Tax Policy, Investment and Profit-Shifting

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Abstract

Multinational firms (MNEs) often pay no tax in high-tax countries because they shift a large fraction of their taxable income to tax havens. We build a model of tax policy and investment that incorporates unobserved heterogeneity in MNEs' profit-shifting capability and different costs of setting up a tax minimization network. The model matches the distribution of taxable profit and investment in detailed UK tax returns data. We use the model to quantify the policy tradeoff between raising tax revenue by combating tax avoidance (via, for example, a Global Minimum Tax) and attracting investment. The results solve a longstanding puzzle in the existing profit-shifting literature: our model reconciles the differences between previous micro- and macro-level estimates of profit-shifting elasticities by accounting for extensive margin decisions (to report positive or no taxable profit in a jurisdiction). We test the model's predictions using a reform in Italy that limited the profit-shifting activities of Italian MNEs as a quasi-natural experiment.[1]

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1 Introduction

In recent years, there has been growing concern over the ability of multinational corporations to shift profit from high-tax jurisdictions to tax "havens" in order to reduce their aggregate tax liabilities. Especially following the global financial crisis in 2008-9, governments seeking additional tax revenue have sought to combat such profit-shifting. This led to the OECD/G20 Base Erosion and Profit Shifting (BEPS) project in 2013-5, with sweeping measures aimed at protecting the tax base in high-tax countries. More recently, in 2021, over 140 members of the OECD's Inclusive Framework have agreed the most far-reaching reform to the international taxation of profit in a century: the introduction of a Global Minimum Tax (GMT), set at 15% of "excess profit".[2]

The idea of the GMT is straightforward: if, at the margin, all profit is taxed at a rate of least 15% then the incentive to shift profit should be much reduced. Also, in principle there would be a floor on tax competition amongst governments aiming to attract inward investment. The agreement has been much hyped. Former US Treasury Secretary, Larry Summers stated *"This agreement is arguably the most significant international economic pact of the 21st century so far."*, while current US Treasury Secretary, Janet Yellen claimed *"Today's agreement represents a once-in-a-generation accomplishment for economic diplomacy. We've turned tireless negotiations into decades of increased prosperity – for both America and the world."*

But the desire for increased revenue from taxing MNE profits needs to be set in the context of the potential welfare gains and losses created. In this paper we study two important aspects of the issues raised by the international taxation of profit more generally, and apply our analysis to an assessment of the GMT proposal.

First, there remains considerable uncertainty about the extent to MNE profit shifting. That uncertainty arises for many reasons: in this paper we focus on the fact that, compared to domestic companies, MNEs are more likely to report no taxable profit in high-tax jurisdictions. This is most likely to reflect the fact that MNEs have the resources to shift a substantial amount of their taxable profits to tax havens. As a result, as shown by Bilicka (2019) for the UK, MNE's profits display sharp bunching at the taxable income zero-lower-bound in high-tax jurisdictions. This highlights the potential importance of extensive-margin decisions about profit-shifting, as some MNES pay no tax at all in some of the jurisdictions in which they operate.[3] Surprisingly, the tax avoidance literature has placed a strong emphasis on intensive-margin profit-shifting decisions, generating a gap

[2]See OECD agreements in July 2021 and October 2021.
[3]See also Koethenbuerger et al. (2019)

between macro- and micro-level studies that explore profit-shifting activities of multinationals (Dharmapala; 2014; Riedel; 2018).[4] We show that this gap may reflect the common approach taken by micro-level studies to ignore MNEs with zero profit, and hence ignore extensive margin decisions.

Second, reducing profit-shifting and setting a minimum tax rate is intended to raise tax liabilities, which in turn will raise the cost of capital and depress investment. We explore the interaction of profit shifting and investment. Our model identifies two sources of welfare loss arising from taxation. The first is a conventional deadweight cost arising from distortions to investment decisions. The second is the private cost to MNEs of shifting profit between countries. We model these costs in detail, allowing for both extensive and intensive margin effects. Theoretically, the impact on global welfare of the GMT is then ambiguous. A rise in the minimum tax rate reduces profit shifting and hence reduces the costs of profit shifting; this reduces deadweight costs. But a rise in the minimum tax rate also depresses investment; this increases deadweight costs. In this paper we evaluate the size of these two offsetting effects.

Specifically, in this paper we develop a model that generates corner solutions in multinationals' choices regarding the proportion of profit that they shift to tax havens. We then use data from UK tax returns to estimate structural profit-shifting parameters and test the model predictions by investigating the intensive- and extensive-margin effects of tax reforms on taxable profit declared in the UK by subsidiaries of foreign-owned multinationals, and on their investment. Finally, we conduct counterfactual policy experiments including the introduction of the GMT at varying rates. These findings allow us to: (i) reconcile the differences across estimates of profit-shifting based on macro- and micro-data; (ii) quantify the impact on investment as a result of curbing tax avoidance and profit-shifting; (iii) identify the overall impact on global welfare of tax reforms, including the GMT.

We start the paper by developing a model that considers MNEs undertaking real productive activity in several possible locations, while also having a subsidiary in a tax "haven", to which it shifts profit. There is a key difference between our model and the existing convex profit-shifting cost model of Hines and Rice (1994), which empirical studies typically use as the basis for empirical work, and which disregards the subsidiaries of MNEs at corner solutions of taxable income reporting. Instead, we model an MNE's irreversible investment in a "tax avoidance asset", which represents a public good for all subsidiaries of the MNE worldwide, reducing the marginal cost of shifting every additional dollar of profit

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

to the haven. Each non-haven subsidiary also invests in productive capital, and chooses how much profit to shift to the haven given the marginal cost schedule. Each MNE faces an idiosyncratic price of investing in each unit of the tax avoidance intangible. This heterogeneity mimics the real-world differences across companies that are not captured by standard sectoral variation: for example, some business lines are more digitalized and have a more international customer base than others. Such firms find it easier to assign profits to lower tax jurisdictions.

In our model, tax reforms induce both an extensive-margin and an intensive-margin effect on profit-shifting. For example, for a company at the intensive margin, a rise in the effective tax rate of the haven reduces the benefit of profit-shifting and induces a new equilibrium with lower shifting. However, a company that initially shifted all its profit may not respond at all if the benefits accruing from shifting still exceed its costs. At the opposite extreme, a company not engaging in shifting at all may not respond to a greater tax benefit from shifting, since to do so requires an upfront entry cost of investing in the tax avoidance asset. We distinguish between this entry cost and the investment cost required to accumulate the tax avoidance asset. A key contribution of our paper is therefore to highlight the importance of unobserved heterogeneity among different types of firms with access to varying degrees of tax avoidance capabilities. The overall effect of tax reforms should aggregate the response of companies at the intensive and extensive margins.

Our model allows us to estimate the elasticity of declared pre-tax profit with respect to the tax rate differential, both taking into account and ignoring the responses at extreme profit-shifting behavior. We find that the aggregate tax base declines by 1.9 percent in response to a one percentage point rise in the home country tax rate. We show that the macro-level semi-elasticity of the tax base, when calculated based on our model, is around 24 percent higher than the micro-level elasticity that would be calculated when ignoring zero taxable income reporters.

Our model also predicts that the investment in tax avoidance asset reduces the cost of capital for productive assets. This highlights a key trade-off between profit shifting and investment.[5] The reforms that increase the costs of profit-shifting for MNEs may reduce their investment in productive assets. This can occur both in high tax jurisdictions and in has feedback effect on investment in low tax jurisdictions where an affected MNE also operates. As such, ignoring profit shifting is likely to yield an under-estimate of the elasticity of investment (and the capital stock) with respect to the tax rate, since profit shifting

[5] A similar type of trade-off has also recently been highlighted in a macro model by Dyrda et al. (2022), who show that policies that reduce profit shifting are also likely to reduce output.

tends to moderate the impact of a change in the tax rate on the cost of capital. This theoretical prediction is in line with the recent literature that shows that anti-tax avoidance regulations have real effects on investment and employment (Bilicka, Qi and Xing; 2022; Suárez Serrato; 2018).

In the second contribution of the paper, we test the empirical implications of our model using the UK tax return data and a reform that limited the extent of profit shifting of Italian MNEs abroad. Our quasi-experimental variation arises from the 2002 Italian Controlled Foreign Company (CFC) reform. The CFC rules stipulate that the income of foreign low tax subsidiaries should be included in the domestic tax base. Hence, they reduce or remove incentives to shift profit to countries with tax rates just above the CFC threshold rule (Clifford; 2019). In the context of our model, the CFC rule is akin to an increase in the tax haven's tax rate. We compare UK subsidiaries of Italian-headquartered MNEs with UK subsidiaries of Spanish-headquartered MNEs. The UK in this context acts as a high-tax subsidiary with the main corporate income tax rate of 30% during the sample period. The treatment group MNEs experienced a rise in the tax rate that applies on profit shifted to the tax haven. We conjecture that this rise in the tax haven tax rate induces an increase in profit reported in various high-tax subsidiaries of an MNE, but depending on the nature of the costs of shifting profits, we anticipate that the reform has a more dominant extensive-margin response than an intensive-margin response. Consistent with our prediction, we find a strong extensive-margin response, manifested by a significant reduction in the probability to report zero taxable income of treatment group firms in the UK. We estimate that the intensive-margin response is more modest and statistically insignificant. We capture the intensive-margin response through the change in the average reported taxable income in the UK. Further, consistent with the predictions of the model, we also show that the Italian CFC reform reduced investment of Italian MNEs relative to Spanish ones in the UK.

In the third step, we carry out counterfactual policy experiments. Compared with the earlier literature, our model splits the profit-shifting cost into a 'fixed tax avoidance investment cost' and a variable cost of profit-shifting. The latter component is aligned with the earlier literature that assumes a cost convex in every dollar of profit shifted to tax havens. We find results consistent with MNEs investing in a tax avoidance intangible, whose price varies across MNEs. We expect that the nature of this price distribution is related to the firm's business, but broad sectors may not capture the heterogeneity in access to tax avoidance assets. Importantly, our structural estimates enable us to simulate the effects of recent reforms such as the global minimum tax. We demonstrate that the impact of the global

minimum tax rests crucially on the chosen threshold rate. A 15% minimum tax threshold implies a substantial reduction in profit-shifting at sufficiently large values of the price of the tax avoidance intangible. This will increase tax revenue in high tax countries, but at a cost of reduced investment in productive assets.

As noted above, our paper contributes to two broad strands of literature. First, is the discussion on the magnitudes of profit-shifting. Using meta-regression study Heckemeyer and Overesch (2017) estimate the semi-elasticity of reported income with respect to the tax rate differential across countries to be -0.8. More recently, 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 increase the pre-tax income reported by the subsidiary in the low-tax country by 8-15 per cent.[6] Estimates based on macro data are also mixed. The OECD BEPS project estimated foregone tax revenue of between $100 billion and $240 billion, between 4% and 10% of worldwide corporation tax revenues (OECD (2015)).[7] Other estimates are higher. Crivelli et al. (2016) estimate foregone revenue at around 1% of GDP for OECD countries and 1.3% of GDP for developing countries, while Tørsløv et al. (2022) estimate that 36% of all multinational profits are shifted to tax havens, implying total shifting of over $600 billion.[8] Our paper contributes to this literature by quantifying the costs of profit shifting relative to firm revenues and profits.

Second, profit shifting has been shown to have real consequences on firm operations that feed through the economy to estimates of GDP and productivity. On the micro level, there is growing evidence that anti-tax avoidance regulations reduce not only the extent of tax avoidance, as intended, but also curb down real business operations of MNEs. Suárez Serrato (2018) shows effects on investment and employment and consequences on local labor markets in the US, while Bilicka, Qi and Xing (2022) show effects for real business operations in the UK and in foreign countries of MNE operations. Bustos et al. (2022) complement this evidence by emphasizing the role that local tax advisors play in enabling profit shifting, while Bilicka and Scur (2021) highlight the role of local organizational capacity.

[6]Other approaches include contributions by Desai et al. (2006); Dharmapala and Riedel (2013); Dischinger et al. (2014); Dischinger and Riedel (2011); Egger et al. (2010); Grubert and Slemrod (1998); Gumpert et al. (2016); Langenmayr and Liu (2020); Slemrod and Wilson (2009).

[7]See also Bradbury et al. (2018).

[8]This picture is complicated by a dispute over the possible misinterpretation of accounting data. In particular, Blouin and Robinson (2020) point out that in some cases there may have been a problem of double-counting. They reapply the analysis of Clausing (2016) to suggest that the tax revenue loss in the United States in 2012 was only $10 billion instead of Clausing's estimate of $77 to $111 billion; see also Clausing's response Clausing (2020) and Clausing (2021).

On the macro level, Guvenen et al. (2022) find that profit-shifting reduces US GDP and productivity estimates in the official statistics and Coppola et al. (2021) find that offshore issuance reduces the scale of portfolio investment from developed countries to emerging market companies. As such, these papers suggest that profit shifting by MNEs affects measurement of GDP, production and international capital flows. Our paper highlights that profit-shifting may reduce the cost of investment in productive assets and our model allows us to quantify the trade-off between investment and tax revenue more systematically.

Our model allows us both to explore the costs of profit shifting, and the links between profit shifting and investment in more detail. It also allows us to simulate the impact of tax reforms such as the successful introduction of the GMT. There is growing theoretical literature that analyses 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 policy simulation exercises (Bares et al.; 2023; Grubert and Altshuler; 2013; Hanappi and Cabral; 2020).

Our model suggests that the GMT will have a significant impact on both profit shifting and investment. Our central estimate is that the GMT at 15% could in the long run in effect eliminate that proportion of MNEs that pay no tax at all in high-rate countries. While there is considerable heterogeneity across MNEs in effects, we estimate a significant impact on aggregate investment. We find that total welfare increases as the minimum rate rises from a low level, as some of the costs of profit shifting are eliminated. However, at higher levels of the minimum rate, this effect is dominated by a negative impact on investment.

The rest of the paper is structured as follows. In Section 2, we develop the theoretical framework. In Section 3, we lay out the empirical strategy, followed by Section 4, in which we present the results from reduced-form analyses. We present our structural estimation approach and results in Section 5. In Section 6, we interpret our results and discuss the implications with reference to the existing literature. In Section 7, we carry out counterfactual policy experiments and we conclude in Section 8.

