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ABSTRACT

Macroeconomic estimates of profit-shifting elasticities typically exceed microeconomic ones. We reconcile these differences by accounting for extensive-margin profit-reporting decisions in a model where multinationals face unobserved and heterogeneous fixed and variable costs of profit shifting. Using UK administrative data, we find that micro semi-elasticities underestimate aggregate semi-elasticities by about 50%. We estimate average fixed and variable costs of profit shifting to be 1.5% and 3.1%of the true tax base, respectively. We validate the model using a quasi-natural experiment that restricted profit shifting by Italian MNEs and use it to evaluate two types of tax policy reforms.

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1 Introduction

Many multinational enterprises (MNEs) report little or no taxable profits in high-tax countries, shifting these profits to tax havens. To evaluate the consequences of such practices, the economic literature has provided many contributions that estimate the scale of profit shifting. However, the magnitude of these estimates varies substantially between studies that use micro-level and macro-level data (Dharmapala; 2014; Riedel; 2018).[2] In fact, the micro-level tax avoidance literature has placed a strong emphasis on intensive-margin profit-shifting decisions, while recent evidence shows that many MNEs shift all profits out of high-tax countries (Bilicka; 2019; Koethenbuerger et al.; 2019). To quantify the importance of the extensive margin of profit shifting, we need to understand MNEs' behavioral responses to tax reforms, in particular for MNEs that do not pay any corporation tax in high-tax countries. This will help inform policymakers about which reforms are likely to be most welfare-improving in tackling profit shifting.

In this paper, we develop a model of MNEs' investment and profit shifting choices that can result in some MNEs shifting all their profit to tax havens. We estimate structural parameters of the model using UK tax return data, which allow us to derive estimates of profit shifting and investment elasticities and to calculate the fixed and variable costs of shifting profits to tax havens. We also test the model predictions in a reduced-form difference-in-differences framework, using a UK tax reform aimed at limiting profit shifting by subsidiaries of foreign-owned multinationals. We use our model, which accounts for the extensive margin of profit shifting, to conduct counterfactual policy experiments in which we analyze changes in corporate tax rates and the introduction of the global minimum tax (GMT) at varying rates. Our findings provide four distinct contributions to the literature as they allow us to: (i) reconcile the differences across previous estimates of the extent of profit shifting based on macro- and micro-data; (ii) quantify the impact of curbing profit shifting on investment, (iii) quantify the size of profit shifting costs, and (iv) identify the overall impact of proposed tax reforms on global welfare.

Our conceptual framework models an MNE that undertakes real productive activity in several possible locations and has a subsidiary in a tax haven to which it shifts profit. A key novelty is in how we model the MNE's ability to avoid taxes. The MNE invests in a tax avoidance asset, which represents a public good for all subsidiaries of the MNE worldwide and which reduces the marginal cost of shifting profit to the tax haven. Our model therefore allows for both the fixed and variable components of profit shifting costs. In this

[2]Such a discrepancy is akin to the gap between macro- and micro-level labor supply elasticities in the presence of frictions in Chetty (2012).

framework, the marginal benefit of shifting can exceed the marginal cost, leading to corner solutions with zero taxable profit in high-tax subsidiaries. This differs from previous literature that typically uses the Hines and Rice (1994) convex profit-shifting cost model that requires subsidiaries to choose an intensive-margin outcome. Empirically, studies that use micro-level data tend to either disregard such corner solutions or apply an ad hoc empirical adjustment.[3]

The tax avoidance asset plays a central role in our model and can represent many forms of MNE organization designed to facilitate profit shifting, for example, debt shifting (Desai et al.; 2004; Huizinga et al.; 2008), transfer pricing (Clausing; 2003; Cristea and Nguyen; 2016; Davies et al.; 2018) and patent location (Bilicka et al.; 2023; Desai et al.; 2006; Dischinger and Riedel; 2011; Griffith et al.; 2014). We introduce heterogeneity across companies in the cost of the tax avoidance asset, which is intended to represent real-world differences across companies in their opportunities for profit shifting and their preferences for different forms of shifting. As an example, consider the case of a business with ownership of intellectual property (IP) that chooses to locate the IP in a tax haven subsidiary. This business may set up a "cost contribution arrangement" in which the haven subsidiary nominally finances the costs of research and development undertaken elsewhere. The revenue generated from the IP will be treated as arising in the tax haven, but the cost of setting up such an arrangement may be high.[4] With that arrangement in place, the costs of shifting profit to the tax haven in any subsequent period are significantly lower than they would otherwise be. These costs can include direct payments to in-house staff and for professional advice, but may also include the expected value of potential penalties or reputation costs. Our model incorporates these and other tax planning activities without a need to detail the bespoke profit shifting strategies used by each company.

The tax avoidance asset introduces both extensive and intensive margin effects of tax reforms on profit shifting. For example, reduction in the marginal benefit of profit shifting due to a rise in the effective tax rate of the tax haven country may not result in any response from an MNE which has invested in the tax avoidance asset, and which continues to face marginal costs below the marginal benefits. The macro-level effect of tax reforms aggregate the response of the companies that, prior to the reform, shift some profit and the companies that shift all their profit – at the intensive and extensive margins of profit-shifting. Micro-level studies that focus only on intensive margin responses are likely to

[3]Other approaches include contributions by Desai et al. (2006); Dharmapala and Riedel (2013); Dischinger et al. (2014); Dischinger and Riedel (2011); Dyrda et al. (2024); Egger et al. (2010); Ferrari et al. (2023); Grubert and Slemrod (1998); Gumpert et al. (2016); Langenmayr and Liu (2023); Slemrod and Wilson (2009); Tørsløv et al. (2022).

[4]See, for example, the descriptions of Apple's and Microsoft's cost sharing arrangements in Chamberlain and Curtis (2021) and Curtis and Avi-Yonah (2023).

understate the impact of tax reforms on the proportion of true profit shifted. A key contribution of our paper, therefore, is to highlight the importance of unobserved heterogeneity across different types of firms with access to varying degrees of tax avoidance capabilities in estimating the magnitudes of firm responses to tax policies.

We estimate our model using corporate tax returns data from the UK. We find the semi-elasticity of the tax base with respect to the tax rates in the high-tax country to be 2.4[5]. This is broadly within the range of the macro-level semi-elasticity estimates proposed by the literature which vary from 2.5-2.9 in Clausing (2016); Ferrari et al. (2023) to 5.2 in Hines and Rice (1994). To quantify the importance of extensive margin responses in explaining the discrepancy between previous micro- and macro-level studies, we calculate the semi-elasticity estimate that ignores the responses of firms at the extensive margin to be 1.3. This is very close to the consensus from the literature that has been summarized in meta-studies by Beer et al. (2019); Heckemeyer and Overesch (2017). For example, in Beer et al. (2019) the average micro-level semi-elasticity is 1.4, while in Heckemeyer and Overesch (2017) it is 1.1. Our contribution to this literature is in building a model that allows for both extensive and intensive margin responses to tax policies which reconciles the differences between micro- and macro-level elasticity estimates.[6]

We further investigate the joint decisions regarding profit shifting and investment in productive assets in the context of our model. We show that a rise in the costs of profit shifting reduces overall investment in productive assets by MNEs, as lower shifting raises the cost of capital in all subsidiaries. The rise in cost of capital due to the rise in the cost of profit shifting can occur even if the MNE continues to shift all of its profit to tax havens. While previous literature also emphasizes the link between profit shifting and investment, our model advances the literature in two dimensions. First, contributions in the prior literature tend to make specific assumptions about the type of profit shifting, focusing either only on debt shifting (Hong and Smart; 2010; Mintz and Smart; 2004) or transfer pricing (Dyrda et al.; 2024; Koethenbuerger et al.; 2019), while our model incorporates all types of profit shifting through the tax avoidance asset, generalizing these previous approaches. Second, our model also captures the profit shifting and investment trade-offs when MNEs shift all of their profits to tax havens. As 42% of MNE subsidiaries in the UK do not pay any corporation tax, we show that accounting for different capital responses of these firms

[5]We refer to all semi-elasticity estimates in absolute value.

[6]Wier and Erasmus (2023) analyze the role of firm size in companies' ability to shift profits and argue that ignoring size heterogeneity in micro data can lead to underestimation of the aggregate profit-shifting elasticity. While our model also allows for heterogeneous productivity (and hence size), we highlight a large role of extensive margin responses, generated by a rich model that incorporates heterogeneity in operational costs and the ability to shift profits in addition to productivity differences.

has important implications for the aggregate elasticity of investment.[7]

We estimate that a percentage point rise in the tax rate of a high-tax country results in a reduction in capital accumulation in that country of 0.8 percent in the presence of profit shifting. If profit shifting did not take place, we find a much larger response; capital accumulation drops by 1.8 percent in response to the rise in the high-tax country tax rate, as the dampening effect of profit shifting on cost of capital is removed. We convert our baseline estimate to a user cost elasticity of 1.81, which is comparable to the estimate of 1.77 from Suárez Serrato (2018) who analyzes a US reform that curbed profit shifting. A similar type of trade-off has recently been highlighted in a macro model by Dyrda et al. (2024), who show that policies that reduce profit shifting are also likely to reduce output.[8]

We then quantify the fixed and variable costs of profit shifting in our model. We find that for an MNE with an average tax avoidance ability, the fixed cost of setting up a profit-shifting strategy is around 1.5% of the total true tax base, while variable costs are a little higher, at 3.1% of the total true tax base, totaling 4.6% of the true global tax base of the MNE. The literature so far has provided few estimates of the size of these costs. An exception is the recent work by McClure (2023), who estimates the costs of avoidance to be 6.4% of pre-tax income.

We test the empirical implications of our model using quasi-experimental variation arising from a 2002 Italian Controlled Foreign Company (CFC) reform. These CFC rules stipulated that the income of low-tax subsidiaries in black-listed tax havens should be subject to tax at the Italian corporate tax rate. This reduced or removed incentives to shift profit to such countries (Clifford; 2019). We compare a treatment group composed of all UK subsidiaries of Italian-headquartered MNEs with a control group composed of UK subsidiaries of non-UK, non-Italian, headquartered MNEs. Consistent with the predictions of our model, we find significant extensive and intensive margin effects. Specifically, for the treatment group we find a significant reduction in the probability of reporting zero taxable income and a significant increase in the average reported taxable profit. The implied semi-elasticity of reported profits is 3.59, consistent with the corresponding structural semi-elasticity. We find no significant effect of the CFC reform on investment on average, but we find suggestive evidence that firms that change their taxable profit reporting behavior from a non-taxable position to a taxable position reduce their investment.

Finally, we carry out counterfactual policy experiments. We consider two types of pol-

[7]Other recent papers that consider the links between profit shifting, the real activity of MNEs, and broader macroeconomic variables include Bilicka et al. (2022); Bilicka and Scur (2024); Bustos et al. (2022); Coppola et al. (2021); Guvenen et al. (2022).

[8]This differs from the recent work by Chodorow-Reich et al. (2024) and Kennedy et al. (2024) who both examine the impact of TCJA on global investment but do not take account of profit shifting.

icy experiments; a reduction in the high-tax country tax rate and an increase in the tax rate in tax haven country, both marginally and using a range of worldwide minimum tax rates including the 15% tax rate of the Global Minimum Tax. We find that, in response to a reduction in the high-tax country tax rate from 30%, the share of profit shifted to a tax haven decreases. This is because a lower home country tax rate reduces the benefits of costly profit shifting. This change in tax rate also reduces the costs of profit shifting and the fraction of firms that shift *all* of their profits out of the high-tax country to tax havens. The reduction in tax rate reduces the cost of capital and increases capital accumulation in high-tax countries. An increase in the tax-haven tax rate, as would happen with a minimum tax, also reduces the share of profits shifted from the high-tax country and the costs of shifting profits. However, this reduction in profit shifting comes at the cost of lower capital accumulation. We evaluate the welfare implications of these two types of policies using the marginal value of public funds (MVPF) framework (Hendren and Sprung-Keyser; 2020, 2022) and show that the MVPF of a tax rate reduction in the high-tax country is higher than that of the tax haven tax rate increase.

We then demonstrate the impact of a global minimum tax at varying threshold rates. A 15% minimum tax substantially reduces profit shifting by MNEs, generating efficiency gains from reduced spending on wasteful tax avoidance activities. These gains are, however, partly offset by reduced investment in productive assets. Overall, for countries with sufficiently high baseline tax rates, we find that the optimal global minimum tax rate (conditional on other tax rates) can be well above zero.

A growing theoretical literature analyzes the implications of global minimum taxes for welfare and revenues of high- and low-tax countries (Hebous and Keen; 2021; Hines Jr; 2022; Janeba and Schjelderup; 2022; Johannesen; 2022) and provides policy simulation exercises (Bares et al.; 2023; Grubert and Altshuler; 2013; Hanappi and Cabral; 2020). Our paper allows us to go beyond these exercises to examine the implications of GMT on global welfare, investment, tax revenue, and profit shifting costs; the model also has a broader application in permitting analysis of a variety of potential tax reforms.

The remainder of the paper is structured as follows. In Section 2, we develop the theoretical framework. In Section 3, we describe the data. In Section 4, we present our structural approach, and in Section 5, we provide reduced-form evidence supporting the structural estimates. In Section 6, we carry out counterfactual policy experiments and we conclude in Section 7.

2 Conceptual framework

2.1 A model of capital accumulation with profit-shifting

We model the behavior of a multinational enterprise (MNE) in a single period. The MNE has subsidiaries in N jurisdictions that have different tax rates on profit. The novelty of the model lies in the MNE investing in an asset which we call the "tax avoidance capability", or "tax avoidance asset", Y. The cost of accumulating the tax avoidance asset varies across MNEs, reflecting the ease with which different businesses can access the legal framework and accumulate know-how to shift profits to tax havens.

Each subsidiary has access to the global tax avoidance capability of the MNE, which makes Y a public good within the MNE. Each subsidiary that is not located in a pure tax haven also invests in productive capital, K. In this structure, two otherwise identical businesses in a jurisdiction may behave differently with respect to profit shifting: one may be part of a large multinational which has already invested substantially in the tax avoidance asset, while another may be a subsidiary of an MNE with very little investment in the tax avoidance asset (or a firm with solely domestic activities). The simplest possible version of the MNE in this model operates in three jurisdictions; one with a high tax rate, one with a lower tax rate (e.g. Ireland), and one that acts as a pure tax haven only used for shifting profit into it. The key features of the haven X are that it has a very low tax rate, labeled τ_X, and that in this location, there is no investment in productive capital.

The decision timing for the MNE is as follows:

1. At the beginning of the period, each government j announces its tax rate, τ_j, and any anti-avoidance measures. The anti-avoidance measures increase the variable cost of shifting profit to the haven X, and affect the MNE-specific cost of purchasing a unit of the tax avoidance asset Y_i, denoted p_i (where $p_i Y_i$ represents the fixed costs of shifting). This cost also reflects characteristics of the MNE's activities, for example, its reliance on hard-to-value intangible assets.[9] Also at the beginning of the period, each MNE i receives a draw in a distribution of jurisdiction-specific productivity, ε_{ij}, which introduces heterogeneity in production both across MNEs and across countries.

2. With knowledge of τ_j and ε_{ij} for all possible countries of operation j, as well as τ_X and p_i, each MNE i simultaneously chooses (i) investment in productive capital K_{ij}

[9] It is possible to add a separate fixed entry cost of investing in the tax avoidance asset. In our simulations and empirical approach, we do not include such a fixed cost and in simulations, we account for the behavior of firms without the tax avoidance asset separately.

in each non-haven country j, and (ii) investment in the tax avoidance asset Y_i that serves its subsidiaries globally.

3. At the end of the period, each subsidiary generates output of $F(K_{ij})$, with $F'(K_{ij}) > 0$ and $F''(K_{ij}) < 0$, and sells the remaining productive capital for $(1-\delta)K_{ij}$, where δ is the depreciation rate of productive capital.

4. Also at the end of the period, the multinational: (i) incurs an exogenous cost of operation Π_{ij}, observed only after it has taken the decisions on capital K_{ij} and tax avoidance asset Y_i – this introduces a third element of heterogeneity, which allows a subsidiary to make a loss ex-post, even in the absence of profit shifting; (ii) based on prior choices and on Π_{ij} in each subsidiary, the MNE chooses the proportion α_{ij} of the "true" tax base B_{ij} to shift from each subsidiary j to a tax haven. We assume that it is not possible to shift more than 100% of the tax base.

We assume that the variable costs of shifting profit out of jurisdiction i to a tax haven (conditional on $Y_i > 0$), are:

$$C_{ij} = c\left(\alpha_{ij}, Y_i, B_{ij}\right) B_{ij} \tag{1}$$

with $c_\alpha > 0$, $c_Y < 0$, and $c_B > 0$. That is, variable profit-shifting costs rise with the size of the tax base, B_{ij}, and the proportion of that base shifted, α_{ij}, but fall with higher investment in the tax avoidance asset, Y_i.

The true tax base in country j for MNE i has tax depreciation equal to true economic depreciation at rate δ and there is no relief for any financing costs:

$$B_{ij} = F(K_{ij}) - \delta K_{ij} - \Pi_{ij} \tag{2}$$

There is no tax deduction for expenditure on the tax avoidance asset, $p_i Y_i$. Since this is determined at the level of the MNE as a whole, we assume that the parent company bears the cost. Any deduction that may be available in the country of the parent can be thought of as affecting the MNE-specific price, p_i.

