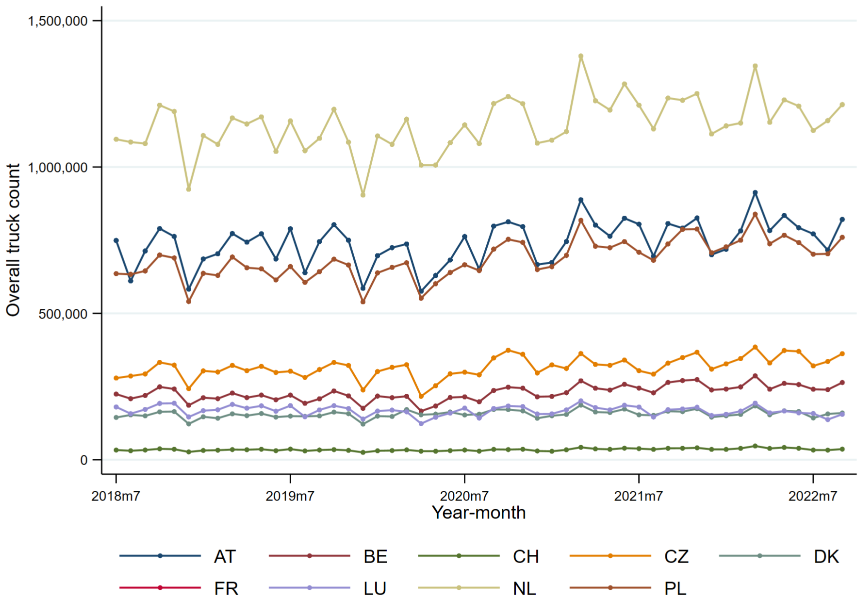
Figure IV.A2.1: Toll Data: Average Truck Count by Axes and Emission Type



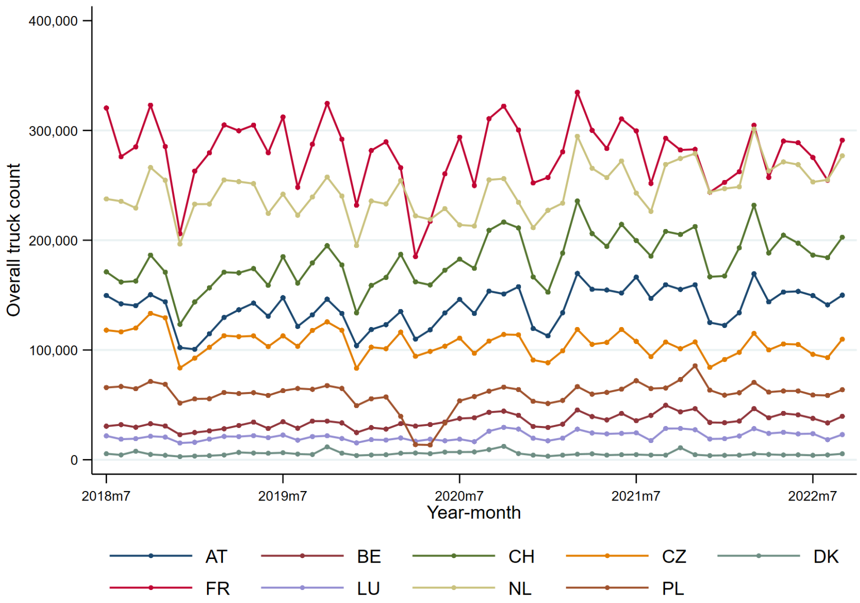
Notes: The figure illustrates the average monthly truck count in our toll data categorized by axis number and emission type. Vehicles with two axes are for example tractors or combined harvesters. Vehicles with three axes are for example car cranes. Trucks in our sample are considered vehicles with more than four axes that are heavily used for road freight transportation. The emission type is based on the european standard for exhaust emissions, Euro 1 to Euro 6. The standards were implemented over time, with Euro 6 being the most recent requirement for newly registered vehicles.

Figure IV.A2.2: Toll Data: Truck Count at Border

(a) Highway



(b) Federal road



Notes: The figure plots the monthly overall truck count at the borders to Germany's neighboring countries. Panel (a) illustrates the monthly truck count at cross-border road-section on highways. Panel (b) displays the monthly truck count at cross-border road-section on federal roads.

Table IV.A2.1: Toll data: Average Monthly Truck Count by Border Distance/Country

		Full Sample	Border	Below 5 km	5-10 km	10-15 km
Overall	*Mean*	7598.59	17727.79	6174.56	6199.36	6469.74
	SD	(17840.57)	(32221.78)	(16257.18)	(13889.69)	(15924.99)
	Obs	691,098	13,094	86,137	72,248	67,178
Austria (AT)	*Mean*	6031.66	19210.92	7125.17	5649.30	4558.28
	SD	(15317.13)	(35621.10)	(19603.19)	(11698.00)	(10663.45)
	Obs	144,389	2,340	13,846	15,897	17,663
Belgium (BE)	*Mean*	3663.81	10165.92	3561.25	1807.36	2825.70
	SD	(11303.86)	(24675.20)	(14278.20)	(2595.45)	(8642.24)
	Obs	65,091	1,326	9,984	7,929	7,242
Switzerland (CH)	*Mean*	6054.93	6765.68	7436.03	6568.55	5141.10
	StD	(6160.11)	(7476.39)	(7616.15)	(6548.51)	(4835.80)
	Obs	77,530	1,632	20,444	14,908	40,546
Czech Republic (CZ)	*Mean*	6542.46	19319.05	5632.14	5446.97	5883.29
	SD	(13095.61)	(29455.54)	(11010.86)	(13949.86)	(14674.59)
	Obs	89,293	1,116	8,964	7,603	9,781
Denmark (DK)	*Mean*	7347.47	26952.02	2344.33	4184.25	5366.37
	SD	(15446.31)	(36443.93)	(1354.03)	(2856.95)	(2612.75)
	Obs	20,880	306	1,836	990	1,632
France (FR)	*Mean*	5481.52	6989.18	4812.66	4697.90	5082.10
	SD	(10744.58)	(12618.05)	(10025.92)	(9632.76)	(9708.28)
	Obs	102,787	2,039	17,118	12,600	7,905
Luxembourg (LU)	*Mean*	3933.19	11826.22	1402.98	4193.85	3626.22
	SD	(8430.01)	(18383.80)	(1439.32)	(6019.25)	(3874.70)
	Obs	44,873	816	5,428	4,831	6,287
Netherlands (NL)	*Mean*	18485.58	33117.67	10999.48	11264.38	20448.70
	SD	(32107.47)	(41153.58)	(27004.83)	(23948.83)	(37228.94)
	Obs	92,305	2,142	12,203	10,196	6,836
Poland (PL)	*Mean*	9058.41	27600.60	7362.24	9457.13	4795.32
	SD	(23800.40)	(46053.79)	(22162.41)	(23624.03)	(6926.83)
	Obs	53,950	1,377	4,790	3,726	3,804

Notes: The table reports average monthly truck counts categorized by road-section and destination country. Full sample includes all road-sections up to 50 km from the border. Border includes only the direct road-section at the border itself. Below 5 km, 5-10 km and 10-15 km comprise all road-sections within the respective corridor distances from the border.

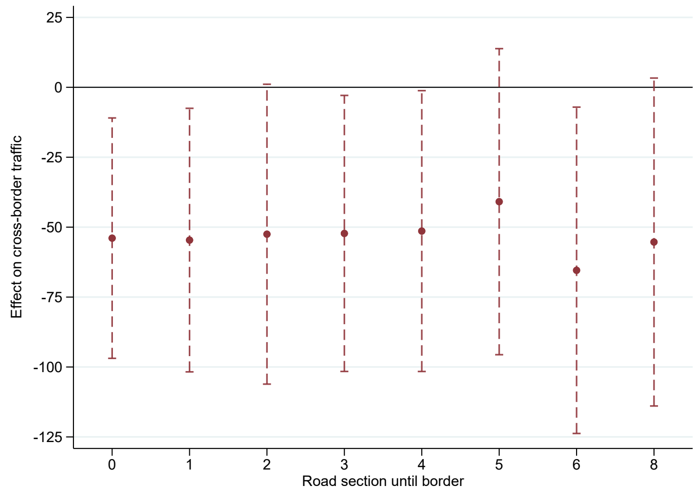
Table IV.A2.2: Toll Data: Alternative Specification

	Log(Cross-border traffic)		
	Highway		
	OLS	*2SLS*	*RF*
	(1)	(2)	(3)
Env. tax differential			-0.002
			(0.002)
Gross price differential	-0.002***	-0.003***	
	(0.001)	(0.001)	
Year-month FE	X	X	X
road-section FE	X	X	X
Observations	2,550	2,550	2,550

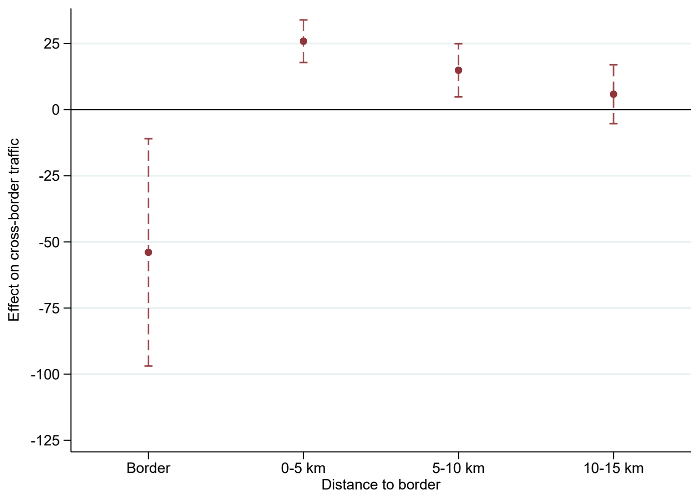
Notes: The table reports results from the toll data analysis using a log specification for the dependent variable cross-border traffic. Column (1) shows results from an OLS specification and (2) from an IV 2SLS regression. The dependent variable is log of the monthly truck count on a cross-border road-section. The independent variable is the (instrumented) gross price differential. Column (3) shows the results of the reduced form regressing log(Cross-border traffic) on the environmental tax differential. The environmental tax differential and the gross price differential are calculated relative to Germany (tax/price in neighboring country - tax/price in Germany) and measured in euro cent per liter of diesel fuel. In all specifications we include road-section and year-month fixed effects. Standard errors are clustered on the road-section level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure IV.A2.3: Toll Data: Full Sample Effect by Distance to Border

(a) By road-section until border



(b) By distance to border



Notes: The figure plots the effect of environmental taxes on commercial traffic by road-section and distance to the border for the full sample including highways and federal roads. The points plotted are the 2SLS estimates regressing the monthly truck count on the instrumented gross price differential. The gross price differential is calculated relative to Germany (price in neighboring country - price in Germany) and measured in euro cent per liter of diesel fuel. Panel (a) presents the effects by road-section until border. Panel (b) presents the estimates by grouping road-section by their distance to the border. 95% confidence intervals are represented by the dashed red lines lines and based on standard errors clustered on the road-section level.

Table IV.A2.3: Toll Data: Robustness Covid-19

	Panel A: Second stage Cross-border traffic		**Panel B: Reduced form** Cross-border traffic	
	Full sample (1)	*Highway* (2)	*Full sample* (1)	*Highway* (2)
Env. tax differential			-44.254**	-326.573***
			(18.049)	(88.811)
Gross price differential	-49.237**	-459.794***		
	(20.815)	(111.871)		
Year-month FE	X	X	X	X
road-section FE	X	X	X	X
Observations	12585	2450	12585	2450

Notes: The table reports robustness tests of the toll data analysis excluding all months (032020 - 04020) that are affected by the Covid-19 pandemic. Panel A shows the results from the second stage regression. Column (2) the results form the reduced form. The dependent variable is the monthly truck count on a cross-border road-section. The independent variable is the instrumented gross price differential in Panel A and the environmental tax differential in Panel B. The environmental tax differential and the gross price differential are calculated relative to Germany (tax/price in neighboring country - tax/price in Germany) and measured in euro cent per liter of diesel fuel. Columns (1) show the results for the full sample, Columns (2) for highways. In all specifications we include road-section and year-month fixed effects. Standard errors are clustered on the road-section level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table IV.A2.4: Toll Data: Robustness Ukraine War

	Panel A: Second stage Cross-border traffic		**Panel B: Reduced form** Cross-border traffic	
	Full sample (1)	*Highway* (2)	*Full sample* (1)	*Highway* (2)
Env. tax differential			-68.992***	-484.053***
			(24.746)	(99.859)
Gross price differential	-165.044***	-552.531***		
	(61.591)	(146.755)		
Year-month FE	X	X	X	X
road-section FE	X	X	X	X
Observations	11034	2150	11034	2150

Notes: The table reports robustness tests of the toll data analysis excluding all months (022022 - 12022) that are affected by the Ukraine. Panel A shows the results from the second stage regression. Column (2) the results form the reduced form. The dependent variable is the monthly truck count on a cross-border road-section. The independent variable is the instrumented gross price differential in Panel A and the environmental tax differential in Panel B. The environmental tax differential and the gross price differential are calculated relative to Germany (tax/price in neighboring country - tax/price in Germany) and measured in euro cent per liter of diesel fuel. Columns (1) show the results for the full sample, Columns (2) for highways. In all specifications we include road-section and year-month fixed effects. Standard errors are clustered on the road-section level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table IV.A2.5: Toll Data: Highway Effect by Country

		Cross-border traffic		
		Second stage (1)	*Reduced form* (2)	*Observations* (3)
Austria (AT)	*Env. tax differential*		-708.090*** (145.250)	510
	Gross price differential	-335.246*** (65.176)		510
Belgium (BE)	*Env. tax differential*		-670.545** (133.209)	204
	Gross price differential	-411.137*** (70.559)		204
Switzerland (CH)	*Env. tax differential*		157.447 (137.209)	102
	Gross price differential	-206.558 (126.654)		102
Czech Republic (CZ)	*Env. tax differential*		-882.522*** (60.238)	204
	Gross price differential	-403.141*** (23.772)		204
Denmark (DK)	*Env. tax differential*		-453.825** (9.138)	102
	Gross price differential	-209.418*** (2.967)		102
Luxembourg (LU)	*Env. tax differential*		-207.071*** (34.003)	204
	Gross price differential	9285.859*** (1317.286)		204
Netherlands (NL)	*Env. tax differential*		-514.451*** (89.554)	816
	Gross price differential	-291.295*** (49.067)		816
Poland (PL)	*Env. tax differential*		-1090.498*** (65.176)	408
	Gross price differential	-509.069*** (205.568)		408

Notes: The table reports results of the toll data analysis by country on highways. Column (1) shows the results from the second stage regression. Column (2) the results form the reduced form. The dependent variable is the monthly truck count on a cross-border road-section. The independent variable is the instrumented gross price differential in the second stage specification and the environmental tax differential in the reduced form specification. The environmental tax differential and the gross price differential are calculated relative to Germany (tax/price in neighboring country - tax/price in Germany) and measured in euro cent per liter of diesel fuel. Standard errors are clustered on the road-section level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

A3 Traffic: Survey

Table IV.A3.1: Survey Data: Meta-information

	Global sampling rate	Response rate (2012)
Austria (AT)	0.8	98.5
Belgium (BE)	0.9	65.3
Bulgaria (BG)	0.2	69.8
Switzerland (CH)	0.3	58.6
Czech Republic (CZ)	0.3	91.9
Germany (DE)	0.4	96.3
Denmark (DK)	0.4	99.0
Estonia (EE)	0.7	75.5
Spain (ES)	0.3	94.3
Finland (FI)	0.1	58.1
France (FR)	0.3	77.9
Greece (GR)	0.1	83.8
Croatia (HR)	0.8	80.1
Hungary (HU)	1.3	87.5
Italy (IT)	0.4	25.5
Lithuania (LT)	0.6	90.1
Luxembourg (LU)	3.3	91.9
Latvia (LV)	0.5	78.4
Netherlands (NL)	0.5	76.6
Norway (NO)	0.3	95.6
Poland (PL)	0.1	84.7
Portugal (PT)	0.9	75.4
Romania (RO)	0.7	97.3
Sweden (SE)	0.4	70.1
Slovenia (SI)	0.7	74.5
Slovakia (SK)	0.1	87.5
Average	0.7	80.5

Notes: The table reports meta-data about the European Road Freight Transport Statistics. The figures are obtained from the 2014 EUROSTAT publication "Methodologies used in surveys of road freight transport in Member States, EFTA and Candidate Countries". The global sampling rate is expressed as a percentage across time (yearly weeks) and space (countries). Response rate is also a percentage.