2 Conceptual framework

2.1 A model of capital accumulation with profit-shifting

We model the behaviour of a multinational enterprise (MNE) in a single period. The novelty of the model lies in the process in which the MNE invests in an intangible asset which we call the "tax avoidance asset", Y. The accumulation of this asset incorporates different

costs of organising the business to reducing its overall tax liability. As an example, consider the case of a business with ownership of intellectual property (IP). Many such businesses create a corporate structure which involves locating the IP in a tax haven subsidiary (and possibly funding that subsidiary under a "cost contribution arrangement" to pay the costs of research and development undertaken elsewhere), with the consequence that the revenue generated from the IP is treated as arising not necessarily in the country in which the R&D takes place, but in the tax haven.[9] Of course, the royalty stream may not arise for several years, and so the tax avoidance asset is a long-term investment. Conditional on having created this arrangement, the costs of shifting profit to the haven in any subsequent period are significantly lower than they otherwise would be.

The costs of setting up such an arrangement may be substantial, and well above any value which a small business may derive from shifting to the haven. So we might expect such activities to be undertaken only by large and profitable businesses. Further, in many countries, simple schemes to achieve this outcome have been increasingly attacked by anti-avoidance rules, resulting in corporate structures becoming more complex in an attempt to circumvent such rules. This has also happened at an international level, most notably through the OECD/G20 BEPS project, which proposed closing a number of loopholes in 2015. In our model, tightening anti-avoidance rules represents an increase in the price of the intangible tax avoidance asset.

We consider a business that has subsidiaries operations in N jurisdictions. Each subsidiary has access to the business's global tax avoidance asset, which is in effect a public good within the business. Each subsidiary also invests in productive capital, K. This implies that two 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 in the tax avoidance asset, while the other, for example, a subsidiary of an MNE without the tax avoidance asset (or a firm with domestic activities).

The timing is as follows:

1. At the beginning of the period, each government j announces its tax rate, τ_j, and introduces anti-avoidance measures. Collectively the anti-avoidance measures determine how much the home government may affect a change in the tax levied on income on operations of tax haven subsidiaries. This 'tax haven tax rate' is labelled

[9] In Bilicka, Devereux and Guceri (2022) we provide extensive descriptive evidence on the location of IP in tax havens. Others have also looked at the location of intangible assets and IP in low-tax jurisdictions (Desai et al.; 2006; Dischinger and Riedel; 2011; Griffith et al.; 2014; Grubert; 2003; Grubert and Slemrod; 1998; Karkinsky and Riedel; 2012).

τ_X. Each MNE i invests in the tax avoidance asset Y_i that serves its subsidiaries globally. The cost to the multinational of purchasing units of the tax avoidance asset is denoted p. There is also a fixed entry cost to investing in this asset, ϕ.

2. Still at the beginning of the period, but with knowledge of τ_j for all countries of operation j, τ_X, p and ϕ, each MNE i chooses investment in productive capital K_{ij} in each country j.

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 $(1-\delta)K_{ij}$. The tax avoidance asset is worthless at the end of the period.

4. Also at the end of the period, the multinational: (i) observes an exogenous demand shock $\Pi_i \sim \mathcal{N}(0, \sigma^2_\Pi)$, and (ii) based on prior choices and the observed demand shock, chooses the proportion α_{ij} of the tax base B_{ij} to shift from each subsidiary j to a tax haven with the tax rate of τ_X.

We assume that profit-shifting is not possible without some positive Y. We also assume that it is not possible to shift more than 100% of the tax base. This yields the following decision making process by the business:

1. Choose $Y_i = 0$, implying $\alpha_{ij} = 0$; or, $Y_i > 0$, in which case, the cost of purchasing Y is $pY + \phi$.

2. Conditional on $Y_i > 0$, choose $0 < \alpha_{ij} \leq 1$.

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

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

The true (i.e. before profit shifting) tax base in country j for MNE i is:

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

This implies that tax depreciation is equal to true economic depreciation and there is no relief for any financing costs.[10].

[10]We ignore the use of debt to keep the model relatively simple

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 remainder 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 centrally chooses Y_i, and K_{ij} (and α_{ij}) for each subsidiary j, to maximise its beginning of period value:

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

subject to constraints:

$$\begin{aligned} Y_i &\geq 0 \\ 0 \leq \alpha_{ij} &\leq 1 \end{aligned}$$

where $\phi(Y_i) = \bar{\phi}$ for positive values of Y and zero otherwise. $\beta = 1/(1+r)$ is the discount factor.

Firms differ in the price p of the tax avoidance intangible asset. Specifically, we envisage that each multinational faces a price of investing in tax avoidance. This price is uniformly distributed over the interval $(0, \bar{p})$.[11]

This model does not have a closed-form solution. But to guide our analysis, we present below two solution regions, with and without any investment in the profit-shifting asset and discuss the implications. In these solution regions, we present the beginning-of-period choices that are based on $\mathbb{E}[\Pi] = 0$.

2.1.1 Region 1: No investment in profit-shifting

Conditional on not investing in the profit-shifting intangible asset, $Y_i = 0$, then the share of profit shifted to the tax haven is zero for all subsidiaries; $\alpha_{ij} = 0 \, \forall j$. This also means that all the costs of profit-shifting are set to zero. In this scenario, the choice of productive capital

[11] In Appendix B.1, we present an alternative analysis where we assume a $\beta-$distribution.

is derived the same way as under the standard neoclassical optimal capital accumulation framework (Hall and Jorgenson; 1967; Jorgenson; 1963), with the optimal productive stock given by the first order condition in Equation 5:

$$F_K(K_{ij}) = \frac{r}{1-\tau_j} + \delta \tag{5}$$

This FOC generates an optimal value of K_{ij} for each subsidiary j, K^*_{ij}, with an associated optimal tax base, B^*_{ij}, and beginning of period firm value, V^*_i.

2.1.2 Region 2: Positive investment in the profit-shifting intangible

Conditional on some positive investment in the tax avoidance intangible asset, $Y_i > 0$, and interior solutions with an *ex ante* expectation of $0 < \alpha_{ij} < 1$, the first order conditions for the tax avoidance intangible Y, the productive capital K and the share of profit shifted to the tax haven are as follows:

$$Y: \qquad p_i = -\beta \sum_{j=1}^{N} c_Y(\alpha_{ij}, Y_i, B_{ij}) B_{ij} \tag{6}$$

$$K: \qquad F_K(K_{ij}) = \frac{r}{1 - [\widehat{\tau_{ij}} + c_B(\alpha_{ij}, Y_i, B_{ij})B_{ij} + c(\alpha_{ij}, Y_i, B_{ij})]} + \delta \tag{7}$$

and

$$\alpha_{ij}: \qquad \{\tau_j - \tau_X - c_\alpha(\alpha_{ij}, Y_i, B_{ij})\} B_{ij} + \eta_{ij} = 0 \tag{8}$$
$$\eta_{ij}(\alpha_{ij} - 1) = 0$$

The first of these conditions identifies the choice of Y_i for the multinational business i as a whole, equating the marginal cost of an extra unit of Y_i, p_i, with the marginal benefit. The latter is the sum of the marginal reductions in variable profit shifting costs, aggregating over all the subsidiaries. Each marginal reduction depends on Y_i, and the optimal choice of Y_i arises where the sum of of marginal reductions is equal to p_i.

Conditional on the investment in the tax avoidance asset Y_i, each subsidiary j chooses its investment in productive capital, K_{ij}, and at the end of the period, how much of its profit to shift to the tax haven, α_{ij}.

For a subsidiary j that shifts less than 100% of its profit, then $\eta_{ij} = 0$, and α_{ij} is determined by equating the marginal benefit of shifting, equal to the difference in tax rates, with the marginal cost:

$$\tau_j - \tau_X = c_\alpha(\alpha_{ij}, Y_i, B_{ij}) \tag{9}$$

This is a conventional expression for the choice of what proportion of profit to shift. However, our model also allows for the subsidiary to shift all its profit. Specifically, if the benefits outweigh the costs for values of $\alpha_{ij} < 1$, then α_{ij} will be driven to the corner solution, with full profit shifting. In this case, with marginal benefits still exceeding marginal costs, $\alpha_{ij} = 1$ and $\eta_{ij} \neq 0$.

The optimal stock of productive capital is determined by (7). This differs from the non-profit shifting case for two reasons. First, the "effective statutory tax rate", $\widehat{\tau_{ij}}$, replaces the statutory tax rate in country j in the cost of capital term. Through this, higher profit shifting reduces the cost of capital, and raises K. But there is a second, offsetting, effect. As K and, consequently, tax base, B, change, this affects the costs of profit shifting, which changes the cost of capital. Specifically, we assume that a higher B tends to increase profit shifting costs, since the amount to be (potentially) shifted increases. One implication of this is that, even if profit is fully shifted, implying that $\widehat{\tau_{ij}} = 0$, the cost of capital - and hence K - does not revert to what it would be in the absence of tax altogether. Instead, raising K incurs additional marginal costs of shifting profit, which add to the total costs and result in a lower K. We discuss some implications of this below.

2.1.3 Functional forms

We solve the model empirically by choosing conventional functional forms for $c\left(\alpha_{ij}, Y_i, B_{ij}\right)$ and $F(K_{ij})$. 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):

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

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. Specifically, 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 $\varepsilon_{ij} \sim \mathcal{N}(0, \sigma^2)$. In Appendix A we describe this simplified production function.

This model does not have a closed-form solution. Hence, we solve numerically for the tax avoidance intangible for the multinational, the optimal productive capital, and the extent of profit shifting for each subsidiary, for each price of the tax avoidance asset p_i, and productivity draw ε_{ij}.

2.2 Variation in investment and profit shifting behaviour

We demonstrate profit-shifting and productive capital accumulation choices for a range of cost draws p_i in Figure 1. We envisage an MNE with three subsidiaries, one in a high-tax country and one in a low-tax country with real operations, and the third one in a tax haven. An MNE with subsidiaries in France (high-tax), Ireland (low-tax) and Bermuda (tax haven) is an example of such a setup. We derive some key predictions that guide our empirical analysis in reduced-form in Section 4, and structurally in Section 5.

1. *Extensive-margin and intensive-margin profit-shifting:* Multinationals with a low draw of p_i are more likely to shift a higher share of their subsidiaries' profit to tax havens, conditional also on the draw for each subsidiary of the productivity parameter, θ_{ij}. The model generates kinks along the distribution of p_i, as illustrated in Figure 1a. Multinationals that face a lower cost of investing in the tax avoidance asset shift all their taxable profit out of both the low-tax country and the high-tax country subsidiaries. As p_i rises, the investment in the tax avoidance asset Y_i falls, and the variable costs of profit shifting rise. At some point, each subsidiary moves to a position where it shifts less than 100% of the profit (ie. $\alpha_{ij} < 1$); this happens at a lower p_i for the low-tax subsidiary, as the marginal benefit of shifting is lower in this case. As p_i continues to rise, then the investment in Y_i falls further, the variable costs of shifting rise, and α_{ij} continues to fall. As p_i continues to rise, there come a point at which the multinational no longer invests in Y at all; at this point, profit shifting from both subsidiaries falls to zero.

2. *Investment in productive capital:* The impact of p_i on investment in productive capital is shown in Figure 1b. At very low levels of p_i, the subsidiary pays no tax on its

profit, since all profit is shifted to the haven. However, as noted above, there remains a marginal cost of profit shifting: as K_{ij} rises, the tax base, B_{ij}, rises and the marginal cost of profit shifting also rises; this increase in marginal costs moderates investment in productive capital by raising the cost of capital, even though no tax is paid. As p_i increases, Y_i falls, and so this marginal cost increases. Even within the region of full profit shifting ($\alpha_{ij} = 1$), this reduces K_{ij}.

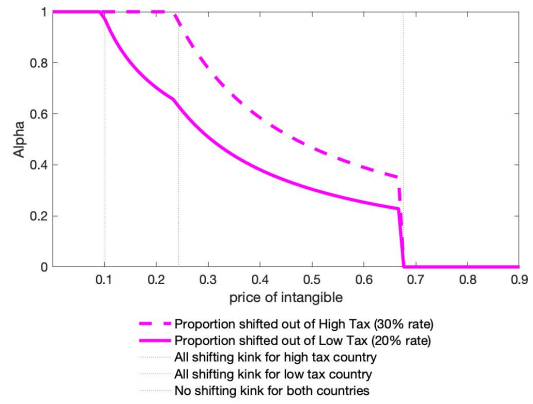
In region $0 < \alpha_{ij} < 1$, the cost of capital effect dampens. Ceteris paribus, the variable cost of shifting profit to the tax haven is lower since α_{ij} is lower. As p_i rises, α_{ij} falls, reducing the impact of profit-shifting on the cost of capital. However, as α_{ij} falls, the subsidiary faces a higher effective tax rate, increasing the cost of capital. In Figure 1b, the net impact is a relatively small reduction in K_{ij} in this region. When p_i is so high that the subsidiary does not shift any profit, the cost of capital and K_{ij} revert to the case of no profit shifting. Under no profit shifting, the accumulated capital K_{ij} in jurisdiction j is lower than all the regions with profit shifting, reflecting the positive net effect of profit shifting on investment in productive capital.

2.3 Impact of tax reform

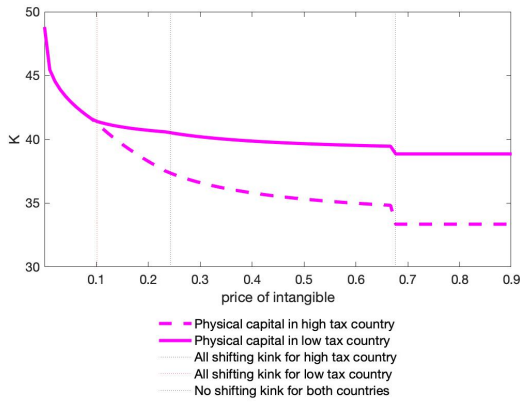
We now consider the impact of two types of tax reforms. The first is a change in the tax rate in one of the countries in which production takes place. The second is a set of two reforms introducing anti-avoidance measures, which have similar properties. Consider, for example, the OECD/G20 BEPS initiative, which introduced various restrictions on the ability to shift profit to a haven. In our model, we can interpret this as a general increase in the price of the tax avoidance asset, p_i. In this case, profit shifting is not ruled out, but it does become more difficult and more costly - for example, by re-organising the multinational structure to meet the new rules. Alternatively, if such restructuring does not take place, then the income arising in the haven is likely to be subject to tax at some rate; this an be interpreted as a rise in the tax haven rate, t_X. The 2021 proposal for a minimum tax is also akin to raising the tax haven rate.

