Tax Loss Carry-Forwards and the Elasticity of Corporate Taxable Income: Evidence from Administrative Tax Records*

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Abstract

We use administrative data on all corporate taxpayers in Slovakia to examine how tax loss carry-forwards (TLCFs) alter business responses to the corporate tax rate. We exploit a reform which permitted TLCFs above minimum corporation tax kinks. Bunching at kinks sharply increased immediately after it became possible to use TLCFs. By decomposing the increase in the estimated taxable income elasticity, we find that the marginal efficiency burden of the corporation tax would be 2-36 p.p. lower across corporate VAT and turnover categories net of inter-temporal tax loss transfers and 0.5-21 p.p. higher if TLCFs were not mitigating taxable income distortions.

Keywords: elasticity of taxable income; corporations; tax losses; carry-forwards; bunching; marginal efficiency burden

JEL: H21, H25, H32

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1 Introduction

The ability of businesses to carry forward prior losses is one of the defining features of corporate taxation. In the U.S., for instance, corporations are allowed to carry forward net operating losses (NOLs) *indefinitely* to offset up to 80 percent of taxable income. In 2013 alone, when carry-forwards were permitted for 20 years, NOLs brought forward by U.S. companies totaled $180 billion (Coles, Patel, Seegert and Smith, 2022). Many countries do not impose any limits on corporate carry-forwards.[1]

From the efficiency perspective, carry-forwards should be permitted if taxation aims to remain neutral with respect to the timing of corporate income and expenditures (Auerbach, 1986; Bonds and Devereux, 1995). Despite their predicted positive impact on efficiency, carry-forwards are often treated only as inter-temporal transfers that are not considered in the estimation of the elasticity of corporate taxable income (ETI), the central parameter in the economic analysis of corporate taxation, which serves in the absence of external effects as *a sufficient statistic* for determining the marginal efficiency burden (MEB) of the corporation tax (Feldstein, 1995, 1999; Chetty, 2009; Saez, Slemrod and Giertz, 2012). Yet if carry-forwards are not mere transfers, but mitigate distortions in business activity and reporting, neglecting their impact can lead to incorrect estimation of the corporate ETI and a biased welfare analysis of the corporate tax rate.

In this paper, we use tax-return administrative data on all corporate taxpayers in 2010-2018 in Slovakia to examine how carry-forwards affect business responses to the corporate tax rate and bias the marginal efficiency burden of the corporation tax. We exploit a unique policy reform which introduced tax liability offsets above kinks in the corporate tax schedule against prior tax losses. We estimate how the ability to carry forward tax losses leads to sharply increased bunching at kinks and a higher implied ETI. We decompose differences in the ETI estimated before and after companies apply tax loss carry-forwards into (i) taxable income distortions mitigated by tax loss carry-forwards and (ii) net inter-temporal tax loss transfers. Using our estimates, we evaluate the implications of tax loss carry-forwards for the MEB of the corporation tax.[2]

Existing literature recently provided a number of estimates of the corporate ETI (Gruber and Rauh, 2007; Dwenger and Steiner, 2012; Devereux, Liu and Loretz, 2014; Bachas and Soto, 2021; Coles et al., 2022), little attention has been however paid to studying the contribution of loss carry-forwards for the ETI. Addressing this question proved difficult especially given the high persistence of the carry-forward option in most tax systems and scarce variation in marginal tax rates (MTR) in typically linear

[1] Table A.1 reviews loss carry-over provisions in OECD countries (Hanappi, 2018).

[2] We study carry-forwards of *tax losses* above kinks in tax liability distributions, but NOL carry-forwards operate on practically the exact same principle of offsetting income above zero by prior losses.

corporate tax schedules.[3] Past losses however remain of first-order importance, especially for large, more formal and more heavily scrutinized firms, which generate most corporate tax revenue and within which a major share of economic activity tends to be concentrated. Understanding the causal impact of carry-forwards on the corporate ETI is therefore highly relevant both from the fiscal and economic welfare perspectives.

Two features of the Slovak institutional setting make it an ideal testing ground for our analysis. The first feature is the existence of kinks in the corporate tax schedule in 2014-2017. Kinks emerged after a reform introduced three levels of a *minimum corporation tax*. Firms with a sales turnover above €500,000 were newly required to pay at least €2,880 in tax annually, even if the proportional rate indicated a lower tax liability. Lower-turnover firms were subject to a €960 minimum tax if they were VAT registered and a €480 tax if not. Corporate income thus became subject to zero MTR below the new minimum tax kinks, but remained subject to positive MTR above these kinks.[4]

The second feature introduced by the policy reform was that starting in 2015 firms could carry forward *tax losses*, i.e. tax payments they had to make to match the minimum tax when the proportional tax rate indicated a lower tax liability. Tax losses could be carried forward for three years, but only to offset tax liability exceeding the minimum tax. The advantage of tax loss carry-forwards was that they largely mitigated the motivation to misreport taxable income beneath the minimum tax levels.[5] Importantly for our empirical design, carry-forwards remained available even after the minimum tax was abolished in 2018, but still only to offset tax liability above the former kinks.

In our empirical strategy, we estimate the ETI using a non-parametric bunching design. We contrast the excess mass of firms at the minimum tax kinks in post-2015 tax liability distributions against appropriately scaled smooth distributions from 2010-2013. We estimate the ETI both before and after firms carry forward tax losses to show how much the ETI can differ. Then, we estimate the ETI for a hypothetical scenario in which tax loss carry-forwards were not introduced. This allows decomposition of differences in the ETI before as compared to after carry-forwards into taxable income distortions mitigated by carry-forwards and net inter-temporal tax loss transfers. In the last step, we estimate the MEB of the corporation tax above the minimum tax kinks for (i) a sce-

[3]Existing studies examined other determinants of the corporate ETI, especially relevant for small owner-managed firms, using the variation from personal tax schedules. Devereux et al. (2014) estimate the impact of shifting profits into the salaries of business owner-managers in response to differences between corporate and personal tax rates. Miller, Pope and Smith (2022) study profit retention within owner-managed firms as a way to avoid personal income tax. Coles et al. (2022) decompose the corporate ETI for small U.S. sub-chapter C companies into real economic responses and overall tax adjustments.

[4]The introduction of the minimum tax also prompted exits by the lowest-profit companies, which effectively had to pay the government to operate, as we discuss further below.

[5]This was because (i) firms were subject to a fixed amount of tax for any level of taxable income beneath the minimum tax amounts, and (ii) future offsets of tax losses over-reported in one year would require reporting higher taxable income above the minimum tax within the next three years anyway.

nario with and after tax loss carry-forwards, (ii) a scenario before tax loss transfers and with income distortions mitigated by carry-forwards, and (iii) a counterfactual scenario net of tax loss transfers and without carry-forwards mitigating distortions.

In our results, we find the corporate ETI ranging from 0.03 for firms with a turnover above €500,000 (top category with 13.7% of firms) to 0.41 for lower-turnover VAT registered firms (middle category with 47.8% of firms) to 1.13 for non-VAT registered firms (bottom category with 38.5% of firms) if we base our estimation on tax distributions before tax loss carry-forwards.[6] The ETI is significantly higher if it is estimated after carry-forwards. In this case, bunching at kinks grows sharply and the ETI jumps to 0.12, 0.75 and 1.44 in the top, middle and bottom categories, respectively. In relative terms, tax loss carry-forwards thus amplify the ETI, especially for high-turnover firms.

Our decomposition of the increase in the ETI suggests that in a hypothetical scenario in which tax loss carry-forwards were not introduced, firms would distort tax liability much more towards kinks compared to the scope of bunching estimated before tax loss carry-forwards, producing a 48-87%, 28-39% and 0.4-16.7% higher ETI in the top, middle and bottom corporate categories, respectively. These results uncover the scope of downward bias in the ETI based on tax distributions before carry-forwards. Relying on distributions after carry-forwards would lead to an over-estimated ETI due to pronounced inter-temporal tax loss transfers. Our decomposition namely suggests that net of tax loss transfers, the ETI after tax loss carry-forwards would decline 50-61%, 24-30% and 8-20% in the top, middle and bottom categories, respectively.

Our results have direct implications for the welfare analysis of the corporate tax rate. We estimate that the marginal welfare loss relative to the mechanical increase in tax revenue, should MTR above minimum tax kinks rise by 1%, would drop from 102.5% to 66.7-86.9% for firms in the bottom category, from 35.6% to 22.5-25% for firms in the middle category, and from 3.8% to 1.5-1.8% for firms in the top category, if we used the ETI implied from tax liability distributions net of inter-temporal tax loss transfers as opposed to the ETI implied from density distributions including tax loss transfers. In contrast, if we used the ETI estimated prior to tax loss carry-forwards, we would under-estimate the MEB by up to 21 percentage points.

Our paper thereby provides strong support for earlier studies which advocated the use of carry-forwards in corporate taxation by highlighting their impact on tax neutrality (Auerbach, 1986; Auerbach and Poterba, 1987; Bonds and Devereux, 1995; Cooper and Knittel, 2010; Dressler and Overesch, 2013). We contribute to this literature by being the first to quantify how the MEB would increase absent tax loss carry-forwards.

[6]The heterogeneity agrees with the evidence by Pomeranz (2015), Almunia and Lopez-Rodriguez (2018) and Naritomi (2019) who show that VAT and (third-party) monitoring can improve tax compliance. The scope of the heterogeneity also agrees quantitatively with earlier results on heterogeneous firm responses to MTR from the U.K. and the U.S. (Devereux et al., 2014; Coles et al., 2022).

At the same time, we extend earlier tax literature which pointed out the relevance of inter-temporal transfers for the magnitude of the ETI in the context of taxing wage-earners, the self-employed and business owner-managers (Slemrod, 1995; Goolsbee, 2000; le Maire and Schjerning, 2013; Kreiner, Leth-Petersen and Skov, 2016; Miller et al., 2022). We add to this literature by quantifying the relevance of inter-temporal transfers of tax losses via carry-forwards in the context of corporate taxation.

In our additional analysis, we provide more evidence about the impacts of the 2014 tax reform and sources of corporate bunching at the minimum tax kinks. Using event-study regressions, we show that especially non-VAT registered firms with tax liability previously below the minimum tax levels became significantly more likely to appear at the new kinks after 2014 compared to non-VAT registered firms previously above the minimum tax amounts. When we non-parametrically compare the mass of firms that emerged at the new kinks against the decline in bunching at zero tax liability, we find that the mass missing at zero can explain the entire new excess mass at the new kinks. Furthermore, we find evidence of a limited *extensive-margin response*: we do not observe a significant decline in the probability of firms operating and filing tax returns in 2014 even if their previous tax liability was below the minimum tax.[7] These results are in line with pronounced tax avoidance or evasion towards zero prior to 2014, especially by non-VAT registered firms. These types of corporate behavior would agree well with our findings of a lower relevance of tax loss carry-forwards for the corporate ETI in the category of non-VAT registered, low-turnover firms, as the minimum tax would have made these firms move towards the minimum tax kinks regardless of the introduction of tax loss carry-forwards.