Table IV.A3.2: Survey Data: Probit Specification

	Panel A: Second stage	**Panel B: Reduced form**
	Deviation	Deviation
	(1)	(1)
Env. tax average		0.034^{***}
		(0.007)
Gross price average	0.054^{***}	
	(0.007)	
Observations	1,182,316	1,182,339

Notes: The table reports results from the survey data analysis using a probit model. Panel A shows results from the second stage regression, Panel B from the reduced form. The dependent variable is the deviation indicator and the independent variable is the instrumented average diesel gross price on the journey for the second stage and the environmental tax differential for the reduced form. Robust standard errors are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table IV.A3.3: Survey Data: Share of Routes by Country

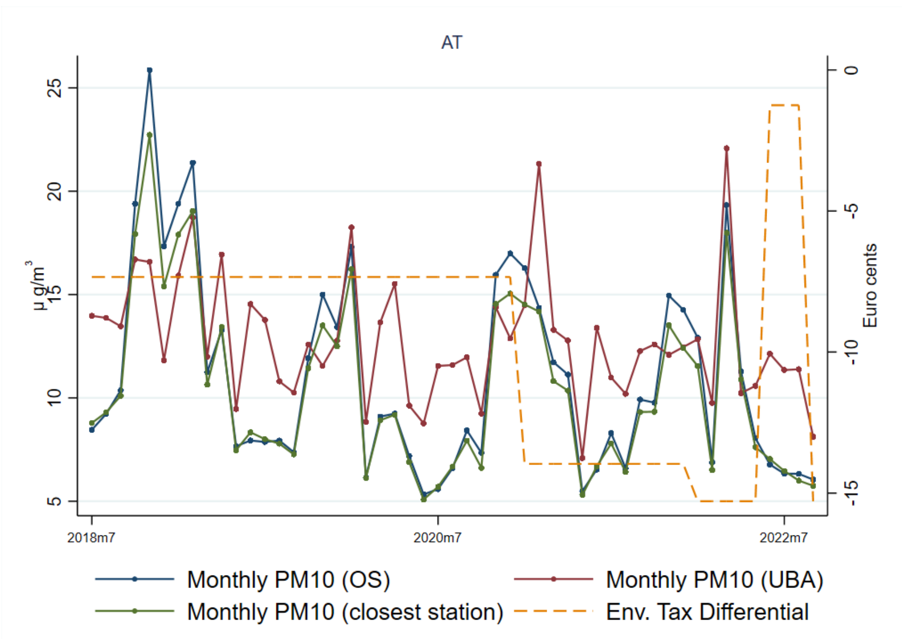
	Share overall routes	Share deviating routes	Ratio per country
Austria (AT)	0.110	0.279	2.531
Belgium (BE)	0.352	0.414	1.177
Bulgaria (BG)	0.001	0.000	0.000
Switzerland (CH)	0.043	0.075	1.733
Czech Republic (CZ)	0.072	0.092	1.274
Germany (DE)	0.522	0.709	1.359
Denmark (DK)	0.013	0.001	0.095
Estonia (EE)	0.007	0.000	0.052
Spain (ES)	0.056	0.012	0.223
Finland (FI)	0.001	0.000	0.285
France (FR)	0.242	0.223	0.919
Greece (GR)	0.000	0.000	0.000
Croatia (HR)	0.008	0.015	1.887
Hungary (HU)	0.065	0.069	1.064
Italy (IT)	0.074	0.113	1.538
Lithuania (LT)	0.022	0.006	0.295
Luxembourg (LU)	0.075	0.135	1.801
Latvia (LV)	0.019	0.004	0.199
Netherlands (NL)	0.377	0.487	1.291
Norway (NO)	0.000	0.000	0.000
Poland (PL)	0.070	0.062	0.882
Portugal (PT)	0.019	0.002	0.130
Romania (RO)	0.009	0.014	1.522
Sweden (SE)	0.003	0.000	0.171
Slovenia (SI)	0.037	0.045	1.220
Slovakia (SK)	0.047	0.068	1.443
Observations	1,285,633	80,687	1,285,633

Notes: This table shows the country share of truck traffic routes in Europe. The first column provides the share of overall journeys passing through a particular country. The second colum provides the same statistic, but only for the subset of routes which diverge from the optimal route calculated via GMAP. The third and last column contains the ratio between the first two columns, indicating whether a specific country is part of detours relative to its overall importance in international truck traffic.

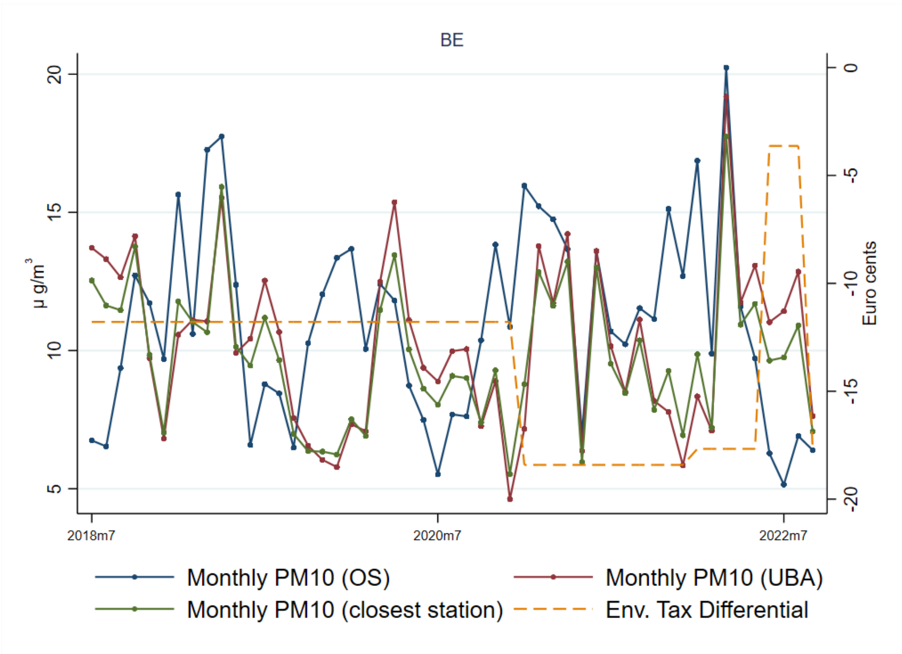
A4 Emissions

Figure IV.A4.1: Emission Data: Environmental Tax Differentials and Emissions by Border-country