1. *Raising the tax rate:* Consider a rise in the tax rate in the high-tax country, H. This increases the benefit of shifting profit out of H, and so profit shifting from H will rise. But it also raises the return to investment in Y_i. So Y_i will also rise; as it does so, that reduces the variable costs of profit shifting in both H and low tax country, L. In

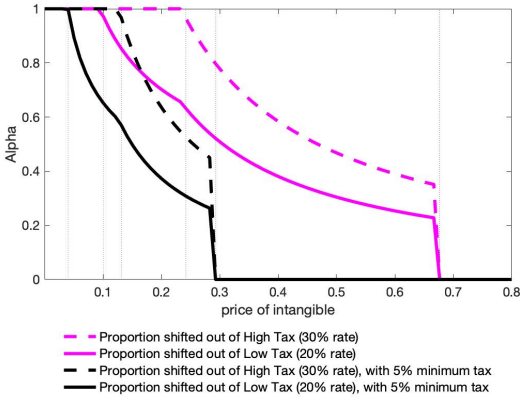
Figure 1: Profit-shifting and investment in productive capital under the status quo and minimum tax



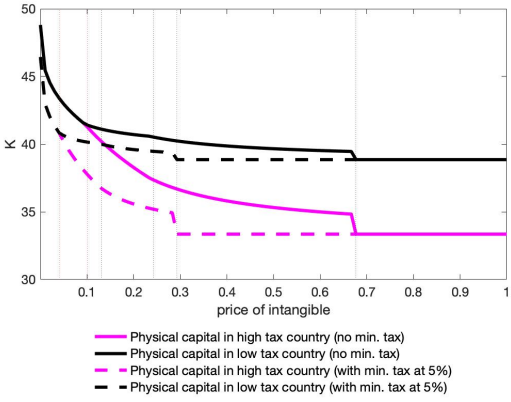
(a) Share of profit shifted, base case



(b) Choice of productive capital, base case



(c) Share of profit shifted, with a min. tax



(d) Choice of productive capital, with a min. tax

Note: The values on this figure are based on calibrated values and do not reflect the estimates that we present in Section 5. The calibrated values are for demonstration purposes only.

sum we would expect to see more shifting of profit from both countries, albeit with a bigger effect in the high tax country.

Increased profit shifting moderate the negative impact of higher taxation on investment. Indeed, given no change in the tax rate in the low-tax country, the lower marginal costs of profit shifting should lead to a rise in K_{iL} in L. The higher tax rate in the high tax country dominates these effects, so that the overall effect on K_{iH} is negative.

2. *Strengthening anti-avoidance measures:* One interpretation of stronger anti-avoidance measures is that the cost of creating the tax avoidance asset, p_i, increases. The impact of this is shown in Figures 1a and 1b. The effects on α_{ij} and K_{ij} are those described above.

   An alternative approach is consider the stronger anti-avoidance measures as raising the tax rate in the haven, τ_X. This is the approach that we take in our counterfactual policy simulations in Section 7. Figures 1c and 1d illustrate the impact of raising τ_X from zero to 5%. The qualitative effects are the same as a rise in p_i. There is a smaller range of values of p_i for which subsidiaries shift all their profit. And the value of p_i which induces the multinational not to invest in Y_i at all is reduced. Hence, given a higher tax haven rate, in both countries there is a steeper decline in both profit shifting and investment in productive capital as p_i rises. For a high enough p_i, no profit shifting takes place for $\tau_X = 0$ or $\tau_X = 0.05$.

2.4 Elasticities

Two separate literatures have estimated (i) the size of the elasticities of investment (and the capital stock) with respect to the tax rate (or the cost of capital), and (ii) declared pre-tax profit with respect to the differential in tax rates between the country where activity takes place, and the haven. In our model, there is considerable heterogeneity in these elasticities across multinationals and across subsidiaries of a multinational.

Investment in productive capital varies across MNEs and their subsidiaries because the cost of capital (and hence investment) depends not only on the domestic tax rate, but also on the extent of profit-shifting and on the marginal costs of profit-shifting. The latter in turn depends on investment in Y_i, which is likely to depend, among other things, on the size and productivity of the multinational.

As implied above, there is also a positive elasticity of the impact of the tax rate in one country (say H) on investment in the other country (say L). That is, a rise in τ_{iH} will induce a rise in Y_i, which will reduce the variable costs of profit shifting in L, and hence, lower the cost of capital in L. This occurs even without any channel for the multinational to move real activity from H to L. As such, ignoring profit shifting is likely to yield an over-estimate of the elasticity, since profit shifting tends to moderate the impact of a change in the tax rate on the cost of capital.

Turning to declared pre-tax profit, there are two channels by which this would be affected by a change in the tax rate differential, $\tau_{ij} - \tau_X$. The first channel is that - for sub-

sidiaries at the intensive margin of profit shifting - the incentive to shift profit is reduced, and so for a given "true" profit, declared profit will tend to rise as τ_X rises. Subsidiaries at the extensive margin that continued to shift all of their profit would not change their pre-tax profit. Some firms may switch from fully shifting to partial shifting, and would therefore also see a rise in pre-tax profit (from zero). The overall effect therefore depends on the responses of all three groups of subsidiaries. Studies that focus only on firms at the intensive margin before the reform would exclude the responses of the other two groups.

The second channel stems from direct and indirect effects of a change in $\tau_{ij} - \tau_X$ on the cost of capital, investment and hence pre-tax profit. The direct effect is that a rise in τ_X would tend to increase the cost of capital, and hence reduce investment and pre-tax profit. This effect would arise even if the subsidiary were shifting 100% of its profit, since the tax paid would increase. The indirect effect is that if the subsidiary reduced its profit shifting, it would also reduce the marginal costs of shifting, which would in turn reduce the costs of capital, and offset the direct effect. The strongest effect via this channel on pre-tax profit would therefore come from subsidiaries at the extensive margin that continued to shift all their profit.

The literature on profit shifting has suggested that studies based on micro data (which tend to ignore the extensive margin) find lower elasticities of pre-tax profit with respect to the tax rate differential than studies based on macro data. Our model implies that ignoring the extensive margin could lead to an overestimate or an underestimate of the aggregate elasticity. In our numerical simulations we find support for the view that ignoring the extensive margin effects tends to lead to an underestimate of the aggregate elasticity.

2.5 Welfare effects of tax system changes

We consider global welfare. The globally-agreed consensus maximizes the sum of private income and the present value of the welfare generated from public expenditure, equal to total revenue, $\mu(G)$ where G is total tax revenue (see, for example, Bustos et al. (2022); Keen and Slemrod (2017)). To fix ideas in a simple setting, consider the case of a single MNE i, operating in a single high tax country H and shifting profit to the haven X. World welfare is:

$$W = V_i + \beta\mu(G) \tag{12}$$

where $G = T_{iH} + T_{iX}$ is the total amount of public goods, and μ the utility derived from total government revenue of G:

$$G = \widehat{\tau_{iH}} B_{iH} = \left[\tau_H \left(1 - \alpha_{iH}\right) + \alpha_{iH}\tau_X\right] B_{iH} \tag{13}$$

Since we are modelling taxes, rather than the impact of government spending, we generally examine the case in whcih the marginal benefit of $1 of government spending is $1 - that is $\mu' = 1$.

The "global consensus" has several instruments that it can use to maximise welfare. In the context of a Global Minimum Tax, consider the case of setting τ_X. The revenue arising from the tax in the haven can be kept by the haven (in the spirit of the Pillar 2 proposal), although the distribution of revenue between the two countries is irrelevant in this case.

In general, the impact of a change in τ_X on W is given by:

$$\frac{dW}{d\tau_X} = \frac{dV_i}{d\tau_X} + \beta\mu'(G)\frac{dG}{d\tau_X} \tag{14}$$

Taking these elements in turn,

$$\frac{dV_i}{d\tau_X} = \frac{\partial V_i}{\partial K_{iH}}\frac{\partial K_{iH}}{\partial \tau_X} + \frac{\partial V_i}{\partial Y_i}\frac{\partial Y_i}{\partial \tau_X} + \frac{\partial V_i}{\partial \alpha_{iH}}\frac{\partial \alpha_{iH}}{\partial \tau_X} + \frac{\partial V_i}{\partial \tau_X} \tag{15}$$

The first three terms of this expression are zero. The first is zero due to the envelope theorem. The second and third depend on whether the MNE is at the extensive margin for Y_i and α_{iH}. If the MNE is not at the extensive margin, then the envelope theorem holds, and, for example, $\frac{\partial V_i}{\partial \alpha_{iH}} = 0$. However, if the MNE is at the extensive margin, then, for example, α_{iH} does not change in response to a change in the tax rate, so that $\frac{\partial \alpha_{iH}}{\partial \tau_X} = 0$. Given this,

$$\frac{dV_i}{d\tau_X} = -\frac{\partial G}{\partial \tau_X} = -\alpha_{iH} B_{iH} \tag{16}$$

The effect of changing τ_X on total revenue is:

$$\frac{dG}{d\tau_X} = \frac{\partial G}{\partial K_{iH}}\frac{\partial K_{iH}}{\partial \tau_X} + \frac{\partial G}{\partial Y_i}\frac{\partial Y_i}{\partial \tau_X} + \frac{\partial G}{\partial \alpha_{iH}}\frac{\partial \alpha_{iH}}{\partial \tau_X} + \frac{\partial G}{\partial \tau_X} \tag{17}$$

where

$$\frac{\partial G}{\partial K_{iH}} = \widehat{\tau_{iH}}(F_K - \delta) \tag{18}$$

$$\frac{\partial G}{\partial Y_i} = 0 \tag{19}$$

and

$$\frac{\partial G}{\partial \alpha_{iH}} = (\tau_X - \tau_{iH})B_{iH} \tag{20}$$

Collecting these terms, and setting $\frac{dW}{d\tau_X} = 0$ implies

$$-(1 - \beta\mu')\alpha_{iH}B_{iH} + \beta\mu'[\widehat{\tau_{iH}}(F_K - \delta)\frac{\partial K_{iH}}{\partial \tau_X} + (\tau_X - \tau_{iH})B_{iH}\frac{\partial \alpha_{iH}}{\partial \tau_X}] = 0 \tag{21}$$

For a given value of the marginal benefit of public spending, μ', and a given tax rate in the high tax country, τ_x, this expression implicitly defines the optimal τ_X.

In assessing welfare in the empirical application we compute W for $\mu' = 1$, taking into account the impact of the tax rate on the choices of the MNE.

An alternative - and in this context, equivalent - approach is to compute the marginal value of public funds (MVPF), based on the analysis of Hendren and co-authors.[12] This is the ratio of the benefit to the recipient of public funds, $\frac{\partial G}{\partial \tau_X}$, to the cost of generating that revenue, $\frac{dG}{d\tau_X}$.[13]

[12] See Hendren (2020), Hendren and Sprung-Keyser (2020), Finkelstein and Hendren (2020) and Hendren and Sprung-Keyser (2022)

[13] In the context of our model, this is equivalent to the value that μ' would need to take for any given tax reform to be optimal.

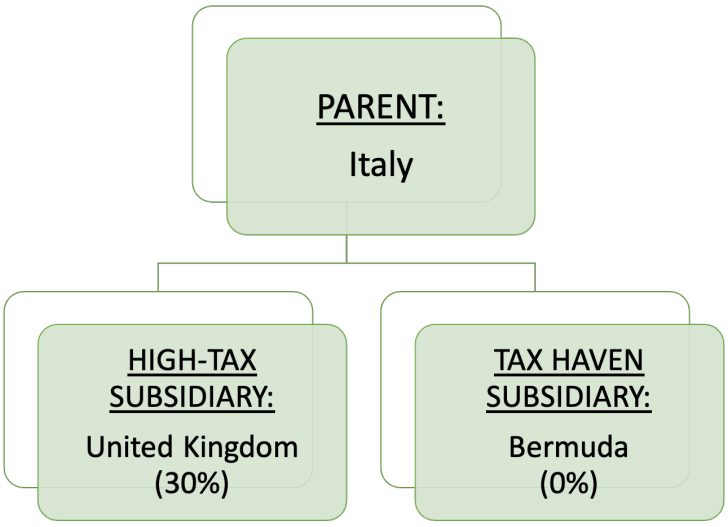
3 Empirical strategy

We make predictions regarding firms' responses to tax policy changes in two steps. First, we present the results from reduced-form difference-in-differences (diff-in-diff) regressions that demonstrate MNEs' responses to tax reforms in a quasi-experimental setting. We then use moments from the distribution of key variables (namely, taxable profit and capital) to match in a simulated method of moments estimation procedure and estimate the parameters of our structural model from Section 2. Finally, we evaluate the impact of counterfactual policy options.

3.1 Evaluating the impact of the CFC reform in Italy

In the absence of special rules, tax policy, including company taxation, applies to a country's residents. A controlled foreign company legislation opens up the possibility for a country to tax the foreign income of a multinational corporation. Under a CFC rule, subsidiaries of MNEs that are wholly or partly owned by a multinational parent that pays tax at an effective rate below a certain threshold (set by the *home* country) become liable to pay extra tax to the revenue authority of the *home* jurisdiction (Clifford; 2019).

Figure 2: Example structure for an MNE parent company in 2002



In 2002, Italy began to impose additional tax on certain types of income of a *tax haven subsidiary* that is financially controlled by a parent located in Italy. The tax haven definition under the Italian CFC regime, for the period of our study, was a jurisdiction with a 13.75%

corporate tax rate.[14] A simple MNE structure with a parent company in Italy, a high-tax subsidiary in the UK and a tax haven subsidiary in Cayman Islands illustrates the relevant corporate structure for our empirical analysis (Figure 2). The introduction of the CFC regime in Italy increased the tax haven tax rate on certain income of Italian MNEs to 13.75% (in some cases from an effective rate of zero).

According to the theoretical framework in Section 2, we expect the *high-tax* UK subsidiary of an Italian parent company to experience changes in its corporate tax return and investment along the following dimensions:

1. *Extensive-margin profit-shifting effect:* High-tax subsidiaries may become **less likely to report zero taxable profit**. If tax haven subsidiaries are taxed more intensively, less profit should be shifted out of any of the high-tax subsidiaries of Italian MNEs. This includes subsidiaries in the UK.

2. *Intensive-margin profit-shifting effect:* High-tax subsidiaries with existing profit in high-tax jurisdictions may **increase the amount of profit reported in high-tax jurisdictions**.

3. *Investment*: High-tax subsidiaries may **reduce their investment**. The reforms that increase the cost of profit shifting increase the cost of capital for productive assets.