These additional results extend the prior literature on the impacts of minimum corporation tax designs, giving evidence in line with earlier findings that minimum taxes can help raise additional revenue by constraining evasion and avoidance (Best, Brockmeyer, Kleven, Spinnewijn and Waseem, 2015; Mosberger, 2016). At the same time, our evidence agrees with earlier studies which pointed out evasion and avoidance as important sources of a high corporate ETI (Bachas and Soto, 2021; Coles et al., 2022).

Finally, our results add to earlier literature which studied taxpayer responses to kinks and notches using bunching methods (Saez, 2010; Chetty, Friedman, Olsen and Pistaferri, 2011; Kleven and Waseem, 2013; see Kleven, 2016 for a review). A unique feature of our setting is that we can observe undistorted tax distributions before the introduction of new kinks, which allows us to propose credible counterfactuals without parametric assumptions about their shape or source of the excess mass at kinks. We show that if we neglected that the dominant source of bunching at kinks is near zero

[7] The likelihood of exit slightly increases in 2015 among low-turnover firms, but a major part of these exits was due to the formal closure of inactive firms with zero turnover.

and assumed instead that the excess mass originates proportionally from the whole distribution to the left of kinks (which would be the default assumption in cross-sectional bunching designs), we would obtain overestimated counterfactuals at kinks and a 60-69% lower ETI compared to our main estimates based on pre-reform data. We argue that similar biases might appear in settings with pronounced tax avoidance and evasion. The insights about the benefits of using counterfactuals based on pre-reform data as well as examining sources of excess mass at kinks generalize to settings outside of the tax literature (e.g., Harasztosi and Lindner, 2019).

We structure the rest of our paper as follows. In section 2, we present the institutional background of corporate income taxation in Slovakia. In section 3, we describe our tax-return data. In section 4, we review the bunching methodology. In section 5, we estimate the ETI separately before and after tax loss carry-forwards. In section 6, we study the mechanisms behind the estimated differences in the ETI. In section 7, we examine the implications of tax loss carry-forwards for the MEB. In section 8, we present additional evidence about the impacts of the minimum tax reform and sources of corporate bunching at the minimum tax kinks. In section 9, we summarize and conclude.

2 Corporate income taxation in Slovakia

Slovakia is a high-income, developed market economy located in Central Europe. After splitting from the former Czechoslovakia in 1993, Slovakia joined the OECD in 2000, the European Union in 2004 and the Eurozone in 2009. In 2017, Slovak tax revenue amounted to 33% of GDP (OECD, 2018). 11% of this revenue was from corporate taxes, 10% from personal taxes, 43% from social security contributions and 33% from taxes on goods and services. Corporation tax is remitted annually by around 190,000 firms.[8]

2014 minimum tax reform. Until 2014, Slovakia applied a flat tax rate on all corporations: 19% in 2004-2012 and 23% in 2013. The effective tax rate was, however, estimated to be 3.6 - 4.7% in 2005-2013 (Ministry of Finance of the Slovak Republic, 2018). Around 60% of corporations paid zero income tax during this period. This was partly due to legitimate reasons, such as the volatility of corporate income and the ability of companies to carry forward losses. However, the Ministry of Finance of the Slovak Republic (2013) also expressed concerns about excessive tax avoidance and evasion.

To tackle low effective tax rates, in 2014 Slovakia introduced a *minimum corporation tax* with three levels, as shown in Table 1. Companies in the top category with a

[8]Sole proprietorships and partnerships are not subject to corporate taxes. Profits of unincorporated firms are attributed to individual partners and taxed according to the personal income tax schedule. Incorporated companies generate around 96% of the total tax revenue obtained from all legal entities.

turnover above €500,000 were subject to a €2,880 minimum tax. The middle category of VAT registered companies below the €500,000 turnover limit had to pay at least €960.[9] The lowest category of non-VAT registered companies with an annual turnover below €500,000 had to pay at least €480 in tax annually.[10,11] All income above the minimum tax levels was subject to a 22% tax rate in 2014-2016 and a 21% rate afterwards.

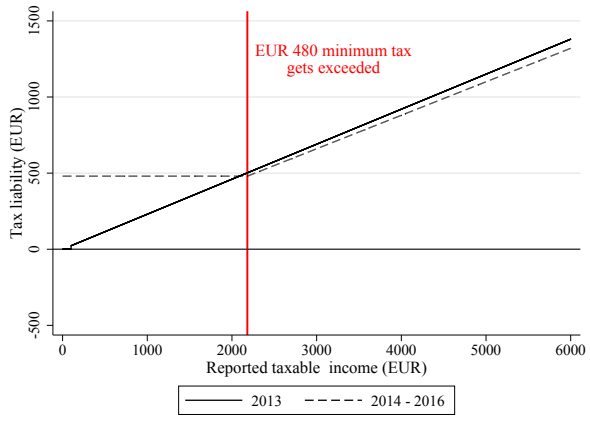
Table 1: Minimum corporation tax in 2014-2017

Corporate category	Sales turnover	Registered for VAT	Minimum tax
Top	≥€500,000	Yes[a]	€2,880
Middle	<€500,000	Yes	€960
Bottom	<€500,000	No	€480

Notes: [a]Companies in specific sectors, such as financial institutions, insurance companies, post offices and public broadcasting companies, do not need to register for VAT. Exemptions from VAT registration are specified in articles 28–42 of the Slovak Tax Code Act no. 222/2004 on VAT.

Figure 1 visualizes the relationship between the reported taxable income and the implied tax liability before and after the introduction of the minimum tax. Using companies subject to the €480 minimum tax as an example, the figure shows that the minimum tax reform increased the tax liability for all companies which would otherwise be below the minimum tax levels. The reform thereby established kinks in the corporate tax schedule with zero MTR below the minimum tax amounts and positive MTR above these amounts. On the extensive margin, the reform additionally prompted the exit of the lowest-profit companies, which effectively had to pay the government to operate.

Figure 1: Tax schedule for companies in the bottom minimum tax category



[9]Corporations had to register for VAT if their turnover in the prior 12 months exceeded €49,790.

[10]Corporations where at least 20% of the employee base was disabled had to pay only 50% of the minimum tax. In practice, this reduction was applied to a negligible number of companies. The tax code also did not require minimum tax payments from companies in the first year after incorporation and from corporations filing for bankruptcy and in liquidation. We account for these rules in our analysis.

[11]In Figure A.1, we use a non-parametric bunching design to estimate corporate responses to incentives created by the €500,000 turnover threshold. We do not find evidence of a statistically significant response.

Tax loss carry-forwards. In addition to establishing the minimum tax, the tax reform also introduced the option of *tax loss carry-forwards*, first applicable in 2015. The rule was that after firms calculated their tax liability using the proportional MTR and found the result to be below the minimum tax, they were required to make an additional payment to bring their tax amount up to the minimum tax. Such tax loss could be carried forward for three years, provided that it was used to offset the tax liability above the minimum tax. Tax loss carry-forwards were not automatic or mandatory, however.

In Table A.2, we provide a stylized example of a calculation of the maximum amount of tax loss carry-forwards.[12] The example illustrates how tax loss carry-forwards decrease the tax liability in some years and increase the mass of companies located at the minimum tax kinks. One way of looking at their use is as a simple non-distortive transfer of corporate income into past fiscal periods, in which a lower MTR is applied on corporate income. From a different perspective, the option to carry forward tax losses may have contributed to mitigating distortions in the (reported) taxable income, because companies do not need to shift expenditures from low-income years into years when they have taxable income above the corresponding minimum tax amount. In our analysis, we aim to disentangle such inter-temporal tax loss transfers from taxable income distortions mitigated by tax loss carry-forwards.

2018 abolition of the minimum tax. As of 2018, Slovakia once again cancelled the minimum tax. The abolition was approved in November 2016, but the minimum tax still applied in 2017. Importantly for our empirical design, the reform maintained tax loss carry-forwards above the abolished minimum tax levels even after 2018.

In Table A.3, we give another stylized example of how to calculate the amount of tax loss carry-forwards after the minimum tax was abolished.[13] The example illustrates that even after the minimum tax was cancelled, one could expect to find an excess mass of companies located at the abolished kinks. For companies without accumulated tax losses, however, the incentive to bunch at kinks disappeared entirely.

[12]The table gives an example of a VAT registered firm with a turnover below €500,000, subject to the €960 minimum tax. If such a firm had a tax liability of €680 in 2014, it was required to pay an additional €280 to bring its tax up to the minimum tax (€960 - €680 = €280). The next year, provided that the firm's tax liability was above €960, which is true in our example, the firm could apply carry-forwards up to €280 against any tax liability exceeding €960. In our example, in the absence of carry-forwards, the company would have to pay €1,100. Therefore, its final tax liability could be reduced to €960.

[13]In the table, a low-turnover, non-VAT registered company paid €180 in 2015, €30 in 2016, and €480 in 2017 to match the €480 minimum tax. The sum of these payments (€690) is the tax loss that could be carried over to 2018 to offset the tax liability exceeding the former minimum tax. In our example, in 2018 the company's tax liability was €700 prior to carry-forwards. As a result, it could carry over €700 - €480 = €220, making its final tax liability equal to the former kink.

Other fiscal reforms. In addition to the 2014 and 2018 policy reforms, Slovakia implemented several other tax changes in 2010-2018. It raised the corporate tax rate from 19% to 23% in 2013 and reduced it to 22% in 2014. In 2017, the tax rate dropped to 21%. Although the tax rate changes affect the amount of bunching at kinks, we take the tax rates into account when estimating the ETI, as in Saez (2010).

Furthermore, Slovakia imposed stricter rules on *loss carry-forwards* in 2014. The maximum time frame from which losses could be carried forward was reduced from seven prior years to four. Firms were also newly limited to forwarding a maximum of 25% instead of 100% of the accumulated loss annually. Although these parametric changes might increase the number of companies with a positive tax base, they do not create incentives for additional bunching at the minimum tax kinks.[14] We are not aware of any further changes in fiscal policy or tax enforcement that could be related to our results.

3 Administrative tax-return data

In our analysis, we use administrative tax-return data that cover the population of corporate taxpayers in Slovakia in 2010-2018.[15] The dataset includes tax variables which correspond to all individual items recorded on tax-return forms. These include annual information about turnover, VAT registration, taxable income, tax liability prior to the minimum tax and tax loss carry-forwards, the amount of tax loss carry-forwards, the applicable minimum tax, and the amount of tax actually paid. Over the nine-year observation period, the data covers around 300,000 distinct companies.