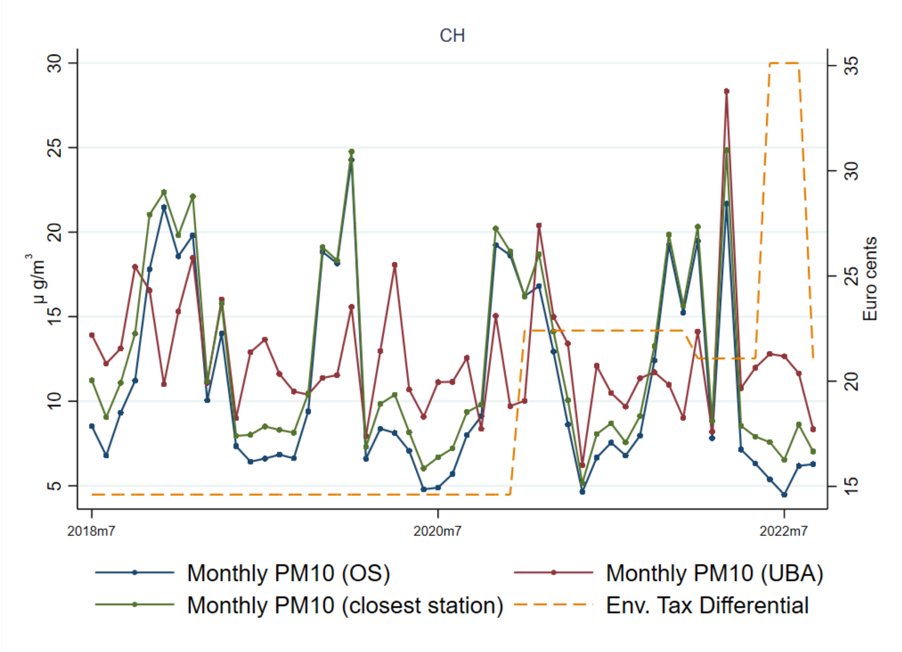
(a) Austria



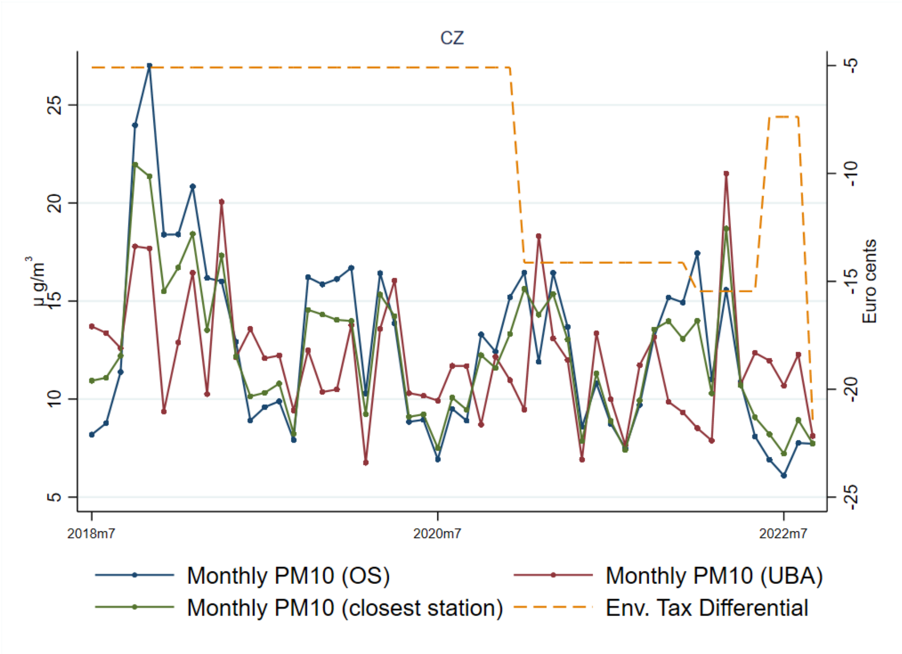
(b) Belgium



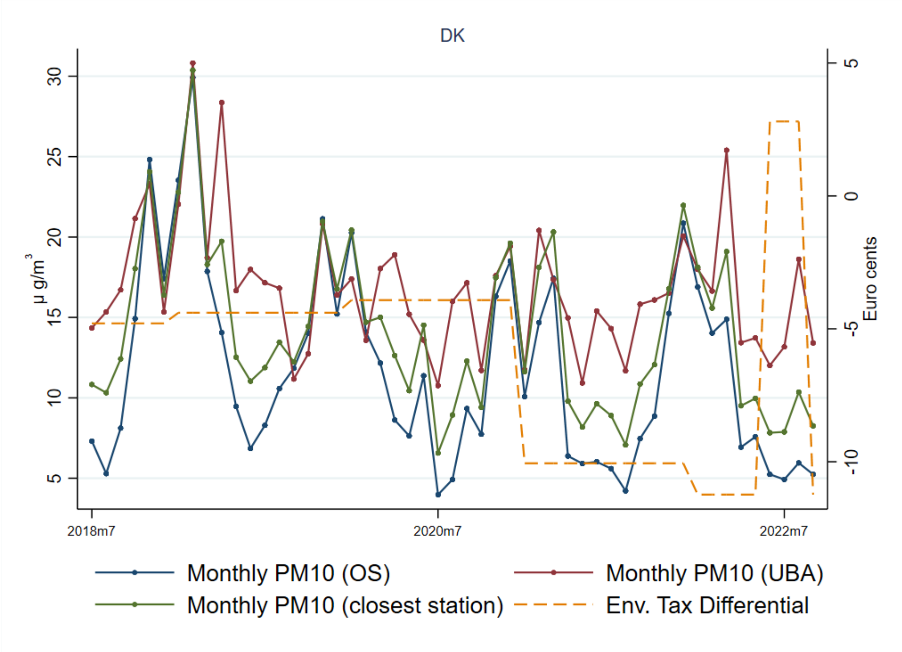
(c) Switzerland



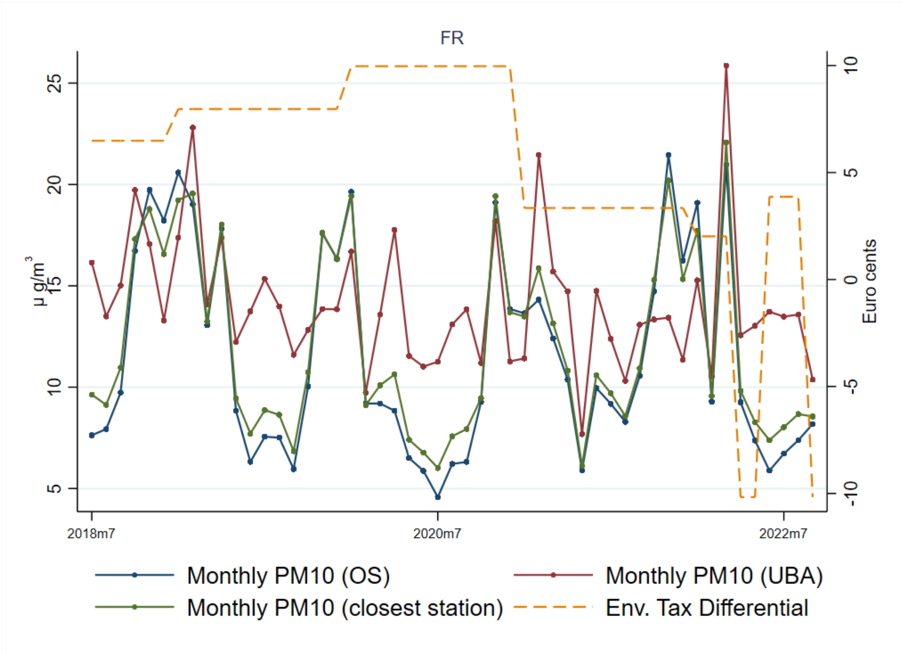
(d) Czech Republic



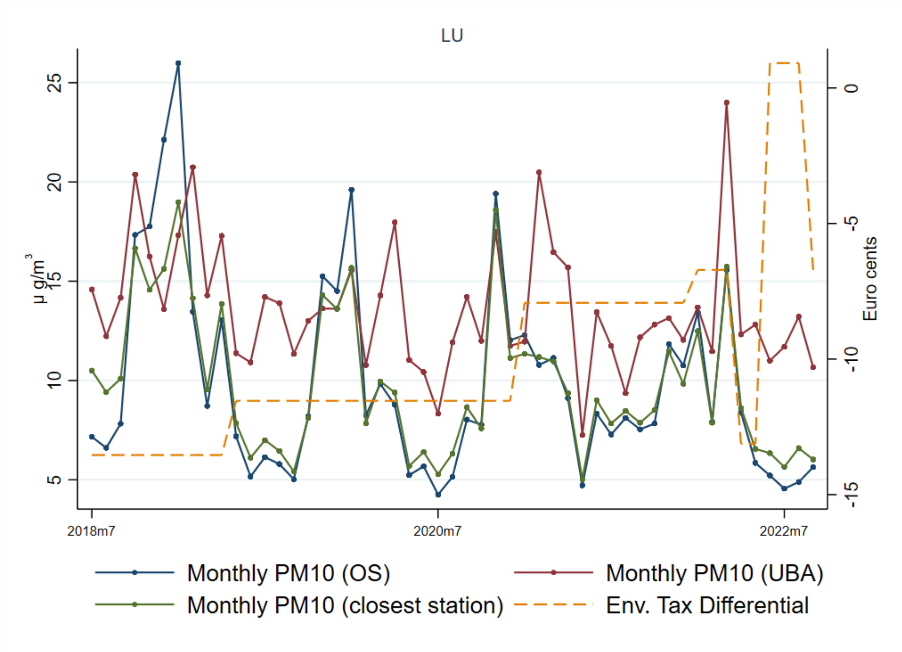
(e) Denmark



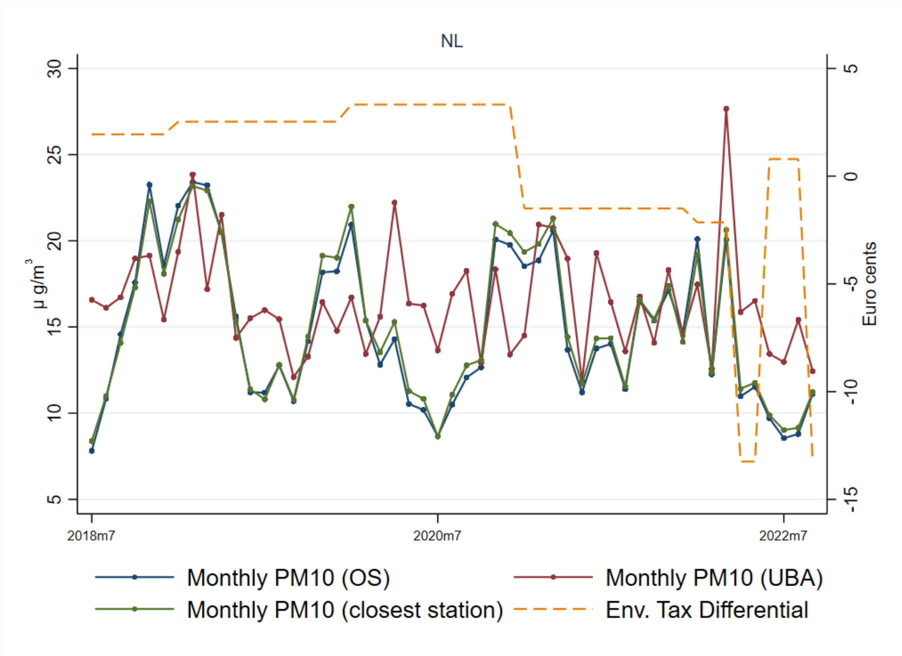
(f) France



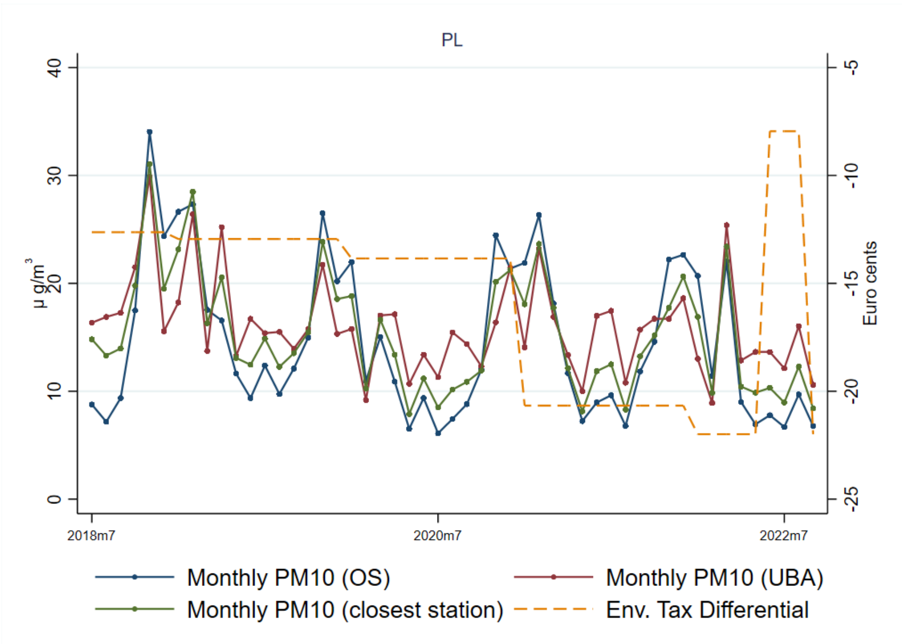
(g) Luxembourg



(h) Netherlands



(i) Poland



Notes: The figure plots average environmental emissions on cross-border roads and the corresponding environmental tax differential between Germany and its neighboring countries over the time period from July 2018 until September 2022. Monthly PM10 is measured in $\mu g/m^3$, and shown for each data source separately. The environmental tax differential is relative to Germany (tax in neighboring country - tax in Germany) and measured in euro cent per liter of diesel fuel.

Table IV.A4.1: Emission Data: Effect of Tax Differential on Local Pollution

	PM10					
Env. tax differential	-0.166**	-0.0749	-0.0982**	0.00165	0.0231	0.0312
	(0.07)	(0.05)	(0.05)	(0.03)	(0.03)	(0.03)
Constant	13.46***	13.02***	12.77***	12.52***	12.96***	13.23***
	(0.51)	(0.15)	(0.09)	(0.02)	(0.05)	(0.11)
Meters	750	1000	1250	1500	1750	2000
Adj. R^2	0.62	0.67	0.65	0.70	0.70	0.70
Obs. Number	278	493	539	885	1,168	1,689

Notes: The table reports reduced form estimates of regressing local, cross-border measures of PM10 on cross-border environmental tax differentials using OLS. Meters refers to the road-section distance to the closest emission sensor station. One-way clustered standard errors are reported in parentheses. All columns include road-section and year-month fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

B Variable Definitions

Variable	Definition
Toll data	
Gross price differential	Difference in the diesel gross price between Germany's neighboring country c and Germany in year-month m.
Env. tax differential	Difference in environmental tax rate on diesel between Germany's neighboring country c and Germany in year-month m.
Cross-border traffic	The number of trucks passing a road-section i in year-month m.
Survey data	
Gross price average	Average diesel gross price on journey j in year-month m.
Env. tax average	Average environmental tax rate on journey j in year-month m.
Deviation	Indicator variable equal to one if the truck deviated on a journey in distance and to another country.
Emission data	
Emissions	PM10 emissions measured by the closest sensor station to road-section i in year-month m.

Chapter V

The Effects of Mandatory Private Disclosure on Public Disclosure – Evidence from CbCR

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Abstract: We analyze the effect of increased mandatory private disclosure to fiscal authorities on voluntary public disclosure decisions. We exploit the introduction of Country-by-Country Reporting (CbCR), which requires large multinational corporations to report detailed geographic segment information to fiscal authorities to prevent income shifting. Using both Difference-in-Differences and Regression Discontinuity designs in our empirical approach, we investigate how multinational corporations respond to CbCR in their public disclosure of geographic information in financial statements and the narrative part of annual reports. We find that firms subject to CbCR decrease their disclosure of qualitative and sensitive geographic information. This effect is particularly pronounced for firms potentially subject to higher scrutiny by tax authorities and for firms with a stronger international presence. Our results suggest that private and public disclosure of geographic information are substitutes in the context of the mandatory private reporting requirement under CbCR.

1 Introduction

Profit shifting by multinational corporations is viewed as a pervasive problem (Tørsløv and Wier, 2023; Clausing, 2016). Profit shifting erodes the tax base, reducing tax revenue and contributing to the fiscal constraints faced by many governments. Additionally, it undermines the political legitimacy and credibility of the existing international framework. Therefore, the OECD is actively engaged in reducing profit shifting. One major initiative of the OECD's Base Erosion and Profit Shifting (BEPS) project is Country-by-Country Reporting (CbCR) (OECD 2015). Under CbCR, companies above a certain revenue threshold are required to file detailed country-level information, which is shared among fiscal authorities upon request.

Firms are subject to several information reporting regimes, each creating specific reporting incentives depending on the intended users of the information (e.g., investors, fiscal authorities). Still, the information demanded by different stakeholders may overlap to a certain extent (Müller et al., 2020). Prior literature has established that firms' mandatory disclosures to selected stakeholders influence public disclosure decisions (Bozanic et al., 2017; Towery, 2017). However, it is not clear how increased mandatory private tax reporting regulations such as CbCR affect the public disclosure decisions of firms. In this context, our study aims to answer the following research question: Did the introduction of CbCR change the public disclosure choices of the affected multinational corporations?

Theory predicts that firms weigh the costs and benefits of voluntarily disclosing tax-related information to investors and other stakeholders (Healy and Palepu, 2001). Whether private disclosure requirements effectively change public disclosure decisions is ambiguous because firms will only react if they assume that investors and other stakeholders will find the public information useful and that those benefits will outweigh the costs of the fiscal authority and competitors using the information. More specifically, stricter private tax reporting might reduce proprietary costs associated with that information. If the fiscal authority already has the information as a result of the confidential disclosure, the public disclosure of the information may be less costly. Thus, both sets of disclosure would be complements from the firm's perspective if firms increase voluntary public disclosure of information that is valuable for investors (Kays, 2022). Alternatively, firms may decrease voluntary public disclosure if CbCR increases the risk that stakeholders exert pressure on fiscal authorities to investigate further if stakeholders are discontent with the firm's geographic distribution of profits. Voluntary public disclosure may also decrease to avoid the risk of unwarranted attention from fiscal authorities if discrepancies between private CbCR and voluntary public disclosure arise.[1] This would suggest that private and public disclosure are substitutes from the firm's perspective (Hope et al., 2013).

This study uses the introduction of CbCR in several countries as an exogenous shock to answer the question whether firms adjust their voluntary disclosure in annual reports. It aims to improve our understanding of how private disclosure requirements may affect public disclosure decisions. Our main identification strategy is based on a Difference-in-Differences (DiD) design that exploits the applicability of CbCR at the revenue threshold. If CbCR alters the costs of public disclosure for the reported information, one would expect changes in disclosure that relate to firms' geographic activities or earnings. We also exploit local variations in disclosure around the revenue threshold through a Regression Discontinuity Design (RDD).

We construct our dataset based on three main sources. We first draw a worldwide selection of financial data for listed multinational corporations from BvD's Orbis database. Second, we use archival data on these firms' segment reporting from the Bloomberg database to analyze changes in their disclosed geographic segments by financial item. Third, we employ textual analysis methods to exploit the rich set of qualitative disclosure contained in the text of annual reports.[2] We obtain the annual reports from Perfect Information's "Filings Expert" database and EDGAR database from the Securities

[1] Firms may also decrease their voluntary public disclosure if investor demand for information decreases due to better monitoring of firms by fiscal authorities after CbCR, thereby mitigating information asymmetries between the firm and its shareholders.

[2] We refer to qualitative disclosure as any textual information provided in the annual report. This also includes sections on management discussion and analysis. In many accounting regimes, these management reports are not required to be audited, although in some regimes, the auditor may have to positively confirm that there are no discrepancies between the financial report and the management report.

and Exchange Commission (SEC).[3] This approach enables us to exploit the information contained in annual reports' narrative sections (Lewis and Young, 2019; Loughran and McDonald, 2016). The resulting sample covers 4,253 firms in the years 2010 to 2020 with 25,950 total observations.

We provide evidence that firms significantly changed their disclosure practices towards less voluntary information provision on their geographic activities and earnings after the introduction of mandatory CbCR. We further find that quantitative disclosure of sensitive geographic information decreased. Similarly, we document a decrease in qualitative country disclosure in annual reports. We find the first effect to be more pronounced for firms located in jurisdictions with higher potential scrutiny by fiscal authorities. Moreover, the decrease in qualitative geographic disclosure is stronger for firms which are more international. Hence, our main results suggest that, in the context of geographic information provision, voluntary public disclosure and mandatory private disclosure are substitutes from the firm's perspective.

Most studies on the interaction of mandatory and voluntary disclosure consider settings in which both types of disclosures are public. Bischof and Daske (2013), for example, confirm, in the context of stress-testing banks' capital buffers, the prediction by Einhorn (2005) that initial mandatory disclosure lowers the threshold for future voluntary disclosures. Furthermore, disclosure theory suggests that firms may increase voluntary disclosure to investors when they have higher-quality internal information (Verrecchia, 1990). Mandating additional disclosure can force firms to improve their internal information environment and to process all available information more effectively (see, e.g. Samuels (2021) for related evidence).

However, which of these existing insights carry over to the case when mandatory disclosure is private, not public, is an open question. Evidence on the setting with mandatory private disclosure is scarce and we contribute to this emerging literature. So far, the few studies on the interaction between private and public disclosure sets have mostly focused on empirical settings in the United States (US) (Bozanic et al., 2017;

[3]For more information, see https://www.perfectinfo.com/filings-expert(accessed on 1 June 2021).

Towery, 2017; Hope et al., 2013). We extend this literature by examining the disclosure responses of a large, international sample of firms with respect to geographic information, which exhibits very different characteristics compared to other disclosure items.

Bozanic et al. (2017) find that, following mandatory private disclosure in the form of Schedule UTP, firms significantly increased the quantity of voluntary tax-related disclosures, consistent with lower tax-related proprietary costs of disclosure. Extrapolating this pattern to the private CbCR setting would imply that voluntary geographic information disclosure increases once mandatory private disclosure to fiscal authorities is introduced. However, our results reveal the opposite pattern after CbCR introduction. This shows that an increase in voluntary disclosure in response to mandatory private disclosure to the fiscal authority cannot be taken for granted. Instead, the relationship between mandatory private disclosure and public voluntary disclosure can even invert under certain circumstances. This is the case in our setting, in which the characteristics of the disclosure content differ from previous analyses in important aspects. Besides the proprietary cost of disclosure to fiscal authorities, there are two other sources of substantial proprietary costs of geographic disclosure: leakage of valuable information to competitors and reputational concerns related to stakeholder discontent with the firm's geographic distribution of profits or investment. Furthermore, full CbCR being available to the fiscal authority may have positive feedback effects on the latter type of proprietary costs related to public scrutiny, because the public expects the fiscal authority to use its information and investigate further if already the publicly disclosed geographic information reveals conspicuous spatial disparities in profitability.

In a related study, Chi et al. (2023) find that multinational corporations are more likely to issue voluntary effective tax rate (ETR) forecasts after CbCR adoptions, with the interpretation that the tax-related internal information environment improves following CbCR compliance. At first glance, this seems contradictory to our results. However, as discussed above, the difference in outcomes is due to the difference in characteristics of the disclosure content. Disclosure of geographic information potentially incurs substantial proprietary costs related to informing competitors and public scrutiny. Voluntary ETR forecasts may not incur these costs as they are frequently not disaggregated at the segment level. Moreover, non-investing stakeholders with an interest in ETRs generally focus on the realized ETRs in annual accounts instead of the forecasts.

Two studies examine corporate disclosure responses to public tax disclosure regulations (Brown et al., 2019; Kays, 2022). In contrast, we investigate the effect of a confidential reporting regime on public disclosure decisions. It is important to keep in mind that CbCR alters only the amount of information available to fiscal authorities, not to other parties. By analyzing the public disclosure responses to increased private disclosure, we also address the call for more research on the effects of tax-related disclosure regulation (Dyreng and Maydew, 2018; Hanlon and Heitzman, 2010).

2 Institutional Background and Related Literature

2.1 Country-by-Country Reporting and Disclosure of Geographic Activities

The revelation of aggressive tax planning strategies and offshore activities of multinational corporations has moved tax planning into the focus of public attention and created the perception that multinational corporations circumvent existing tax regulations at the expense of the public budgets. Consequently, ensuring tax transparency has become a primary regulatory concern for policymakers around the world. Following its mandate to develop binding policy instruments against BEPS, the OECD proposed a new transfer pricing documentation framework, including a comprehensive CbCR and information exchange system to enhance transparency for fiscal authorities (Action 13). The OECD argues that CbCR should equip fiscal authorities with the information necessary to identify potential transfer pricing risks associated with tax planning strategies (OECD 2015). Unlike other existing CbCR frameworks for banks or the extractive industry, the reports are not made publicly available and are exchanged upon request among fiscal authorities only. The OECD issued detailed guidelines and model rules to harmonize the implementation of CbCR across participating countries. So far, over 100 jurisdictions have adopted the CbCR framework, including a significant fraction of the world's major offshore financial centers (i.e., tax havens).[4] Most countries opted to apply CbCR regulation as of the fiscal year 2016.

The obligation to file a CbC report applies to all multinational corporate groups whose ultimate parent is resident for tax purposes in a country with CbCR legislation in place or which has at least one subsidiary or permanent establishment located in such a country. Multinational corporate groups are exempt from the CbCR filing obligation if the consolidated group revenues in the preceding fiscal year remain below a certain revenue threshold. While governments may set their own thresholds, most legislators adopted a threshold roughly equivalent to EUR 750 million. Given the widespread adoption of CbCR, most multinational corporate groups that exceed the revenue threshold are likely to incur a reporting obligation in at least one country.

The CbC reports consist of three tables. In the first table, multinational corporate groups have to report financial items – aggregated on a country level. These items include, among others, (un-)related party revenues, total revenues, profit before income taxes, income tax paid, and tangible assets. The second table contains a list of all constituent entities of the group by country of residence and their primary business activities. The third table allows multinational corporate groups to explain and specify the financial figures and activities from the previous tables to facilitate the interpretation of the disclosed information for fiscal authorities. Companies may also voluntarily disclose additional qualitative information to avoid ambiguity, for example, by motivating legitimate operations in a tax haven country.

The content of the confidential CbC reports, i.e., the detailed geographic breakdown of financial items and international activities, goes far beyond the normal public disclosure requirements of large firms under IFRS or US GAAP. In fact, geographic reporting only plays a minor role in financial statements. Both standards require companies to report sales and assets in the notes of the financial statements for each material country in which they operate. The disclosure of additional financial items, such as earnings before taxes

[4] The OECD summarizes the current status of implementation for participating countries. See (accessed on 3 January 2023).

or income taxes, is voluntary. Since the standards lack a clear definition of materiality, companies frequently report their home country and aggregate all foreign operations into regions or simply in "foreign area" (Akamah et al., 2018).

Thus, while companies might decide to disclose more granulated information on geographic activities and earnings, they are not required to report on a country-by-country basis. In addition to geographic segment reporting, European firms need to disclose a list of all subsidiaries in the notes. Similarly, US firms must disclose a list of all significant subsidiaries, including their locations in Exhibit 21 (Dyreng et al., 2020). However, no financial items are required to be reported.

Public disclosure of geographic information in annual reports is not limited to accounting figures in financial statements. Most of the other sections of annual reports are narrative in nature and allow managers to convey contextual information about developments that are relevant for future value creation or affect business fundamentals but are not well-captured by the accounting measures. This information could include discussions about firms' foreign business activities, ongoing litigation, or compliance with regulatory requirements. The disclosure of additional content in annual reports is subject to many country-specific regulations and is usually not harmonized across firms. Still, most jurisdictions require firms to include some qualitative "management report" on their business model and the risk environment of the firms to provide a contextual, narrative basis for the backward-looking financial figures. The management reports cover various topics, and managers have considerable discretion in selecting the content and type of information. Beyond these legal provisions, firms often include supplementary information on growth opportunities and risk exposure in foreign markets.