At the end of the period, a proportion α_{ij} of the tax base is shifted to the tax haven where it is liable to tax at rate τ_X. The remaining profit is taxed in country j at rate τ_j. The overall tax liability for each MNE in each jurisdiction is therefore:

$$T_{ij} = \widehat{\tau_{ij}} B_{ij} = \left[\tau_j\left(1-\alpha_{ij}\right) + \alpha_{ij}\tau_X\right] B_{ij} \tag{3}$$

where $\widehat{\tau_{ij}}$ can be thought of as an "effective statutory rate" on profit generated by MNE i in the subsidiary in j.

The MNE chooses Y_i, and for each subsidiary j, it chooses K_{ij} and α_{ij} to maximize its beginning-of-period value. The following value maximization problem summarizes the MNE's decision-making process at the beginning of the period:

$$\max_{Y_i, K_{ij} \forall j} V_i = -p_i Y_i - \sum_{j=1}^{N} K_{ij} + \beta \sum_{j=1}^{N} \left[F(K_{ij}) - \mathbb{E}[\Pi_{ij} - T_{ij} - c\left(\alpha_{ij}, Y_i, B_{ij}\right) B_{ij}] + (1-\delta) K_{ij} \right] \tag{4}$$

subject to the constraint:

$$0 \leq \alpha_{ij} \leq 1$$

where $\beta = 1/(1+r)$ is the discount factor. This formulation of the maximand reflects the timing considerations that we have described earlier in this section, namely the fact that the MNE chooses K_{ij} and Y_i before it observes the cost of operation, Π_{ij}. These decisions are therefore made based on the expected cost of operation Π_{ij}.

Conditional on some positive investment in $Y_i > 0$, the first order conditions for Y_i, K_{ij} and α_{ij} are as follows:

$$Y_i: \qquad p_i = -\beta \sum_{j=1}^{N} \mathbb{E}[c_Y(\alpha_{ij}, Y_i, B_{ij}) B_{ij}] \tag{5}$$

$$K_{ij}: \qquad F_K(K_{ij}) = \frac{r}{1 - \mathbb{E}[\widehat{\tau_{ij}} + c_B(\alpha_{ij}, Y_i, B_{ij}) B_{ij} + c(\alpha_{ij}, Y_i, B_{ij})]} + \delta \tag{6}$$

$$\alpha_{ij}: \qquad \left\{ \tau_j - \tau_X - c_\alpha\left(\alpha_{ij}, Y_i, B_{ij}\right) \right\} B_{ij} \; + \eta_{ij} = 0 \tag{7}$$

$$\eta_{ij} \left(\alpha_{ij} - 1\right) = 0$$

Equation 5 shows that the marginal cost of an additional unit of investment in the tax avoidance capability Y_i, p_i, equals the marginal benefit. The marginal benefit is the sum of the expected marginal reductions in variable profit shifting costs, aggregating over all the subsidiaries.

The condition for the optimal stock of K_{ij} in each subsidiary (Equation 6) resembles the standard, single-country expression for the marginal product of capital being equal to the cost of capital as in Hall and Jorgenson (1967), with adjustments for profit shifting. First, the "effective statutory tax rate", $\widehat{\tau_{ij}}$, replaces the statutory tax rate in country j. Higher

profit shifting therefore reduces the cost of capital, and raises K. Second, the expression for cost of capital in Equation (6) depends on K_{ij} through B_{ij}. As K_{ij}, and consequently B_{ij}, rise, the costs of profit shifting increase, which also raises the cost of capital.

In Equation 7, for a subsidiary j that shifts less than 100% of its profit, then $\eta_{ij} = 0$, and α_{ij} is determined at the point where the marginal benefit of shifting is equal to the difference between the tax rate differential and the marginal cost:

$$\tau_j - \tau_X = c_\alpha(\alpha_{ij}, Y_i, B_{ij}) \tag{8}$$

This is a conventional expression for the choice of what proportion of profit to shift. Unlike the conventional expression, our model also allows the subsidiary to shift all its profits. Specifically, if the benefits of shifting outweigh the costs for the values of $\alpha_{ij} < 1$, then α_{ij} will be driven to the corner solution of full shifting, with $\alpha_{ij} = 1$.

Welfare. We evaluate the welfare implications of actual and possible reforms to the tax system. To do so, we use a simple measure of welfare, equal to the sum of the net present value of firm cash flows, V_i, and tax revenue, which is appropriate when tax revenue is returned to the private sector as a lump sum. We evaluate welfare from a global perspective, as additional assumptions would be needed to attribute either private income or tax revenue to individual countries. We calculate global welfare numerically, computing for example for each value of τ_X the private income (V_i) and tax revenue (T_i) associated with each firm, and aggregating across firms and countries.

To compare the impact of reform options on global welfare, we use the marginal value of public funds (MVPF) framework. We compare the MVPF of a small tax reduction in the high-tax country with a small tax rise in the tax haven. We calculate changes in private income and tax revenues in response to a percentage point change in tax rates (following the approach of Hendren and Sprung-Keyser (2020, 2022)). The MVPF is the ratio of change in welfare of all firms to the change in cost to the government, which captures both the mechanical and behavioral responses to tax policies. We numerically calculate the following:

$$MVPF = \frac{\sum_{i=1} \Delta V_i}{\sum_{i=1} \Delta T_i} \tag{9}$$

In Appendix D, we also set out an approach that provides a closed-form solution to calculate changes in welfare and MVPF and shows that, similar to Risch (2024), the elasticity of taxable income is no longer the sufficient statistic for welfare analysis. Instead, we

require (1) the elasticity of the true tax base with respect to the effective statutory tax rate and (2) the elasticity of the proportion of the tax base shifted to the tax haven with respect to the difference in statutory tax rates between the high tax country and a tax haven.

Functional forms. We follow the conventional functional forms used in the existing literature for $c(\alpha_{ij}, Y_i, B_{ij})$ and $F(K_{ij})$, namely, a convex profit-shifting cost function and a Cobb-Douglas production function. The main distinction in our framework is the role of Y_i in the cost function for profit shifting. Specifically, we assume a functional form for the cost of profit-shifting in Equation (10) which exhibits convexity in α_{ij}, along the lines of conventional models (Dharmapala; 2014; Hines and Rice; 1994; Riedel; 2018):

$$c(\alpha_{ij}, Y_i, B_{ij}) = \frac{\gamma}{2}\left(\frac{B_{ij}}{Y_i}\right)^m \alpha_{ij}^2 \tag{10}$$

We assume that costs increase with the size of profit available to be shifted from the subsidiary in j, B_{ij}, and fall with the size of the multinational's tax avoidance asset, Y_i. We include the ratio of these two factors, and assume costs to be concave in this ratio, depending on the parameter m, where $m \in (0, 1)$.

We also use a simple functional form for $F(K_{ij})$:

$$F(K_{ij}) = \theta_{ij} {K_{ij}}^a \tag{11}$$

where productivity draw $\theta_{ij} = \theta \exp(\varepsilon_{ij})$ may vary amongst subsidiaries following the process $\varepsilon_{ij} \sim \mathcal{N}(0, \sigma^2)$. We assume that the cost of operation has the distribution $\Pi_{ij} \sim \Gamma(1, \beta_\Pi)$. Chen et al. (2022) derive a dynamic version of a production function with labor optimized out, in a similar spirit to our approach in this paper.

3 Datasets

We use detailed administrative tax returns data from the HM Revenue and Customs (HMRC; the UK tax authority) matched with financial accounts information and ownership links provided by the FAME dataset to test the predictions of the model. Our tax returns dataset starts in the fiscal year 2000 and comprises all items that are submitted on the corporation tax return form (CT600 form). The unit of observation is an unconsolidated statement of a company in each of the years. Each subsidiary of a company operating in the UK files a separate tax return. We use a variable called 'profits chargeable to corporation tax' from the tax return to measure taxable income. This variable is censored at 0, with losses re-

ported separately on the tax form.[10] These data are matched with financial accounts data that contains information on operating profits, firm assets, employment, and other balance sheet items (FAME dataset).

The ownership data from FAME allows us to identify the global ultimate parent companies that own UK subsidiaries and separate firms into domestic and multinational, as well as differentiate by country where the ultimate owner is headquartered. We focus on UK subsidiaries that belong to multinational companies headquartered in foreign countries and that report positive turnover. We use these firms in both our structural model and our reduced-form analysis because, unlike domestic firms, they have the ability to shift profits to foreign jurisdictions, in line with the MNE behavior outlined in our conceptual framework. Following Bilicka (2019), we do not consider multinational firms that are headquartered in the UK, domestic MNEs, for two reasons. First, a majority of them do not report unconsolidated balance sheet information in FAME making us unable to estimate their capital responses. Second, their incentives with regards to profit shifting into and out of the UK, which is their headquarter country, may differ from those of foreign MNEs (Dischinger et al.; 2014).

Our sample comprises 8,922 subsidiaries, of which 248 are headquartered in Italy and are affected by the Italian reform we use for identification in Section 5 and 8,674 are headquartered across all other countries in the world. We use information for all these subsidiaries for years 2000 - 2005 in the reduced form estimations and we use the subsidiaries of all non-Italian MNEs in 2001 to identify the structural parameters in our model. The reason we choose this particular group of firms in 2001 to identify structural parameters is to avoid any influence of the 2002 Italian reform on structural estimates. In Appendix A, we provide a more detailed data description and a definition of the variables.

4 Estimating profit shifting and investment behavior

We analyze firms' responses to tax policy changes in two steps. First, in this section, we use moments from the distribution of key variables in our administrative tax returns dataset to match in a simulated method of moments estimation procedure and estimate the key structural parameters of our model. Second, in Section 5, we present results from the reduced-form difference-in-differences regressions that demonstrate MNEs' responses to a reform aimed at curbing tax avoidance for a particular group of firms.

[10] Note that the CT600 form does not require reporting of all losses, just trading losses.

4.1 Estimating key model parameters

To estimate the structural parameters, we use an indirect inference approach (Gallant and Tauchen; 1996; Gourieroux et al.; 1993) and a method of simulated moments (MSM) procedure, in which we simulate firms over the distributions of unobserved relative unit price of the tax avoidance capability, p_i, productivity draws with $\varepsilon_i \sim \mathcal{N}(0, \sigma^2)$, and cost of operation that has an exponential distribution with scale parameter β_Π. We minimize the MSM criterion function, which takes the form:

$$L(\Theta) = h(\Theta)^{'} W_N h(\Theta) \tag{12}$$

where Θ is the vector of structural parameters of interest. The two key parameters related to profit-shifting behavior are $\bar{p}$, which is the upper bound of the uniformly distributed relative unit price of the tax avoidance capability, and the convex profit-shifting cost parameter γ.

In Table 1, we show the correspondence between the specific moments and the parameters that each moment helps to identify in the estimation. The model presents a link between the profit-shifting cost parameters ($\bar{p}$ and γ) and the moments of the taxable income distribution. The zero-taxable income share in particular is strongly linked to the upper limit of our profit-shifting 'fixed cost' distribution $\bar{p}$. This link is visible in Appendix B, where we demonstrate the sensitivity of the structural parameters to the moments. This parameter defines the unit cost of investing in tax avoidance – a higher $\bar{p}$ means that the unit cost of investing in tax avoidance is higher across the board. As a result, $\bar{p}$ is identified by the mean and median of taxable profit as well as by the share of MNE subsidiaries that report zero taxable income. This share reflects the proportion of firms that engage in more aggressive profit shifting, as discussed in Bilicka (2019). In a similar vein, the 'variable cost' γ that predominantly drives the intensive-margin profit reporting behavior is identified by the moments of the distribution of taxable income and operating profit. The dispersion of capital is highly influenced by the cost of capital, which in turn is impacted by the two key tax avoidance parameters, $\bar{p}$ and γ.

Firms can report zero taxable income not only because of profit shifting but also when they experience real losses. We capture these real losses through the cost parameter Π where the structural parameter β_Π multiplies a random variable with an exponential distribution, Exponential(1, 1). Each MNE has a random draw from this distribution, but all states of those real losses are scaled by the same multiplier Π. To capture the fact that Π represents 'true' losses of MNE subsidiaries, it is identified primarily by the first quartile of

the distribution of the operating profit which is negative.[11] Mean values of taxable income and capital also help to pin down Π. Finally, our production function parameters θ (total factor productivity) and a (elasticity of output with respect to capital) are identified by the mean and variance of capital as well as the average taxable profit.

Our analysis is based on an MNE with three subsidiaries; one in a high-tax country, H, with a tax rate of 30%, one in a low-tax country, L, with a tax rate of 12.5% and where the MNE also has real activity, and the third subsidiary without any real operations located in a tax haven, X, with a zero tax rate to which profit is shifted.[12] An MNE with subsidiaries in UK (high-tax), Ireland (low-tax) and Bermuda (tax haven) is an example of such a setup. As such, we explicitly model behavior of low-tax jurisdictions, such as Ireland, where MNEs have real activity, but which also play an important role in profit shifting. We assume that the cost of setting up a network of subsidiaries for tax avoidance purposes is absorbed into the cost of the tax avoidance capability captured at the MNE level by p_i, for which the distribution over MNEs is uniform between zero and $\bar{p}$.

In Table 2, we present the estimates from our MSM procedure. We calculate the standard errors of these estimates using the Delta method. All estimates are highly significant and responsive to changes in moments that we use to identify them, as we demonstrate in Figure B1 in the Appendix. We estimate that the elasticity a of output with respect to productive capital K is 0.535 and the total factor productivity θ is 175.403; the unit cost of accumulating the tax avoidance capability is distributed Uniform$(0, 1.81)$, and the key parameter in the convex cost of profit shifting $\gamma$is 0.145. Then, in Figure 1, we present the fit of the model against 6 moments from the data listed in Table 1 and show that the estimated moments closely match their simulated counterparts.

4.2 Implications of the model

We solve the model numerically for the three choices of the firm: investment in the tax avoidance asset for the MNE, Y_i, the optimal productive capital, K_{ij}, and the extent of profit shifting – the share of tax base shifted to the haven, α_{ij} – for each subsidiary. In Figure 2, we illustrate the implications of the model for K_{ij} and α_{ij} and show the heterogeneity across MNEs due to variation in p_i. On the horizontal axis of all three figures, as we vary

[11] We assume that operating profit is a proxy for true profits. This is more likely to be true for negative values of operating profits as companies first use losses before shifting profits to tax havens (De Simone et al.; 2017). Upper quartiles of operating profit are likely also manipulated for tax avoidance reasons and hence do not provide useful moments to identify true losses.

[12] Since we use UK data to estimate our model, we use the UK tax rate over the relevant time period as a high-tax rate country rate. We run our simulations using a low-tax location with 12.5% rate, but the availability of this alternative investment location in the model does not have a material impact on our estimates.

the ease of access to (or unit cost of) the MNE's tax avoidance capability p_i, we hold the productivity draw, ε_{ij}, and the cost of operation, Π_{ij}, constant at their mid-point values across all subsidiaries in high-tax and low-tax countries.

In Figure 2a, the black solid line shows the share of profit that the MNE shifts out of H and the blue dashed line shows the share of profit shifted out of L. For MNEs that have very low p_i, i.e., very easy access to tax avoidance, it is optimal to shift the entire tax base in both countries to the tax haven. As p_i increases and the cost of shifting rises, the "full-shifting" behavior becomes less prevalent, first in L and then, as p_i increases further, also in H. This generates the two kinks in the share of shifted profits. Except at very low values of p_i, a larger share of profits is shifted out of H than out of L, reflecting the greater benefit of shifting from the higher-tax country.

In Figure 2b we show capital accumulation in H and L, again with the solid black line and the blue dashed line, respectively. For very small values of p_i, as the MNE shifts all profits out of both countries, the capital accumulation in the two countries is the same. However, as p_i increases capital accumulation trajectories diverge, with capital accumulation falling in both countries. Note that capital accumulation falls in H with a rise in p_i even when profit is fully shifted to X so that no tax is paid. This is because profit-shifting costs rise, increasing the cost of capital. Capital accumulation also falls in L, but by a smaller amount, reflecting the fact that the sum of taxation and profit shifting costs is lower in L than in H, even for MNEs that face a higher unit cost of tax avoidance.

In Figure 2c, we plot the relationship between the price of the tax avoidance asset, p_i, and the total amount shifted (which is the difference between true and observed tax bases). The black lines represent the high-productivity firms, while the red lines represent the low-productivity firms. The dashed lines show the amount of profit shifted out of low-tax countries, while solid lines out of high-tax countries. Our model predicts that more productive, i.e., larger, firms shift more profit to tax havens, both from low- and high-tax rate countries. This demonstrates a direct relationship between productivity, firm size and the extent of profit shifted to tax havens and is consistent with empirical evidence from Wier and Erasmus (2023) who demonstrate the disproportionate role of large firms in profit shifting. In Appendix B, we expand Figure 2c for further visibility.