Depending on the size of the structural parameters $\bar{p}$ and γ, there may be more pronounced effects through the extensive-margin or the intensive-margin. We use the difference-in-differences approach to investigate the profit reporting behavior of multinational firms in the UK in response to the change in the CFC regime in Italy. According to country characteristics and tax reform trajectories, we select MNEs headquartered in Spain as a suitable control group against which we can benchmark the change in the profit reporting and investment behavior of MNEs headquartered in Italy. We run three sets of regressions to assess: (i) the change in the probability to report zero taxable profit in the UK (using a linear probability model), (ii) the change in the average profit reported in the UK, and (iii) the change in investment in the UK:

$$\mathbb{1}(\text{Taxable Profit} \leq 0)_{it} = \alpha_0 + \beta_0 \text{Treated}_i \times \text{Post-reform}_t + \sigma_0 X_{it}^{'} + \theta_{i0} + \eta_{t0} + \varepsilon_{it0} \quad (22)$$

$$\ln(\text{Taxable Profit}_{it}) = \alpha_1 + \beta_1 \text{Treated}_i \times \text{Post-reform}_t + \sigma_1 X_{it}^{'} + \theta_{i1} + \eta_{t1} + \varepsilon_{it1} \quad (23)$$

$$\ln(K_{it}) = \alpha_2 + \beta_2 \text{Treated}_i \times \text{Post-reform}_t + \sigma_2 X_{it}^{'} + \theta_{i2} + \eta_{t2} + \varepsilon_{it2} \quad (24)$$

[14] A summary is available from the Library of Congress in the linked article here.

In Equations 22 and 23, the outcome variables relate to the extensive-margin and the intensive-margin profit-shifting effects, respectively. $\mathbb{1}(\text{Taxable Profit} \leq 0)_{i,t}$ represents a dummy equal to one when a firm reports zero taxable profits in a given year. Treated_i is a dummy variable that equals one, if a subsidiary is headquartered in Italy and zero otherwise; Post-reform_t is a dummy variable that equals one from 2003 onward for the Italian CFC reform. X'_{it} is a set of firm-level control variables, θ_is are firm fixed effects, η_ts are time fixed effects, and ε_{it}s are the error terms. In Equation 24, the dependent variable is the natural logarithm of investment.[15]

β_0 captures the effect of the reform on the propensity of the firm to report zero taxable profit in the high-tax jurisdiction (UK), i.e. the extensive margin. Under the model in Section 2, β_0 should be negative for the case of the Italian anti-tax avoidance reform. Italian subsidiaries should report higher profits in the UK now that Italy is taxing profits located in lower tax jurisdictions in Italy. β_1 represents the intensive margin response to the introduction of the CFC legislation. This parameter is closely related to the variable cost parameter γ in the model that we developed in Section 2. Under convex variable cost assumption, γ represents the sensitivity of profit-shifting to each additional dollar shifted to the tax haven. We posit that the *fixed* investment cost in the tax avoidance intangible represented by $\bar{p}$ dominates the variable cost channel, in which case β_1 may be close to zero or statistically not significant. Finally, the impact of tax system changes on the cost of capital, reflected in each subsidiary's decision to invest in real activity in each jurisdiction is captured by β_2.

3.2 Administrative data and balance sheet information

We use detailed administrative tax returns data from the UK (starting in 2000), matched with financial accounts information and ownership links provided by Bureau van Dijk data and test the predictions of the model. A change in the tax rate differential between high-tax jurisdictions and tax haven countries is sufficient for us to evaluate intensive- and extensive-margin profit-shifting elasticities and estimate our model's key structural parameters. However, tax rate changes are hardly ever exogenous to profit-shifting tendencies of multinationals. We therefore leverage exogenous variation in profit-shifting behavior triggered by a change in the controlled-foreign company (CFC) legislation in Italy.[16]

[15] In our static model, capital stock is accumulated as a result of the beginning-of-period investment.

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

Before the changes to CFC rules, Italian-owned multinationals operating in the UK could freely shift profit to jurisdictions that are considered to be tax havens without any penalty and reduce their effective tax rate to close to zero. For the period that we study, the UK had a main corporate tax rate of 30% and was considered a high-tax country. This status changes in the years that followed, but we focus our attention to the 2000-2005 period without significant tax reforms.

The dataset comprises all items that are submitted on the corporation tax return form (CT600 form) and the unit of observation is an unconsolidated statement in each of the years. Each subsidiary of a company operating in the UK files a separate tax return. We merge the HMRC data with the accounting data from the FAME dataset, collected by Bureau van Dijk. This data contains information on firm assets, employment, and other balance sheet items. Further, the ownership data from FAME allows us to identify the global ultimate parent companies that own UK subsidiaries and link their corporate tax returns with Italian and Spanish ultimate owners.

3.3 Summary statistics

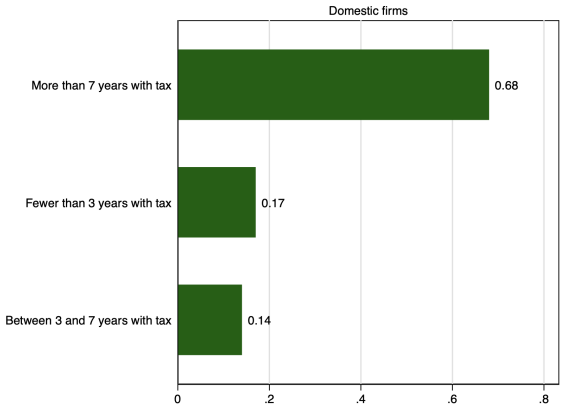
We use matched tax return-financial accounts data over the years 2000 - 2005, corresponding to three years before the reform and three years after the reform. To begin with, we observe the patterns of reporting taxable profit or losses for the whole population of firms compared with the subsidiaries of multinational companies. In Figure 3, we demonstrate taxable profit or loss reporting behavior of companies that have filed company tax returns for a consecutive minimum of ten years (starting in the year 2000). The left-hand panel shows the patterns of taxable income reporting for domestic firms. The most common pattern for reporting over 10 years for domestic firms is to report positive taxable profit in most years. 68% of domestic firms in the company tax register report taxable profit in more than seven of the ten (or more) years of data. The second most common pattern is to report zero taxable profit every year, and 17% of active domestic firms report positive taxable income in fewer than three years. This may be due to company life-cycle or domestic avoidance and evasion activities.

Figure 3 looks completely different for subsidiaries of multinational companies (right-hand panel). Of the multinational taxpayers, half of them always report zero taxable income in the UK. The next most common pattern is MNEs that always report zero taxable income, with 43% of MNEs reporting positive taxable income in fewer than three years.

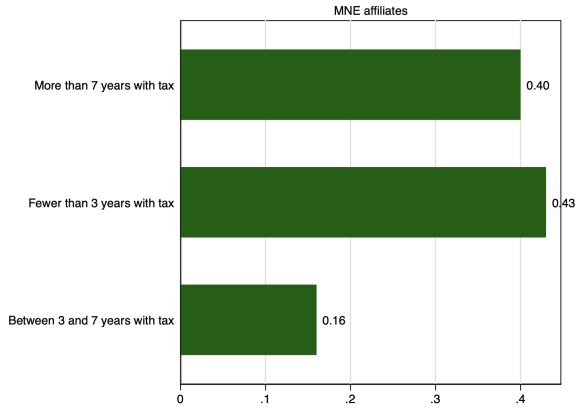
The taxable profit reporting patterns support the view that multinationals either con-

Figure 3: Patterns of reporting taxable profit or loss over 10 years for surviving firms

(a) Domestic firms



(b) MNE subsidiary firms



Note: This figure shows the corporate tax payment patterns for corporate taxpayers that are in the dataset for at least 10 years continuously. We pool all available years in the population of corporate tax returns to generate the statistics. We split these companies into three groups: (1) firms that had positive taxable profit in more than 7 years, (2) firms that had positive taxable profit in fewer than 3 years, (3) firms that had between 3 and 7 years with taxable profit. The left hand panel shows the ratios for domestic firms and the right hand panel shows the ratios for MNEs. The ratios sum to one for each panel.

sistently move profit out of the high-tax subsidiary's jurisdiction, or consistently report positive profit in the high-tax jurisdiction over time. We interpret this to be consistent with firms choosing time-invariant *tax minimizing* or *tax-paying* types and supporting our simplifying choice of building the conceptual framework as a static model.

In Table 1, we present descriptive data on key variables for the pre-reform period separately for the Control Group (MNEs with parent company resident in Spain) and the Treatment Group (MNEs with parent company resident in Italy). UK subsidiaries of both Italian MNEs and Spanish MNEs report around 150 thousand pounds of average taxable profit. In Table 2, we narrow the sample down to companies that persistently report positive taxable profit, and show, as expected, that the average taxable profit is much higher for this latter group of MNE subsidiaries.

Strikingly, in both the Treatment Group and the Control Group, close to half of all MNE subsidiaries in the UK report zero taxable profit in the pre-reform period; this share is 49.8% for the control group and 47.8% for the treatment group. Our extensive-margin response to tax reform traces the changes in the prevalence of reporting zero taxable profit. Average size of the subsidiaries in the control group is larger than the subsidiaries in the treatment group, and this is somewhat reflected in the profitability measure that is the

Table 1: All sampled companies – key descriptive statistics by treatment status, pre-reform period

Variable	*Control Group*			*Treatment Group*		
	Mean	**95% CI**		**Mean**	**95% CI**	
		lb	ub		lb	ub
Taxable profit (GBP)	155,891	134,253	177,530	145,155	130,886	159,424
Zero taxable profit (share)	50%	46%	54%	48%	45%	51%
Total assets ('000 GBP)	20,817	18,399	23,235	10,253	9,070	11,436
Profitability	6%	5%	7%	8%	7%	10%
Revenue / Assets	2.04	1.82	2.26	1.73	1.62	1.85

Note: This table shows selected descriptive statistics, pooled over the pre-reform period years available in the data (2000-2002). Control group companies are the UK subsidiaries of MNEs with parent companies located in Spain. 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, with asset size values presented in thousands. Profitability is obtained by dividing taxable profit by total assets at the company-year level, then average over all pre-reform group observations. 'lb' and 'ub' represent lower and upper bounds of the 95% confidence intervals.

ratio of taxable profit to balance sheet size. Consistently, the revenue as a share of firm size is also somewhat larger in levels for the control group firms. In Table 2, we show

Table 2: Sampled companies with persistently positive taxable profit – key descriptive statistics by treatment status, pre-reform period

Variable	*Control Group*			*Treatment Group*		
	Mean	**95% CI**		**Mean**	**95% CI**	
		lb	ub		lb	ub
Taxable profit (GBP)	389,442	346,397	432,488	314,389	285,566	343,212
Zero taxable profit (share)	0%			0%		
Total assets ('000 GBP)	21,217	17,168	25,266	8,221	6,554	9,887
Profitability	13%	11%	15%	15%	14%	17%
Revenue / Assets	2.34	1.88	2.80	1.83	1.71	1.95

Note: This table shows selected pre-reform period descriptive statistics in the same format as Table 1. In this table, we limit the sample to firms that report positive taxable profit in each of the pre-reform periods, 2000, 2001 and 2002.

key descriptive statistics for firms that reported positive taxable profit in each of the pre-reform periods. As expected, the average reported profit for both treatment and control group subsidiaries is high, at more than double the average taxable profit for the whole

sample. Similar to Table 1, the average asset size for the control group is higher than that of the treatment group, and the two groups have similar profitability ratios.

4 Graphical evidence and reduced-form regression results

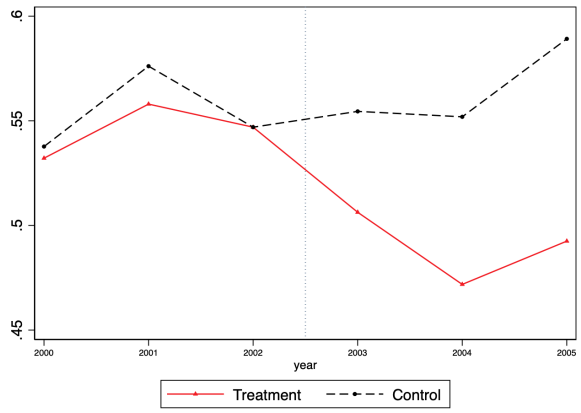
For the validity of the difference-in-difference approach, treatment and control groups should satisfy common counterfactual trends. In the absence of treatment, the change in average outcome measures for the control and treatment group firms should be similar. Based on our data, we assess whether common counterfactual trends is a plausible assumption by exploring the trajectory of the average outcome variable in pre-reform years. In Figure 4, we demonstrate the time variation in our outcome variables for interest separately for treatment and control groups. In panel (a), we show the average probability to report zero taxable income. The two trends are parallel until the reform. After the reform, the average probability to report zero taxable profit drops significantly for the treatment group, but not for the control group. The drop in the average probability to report zero taxable profit is in line with our prediction that the CFC reform in Italy leads to a drop in the probability to shift profit out of the UK for Italian subsidiaries.

In panels (b) and (c), we show the average taxable income in level and in natural logarithm, respectively. If there is a clear intensive margin effect of the CFC regime, then we should expect the treatment group to report a substantially higher taxable income than the control group. Examining the patterns in Figure 4b, the average taxable profit for treatment group firms exceed the average for the control group firms only after the reform, nevertheless, we do not observe a clear impact of the policy at this margin. In panel (d), we show results using the logarithm of investment as an outcome variable. We define investment as total assets in period t minus total assets in period t-1. Before the reform, investment of Italian MNEs in the UK evolves in a similar way to that of Spanish MNEs. After the reform, investment of treated firms declines relative to that of control group firms. We now present the results of panel regressions that address the same question, controlling for time-varying firm-level characteristics alongside time-invariant company effects and time trends.