2.2 Effects of Private Tax Reporting on Public Disclosure Decisions

The financial reporting standards define the minimum level of public information disclosure concerning geographic segmentation. Beyond these reporting requirements, managers will assess the costs and benefits of disclosing additional information to their investors and other stakeholders (Healy and Palepu, 2001). Several explicit costs may have impeded managers from voluntarily disclosing more information about geographic activities and performance. First, the cost of preparing the information may have hindered disclosing geographic information in the past. While the costs of preparing such reports may not be substantial, the cost of complying with CbCR was a major concern firms raised against the CbC requirement (Spengel et al., 2019). However, after the introduction of CbCR, the cost of publicly disclosing this information (at least partially) is substantially reduced. This would tend to increase firms' voluntary disclosure of geographic information as a response to mandatory private CbCR.

The assumption that mandatory disclosure may spur firms to produce new (and potentially beneficial) information is consistent with the results of Shroff (2017). The author finds that after changes in GAAP, the firm's investments change, as the act of complying with GAAP presents the manager with more information that helps inform investment. Another reason why companies were hesitant to disclose geographic information prior to CbCR could be that they expected fiscal authorities to access and use the information from the public financial disclosures.[5] Hope et al. (2013), for instance, show that firms opting for disclosing less geographic earnings in their segment report have lower effective tax rates (ETRs). The authors conclude that firms with low ETRs reduce voluntary disclosure to disguise their tax planning behavior from fiscal authorities. Similarly, Deng et al. (2021) document that tax-avoiding firms are less likely to disclose segment-level tax information. The introduction of a private CbCR makes these considerations obsolete, as fiscal authorities now have very detailed information at their disposal. Hence, firms might be more inclined to disclose this information publicly in their annual reports after CbCR. The firm's voluntary public information provision and its mandatory private disclosure would then be complements, the same pattern as in Bozanic et al. (2017).

Yet, disclosing geographic information might still be prohibitively costly for some firms. For instance, information about the profitability of operations in foreign markets might be helpful to competitors. In support of the idea that firms expect competitors to

[5]For the US, Bozanic et al. (2017) show that the IRS indeed downloaded firms' financial disclosures as an additional source of information.

learn from their corporate disclosures, Leung and Verriest (2019) show that companies tend to hide information about operations in economically attractive regions and regions with low market entry barriers. These competitor-related proprietary concerns could lead to firms being unwilling to disclose the information, despite having the information compiled already.

In addition to proprietary costs of geographic disclosure remaining high – due to proprietary information leaking to competitors or due to concerns about public scrutiny – there are three reasons for which mandatory private CbCR can have a substitutive effect on firms' voluntary public provision of geographic information. First, the country-level numbers in the private CbCR may not add up to the same geographic proportions that one would expect based on the geographic segment information disclosed before CbCR – either because firms have responded to CbCR by shifting input factors (De Simone and Olbert, 2022), or also because firms consolidate country-level information differently for private CbCR and for public disclosure. By reducing the level of detail in their voluntary geographic information, firms can cloud shifts in the proportions of geographic segments which are directly related to the introduction of CbCR, thereby lowering the risk of unwarranted attention from fiscal authorities and other stakeholders. In a related setting, Towery (2017) examines whether firms adjust their reserves for uncertain tax benefits in financial reports following the private reporting requirements under Schedule UTP. Her results indicate that firms changed their financial reporting for uncertain tax positions to avoid the disclosure of additional information to the IRS.[6]

Second, it is common knowledge that the fiscal authorities have access to the full CbCR information. Hence, the public, the media, or politicians may exert pressure on fiscal authorities to investigate further once they suspect a discrepancy between the firms' public geographic disclosure and the deemed actual firm behavior (Müller et al., 2024). After CbCR, firms consequently reduce voluntary geographic reporting to counteract the

[6]Moreover, firms may have used the degrees of freedom in voluntary geographic reporting to pick a specific geographic segmentation suited to signal low levels of tax avoidance. However, CbCR leads to fiscal authorities being informed at the granular country level. This eliminates the opportunity to portray a specific geographic picture of the firm to fiscal authorities via voluntary reporting. Hence, mandatory private CbCR decreases a specific incentive for voluntary geographic reporting.

increased risk from public scrutiny.

Third, investors may perceive fiscal authorities as de facto the largest minority shareholders of firms due to their tax claim on firm profits. The authorities' monitoring of firms benefits regular shareholders as it inhibits not only tax avoidance activities but also related opportunities for managers to extract private benefits (Bennedsen and Zeume, 2018; Desai et al., 2007; Desai and Dharmapala, 2006; Dutt et al., 2019; Hanlon et al., 2014). In this case, CbCR leads to better informed fiscal authorities and thus better external monitoring. Consequently, voluntary geographic information disclosure becomes less relevant for mitigating information asymmetries between firms and investors. The introduction of private CbCR – a geographic breakdown of activities and profitability – hence constitutes a major regulatory shock to the information environment of multinational corporations reducing the information asymmetry between international firms and fiscal authorities. Whether and how the public disclosure of geographic information changes following CbCR is eventually an empirical question. Considering the competing predictions from the previous arguments, we do not make a directional prediction, but state the hypothesis in null form:

Hypothesis V.1: *Firms will not change their (voluntary) public disclosure of geographic information following the implementation of CbCR.*

3 Empirical Approach and Methodology

3.1 Empirical Strategy

DiD approach

As a baseline identification approach, we use the introduction of CbCR as an exogenous policy shock to companies' information environment affecting their voluntary disclosure decisions. Therefore, our identification strategy is based on a DiD approach estimated via OLS. This allows us to isolate the effect of the policy (Angrist and Pischke, 2014). CbCR is implemented via staggered introduction at a country level, and only firms above a certain revenue threshold are subject to the confidential reporting requirement (Joshi, 2020). Thus, we can compare firms subject to CbCR's disclosure requirements before and after the implementation of CbCR with firms below the revenue threshold. Equation (1) depicts the baseline DiD analysis of our research question:

$$y_{i,t} = \beta_0 + \beta_1 \text{Treat}_i \times \text{Post}_t + \sum_j^J \gamma_j X_{j,i,t} + \sum_i^I \theta_i Firm_i + \sum_t^T \lambda_t \text{Year}_t + \mu_{i,t} \tag{V.1}$$

where $y_{i,t}$ is a measure indicating geographic disclosure for a given firm i and year t. We explain our dependent variables in Section 3.2 and Table V.A1. The variables Treat_i and Post_t capture the effect of being treated, i.e. being subject to CbCR. Treat_i is a dummy variable equal to 1 for firms whose turnover is above the CbCR threshold in the periods preceding CbCR implementation, and equal to 0 otherwise. Likewise, Post_t is equal to 1 if the firm is located in a country which implemented CbCR in year t. We also include two-way fixed effects Firm_i and Year_t that capture unobserved constant factors at the firm and year level. Standard errors $\mu_{i,t}$ are clustered at the firm level.[7]

We follow prior literature and include several variables control variables to control for factors associated with the choice to disclose. These are denoted by $X_{j,i,t}$ and explained in Table V.A1. We include a proxy for firm size (firm $\text{size}_{i,t}$) calculated as the log of total assets. Moreover, we control for profitability (return on $\text{assets}_{i,t}$ and return on $\text{sales}_{i,t}$, debt capacity ($\text{leverage}_{i,t}$), and intangible intensity ($\text{intangibles}_{i,t}$).

In addition, we include a proxy that measures the international exposure of firms (foreign $\text{subsidiaries}_{i,t}$). The variable is equal to the logarithmic count of all majority-owned foreign subsidiaries of a firm in a given year. Importantly, foreign $\text{subsidiaries}_{i,t}$ allows us to control for organizational changes in firm structure that might affect geographic disclosure decision. The last control variable, share of tax-haven $\text{subsidiaries}_{i,t}$, measures the share of subsidiaries that are located in tax haven jurisdictions to control for tax aggressiveness of the firms.[8] Together, both variables allow us to respond to

[7] As we combine fixed effects with clustered standard errors, we drop singleton observations because these could otherwise lead to overstated significance (Correia, 2015).
[8] We follow the tax haven definition applied by Law and Mills (2022).

evidence on private CbCR reporting that examines the organizational structure of large multinational corporations. Specifically, De Simone and Olbert (2022) find that firms affected by CbCR reduce ownership in tax haven subsidiaries. By including both the number of foreign subsidiaries and the share of tax haven subsidiaries in our regression, we hence account for these real responses to CbCR.

RDD approach

Because CbCR constitutes a policy intervention that conditions its applicability based on a size threshold, relying on DiD only to identify the causal impact of CbCR on geographic disclosure choices is susceptible for the omission of size-related unobservable factors that influence disclosure behavior. Henceforth and following prior work on CbCR, we complement our existing empirical strategy by implementing a RDD that allows us to identify the local effect of CbCR (Chi et al., 2023; De Simone and Olbert, 2022). To this end, we first restrict the sample to a smaller range above and below the country-specific turnover threshold relevant for CbCR (see Table ?? for details). We then choose turnover bandwidths of EUR 150 Mio. and EUR 300 Mio. around the CbCR threshold. We subsequently estimate the following linear specification:

$$\begin{aligned} y_{i,t} = \beta_0 + \beta_1 \text{Above CbCR Threshold}_{i,t} + \beta_2 \text{Diff CbCR Threshold}_{i,t} + \\ \beta_3 \text{Above CbCR Threshold}_{i,t} \times \text{Diff CbCR Threshold}_{i,t} + \mu_{i,t} \end{aligned} \tag{V.2}$$

Above CbCR Threshold$_{i,t}$ is a binary variable equal to 1 if Diff CbCR Threshold$_{i,t}$, i.e. the difference of a firm i's turnover in year t to the CbCR threshold, is positive, and equal to zero otherwise. Our coefficient of interest is β_1, which measures the discontinuity in outcome variable $y_{i,t}$ at the CbCR threshold. Again, we cluster standard errors $\mu_{i,t}$ at the firm level. In our primary approach, we estimate the above regression for observations after CbCR implementation. As a test whether a supposed effect on disclosure has existed prior to CbCR, we also run the above regression for the pre-CbCR period. If CbCR is the cause of negative changes to disclosure behavior at the threshold, we expect the coefficient β_1 to decrease when comparing the results for the post-CbCR period with the pre-CbCR period. Moreover, prior CbCR research acknowledges the possibility of potential revenue manipulation around the thresholds (De Simone and Olbert, 2022). Firms might also have expectations about how their future treatment status changes and adjust their disclosure behavior accordingly. We thus also estimate our specification of RDD by excluding observations with turnover levels inside a bin of EUR 10 Mio. around the CbCR threshold (Dowd, 2021).

3.2 Measures of Geographic Disclosure

To examine our research question, we use two different types of measures for geographic disclosure: first, we use quantitative segment disclosure data from Bloomberg. We collect the geographic segment information for the following variables: revenues, gross profits, EBITDA, operating income and assets. We then classify these quantitatively disclosed data into two categories. We denote the first category as insensitive geographic information and measure it as the maximum of reported geographic segments for the variables revenues and assets. We qualify the information contained in both variables as insensitive as they pertain to information that a) does not reveal regional firm profitability (which could be interesting to both fiscal authorities and competitors) and b) is already subject to minimum mandatory reporting requirements according to IFRS 8. In contrast, the remaining variables all relate to earnings information contained in the P&L statements of firms, albeit not necessarily disclosed at a geographic level in the absence of such reporting requirements in the IFRS guidelines. We hence denote the second category sensitive geographic information and measure it as the maximum number of reported geographic segments for gross profits, EBITDA and operating income. It is hence not only a measure of disclosure that potentially conveys sensitive proprietary and tax-related information, but also an approximation of the degree to which firms voluntarily disclose beyond what is mandatorily required by accounting regulation.[9]

Second, in addition to our two measures based on quantitative information disclosed

[9]An alternative measure of disclosure with similar properties may be the tax reconciliation statement, although measuring the intensity of information would require a different approach.

in firms' geographic segment reporting, we apply textual analysis methods to capture the qualitative discussion of foreign operations in annual reports. Most firms explain their activities and the corresponding risk exposure in the sections on management discussion and analysis or risk disclosure of their reports. This information provides additional context to the accrual-based accounting figures and often includes forward-looking information. Since non-US reports are not standardized, it is hard to identify common sections across reports or years. This is one reason why previous studies in accounting and finance literature have mainly analyzed standardized Form 10-K documents (Lang and Stice-Lawrence, 2015). To measure voluntary geographic disclosure in the narrative sections, we apply the bag-of-words approach (Li, 2010; Loughran and McDonald, 2011). This conservative approach measures the level of discussion of topics related to information that would also be reported in CbCR.

In contrast to more sophisticated methods, keyword search allows targeting single sentences with explicit reference to selected words or phrases. Despite its simplicity, the method is very powerful, easily replicable, and frequently used in the literature (Bilicka et al., 2022; Ehinger et al., 2024; Loughran and McDonald, 2016). As described in Section 2.2, the introduction of the confidential CbCR might have affected firms' cost-benefit considerations with respect to the optimal level of geographic disclosure. We apply the keyword search using a word list containing country names and their variations[10] to identify sentences with country-specific information. Subsequently, we count all sentences in the document which mention at least one foreign country. References to the firm's country of incorporation are, therefore, excluded. The number of relevant country sentences is then scaled by the total number of sentences (qualitative geographic information). This allows us to assess changes in the relative importance of foreign activities and might be more informative than simply counting the occurrence of country references.[11]

[10]Besides the official country names, we also include the respective adjectives, i.e., "British" or "French", and their inflections on the list.

[11]In regressions with qualitative geographic information as a dependent variable, we further include the fog-index, report length and additional sentiment scores as control variables.

3.3 Sample Selection

In order to analyze whether firms change their disclosure of geographic information following CbCR introduction, we use BvD's Orbis database to identify worldwide, ultimate parent entities (UPE) of listed firms with turnover exceeding EUR 50 Mio. at least once during the period of 2010-2020 (see Table V.A3). We require all firms to have sufficient financial data available in Orbis to estimate our baseline models.[12] From this initial sample, we drop observations without turnover data, which are needed to determine the treatment status of the firm. Next, we exclude firms operating in the banking and extractive industry as these firms may be subject to a public CbCR regime in the EU (Joshi, 2020; Johannesen and Larsen, 2016). Moreover, we lose 3,938 observations which have no international security identifier (ISIN), leaving us with 13,992 unique firms.

We obtain our geographic segment data from the Bloomberg database. Bloomberg extracts these data from publicly available company documents (e.g., annual reports, sustainability reports, investor presentations etc.) of publicly listed firms worldwide. The database hence contains both voluntary and mandatory disclosure items. We disregard highly aggregated information at the supra-national level and consider only items reported at a country level to ensure comparability across observations. To construct our qualitative measure of geographic disclosure from annual reports, we use Perfect Information's "Filings Expert" database. The database contains over 15 million corporate documents for roughly 50,000 globally listed public companies. We convert the annual reports from PDF into machine-readable format and parse the text into sentences to construct our variable of interest (see Appendix B for more details). For US companies, we download the Form 10-Ks by accessing the EDGAR database and use these reports to determine the level of geographic disclosure. After merging the data from Bloomberg and from the annual reports by Perfect Information to our main sample, we are left with 31,459 firm-year observations from 5,339 unique firms.

Given that CbCR only affects firms that operate internationally, we continue by drop-

[12]For the US and Canada, financial data are drawn from Compustat North America, which has a broader coverage of financial information for listed firms from these two jurisdictions.

ping domestic firms as well as holding companies. Domestic firms are neither affected by CbCR nor relevant in their geographic disclosure.[13] We exclude holding companies because we cannot safely attribute a CbCR specific for one country in these cases.[14] For the remaining sample, we follow the cleaning procedure by Lang and Stice-Lawrence (2015), who also used a large sample of annual reports of international firms for their analysis.[15] We also restrict the sample to countries with no less than ten unique firms, reducing our sample again by 252 observations. Together, these requirements reduce our final sample size to 25,950 firm-year observations by 4,253 unique firms from 37 countries.

3.4 Descriptive Statistics

Table V.A2 depicts the geographic composition of our sample firms, the applicable revenue threshold, and the implementation year in the respective country. The vast majority of countries started to apply the CbCR requirement for the fiscal year 2016. The latest implementation in our sample occurred in 2019 for Turkey. The applicable size thresholds vary mainly due to exchange rate fluctuations but are mostly comparable across countries. Some notable exemptions can be observed, for instance, for Mexico and Nigeria. Concerning the geographic distribution of our observations, two aspects are noteworthy. First, the country with the highest number of observations is the US, followed by Japan and Australia. In general, Perfect Information also covers firms in developing and emerging economies, providing an interesting setting for our analysis. This distinguishes our sample from other studies in the context of CbCR, which often focus on European firms (De Simone and Olbert, 2022; Joshi, 2020). Second, we still observe a reasonable number of reports for Western Economies. The differences in observations between same-sized economies as France and Germany might be driven by our requirement that the reports

[13] We define firms as domestic when they have no foreign subsidiaries and no reported foreign segments.