4.3 Semi-elasticity of taxable income reporting in high-tax jurisdictions

We present implied tax base semi-elasticity estimates based on our structural parameters in Table 3. We take our baseline case to be a high-tax country tax rate of 30%, but we show results with 40% and 20% as well. For each case, we present four estimates of semi-elasticities indicating the percentage change in the declared tax base in the home country

with respect to a one percentage point rise in the home country tax rate, distinguishing across two dimensions. First, we present estimates that account for the extensive margin profit-shifting responses and estimates that our model would generate if we did not account for the extensive margin. The latter are equivalent to many of the micro-level estimates from the literature, obtained from a regression analysis that ignores zero-taxable income reporters. Second, we present long-run semi-elasticities which correspond to the case where capital and tax avoidance capability adjust fully in equilibrium, as well as short-run semi-elasticities which capture the case before the adjustment in capital and tax avoidance capability, just after the MNE incurs the cost of operation Π_i. In all these estimates, we present the weighted average of the response of subsidiaries of MNEs and other firms, where we use the Office for National Statistics (ONS) gross value added number for foreign firms operating in the UK as the weight for MNE subsidiaries. In our case, only the subsidiaries of MNEs shift profit to the tax haven, but in the long run all firms adjust their capital.[13]

We find large differences between the estimated semi-elasticities. In the long run, our estimated semi-elasticity of the tax base in the high-tax country with respect to the tax rate is 2.4, which is almost twice as large as the micro-level estimate (1.3) that does not take into account zero-taxable income reporting MNEs. In the short run, our estimated tax base semi-elasticity is 3 times as large as the micro-level estimate. This difference highlights the importance of taking the extensive margin responses into account when estimating the effects of tax rate changes on tax bases. Crucially, both our aggregate and micro-level estimates are similar to the consensus estimates from the literature on their respective magnitudes of around 1.1-1.4 and 2.3-2.8 (Beer et al.; 2019; Heckemeyer and Overesch; 2017).[14]

We also show that the level of the home country tax rate matters for the magnitude of the estimated tax base semi-elasticities. In a high-tax country with a 40% tax rate, we find the long-run aggregate tax base semi-elasticity to be 4.3. In a 'high-tax' country with a 20% tax rate, that semi-elasticity is 1.5.[15] Across all cases, the long-run responses are larger in magnitude than short-run responses, and the overall responses exceed the corresponding micro-level estimates that ignore zero taxable income reporters. In Appendix B.3, we also show how these semi-elasticities vary for firms that face different unit prices of tax avoidance capability and have different productivity draws.

[13] Using information from ONS, we use the information that foreign MNEs in the UK comprise 28.5% of gross value added. We do this to make our estimates comparable to the existing literature.

[14] We provide a detailed discussion of how these magnitudes compare to the existing estimates from the literature in Appendix B.2.

[15] This is different than the heterogeneity explored in Dowd et al. (2017), who look at different non-home tax rates and show that the elasticity for tax haven subsidiaries is higher than that for high tax countries.

4.4 Semi-elasticity of capital in high-tax jurisdictions

We next investigate how the semi-elasticity of tangible capital with respect to the tax rate depends on profit shifting. As a higher tax rate induces both a rise in profit shifting and a fall in capital accumulation due to the higher cost of capital, the magnitude of the tangible capital response depends on the extent to which firms engage in profit shifting.

In Table 4, we summarize the semi-elasticities of K_{ij} with respect to the tax rate τ_j . In the first row, we show semi-elasticities for our sample of subsidiaries of foreign-owned MNEs, labeled "Shifters". Using the baseline 30% tax rate in the high-tax country, we find this semi-elasticity to be a modest -0.8. In the second row, we disallow profit shifting by setting $\alpha_{ij} = 0$ and find a considerably higher semi-elasticity of -1.8 for firms we label "Non-Shifters". This difference highlights the importance of profit shifting in how the capital stock responds to changes in tax rates – those firms that shift profit respond considerably less to a change in the tax rate than those that do not. The lower capital response of "Shifters" reflects a high semi-elasticity of the share of the tax base shifted, α_i, with respect to the tax rate. This suggests that MNEs respond to a change in the tax rate far more on the profit-shifting margin than on the capital stock margin and explains large differences in capital responses between "Shifters" and "Non-Shifters".[16]

In the last row of Table 4, we construct a weighted average of the two semi-elasticities, assigning weights based on aggregate data on the share of MNEs in the UK, following our approach above. This aggregate allows us to make a comparison with the existing literature. We convert our semi-elasticity estimate of -1.52 to an estimate of the elasticity of capital stock with respect to the cost of capital – user cost elasticity – of -1.81.[17] While this estimate is high relative to the range of capital stock elasticities from older literature that are between -0.5 and -1 (Bond and Van Reenen; 2007; Hassett and Hubbard; 2002), our estimates are more closely aligned with the more recent literature that found larger responses using administrative data.[18]

We present estimates of the semi-elasticity of K_{ij} with respect to τ_j for cases where $\tau_j = 20\%$, $\tau_j = 30\%$ and $\tau_j = 40\%$ in Table 4. For "Non-Shifters", the semi-elasticity rises in absolute terms with the tax rate, indicating a rise in the marginal impact of the tax. But for

[16] Chodorow-Reich et al. (2024) estimate consolidated capital stock elasticities for domestic and MNEs and find these to be 0.42 and 0.61 respectively. While their approach focuses on the implications of TCJA as a whole and abstracts away from the role of profit shifting, their estimate for MNEs is within our range for the case where the high-country tax rate is between 40 and 30% (0.37-0.8) Differently from us, they focus on the implications of TCJA for consolidated capital stock of US-based MNEs, while we consider the capital stock of individual subsidiaries.

[17] In Appendix E we outline the calculation behind that transformation.

[18] Some examples of which include Chen et al. (2022); Giroud and Rauh (2019); Maffini et al. (2019); Moon (2022); Ohrn (2018); Suárez Serrato (2018); Zwick and Mahon (2017).

"Shifters", the opposite is true: the marginal impact of the tax on K_{ij} falls as the tax rate increases. This indirectly indicates the marginal effect of a tax rise on profit shifting, which rises with the tax rate. This effect suggests that, at high tax rates, the response of profit shifting becomes so great that the "effective" tax rate rises much less, with consequently a small effect on capital accumulation.

4.5 Profit shifting costs

We now consider the level of profit-shifting costs implied by our model, distinguishing between fixed and variable components of these costs. These are indirect and comprehensive estimates of profit shifting costs inferred from the degree of profit shifting and the estimated parameters. They include the direct costs of any in-house tax department as well as professional and legal fees. They may also include more general anticipated costs, such as any additional tax liabilities or penalties that may arise if risky avoidance schemes turn out ex-post not be consistent with complex international tax law, and any perceived reputational costs of being considered by shareholders or third parties to be aggressive tax avoiders.

In Figure 3, we scale the costs of profit shifting by the total true tax base (before shifting) in both H and L. In Figure B3 in the Appendix, we show these costs scaled by the tax base in high-tax country and also by capital. For the average value of p_i, the fixed costs are 3.1% of the true tax base, while the variable costs are slightly higher, around 4.6% of the true tax base.[19] We also generate fixed and variable costs of profit shifting for each of our simulated MNEs, as each has different unit costs of tax avoidance, entry cost, and productivity draw. The average fixed cost is 1.48% of the true tax base, while the average variable cost is 3.1% of the true tax base. The average simulated value of total shifting cost as a share of the true tax base therefore amounts to 4.58%.

We then investigate the heterogeneity of the profit shifting costs according to the price of the tax avoidance asset, p_i. The two kinks in the schedule for profit shifting from Figure 2a are also present in Figure 3. The fixed cost, $p_i Y_i$, rises while at least one of the subsidiaries continues to shift its entire tax base. However, within this region Y_i falls as p_i increases, implying that the variable costs required to shift all profit also rise. This increase is steeper for both costs when an MNE shifts all profits out of both high and low tax countries. As p_i increases further, the higher costs prove prohibitive and the subsidiary in H no longer shifts all its profit. Beyond this point, first fixed, then also variable, costs fall as a proportion of the total true tax base. While the kinks in the variable costs follow the kinks in the share

[19] Note that to calculate results in this section, we keep ε_{ij} and Π_{ij} constant at their mid-point values.

of profits shifted out of high and low tax countries precisely, kinks in fixed costs are also affected by changes in K. As accumulation of capital in high tax country slows down, fixed costs start falling before the variable costs do. We find that fixed costs of profit shifting reach a maximum of 7.7% of the total true tax base at the point where p_i is the highest value that allows MNEs to still shift all profits away from high tax countries. At that same point, the variable costs of profit shifting are 8.2% of the true tax base.

5 Reduced-form estimates

We now evaluate the intensive- and extensive-margin profit-shifting responses to a tax reform to benchmark against our structural estimates. To identify profit-shifting responses, we use exogenous variation in incentives introduced by a reform to the controlled foreign company (CFC) legislation in Italy in 2002.[20] A CFC regime change provides a useful experiment, as it is equivalent to a tax haven tax rate change for certain types of income. This reform generated distinct treatment and control group tax rates that can trigger differential changes in reported UK taxable income; at the time, a high-tax country. Before the reform, profit shifted from the UK to a tax haven by an Italian-owned MNE was subject to the haven tax rate. After the reform, Italy began to levy corporation tax at the Italian rate on certain types of profit reported in subsidiaries of Italian MNEs located in blacklisted tax havens.

The tax reform therefore reduced, or removed, incentives for some UK subsidiaries of Italian MNEs to shift profit from the UK to a haven. According to the theoretical framework in Section 2, such UK subsidiaries would become less likely to report zero taxable profit in the UK (the extensive margin effect), and those that reported positive taxable profit would be likely to increase the profit reported in the UK (the intensive margin effect). In the short run, this would reflect the reduced tax savings from shifting, even given some previous investment in the tax avoidance asset. In the longer run, there could be a larger effect as investment in the tax avoidance asset would be reduced. Depending on the size of the structural parameters $\bar{p}$ and γ, the reform may cause more pronounced effects on the base through either the extensive- or the intensive-margin. Also, if investment in productive activity responds quickly, there may be a fall in investment due to the higher cost of capital.

To causally identify the effects of the reform, we use a difference-in-differences approach and compare the reporting behavior of UK subsidiaries of Italian MNEs – the treatment group – with UK subsidiaries of other foreign MNEs – the control group – over the

[20] Clifford (2019) provides further information on CFC legislation around the world and studies their impact on companies' behavior.

period 2000 - 2005. The control group is composed of the entire sample of UK subsidiaries of foreign MNEs operating in the UK and we use entropy balancing weights to obtain the most comparable control group to the treatment group. In the paper, we present results using our preferred set of entropy balancing weights, while in the Appendix C, we present results using the unweighted sample of control firms and a series of alternative entropy balancing weights.

Empirical specification To assess the effect of the reform on (i) the change in the probability of reporting zero taxable profit in the UK, (ii) the change in the average profit reported in the UK, and (iii) the change in capital in the UK, we run regressions of the following form:

$$\text{Outcome}_{it} = \alpha_1 + \beta \text{Treated}_i \times \text{Post-reform}_t + \chi_i + \eta_{tj} + \varepsilon_{it} \tag{13}$$

where $Outcome_{it}$ is one of: (i) a dummy equal to one when a firm reports zero taxable profits in a given year, (ii) the level of taxable profit reported in a given year, and (iii) the natural logarithm of total assets which we use to proxy for the real capital in the subsidiary. The first two outcomes correspond to the extensive-margin and the intensive-margin profit-shifting effects, respectively. Treated_i is a dummy variable that equals one if a subsidiary belongs to an MNE that is headquartered in Italy and zero otherwise; Post-reform_t is a dummy variable that equals one from 2003 onwards. χ_i are firm fixed effects, η_{tj} capture sector-specific time effects, with subscripts j representing two-digit sectors, and ε_{it} are the error terms. Table 5 presents descriptive statistics on key variables (before applying entropy-balancing weights) for the pre-reform period for the treatment and control groups.

Graphical evidence and reduced-form regression results For the validity of the difference-in-differences approach, treatment and control groups should satisfy the assumption of common counterfactual trends. In the absence of treatment, the change in the average outcome variables of interest for the control and treatment group firms should be similar. We assess whether common counterfactual trends is a plausible assumption in our matched sample by exploring the trajectory of the average outcome variables in pre-reform years. In panel (a) of Figure 4, we show the average probability of reporting zero taxable income. After the reform, this drops significantly for the treatment group, but not for the control group. This is consistent with the prediction that the reform reduces the likelihood of Italian subsidiaries fully shifting all profit out of the UK. In panel (b) we show the evolution of the average taxable income in levels, which highlights a positive response to the CFC

reform in terms of reported taxable profits. In panel (c), we show the evolution of the logarithm of total assets, which suggests a small (statistically insignificant) rise after the reform.

In Table 6, we quantify the magnitudes of these responses. In columns (1) - (3), we consider the effect of the CFC reform on taxable income. We start by presenting results using OLS and find that subsidiaries of Italian MNEs report £1.33 million more taxable income on average in the UK, after the CFC reform relative to the control group (column 1). As Table 5 shows that there is a high prevalence of zero taxable income in our sample, we further estimate the general average response of taxable income using the inverse hyperbolic sine and Poisson transformations in columns (2) and (3), respectively. Our preferred estimate from Poisson regression, suggests that the semi-elasticity of taxable income with respect to tax rate is 3.59. In column (4), we estimate the effect of the reform on the extensive margin of taxable income reporting. We find that after the reform, treatment group firms reduce their probability to report zero taxable income in the UK by 5.6 percentage points, which is a 13.3% reduction relative to the control group mean of 0.42.

Column (5) of Table 6 presents the effect of the reform on productive capital. In contrast to our prediction of a reduction in capital for aggressive profit shifters, we find no statistically significant average effect of the CFC reform on capital. One potential explanation is that investment in both forms of capital adjusts slowly so that there are only small effects on real capital during the data period. Our experiment indeed covers a short-term response – because of subsequent reforms after 2005, we cannot extend the analysis period to later years. We complement this result with Figure 5, in which we plot the evolution of capital according to whether a firm switched their status from zero taxable profit reporting before 2003 to positive profit in at least one period after (and including) 2003 (in red) or did not switch their status (in green). These figures suggest that both control and treatment firms that change their taxable income status in this way tend to reduce their capital. This is consistent with the higher tax raising the cost of capital and hence leading to a reduction in investment. In the short-run, our structural model assumes no capital response, while in the long-run, the semi-elasticities we present in Table 4 suggest a reduction in capital. As our reduced-form model only considers 3 years after the reform, it is unsurprising that we find no significant effect on capital. Nevertheless, there is suggestive evidence that companies moving from untaxed to taxed status display some negative capital response (Figure 5).

To compare these reduced-form estimates with the results from the structural model, we proceed in two steps. First, we convert the coefficient estimates into semi-elasticities and report these in Table 6. Because our data contain many observations with zero taxable

profits, we expect OLS to underestimate the semi-elasticity of the tax base with respect to the tax rate. Indeed, the semi-elasticities obtained from OLS are slightly smaller than those from the Poisson model, and our preferred estimate is therefore based on the Poisson specification. Second, we cannot directly compare these semi-elasticities to those reported in Table 3, since we expect that the response to a 1 percentage point decline in the tax rate in a high-tax country will differ from the response to a 1 percentage point increase in a tax haven's rate. In the next section, we show that this is indeed the case. We compute the semi-elasticities for a 1 percentage point tax rate increase in a tax haven—from 0 to 1%—to be 2.31 in the short run and 7.44 in the long run. We focus on the response of MNEs only, as these are the firms included in our reduced-form sample. Our reduced-form estimates lie within the range of the structural ones, and are closer to the short-run response.

6 Counterfactual policy experiments and welfare implications

We analyze the impact of three types of tax reforms: (i) a change in the tax rate in the country of production, H or L; (ii) a change in the tax rate applied to profit declared in the haven; and (iii) strengthening anti-avoidance measures, which may imply changes in the tax haven tax rate or may increase the cost of shifting profit by altering the cost of accumulating profit-shifting capability. Governments have used tax rate changes, controlled foreign company rules, and other anti-tax avoidance policies to deter profit shifting and to increase tax revenue. In the context of our model, raising the tax rate in the haven is equivalent to introducing a global minimum tax (GMT), which sets a lower bound on the tax rate levied on all profit wherever it is declared. As several countries have already started implementing the OECD's GMT in 2024, we also consider the welfare implications of the GMT. Throughout this section, we analyze the responses of multinational firms only and do not include the responses of domestic companies.

6.1 Tax rate changes in high tax country

We start by demonstrating the effects of a small tax rate change for the high-tax country, initially with the tax rate of 30%. In Figure 6a, we show, based on our model and estimates, how a one percentage point reduction in the high-tax country tax rate, to 29%, would affect the share of profit shifted from the high-tax country to the tax haven, capital accumulation in the high-tax country, and MNE's profit shifting costs scaled by the global true tax base. The solid lines in each subfigure represent the pre-reform evolution of each variable across

the distribution of p_i. The dashed lines show what happens after the tax rate reduction by 1 percentage point.

The lower tax rate reduces the benefit from shifting profit from the high-tax country to the tax haven. Firms with very low p_i, which shift all their profit before the reform, continue to do so, as the benefit of it continues to outweigh the costs. For higher values of p_i, some firms respond on the extensive margin by reducing their profit-shifting activity from 100% of their true profit to a lower share, reflected in the full-shifting kink moving to the left. As p_i increases further, firms that are already partial shifters reduce their shifting since the marginal benefits are reduced.

The cost of capital does not change for firms that continue to shift all of their profit. They pay no tax, and their costs of shifting are also unaffected by the change in the tax rate. Consequently, as we show in Figure 6b, their capital accumulation is unaffected by the tax rate change. However, for firms that respond on the extensive profit-shifting margin, and for firms that were partial shifters, the cost of capital falls. This is reflected in slightly higher capital accumulation in the high-tax country for higher values of p_i.