Table 2 reports the averages of the key variables in our data, separately for 2010-2013 before the 2014 reform and for 2015-2017 when companies were subject to the minimum tax and could carry forward tax losses. In both periods, we note substantial heterogeneity across firms in terms of tax paid. In 2010-2013, the average tax paid in the top category of high-turnover companies was 45 times higher than the average tax paid by VAT-registered, low-turnover firms in the middle category and 100 times higher than the average tax paid by non-VAT registered firms in the bottom category. After the reform, the heterogeneity was partially reduced. The average tax paid in the top category was "only" 37 times higher than in the middle category and 63 times higher than in the bottom category. The table thus indicates that the minimum tax and tax loss carry-forwards impacted low-turnover and high-turnover companies unequally.

[14] Table A.4 summarizes other fiscal reforms pertaining to social security contributions, personal income tax, and other fees and tariffs implemented in 2013 and 2014, along with their fiscal impact estimated by the Ministry of Finance of the Slovak Republic (2014).

[15] The dataset is confidential and owned by the Financial Directorate of the Slovak Republic, which provides it to other state bodies of the Slovak Republic according to article 11 of the Slovak Tax Code Act no. 563/2009 on tax secrecy. For details, see: https://www.zakonypreludi.sk/zz/2009-563

Table 2: Summary statistics

	2010 - 2013				2015 - 2017			
	All companies	Bottom category	Middle category	Top category	All companies	Bottom category	Middle category	Top category
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Turnover	1,192,632	18,113	102,364	7,807,194	1,116,979	22,534	109,067	7,880,856
	[33,412,200]	[40,969]	[119,865]	[87,337,095]	[32,844,049]	[42,553]	[119,879]	[89,354,143]
Taxable income	50,755	3,071	6,931	317,784	59,431	5,490	8,910	395,681
	[1,833,995]	[169,554]	[418,961]	[4,730,628]	[2,109,150]	[343,670]	[27,952]	[5,714,202]
Tax liability prior to tax loss carry-forwards and MT	9,919	618	1,372	62,002	12,640	1,191	1,925	83,987
	[362,805]	[34,096]	[79,644]	[936,789]	[452,277]	[75,316]	[6,062]	[1,225,081]
- % of companies with zero tax liability	59.1	66.3	60.9	35.1	39.5	44.5	40.8	19.6
- % of companies with zero tax liability and no reported loss	19.5	30.7	13.9	11.2	12.3	18.8	8.3	6.1
Tax loss carry-forwards	.	.	.	.	69	25	72	195
					[351]	[119]	[280]	[765]
Tax liability after carry-forwards but before MT	.	.	.	.	12,571	1,166	1,853	83,792
					[452,276]	[75,316]	[6,043]	[1,225,086]
% subject to €480 MT	35.5[a]	.	.	.	40.7	100.0	0.0	0.0
% subject to €960 MT	50.0[a]	.	.	.	45.9	0.0	100.0	0.0
% subject to €2880 MT	14.5[a]	.	.	.	13.4	0.0	0.0	100.0
Tax actually paid	9,919	618	1,372	62,002	12,925	1,343	2,275	84,445
	[362,805]	[34,096]	[79,644]	[936,789]	[452,267]	[75,314]	[5,932]	[1,225,042]
Observations	669,943	237,506	335,040	97,397	618,801	251,889	283,856	83,056

Notes: The variables are reported in Euro in 2010 prices. Standard deviations are reported in brackets. [a]In 2010-2013, we report the proportion of companies that would be subject to the minimum tax. Averages for 2014 and 2018 are reported separately in Table A.5.

The unequal impact of the policy reform is also observable when initial tax liabilities prior to the application of tax loss carry-forwards and the minimum tax in 2015-2017 are compared to taxes actually paid in this period. In the bottom and middle corporate categories, the final tax liability is 13% and 18% higher, respectively, compared to the initial tax liability. In contrast, the tax bill is only 0.5% higher in the top category.[16]

Finally, Table 2 indicates that one of the likely reasons for the heterogeneous impact of the tax reform might have been that the growth in tax liability was less notably mitigated by tax loss carry-forwards in the bottom and middle categories than in the top category. Tax loss carry-forwards constitute 16% and 21% of the difference between the initial tax liability before tax loss carry-forwards and the tax eventually paid in the bottom two categories, respectively. Yet, carry-forwards correspond to 43% of the difference in the top category. This finding indicates that tax loss carry-forwards are more relevant for large corporations than for less formal and less scrutinized firms in the bottom two corporate categories.

4 Empirical bunching methods

In our analysis, we estimate the corporate ETI from the number of companies bunching at kinks in the corporate tax schedule. We build on Saez (2010), who demonstrates that the compensated elasticity of taxable income with respect to one minus the tax rate is proportional to the amount of bunching at kinks:

$$e \simeq \frac{b\,(t_1,\ t_2)}{K \ln\left(\frac{1-t_1}{1-t_2}\right)} \tag{1}$$

where K is some income level at which the MTR increases by a small amount from t_1 to t_2 and $b(t_1, t_2)$ corresponds to the fraction of companies which bunch at K relative to the counterfactual density. In most empirical applications, the value of K and the tax rates t_1 and t_2 are known policy parameters. The key remaining step to identify e is to estimate the excess mass $b(t_1, t_2)$ bunching at K.

Cross-sectional bunching approaches. Two cross-sectional bunching methods for estimating the scope of bunching at kinks dominate in modern tax literature: one by Saez (2010) which we label as the *baseline* method and a second by Chetty et al. (2011) which we label the *adjusted* method.[17] In both methods, the counterfactual density dis-

[16] In accordance with these figures, Figure A.2 shows that €114 million growth in tax revenue from the smallest firms with a tax liability below €4,000 between 2013 and 2014 coincides almost perfectly with the overall fiscal impact of the 2014 tax reform estimated in Table A.4 by the Ministry of Finance of the Slovak Republic (2014).

[17] We revise the exact regression specifications and bunching formulas in Online Appendix B.

tribution of taxable income (or tax liability) is obtained by first plotting the empirical distributions in a histogram of firms separated into small bins with a fixed width. In the second step, a flexible high-order polynomial is fitted to the histogram bins excluding data within a narrow window around the kink. The counterfactual is defined as predicted values from the polynomial regression, omitting the contribution of bins around the kink. In the *adjusted* method, one additionally shifts the counterfactual to the right (left) of the kink upwards until the area under the counterfactual equals the area under the empirical distribution. The assumption underlying causal inference in both methods is that density distributions would be smooth in the absence of kinks.

A complication to identification might arise in cross-sectional bunching approaches if taxpayers tend to bunch at round numbers in taxable income distributions (Kleven and Waseem, 2013). As we later show, another complication arises if one cannot credibly assume that the excess mass at kinks originates proportionally from the whole distribution to the right (or left) of the kink. In our setting, for example, many companies would plausibly bunch at zero taxable income in the counterfactual scenario without the minimum tax. If we assumed that the excess mass at the kink originated proportionally from the whole distribution to the left of the kink, we might overestimate the counterfactual density at the kink, producing attenuated estimates of the corporate ETI.

Exploiting pre-reform distributions. In order to address potential challenges associated with cross-sectional bunching approaches, we employ a *non-parametric* bunching strategy also used by Devereux et al. (2014), in which one relaxes the assumption of a smooth counterfactual and makes no assumptions about the source of bunching. Instead, the strategy exploits the timing of the tax reform and assumes that tax liability distributions after the reform would look the same as before the reform in the counterfactual scenario in which the reform had not been implemented.[18]

Under this stationarity assumption, one can estimate a probability density function $\widehat{p}_H(j)$ over a finite interval $(Z_{\min}, Z_{\max})$ using a histogram estimator:

$$\widehat{p}_H(j) = \frac{C_{j,t_{pre-reform}}}{\sum_{i=Z_{\min}}^{Z_{\max}} C_{i,t_{pre-reform}}} \tag{2}$$

where $C_{j,t_{pre-reform}}$ is the number of companies in a histogram bin j from the tax liability distribution prior to the minimum tax reform. The counterfactual density is then:

$$\widehat{C}_j = \widehat{p}_H(j) \cdot \sum_{i=Z_{\min}}^{Z_{\max}} C_{i,t_{post-reform}}. \tag{3}$$

[18]We provide empirical support for this assumption in Figure A.3, in which we show that tax liability distributions were stable in 2010-2013 prior to the introduction of the minimum tax and also across 2013 and 2018, i.e. prior to the introduction of the minimum tax and after its abolition.

The implied excess number of companies bunching within a narrow window (Z_L, Z_U) around the kink is computed as:

$$\widehat{B}\left(t_1,\ t_2\right) = \sum_{j=Z_L}^{Z_U} C_j - \widehat{C}_j \tag{4}$$

Finally, the estimated excess mass of companies bunching at the kink relative to the average density of the counterfactual distribution between Z_L and Z_U is:

$$\widehat{b}\left(t_1, t_2\right) = \frac{\widehat{B}\left(t_1, t_2\right)}{\sum_{j=Z_L}^{Z_U} \widehat{C}_j / N_j} \tag{5}$$

where N_j is the number of bins between Z_L and Z_U.