[14] We define firms as holding companies when their country of domicile does not coincide with the country of listing, as measured through differing country attributions between our three databases Orbis, Bloomberg and Perfect information. In our sample, these firms are mainly of Chinese origin and listed in common tax haven countries like the Bermudas or Cayman Islands for easier access to capital markets (Coppola et al., 2021).

[15] In particular, we exclude annual reports with a Fog-Index below 12 and above 30. We also exclude documents with less than 50 sentences or less than 100 words as the average annual report is substantially longer and drop remaining duplicates.

must be available in English.

Table V.A4 reports descriptive statistics for our disclosure variables of interest. We report these separately for firms below the country-specific threshold (control group) and firms above the threshold (treatment group), both before and after the introduction of CbCR. First, note that firms in the treated group form the majority of firms within the overall sample. Sensitive and insensitive geographic segments are disclosed at a higher rate for the treated group than for control firms, both before and after the introduction of CbCR. Similarly, textual geographic segment information is also disclosed more often by treated firms than by control firms throughout the observed period. Both observations relate to larger firms possibly being more exposed to international business activities than smaller firms, which we account for in our following regression setting through control variables. Figure V.A1 depicts the development of absolute levels of disclosure relative to the introduction of CbCR. One can see directly that while sensitive and insensitive disclosure of quantitative geographic information is relatively stable across time, qualitative disclosure of country information decreases for both the treated and the control group of firms.

Table V.A5 reports descriptive statistics for firms separately by treatment group and control group. By nature, treated firms have substantially higher consolidated revenues than the control firms. The same holds true for the number of employees and foreign subsidiary count as well as the volume of total assets. Similarly, firms in the treated group are more leveraged, reflecting differences in access to capital markets or risk profiles. Still, the variation especially within the group of larger firms is substantial, as exemplified by the differences between median and mean values. Moving from differences in absolute values (which result from our classification in treatment and control group based on a size criterion) to relative differences, one can observe that firms are also similar along several dimensions: they are similarly profitable (measured by return on assets), they have a similar share of intangible assets and they both have average effective book tax rates closely below thirty percent. A noteworthy difference concerns the share of subsidiaries in tax havens, which is higher for firms in the control group. This surprises insofar as firms in the treated group have a substantially higher foreign presence measured by the number of foreign subsidiaries. A possible explanation could be that the existence of tax planning motivations requires a minimal setup of firms in tax havens, which becomes more obvious in relative terms for firms that do not have a substantial overall level of foreign activity.

4 Results

4.1 DiD results

We provide the results of our baseline DiD regression for our three dependent variables of interest in Table V.A6. These results capture the average effect of the private CbCR on public disclosure decisions. We first consider our baseline regression results in columns (1), (3) and (5) without control variables. The coefficient on the interaction term of $Treat_i$ and $Post_t$ is negative across all three specifications, and statistically significant for sensitive and qualitative geographic disclosure. Private CbCR leads to less disclosure of sensitive geographic information by 0.075 segment counts. Disclosure of qualitative geographic information decreases by 0.339 percentage points. While the magnitude of both effects seems somewhat small, one should keep in mind that the average treated firm only reports 0.84 geographic segments with sensitive information, implying a decrease of about 8.9 percent. Likewise, the share of country sentences in annual reports is at about 4.2 percentage points on average, yielding a similar relative decrease of about 8.1 percent. Unlike the other two outcome variables, the disclosure of insensitive geographic information does not seem to be affected by CbCR. Our regression results are robust to the country-wise exclusion of firms from the sample, implying that country-specific phenomena do not drive our results.[16]

[16] We also vary the dependent variable for qualitative geographic disclosure to include not only individual countries, but to condition on the country being mentioned in the same sentence as the word "tax". We do not find any significant disclosure response in this case. We attribute this to the respective average outcome value being very low (0.132 percentage points) in comparison to the initial outcome variable that includes any sentence with a country mention (3.75 percentage points). There is thus less downward response possible for a variable that conditions on both countries and taxes being mentioned in the same sentence.

Our findings are also robust to the inclusion of control variables in columns (2), (4) and (6), even though not all firms are retained in the sample because of missing values in control variables. While sensitive geographic disclosure decreases more strongly when controlling for relevant variables, the decrease in qualitative geographic information is slightly less pronounced. Concerning the relevance of the control variables, we observe that firm size and a large count of foreign subsidiaries positively affect the disclosure of both insensitive and qualitative geographic information. Interestingly, both factors seem to play no role for sensitive information disclosure. Instead, firms with a larger share of intangible assets are disclosing substantially less sensitive information at a geographic level, amounting to 0.032 segment counts less per 10 percentage point increase in the intangible share. This finding is consistent with considerations of proprietary costs playing a role in the decision to voluntarily disclose sensitive financial information at a detailed geographic level.

An essential identifying assumption for DiD designs is that affected firms and control firms would have developed similarly with respect to their disclosure decisions absent the policy reform (Angrist and Pischke, 2014). This condition is usually considered to hold if both groups follow a parallel trend before the treatment. We investigate the dynamic effect and verify the plausibility of parallel trends using an event study specification for our three outcome variables (Schmidheiny and Slotwinski, 2018; Fuest et al., 2018). To this end, we replace the term $\beta_1 \text{Treat}_i \times \text{Post}_t$ from Equation V.1 with a sequence of binary treatment variables denoted by $\sum_{k=-5}^{k=3} \beta_k D_{k,i,t}$ that indicate k periods prior and posterior to the introduction of CbCR. We use the identical structure of fixed effects and the same clustering procedure of standard errors as in Equation V.1 without control variables. In Figure V.A2, we plot the resulting regression coefficients for five years prior to and three years after the treatment. The effect is estimated relative to the control group and normalized to the year prior to the implementation of CbCR. We observe no significant pre-trends for sensitive and qualitative geographic information. Disclosure of insensitive geographic information shows a slight pre-trend, hence the respective results should be interpreted more cautiously. The dynamic patterns also reveal that while the disclosure of qualitative geographic information decreased directly after the introduction of CbCR, firms were not immediately adjusting their public disclosure of sensitive geographic information. Instead, firms seem to have changed their disclosure behavior of sensitive geographic information only after learning about potential responses by fiscal authorities.

Overall, our findings support the notion that the implementation of mandatory private disclosure rules induced negative public disclosure responses. So far, empirical assessments of disclosure theory have reinforced the belief in a complementary relationship between private and public disclosure (Bozanic et al., 2017). On the contrary, our results reveal the opposite pattern: firms' public disclosure of geographic information decreases when private CbCR is introduced. This implies that both types of disclosure can also be substitutes. This effect can be explained by the arguments brought forward in Section 2.2.

First, the fear of firms to possibly include numbers in their public reporting that are difficult to square with financial figures privately reported to fiscal authorities might make them more hesitant to voluntarily disclose further geographic information to the public. This fear of contradiction could arise due to varying accounting standards between reports filed for accounting and tax purposes. Moreover, the aggregation of financial figures across different geographic regions can lead to inconsistencies, particularly for sensitive, profit-related items. On the contrary, insensitive information disclosure, which does not react to CbCR implementation, pertains to information that is not of primary relevance to fiscal authorities, as revenues and assets are not as directly linked to the tax burden. Also, unlike voluntary disclosure of sensitive information, it is bounded from below by IFRS regulation. Second, firms reduce their voluntary reporting of geographic information to lower the risk that someone raises suspicion about discrepancies between the firm's public geographic disclosure and the deemed actual behavior of the firm. This risk is more costly after CbCR, because the public may exert pressure on fiscal authorities to use its access to full CbCR information and investigate further.

We further assess potential channels that might be driving our main results. We consider two aspects that could influence the degree to which firms affected by CbCR adjust their disclosure choices: the role of tax enforcement and the degree of intra-firm complexity as measured by its international presence (via subsidiaries). Throughout this section, we assess the heterogeneity of our main results by modifying our baseline DiD approach as depicted in Equation V.1 as follows: we replace our DiD interaction $\text{Treat}_i \times \text{Post}_t$ with the term $\text{Treat}_i \times \text{Post}_t \times Z_i$, where Z_i denotes a binary variable that changes for each of the two subgroups of interest and is constant at the firm level. Effectively, we hence estimate a Difference-in-Difference-in-Differences. This way, we can measure differential responses of firms to CbCR without changes in observation numbers due to sample splits.

Table V.A7 provides the estimated disclosure effect of CbCR for firms located in countries with high levels of tax enforcement. The variable Z_i in this case is equal to 1 when the number of tax staff relative to a population of 10,000 inhabitants per country, as provided by the OECD, is above the cross-country median. Our coefficient of interest now becomes the triple interaction $\text{Post}_t \times \text{Treat}_i \times \text{High Tax Enforcement}_i$. We observe that after controlling for the disclosure environment, the decrease in disclosure of sensitive geographic information is driven by firms who can reasonably expect their local fiscal authorities to be more able to process the additional financial information provided voluntarily by firms. The same pattern holds true for the disclosure of qualitative geographic information, both with and without the inclusion of control variables. This finding is also in line with evidence in the literature that fiscal authorities indeed access published financial information by companies (Bozanic et al., 2017).

Table V.A8 reports the regression results for our second aspect of heterogeneity, organizational complexity, which we proxy through high numbers of foreign subsidiaries. The variable Z_i is now equal to 1 if the number of foreign subsidiaries is above the median of all firms in the sample and equal to 0 otherwise. We posit that the more country subsidiary information a company needs to consolidate in its annual report, the higher the risk of potential mismatches with bilateral private reporting to fiscal authorities. Hence, we expect the effect on disclosure to be more negative the higher the foreign subsidiary presence. Interestingly, our results provide evidence that such a link only plays a role in qualitative disclosure of geographic information.

Further heterogeneity analyses reveal that the results for geographic disclosure responses to CbCR are robust when considering individual countries and regions.[17] One exception to this finding stands out: the decrease in qualitative geographic reporting due to CbCR is subdued, albeit still significant, for US firms. We attribute this to the average qualitative geographic disclosure of US firms (2.52 percent share of country sentences) already being substantially lower than the sample average (3.75 percent share of country sentence), which limits the leeway to exhibit a negative response.

4.2 RDD results

We subsequently proceed to the estimation results under the RDD approach to verify whether our initial results using DiD are also robust when specifying the identification of a local treatment effect. We depict the results in the form of both tables and figures. Table V.A9 and Figure V.A3 contain the baseline specification outlined in Equation V.2, with the first table row providing our coefficient of interest. Columns (1), (3) and (5) include firm-years within a turnover bandwidth of EUR 150 Mio. For countries with a CbCR threshold of EUR 750 Mio., this implies a bandwidth of EUR 675 - 825 Mio., and for the remaining columns (2), (4) and (6) with a turnover bandwidth of EUR 300 Mio., it implies a wider bandwidth of EUR 600 - 900 Mio.

Despite the low number of observations compared to our DiD analysis, we find similar effects of CbCR on geographic disclosure. While insensitive disclosure does not (significantly) change in any direction after CbCR introduction, disclosure of sensitive geographic information decreases stronger (quantitatively) than in our baseline DiD specification on Table V.A6, columns (3) and (4). Qualitative geographic information, however, only decreases for the larger bandwidth. Due to the reasons outlined in Section 3.1, we repeat the RDD with the exclusion of a small, symmetric bin of EUR 10 Mio. directly located

[17] Results for country and region heterogeneity are not tabulated, but available from the authors upon request. For instance, results do not differ for the three outcome variables when considering a differential response for member countries of the European Union. For France, we find a stronger reduction in the disclosure of sensitive and qualitative geographic information, consistent with having an effective tax enforcement authority. The decrease in qualitative geographic disclosure is also more pronounced for Japanese, Russian and South Korean firms.

around the CbCR threshold. The results are depicted in Table V.A10 and Figure V.A4. The coefficients are now closer to our initial DiD estimates, as the decrease in sensitive geographic disclosure is less pronounced. Also, the decrease in qualitative geographic information is consistently negative for both bandwidth specifications, and similar in magnitude to the results in Table V.A6.

The main estimation results of the RDD specification for periods before the introduction of CbCR are provided in Table V.A11 and Figure V.A5. When comparing our RDD estimates before and after the introduction of CbCR, we find a negative change in the discontinuity at the threshold, further strengthening the robustness of our results. This holds also true for the RDD analysis when comparing the results without observations inside the bin of EUR 10 Mio. after the introduction of CbCR (Table V.A10) with the results in the pre-CbCR period, as shown in Table V.A12 and Figure V.A6.

5 Conclusion

This study exploits the introduction of CbCR as an exogenous shock to the disclosure environment for geographic reporting of affected firms to examine the effect of private (mandatory) disclosure requirements on (voluntary) public disclosure choices. In our analysis, we find that firms affected by CbCR significantly decreased their public disclosure of sensitive and qualitative geographic information. In contrast, the provision of insensitive geographic information does not seem to be affected, which could be due to the already extensive reporting requirements under IFRS. We further document that the decrease in public disclosure of geographic information following the introduction of CbCR is particularly pronounced for more internationally exposed firms and those located in countries with higher levels of tax enforcement. Our results thus imply that mandatory private disclosure and voluntary public disclosure are not necessarily complements for the firm, but can also be substitutes, at least in the context of geographic information disclosure.

Our empirical setting provides two major advantages. First, the reports required by

CbCR are not (yet) published. Therefore, we can link any corporate disclosure responses directly to expected changes in the interaction with fiscal authorities. Second, the content of the reports is standardized such that all firms subject to the transparency regulation must report the same information, making the reform comparable across countries. We also acknowledge the existence of several caveats to our analysis. Foremost, a simultaneous shock to actual geographic operations due to geopolitical tensions, such as for instance a trade war, might affect (larger) firms in our treatment group differently than (smaller) firms in our control group. This could be due a higher exposure of larger firms to international markets. In consequence, these firms might reduce their actual geographic activities stronger than smaller firms, implying a decrease in disclosed geographic segments that is not due to discretionary disclosure choices. However, in such a case both sensitive and insensitive segment disclosure should decrease, which does not correspond to the results of our analysis.

The sample in our study is further limited to publicly listed firms due to data availability and comparability of the information environment. However, sufficiently large non-listed firms are also subject to CbCR. This raises the question for future research if their reaction is similar to listed firms' behavior. Their reaction might differ from the results found for our sample in two aspects: first, non-listed firms have less dispersed ownership, and hence face less public information demand from investors. Relatedly, non-listed firms lack a uniform minimum public reporting standard of geographic segment information. Taken together, these firms likely start from a lower level of geographic disclosure than their listed counterparts. Hence the improvement in the information environment due to the introduction of CbCR could dominate the fear of contradiction between private and public reporting. This might entail a muted negative or even positive public disclosure response. Second, majority owners of these firms may have strong preferences that their firm adheres to a specific policy of transparency. This could widen the dispersion of disclosure responses.

A last caveat relates to our choice of public disclosure of geographic information as a possible outcome affected by CbCR. Our results suggest that public disclosure of sensitive and qualitative geographic information faces substantial proprietary costs related to providing valuable information to competitors and/or bearing the consequences of public scrutiny. However, the public disclosure response could change when considering other disclosure dimensions with lower proprietary costs, such as the disclosure of effective tax rate forecasts. This would also reconcile our findings with converse results from other studies.[18]

For large firms active in the European Union, public CbCR will become mandatory for financial years starting after 21 June 2024. Given the implicitly documented importance of proprietary costs for the firms' disclosure choices in our setting, policy makers should watch carefully whether there are any signs that firms subject to the new regulation are put at a disadvantage relative to competitors not subject to the regulation. If that is the case, a revised regulation should include targeted carve-out rules, which apply for sub-items that are published with a sufficient delay. After such a period, the relevant information may not be valuable to competitors anymore and would become public. A generous form of such a carve-out rule is part of the current European directive on public CbCR, which provides a period of up to five years during which disclosure of commercially sensitive information may be deferred.[19] Another more restrictive alternative would be a fee schedule according to which firms pay increasing contributions for longer delays in item publication. In such a scenario, firms for which proprietary costs play a significant role would pay a fee to compensate for opaqueness. An unintended consequence of such a policy design could be, however, that affected firms move their corporate headquarters to locations with suitable carve-out rules or a more lenient regulation enforcement. Such reactions of multinational corporations with relevant proprietary costs could be akin to those documented in the literature on corporate tax avoidance, particularly in the context of corporate inversions (Desai and Hines, 2002; Voget, 2011).

[18] Consider for instance Chi et al. (2023).