Figure 6c illustrates the impact of the tax rate change on profit-shifting costs. Since there is no change in profit shifting for firms that continue to fully shift, the costs of shifting for these firms are also unaffected. However, the kink in the cost of shifting across p_i moves to the left, consistent with the extensive margin response in panel (a). As p_i increases, the lower shifting induced by the lower tax rate in the high tax country reduces both the fixed and the variable costs of profit shifting.[21]

6.2 Tax rate changes in tax havens

In Panel B of Figure 6, we examine the effects of a small tax rate increase in the tax haven country, from 0% to 1%. The effects on profit shifting are similar to those of a reduction in the tax rate in the high tax country, since the rise in the haven rate also reduces the benefit of profit shifting (Figure 6d). However, we find the opposite effect on capital accumulation. In Figure 6e we show that as the increase in the tax haven tax rate increases the effective tax rate, $\widehat{\tau_{ij}}$, even for firms that shift all their profit out of the high-tax country, this leads to an increase in the cost of capital and a reduction in K_{ij} for all firms.

Further, the higher tax haven tax rate reduces the benefits of shifting from both the high- and the low-tax countries, leading to a larger decline in both fixed and variable costs of shifting than in the case of tax rate reduction in high-tax country. This happens because the higher tax haven tax rate reduces investment in the tax avoidance asset, Y_i, for all firms,

[21] In Figure B5 we also demonstrate the effects of a much larger, 10 percentage points, reduction in the high-tax country tax rate.

including those in the low-tax country and those that continue to fully shift profits out of the high-tax country. The extensive margin effect in Figure 6d reduces the value of p_i at which the kink point in the shifting costs occurs in Figure 6f. Therefore, the change in shifting costs after the rise in the tax haven rate is larger for values of p_i higher than at the kink point.

6.3 Marginal value of public funds

How can we compare the welfare implications of a home country tax rate reduction and a tax haven tax rate increase that both reduce profit shifting? To answer this question, we use the MVPF framework (Hendren and Sprung-Keyser; 2020, 2022) and compute the ratio of a change in the welfare of firms (benefits) to the change in the net cost of these policies to governments globally. The cost of each of these policies is the change in tax revenues in response to the one percentage point change in the tax rate. This captures both the mechanical and behavioral effects of tax policies through changes in capital accumulation and profit shifting.[22]

For the increase in the tax haven tax rate, we find the 'global' MVPF influenced by the behavioral response of our sample of MNEs to be 0.33. Because the increase in tax haven tax rate is a tax revenue gain (rather than a cost) to the government in the tax haven country, we interpret this MVPF to say that for a \$1 gain to the government from increasing the tax rate, the taxpayer – the firm – is worse off by \$0.33. As such, this policy imposes a welfare cost of only \$0.33 per dollar of revenue raised. This is lower than \$1 since the resulting gain in income from a reduction in profit-shifting costs outweighs the loss in private income due to a reduction in K_i.

We calculate the MVPF of a 1 percentage point tax rate reduction in the high tax country moving from 30% to 29% to be infinitely large. That is because this rate reduction not only increases NPV of MNEs, but also generates an increase in tax revenues, resulting from the combined behavioral response of lower profit shifting and higher investment across the world. This implies that that a marginal tax rate reduction in the home country would be more welfare improving (globally) than a marginal tax rate increase in tax haven. This MVPF calculation depends on the starting point for the tax rate. For example, the MVPF of a home country tax rate reduction from 20 to 19% is 5.2. These MVPF calculations only consider the behavioral responses of MNEs. The high-tax country tax rate reduction would impact domestic firms differently than MNEs and their inclusion could change this calculation.

[22] Our approach implicitly assumes that all profit-shifting costs represent a welfare loss to society.

6.4 Global Minimum Tax

We then turn to analyzing the implications of setting a range of different tax rates in the tax haven on profit-shifting, capital accumulation, shifting costs and global welfare. Both the Global Minimum Tax (GMT) and some controlled foreign company rules can be modeled as a change in the tax rate in the tax haven. We focus our discussion here on the GMT, considering first the 15% rate and then a range of minimum rates. A GMT at 15% is currently implemented in the EU, UK, Japan and others.[23]

First, in Figure B6, we show that our findings are directionally similar to the effects of a small change in the tax rate of the tax haven in Figure 6, but much stronger in magnitude. Our model predicts that a GMT introduced at the 15% rate almost completely eliminates full-shifting out of the high-tax country, accompanied by very large intensive margin responses. These responses are also reflected in a large reduction of both the variable and fixed costs of profit shifting. The introduction of GMT increases the cost of capital for all firms, adversely affecting capital accumulation.

What about the impact of minimum tax rates other than 15%? To answer this question, we analyze the implications of introducing a GMT at varying rates between 0% and 25%. In Figure 7, we first explore the impact of this range of GMT rates on some key aggregate outcomes. We start by showing in the left panel the changes in capital accumulation in the high-tax and low-tax countries, and in aggregate. For each GMT threshold level, we assume that the tax haven tax rate (and when the GMT rate reaches the low-tax country tax rate, also the low-tax country's tax rate) automatically increases to the threshold level. Capital accumulation falls in both countries as the minimum tax rate rises. The fall is steeper in the low-tax country after the minimum tax rate exceeds its home rate, as the effective tax rate in that country rises more steeply in line with the minimum tax rate.

In the right panel of Figure 7, we demonstrate the trajectories of tax revenue in the high-tax country (black smooth line), in the low-tax country (black dashed line), and in the tax haven (black dotted line)[24]. Tax revenues rise steeply in both the high-tax and low-tax countries as a higher GMT reduces profit shifting; this is more pronounced initially in the high tax country as the rate of profit shifting falls more sharply there, but the revenue in the low-tax country rises more steeply for rates above 12.5%. Revenues in the haven initially rise (from zero) as firms continue to shift profits for low values of GMT, but shifted profits

[23] Australia, Canada, South Korea, South Africa have also adopted legislation to start the implementation of the OECD's GMT at 15% minimum rate. The OECD's GMT has some features that we do not model: since we assume there is no real activity in the haven, the "substance-based income inclusion" is zero. We also abstract away from differences in the measure of profitability for tax and accounting purposes.

[24] We assume in this Figure that the additional revenue from the rise in the haven tax rate is captured by the haven itself.

begin to decline even at relatively low haven tax rates as higher GMT reduces profit shifting to tax havens.

We demonstrate the impact on fixed and variable profit-shifting costs, also in the right panel of Figure 7. We depict the aggregate fixed cost of profit-shifting $(p_i Y_i)$ with the red smooth line and the aggregate variable cost of profit-shifting with the red dashed line. Both types of costs gradually decline as profit-shifting declines.

In Figure 8, we summarize these effects using a simple measure of global welfare which aggregates total private value and tax revenue: $W = \sum_{i=1}(V_i + T_i)$. We also show the evolution of the two components separately. In the left panel, total tax revenue rises with the minimum tax rate, and total private income declines. However, consistent with the MVPF framework that we discussed in Section 6.3, global tax revenue initially rises more quickly than private income declines. That is because the reduction in profit shifting costs outweighs the reduction in private income due to lower capital accumulation. Aggregating these components into the welfare measure at different GMT tax rates, a higher GMT initially raises global welfare. However, as the rate of decline in profit shifting falls with a higher minimum tax rate, the reduction in capital accumulation eventually becomes more important and welfare reaches a maximum and then declines. In the left panel of Figure 8, we show that, where the high-tax country has a 30% tax rate, the welfare-maximizing GMT rate is 18%. In the right panel of Figure 8, we demonstrate that this optimum depends on the tax rate in the high tax country; if that rate is 20%, the welfare-maximizing GMT rate is 13%.

7 Conclusion

In this paper, we explore the joint decisions of MNEs with respect to profit shifting and capital investment. An innovative feature of our approach is in how we model profit shifting costs by introducing the possibility of investing in a tax avoidance asset, intended to capture the costs of complex structures set up by MNEs to facilitate profit shifting to tax havens. We make four distinct contributions to the literature.

First, we find considerable heterogeneity in profit shifting across MNEs, depending on their characteristics. In particular, we account for the fact that a substantial proportion of MNES pay no tax on profit in high tax countries. We show that, by ignoring extensive margin effects, the traditional convex cost model underestimates the average profit-shifting semi-elasticity with respect to tax rate differentials between high-tax jurisdictions and tax havens. Second, we find considerable interdependence between profit shifting and capital investment. Some MNEs - with high elasticities of profit shifting - respond to changes in

tax rates primarily by adjusting their profit shifting, with only a small impact on capital investment. Firms that do not shift profit have much higher elasticities of capital investment with respect to tax rates. Differences in profit shifting can therefore account for large disparities in the elasticity of capital investment with respect to tax rates. Third, we estimate the size of the costs of profit shifting to be substantial, with average fixed costs at 1.5% of the true tax base, and average variable costs to be 3.1% of the true tax base.

Fourth, we use our model to identify the behavioral responses and welfare implications of possible reforms to taxation. The sensitivity of profit shifting and its related costs to changes in the tax rate in the high tax country and the tax haven leads to the possibility of welfare enhancing reforms. For example, we find evidence that, for MNEs, a rate reduction in the high tax country may result in an increase in both tax revenue and investment as profit shifting declines. A rise in the tax haven rate up to a point, as envisaged as part of the Global Minimum Tax, can also raise welfare by reducing wasteful profit-shifting costs, despite having a negative impact on capital investment. Our results therefore also carry significant policy implications, especially for the GMT. Our counterfactual policy experiments highlight that the optimal GMT tax rate may need to balance the benefits of reduced profit shifting and its associated costs against reduced investment and economic activity.

Our framework can be adapted to analyze alternative policy proposals, offering a versatile tool for evaluating the impact of ongoing and proposed international tax reforms. Future work could extend our model to analyze labor market complementarities and examine implications of profit shifting for employment and wage setting. This could shed light on broader welfare implications of corporate tax reforms beyond firm value and tax revenues.

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Table 1: List of moments that identify key structural parameters

Description	**Moments**	$\bar{p}$	γ	β_{Π}	θ	a
Zero taxable income	Mean	✓	✓	✓		
Operating profit	25th percentile			✓	✓	✓
Taxable profit	Mean	✓	✓	✓	✓	✓
	Median	✓	✓	✓		✓
Total assets (in log)	Mean	✓	✓		✓	✓
	Variance			✓	✓	✓

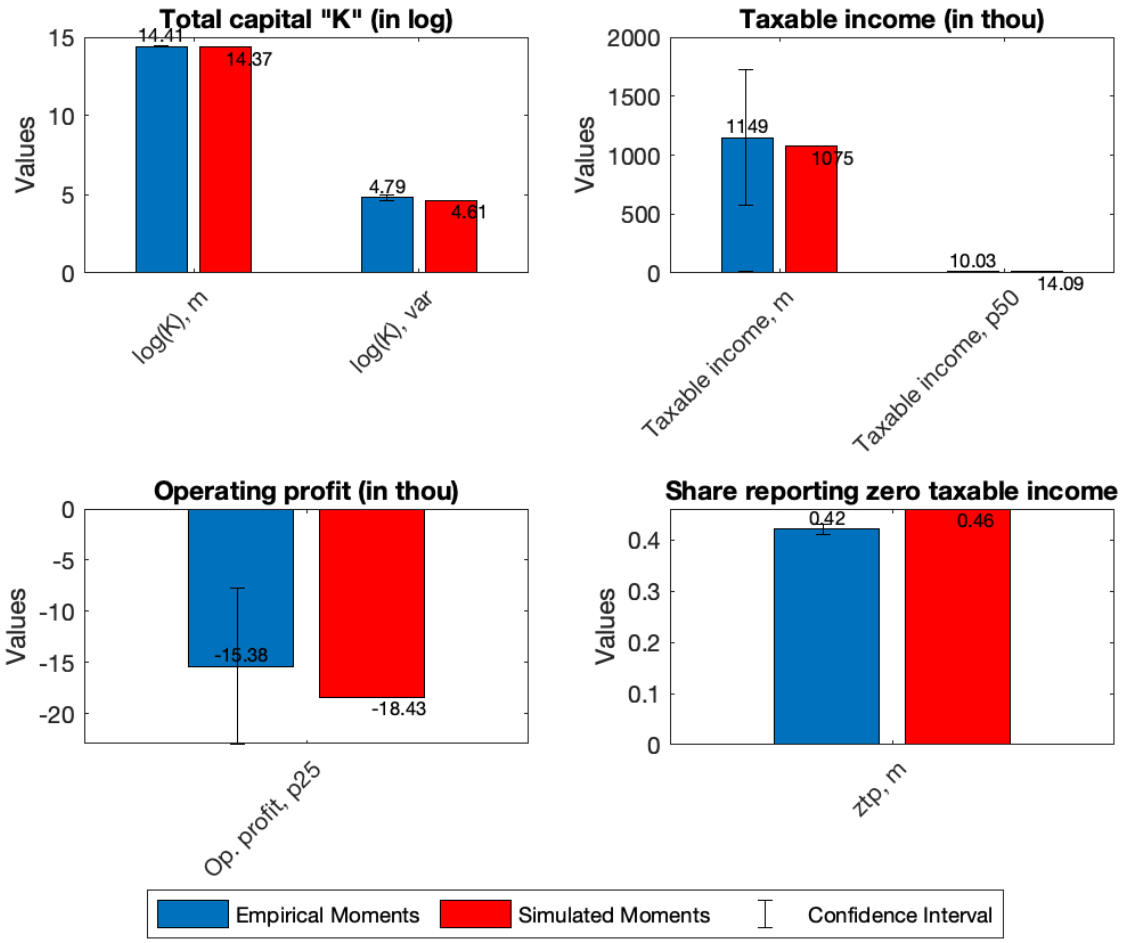
Note: This table shows the list of moments used in the MSM procedure. The tickmarks in red indicate the moments that are theoretically the key moments in identifying the specified parameters. For example, the mean of zero taxable income identify $\bar{p}$, γ and β_{Π}, but this moment is particularly important in the identification of $\bar{p}$. In Appendix B, we show the results of a sensitivity check following Andrews et al. (2017).

Table 2: Structural estimates

	Assumed and Estimated Parameters		Method
δ:	Depreciation Rate	0.05	Assumed
β:	Discount Factor	0.95	Assumed
$\hat{\bar{p}}$:	Upper bound, unit price of tax avoidance asset	1.810 (0.637)	MSM
$\hat{\gamma}$:	Convex cost of shifting	0.145 (0.026)	MSM
$\hat{\theta}$:	Total factor productivity (in log)	175.403 (16.427)	MSM
$\hat{a}$:	Output elasticity wrt K	0.535 (0.006)	MSM
$\hat{\beta_{\Pi}}$	Scale parameter of linear cost term	119,793 (16,343)	MSM
$\hat{\sigma}$	Std.dev of productivity draw	1	Assumed

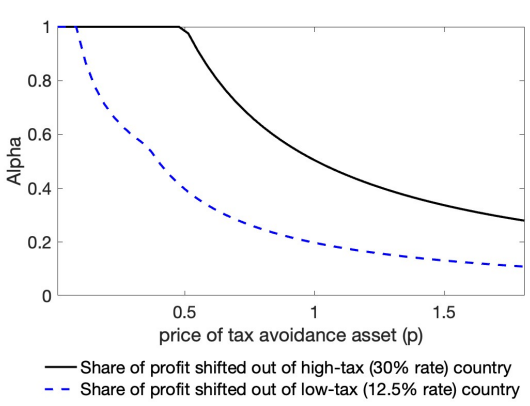
Note: This table shows the assumed parameters and our estimates for the structural profit-shifting cost parameters using our MSM procedure. We use the moments listed in Table 1 to match to simulated counterparts. To construct the weight matrix, we use the diagonal elements of the inverse variance-covariance matrix of empirical moments. We assume that the relative unit price of the tax avoidance asset is uniformly distributed over the interval $(0, \bar{p}]$. In the discrete choice application, we use 0.01 to be the lowest value for p.

Figure 1: Model fit

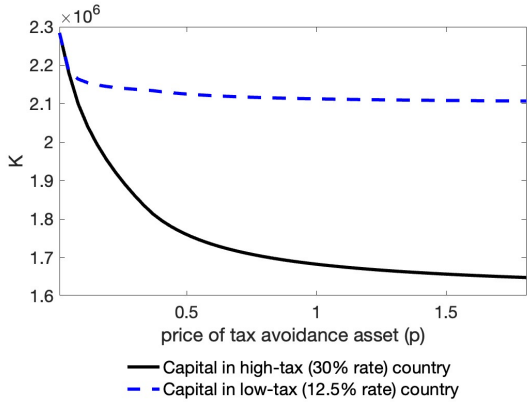


Note: This figure shows the comparison between data and simulated moments. The blue bars show the empirical moments, with error bars indicating the 95% confidence intervals. The red bars indicate simulated moments constructed using the estimated values for the structural parameters. In the horizontal axes of the figures: 'm' stands for the mean, 'var' stands for the variance, p25 and p50 stand for the 25-th and 50-th percentile values. In this figure, the empirical moments are drawn from the 2001 snapshot of corporation tax returns data, and only the observations that are in the control group (of our reduced-form estimation sample) are used. This means that the UK subsidiaries of Italian-headquartered multinationals are left out to align the structural estimation sample with the reduced-form estimation sample discussed in Section 5.