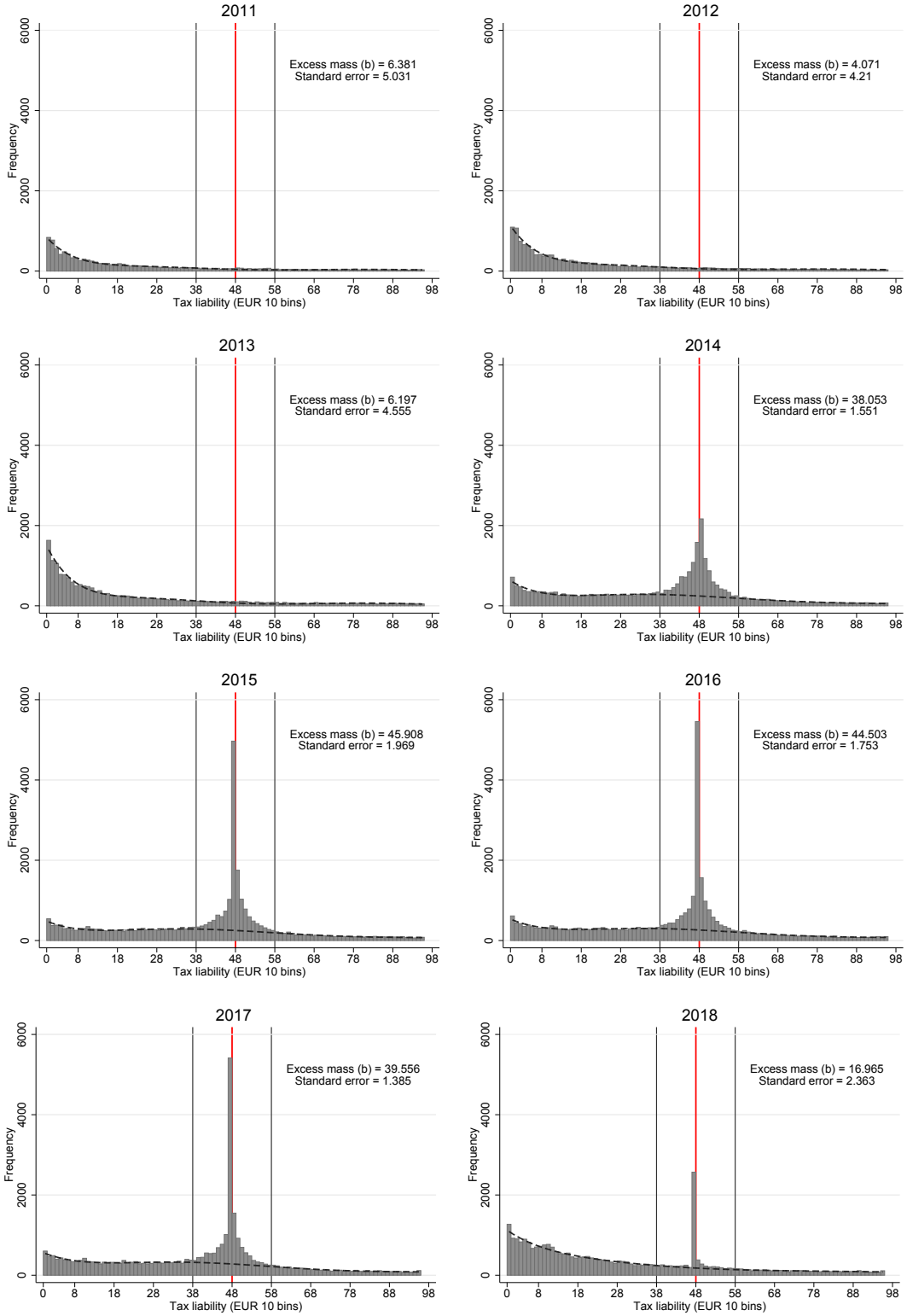
We calculate standard errors using a parametric residual-resampling bootstrap procedure with replacement. More specifically, we draw values from the estimated vector of residuals to generate a new set of bin counts and apply the above bunching method to calculate a new estimate of $\widehat{b}^k$. We define the standard error of $\widehat{b}$ as the standard deviation of the distribution of $\widehat{b}^k$s. We estimate the corporate ETI as a non-linear function of the bunching estimate, kink K and the relative change in the net-of-tax rate $\ln\left(\frac{1-t_1}{1-t_2}\right)$ at K using Eq. (1). We obtain standard errors for the elasticity again by bootstrapping.

5 Baseline estimates of the corporate ETI

We start the empirical analysis by obtaining separate baseline estimates of the corporate ETI for before and after firms offset part of their tax liability by previous tax losses.

Corporate ETI after tax loss carry-forwards. Figure 2 gives the first visual evidence of pronounced bunching at the minimum tax kinks in otherwise declining tax liability distributions. The figure displays distributions annually for low-turnover, non-VAT registered companies after tax loss carry-forwards, but prior to the application of the minimum tax. Bunching at the €480 kink clearly appears first in 2014, that is, immediately after companies became subject to the minimum tax. The excess mass is diffused around the kink rather than forming a point mass, as it is presumably difficult to control profits perfectly. Bunching grows sharply in 2015 when companies could carry forward tax losses for the first time. Bunching then remains pronounced up to the end of the observation period, including in 2018 after the minimum tax was abolished but tax loss carry-forwards remained available above the former minimum tax levels. Figures A.4 and A.5 in the Appendix show very similar evidence of bunching at the €960 and €2,880 kinks for companies in the middle and top corporate categories.

Figure 2: Annual tax liability distributions around the €480 minimum tax kink



Notes: Series shown in bars are annual histograms of corporate tax liability around the €480 minimum tax kink. The liabilities are after tax loss carry-forwards, but prior to the application of the minimum tax. Each bar shows the number of observations in €10 bins. The dashed lines above the histograms are eighth-degree polynomials fitted to the empirical distributions using the *baseline* cross-sectional bunching approach. The excluded intervals around the kinks are demarcated by vertical solid lines.

Table 3: Corporate ETI estimated using pre-reform distributions

	non-VAT registered, turnover $<$ €500k	VAT registered, turnover $<$ €500k	Turnover $\geq$ €500k
	(1)	(2)	(3)
	Panel A: Tax liability distribution after tax loss carry-forwards		
$\widehat{e}$	1.436	0.745	0.118
	[0.123]	[0.058]	[0.002]
$\widehat{b}$	77.843	80.748	38.226
	[6.309]	[6.075]	[0.731]
$\widehat{B}$	26,343	18,582	1,810
	Panel B: Tax liability distribution before tax loss carry-forwards		
$\widehat{e}$	1.13	0.408	0.031
	[0.123]	[0.054]	[0.002]
$\widehat{b}$	61.272	44.252	10.005
	[6.695]	[5.809]	[0.798]
$\widehat{B}$	20,652	9,840	396
N	73,899	72,829	5,383

Notes: The table reports the corporate ETI $\widehat{e}$ in 2015-2016 estimated using pre-reform tax liability distributions and the histogram estimator in Eq. (2). The pre-reform distributions $C_{j,t_{pre-reform}}$ are defined by pooling the number of companies in histogram bins across 2010-2013. The excluded intervals around the minimum tax kinks are +/-€100 for the €480 and €960 kinks and -€30/€70 for the €2,880 kink, as in Figures 2, A.4 and A.5, respectively. $\widehat{B}$ is the estimated excess number of companies located at the kinks. $\widehat{b}$ is the excess mass relative to the average density of companies at the kinks. Bootstrapped standard errors are reported in brackets.

In Table 3, we employ pre-reform 2010-2013 distributions of corporate tax liability and the histogram estimator from Eq. (2) to estimate excess bunching and the ETI in 2015-2016, when firms were subject to the minimum tax and could carry tax losses from 2014-2015 forward.[19] According to panel A, the excess mass at kinks is equal to 7,784%, 8,075% and 3,822% of the average density at kinks in the lowest, middle, and top category, respectively. The ETI is respectively equal to 1.436, 0.745, and 0.118. This means that in response to a 10% rise in the net-of-tax rate, companies would increase taxable income by 14.36%, 7.45% and 1.18%, respectively. All estimates are significant at the 1% level.

Our baseline ETI estimates thus indicate highly heterogeneous business responses to variation in the MTR. The heterogeneity conforms with the ability of small business owner-managers to shift income across corporate and personal tax bases (Devereux et al., 2014; Miller et al., 2022). Lower elasticity for VAT registered firms also agrees with the evidence that VAT and (third-party) monitoring can improve compliance (Pomeranz, 2015; Almunia and Lopez-Rodriguez, 2018; Naritomi, 2019). It is necessary to note

[19] In Table A.7, we examine the impact of omitting 2013 from the construction of the counterfactual, as tax liability distribution might have been affected in this year by the change in the main corporate tax rate. We show that ETI estimates are highly robust to employing only 2010-2012.

that bunching designs yield a short-term, local interpretation to the estimates. Given relatively low minimum tax obligations especially in the top corporate category (compared to the average tax bill), many profitable firms may not have even considered the possibility of bunching. This could have contributed to a lower ETI in the top category.

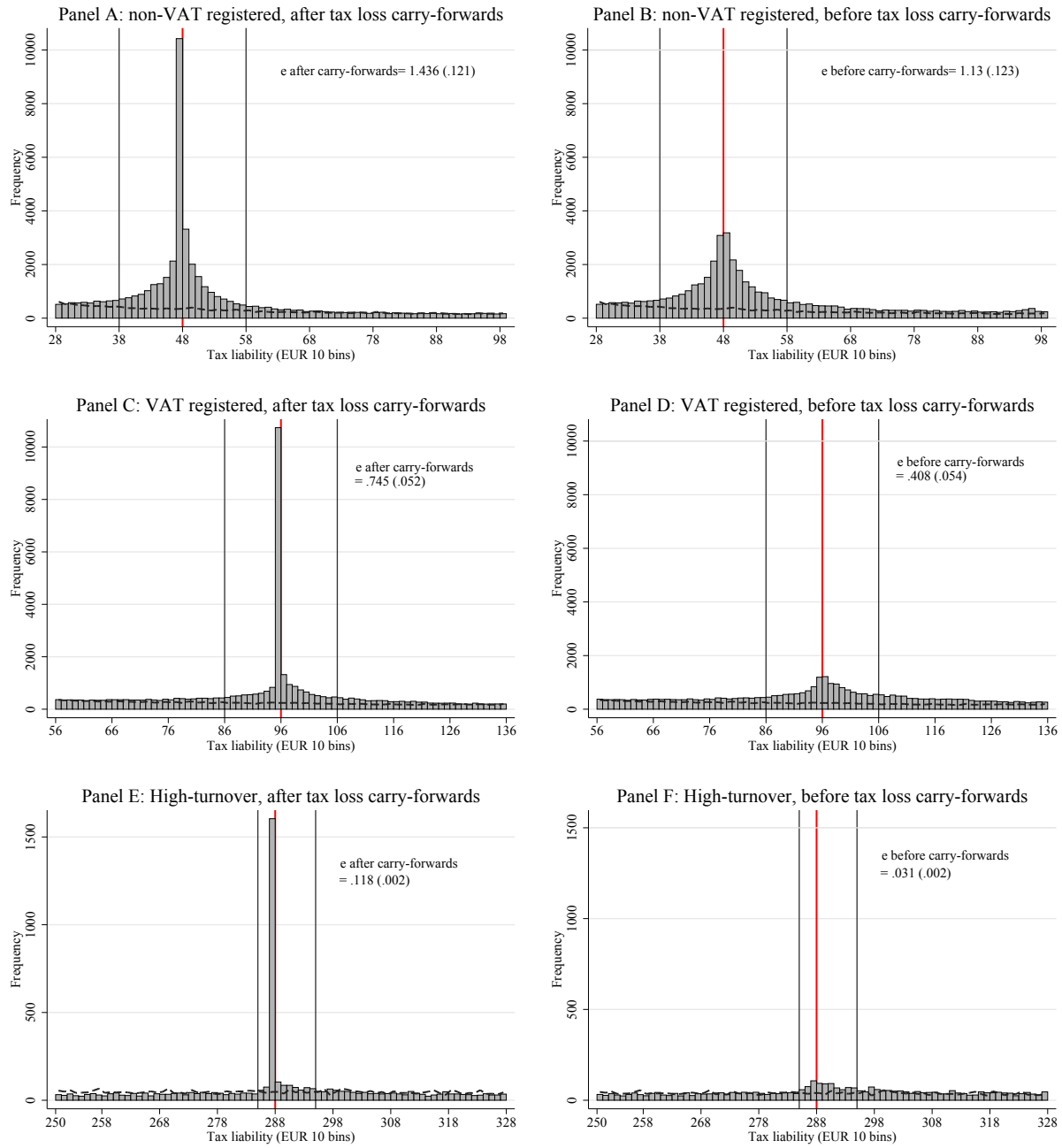
Corporate ETI before tax loss carry-forwards. We continue by asking how the ETI differs if we base our bunching design on tax liability distributions observed before firms carry forward tax losses. Figure 3 provides an initial glimpse into this question by plotting tax liability distributions for each corporate category before and after tax loss carry-forwards side by side. The figure clearly indicates that tax liability distributions after tax loss carry-forwards in panels A, C and E exhibit much sharper bunching at the minimum tax kinks in all three corporate categories compared to the corresponding tax liability distributions before tax loss carry-forwards in panels B, D, and F.