[19] This deferral is conditional on the information not pertaining to tax haven operations (Directive 2021/2101/EU)

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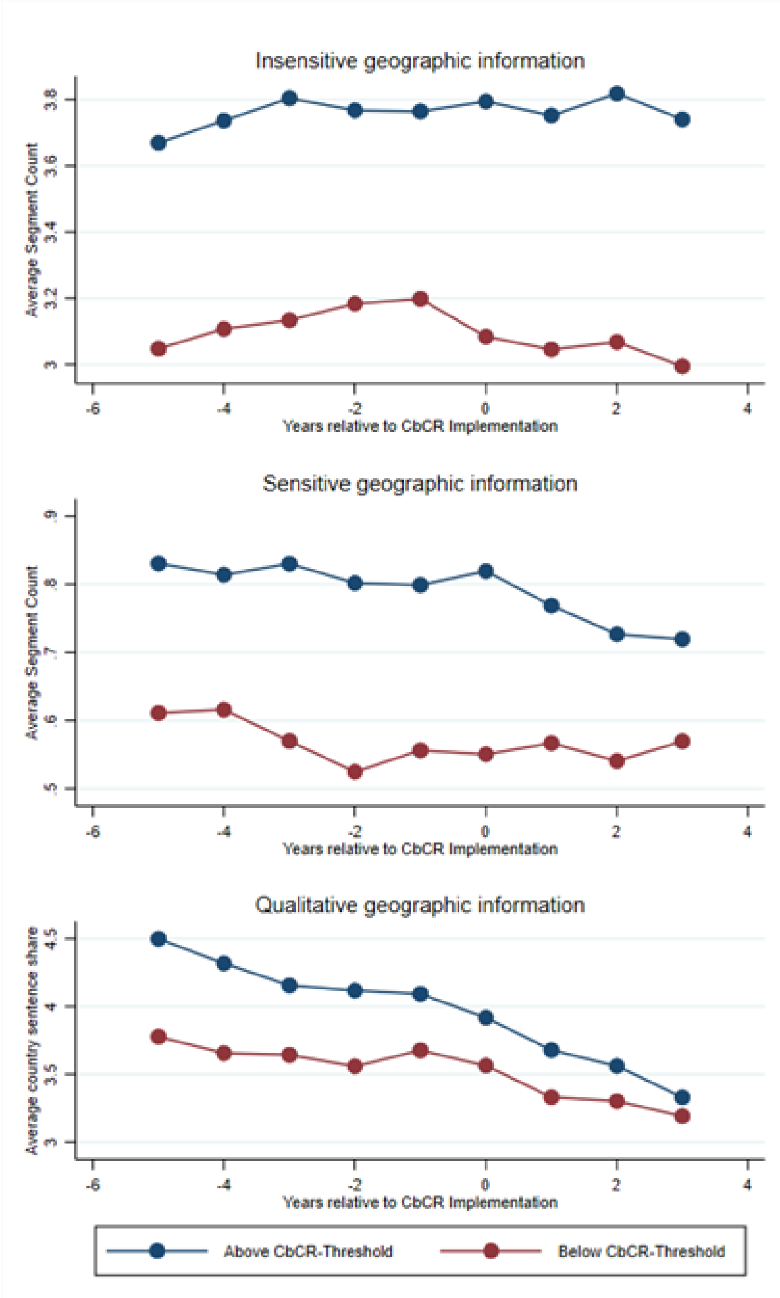
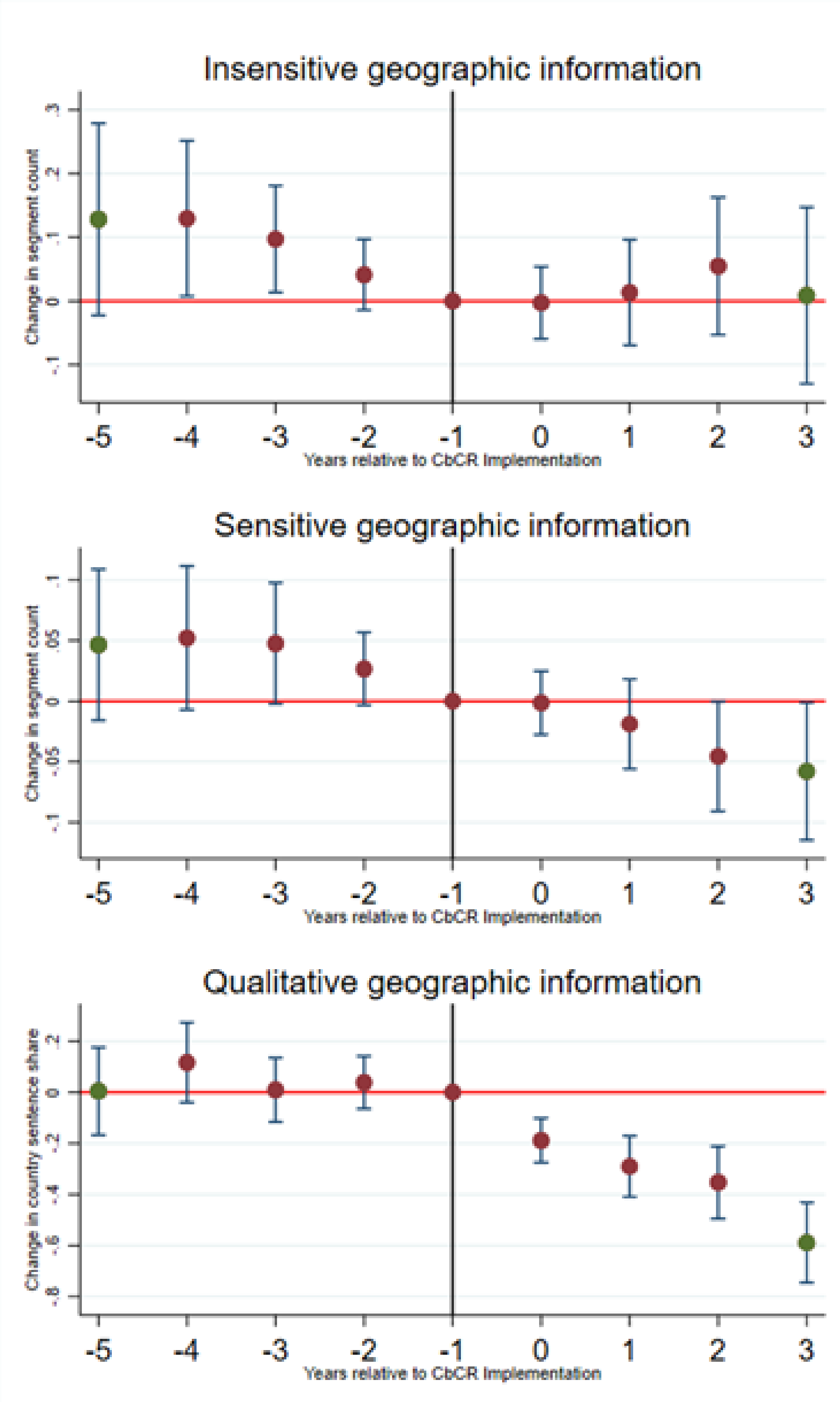
A Additional Tables and Figures

Figure V.A1: Disclosure Levels Before and After Introduction of CbCR



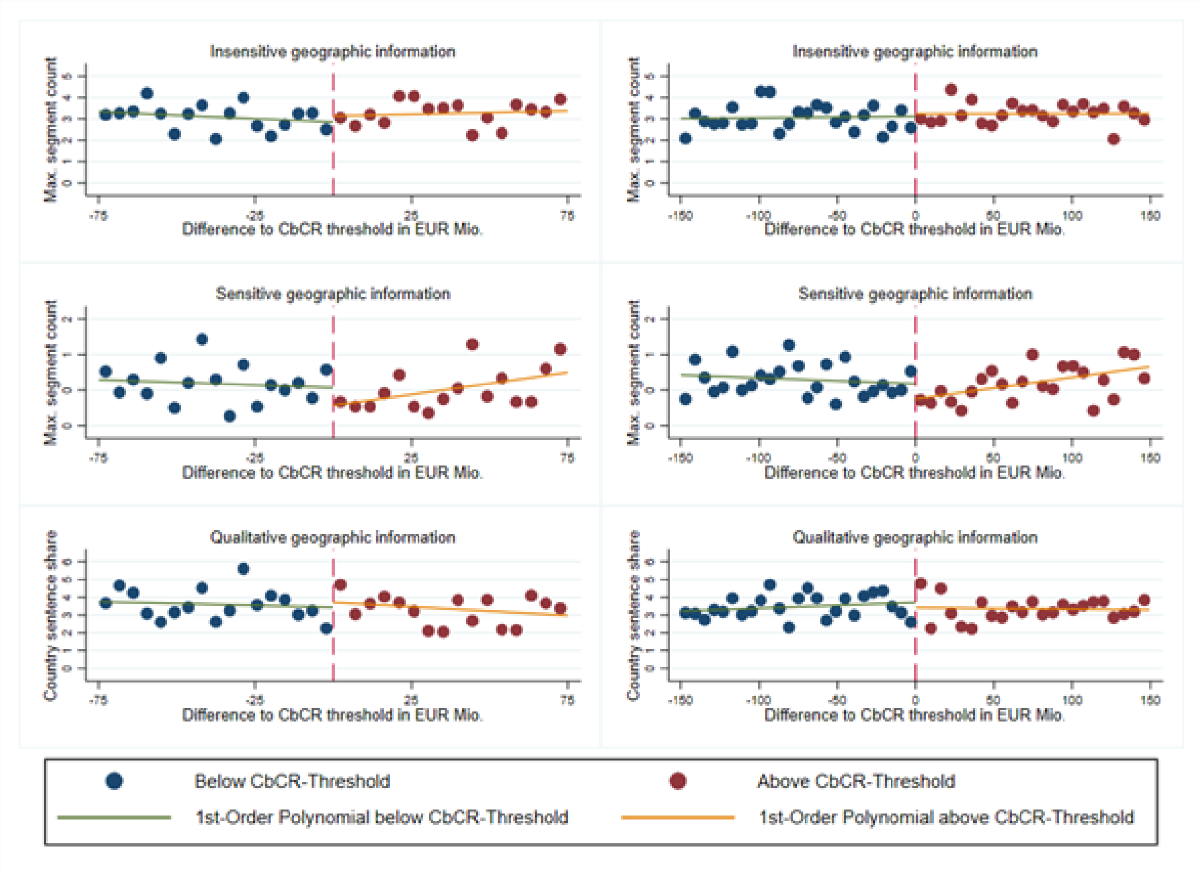
Notes: This figure provides the development of the mean levels for the three outcomes variables of interest over time (see Section 3.2 for a description). The first two subfigures provide average values for quantitative disclosure of insensitive and sensitive geographic information, measured in segment counts. The third subfigure shows the share of country sentences in annual reports. Values are conditional on whether firms belong to the treatment group (blue) or control group (red). The horizontal axis provides the years relative to CbCR implementation, with a relative year equal to zero denoting the onset of CbCR.

Figure V.A2: Event Study for Assessing Pre-trends in Outcome Variables



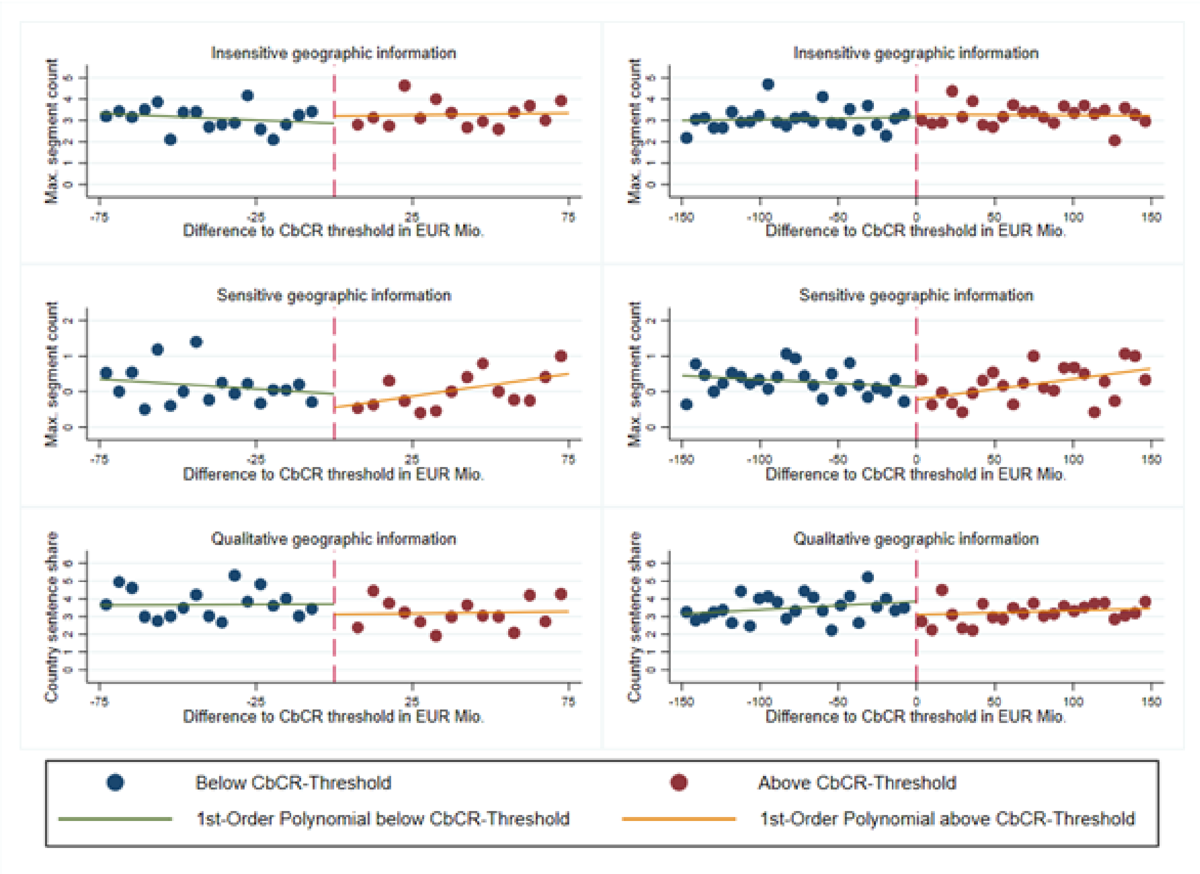
Notes: This figure provides the coefficients obtained from estimating event study regressions for the three outcomes variables of interest (see Section 4.1 for further detail). Point estimates (red) denote the coefficient estimates for treatment in the periods before and after the actual treatment by CbCR. Blue whiskers indicate the respective 95% confidence intervals. All coefficients are estimated relative to the normalization period -1. Coefficient estimates in periods -5 and +3 (green) are binned off to the left and to the right of the sample. This implies that coefficients for periods -5 and +3 control for any long-term prior or posterior effects. Standard errors underlying the confidence intervals are robust to heteroscedasticity and clustered at the firm level.

Figure V.A3: RDD Results



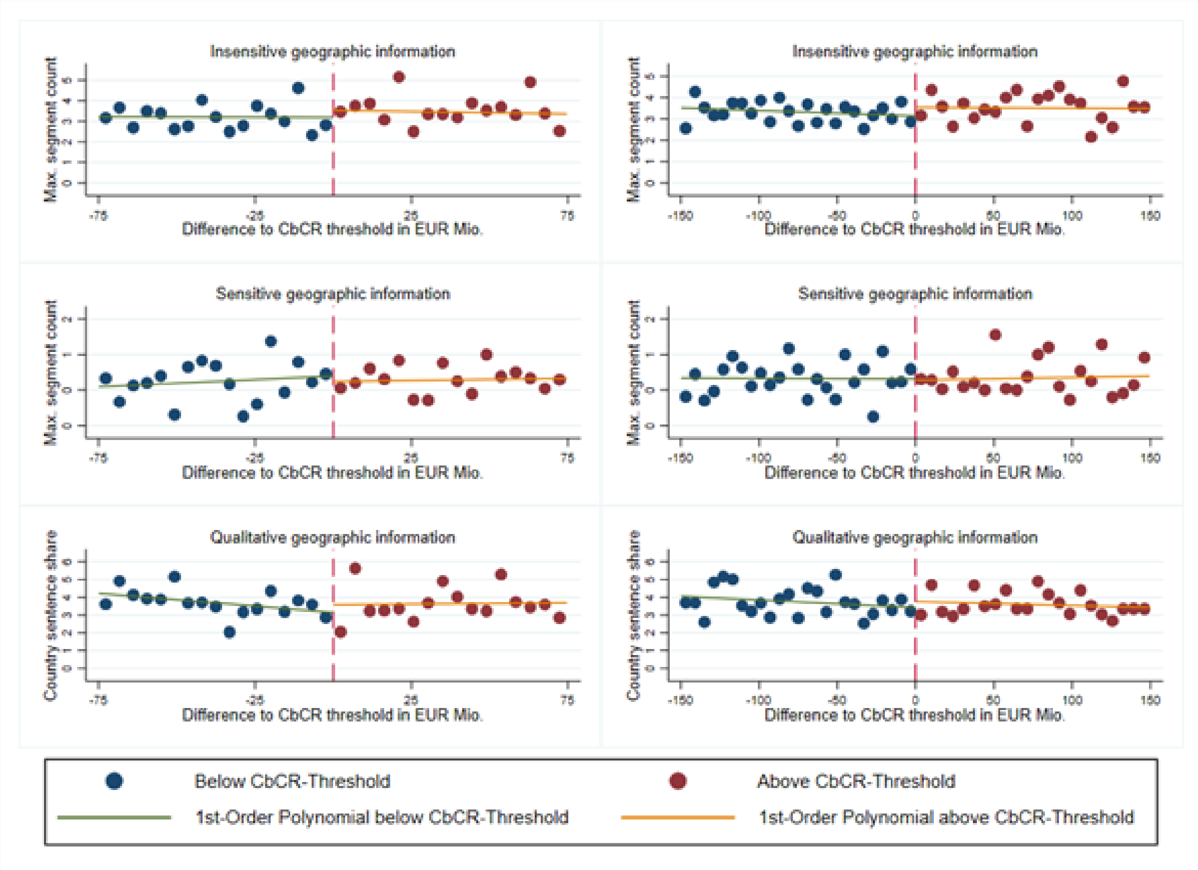
Notes: This figure visualizes the results of the regression discontinuity design for the three geographic disclosure outcomes depicted in Table V.A9. It includes firm-year observations in the period after the introduction of CbCR within a bandwidth of EUR 150 Mio. (left panel) and EUR 300 Mio. (right panel) around the CbCR threshold. In each subfigure, the horizontal axis provides the distance to the CbCR threshold. The colored dots represent binned average values of the respective geographic disclosure below (blue) and above (red) the CbCR threshold. The effect of CbCR on geographic disclosure can be visually identified as the local difference in the linear trend above (orange line) and below (green line) the CbCR threshold (vertical red dashed line).