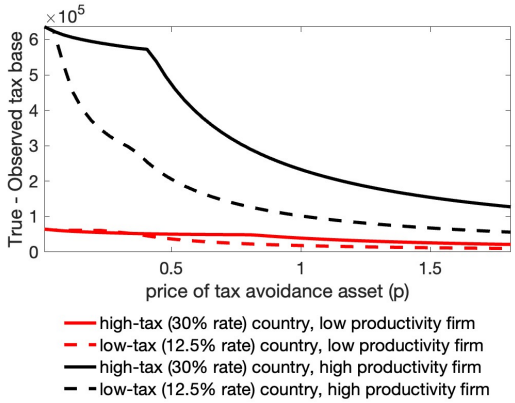
Figure 2: Profit-shifting and investment.



(a) Share of profit shifted, base case



(b) Choice of productive capital, base case



(c) True - Observed tax base; high vs low productivity

Note: The first panel shows the share of profit shifted out of each of the high-tax and low-tax countries as p_i varies. The second panel traces the total capital in each of the two countries. In both cases, the productivity draw ε and cost of operation Π are fixed at their mid-point values using the parameters that we estimate in Section 4. In the third panel, we compare the amount of profit shifted to the tax haven out of high-tax and low-tax countries, separately for relatively higher-productivity and lower-productivity firms. The black lines represent the amounts for higher-productivity firms and the red lines represent the amounts for lower-productivity firms. The levels of productivity are chosen as the ε draws just above and just below the average discrete values in the epsilon space. The dashed lines are profits shifted out of the low-tax country and straight lines are the profit shifted out of the high-tax country.

Table 3: Tax base responses to a percentage point rise in high-tax country tax rate.

High-tax country tax rate:	40%		30%		20%	
Horizon:	Short-run	Long-run	Short-run	Long-run	Short-run	Long-run
Overall semi-elasticity	-1.239	-4.286	-0.644	-2.418	-0.350	-1.463
Ignoring zero-reporters	-0.317	-1.931	-0.148	-1.324	-0.186	-1.107
Discrepancy	290%	122%	336%	83%	88%	32%

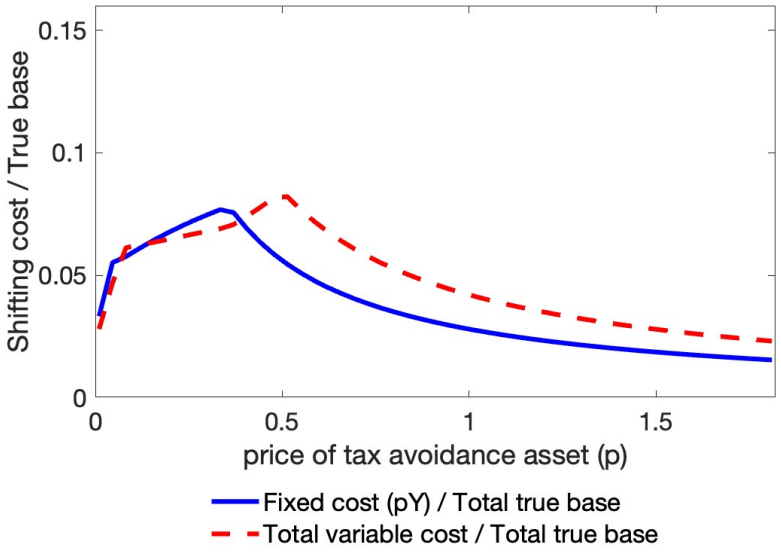
Note: This table shows short-run and long-run average percentage responses in the tax base to incremental changes in the tax rate in the high-tax country (ie. the semi-elasticities) implied by our structural estimates. These results are the weighted average of the response of subsidiaries of MNEs and other firms, weighted by UK gross value added. The first two columns show the average responses for firms operating in a high-tax country with a 40% statutory tax rate, the middle two columns for a country with a 30% tax rate (our base case), and the final two columns for a country with a 20% tax rate. Short-run estimates assume firms can change the share of profit shifted to the tax haven only, and the long-run estimates allow firms to also adjust capital and tax avoidance capability. 'Discrepancy' shows the differential change in semi-elasticity as we move from the estimate that ignores zero-taxable-income-reporters to our 'overall' semi-elasticity.

Table 4: Capital responses to a percentage point rise in high-tax country tax rate.

High-tax country tax rate:	40%	30%	20%
Shifters	-0.370	-0.803	-1.097
Non-Shifters	-2.241	-1.808	-1.494
All Firms	-1.708	-1.522	-1.381

Note: This table shows the percentage change in capital in response to incremental changes in the tax rate in the high-tax country (ie. the semi-elasticity) implied by our structural estimates . The first column show the average responses of firms operating in a high-tax country with a 40% statutory tax rate, the second column show the average responses of firms operating in a high-tax country with a 30% tax rate (our base case), and the last column show the responses of firms operating in a high-tax country with a 20% tax rate. Shifters are MNEs, non-shifters are firms for which we switch off the profit shifting channel. The aggregate is the weighted average of shifters and non-shifters using the ONS share of MNEs in the UK as the weight for shifters. The interpretation of the quantities is the same as for Table 3.

Figure 3: Profit-shifting costs.



Note: This figure shows the total fixed and variable shifting costs of the MNE as a proportion of the total "true" tax base as p_i varies. The productivity draw ε and cost of operation Π are fixed at their mid-point values using the parameters that we estimate in Section 4.

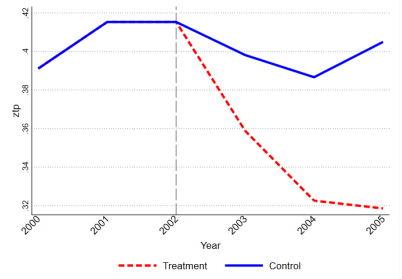
Table 5: All sampled companies – key descriptive statistics by treatment status, pre-reform period

Group:	Treatment	Control	Treatment-Control Difference	t-test
Zero taxable profit (share)	0.42	0.42	0.006	0.19
Taxable income (thousand GBP)	893	1,146	253.386	0.568
Total assets (in thousand of GBP)	2,027	2,018	-9.337	-0.1
Total assets (in log)	12.43	12.51	0.086	0.488
Observations	248	8674	8922	

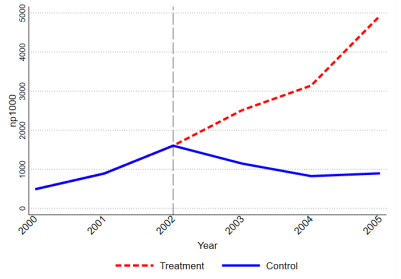
Note: This table shows selected descriptive statistics for means of key variables in the pre-reform period available in the data (2001). Control group companies are the UK subsidiaries of MNEs with parent companies located in countries outside the UK and Italy. Treatment group companies are the UK subsidiaries of MNEs with parent companies located in Italy. Units for taxable profit and asset size are nominal British Pounds. For variable definitions, see Table A1.

Figure 4: The evolution of taxable income and capital by treatment status.

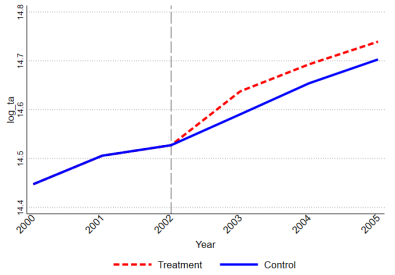
(a) Probability to report zero taxable profit



(b) Average taxable income (in level)



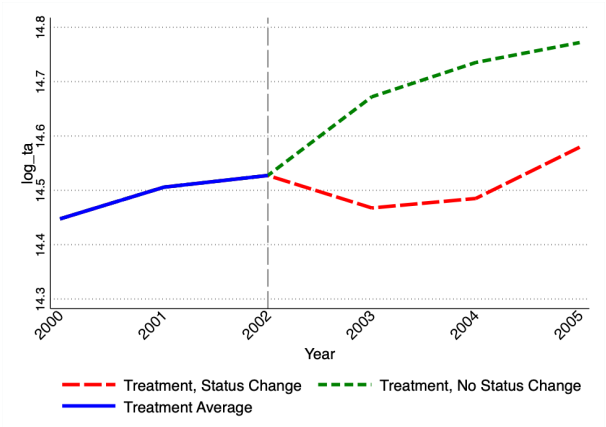
(c) Average capital (in log)



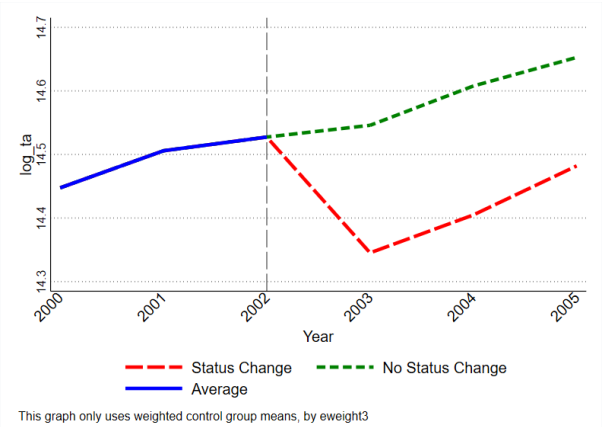
Note: In Panel (a), we show the evolution of the average probability to report zero taxable income in the United Kingdom, in Panel (b) the evolution of the average taxable income, and in Panel (d) the evolution of the logarithm of total assets. We present the trends separately for the treatment group of Italian-headquartered MNEs (red, dashed line) and for the control group of entropy-weighted subsidiaries of MNEs headquartered outside of the UK and Italy (blue, solid line). We use the following weighting variables: logarithm of total assets in 2001 and 2002, dummy equal to 1 if a firm reported zero taxable profit in 2000, 2001 and 2000, a dummy equal to 1 is a firm has a tax haven subsidiary in its ownership structure.

Figure 5: Capital response for firms that switch reporting status.

(a) Treated group firms



(b) Control group firms



Note: This figure plots the evolution of the average of the logarithm of total assets between 2000 - 2005 for treatment and control group firms. For the years before the reform, we plot the average assets of all firms using blue solid lines. After the reform, we show the differential evolution between firms that change status from reporting zero taxable income in all years 2000 - 2002 to at least one year of positive taxable income in 2003 - 2005 in red dashed line and in green dashed line the evolution of assets for firms that do not switch their taxable income status. We use the following weighting variables in the entropy balancing match procedure: logarithm of total assets in 2001 and 2002, dummy equal to 1 if a firm reported zero taxable profit in 2000, 2001 and 2000, a dummy equal to 1 is a firm has a tax haven subsidiary in its ownership structure.

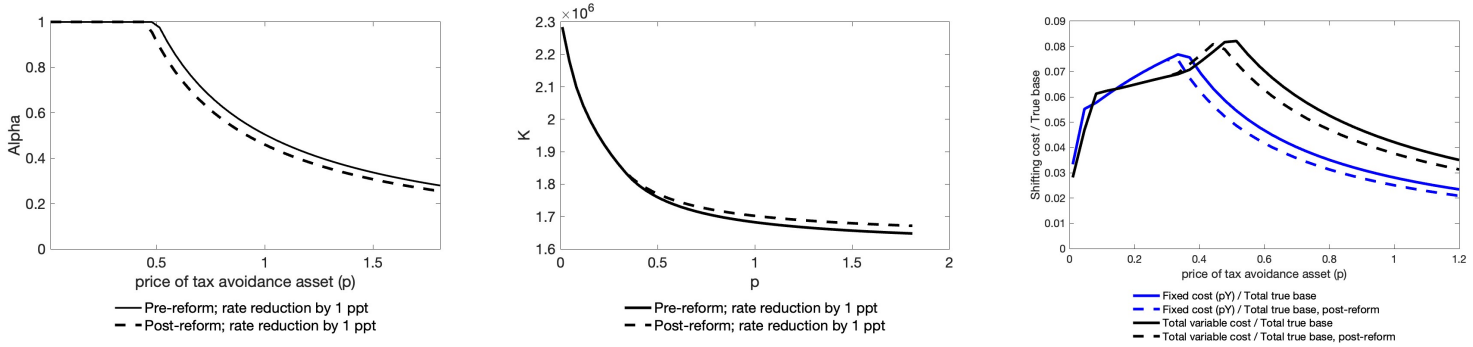
Table 6: Baseline reduced-form regression results

Outcome variables	(1) np	(2) invhs (np)	(3) Poisson (np)	(4) ztp	(5) log(ta)
treat × post	1333.401*	0.520*	1.197***	-0.056**	0.055
	(715.995)	(0.276)	(0.330)	(0.023)	(0.033)
Observations	53485	53485	45044	53485	53485
Firm FE	Yes	Yes	Yes	Yes	Yes
Sector-year effects	Yes	Yes	Yes	Yes	Yes
Implied semi-elasticity					
Point estimate	3.42		3.59		
90% CI lower bound	0.40		1.94		
90% CI upper bound	6.44		5.25		
Structural semi-elasticity					
Short-run	2.31		2.31		
Long-run	7.44		7.44		

Note: This table shows the results of difference-in-difference regression estimates. Columns (1) - (3) use as a dependent variable np, which is the level of taxable income in 1,000 of GBP. In Column (1), we estimate the model using OLS, in column (2) using inverse hyperbolic sine transformation, and in column (3) we use Poisson transformation. In column (4) the outcome variable is a dummy equal to 1, if the taxable income is equal to zero, and zero otherwise. In column (5) the outcome variable is the logarithm of total assets. treat is a dummy equal to 1 for subsidiaries of Italian MNEs, 0 for subsidiaries of all other non-UK MNEs. post is equal to 1 is 2003 - 2005, zero before that. We use entropy balancing to weight the control group using the logarithm of total assets in 2000 - 2002, taxable profits in 2000 - 2002, and zero taxable profit share in 2000 - 2002 as matching variables. We do not apply weights to Poisson regressions. In all columns we include firm and sector-year fixed effects. Standard errors are clustered at the subsidiary level. We obtain the implied semi-elasticity estimates of taxable profit with respect to the tax rate by taking into account the fact that the reform increased blacklisted tax haven tax rate for Italian subsidiaries from 0% to 34% and the pre-reform control group average taxable income was £1.146 million. Following Chen and Roth (2023), we do not report an implied semi-elasticity for the specification with the inverse hyperbolic sine transformed specification in column (2). The last two rows provide a comparison with our structural estimates of the short-run (SR) and the long-run (LR) semi-elasticities.

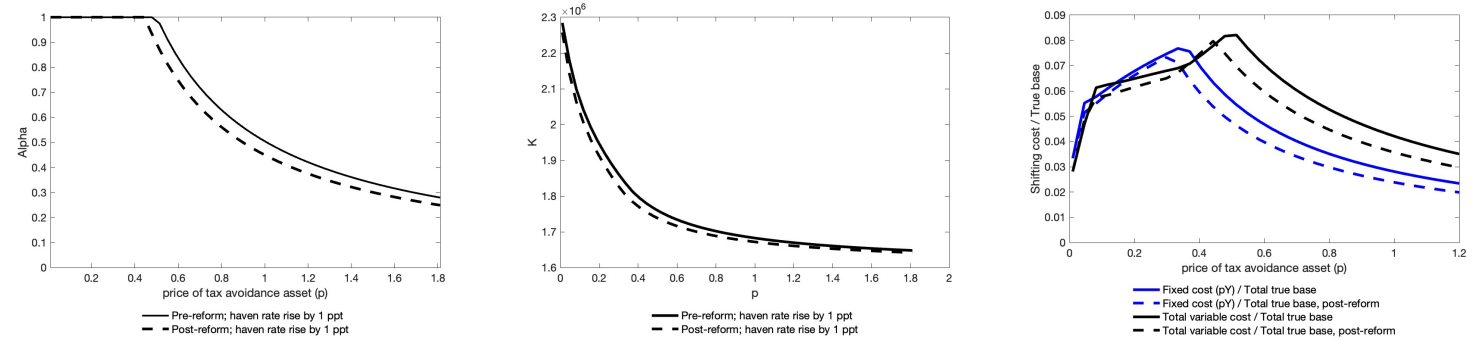
Figure 6: Effects of changing the high-tax country and tax haven tax rates by 1ppt.