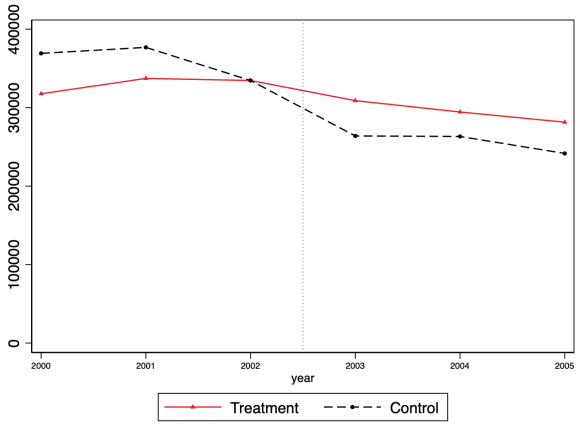
In Table 3, we present the baseline difference-in-differences results. In columns (1) and (2), we show results from panel regressions of the dummy variable that takes the value one for firms that report zero taxable income and zero for firms with positive taxable income. After the reform, treatment group firms reduce their probability to report zero

Figure 4: Trends in average propensity to report positive taxable income and average income by treatment status

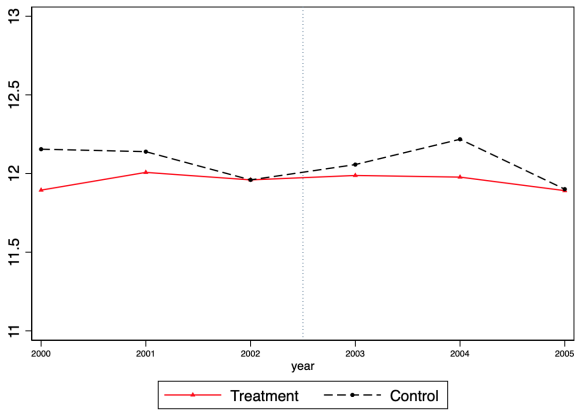
(a) Probability to report zero taxable profit



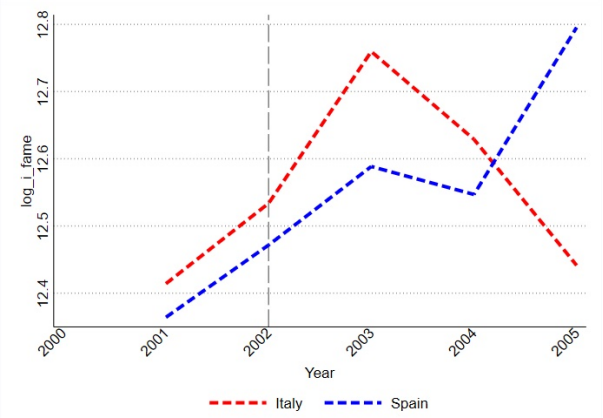
(b) Average taxable income (in level)



(c) Average taxable income (in log)



(d) Average investment (in log)



Note: In panel (a), we show the average probability to report zero taxable income in the United Kingdom (a high-tax country) for all sampled firms. In panel (b), we show the average taxable income ('Profits chargeable to Corporation Tax' in the UK corporation tax return) for firms that report positive taxable profit in all pre-reform years. In panel (c), we present average taxable income in natural logarithm. In panel (d), we show the evolution of the logarithm of investment, defined as the difference between assets in year and assets in year t-1. We present the trends separately for the treatment group of Italian-headquartered MNEs (red line) and for the control group of Spanish-headquartered MNEs (black, dashed line). We demean all observations to remove individual effects and rescale the two trends to overlap in the last pre-reform period. 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 3: Baseline reduced-form regression results

	Extensive Margin		*Intensive Margin*	
Outcome:	$\mathbb{1}$(Taxable Profit ≤ 0)		ln(Taxable Profit)	
	(1)	(2)	(3)	(4)
Treated × Post-reform	-0.065**	-0.054*	0.073	0.076
	(0.032)	(0.032)	(0.154)	(0.165)
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Year-Sector FE	N	Y	N	Y
No of obs	3876	3876	1096	1096

Note: This table shows the results of difference-in-differences regression estimates based on Equations 22 and 23. The results in columns (1) and (3) are based on a specification that includes firm and year effects, columns (2) and (4) are based on a specification that includes firm, year and sector-year effects. The sample in column (1) and (2) is the whole sample including all control and treatment group companies. The sample in column (2) and (4) includes only the firms with taxable profit in all pre-reform periods. Standard errors are clustered at the firm level.

taxable income in the UK by 5.4%. In columns (3) and (4), we show the intensive margin effect, in other words, the change in the average taxable income (in natural logarithm), after the reform. We find a positive and imprecise effect of the policy change on the average taxable income reported in the high-tax country (UK) after the CFC rule change for Italian-headquartered multinationals. In Appendix F, we show additional results demonstrating the robustness of the extensive and intensive margin profit-shifting effects (Tables 9 and 10).

The model shows that the rise in the tax haven tax rate increases the cost of capital for firms that have some taxable profit but that do not shift all of their taxable income to the tax haven. These firms would then reduce investment in the high tax country. In Table 4, we show the regression results based on the specification in Equation 24, and subsequently in Table 5, we show the effect on firms that we hypothesize would be affected the most – the group of firms with small losses in the pre-reform period, where we define 'small' loss to be below the median value of trading losses. We argue that firms with large losses and no taxable income would be incurring genuine losses and would not need to engage in a costly profit-shifting activity. Small loss-makers, on the other hand, would be the most likely candidates for being in the group of full-shifters in the pre-reform period. To the

extent that these full-shifters move from a small loss position to a profitable position with a reduction in the tax saving from profit-shifting, they should both become less likely to report zero taxable income in the high tax country and should reduce investment in the high tax country. We find a negative, but insignificant, average effect on investment by all treated firms in Table 4. Refining the sample to the most-likely affected group of firms with zero taxable income and small losses in the last pre-reform period, we show that these firms respond by strongly and significantly reducing their investment in the high-tax country. In Appendix F, we show that the extensive margin taxable income response for the group with small (below median) losses in the final pre-reform period is larger (about twice as large) in magnitude than the overall response.

Table 4: Effect of policy change on average investment in the high-tax country, all firms

Outcome: ln(investment)	(1)	(2)	(3)	(4)	(5)
Treated × Post-reform	-0.100	-0.092	-0.097	-0.073	-0.076
	(0.129)	(0.128)	(0.129)	(0.137)	(0.138)
Total assets, lagged	-0.000**		-0.000**		0.000
	(0.000)		(0.000)		(0.000)
Firm FE?	Y	Y	Y	Y	Y
Year FE?	N	Y	Y	Y	Y
Sector-Year FE?	N	N	N	Y	Y
N	1525	1525	1525	1522	1522

Note: This table shows the results of difference-in-differences regression estimates based on Equation 24. The outcome variable in all columns is the logarithm of investment, which we define as total assets in period t minus total assets in period t-1. Across columns, we include a different set of fixed effects and in odd columns, we additionally control for for the lagged value of total assets. Standard errors are clustered at the firm level.

5 Structural profit-shifting elasticities

In this section, we present structural estimates for the parameters of the distribution of our key *fixed* investment for tax avoidance price p and the variable cost γ of this model, using an indirect inference approach (Gallant and Tauchen; 1996; Gourieroux et al.; 1993). In our method of simulated moments (MSM) procedure, we simulate firms over unobserved productivity draws with $\varepsilon_i \sim \mathcal{N}(0, \sigma^2)$. Our structural estimates minimize the MSM criterion

Table 5: Effect of policy change on average investment in the high-tax country, firms with zero taxable income and small reported trading losses

Outcome: ln(investment)	1	2	3	4	5
Treated × Post-reform	-0.406*	-0.418*	-0.434*	-0.621**	-0.628**
	(0.240)	(0.238)	(0.240)	(0.270)	(0.272)
Total assets, lagged	-0.000***		-0.000***		0.000
	(0.000)		(0.000)		(0.000)
Firm FE?	Y	Y	Y	Y	Y
Year FE?	N	Y	Y	Y	Y
Sector-Year FE?	N	N	N	Y	Y
N	445	445	445	437	437

Note: This table shows the results of difference-in-differences regression estimates based on Equation 24. Here, we limit the sample to firms with small losses in the pre-reform period, where we define 'small' loss to be below the median value of trading losses. The outcome variable in all columns is the logarithm of investment, which we define as total assets in period t minus total assets in period t-1. Across columns, we include a different set of fixed effects and in odd columns, we additionally control for for the lagged value of total assets. Standard errors are clustered at the firm level.

function, which takes the form:

$$L(\Theta) = h(\Theta)^{'} W_N h(\Theta) \tag{25}$$

where Θ is the vector of structural parameters of interest. $h(\Theta)$ is the vector of M moment conditions constructed as the difference between simulated moments computed over S simulated firms and empirical moments computed over the population of corporation tax returns composed of N companies. As the weight matrix, we use the diagonal elements of the inverse variance-covariance matrix of empirical moments.

The policy environment consists of a *high-tax* location, a *low-tax* location and a *tax haven*. All real investment takes place in the high-tax and the low-tax countries, but profit is then shifted to the tax haven. The high-tax location in our case is the United Kingdom with 30% main corporate income tax rate over the relevant period. We envisage a low-tax location with 20% rate, but the availability of this alternative investment location in the model does not have a material impact on our estimates. The tax haven initially applies a tax rate of zero percent, which subsequently rises to 13.75% after the introduction of the CFC reform for treatment group companies, but the haven rate remains at 0% for the control group. We assume that the entry cost parameter $\bar{\phi}$ in Equation 4 is zero for the MNEs that are in our sample. We assume that the set-up cost for a network of subsidiaries is absorbed into

the cost of the tax avoidance intangible captured at the MNE level by p_i and for which the distribution over firms is uniform between zero and $\bar{p}$.

We estimate production function parameters outside of the MSM procedure and find consistent estimates across various specifications. In Equation 11, we propose a static constant returns to scale (CRTS) production function that can be linearized and estimated as follows:

$$\ln R_{ij} = \ln \theta + A \ln K_{ij} + \varepsilon_{ij} \tag{26}$$

where R_{ij} is the output of subsidiary j that belongs to MNE i. We recover the production function parameters from the regression of the turnover (in natural log) on capital (in natural log) at the firm level.

In Table 6, we present the estimates from our preferred specification and show additional results in Appendix E. We estimate that the elasticity A of output with respect to productive capital K is 0.578, and the total factor productivity θ (in log) is 5.979. We then take the residuals from this regression and use the standard deviation of residuals as an assumed parameter in our MSM procedure.

In our MSM procedure, we use simulated annealing with a simulated dataset size of 100,000, matching key reduced-form moments to their simulated counterparts. We argue that the list of moments in Table 7 are useful in identifying the structural parameters $\bar{p}$ and γ.

We estimate that the unit cost of the tax avoidance intangible is distributed uniformly over the interval $(0, 2)$, meaning that the unit cost of the tax avoidance intangible is twice as high as the unit cost of productive capital. We also estimate the convex cost parameter γ to be significant, but not very large, at 0.36. We infer that the inclusion of what we call the *fixed* tax avoidance cost also helps to pin down the convex cost parameter more precisely.

Model fit is satisfactory, with simulated moments estimated to be 0.095 for the intensive-margin reduced-form coefficient, relative to the corresponding data moment of 0.073 (0.154) and -0.040 for the extensive-margin reduced-form coefficient, relative to the corresponding data moment of $-0.065^{**}(0.032)$.

Table 6: Structural estimates

	Assumed and Estimated Parameters		Method
δ:	Depreciation Rate, assumed	0.1	Assumed
β:	Discount Factor, assumed	0.95	Assumed
$\hat{\bar{p}}$:	Upper bound, cost of intangible	2.000***	MSM
		(0.239)	
$\hat{\gamma}$:	Convex cost of shifting	0.120***	MSM
		(0.003)	
$\hat{\theta}$:	Total factor productivity (in log)	5.979***	Regression
		(0.081)	
$\hat{a}$:	Output elasticity wrt K	0.0.578***	Regression
		(0.005)	
$\hat{\sigma}$	Std.dev of productivity draw	1.507	Post-estimation residuals
$\hat{\sigma_\Pi}$	Std.dev of linear demand shock	1000	Calibrated

Note: This table shows the assumed parameters, the parameters estimated outside of the MSM procedure and our estimates for the structural profit-shifting cost parameters using our MSM procedure. We use the diff-in-diff coefficient estimates from Section 4 to match to simulated counterparts, as well as the level of average (log) taxable income and the share of reporters of zero taxable profit for the control group in the pre-reform period.

Table 7: List of moments that identify key structural parameters

			Param.		
Type	Description	Empirical moment	$\bar{p}$	γ	σ_Π
Treated $\times$ Post-ref. coeff.	Spec. in Eq.24; ext. margin	$\hat{\beta}_0$	✓	✓	
Treated $\times$ Post-ref. coeff.	Spec. in Eq.26; capital	$\hat{\beta}_2$	✓	✓	
Pre-reform mean	ln Revenue / Assets	$f(K)/K$, mean	✓	✓	
Pre-reform s.d.	ln Revenue / Assets	$f(K)/K$, s.d.	✓	✓	
Pre-reform mean	Trading Profit	$(f(K)-\Pi)/K$, mean			✓
Pre-reform s.d.	Trading Profit	$(f(K)-\Pi)/K$, s.d.			✓
Pre-reform mean	$\ln$(assets)	$\ln(K)$, mean	✓	✓	
Pre-reform mean	$\ln$(Taxable Profit$_{it}$)	$\ln$(Taxable Profit$_{it}$), mean	✓	✓	

6 Discussion: reconciling micro- and macro-level estimates of profit-shifting elasticities

As Beer et al. (2019) describe in their meta-study, the estimates of profit-shifting semi-elasticities vary substantially between studies. For example, the average semi-elasticity in Hines and Rice (1994) is 5.16 (in absolute value), while Collins et al. (1998) estimate it to be 0.32. More recent micro papers which use more flexible functional assumptions for the relationship between profits and tax rate differential find larger semi-elasticties (Dowd et al.; 2017; Garcia-Bernardo and Janskỳ; 2022). Further, the majority of previous estimates were done using financial statements, rather than tax returns data. Given that Bilicka (2019) documents much larger bunching at zero for taxable profits than for financial profits, we may expect the semi-elasticities calculated using taxable profits to be larger.

As such, there are three major ways in which our approach differs from the earlier treatments of profit-shifting in the literature. First, we modify the profit-shifting cost structure to demonstrate the impact of investment in a tax avoidance network. Second, by modeling the nonconvex profit-shifting cost, we also account for zero profit-reporting MNEs in a jurisdiction in our elasticity calculation. This naturally leads to a comparison between macro-level and micro-level semi-elasticities of declared profit in a jurisdiction with respect to the tax rate differential with the lowest tax haven tax rate. Combining these first effects, we find that the macro-level profit-shifting elasticity is 24% higher than the micro-level profit-shifting elasticity that ignores zero taxable income reporters.

Third, we model unobserved heterogeneity across firms in their ability to shift profits to tax havens through the idiosyncratic price of the tax avoidance intangible faced by the multinational, p_i. The most flexible multinationals in their profit-shifting ability respond to changes in the tax rate differential 17 times more than the average micro-level elasticity and 13 times more than the macro-level elasticity. The macro taxable income elasticity estimate of -1.9% (in response to a percentage point rise in the tax rate differential) masks the high-elasticity firms' response of around -28% and the low elasticity firms' response of close to zero. The policy response depends on what types of firms the government would like to tax. Often, in policy discussions, government officials point at 'the worst offenders' as the digital firms such as Google or Facebook. Arguably, these firms are in the high-elasticity group as they face low prices to set up tax avoidance networks thanks to the nature of their business.