Figure V.A4: RDD Results Without Observations Close to the Threshold



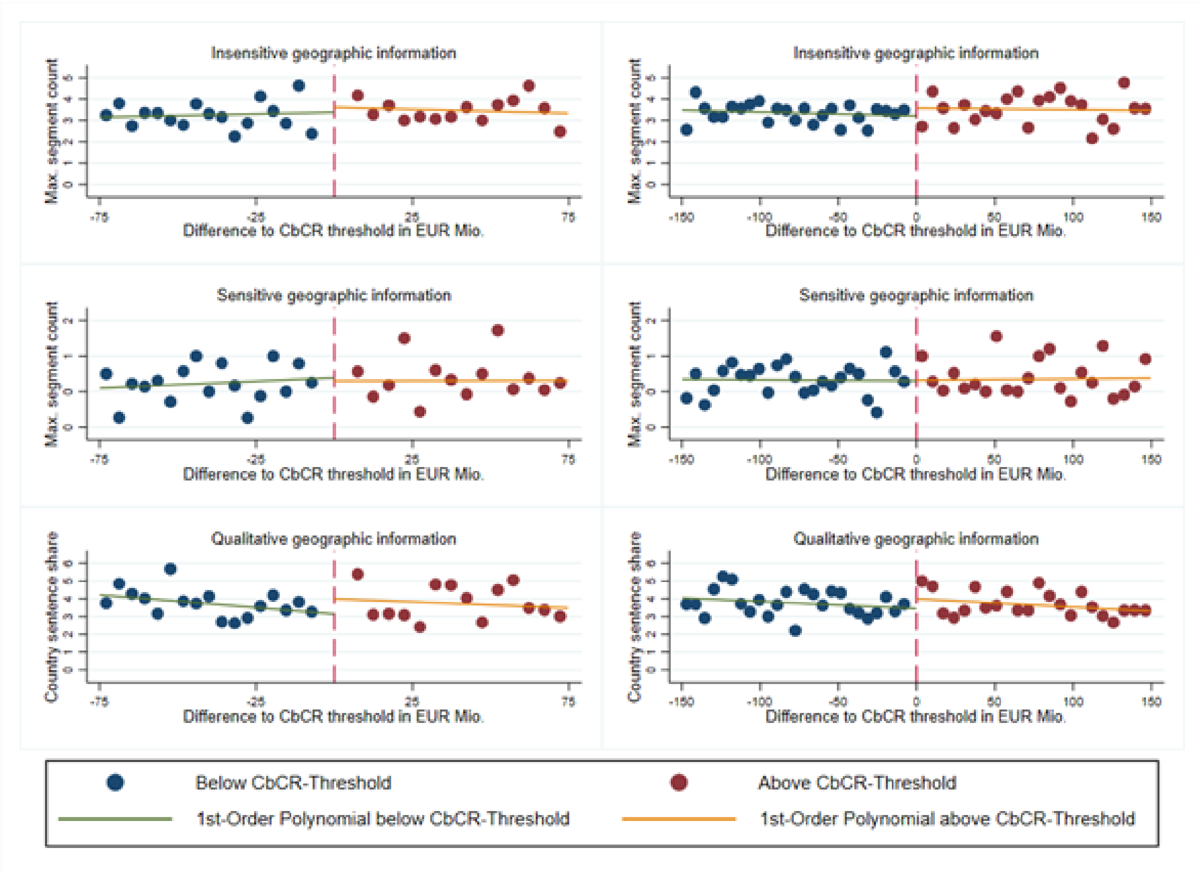
Notes: This figure visualizes the results of the regression discontinuity design for the three geographic reporting outcomes depicted in Table V.A10. It includes firm-year observations in the period after the introduction of CbCR within a bandwidth of EUR 150 Mio. (left panel) and EUR 300 Mio. (right panel) around the CbCR threshold. In each subfigure, the horizontal axis provides the distance to the CbCR threshold. The colored dots represent binned values of the respective geographic disclosure below (blue) and above (red) the CbCR threshold. Firms with turnover within a bin of EUR 10 Mio. around the CbCR threshold are excluded. The effect of CbCR on geographic reporting can be visually identified as the local difference in the linear trend above (orange line) and below (green line) the CbCR threshold (vertical red dashed line).

Figure V.A5: RDD Results Before the Introduction of CbCR



Notes: This figure visualizes the results of the regression discontinuity design for the three geographic disclosure outcomes depicted in Table V.A11. It includes firm-year observations in the period before the introduction of CbCR within a bandwidth of EUR 150 Mio. (left panel) and EUR 300 Mio. (right panel) around the CbCR threshold. In each subfigure, the horizontal axis provides the distance to the CbCR threshold. The colored dots represent binned values of the respective geographic disclosure below (blue) and above (red) the CbCR threshold. The effect of CbCR on geographic disclosure can be visually identified as the local difference in the linear trend above (orange line) and below (green line) the CbCR threshold (vertical red dashed line).

Figure V.A6: RDD Results Before the Introduction of CbCR Without Observations Close to the Threshold



Notes: This figure visualizes the results of the regression discontinuity design for the three geographic disclosure outcomes depicted in Table V.A12. It includes firm-year observations in the period before the introduction of CbCR within a bandwidth of EUR 150 Mio. (left panel) and EUR 300 Mio. (right panel) around the CbCR threshold. In each subfigure, the horizontal axis provides the distance to the CbCR threshold. The colored dots represent binned values of the respective geographic disclosure below (blue) and above (red) the CbCR threshold. Firms with turnover within a bin of EUR 10 Mio. around the CbCR threshold are excluded. The effect of CbCR on geographic disclosure can be visually identified as the local difference in the linear trend above (orange line) and below (green line) the CbCR threshold (vertical red dashed line).

Table V.A1: Variable Description

Variable	Description	Data Source
Insensitive geographic information	Maximum count of reported segments for the financial items revenues and assets	Bloomberg
Sensitive geographic information	Maximum count of reported segments for the financial items gross-profits, EBITDA and operating income	Bloomberg
Qualitative geographic information	Share of sentences containing geographic information in the annual report, i.e. sentences with at least one reference to a foreign country. The variable is computed as follows: *Number of sentences with country reference / Number of sentences in annual report*	"Filings Expert" and EDGAR
Firm size	Natural logarithm of firm total assets.	Orbis.
Return on assets	Variable measuring profitability computed as follows: *Earnings before taxes / total assets*	Orbis
Return on sales	Variable measuring profitability computed as follows: *Earnings before taxes / turnover*	Orbis
Leverage	Variable measuring level of debt financing computed as follows: *Total liabilities / Total assets*	Orbis
Intangibles	Variable measuring level of intangible assets computed as follows: *Intangibles / Total assets*	Orbis
Foreign subsidiaries	Variable capturing the total number of majority-owned foreign subsidiaries.	Orbis
Share of tax-haven subsidiaries	Variable measuring the share of majority-owned subsidiaries located in tax haven jurisdictions relative to all foreign subsidiaries.	Orbis.
Turnover	Variable capturing total turnover in million euros.	Orbis
Number of employees	Variable capturing total number of employees.	Orbis
Firm age	Variable measuring firm age in years since year of incorporation.	Orbis
Book ETR	Variable measuring the effective book tax rate computed as: *Tax expense / Pre-tax earnings*	Orbis
Fog-Index	Variable capturing the complexity based on the Fog-Index, which measures the readability of a text. A high Fog-Index implies a high complexity level and thereby a high level of difficulty in readability. The measure is frequently used in the accounting and finance literature (Bilicka et al., 2022; Li, 2010).	"Filings Expert" and EDGAR
Negativity score Positivity score Uncertainty score	Variables capturing word sentiment in textual analysis of annual reports, based on a word list approach (Loughran and McDonald, 2011)	"Filings Expert" and EDGAR.
Report length	Variable capturing the length of the annual report computed as the natural log of the number of sentences.	"Filings Expert" and EDGAR
Tax enforcement	Variable measuring tax enforcement per country as the number of tax administration staff relative to 10,000 habitants	OECD Tax Administration 2019

Notes: This table lists all variables used for analyses in this paper, including a description of their components, calculation and the respective data sources. "Filings Expert" and EDGAR refer to information obtained from annual reports and/or similar documents.

Table V.A2: CbCR Implementation and Country Characteristics

Country	Threshold (EUR Mio.)	Implementation Year	Unique firms	Firm-year observations	Tax staff per 100,000 Pop.
Australia	633	2016	155	1,190	8
Austria	750	2016	13	105	10
Belgium	750	2016	24	177	18
Bermuda	720	2016	56	435	
Brazil	525	2016	27	163	1
Canada	750	2016	12	50	12
Cayman Islands	720	2016	148	849	
China	705	2016	92	475	5
Denmark	751	2016	28	223	15
Finland	750	2016	39	275	9
France	750	2016	65	475	15
Germany	750	2016	107	810	13
Greece	750	2016	16	124	11
Hong Kong	735	2018	40	295	4
India	683	2016	337	1,040	
Ireland	750	2016	18	102	13
Italy	750	2016	24	169	6
Japan	767	2016	643	3,254	
Luxembourg	750	2016	10	51	20
Malaysia	630	2017	96	561	4
Mexico	529	2016	18	106	3
Netherlands	750	2016	37	246	19
New Zealand	750	2016	16	115	10
Norway	677	2016	37	253	12
Poland	750	2016	33	153	15
Russia	676	2017	10	56	10
Saudi Arabia	723	2018	25	89	1
Singapore	707	2017	97	515	3
South Africa	641	2016	65	318	2
South Korea	771	2016	50	168	4
Spain	750	2016	38	258	5
Sweden	683	2016	115	731	10
Switzerland	779	2018	75	524	1
Taiwan	758	2017	218	652	4
Turkey	750	2019	16	72	5
UK	750	2016	196	878	10
US	720	2016	1,257	9,991	2
Overall			4,290	25,950	

Notes: This table provides institutional characteristics of the countries present in our firm sample. Threshold refers to the country-specific CbCR threshold, converted to EUR in the year of implementation.
Source: Orbis and OECD, see Table V.A1 for further information.

Table V.A3: Sample Selection

Sample Selection Process	Observations	Unique Firms
Publicly Listed Ultimate Parent Entities from Orbis for 2010-2020	140,893	17,567
Missing Turnover Data	-1,542	
Exclude Banking and Extractive Industry	-18,181	
Missing ISIN	-3,938	
= Sample Prepared for Analysis with Disclosure Data	117,232	13,992
Not Matched to Bloomberg Segment Data	-29,432	
No Annual Report from Perfect Information/Form 10-K from EDGAR	-56,341	
= Observations with Segment & Textual Data	31,459	5,339
Exclude Domestic and Holding Firms	-4,408	
Cleaning Steps Applied by Lang & Stice-Lawrence (2015)	-849	
Exclude countries with less than 10 unique firms	-252	
= Final Sample	25,950	4,253

Notes: This table provides the selection process for deriving at our final sample. The first four rows present the steps for selecting our initial sample based on various selection criteria from Orbis. Rows (6) and (7) depict the process of selecting further based on availability of both quantitative and qualitative information in Bloomberg and Perfect Information/Edgar. The requirement for firms to be covered by Bloomberg and Perfect Information results in a lower representation of Chinese, South-Korean and Taiwanese firms. This may reflect that these countries have a substantial number of small, publicly listed firms without an international investor base. The remaining steps in rows (9)-(11) relate to cleaning the sample to ensure data validity and suitable observations for further analysis. We define companies as domestic if they have no foreign subsidiaries. We exclude domestic firms because they are not affected by CbCR and not relevant in their geographic disclosure. Holding companies are identified via name-matching. We exclude those holding companies whose country of residence and country of domicile do not coincide according to our data sources. Otherwise, we would not be able to assign a country-specific treatment by CbCR. This affects mainly Chinese companies that are established simultaneously in e.g. Hong Kong, Bermudas or the Cayman Islands. See Section 3.3 for further detail.

Table V.A4: Descriptive Statistics of Outcome variables by Treatment Status

	Below CbCR threshold (control)				Above CbCR threshold (treated)			
	Before CbCR		After CbCR		Before CbCR		After CbCR	
Variable	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.
Geo. Seg. count of EBITDA	1.32	662	1.46	496	2.34	493	2.90	347
Geo. Seg. count of Gross Profits	1.25	560	1.22	755	1.58	663	1.53	677
Geog. Seg. count of Operating Income	1.70	1,576	1.57	1,833	2.22	2,540	2.11	2,210
Sensitive geographic information	0.57	5,391	0.56	5,915	0.81	7,708	0.76	6,936
Geo. Seg. count of Revenues	3.13	5,314	3.04	5,847	3.76	7,641	3.77	6,898
Geo. Seg. count of Assets	1.94	2,311	1.81	2,425	2.33	3,074	2.15	2,516
Insensitive geographic information	3.14	5,391	3.05	5,915	3.75	7,708	3.78	6,936
Share of Country Sentences in Annual Reports	3.66	5,391	3.34	5,915	4.23	7,708	3.63	6,936

Notes: This table presents summary statistics for our main outcome variables of interest and its individual components at the firm-year observation level. If a firm does not disclose any sensitive geographic segment information (rows (1)-(3)), the measure for sensitive geographic information for that firm is equal to zero. This explains that the average value of the composite measure is lower than its individual components. The same holds true for insensitive geographic segment disclosure, albeit here the disclosure of its constituents (disclosed revenues and assets) is higher. Average values and observations are split up according to whether firms belong to the treated or control group before or after treatment. The analysis proceeds at the unique firm-year level.

Source: Bloomberg and Perfect Information/EDGAR. See Table V.A1 and Sections 3.2 and 3.3 for a more detailed description of data sources and variables used.

Table V.A5: Descriptive Statistics by Treatment Status

	Below CbCR Threshold (control)				Above CbCR Threshold (treated)			
Variable	p25	p50	p75	Mean	p25	p50	p75	Mean
Insensitive geographic information	1	3	5	3.41	2	3	5	3.91
Sensitive geographic information	0	0	1	0.64	0	0	1	0.84
Qualitative geographic information	2	3	5	4.03	2	3	6	4.20
Firm age (in years)	15	27	50	38	19	35	76	51
Number of employees	642	1,306	2,598	2,376	5,129	11,613	27,415	30,787
Leverage in p.p.)	30	43	56	44	45	58	69	57
Intangibles (p.p.)	1	7	28	16	3	14	33	20
Return on assets (in p.p.)	4	7	12	9	4	7	11	8
Firm size (EUR Mio.)	180	354	681	678	1,669	3,726	10,546	12,539
Turnover (EUR Mio.)	167	304	498	361	1,508	3,044	7,879	9,238
Book ETR ()p.p.)	19	26	33	28	21	28	34	29
Foreign subsidiaries	4	12	25	21	16	58	162	181
Share of tax-haven subsidiaries (p.p.)	0	8	24	17	2	7	15	12
Number of firm-year observations	11,360				14,644			

Notes: This table provides summary statistics of outcome and control variables, split up into two categories: whether a firm is located above the CbCR threshold (columns (5) – (8) to the right) or not (columns (1) – (4) to the left). P25/P50/P75 denote the respective 25%, 50% or 75%-percentile in columns (1) – (3) and (5) – (7). Columns (4) and (8) provide the average value of the variable. Firm size in this table is measured in EUR Mio. without taking the natural logarithm. Variable shares (i.e. leverage, intangibles, return on assets, book ETR and share of tax-haven subsidiaries) are provided as decimal numbers.
Source: Orbis, Bloomberg and Perfect Information/EDGAR. We describe and explain variables and data sources in Table V.A1 and Sections 3.2 and 3.3.