Panel A: reducing the high-tax country tax



(a) Profit shifted (b) Capital (c) Shifting costs

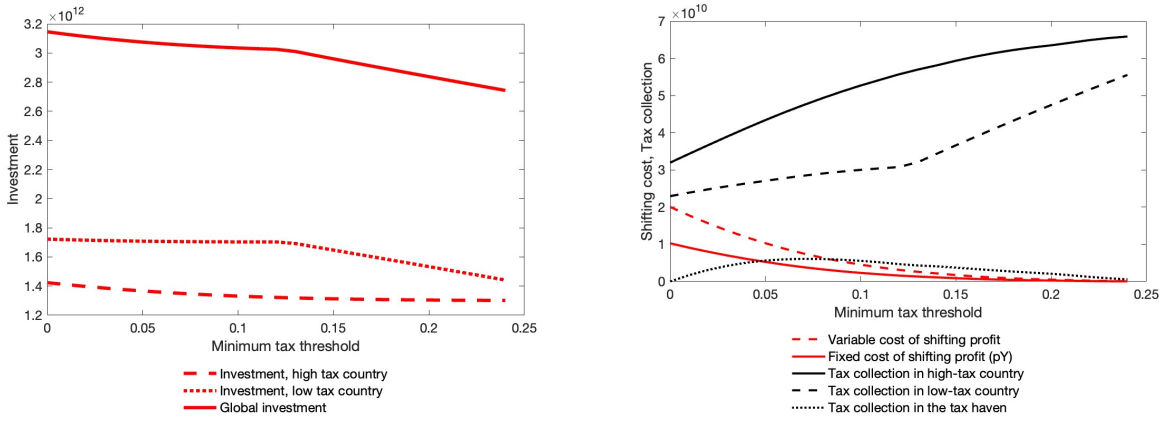
Panel B: raising the tax haven tax rate



(d) Profit shifted (e) Capital (f) Shifting costs

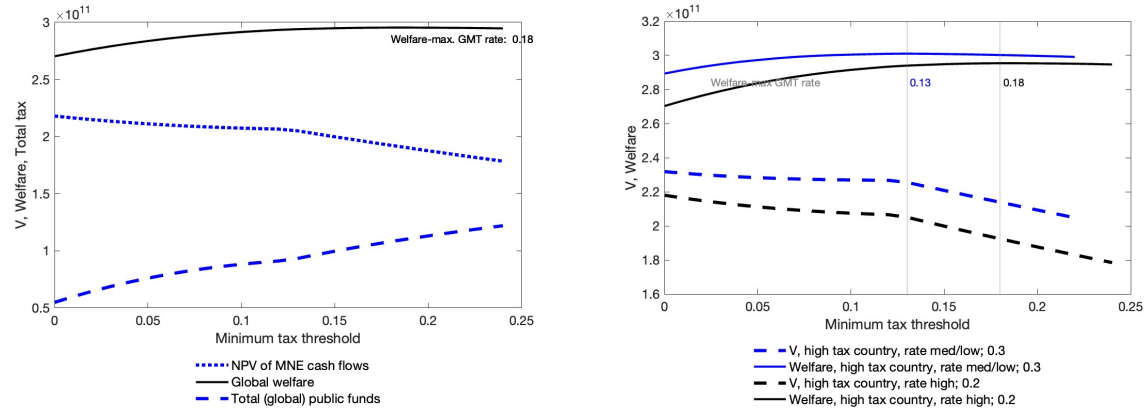
Note: In this figure, we compare the trajectories before and after a one percentage point reduction in the high-tax country tax rate (Panel A) and increase in the tax haven tax rate (Panel B) along the unit price of accumulating the tax avoidance asset (p_i) for: the share of profit shifted to the tax haven from the high-tax country (α) in panels a and d, capital accumulation in the high tax country (K) in panels b and e, and profit-shifting costs as a share of the true tax base in panels c and f as p_i varies. In all cases, the productivity draw ε and cost of operation Π are fixed at their mid-point values using the parameters that we estimate in Section 4. The straight lines trace the status quo and dashed lines trace the values after the change in the tax rate. In Panel (c), the blue lines show the ratio of fixed costs to the total true tax base, black lines show the ratio of variable costs to the total true tax base.

Figure 7: Impact of global minimum tax at varying threshold rates on capital accumulation, shifting cost and tax collection



Note: In this figure, we show the effects on our sample of MNEs of a Global Minimum Tax introduced at rates between zero and 25%, assuming that the GMT revenue is collected in the tax haven. Panel (a) shows the impact on capital investment in the high-tax and low-tax countries, as well as in aggregate. Panel (b) shows the effect on revenue collected in each country, as well as the fixed and variable costs of profit shifting in aggregate. The low-tax country tax rate is fixed at 12.5% until the minimum tax threshold reaches this level. It matches the minimum tax rate after this point. We assume that domestic firms are unaffected by a change in the minimum tax threshold.

Figure 8: Impact of global minimum tax at varying threshold rates on global welfare



(a) NPV, tax and global welfare; τ_H=0.3 (b) Global NPV & welfare; τ_H=0.3 and τ_H=0.2

Note: In this figure, we show the effects on global welfare of a Global Minimum Tax introduced at rates between zero and 25%. Panel (a) shows the impact on the sum of NPV of cash flows for the sample of MNES, as well as aggregate tax revenue; welfare is the sum of the two. Panel (b) shows the sum of the NPV of MNE cash flows and welfare under two scenarios: where the high-tax rate country has a rate of 30%, and where it has a rate of 25%. The low-tax country tax rate is fixed at 12.5% until the minimum tax threshold reaches this level. It matches the minimum tax rate after this point. We assume that domestic firms are unaffected by a change in the minimum tax threshold.

ONLINE APPENDIX—NOT FOR PUBLICATION, October 13, 2025
"Tax Policy, Investment and Profit Shifting"

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A Data descriptives

A.1 Variable definitions, UK tax returns

Table A1: Variable descriptions.

variable name	definition	source
taxable income (np)	Profits chargeable to corporation tax. This is profits before other deductions and reliefs (box 21) minus total of deductions and reliefs (box 33) minus all charges paid (box 35) and group relief (box 36)	box 37 on CT600 form
zero taxable profits (ztp)	This is a dummy that takes value 1 when taxable income (box 37) is zero and it takes value 0 when taxable income is positive	box 37 on CT600 form
turnover	Total turnover from trade or profession	box 1 on CT600 form
total assets	the combined value of all assets owned by a company, including both current and non-current assets, as listed on its financial statements	FAME
operating profits	profit and loss before taxes	FAME

Note: In this table we refer to boxes as reported on the 2008 tax form, which can be found at: https://assets.publishing.service.gov.uk/media/5a7e0a99e5274a2e87daf294/ct600-2008.pdf

A.2 Additional descriptives, UK tax returns

In Table A2, we show the mean and median values for some of the key variables in our balanced panel of MNEs operating in the UK that we use in our structural estimation. 42% of MNEs report zero taxable income. These zero-profit-reporters include those with no tax liability for other reasons than profit shifting, such as genuine operational losses, investment allowances and other reliefs available in the tax system that reduce taxable income for firms. However, many subsidiaries of MNE groups report positive operating profit while reporting zero taxable income, providing the first suggestive descriptive evidence on the importance of the extensive margin of profit shifting that we model in this paper. We depict the prevalence of this behavior in Figure A1, where we plot the distribution of the difference between operating profit and taxable profit scaled by operating profit – the 'operating profit deviation ratio' – for all subsidiaries of MNEs that report a positive operating profit in their financial statements. A striking degree of bunching occurs at the point at which the operating profit deviation ratio is equal to one, indicating that 25% of all subsidiaries that report a positive operating profit also report zero taxable profit. A much smaller proportion of subsidiaries bunch at the zero deviation ratio, which indicates no difference between operating and taxable profit.

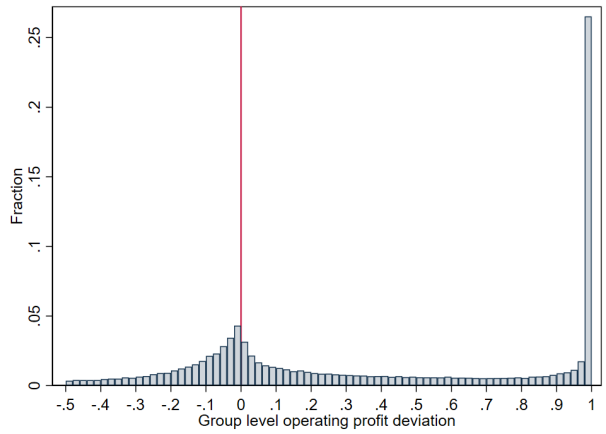
In Figure A2, we plot asset accumulation for firms at different taxable income reporting percentiles, grouping firms into 5% bins. Because of large bunching of observations at zero taxable profit, a large share of observations are clustered in the first percentile value, or the leftmost bin in Figure A2. Asset size rises monotonically with taxable income for companies reporting positive taxable income. In turn, companies that report zero taxable profit have a much larger average asset size than the majority of those reporting a positive taxable profit. This indicates a negative relationship between firm size and taxable income reporting. Our model predicts that aggressive profit-shifting MNEs tend to face lower costs of capital, allowing them to grow larger. We explore this relationship in the paper.

Table A2: Descriptive statistics

	Mean	Median
Zero taxable profit (share)	0.421	0
Taxable income (in log)	11.544	11.748
Total assets (in log)	14.409	14.391
Turnover (in log)	14.697	14.785
Observations	8674	8674

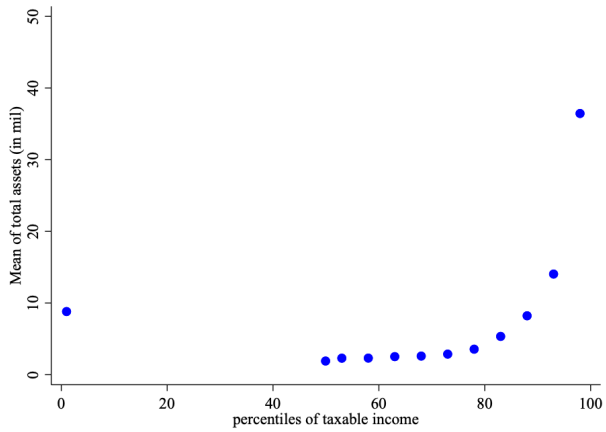
Note: This table shows the mean and median for the set of key descriptive variables, namely, the incidence of zero taxable income reporting, taxable income measures and asset values. In constructing the means and medians for this table, we only include the observations that are used to generate the moments in our simulated method of moments estimation. These are the cross-sectional snapshots of non-Italian MNEs in the final pre-Italian reform period of 2001.

Figure A1: Deviation of operating profit from taxable profit for company groups, pooled data



Note: This figure shows the histogram (by fraction) of the ratio of the difference between operating profit and taxable profit as a share of operating profit for all groups that have reported positive operating profit in a given tax year. We pool all years for MNEs available in the data to maintain observation frequencies above the data provider's requirements in each bin. For the same reason, we restrict the sample to contain group level operating profit deviation values between -0.5 and 1.

Figure A2: Average company asset size by percentiles of taxable income reporting

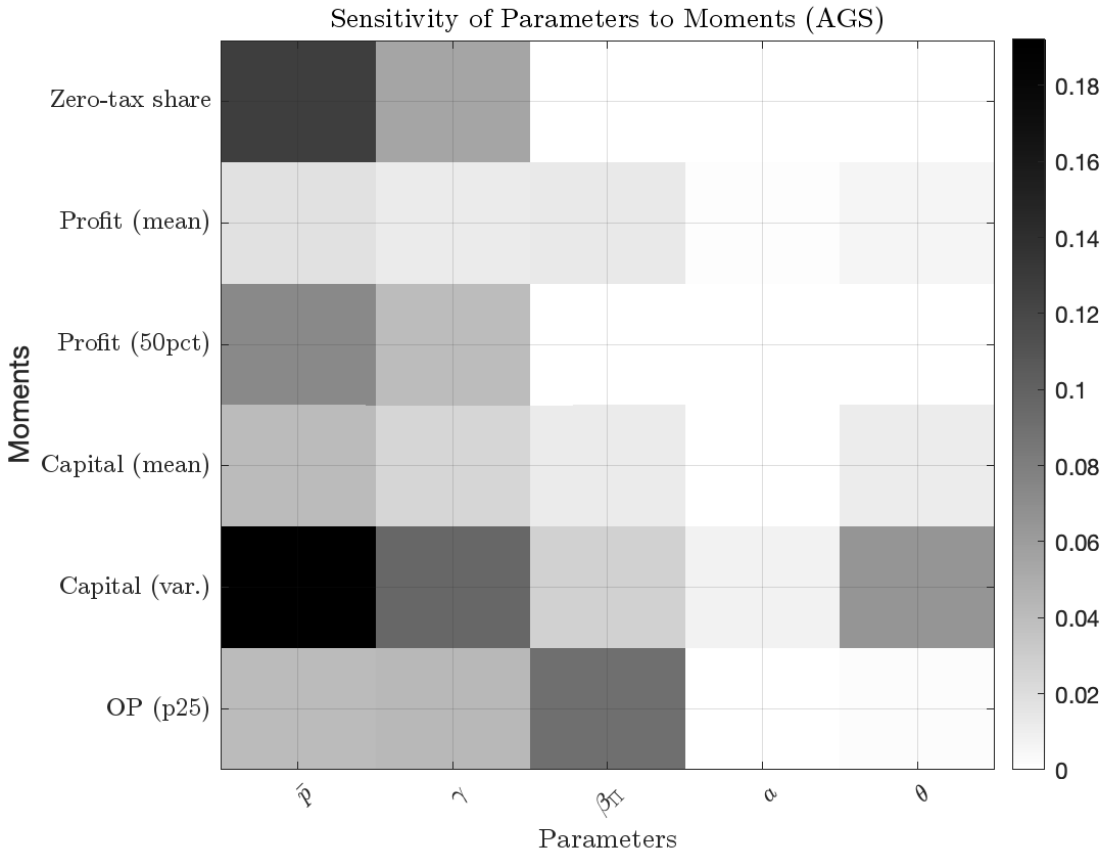


Note: This figure shows the average total asset size (in million GBP) along the distribution of taxable income. We generate percentiles of taxable incomes in our sample, then show average asset values for clusters of bins. Almost half the observations are grouped in the lowest percentile of taxable income reported, that is, at zero taxable profit, generating the gap between the leftmost bin and the next quantile bins. Asset sizes include values between the 5th and 95th percentiles in the overall pooled data.

B Structural estimates: supplementary analyses

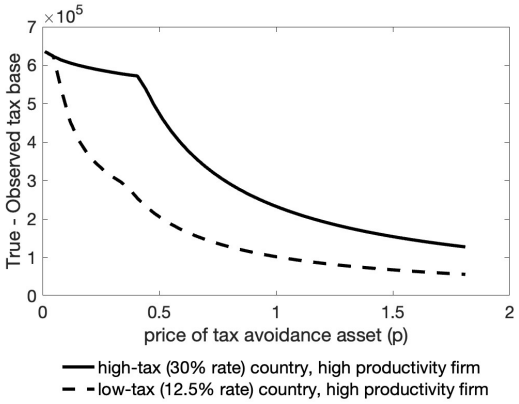
B.1 Additional results

Figure B1: Sensitivity of structural parameters

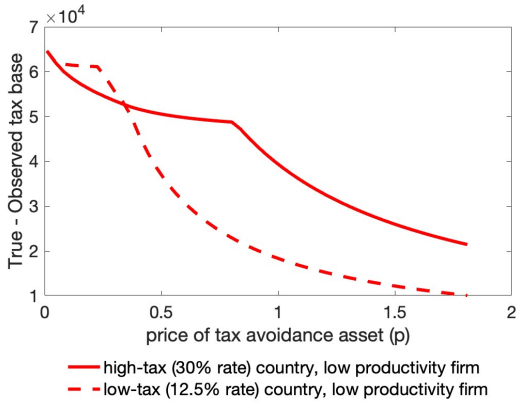


Note: In this figure, we show the sensitivity of structural parameters to incremental changes (1%) following Andrews et al. (2017).

Figure B2: Profit shifted to tax havens, by productivity

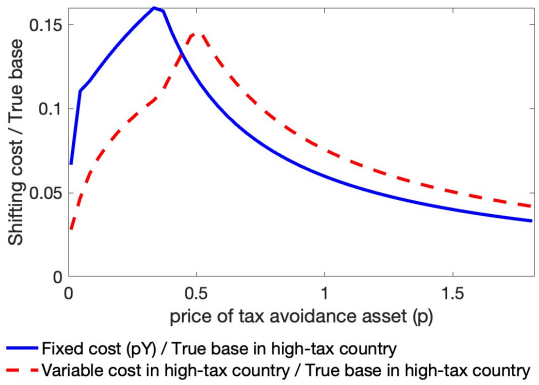


(a) Profit shifted by high-productivity firms

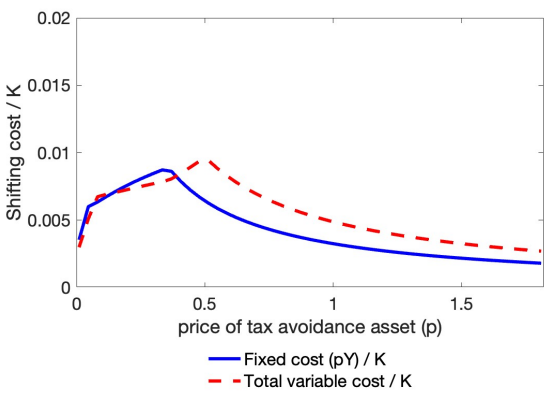


(b) Profit shifted by low-productivity firms

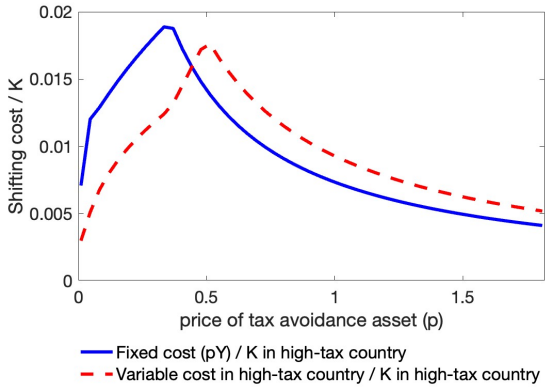
Figure B3: Fixed and variable costs of shifting profit to tax havens



(a) Profit shifting costs / True base (high-tax country)



(b) Profit shifting costs / capital



(c) Profit shifting costs / capital in high tax country

Note: This figure shows the total amount of profit shifted out of each of the high-tax and low-tax countries as p_i varies. The first panel shows the response of firms that have a relatively high productivity and the second panel shows the response of firms that have a relatively low productivity captured by ε. In both cases, the cost of operation Π is fixed at its mid-point value using the parameters that we estimate in Section 4. The dashed lines are profits shifted out of the low-tax country and straight lines are the profit shifted out of the high-tax country.