7 Counterfactual policy experiments

The model that we have developed in Section 2 provides a convenient tool to examine the effects of counterfactual policies relating to investment and profit shifting. Governments have varied tax rates and tax bases to stimulate investment, and have reduced tax rates and introduced various anti-avoidance measures to combat profit shifting and avoidance. Recently, as we have outlined in Section 1, over 140 countries have agreed in principle to set a global minimum effective tax rate of 15%. The details of the proposal are complex. However, in the context of our model, where there is no real activity in the haven country, the minimum tax would simply raise τ_X to 15%. There is some uncertainty in the outcome of which country would collect the additional revenue generated. Here we consider only the welfare of the world as a whole, and so we can neglect the allocation of revenues across countries.

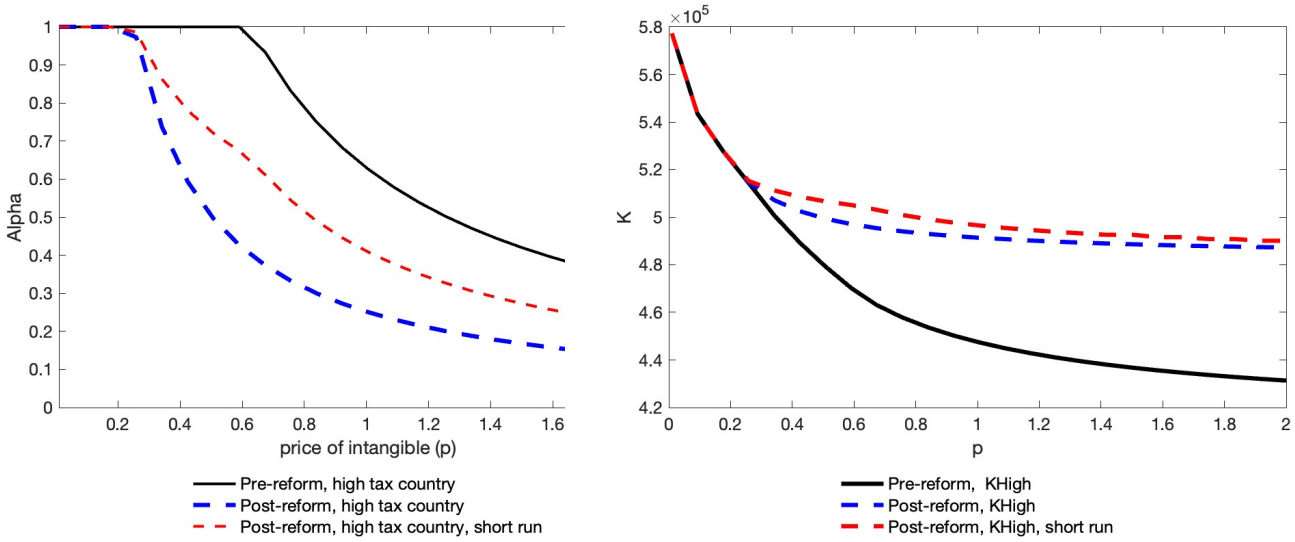
We consider two policy experiments, which have different characteristics. First we consider a reduction in τ_H, the tax rate in the high tax country. To begin with, we consider a relatively large change, reducing the tax rate from 30% to 20%. Second, we model a simple version of global minimum tax (GMT), which implies raising τ_X to 15%.

Impact on investment and profit shifting. Figure 5 sets out the impact on investment and profit shifting of a reduction in τ_H from 30% to 20%. It shows the heterogeneity of effects across firms, based on the price of the intangible asset, p, that each firms faces.

The original position is given by the unbroken black line, indicating both the extensive and extensive margin effects of p on profit shifting. Firms with values of p_i below a cut-off point of around 0.7 shift all of their profit; the proportion of profit shifted then declines as the cost of profit shifting, p, rises above this cut-off. Investment also declines as p increases even below the cut-off point - a higher p increases the cost to the firm of shifting profit and this translates into a higher cost of capital, even though the firm does not pay any tax. For values of p above the cut-off point, firms pay tax so that the cost of capital rises further and investment declines further.

At a lower value of τ_H, there is a similar pattern for the extent of profit shifting. However, the lower tax rate reduces the marginal benefit of shifting. We distinguish between a long-run and short-run effect. By short-run, we consider the case in which investment in the intangible asset, Y, is set before the tax reform is announced, and is therefore based on the belief that the tax rate will be 30%. However, despite Y being fixed in the short run, the lower tax rate is apparent to the firm at the end of the period when it chooses how much

Figure 5: Effects of reducing the high-tax country tax rate from 30% to 20%



(a) Proportion of profit shifted

(b) Capital

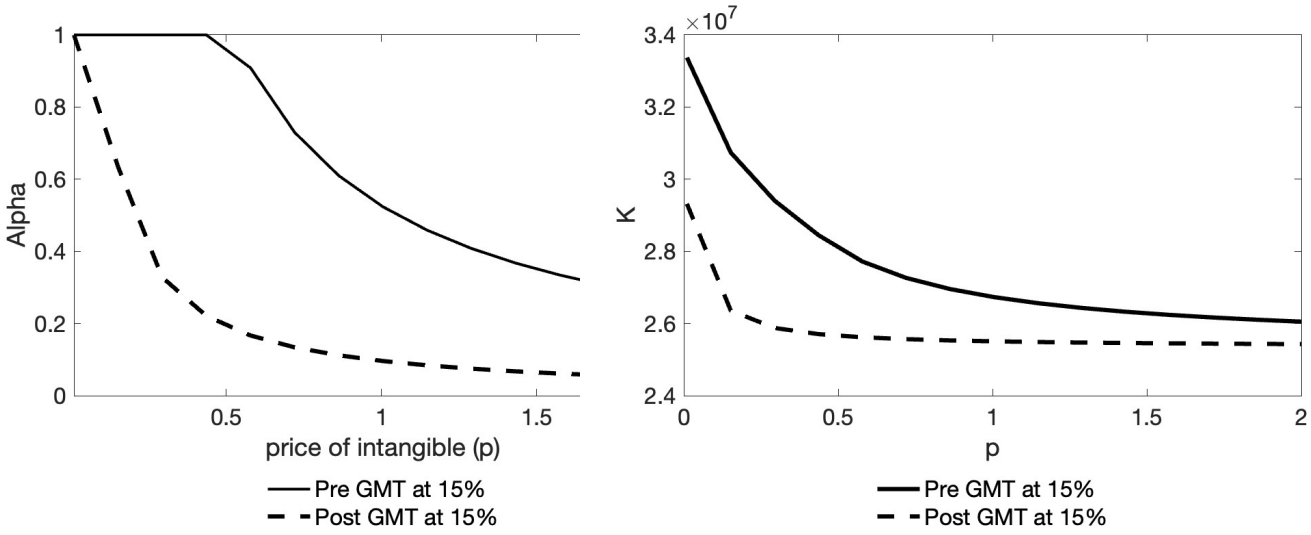
profit to shift. As a result, the cut-off value of p is much lower, at around 0.25. For values above this, the firm no longer shifts all of its profit, and the proportion shifted is lower for all values of p above the cut-off. For the long-run effect, we consider the case in which the firm knows that the τ_H is 20% when it invests in Y. this induces the firm to invest less in Y. This induces an even lower cut-off point, at less than 0.2, and even less profit shifting for values of p above this cut-off.

Figure 6 sets out an equivalent analysis for a different tax reform: the GMT, or more specifically in the context of our model, raising τ_X from zero to 15%, keeping τ_H at 30%.

The unbroken black lines represent the situation before the reform and are identical to those in Figure 5. Again, we consider a short-run and long-run impact of the tax reform. The impact of the GMT on profit shifting is broadly similar to the impact of reducing τ_H, though the effects are larger than a 10 percentage point cut in τ_H. Both reforms reduce the benefit of profit shifting, and so the cut-off point for paying any tax is lower than before the reform. In this case, the cut-off point for the long-run is around zero, implying that the reform would largely eliminate the case in which firms shift all of their profit.

However, this reform has an opposite effect on investment. This is clearly because the overall tax rate rises - with less shifting, more profit is taxed at a rate of τ_H, and even profit that is shifted now faces a rate of 15% instead of zero. The impact of higher tax liabilities

Figure 6: Impact of 15% GMT on profit-shifting and capital accumulation



(a) Proportion of profit shifted

(b) Capital

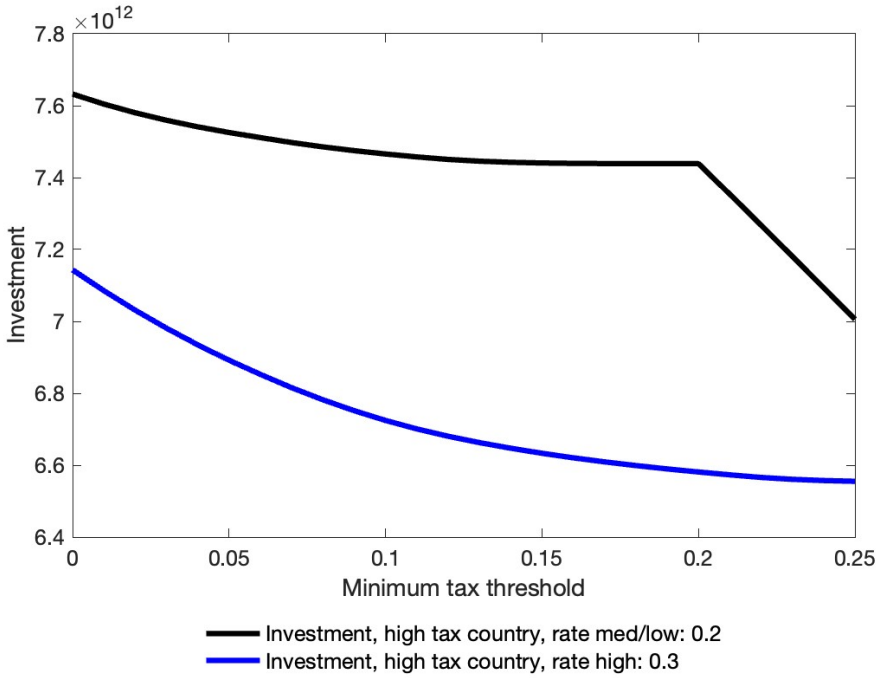
at the margin outweigh the reduction in marginal profit shifting costs, raising the cost of capital overall, and hence reducing investment. This effect is stronger in the long-run, where the firm also invests less in the intangible asset.

In Figures 7 and 8 we analyse the impact of the GMT on aggregate investment in the high tax country and the share of aggregate "true" profit shifted from the high tax country to the haven. Instead of showing heterogeneity across firms, we show these aggregate responses for a range of values of the minimum tax threshold, from zero to 25%. We show this for two alternative values of τ_H, 20% and 30%.[17]

Figure 7 shows that the impact of the GMT on investment is greatest when τ_H is highest. This is the case where profit shifting is greatest, as shown in Figure 8; profit shifting in this case therefore has the strongest impact on the cost of capital. Marginally reducing the benefits of shifting profit, by raising the minimum tax threshold, has a greater impact on the cost of capital and hence investment in this case. There is also a striking impact on investment where the minimum tax threshold meets τ_H; above this, there is no profit shifting, and the marginal tax rate is equal to the minimum tax threshold. Further increases in the threshold then raise the cost of capital more strongly, with a corresponding impact

[17]Note that, in this exercise, we simplify the GMT proposal in several important ways. Notably, we exclude any adjustment for relief for the "substance-based income exclusion" (SBIE).

Figure 7: Impact on investment of global minimum tax at varying threshold rates



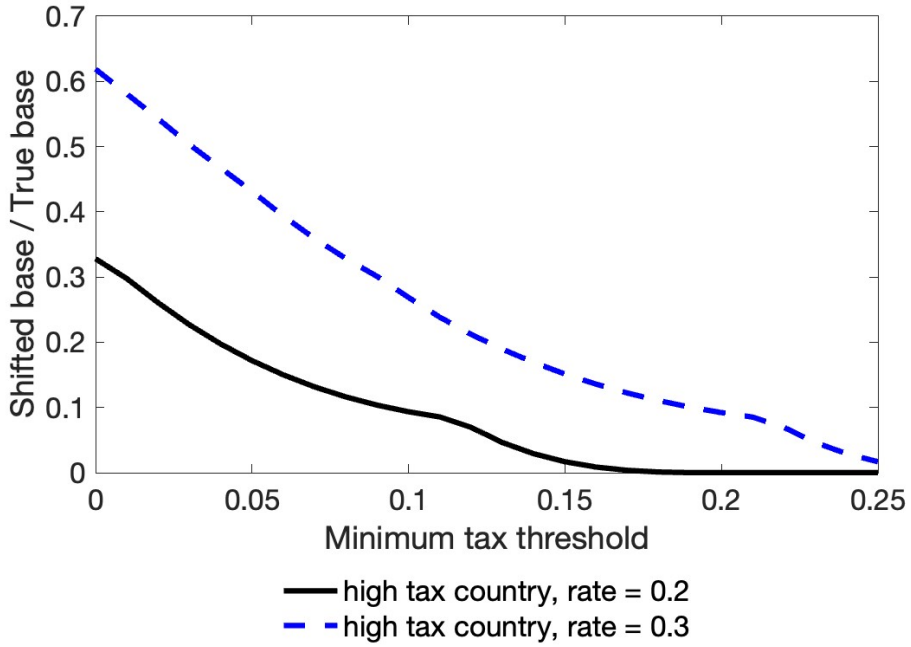
Note: $x-$axis values show the different minimum tax thresholds, and the vertical axis shows the aggregate investment values at each global minimum tax threshold value. We depict the values for two hypothetical countries; one with a high-tax country tax rate of 20 percent and the other with a high-tax country tax rate of 30 percent. The low-tax country tax rate is assumed to be 12.5 percent.

on investment.

Figure 8 shows that just over 60% of MNE profit would be shifted out of a high tax country with a tax rate of 30% if there is the possibility of shifting it to a zero-rate haven. This proportion is much lower, at just over 30% if the tax rate were only 20%. Both these proportions fall strongly as the minimum tax threshold is increased. At a 15% threshold, shifting from a country with a corporate tax rate of 20% would be largely eliminated (since the gross benefit would be only 5 percentage points). There would still be considerable shifting from a country with a 30% tax rate, though even this would be much diminished by the introduction of the GMT.

In sum, the GMT would clearly reduce both aggregate profit shifting and aggregate investment. These have opposite effects on global welfare; we therefore now turn to measures of welfare that take account of both effects.