We report the corresponding estimates of the corporate ETI before tax loss carry-forwards in panel B of Table 3. The table confirms that both the level of bunching and the ETI are significantly lower in all corporate categories if they are estimated prior to tax loss carry-forwards. The reduction in the ETI is most pronounced for companies in the top category, where it is 73.7% lower compared to the ETI after tax loss carry-forwards. There are also sizable decreases in the ETI, however, for companies in the middle and bottom categories, where the ETI drops 45.2% and 21.3%, respectively.

The differences in the ETI implied from tax liability distributions before and after tax loss carry-forwards are therefore highly empirically relevant. Yet, the drawback of such comparisons is that firms likely choose the two tax liabilities simultaneously. The density distributions prior to tax loss carry-forwards thus might not correctly approximate what the distributions would have looked like if tax loss carry-forwards had not been introduced. It is plausible that true counterfactuals would exhibit far more bunching at the kinks in Panels B, D, and F, as firms would adjust other margins of their responses to locate themselves at kinks, for instance, by under-reporting taxable income more fiercely. We thus cannot assign the entire difference in the ETI based on before-after comparisons to a sole reason, such as inter-temporal tax loss transfers.[20] In the next section, we aim to disentangle the mechanisms behind the estimated differences in the corporate ETI.

[20]In a similar fashion, in Table A.6 we estimate the ETI from tax liability distributions after tax loss carry-forwards in 2018, i.e. after the minimum tax had been cancelled. Using these estimates, we adjust the baseline ETI after tax loss carry-forwards in 2015-2016 downwards, as the excess mass after cancelling the minimum tax consists solely of firms carrying forward tax losses. We find that the ETI drops 23.5%, 46.6% and 99.2% across the three corporate categories, respectively. Although the evidence confirms that tax loss carry-forwards are very important for the scope of the estimated ETI, we cannot assign the entire drop in the ETI to a sole reason, such as inter-temporal tax loss transfers. This is because tax liability reductions towards former kinks might have been reinforced by other margins of corporate responses, such as outright evasion.

Figure 3: Tax liability distributions before and after firms apply tax loss carry-forwards



Notes: The histograms show tax liability distributions around the minimum corporation tax kinks in 2015-2016 separately, before and after companies apply tax loss carry-forwards. The minimum tax kinks are demarcated in all panels by red vertical lines. The excluded intervals around the kinks are demarcated by black vertical lines. The dashed lines above the histograms are the re-scaled pre-reform density distributions of tax liability from 2010-2013. e is the estimated ETI for different corporate categories, before and after tax loss carry-forwards, respectively. Bootstrapped standard errors are in parentheses.

6 Decomposing growth in the ETI after tax loss carry-forwards

So far we have provided clear-cut evidence of pronounced business responses to the variation in the corporate MTR and verified that the corporate ETI is sharply higher if it is estimated after companies carry forward tax losses.

In this section, we decompose the differences in the corporate ETI estimated after and before tax loss carry-forwards into (i) taxable income distortions mitigated by tax loss carry-forwards and (ii) inter-temporal tax loss transfers. We implement two empirical approaches with the aim of determining what the scope of bunching at kinks would have been in a hypothetical scenario in which tax loss carry-forwards were not introduced. We compare the estimated counterfactual ETI with the one before tax loss carry-forwards to infer the scope of taxable income distortions mitigated by tax loss carry-forwards. We attribute the residual difference between the counterfactual ETI and the ETI after tax loss carry-forwards to non-distortive transfers of tax losses over time.

Corporate ETI in 2014. Our first approach to determining the ETI for the hypothetical scenario without tax loss carry-forwards builds on estimating the ETI from tax liability distributions observed in 2014. The approach assumes that 2014 distributions reasonably approximate what business responses to the minimum tax kinks without tax loss carry-forwards would have been, as companies in 2014 were indeed subject to the minimum tax obligation, but could not yet carry forward tax losses. We view this assumption as plausible, as even with tax loss carry-forwards in 2014 firms did not have strong incentives to misreport taxable income once it was below the minimum tax levels.

Table 4: Decomposing differences in the ETI before and after tax loss carry-forwards

	Baseline corporate ETI		Approach 1: Corporate ETI in 2014			Approach 2: Corporate ETI for firms ineligible for TLCF in 2015		
	After TLCF	Before TLCF	ETI	% increase compared to (2)	% decrease compared to (1)	ETI	% increase compared to (2)	% decrease compared to (1)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bottom cat.	1.436 [0.121]	1.13 [0.123]	1.319 [0.110]	+16.7%	-8.1%	1.135 [0.135]	+0.4%	-20.1%
Middle cat.	0.745 [0.052]	0.408 [0.054]	0.521 [0.048]	+27.7%	-30.1%	0.568 [0.064]	+39.2%	-23.8%
Top cat.	0.118 [0.002]	0.031 [0.002]	0.046 [0.003]	+48.4%	-61.0%	0.058 [0.003]	+87.1%	-50.1%

Notes: ETI estimates in all columns are obtained using pre-reform 2010-2013 distributions of tax liability and the histogram estimator from Eq. (2). Bootstrapped standard errors are in brackets.

We report the results of our decomposition of the differences in the ETI in Table 4. For easier comparison, we repeat the baseline ETI estimates from Table 3 after and before tax loss carry-forwards in columns (1) and (2), respectively. In column (3), we report ETI of 1.319, 0.521 and 0.046 in the bottom, middle and top corporate categories, respectively, based on tax liability distributions in 2014. Column (4) calculates that these elasticities are 16.7%, 27.7% and 48.4% higher across the corporate categories, respectively, compared to the baseline ETI before tax loss carry-forwards in column (2). The results strongly support our hypothesis that the baseline ETI before firms carry forward tax losses is downward biased, as companies would have used other margins of responses to variation in the MTR to locate themselves at kinks in the absence of tax loss carry-forwards. The bias is highest in relative terms for high-turnover companies in the top category, but quantitatively relevant in all corporate categories.

At the same time, in column (5) we find that counterfactual ETI estimates are notably lower compared to the ETI estimated after tax loss carry-forwards. We interpret this residual difference in the ETI as due to inter-temporal tax loss transfers, which once again seem to be most relevant for companies in the top-turnover category.

Corporate ETI for firms ineligible for tax loss carry-forwards. Our second approach for decomposing differences in the ETI estimated before and after tax loss carry-forwards employs estimates of the ETI for firms which were not eligible for tax loss carry-forwards. We focus specifically on ineligible firms in 2015, i.e. in the first year when offsetting tax liability by tax losses became possible for some companies above the minimum tax kinks.[21] We argue that density distributions for companies without prior tax losses can serve as a credible approximation for the extent to which the remaining companies would have been bunching at kinks, as we do not observe evidence of specific corporate selection into ineligibility for tax loss carry-forwards in 2015.[22]

In column (6) of Table 4, we report the estimated ETI for firms which could not carry forward tax losses in 2015. In column (7), we calculate that this ETI is 0.4%, 39.2%, and 87.1% higher, respectively, in the bottom, middle and top firm categories than the ETI before tax loss carry-forwards. Even our second approach for decomposing the differences in the ETI thus suggests that there would be many more distortions in the middle and top firm categories if companies had not had the opportunity to offset tax liability above kinks by prior tax losses. Bunching would not, however, increase for

[21] In particular, 16.3% of companies in the bottom category in 2015 could not carry forward tax losses because their tax liability was above the minimum tax level in 2014. In the middle and top categories, the fraction of companies that could not use carry forwards equaled 14.6% and 10.2%, respectively.

[22] In Table A.8, we show that a range of corporate characteristics, including legal form, employment size and industry, for firms ineligible for tax loss carry-forwards in 2015 within a €100 bandwidth around the minimum tax kinks do not meaningfully differ from average firms within this bandwidth.

non-VAT registered firms, which suggests that most of the difference in the ETI estimated after versus before tax loss carry-forwards for these firms might only be due to inter-temporal tax loss transfers. The comparison of elasticities reported in columns (6) and (1) suggests that tax loss transfers are relevant to the ETI in all corporate categories.

7 Implications for the marginal excess burden

We now study the implications of neglecting the impact of tax loss carry-forwards on the corporate ETI in the estimation of the marginal excess burden (MEB) of the corporation tax. Following the framework by Saez et al. (2012), we estimate the MEB above the minimum tax kinks as if in the top bracket of the corporation tax, using the estimates of (i) the corporate ETI after tax loss carry-forwards, (ii) the corporate ETI before inter-temporal tax loss transfers and with income distortions mitigated by carry-forwards, and (iii) the corporate ETI net of tax loss transfers and without taxable income distortions being mitigated through the use of tax loss carry-forwards.

Conceptual framework. To calculate the MEB, we consider a situation with a constant MTR τ above a given level of reported income $\bar{z}$. In our setting, this tax rate corresponds to the rate on firms which earn income implying a tax liability above the minimum tax amounts. We further assume that corporate income depends on the net-of-tax rate $(1-\tau)$. We assume that there are N corporations with taxable income above $\bar{z}$ when the MTR is τ. We use $z^m(1-\tau)$ to denote the average income reported by those N corporations, as a function of the net-of-tax rate. The aggregate elasticity of taxable income implying a tax liability above the minimum tax amount is thus defined as $e = \left[\frac{\partial z^m}{\partial(1-\tau)}\right]\left[\frac{1-\tau}{z^m}\right]$.

We now suppose the government increases τ by a small amount $d\tau$ while keeping the minimum tax amount fixed. We can contemplate two effects on government revenue. First, there is a "mechanical" increase in revenue due to the fact that corporations face a higher tax rate on income above $\bar{z}$. We define this mechanical effect as:

$$dM \equiv N\left(z^m - \bar{z}\right) d\tau > 0. \tag{6}$$

The mechanical effect can be viewed as the projected increase in tax revenue in the absence of behavioral responses to the tax change.