B.2 Elasticity magnitudes: comparison with related literature

Two recent papers use meta-regressions to analyze estimates of the semi-elasticity of reported profit with respect to the tax rate differential across countries and provide very comprehensive overviews of the literature and discussions of all potential determinants of the differences between estimates. Heckemeyer and Overesch (2017) find the average semi-elasticity to be -0.8., while Beer et al. (2019) find that this semi-elasticity has increased (in absolute value) in recent years to -1.5. These papers imply that a 10 percentage point increase in the tax rate differential between two countries would reduce the pre-tax income reported by the subsidiary in the low-tax country by 8-15 per cent. However, these aggregates mask a wide range of existing estimates and heterogeneity. As one of the main objectives of our paper is to build a model which reconciles the differences between existing micro- and macro-estimates of tax base, we focus on those differences specifically.

Both meta-studies by Beer et al. (2019); Heckemeyer and Overesch (2017) emphasize in their regressions differences between macro semi-elasticity estimates that use aggregate data and micro semi-elasticity estimates that use detailed firm-level data. Beer et al. (2019) calculate that the implied semi-elasticity for studies that use micro-level data is 1.2, while the one for aggregate level data is 2.3, almost twice as large. Heckemeyer and Overesch (2017) estimate that the micro-level studies have semi-elasticity which is 1.65 lower in absolute terms than the average of the aggregate ones. Taking the average aggregate semi-elasticity of 2.77 that Heckemeyer and Overesch (2017) calculate from the papers that use tax returns data from the IRS, suggests a 1.65/2.77=73% difference.

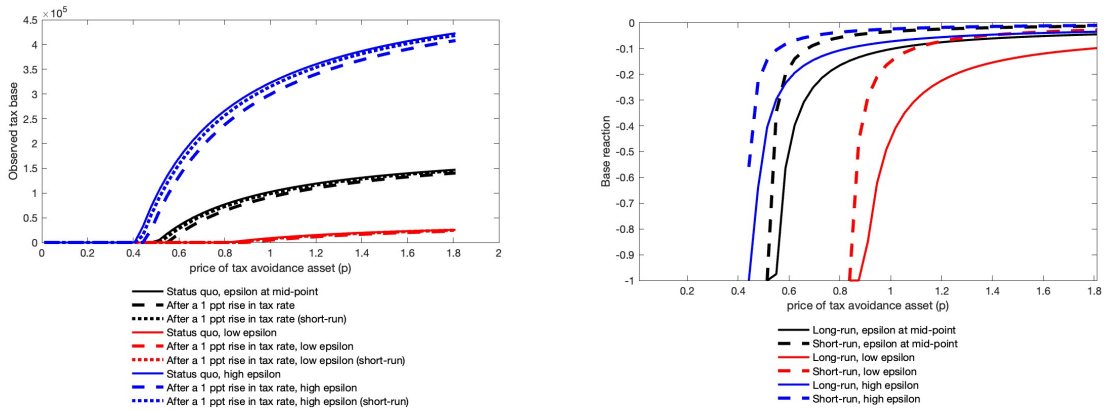
Our semi-elasticity estimates from Table 3 show that the differences between estimates that ignore the zero-profit reporters and the ones that include these firms are 83%. This would suggest that the extensive margin response that we have in our model is able to explain all of the difference between the macro- and micro-elasticity estimates.

B.3 Heterogeneity of the elasticity estimates

In Figure B4, we demonstrate the heterogeneity in the declared tax base responses in high-tax-rate countries for firms that face different unit prices of tax avoidance capability and have different productivity draws. The left-hand side panel shows the size of the declared tax base in certain states, while the right-hand side panel shows the changes in the declared tax base in response to the one percentage point rise in the high-tax country tax rate. In Figure B4, unbroken lines indicate the status quo before any tax rate change. In black, we plot responses for firms with the values for productivity draws at the mid-point level, in blue for firms with higher productivity than the mid-point, while in red for firms with lower productivity than mid-point. Dotted lines show short-run responses that keep K and Y constant, only allowing the share of profit α to change, and dashed lines allow all three choices to adjust.

Both the short-run and the long-run figures show that for sufficiently low unit prices of the tax avoidance asset, firms shift all their profit. At a value of p_i just over 0.5, firms begin to reduce their profit shifting; the effect of the rise in p_i is strongest for high-productivity firms and weakest for low-productivity firms. As expected, there is also a larger impact in the long-run, compared to the short-run. For values of p_i between 0.504 and 0.527, the long-run response is at the extensive margin: within that range firms respond to a rise in the tax rate by starting to pay zero tax; this is also reflected in the right-hand side panel, where a tax base reaction of -1 shows a firm moving from a positive declared tax base to a zero declared tax base. For higher values of p_i, the magnitude of the short-run response in the declared tax base shrinks rapidly to stabilize to a reduction below 10%. In the long-run, the gradient of the tax base reaction is smaller, indicating a larger tax base reaction for the same unit price of the tax avoidance capability relative to the short-run.

Figure B4: Heterogeneity in responses to an incremental rise in the home country tax rate

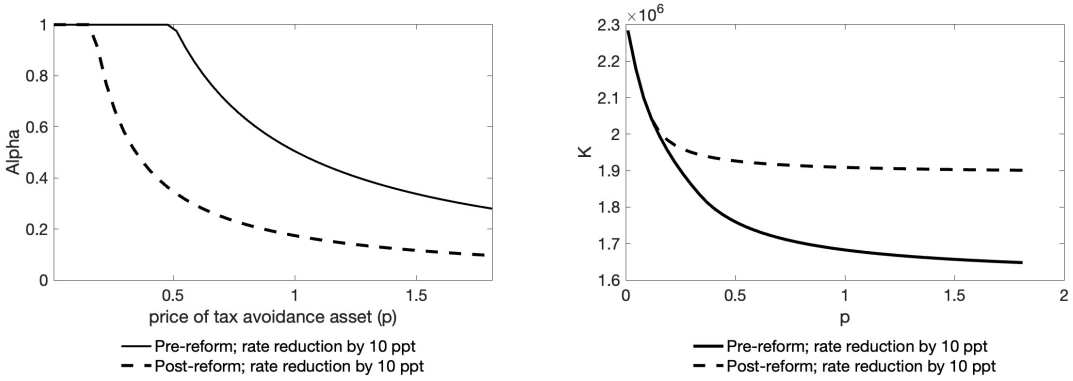


(a) Response of the observed tax base (b) Relative change in tax base

Note: This figure shows heterogeneous responses to a one percentage point rise in the high-tax country tax rate depending on the unit price of tax avoidance capability at the MNE level. Responses are only for the tax base reported in the high-tax country. The left-hand panel shows the theoretical change in observed tax base for different states along the unit price of the tax avoidance intangible. Black lines represent the values for productivity draws at the mid-point level. Blue lines represent the responses by firms that have slightly higher productivity than the mid-point level. Red lines represent the responses by firms that have slightly lower productivity than the mid-point level. Dashed lines show long-run responses after K and Y adjust as well as α. Dotted lines show short-run responses that keep K and Y constant, only allowing the share of profit α to change. The right hand panel shows the change in base for different levels of the productivity draw.

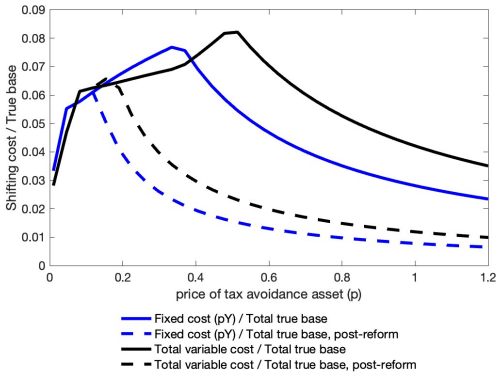
B.4 Additional counterfactuals

Figure B5: Effects of reducing the high-tax country tax rate by 10ppt on profit-shifting, capital accumulation and the costs of profit shifting.



(a) Profit shifted

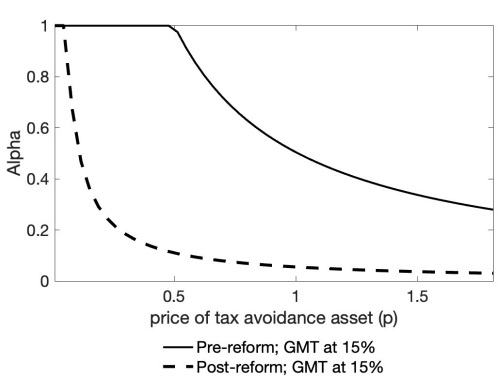
(b) Capital



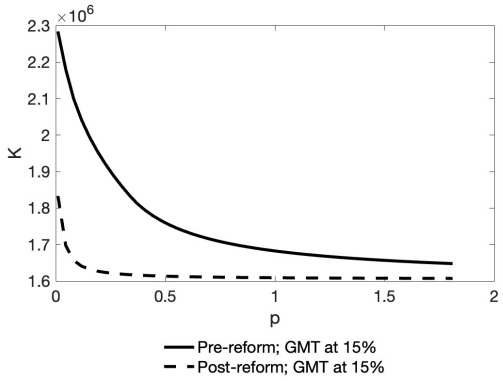
(c) Costs of shifting

Note: In this figure, we compare the trajectories before and after a 10 percentage point reduction in the high-tax country tax rate along the unit price of accumulating the tax avoidance asset (p_i) for: the share of profit shifted to the tax haven from the high-tax country (α), capital accumulation in the high tax country (K) and profit-shifting costs as a share of the true tax base as p_i varies. Panel (a) shows the share of profit shifted out of the high-tax country in each scenario. Panel (b) traces the total capital in the high-tax country. Panel (c) shows the ratio of fixed and variable profit-shifting costs to the total true tax base. In all cases, the productivity draw ε and cost of operation Π are fixed at their mid-point values using the parameters that we estimate in Section 4. The straight lines trace the status quo and dashed lines trace the values after the change in the tax rate. In Panel (c), the blue lines show the ratio of fixed costs to the total true tax base, black lines show the ratio of variable costs to the total true tax base.

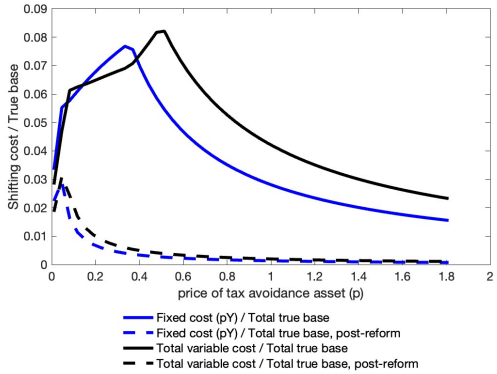
Figure B6: Impact of 15% GMT on profit-shifting, capital accumulation and shifting costs.



(a) Profit shifted



(b) Capital



(c) Shifting costs

Note: In this figure, we compare the trajectories before and after the introduction of a Global Minimum Tax at 15% along the unit price of accumulating the tax avoidance asset (p_i) for: the share of profit shifted to the tax haven from the high-tax country (α), capital accumulation in the high tax country (K) and profit-shifting costs as a share of the true tax base as p_i varies. Panel (a) shows the share of profit shifted out of the high-tax country in each scenario. Panel (b) traces the total capital in the high-tax country. Panel (c) shows the ratio of fixed and variable profit-shifting costs to the total true tax base. In all cases, the productivity draw ε and cost of operation Π are fixed at their mid-point values using the parameters that we estimate in Section 4. The straight lines trace the status quo and dashed lines trace the values after the change in the tax rate. In Panel (c), the blue lines show the ratio of fixed costs to the total true tax base, black lines show the ratio of variable costs to the total true tax base.

C Reduced-form evidence: supplementary analyses

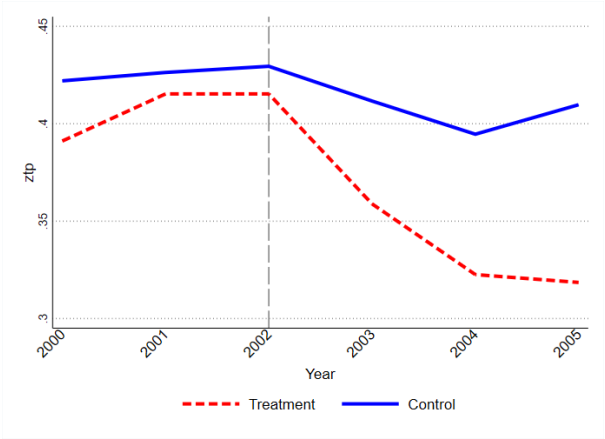
Table C1: All sampled companies – key descriptive statistics by treatment status, pre-reform period

	Treatment	Control entropy weight 3	Control entropy weight 4
Zero taxable profit (share)	0.415	0.415	0.426
Taxable income (thousand GBP)	892.507	893.209	1340.706
Taxable income (in log)	11.594	11.666	11.601
Fixed Assets (in thousand of GBP)	635.021	668.748	676.494
Fixed assets (in log)	12.427	12.605	12.606
Assets (in thousand of GBP)	2027.081	2065.89	2075.13
Assets (in log)	14.506	14.506	14.503
Observations	248	8669	8669

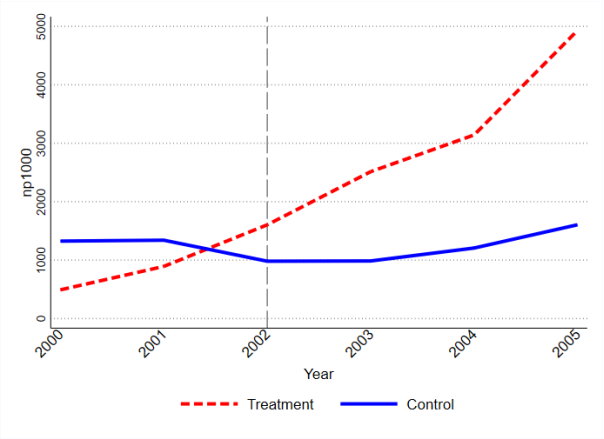
Note: This table shows selected descriptive statistics for a pre-reform period available in the data (2001). Control group companies are the UK subsidiaries of MNEs with parent companies located in countries outside the UK and Italy. Entropy weight 3 is an entropy balanced sample of control group firms that uses logarithm of total assets in 2000 - 2002, taxable profits in 2000 - 2002, and zero taxable profit share in 2000 - 2002 as matching variables. Entropy weight 4 is an entropy balanced sample of control group firms that uses logarithm of total assets in 2001 and 2002, and a dummy for whether the MNE has a tax haven subsidiary as matching variables. Treatment group companies are the UK subsidiaries of MNEs with parent companies located in Italy. Taxable profit data are from the tax return and data on balance sheet size are from company accounts. Units for taxable profit and asset size are nominal British Pounds.

Figure C1: Trends in average propensity to report positive taxable income, average income, and capital by treatment status: robustness to different weighting scheme.