Table V.A6: Effect of CbCR on Disclosure Behavior

VARIABLES	(1) Insensitive geo.	(2) information	(3) Sensitive geo.	(4) information	(5) Qualitative geo.	(6) information
Post X Treat	-0.0567	-0.08	-0.0664***	-0.075***	-0.349***	-0.339***
	(-1.114)	(-1.210)	(-2.756)	(-2.794)	(-5.680)	(-4.717)
Firm size		0.347***		0.003		0.395***
		-3.555		(0.06)		(5.078)
Share of intangible assets		-0.165		-0.322**		0.176
		(-0.553)		(-2.322)		(0.531)
Return on assets		0.243		0.21		-0.426
		(0.454)		(0.859)		(-0.655)
Return on sales		-0.333		-0.125		0.941*
		(-0.758)		(-1.091)		(1.941)
Leverage		-0.098		0.01		0.840***
		(-0.429)		(0.108)		(3.674)
Foreign subsidiary		0.089***		0.001		0.082**
count (log.)		(-3.393)		(0.057)		(2.197)
Share of tax-haven		0.219		0.03		-0.191
subsidiaries		(1.613)		(0.598)		(-1.108)
Book ETR						-0.073
						(-0.675)
Fog-Index						-0.264***
						(-5.542)
Sentence count						-0.539***
(log.)						(-3.814)
Negativity score						0.004
						(0.753)
Positivity score						0.061***
						(5.65)
Uncertainty Score						-0.108***
						(-5.940)
Constant	3.468***	-1.529	0.680***	0.722	3.821***	6.599***
	(232.1)	(-1.141)	(90.42)	(1.128)	(166.3)	(4.078)
Observations	25,643	19,214	25,643	19,214	25,643	18,148
Adj. R-squared	0.868	0.869	0.85	0.858	0.802	0.798
Fixed Effects	Firm & Year	Firm & Year	Firm & Year	Firm & Year	Firm & Year	Firm & Year
Clustered SE	Firm	Firm	Firm	Firm	Firm	Firm
Controls	No	Yes	No	Yes	No	Yes

Notes: This table presents the results of estimating Equation V.1 using Ordinary Least Squares for our overall firm sample. All columns include fixed effects at the firm-year level. The row named 'Controls' specifies whether the control variables mentioned in Section 3.1.1 are included. Columns (2), (4) and (6) include control variables. The observation number between columns (2) and (4) and column (6) differs because the set of control variables slightly varies to account for the different nature of qualitative geographic disclosure. All columns include standard errors clustered at the firm-level. Values in parentheses represent robust t-statistics. ***, **, and * denote significance at the one-, five-, and ten-percent level for two-sided tests of significance.

Source: Orbis, Bloomberg and Perfect Information/EDGAR. See Table V.A1 and Sections 3.2 and 3.3 for a more detailed description of data sources and variables used.

Table V.A7: Effect of High Tax Enforcement on Disclosure Behavior

VARIABLES	(1) Insensitive geographic information	(2)	(3) Sensitive geographic information	(4)	(5) Qualitative geographic information	(6)
Post X Treat	-0.121*	-0.150*	-0.035	-0.020	-0.195***	-0.187**
	(-1.958)	(-1.699)	(-1.196)	(-0.625)	(-3.048)	(-2.422)
Post X High Tax enforcement	-0.120	-0.094	0.044	0.076	-0.125	-0.074
	(-1.194)	(-0.706)	(0.880)	(1.353)	(-1.277)	(-0.649)
Post X Treat X High Tax Enforcement	0.049	0.013	-0.097	-0.150*	-0.462***	-0.395**
	(0.317)	(0.071)	(-1.321)	(-1.884)	(-2.944)	(-2.295)
Constant	3.535***	-2.655*	0.679***	1.051	3.392***	6.796***
	(188.977)	(-1.663)	(71.039)	(1.337)	(139.406)	(3.634)
Observations	20,209	14,823	20,209	14,823	20,209	13,887
Adj. R-squared	0.865	0.863	0.839	0.847	0.810	0.810
Fixed Effects	Firm & Year	Firm & Year	Firm & Year	Firm & Year	Firm & Year	Firm & Year
Clustered SE	Firm	Firm	Firm	Firm	Firm	Firm
Controls	No	Yes	No	Yes	No	Yes

Notes: This table presents the results of estimating Equation V.1 using Ordinary Least Squares for a subset of firms that is located in countries with an above-median level of tax enforcement. All columns include fixed effects at the firm-year level. The row named 'Controls' specifies whether the control variables mentioned in Section 3.1 are included. Columns (2), (4) and (6) include control variables. The observation number between columns (2) and (4) and column (6) differs because the set of control variables slightly varies to account for the different nature of quantitative disclosures (see Table V.A6). All columns include standard errors clustered at the firm-level. Values in parentheses represent robust t-statistics. ***, **, and * denote significance at the one-, five-, and ten-percent level for two-sided tests of significance.
Source: Orbis, Bloomberg, Perfect Information/EDGAR and OECD. See Table V.A1 and Sections 3.2 and 3.3 for a more detailed description of data sources and variables used.

Table V.A8: Effect of Foreign Subsidiary Presence on Disclosure Behavior

VARIABLES	(1) Insensitive geographic information	(2)	(3) Sensitive geographic information	(4)	(5) Qualitative geographic information	(6)
Post X Treat	-0.079	-0.080	-0.038*	-0.058**	0.005	0.099
	(-1.381)	(-1.008)	(-1.667)	(-2.159)	(0.070)	(1.063)
Post X High Number of foreign subsidiaries	-0.000	0.023	0.002	0.041	-0.292**	-0.054
	(-0.001)	(0.190)	(0.042)	(0.816)	(-2.477)	(-0.400)
Post X Treat X High N. of for. Subs.	0.027	-0.014	-0.036	-0.048	-0.319**	-0.561***
	(0.223)	(-0.098)	(-0.653)	(-0.807)	(-2.203)	(-3.393)
Constant	3.482***	-1.534	0.680***	0.721	3.872***	6.842***
	(239.045)	(-1.144)	(89.353)	(1.129)	(166.553)	(4.250)
Observations	25,114	19,214	25,114	19,214	25,114	18,148
Adj. R-squared	0.869	0.869	0.849	0.858	0.800	0.799
Fixed Effects	Firm & Year	Firm & Year	Firm & Year	Firm & Year	Firm & Year	Firm & Year
Clustered SE	Firm	Firm	Firm	Firm	Firm	Firm
Controls	No	Yes	No	Yes	No	Yes

Notes: This table presents results of estimating Equation V.1 using Ordinary Least Squares for a subset of firms that has a count of foreign subsidiaries above the sample median. All columns include fixed effects at the firm-year level. The row named 'Controls' specifies whether the control variables mentioned in Section 3.1 are included. Columns (2), (4) and (6) include control variables. The observation number between columns (2) and (4) and column (6) differs because the set of control variables slightly varies to account for the different nature of quantitative disclosures (see Table V.A6). All columns include standard errors clustered at the firm-level. Values in parentheses represent robust t-statistics. ***, **, and * denote significance at the one-, five-, and ten-percent level for two-sided tests of significance.
Source: Orbis, Bloomberg and Perfect Information/EDGAR. See Table V.A1 and Sections 3.2 and 3.3 for a more detailed description of data sources and variables used.

Table V.A9: RDD Results

VARIABLES	(1) Insensitive geographic information	(2)	(3) Sensitive geographic information	(4)	(5) Qualitative geographic information	(6)
Above CbCR Threshold	0.299	0.112	-0.250*	-0.211*	0.278	-0.290
	(0.737)	(0.403)	(-1.754)	(-1.710)	(0.492)	(-0.772)
Difference to CbCR Threshold	-0.007	0.001	-0.001	-0.001	-0.004	0.003
	(-1.079)	(0.341)	(-0.528)	(-0.782)	(-0.542)	(1.131)
Ab. CbCR Thrshd. X Diff. to CbCR Thrshd.	0.010	-0.001	0.008*	0.004*	-0.005	-0.004
	(1.096)	(-0.175)	(1.932)	(1.963)	(-0.456)	(-0.850)
Constant	2.845***	3.128***	0.534***	0.589***	3.431***	3.703***
	(10.508)	(14.736)	(4.733)	(6.221)	(9.243)	(13.398)
Observations	579	1,200	579	1,200	579	1,200
Bandwidth (in EUR Mio.)	150	300	150	300	150	300

Notes: This table presents results of estimating Equation V.2 using Ordinary Least Squares for a subset of firm-years with turnover values within a narrow bandwidth around the CbCR threshold after the introduction of CbCR. Row (1) depicts our coefficients of interest, i.e. the local discontinuities that identify the treatment effect of CbCR. Changes to geographic information disclosure are estimated for firms inside a symmetric EUR 150 Mio. bandwidth around the CbCR threshold in columns (1), (3) and (5). A larger bandwidth of EUR 300 Mio. is used for columns (2), (4) and (6). Standard errors are clustered at the firm level. Values in parentheses represent robust t-statistics. ***, **, and * denote significance at the one-, five-, and ten-percent level for two-sided tests of significance.
Source: Orbis, Bloomberg and Perfect Information/EDGAR. See Table V.A1 and Sections 3.2 and 3.3 for a more detailed description of data sources and variables used.

Table V.A10: RDD Results Without Observations Close to the Threshold

VARIABLES	(1) Insensitive geographic information	(2)	(3) Sensitive geographic information	(4)	(5) Qualitative geographic information	(6)
Above CbCR Threshold	0.354	0.124	-0.190	-0.174	-0.578	-0.746**
	(0.707)	(0.409)	(-1.065)	(-1.275)	(-1.052)	(-2.162)
Difference to CbCR Threshold	-0.006	0.001	-0.003	-0.001	0.001	0.005
	(-0.915)	(0.485)	(-0.951)	(-0.983)	(0.094)	(1.553)
Ab. CbCR Thrshd. X Diff. to CbCR Thrshd.	0.008	-0.001	0.009**	0.004*	0.001	-0.002
	(0.796)	(-0.349)	(2.058)	(1.900)	(0.114)	(-0.520)
Constant	2.854***	3.162***	0.466***	0.564***	3.693***	3.849***
	(9.212)	(14.505)	(3.761)	(5.615)	(8.522)	(13.048)
Observations	541	1,162	541	1,162	541	1,162
Bandwidth (in EUR Mio.)	150	300	150	300	150	300

Notes: This table presents results of estimating Equation V.2 using Ordinary Least Squares for a subset of firm-years with turnover values within a narrow bandwidth around the CbCR threshold after the introduction of CbCR. Row (1) depicts our coefficients of interest, i.e. the local discontinuities that identify the treatment effect of CbCR. Changes to geographic information disclosure are estimated for firms inside a symmetric EUR 150 Mio. bandwidth around the CbCR threshold in columns (1), (3) and (5). A larger bandwidth of EUR 300 Mio. is used for columns (2), (4) and (6). In addition, we exclude turnover observations located directly around the CbCR threshold within a EUR 10 Mio. bin, i.e. EUR 5 Mio. below and above the threshold. Standard errors are clustered at the firm level. Values in parentheses represent robust t-statistics. ***, **, and * denote significance at the one-, five-, and ten-percent level for two-sided tests of significance.
Source: Orbis, Bloomberg and Perfect Information/EDGAR. See Table V.A1 and Sections 3.2 and 3.3 for a more detailed description of data sources and variables used.

Table V.A11: RDD Results Before the Introduction of CbCR

VARIABLES	(1) Insensitive geographic information	(2)	(3) Sensitive geographic information	(4)	(5) Qualitative geographic information	(6)
Above CbCR Threshold	0.341	0.395	-0.077	-0.017	0.436	0.354
	(0.690)	(1.196)	(-0.417)	(-0.130)	(0.835)	(0.971)
Difference to CbCR Threshold	-0.000	-0.002	0.002	-0.000	-0.015*	-0.004
	(-0.074)	(-1.016)	(0.712)	(-0.056)	(-1.837)	(-1.452)
Ab. CbCR Thrshd. X Diff. to CbCR Thrshd.	-0.002	0.002	-0.001	0.000	0.016	0.002
	(-0.174)	(0.533)	(-0.364)	(0.262)	(1.502)	(0.486)
Constant	3.200***	3.145***	0.700***	0.660***	3.138***	3.407***
	(9.668)	(13.008)	(4.565)	(5.848)	(10.069)	(14.240)
Observations	577	1,179	577	1,179	577	1,179
Bandwidth (in EUR Mio.)	150	300	150	300	150	300

Notes: This table presents results of estimating Equation V.2 using Ordinary Least Squares for a subset of firm-years with turnover values within a narrow bandwidth around the CbCR threshold prior to the introduction of CbCR. Row (1) depicts our coefficients of interest, i.e. the local discontinuities that identify the treatment effect of CbCR. Local changes to geographic information disclosure are estimated for firms inside a symmetric EUR 150 Mio. bandwidth around the CbCR threshold in columns (1), (3) and (5). A larger bandwidth of EUR 300 Mio. is used for columns (2), (4) and (6). Standard errors are clustered at the firm level. Values in parentheses represent robust t-statistics. ***, **, and * denote significance at the one-, five-, and ten-percent level for two-sided tests of significance.
Source: Orbis, Bloomberg and Perfect Information/EDGAR. See Table V.A1 and Sections 3.2 and 3.3 for a more detailed description of data sources and variables used.

Table V.A12: RDD Results Before the Introduction of CbCR Without Observations Close to the Threshold

VARIABLES	(1) Insensitive geographic information	(2)	(3) Sensitive geographic information	(4)	(5) Qualitative geographic information	(6)
Above CbCR Threshold	0.235	0.361	-0.045	0.008	0.852	0.540
	(0.399)	(1.034)	(-0.218)	(0.059)	(1.371)	(1.384)
Difference to CbCR Threshold	0.003	-0.002	0.002	-0.000	-0.014	-0.004
	(0.379)	(-0.656)	(0.666)	(-0.126)	(-1.613)	(-1.224)
Ab. CbCR Thrshd. X Diff. to CbCR Thrshd.	-0.007	0.001	-0.002	0.000	0.008	-0.001
	(-0.552)	(0.250)	(-0.469)	(0.203)	(0.634)	(-0.132)
Constant	3.378***	3.214***	0.695***	0.652***	3.145***	3.453***
	(7.910)	(11.743)	(4.594)	(5.873)	(8.642)	(13.354)
Observations	534	1,136	534	1,136	534	1,136
Bandwidth (in EUR Mio.)	150	300	150	300	150	300

Notes: This table presents results of estimating Equation V.2 using Ordinary Least Squares for a subset of firm-years with turnover values within a narrow bandwidth around the CbCR threshold prior to the introduction of CbCR. Row (1) depicts our coefficients of interest, i.e. the local discontinuities that identify the treatment effect of CbCR. Changes to geographic information disclosure are estimated for firms inside a symmetric EUR 150 Mio. bandwidth around the CbCR threshold in columns (1), (3) and (5). A larger bandwidth of EUR 300 Mio. is used for columns (2), (4) and (6). In addition, we exclude turnover observations located directly around the CbCR threshold within a EUR 10 Mio. bin, i.e. EUR 5 Mio. below and above the threshold. Standard errors are clustered at the firm level. Values in parentheses represent robust t-statistics. ***, **, and * denote significance at the one-, five-, and ten-percent level for two-sided tests of significance.
Source: Orbis, Bloomberg and Perfect Information/EDGAR. See Table V.A1 and Sections 3.2 and 3.3 for a more detailed description of data sources and variables used.

B Download of Annual Reports from Filings Expert

We begin by identifying documents classified as English language annual reports by the data provider for all countries (except for the US)[20], which leaves us with roughly 300,000 documents and 46,000 unique firms. Since the companies do not have a common identifier (i.e. ISIN, etc.), we create a list of all companies for which we observe annual reports. In the next step, we match that list based on firm name and country of incorporation with the firms from BvD's Orbis database, which provides us with firm financial and descriptive information about the structure of the corporate group including subsidiaries. For the matched firms, we retrieve the annual reports automatically to construct our sample of text corpora. The file format for the documents is standard PDF which must be converted to machine-readable text format. Before the text files can be used for textual analysis, extraneous attributes as well as other artifacts (i.e., graphs and tables, etc.), must be excluded because they are difficult to analyze and likely to add noise to the analysis (Loughran and McDonald, 2016). Subsequently, the remaining text elements are parsed into sentences. Manual inspection reveals that some documents classified as annual reports are fourth-quarter interim reports or annual results containing only basic financial statement information. We thus require each document to mention the bigram "annual report" on the first two pages to ensure that the remaining documents are indeed annual reports with a rich set of narrative disclosures. We verified for a representative subset of firms that the resulting documents coincide with the relevant annual reports published on their website. Hence, whenever a firm provides an integrated report with additional information on their website, the complete document is used in our data.

[20]In the US, the Form 10-K documents are highly standardized. Therefore, reports are frequently used in the accounting literature (Li, 2010; Loughran and McDonald, 2011). However, we also want to focus on less regulated, glossy annual reports published by non-US firms. Moreover, the database only has a limited coverage of Form 10-Ks. Therefore, we download these reports directly from EDGAR.

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