Second, the increase in the tax rate produces a behavioral response that reduces the average reported income for N corporations by $dz^m = -ez^m d\tau/(1-\tau)$. A change in the reported income of dz^m changes the tax revenue by τdz^m. The aggregate change in tax

revenue due to the behavioral response is therefore equal to:

$$dB \equiv -Nez^m \frac{\tau}{1-\tau} d\tau < 0. \tag{7}$$

Summing up the mechanical and behavioral effects, we can express the total change in tax revenue due to the tax change as:

$$dR = dM + dB = N\left(z^m - \bar{z}\right)\left[1 - e\frac{z^m}{z^m - \bar{z}}\frac{\tau}{1-\tau}\right] d\tau. \tag{8}$$

We denote the ratio $\frac{z^m}{z^m - \bar{z}}$ as a. If the top tail of the corporate taxable income distribution is Pareto distributed, then parameter a does not vary with $\bar{z}$ and is exactly equal to the Pareto parameter. Using the definition of a, we can rewrite the effect of the small tax reform on tax revenue as:

$$dR = dM\left[1 - \frac{\tau}{1-\tau} ea\right]. \tag{9}$$

Formula (9) shows that the fraction of the tax revenue lost due to the behavioral response, which is the second term in the square bracket, is a simple function increasing in the tax rate τ, corporate ETI e, and parameter a.

According to the envelope theorem, utility loss measured in monetary terms due to the small tax change $d\tau$ is exactly equal to the mechanical effect dM. Applying formula (9) and because $dR = dM + dB$, we can express the MEB per one euro of extra tax raised as:

$$-dB/dR = \frac{ea\tau}{1 - \tau - ea\tau} \tag{10}$$

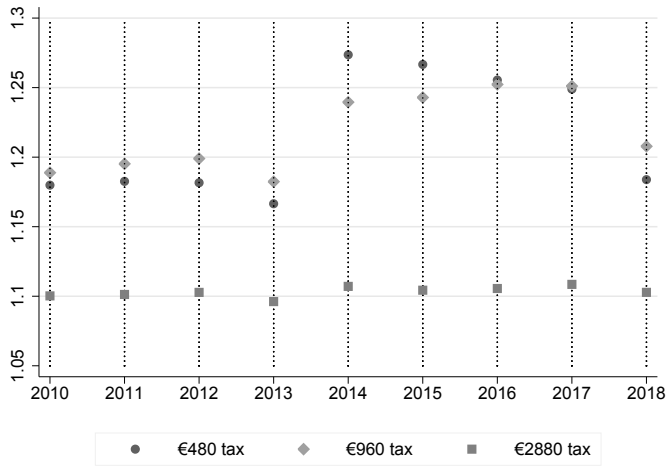
This means that for each extra euro raised, the government imposes an extra cost equal to $-dB/dR > 0$ on taxpayers.

MEB estimates. In Figure 4, we first estimate the parameter ratio a at $\bar{z}$ annually in 2010-2018 for all companies with a tax liability between the minimum tax and €200,000. We observe that a is stable over time at the €2,880 kink and equal to around 1.1. For the €480 and the €960 kinks, the values of a increase slightly from around 1.18 in 2010-2013 to around 1.25 in 2014-2017. To calculate the MEB, we choose a from 2015 when companies were subject to the minimum tax, could apply loss tax carry-forwards and had to pay a MTR of 22% on all taxable income above $\bar{z}$.

In the next step, we estimate that the marginal welfare loss would be equal to 102.5% of the mechanical increase in tax revenue should we raise the MTR above the minimum tax kink for non-VAT registered firms in the bottom category by 1% and consider an ETI

of 1.436 implied from tax liability distributions after tax loss carry-forwards. Ignoring that this ETI is not adjusted for inter-temporal tax loss transfers would thus make us conclude that the MEB even exceeds tax revenue expected from increasing the MTR.

Figure 4: Parameter ratio *a*



Notes: The figure reports values of parameter ratio *a* at the levels of taxable income corresponding to the minimum corporation tax kinks.

In contrast, we estimate a MEB equal to 66.7% (resp. 86.9%) of the mechanical increase in tax revenue once we use ETIs of 1.135 (resp. 1.319) from Table 4, which are estimated for the counterfactual scenario in which tax loss carry-forwards were not introduced. The implied 15-36 percentage point decline in the MEB is substantial and suggests that inter-temporal transfers via tax loss carry-forwards should not be neglected in the applied work. At the same time, these estimates are 0.5-20.7 percentage points higher compared to the MEB of 66.2% implied from tax liability distributions before firms carry forward tax losses. The range of the increase constitutes evidence in favor of the hypothesis that tax loss carry-forwards are important for mitigating taxable income distortions in the bottom corporate category. One still needs to remain cautious with conclusions in the bottom category, as one of our methods for estimating the ETI for the counterfactual scenario suggests that companies would have been bunching at kinks to a comparable degree regardless of whether tax loss carry-forwards had been introduced or not.

We arrive at more robust conclusions when estimating the MEB in the middle corporate category of VAT registered companies with a turnover below €500,000. Using an ETI of 0.745 after tax loss carry-forwards, we estimate the fraction of the welfare loss relative to the mechanical increase in tax revenue as equal to 35.6% should the MTR above the minimum tax kink rise by 1%. Our MEB estimates drop to 25.0% (resp. 22.5%) when we consider ETIs of 0.568 (resp. 0.521), which are corrected for inter-temporal

tax loss transfers. The MEB would further incorrectly decline to 16.8% if we considered an ETI of 0.408 based on tax liability distributions before companies carry forward tax losses. These calculations both underline the high empirical relevance of inter-temporal tax loss transfers and reveal that companies in the middle category would be distorting taxable income more substantively exactly towards kinks if tax loss carry forwards had not been introduced.

Finally, we arrive at the same conclusions for high-turnover firms in the top category. In particular, we estimate an MEB equal to 3.8% of the mechanical increase in tax revenue when we ignore upward bias in the ETI stemming from inter-temporal tax loss transfers. The MEB decreases by more than half (equal to 1.5-1.8%) after adjusting the ETI for such transfers. The MEB would be close to 1% if we used an ETI based on tax distributions before tax loss carry forwards. Although the MEB is small in absolute value for top turnover firms in all of the considered scenarios, we can still note that in relative terms tax loss carry-forwards mitigate taxable income distortions, especially in the top turnover category.

8 Additional evidence

In this section, we provide additional evidence of the impacts of the 2014 minimum tax reform, seeking to shed more light on the reasons behind the heterogeneous relevance of tax loss carry-forwards to the ETI across corporate turnover and VAT categories. First, we provide evidence that provides information about the sources of the excess mass of firms located initially below the minimum tax amounts at the new kinks. Next, we estimate extensive-margin responses to the reform, asking to what extent the minimum tax influenced firms' decisions to exit. Results about which companies would have moved directly towards new kinks regardless of whether tax loss carry-forwards were introduced can help us understand why tax loss carry-forwards were less relevant for some companies.

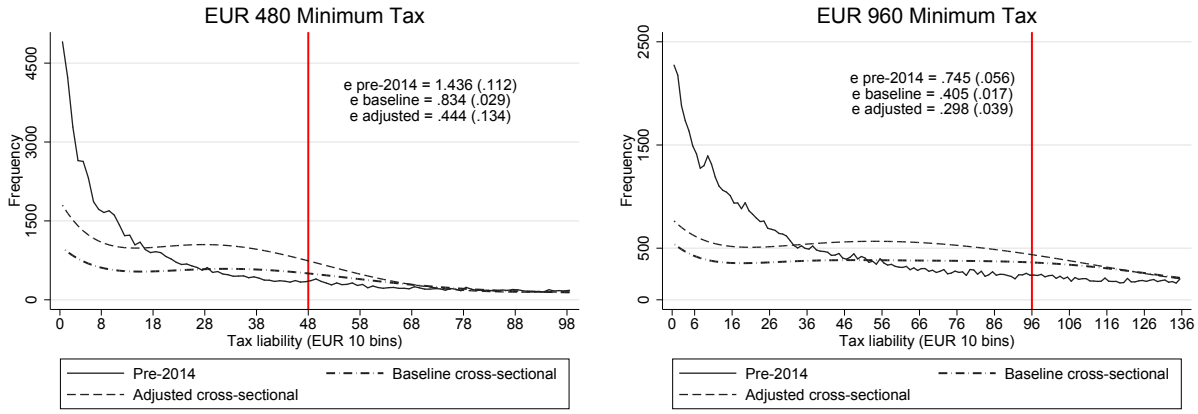
8.1 Sources of the excess bunching at minimum tax kinks

Pre-reform vs. cross-sectional counterfactuals. We start exploring sources of the excess mass of companies at the minimum tax kinks by comparing outcomes of bunching methods for estimating counterfactual density distributions of corporate tax liability.

In Figure 5, the dashed and dotted lines in panels A and B represent counterfactual distributions predicted using the *baseline* cross-sectional approach around the €480 and €960 kinks, respectively (see Appendix B for specification details). The dashed lines are the counterfactuals obtained using the *adjusted* cross-sectional method, which shifts

the left part of tax liability distributions from the *baseline* method upwards so that they satisfy the integration constraint. Finally, to allow a direct comparison with our main estimates in Table 3, the solid lines correspond to counterfactuals predicted using the non-parametric histogram estimator based on pre-reform 2010-2013 distributions. For all of these approaches, we report the implied ETI and bootstrapped standard errors.[23]

Figure 5: Comparison of cross-sectional and pre-reform counterfactuals



Notes: The figure compares estimates of the corporate ETI in 2015-2016 obtained using three alternative methods for quantifying bunching at minimum tax kinks. "*e pre-2014*" refers to the ETI obtained using the non-parametric estimator in Eq. (2) which builds on pre-reform 2010-2013 data. "*e baseline*" refers to the ETI based on the cross-sectional model in Eq. (B.1) which ignores the integration constraint. "*e adjusted*" refers to the ETI obtained using the cross-sectional bunching method in Eq. (B.4) which preserves the total number of companies under the counterfactual equal to the number in the empirical distribution. Bootstrapped standard errors are presented in parentheses.