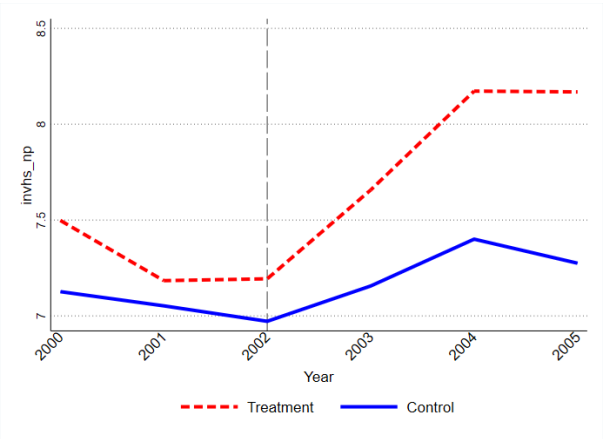
(a) Probability to report zero taxable profit



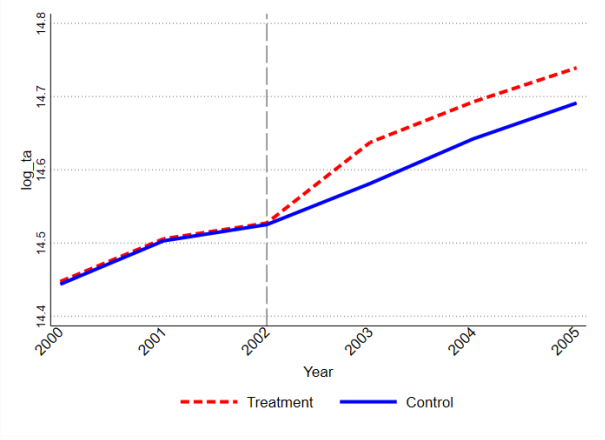
(b) Average taxable income (in level)



(c) Average taxable income (inverse hyperbolic sine)



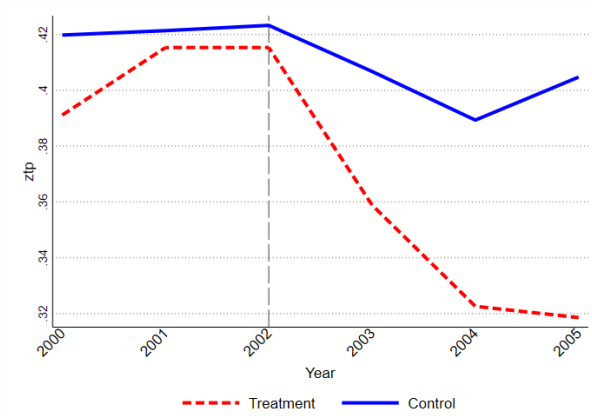
(d) Average capital (in log)



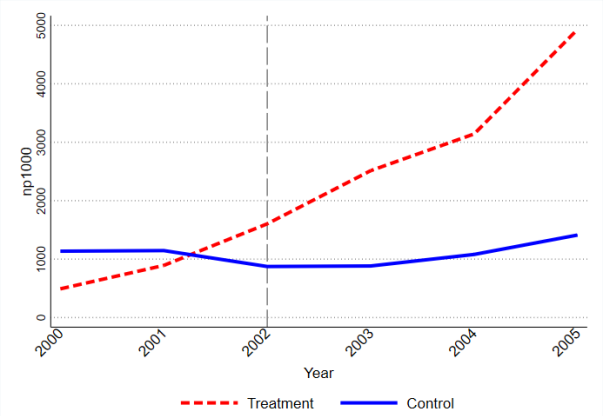
Note: In Panel (a), we show the evolution of the average probability to report zero taxable income in the United Kingdom, in Panel (b) the evolution of the average taxable income ('Profits chargeable to Corporation Tax' in the UK corporation tax return), in Panel (c) the evolution of the inverse hyperbolic sine transformation of the average taxable income, and in Panel (d) the evolution of the logarithm of total assets. We present the trends separately for the treatment group of Italian-headquartered MNEs (red, dashed line) and for the control group of entropy-weighted subsidiaries of MNEs headquartered outside of the UK and Italy (blue, solid line). We use the following weights: logarithm of total assets in 2001 and 2002, and a dummy for whether the MNE has a tax haven subsidiary as matching variables. We demean all observations to remove individual effects and rescale the two trends to overlap in the last pre-reform period for ease of comparison. To do this, we subtract from each dot the group mean in the last pre-reform year and add back the pooled mean from the same year.

Figure C2: Trends in average propensity to report positive taxable income, average income, and capital by treatment status: against unweighted control group.

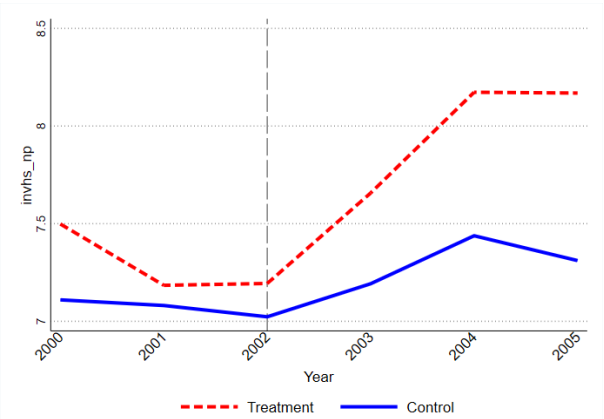
(a) Probability to report zero taxable profit



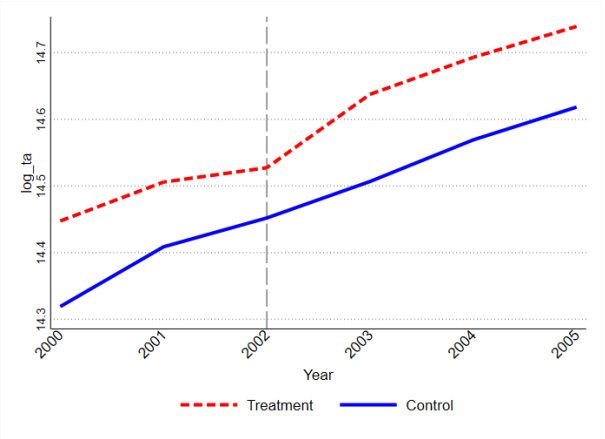
(b) Average taxable income (in level)



(c) Average taxable income (inverse hyperbolic sine)



(d) Average capital (in log)



Note: In Panel (a), we show the evolution of the average probability to report zero taxable income in the United Kingdom, in Panel (b) the evolution of the average taxable income ('Profits chargeable to Corporation Tax' in the UK corporation tax return), in Panel (c) the evolution of the inverse hyperbolic sine transformation of the average taxable income, and in Panel (d) the evolution of the logarithm of total assets. We present the trends separately for the treatment group of Italian-headquartered MNEs (red, dashed line) and for the control group of un-weighted subsidiaries of MNEs headquartered outside of the UK and Italy (blue, solid line). We demean all observations to remove individual effects and rescale the two trends to overlap in the last pre-reform period for ease of comparison. To do this, we subtract from each dot the group mean in the last pre-reform year and add back the pooled mean from the same year.

Table C2: Baseline reduced-form regression results: robustness to different weighting schemes.

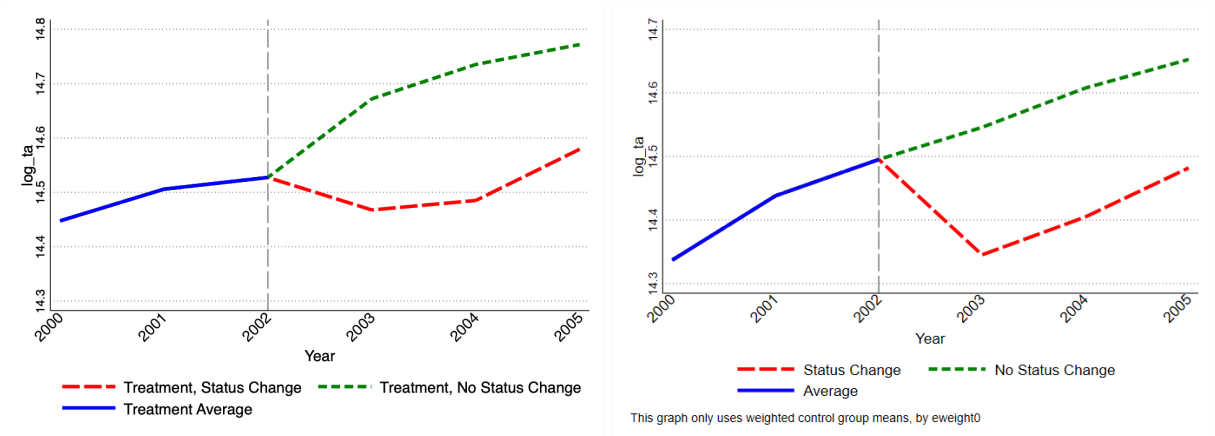
Outcome variables	(1) np	(2) invhs (np)	(3) Poisson (np)	(4) ztp	(5) log(ta)	(6) log(ta)
Panel A: Entropy balancing alternative weight						
treat × post	1260.450*	0.399	1.197***	-0.044*	0.063*	0.065*
	(683.797)	(0.270)	(0.330)	(0.023)	(0.033)	(0.037)
post × ztp pre-2002						-0.085***
						(0.015)
treat × post × ztp pre-2002						-0.018
						(0.075)
Observations	53485	53485	45044	53485	53485	53485
Panel B: unweighted control group						
treat × post	2275.633*	0.451*	1.197***	-0.051**	0.035	0.042
	(1370.390)	(0.271)	(0.330)	(0.023)	(0.033)	(0.036)
post × ztp pre-2002						-0.075***
						(0.014)
treat × post × ztp pre-2002						-0.029
						(0.078)
Observations	53558	53558	45044	53558	53558	53558
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year FEs	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table shows the results of difference-in-difference regression estimates based on equations **??**, **??**, and **??**. Columns (1) - (3) use as a dependent variable np, which is the level of taxable income in 1,000 of GBP ('Profits chargeable to Corporation Tax' in the UK corporation tax return). In Column (1), we estimate the model using OLS, in column (2) using inverse hyperbolic sine transformation, and in column (3) we use Poisson transformation. In column (4) the outcome variable is a dummy equal to 1, if the taxable income is equal to zero, and zero otherwise. In columns (5) and (6) the outcome variable is the logarithm of total assets. treat is a dummy equal to 1 for subsidiaries of Italian MNEs, 0 for subsidiaries of all other non-UK MNEs. post is equal to 1 is 2003 - 2005, zero before that. ztp pre-2002 is a dummy equal to 1 if a subsidiary reports zero taxable income in all years pre 2002. In Panel A, we use entropy balancing to weight the control group using the logarithm of total assets in 2001 and 2002, and a dummy for whether the MNE has a tax haven subsidiary as matching variables. In Panel B, we use unweighted control group. In all columns we include firm and sector-year fixed effects. Standard errors are clustered at the subsidiary level. We do not apply weights to Poisson regressions.

Figure C3: Capital response for firms that switch reporting status: robustness to different weighting scheme.

(a) Treated group firms

(b) Control group firms



Note: This figure plots the evolution of the average of the logarithm of total assets between 2000 - 2005. In Panel (a) we show responses for treated firms and in panel (b) for control group firms. Before the reform we plot the average assets of all firms using blue solid lines. After the reform, we show the differential evolution between firms that change status from reporting zero taxable income in all years 2000 - 2002 to at least one year of positive taxable income in 2003 - 2005 in red dashed line and in green dashed line the evolution of assets for firms that do not switch their taxable income status. In Panel (b), we use the entropy weighted sample of control group firms. We use the following weighting variables: difference between total assets between 2001 and 2000 and between 2002 and 2001, difference in taxable income between 2001 and 2000 and 2002 and 2001, the level of taxable income in 2000, 2001 and 2002, the level of total assets in 2000, 2001 and 2002, the difference in the zero taxable profit reporting status between 2001 and 2000 and 2002 and 2001, the likelihood od reporting zero taxable profits in 2000, 2001 and 2002. We demean all observations to remove individual effects and rescale the two trends to overlap in the last pre-reform period for ease of comparison. To do this, we subtract from each dot the group mean in the last pre-reform year and add back the pooled mean from the same year.

D Welfare

There are two elements of welfare in the model: the private value of the MNE and tax revenue. Consider a tax reform, such as the introduction of a global minimum tax. We model that as raising the rate of tax on income declared in the tax haven (without identifying which country receives the tax revenue). For ease of exposition, consider initially the effect of the change in haven tax rate on a subsidiary j of the MNE.

The impact on V_i of this change is:

$$\frac{dV_i}{d\tau_X} = \frac{\partial V_i}{\partial K_{ij}}\frac{\partial K_{ij}}{\partial \tau_X} + \frac{\partial V_i}{\partial Y_i}\frac{\partial Y_i}{\partial \tau_X} + \frac{\partial V_i}{\partial \alpha_{ij}}\frac{\partial \alpha_{ij}}{\partial \tau_X} - \frac{\partial T_{ij}}{\partial \tau_X} \tag{D.1}$$

For interior solutions, the first three terms of this expression are zero by the envelope theorem. If the MNE subsidiary in country H reports zero taxable income, then $\frac{\partial V_i}{\partial \alpha_{ij}} \neq 0$. However, in this case, α_{ij} will not respond to a infinitesimal change in the tax rate, so $\frac{\partial \alpha_{ij}}{\partial \tau_X} = 0$. The impact on private value is therefore just the "mechanical" effect of a change in the tax rate, given business decisions:

$$\frac{dV_i}{d\tau_X} = -\frac{\partial T_{ij}}{\partial \tau_X} = -\alpha_{ij} B_{ij} \tag{D.2}$$

The impact on the tax liability $T_{iH} = \widehat{\tau_{ij}} B_{ij}$ of this change is:

$$\frac{dT_{ij}}{d\tau_X} = \frac{\partial T_{ij}}{\partial \tau_X} + \widehat{\tau_{ij}}\frac{\partial B_{ij}}{\partial \tau_X} - (\tau_j - \tau_X)\frac{\partial \alpha_{ij}}{\partial \tau_X} B_{ij} \tag{D.3}$$

Noting that $\partial B_{ij}/\partial \tau_X = \alpha_{ij}\partial B_{ij}/\partial \widehat{\tau_{ij}}$ and $\partial \alpha_{ij}/\partial \tau_X = -\partial \alpha_{ij}/\partial(\tau_j - \tau_X)$, then in the spirit of the literature relating welfare to the elasticity of taxable income, Equation (D.3) can be rearranged as

$$\frac{dT_{ij}}{d\tau_X} = \alpha_{ij} B_{ij}(1 + \epsilon_{ij} + z_{ij}) \tag{D.4}$$

where ϵ_{ij} is the elasticity of the true tax base, B_{ij} with respect to the effective statutory rate, $\widehat{\tau_{ij}}$ (conditional on α_{ij}), and z_{ij} is the elasticity of the proportion of the tax base shifted to the tax haven, α_{ij}, with respect to the difference in statutory rates between country j and the haven, $\tau_j - \tau_X$ (conditional on B_{ij}). This case is therefore an extension - along the lines of Devereux et al. (2014) - of the standard result that the elasticity of taxable income is a sufficient statistic for welfare analysis, see Feldstein (1995, 1999). In this case, a change in the haven's tax rate affects not only the tax base, but also the "choice" of the overall tax rate

through the proportion of profit shifted. Welfare therefore depends on the elasticity of both the base and "effective" statutory rate, determined in this case by the extent of profit shifting.

Considering the overall effect on welfare of a change in the tax haven rate, aggregating over subsidiaries in different countries, different approaches are possible. First, a conventional option would be to assign welfare as a concave function of total tax revenue from the MNE, T_i, where $T_i = \sum_{j=1}^{N}(T_{ij})$, so that:

$$W = V_i + \beta\mu(T_i) \tag{D.5}$$

In the case in which revenue is simply distributed lump-sum back to the taxpayer, then $W = V_i + \beta T_i$. In this case transfers between the private sector and the government wash out, and welfare is equal to the weighted sum of the two elasticities identified above, where the weight is the income from each subsidiary declared in the tax haven:

$$\frac{dW}{d\tau_X} = \frac{dV_i}{d\tau_X} + \beta \sum_{j=1}^{N} \frac{dT_{ij}}{d\tau_X} = \beta \sum_{j=1}^{N} \alpha_{ij} B_{ij} (\epsilon_{ij} + z_{ij}) \tag{D.6}$$

Note that, conditional on other tax rates, there are two offsetting effects of the change in the tax haven rate. On the one hand it raises the cost of capital and hence reduces investment and output, $\epsilon_{ij} < 0$. On the other, it also reduces profit-shifting and its associated costs, $z_{ij} > 0$. The optimal rate would balance these two effects.[25]

This approach can also be used to calculate the "marginal value of public funds" (MVPF) of (Hendren and Sprung-Keyser; 2020, 2022),[26], defined in this case as:

$$MVPF = -\frac{\frac{dV_i}{d\tau_X}}{\frac{dT_{iH}}{d\tau_X}} = \frac{\sum_{j=1}^{N} \alpha_{ij} B_{ij}}{\sum_{j=1}^{N} \alpha_{ij} B_{ij} (1 + \epsilon_{ij} + z_{ij})} \tag{D.7}$$

Note that the inverse of the value of the MVPF is 1 plus the sum of the means of the two elasticities, each weighted by the tax base in the haven. The MVPF exceeds 1 when the average absolute value of ϵ_{ij} exceeds the average value of z_{ij}, and vice versa.

[25] Note that this approach gives no additional value to tax revenue raised from multinational profit, which may seem at odds with much of the public discourse on the global minimum tax rate.

[26] See also Finkelstein and Hendren (2020) among others

E User cost elasticity transformation

In the case of $\alpha_{ij} = Y_i = 0$, our cost of capital is

$$v_{ij} = \frac{r}{1-\tau_j} + \delta \tag{E.1}$$

Our semi-elasticity of K_{ij} with respect to τ_j is

$$e_{ij} = \frac{\partial K_{ij}/K_{ij}}{\partial \tau_j} \tag{E.2}$$

This implies:

$$e_{ij} = \frac{\partial K_{ij}/K_{ij}}{\partial \tau_j} = \frac{\partial K_{ij}/K_{ij}}{\partial v_i}\frac{\partial v_i}{\partial \tau_j} = \frac{\partial K_{ij}/K_{ij}}{\partial v_i}\frac{r}{(1-\tau_j)^2} \tag{E.3}$$

And the elasticity of K_{ij} with respect to the cost of capital is x_{ij}:

$$x_{ij} = \frac{\partial K_{ij}/K_{ij}}{\partial v_i/v_i} = e_{ij}v_i\frac{(1-\tau_j)^2}{r} \tag{E.4}$$

Using the parameters from our data, $r = 0.05$, $\delta = 0.05$, and $\tau_j = 0.3$, we obtain $v_{ij} = 0.1214$, hence $\frac{(1-\tau)^2}{r} = 9.8$ and $x_{ij} = 1.19e_{ij}$. For a capital stock elasticity with respect to tax rate of 1.522, we obtain elasticity with respect to cost of capital of 1.81=(1.19×1.522).