Figure 8: Impact of global minimum tax at varying threshold rates on aggregate profit shifting from high tax country



Note: $x-$axis values show the different minimum tax thresholds, and the vertical axis shows the aggregate proportion of true profit shifted at each global minimum tax threshold value. We depict the values for two hypothetical countries; one with a high-tax country tax rate of 20 percent and the other with a high-tax country tax rate of 30 percent. The low-tax country tax rate is assumed to be 12.5 percent.

Impact on welfare. As set out in Section 2.5, our framework enables an analysis of the welfare consequences of tax reforms, taking into account both the effect on profit shifting and on investment. In our model there are two sources of deadweight costs. First, taxes tend to increase the cost of capital, thereby reducing investment and hence private wealth. This effect can occur even if profit is fully shifted to a zero-rate haven, as the marginal costs of shifting also increase the cost of capital. Second, we treat the costs of the intangible shifting asset, and the marginal costs of profit shifting, as deadweight costs. They arise only in the context of avoiding tax, and represent costs that are unproductive for society as a whole. Strictly, if these costs represent, for example, the time of lawyers and accountants engaged in profit shifting, the deadweight cost of diverting their time to tax avoidance would be the output that they would otherwise create in the time that would be available. We measure this by the actual costs incurred by firms.

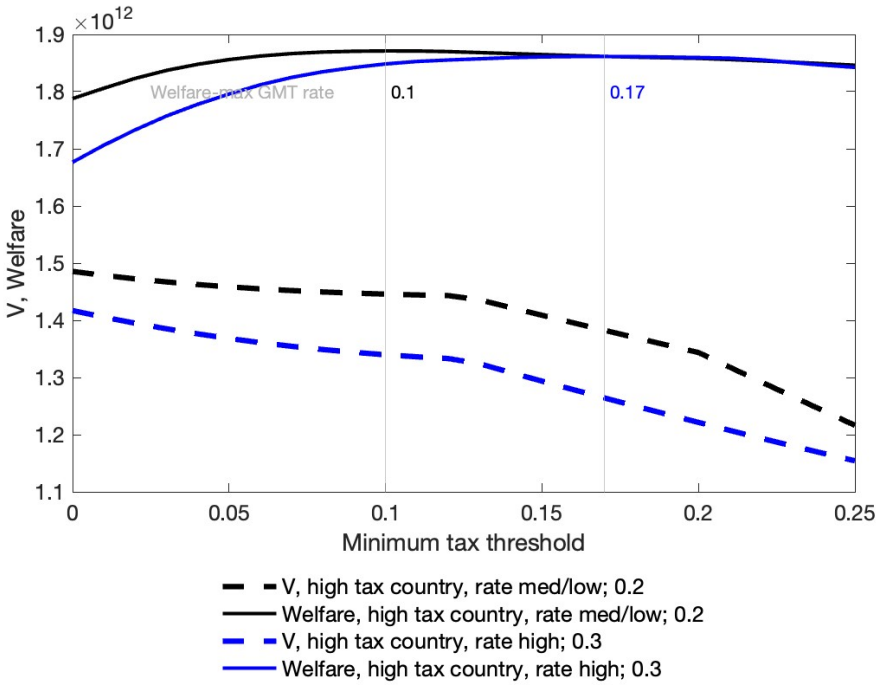
In Figure 9, we set out estimates of global welfare generated in our model in the presence of the GMT for values of the threshold between zero and 25%. We value an additional $1 of government expenditure at $1 - that is $\mu' = 1$.

As the GMT threshold increases, there are offsetting effects on welfare. First, since the benefits of profit shifting shrink, firms spend less on profit shifting - both through the purchase of Y and through the marginal costs. This represents an unambiguous gain in welfare. Second, as described above, as the GMT threshold rises, the cost of capital also rises, and hence depresses investment. This is an unambiguous fall in welfare. The net impact on welfare of a given GMT threshold therefore depends on the relative size of these two effects.

Figure 9 reports the consequences for welfare of the introduction of a GMT under two different values of τ_H. It also shows the value of aggregate private wealth, the sum of V_i, under the same two scenarios. Not surprisingly, V_i falls as the GMT threshold increases, for all values of τ_H, since firms pay progressively more tax, and this tax is not fully offset by the reduction in shifting costs. There is a kink in the values of V_i corresponding to the kinks in Figure 7.

Welfare initially rises and then declines as the GMT threshold increases. At low levels of the threshold, then, the gains from reducing profit shifting outweigh the losses associated with declining investment. This gain is larger the higher is τ_H, reflecting the proportionately greater reduction in profit shifting from higher-taxed countries. Eventually, the rise in the overall tax rate creates a more significant impact on investment, which at the margin begins to outweigh the benefits of reducing shifting costs. The model therefore identifies an optimal threshold of the GMT. That optimum depends on τ_H, and is at a higher thresh-

Figure 9: Impact on welfare of global minimum tax at varying threshold rates



Note: $x-$axis values show the different minimum tax thresholds, and the vertical axis shows the aggregate investment values at each global minimum tax threshold value. We depict the values for two hypothetical countries; one with a high-tax country tax rate of 20 percent and the other with a high-tax country tax rate of 30 percent. The low-tax country tax rate is assumed to be 12.5 percent. The marginal value of public funds is assumed to be one.

old the higher is τ_H. Overall, the optimal threshold is close to that proposed, of 15%.

This analysis also illustrates the total marginal distortion of the combined taxes at different rates. That is, we can alternatively calculate the MVPF for each value of the GMT threshold. At low levels of the GMT threshold, the MVPF is greater than 1; this is consistent with welfare rising at such levels. As the threshold rises further, the MVPF declines, until beyond, $\tau_X = 0.17$, it falls below 1, consistent with a falling welfare for further rises in the threshold.

8 Conclusion

Using administrative data from the UK and global ownership information, we document the patterns of zero taxable income reporting by multinationals (MNEs) both descriptively and in a difference-in-difference setting that changed the effective tax haven tax rate for a subset of MNEs that operate in the UK. We use these reduced-form observations to guide a flexible model that demonstrates extreme profit-shifting behavior that fits the data well. The model identifies the impact of taxes on investment, and the impact of profit shiftign on investment.

Four new takeaways emerge from our analysis. First, there is large unobserved heterogeneity across MNEs in their profit-shifting responses to tax system changes. Second, 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. Third, we quantify the trade-off between combating tax avoidance and increasing the cost of capital for MNEs that engage in tax avoidance. Fourth, we show that in principle the GMT has ambiguous effects on total welfare, as reduced costs of profit shifting must be set against lower investment. In our model, the welfare gain from the reduction in profit shifting dominates at low levels of the GMT threshold, although at higher thresholds the adverse effect on investment dominates.

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Appendices

A Production Functions

A.1 Simple Case

Choose K and L to maximise profit:

$$\pi = p(Y)Y - rK - wL \tag{27}$$

where

$$Y = AK^{\alpha}L^{\beta} \tag{28}$$

Profit maximising choices require either imperfect competition or non-constant returns to scale. We leave both options open.

Conditional on K, the optimal L is given by

$$\pi_L = (p_Y Y + p)Y_L - w = 0 \tag{29}$$

Rearranging,

$$p(1 - \frac{1}{\epsilon})\beta AK^{\alpha}L^{\beta-1} = p(1 - \frac{1}{\epsilon})\beta\frac{Y}{L} = w \tag{30}$$

where

$$\epsilon = -Y_p\frac{p}{Y} \tag{31}$$

which is a function of Y. Define $R = p(1 - \frac{1}{\epsilon})$ to be marginal revenue.So

$$L = \frac{R\beta}{w}Y \tag{32}$$

Then

$$Y = AK^{\alpha}(\frac{R\beta}{w}Y)^{\beta} = (\theta K^{\alpha})^{\frac{1}{1-\beta}} \tag{33}$$

where

$$\theta = A(\frac{R\beta}{w})^{\beta} \tag{34}$$

In the case of constant returns to scale in K and L, so that $\alpha + \beta = 1$, this is

$$Y = \theta^{\frac{1}{1-\beta}}K \tag{35}$$

where, to recall in the absence of perfect competition, θ depends on Y. With perfect competition and CRS, the optimal scale of the investment / company is not defined.

A.2 Slightly More Complicated Case

Now think of A reflecting some knowledge capital, and set out a production function as:

$$Y = A^{\phi}(K^{\alpha}L^{\beta})^{1-\phi} \tag{36}$$

which imposes CRS on A and the composite of K and L.
Conditional on K, the foc for L is

$$L = \frac{R\beta(1-\phi)}{w}Y \tag{37}$$

Substituting,

$$Y = A^{\phi}(K^{\alpha}(\frac{R\beta(1-\phi)}{w}Y)^{\beta})^{1-\phi} \tag{38}$$

So

$$Y^{(1-\beta(1-\phi))} = A^{\phi}(\frac{R\beta(1-\phi)}{w})^{\beta(1-\phi)}K^{\alpha(1-\phi)} \tag{39}$$

$$Y = \theta^{\lambda}K^{\alpha(1-\phi)\lambda} \tag{40}$$

where

$$\theta = A^{\phi}(\frac{R\beta(1-\phi)}{w})^{\beta(1-\phi)} \tag{41}$$

and

$$\lambda = \frac{1}{1-\beta(1-\phi)} \tag{42}$$

B Alternative specifications

B.1 Accounting for dispersion in the price of the tax avoidance asset

[results here.]

C Guiding cases

Consider first the case in which $0 < \alpha_{ij} < 1$ for subsidiary j. Then the first order condition for α_{ij} and K_{ij} is:

$$\alpha_{ij} = \frac{(\tau_{ij} - \tau_X)}{\gamma}(\frac{Y_i}{B_{ij}})^m \tag{43}$$

$$F_K(K_{ij}^{\text{Interior}}) = \frac{r}{1 - \tau_{ij} + (1-m)\frac{\gamma}{2}\left(\frac{B_{ij}}{Y_i}\right)^m \alpha_{ij}^2} + \delta \tag{44}$$

Note that Equation 44 has an additional term in the denominator compared to the traditional case with no profit-shifting. In what might be regarded as a normal case, we would expect this term to be positive, lowering the cost of capital and hence raising the optimal level of the tangible capital stock, K_{ij}. This requires $m < 1$.

If $\alpha_{ij} = 1$, the first order condition for K_{ij} becomes:

$$F_K(K_{ij}^{\text{Full shifting}}) = \frac{r}{1 - \tau_X - (1+m)\frac{\gamma}{2}(\frac{B_{ij}}{Y_i})^m} + \delta \tag{45}$$

In Equation 45, the cost of capital is independent of the domestic tax rate τ_j, since all profit is shifted to the haven, but now the haven tax rate, τ_X is relevant. Note though, that even if $\tau_X = 0$, tax still has an indirect impact on the cost of capital through the marginal cost of profit-shifting in the last term of the denominator.

The optimal choice of tangible capital K_{ij} for each subsidiary still depends on the optimal level of Y. With $Y_i > 0$ there are three possible outcomes of interest that generate kinks in the policy function:

1. $0 < \alpha_{ij} < 1$ for all α_{ij};
2. $0 < \alpha_{ij} < 1$ for at least one subsidiary j, and α_{ij}=1 for at least one subsidiary j;
3. $\alpha_{ij} = 1$ for all α_{ij}.

Using the functional form for $c\left(\alpha_{ij}, Y_i, B_{ij}\right)$ set out above, the first order condition for Y_i is:

$$Y_i = \left\{ \frac{m\gamma}{2p(1+r)} \sum_{i=1}^{N} B_{ij}^{1+m} \alpha_{ij}^2 \right\}^{\frac{1}{1+m}} \tag{46}$$

D Model solution

We now illustrate the properties of the model in a numerical simulation. We consider a multinational with real activities in two subsidiaries, one in a relatively high-tax country, H and one in a relatively low-tax country, L. In our base case the tax rates in the two countries are 30% and 20% respectively. The multinational also has a third subsidiary, located in a tax haven, initially with a zero tax rate. The multinational optimally chooses its investment in the tax avoidance asset, Y, the tangible capital located in H, K_H, and L, K_L, and the proportion of the tax base shifted to the haven from H, α_H, and from L, α_L.

D.1 Base case

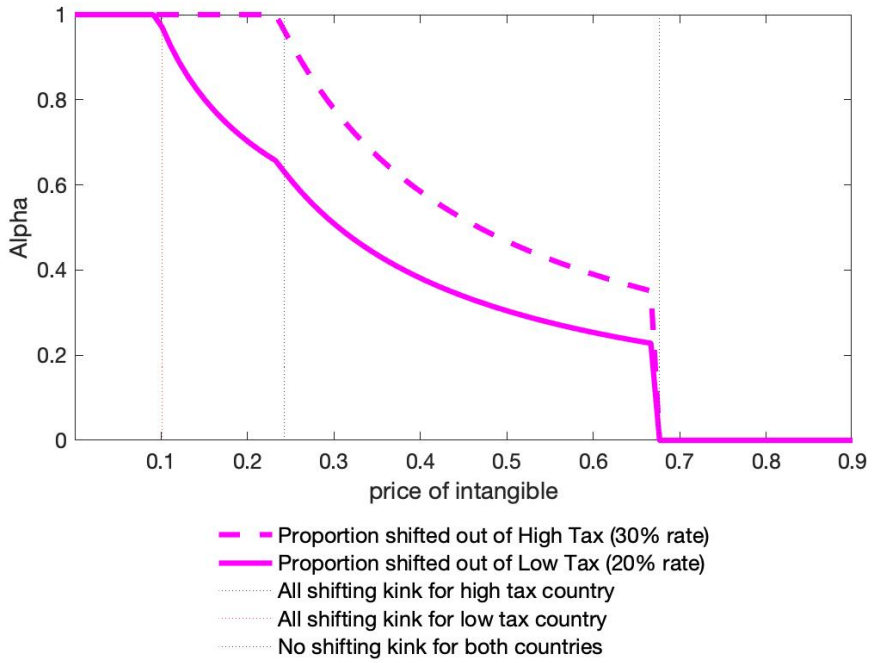
Figure 10 illustrates the choices of α_H and α_L for a range of values of the unit price of Y, p. The price of a unit investment in physical capital is normalized to one. Values of the structural parameters used in this base case are: $\gamma = 0.2$, total factor productivity $\theta = 0.9$, output elasticity with respect to physical capital $a = 0.65$, depreciation rate for physical capital $\delta = 0.1$. We also allow for a fixed cost of investing in the tax avoidance intangible of ϕ that only applies to those firms with any profit-shifting. In the simulations, we set ϕ to be 0.2. The dashed line shows α_H and the continuous lines shows α_L.