The figure reveals that the principal difference between the estimated counterfactual densities consists in the assumed source of bunching at the minimum tax kinks. While the *baseline* cross-sectional bunching method does not address the source of bunching, the *adjusted* method assumes that the excess mass originates proportionally from the whole distribution to the left of the kinks. More plausibly, the *non-parametric* histogram estimator suggests that the dominant source of bunching is from around zero tax liability and much less from the area near the kinks. At the €480 kink, this difference means that the ETI based on pre-reform distributions is 3.2 times higher than the ETI based on *adjusted* cross-sectional distributions. At the €960 kink, the ETI is 2.5 times higher if it is based on pre-reform data. An alternative lens through which this may be viewed is that the ETI based on the *adjusted* cross-sectional method is 69% and 60% lower for

[23]We do not compare bunching methods for firms in the top category, as cross-sectional methods for this category cannot consider those parts of tax liability distributions which are below €2,500. Below this limit, companies do not need to pay quarterly advances to the tax office.

firms in the bottom and middle categories, respectively, compared to the ETI based on pre-reform data.[24] The differences are significant at least at the 5% level.[25]

Overall, the above comparison demonstrates that bunching methods based on undistorted empirical pre-reform data can be very useful for obtaining credible estimates of counterfactual density distributions, especially when taxpayers possess substantial flexibility in relocating themselves along the inspected distributions, for instance, due to pronounced income shifting, tax avoidance or evasion. Such types of corporate behavior could well explain the heterogeneous relevance of tax loss carry-forwards to the ETI across corporate turnover and VAT categories, because, for instance, if tax evading non-VAT registered companies that were initially below the minimum tax kinks shifted directly towards the new kinks, they did not incur any tax losses, making tax loss carry-forwards unavailable for them in future fiscal periods. We examine the hypothesis of relocation of companies from zero tax liability towards new kinks in greater detail in the next step by quantifying the decline in corporate bunching around zero tax liability for every minimum tax category and comparing our estimates to the scope of newly emerged bunching at the minimum tax kinks.

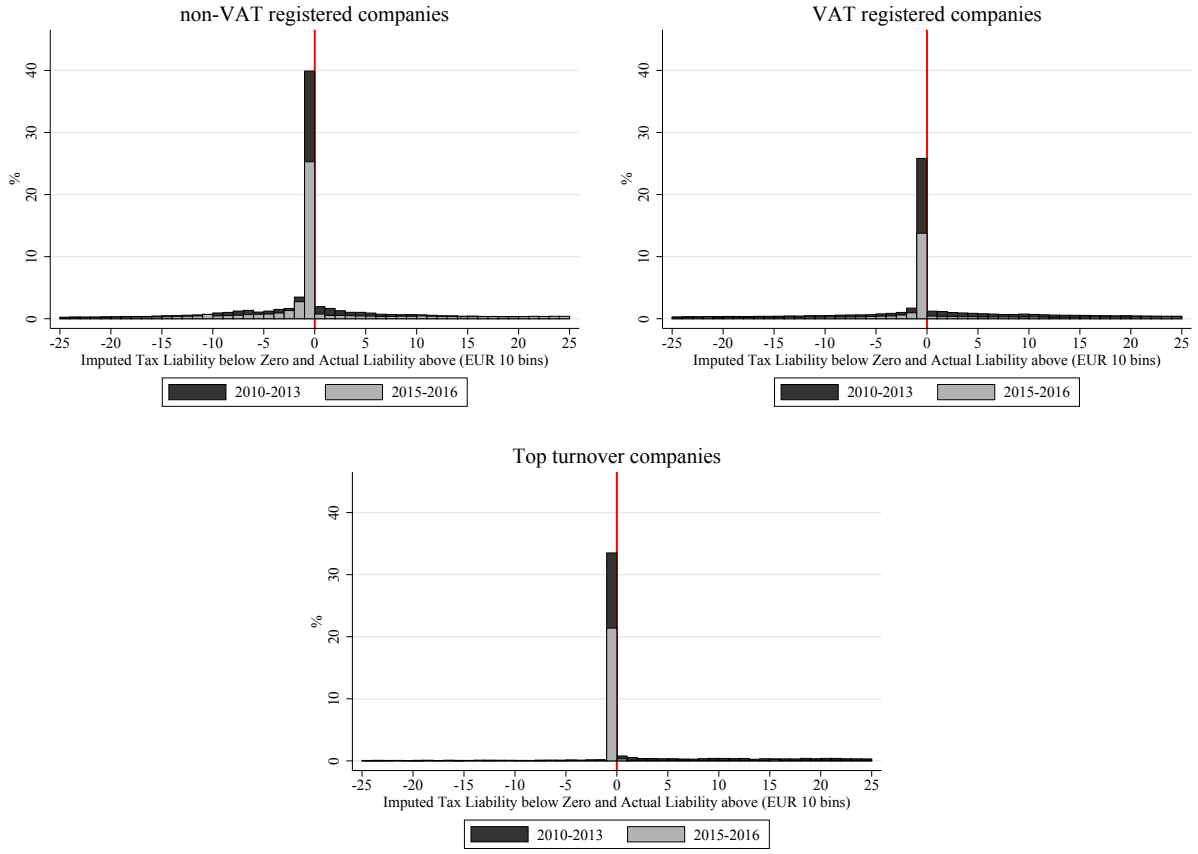
Missing bunching at zero tax liability. In order to estimate the mass of firms which disappeared from the area around zero tax liability after the 2014 reform, we employ corporate profit/ loss data and the histogram estimator from Eq.(2). More specifically, we apply corporate tax rates for each corresponding fiscal period to both positive and negative values of profits to obtain density distributions of "hypothetical" tax liability even below zero. We then plot the appropriately re-scaled histograms of tax liability around zero before and after the 2014 reform to infer the missing mass of companies.

In Figure 6, we observe a pronounced drop in the share of firms massing at zero after the introduction of the minimum tax in all corporate categories. After re-scaling 2010-2013 tax distributions so that the total number of corporations in the counterfactual distributions equals the total number of companies in 2015-2016, we estimate that 29,383 non-VAT registered companies from the bottom category disappeared within a symmetric +/-€30 interval around zero tax liability compared to the same interval before 2014. This missing mass corresponds to 111.54% of the estimated excess mass of companies bunching at the €480 minimum tax kink in 2015-2016. In the same fashion, we estimate 22,259 VAT registered companies from the middle category missing around zero, which corresponds to 119.78% of the estimated excess mass at the €960 minimum

[24] In Tables A.9 and A.10, we show that the cross-sectional bunching estimates are not sensitive to parametric choices of the polynomial order and bin size.

[25] We note that 95% confidence intervals from the *adjusted* cross-sectional method and the histogram estimator do not overlap. Checking whether they overlap results in a conservative test of the difference in the elasticity in case of a positive covariance between the two estimates.

Figure 6: Corporate tax liability distributions around zero



Notes: The figure plots density distributions of corporate tax liability around zero before and after the 2014 tax reform, respectively, across the three examined corporate categories. Tax liabilities below zero are imputed using data on corporate losses. Tax liabilities above zero are the actual tax liabilities. Each bar shows the share of observations in €10 bins.

tax kink. Finally, we estimate 2,251 companies from the top category missing at zero, which corresponds to 124.36% of their estimated excess mass at the €2,880 kink.

Our estimates therefore suggest that the missing mass of firms at zero after 2014 even exceeds the scope of bunching at the new kinks, allowing for the option that many firms did not relocate exactly towards the new kinks and incurred tax losses that could be carried forward. The greatest excess of companies which could have moved from zero not exactly towards new tax kinks is estimated for high turnover firms in the top category. If these firms did not exit the market, as we check further below, their low tax liability below the minimum tax kinks should have provided them with the highest amount of tax loss carry-forwards, in contrast to lower-turnover firms in the middle and bottom categories. In the next step, before we proceed to studying the extensive-margin response, we use an event-study design to formally test whether the source of the excess mass at the minimum tax kinks is from below the minimum tax levels.

Event-study regressions. We use an event-study design to test that corporate tax liability below the minimum tax levels before 2014 can predict growth in tax liability towards the new kinks in subsequent years. The main advantage of event-study designs is that they provide insights about potential pre-trends, which are key to identification.

The main outcome variable in our model is a binary indicator equal to one if company i in corporate category c and fiscal period t has a tax liability within a fixed narrow bandwidth around the minimum tax level, and zero otherwise.

The model can be formally expressed as follows:

$$Atkink_{it} = \alpha_0 + \sum_{j=-J}^{K} \beta_j Below\ MT^{j}_{it-1} + \gamma \mathbf{X}_{it-1} + \lambda_i + \psi_{st} + \varepsilon_{it} \tag{11}$$

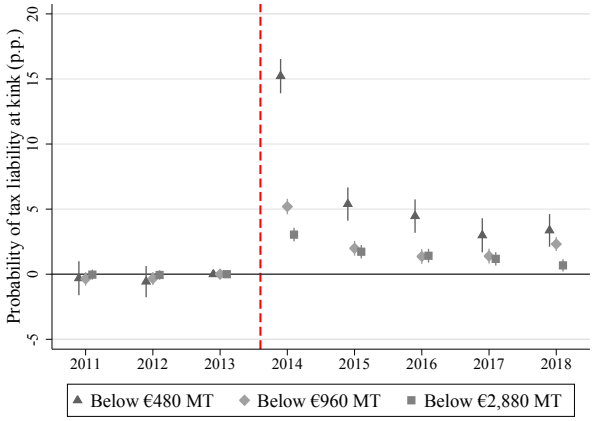
The independent variables of interest are a set of $J + K$ event variables $Below\ MT^{j}_{it-1}$ generated as indicators for the tax liability being lower than the minimum tax amount that would apply to firms in corporate category c one year prior to j. The model controls for company fixed effects (λ_i) and diverse time-varying corporate characteristics $\mathbf{X}_{it-1}$, which include a non-interacted indicator for tax liability being below the minimum tax amount in $t-1$ and dummy variables for employment size categories, ownership type and legal form. The model accounts for potential industry-specific shocks by including "industry $\times$ year" fixed effects (ψ_{st}). The stochastic error term is denoted by ε_{it}.

We estimate the model separately for each corporate category. We always set the regressor for period $j = 0$ equal to zero so that all coefficients are interpreted relative to this period. We cluster standard errors at the firm level, allowing for any unconditional heteroscedasticity and correlation over time for all observations of the same firm.

Regarding identification, our model is a version of conditional difference-in-differences, which rely on a parallel trends assumption. Put informally, identification requires that in the absence of the 2014 reform, the probability of having a tax liability around the corresponding minimum tax kink would evolve within the corporate categories along parallel paths for firms that previously had a tax liability below and above the minimum tax levels, respectively. This assumption, as we show below, is strongly supported by a finding of no differential pre-trends prior to 2014.

We visualize estimates obtained from our event-study model in Figure 7. The figure delivers evidence of a highly significant hike in the probability of having a tax liability around the minimum tax kinks in 2014 for firms that had a tax liability below the minimum tax amounts versus above the amounts one year earlier. In the bottom category of non-VAT registered firms, the probability rises by 15 percentage points in 2014, relative to the baseline of 6.2%. In the middle and top categories, the probability increases by 5.2 and 3 percentage points, respectively, relative to the baselines of 3.8% and 0.8%. We

Figure 7: Event-study estimates: The probability of having a tax liability at the minimum tax kinks for firms one year earlier below versus above the kink



Notes: The figure plots coefficients β_j estimated using the event-study model in Eq.(11). The estimates correspond to differences in the probability of having a tax liability at the minimum tax kinks in year t for firms whose tax liability was below the kink in $t-1$, as compared to above it. All coefficients are multiplied by 100 to show percentage differences. Companies are considered to be located at the minimum tax kink if they had a tax liability within a €100 bandwidth around the kink. All specifications include company- and industry $\times$ year fixed effects and control for employment size, ownership type and legal form. The dashed vertical line indicates the 2014 reform. The figure displays 95% confidence intervals. Standard errors are clustered at the firm level.

report coefficient estimates for all years and corporate categories in Table A.11.

In sum, the event-study estimates constitute strong evidence in line with the hypothesis of pronounced corporate tax avoidance (or evasion) towards zero prior to 2014, especially by companies in the bottom category. The estimates therefore agree well with our earlier findings that tax loss carry-forwards are less relevant to the ETI for non-VAT registered firms, as they suggest that these companies would have credibly moved towards minimum tax kinks with or without the availability of tax loss carry-forwards. In the next step, we examine extensive-margin corporate responses to the 2014 reform to test whether there were any massive market exits of companies below the minimum tax amounts in some corporate categories, which could constitute an alternative explanation for the lower relevance of tax loss carry-forwards for these companies.

8.2 Extensive-margin responses

We examine companies' extensive-margin responses to the 2014 tax reform, once again using an event-study design. The main outcome variable in our model is a binary indicator for company i in corporate category c having been liquidated in year t.[26]

[26]We infer corporate exit from the failure of firms to file mandatory tax returns to the fiscal authority.

The model can be formally expressed as follows:

$$Exit_{it} = \alpha_0 + \sum_{j=-J}^{K} \beta_j Below\ MT^j_{it-n} + \gamma \mathbf{X}_{it-n} + \psi_{st} + \varepsilon_{it} \tag{12}$$

The independent variables of interest are again a set of $J + K$ event variables $Below\ MT^j_{it-n}$ generated as indicators for the tax liability being lower than the minimum tax amount that would apply to firms in category c n years prior to j .[27] The model further controls for the same rich set of time-varying corporate characteristics $\mathbf{X}_{it-n}$ as in Eq.(11), i.e. for a non-interacted indicator for the tax liability being below the minimum tax amount in year $t - n$, binary indicators for employment size categories, ownership type and legal form. The model includes "industry $\times$ year" fixed effects (ψ_{st}). The stochastic error term is denoted by ε_{it}. We again estimate the model separately for each corporate category and always set the regressor for period $j = 0$ equal to zero so that all coefficients are interpreted relative to this period. We cluster standard errors at the firm level.

For identification, our model requires that in the absence of the 2014 reform, the probability of exit would evolve within corporate categories along parallel paths in the immediate short run for firms whose previous tax liability was below versus above the minimum tax levels. The validity of the assumption might be threatened if companies before 2014 selectively targeted their tax liability with respect to the minimum tax levels, which seems highly implausible given no previous knowledge of the minimum tax amounts.[28] Our identification assumption, as we show below, is further supported by finding no evidence of differential pre-trends in corporate exits across companies in the treatment and control groups prior to 2014. To mitigate survivor bias, we restrict the sample to companies established after the beginning of 2010.

Figure 8 provides evidence of a very mild extensive-margin response by corporations to the introduction of the minimum tax within two years after the 2014 reform.[29] In particular, the evidence suggests no statistically significant corporate exits in the top category of firms with a turnover above €500,000. The response is also not significant in the bottom and middle categories in 2014 if one focuses in Panel B only on active companies with positive prior turnover. The estimates suggest a statistically signifi-

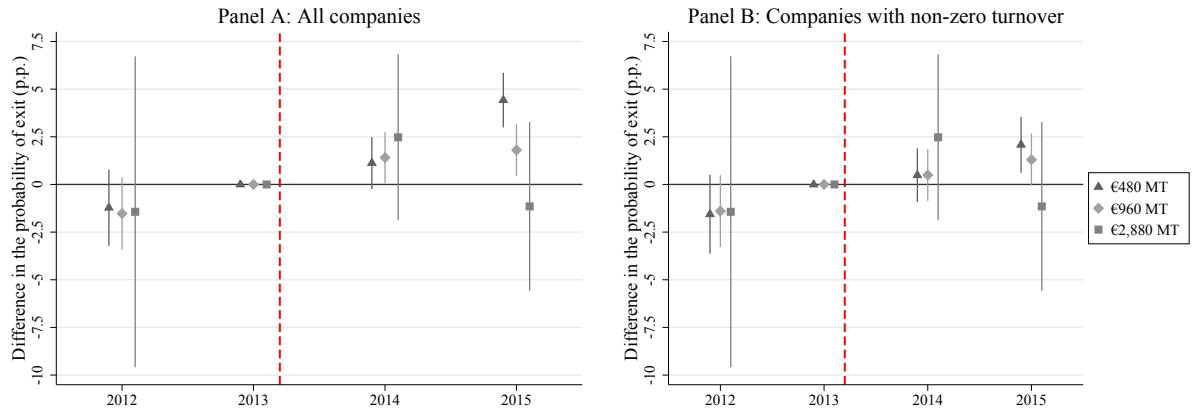
[27] In the reported specifications, we choose $n = 2$, which allows us to observe outcomes in two pre-reform periods in which corporate exits could not have been affected by the 2014 tax reform, while we are able to estimate the post-reform impact of the minimum tax reform in 2014 and 2015, conditional on using only pre-reform years 2010-2013 to define the treatment status. If we selected $n = 3$, our models would include one pre-reform period in 2013, although we would be able to estimate extensive-margin responses in three periods after the tax reform up until 2016. We prefer the former option of $n = 2$, given a likely much higher relevance of our event variables in the immediate short run.

[28] Figures 2, A.4 and A.5 give no indications of undesirable sorting below the minimum tax values prior to 2014, as evidenced by perfectly smooth tax liability distributions before 2014.

[29] We report exact coefficient estimates for all corporate categories and samples in Table A.12.

cant response in the bottom and middle categories in 2015: the likelihood of having a firm liquidated in 2015 is 2.1 and 1.3 percentage points higher for active companies in the bottom and middle categories, respectively, relative to the baseline probability of 8.3% and 11%, if their tax liability in 2013 was below the minimum tax amounts rather than above. The estimated coefficients are higher if one considers all firms, including companies with zero prior turnover. This result suggests that a notable component of the extensive-margin response to the minimum tax reform consisted in closing down economically inactive companies, as proxied by no turnover.

Figure 8: Extensive-margin response to the 2014 tax reform



Notes: The figure reports the estimated differences in the probability of exit across companies whose tax liability was below and above the minimum tax amounts two years prior to year t, respectively. The estimates are obtained using Eq.(12) separately for each corporate category. Panel A shows coefficient estimates for all companies established after the beginning of 2010. Panel B shows estimates for companies with a non-zero turnover two years prior to t. All specifications control for employment size category, ownership type and legal form. All coefficients are multiplied by 100 to show percentage differences in the examined probabilities of exit. The dashed vertical line indicates the 2014 tax reform. The figure displays 95% confidence intervals. Standard errors are clustered at the firm level.

In sum, the relatively mild extensive-margin response per se cannot explain the heterogeneous relevance of tax loss carry forwards across corporate VAT and turnover categories. On the contrary, the evidence further supports the hypothesis of corporate tax avoidance/evasion towards zero prior to 2014, as one would otherwise expect firms with true tax liability below the minimum tax amounts to close down. On top of it, one can argue that our estimates are likely close to the upper bound of the true extensive-margin response, as many small- and medium-sized firms in the open Slovak economy might have moved their formal residence to neighbouring countries or changed their organizational form from incorporated to unincorporated businesses in response to the reform, without significantly affecting the real output of these companies.

9 Conclusion

In this study, we examined how the introduction of new carry-forwards of corporate tax losses increases the elasticity of corporate taxable income (ETI) and biases the marginal efficiency burden (MEB) of the corporation tax.

Using state-of-the-art bunching techniques and administrative tax-return data on all corporate taxpayers in 2010-2018 in Slovakia, we estimated the corporate ETI from the excess mass of companies bunching at kinks created by the 2014 minimum tax reform. We employed tax liability distributions uniquely observable before the reform to predict counterfactual density distributions around the new kinks. We showed that corporate taxable income is highly heterogeneously sensitive to the variation in marginal corporation tax rates across corporate VAT and turnover categories. The ETI ranged from 0.03 for firms with a turnover above €500,000 to 0.41 for lower-turnover VAT registered firms and 1.13 for non-VAT registered firms. Smooth pre-reform density distributions and the sudden disappearance of a large mass of companies at zero tax liability right after 2014, validated by a set of event-study regressions, suggest that many firms used to reduce taxable income towards zero prior to 2014.

Importantly, we found that bunching at kinks sharply increased immediately after firms gained the option to offset tax liability above the minimum tax kinks by prior tax losses. By decomposing the differences in the ETI estimated after firms carry forward tax losses, we showed that tax loss carry-forwards mitigate distortions in tax liability distributions, leading to an under-estimated MEB of the corporation tax. At the same time, tax loss carry-forwards permit inter-temporal tax loss transfers which elevate the MEB implied from tax liability distributions after tax loss carry-forwards. We consider our results important, as they highlight non-trivial challenges in the estimation of appropriate statistics sufficient for the evaluation of fiscal and economic welfare implications of the corporation tax.

How relevant are our results for other countries? We discuss three dimensions of the external validity of our results. First, we analyzed *tax loss* carry-forwards above minimum tax kinks, while *net operating loss* carry-forwards operate on practically the exact same principle of offsetting taxable income above zero by prior losses. Loss carry-forwards are available to firms all around the world, as shown in Table A.1. Second, the ETI in our setting was estimated for companies at the minimum tax kinks, but might not exactly relate to large, multi-national firms which might have access to more sophisticated tax avoidance technologies. Third, companies in our setting could carry forward tax losses for a maximum of three years and only since 2014. The regulation of loss carry-forwards is much less strict in many other countries. Corporations in the U.S. in 2022, for instance, could carry forward NOLs indefinitely to offset up to 80% of

taxable income. Many European countries do not specify any time limit on loss carry-forwards. The relevance of loss carry-forwards might be much higher in other countries compared to our setting.

Finally, a related question, which we leave open for future research, relates to the overall welfare evaluation of the minimum tax legislation. International Monetary Fund (2021) shows that minimum corporation taxes are an increasingly popular fiscal tool available in various forms (asset-based, turnover-based, modified income-based) in more than 50 countries. According to the Ministry of Finance of the Slovak Republic (2014), the minimum tax in our setting helped to raise non-trivial revenue of €110 million just in 2014. At the same time, our estimates indicated a limited extensive-margin response immediately after the minimum tax reform. The exit was in large part driven by closures among the smallest companies and formally registered but inactive companies. To calculate the total implications of the minimum tax, one would, however, need further information about firm incorporation decisions, growth and investments to be able to evaluate the dynamic aspects of the minimum tax design. Despite finding no evidence of immediate negative impacts of the minimum tax, we leave the question unanswered in this paper.

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