The Figure is mostly easily interpreted as the value of p falls from 1. At the right had since of the Figure, for $p = 1$, $\alpha_H = \alpha_L = 0$ - there is no profit shifting from either country. As shown in 11, this reflects the fact that the multinational has also not invested in the tax avoidance asset, Y. However, as p falls to around 0.68, it becomes worthwhile for the firm to invest in Y. As p falls further, investment in Y increases (Figure 11). The higher Y reduces the variable costs of profit shifting, and so both α_H and α_L rise (Figure 10).

There are two offsetting effects on the relative values of α_H and α_L. First, the higher tax rate in H would induce more profit shifting. Second, however, the tax base in L is higher, since K_L is higher, as set out below. The first of these effects dominates in our base case, so that over this region $\alpha_H > \alpha_L$. However, this depends on the productivity in each location: for example, if L is more productive ($\theta_L > \theta_H$), then it is possible for this ordering to be reversed.

In this base case, we are assuming the same production functions in H and L ($\theta_L = \theta_H$). In the absence of profit shifting, for $p > 0.68$, the difference in tangible capital between the two countries is determined only by the difference in tax rates, implying that $K_L > K_H$. This is shown in Figure 12, where again H is represented by the dashed line and L by the

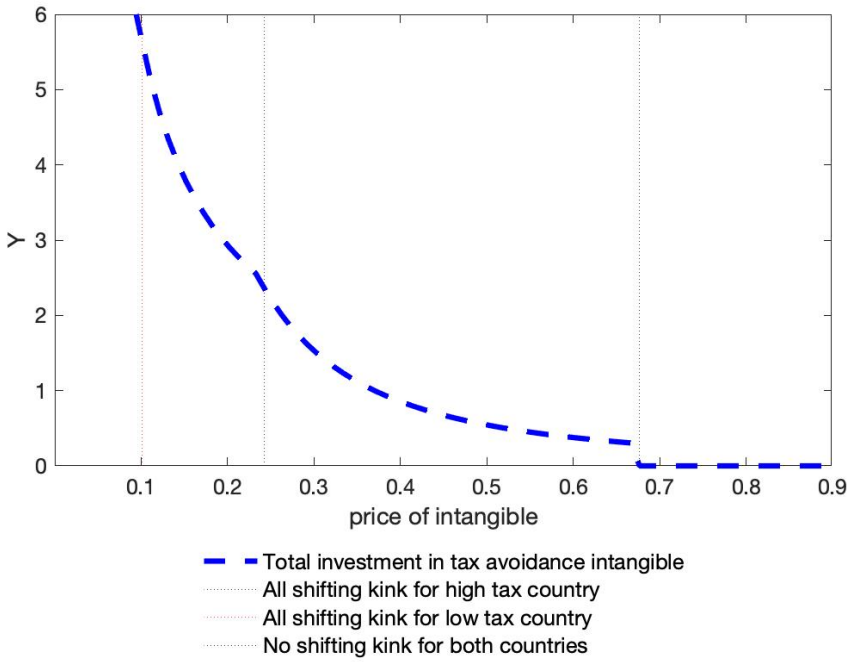
Figure 10: Extent of profit shifting in H and L



unbroken line. However, at values of p where both subsidiaries begin to shift profit, the tax rates fall in both countries, and so K_L and K_H both rise. Note that the difference in the "effective" statutory tax rates is diminished due to profit shifting, and so K_H rises more quickly than K_L.

As p falls to around 0.24, profit shifting from H hits the constraint of $\alpha_H = 1$. All profit in H is shifted to the haven; no tax is then paid in H, although H continues to bear the variable costs of shifting. This reduces the marginal benefit of Y, generating a small kink in Y, and also in K_H. The same happens for L when p reaches around 0.09. At this point, all profit is being shifted to the haven, and no tax is paid anywhere. At this point, there is no benefit in increasing Y any further, and so Y is at its maximum level for all values of p below this. At this point, investment in tangible capital is no longer affected by tax, but it is affected by the costs of profit shifting. However, the costs of profit shifting are now the same in H and L, and so K_H and K_L are also equal. Lowering p further does not induce more investment in Y, but it does reduce costs for the multinational, resulting in further increases in both K_H and K_L.

Figure 11: Investment in the Tax Avoidance Asset Y



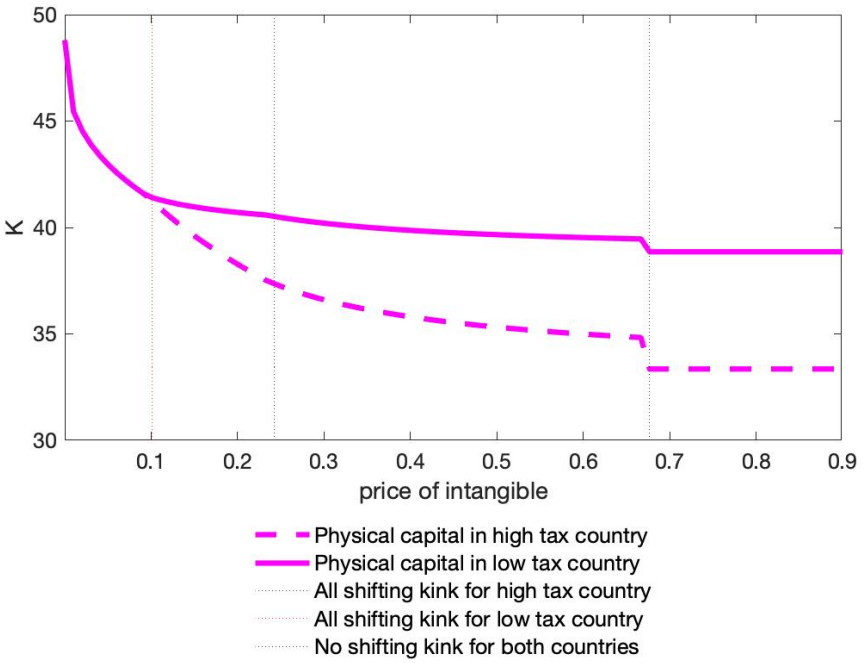
D.2 Minimum worldwide tax

In October 2021, the OECD's Inclusive Framework agreed to introduce a worldwide minimum tax at a 15% effective tax rate. This would be implemented in the first instance by the country of the parent introducing a tax to top up any tax in any other location to make it up to at least 15% of profit. A key aim of this policy is to raise more tax revenue from profit, either by more tax being levied from profit arising in low-tax jurisdictions, or by discouraging profit being shifted to such countries in the first place. We now consider the likely effects of this policy in the context of our model, and the base case set out above.

We model the minimum tax by raising the tax rate in the tax haven to either 5% or 15%. This clearly reduces the benefits from shifting profit to the haven. This in turn reduces the incentive to invest in the tax avoidance asset, Y, and so makes it more likely that multinationals will respond on the extensive margin by no longer shifting any profit.

Figure 13 describes the impact on profit shifting in our base case. The Figure reproduces the position in the absence of the minimum tax from Figure 10. The new lines represent the case of the minimum tax at 5% and 15%. Given the parameters in the base case, this has a dramatic impact on profit shifting. At a minimum tax of 5%, the multinational chooses

Figure 12: Investment in tangible capital, K_H and K_L

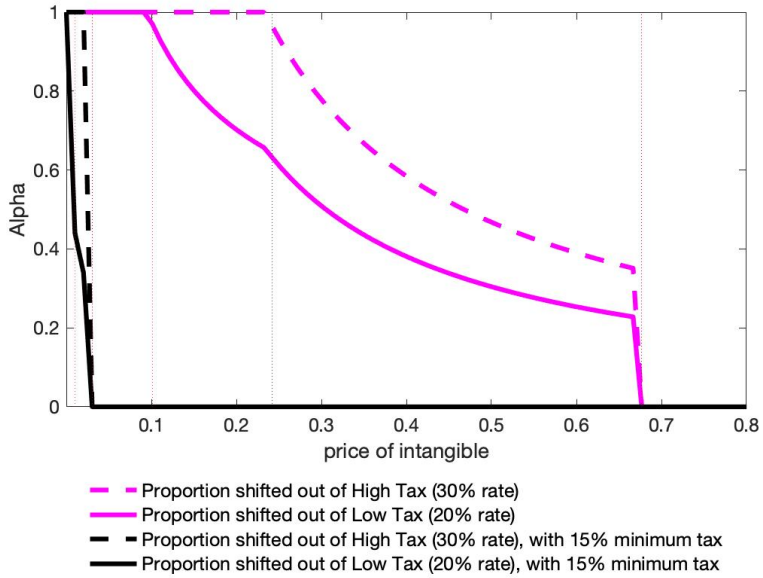


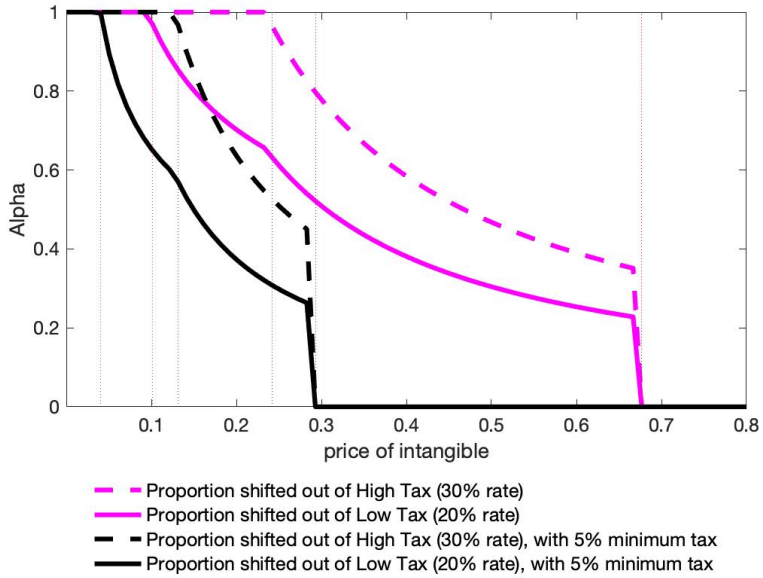
not to invest in Y unless its price is below around 0.3. For a minimum tax of 15%, this falls to 0.04. In the latter case, especially, apart from at very low values of p - which in the absence of the minimum tax yielded 100% profit shifting in both H and L - the minimum tax prevents any profit shifting from taking place. For low values of p, the subsidiary in country H moves almost directly from zero profit shifting to full profit shifting. By contrast, even at p very close to zero, the subsidiary in country L does not reach full profit shifting.

This suggests that there are plausible cases in which the key response to the minimum tax is on the extensive, rather than the intensive, margin. At moderate values of p, both subsidiaries would move from partial shifting to no shifting. Only at very low values of p wold there be any profit shifting at all. We now turn to estimating the parameters of the model.

We demonstrate the importance of the statutory minimum tax rate in the second panel of Figure 13, which establishes the minimum tax rate at 5%. The change in profit shifting substantially more mild in the second panel of the figure.

Figure 13: Extent of profit shifting in H and L with a 15% (top panel) and 5% (bottom panel) minimum tax





D.3 Response to changes in other variables

In this section, we revert back to the case without any minimum tax, but we present the response of profit shifting, investment in the tax avoidance intangible and investment in

physical capital when policy parameters and structural parameters change.

E Production function estimates

Table 8: Production function estimates

Dep var: $\ln y$	1	2	3	4	5	6
$\ln k$	0.688***	0.687***	0.675***	0.571***	0.578***	0.578***
	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)
Constant	4.352***	4.464***	4.430***	6.024***	5.951***	5.979***
	(0.043)	(0.044)	(0.046)	(0.070)	(0.073)	(0.081)
No of obs	352,000	352,000	352,000	352,000	352,000	352,000
Firm FE?	Y	Y	Y	N	N	N
Mean($\hat{\varepsilon}$)	0	0	0	0	0	0
St.dev($(1-A)\hat{\varepsilon}$)	1.483	1.482	1.446	1.512	1.508	1.507

F Reduced-form evidence: supplementary analyses

Table 9: Additional results on extensive margin, zero taxable income reporting

Dep.var: $\mathbb{1}(\text{Taxable Profit} \leq 0)_{i,t}$	1	2	3	4	5	6	7	8
Treated × Post-reform	-0.080**	-0.080**	-0.077**	-0.081**	-0.081**	-0.077**	-0.065**	-0.054*
	(0.034)	(0.034)	(0.035)	(0.034)	(0.034)	(0.035)	(0.032)	(0.032)
Total assets, lagged	0.000	0.000	0.000					
	(0.000)	(0.000)	(0.000)					
Firm FE?	Y	Y	Y	Y	Y	Y	Y	Y
Year FE?	N	Y	Y	N	Y	Y	Y	Y
Sector-Year FE?	N	N	Y	N	N	Y	N	Y
Sample requires lagged assets?	Y	Y	Y	Y	Y	Y	N	N
N	2900	2900	2900	2900	2900	2900	3876	3876

Table 10: Additional results on intensive margin, taxable income reporting (natural log)

Dep.var: $\ln(\text{Taxable Profit})$	1	2	3	4	5	6	7	8
Treated × Post-reform	-0.006	0.001	0.015	-0.006	0.001	0.015	0.073	0.076
	(0.156)	(0.156)	(0.165)	(0.156)	(0.155)	(0.165)	(0.154)	(0.165)
Total assets, lagged	0.000	0.000	0.000					
	(0.000)	(0.000)	(0.000)					
Firm FE?	Y	Y	Y	Y	Y	Y	Y	Y
Year FE?	N	Y	Y	N	Y	Y	Y	Y
Sector-Year FE?	N	N	Y	N	N	Y	N	Y
Sample requires lagged assets?	Y	Y	Y	Y	Y	Y	N	N
N	865	865	865	865	865	865	1096	1095

Table 11: Effect of policy on the probability to report zero taxable income in the high-tax country, firms with zero taxable income and small reported trading losses in the final pre-reform period

Outcome: $\mathbb{1}(\text{Taxable Profit} \leq 0)_{i,t}$	(1)	(2)	(3)	(4)	(5)
Treated × Post-reform	-0.140**	-0.141**	-0.141**	-0.131**	-0.131**
	(0.060)	(0.059)	(0.059)	(0.058)	(0.058)
Total assets, lagged	0.000		0.000		0.000
	(0.000)		(0.000)		(0.000)
Firm FE?	Y	Y	Y	Y	Y
Year FE?	N	Y	Y	Y	Y
Sector-Year FE?	N	N	N	Y	Y
N	966	966	966	966	966