Profit-shifting Frictions and the Geography of Multinational Activity*

Alessandro Ferrari† Sébastien Laffitte‡ Mathieu Parenti§
Farid Toubal¶

August 2023

Abstract

International tax rules are commonly viewed as obsolete as multinational corporations exploit loopholes to move their profits to tax havens. This paper uncovers how international tax reforms can curb profit shifting and impact real income and welfare across nations. We build a model of international corporate tax avoidance under imperfect competition that disentangles profits that stem from real economic activity from paper profits that are booked in tax havens. Our framework delivers a set of "triangle identities" through which we recover bilateral profit-shifting flows. Using different data sources ranging from publicly available to firm-level datasets, we find an elasticity of paper profits that is three times larger than the elasticity of the tax base. In our quantitative model, a global minimum tax increases welfare by inducing higher tax revenues and public good provision. It also encourages countries to raise their statutory corporate tax rates as it effectively reduces tax competition. Instead, a border adjustment tax (BAT) that eliminates profit shifting distorts multinational production and may result in welfare losses. A tax reform in the spirit of the destination-based cash-flow tax, combining a BAT with a reduction in the corporate income tax rate may induce efficiency gains at the expense of public good provision.

Keywords: Profit Shifting; Tax Avoidance; Tax Havens, International Tax Reforms; Minimum taxation; DBCFT; Multinational firms.

JEL codes: F23, H25, H26, H32, H73.

*We wish to thank James Albertus, Alan Auerbach, Pierre Boyer, Michael Devereux, Rafael Dix-Carneiro, Peter Egger, Clemens Fuest, Philipp Kircher, Marko Köthenbürger, Niels Johannesen, Isabella Manelici, Julien Martin, Philippe Martin, Nora Paulus, Nadine Riedel, Florian Scheuer, Juan Carlos Suarez-Serrato, José P. Vasquez, Gabriel Zucman and seminar participants at Banque de France, City University of London, CESifo, CREST, ECARES, ETH Zurich, European University Institute, Geneva, Kiel, Moscow Higher School of Economics, Nottingham, OECD, Paris 1, Paris School of Economics and at the ERWIT conference, the Villars CEPR Workshop on International Trade, the Mannheim Taxation Conference, the NTA Congress, the CESIfo Area Conference on Public Economics, the 31st FIW Workshop, the Mainz "Shaping Globalization" Workshop, the ECARES Workshop on International Corporate Taxation, Bank of Italy "Trade, value chains and financial linkages in the global economy" Conference, the NBER Business Taxation in a Federal System Conference and the NBER Summer Institute Macro Public Finance for useful comments and discussions. We thank the Booster program of the ENS Paris-Saclay for financial support. We thank Baptiste Souillard for his contributions to the earlier stages of this project. Felix Samy Soliman provided excellent research assistance.

†Department of Economics, University of Zurich, alessandro.ferrari@econ.uzh.ch.

‡THEMA, CY Cergy Paris University, sebastien.laffitte@cyu.fr.

§Corresponding author. ULBruxelles, ECARES, CESifo & CEPR, mathieu.parenti@ulb.be.

¶Université Paris-Dauphine, CEPII, CESifo & CEPR, farid.toubal@dauphine.psl.eu.

1 Introduction

The current tax system has inherited the broad principles the League of Nations set out in 1928. Based on separate accounting, it treats multinational corporations (MNCs) as a loose collection of legal entities across different host countries. Mounting empirical evidence shows that MNCs exploit outdated international tax rules to shift profits to low or no-tax jurisdictions and avoid taxes.[1] In response, international taxation is undergoing an important reform supported by the OECD/G20 Inclusive Framework on Base Erosion and Profit Shifting (OECD, 2021). While this reform is meant to reduce the erosion of government tax revenues, its impact is hard to evaluate without considering the responses of multinational corporations regarding the location of their real activities and profit shifting.

In this paper, we build a general equilibrium model of international tax avoidance to study the consequences of changes in corporate tax rates and taxing rights allocation on firms' real activity, on MNC's profit shifting, and on countries' tax revenues. In addition to endogenous country characteristics (market potential, production costs) and determinants of trade and investment, our model features profit-shifting frictions (*i.e.*, the cost of moving profits from a production country to a low-tax jurisdiction) that impact the location choices of multinationals.

We discipline the model through a new and theory-consistent methodology to calibrate bilateral profit-shifting frictions. Our framework is tractable and readily applies to a broad range of tax policy scenarios using widely available data. Importantly, it allows us to evaluate the effect of international and domestic tax reforms on real activity and welfare, accounting for the relocation of firms in general equilibrium.

In the model, the location of multinationals' real activity depends on their ability to shift profits to tax havens. We allow firms to choose production, investment, and profit shifting jointly. They choose their production location based on real economic forces (productivity of the production country, proximity to demand, wages) and profit-shifting forces (*e.g.*, proximity to tax havens). We let profit-shifting frictions be bilateral to reflect different profit-shifting technologies, bilateral communication costs, and compatibility between tax and legal systems of the source and tax haven countries. Our model delivers standard gravity equations for bilateral real and paper profits respectively. These equations are then used to calibrate the model's key tax elasticities. These elasticities and profit-shifting frictions govern how international tax reforms affect firms' profitability in a given location and reshape the geography of global production and profit shifting.

The calibration of our framework requires estimates of bilateral profit-shifting flows.

[1] A large literature has documented the use of low-tax jurisdictions and, in particular, tax havens by multinational firms. See for instance Hines and Rice (1994), Desai et al. (2006), Gumpert et al. (2016), Bilicka (2019) or Tørsløv et al. (2022). Many papers have also discussed how these tax havens are used for tax avoidance. See for instance Gravelle (2015) for a general perspective, Beer et al. (2020) for a meta-study, Dyreng and Lindsey (2009), Clausing (2016), Dowd et al. (2017), Wright and Zucman (2018), Blouin and Robinson (2021), Laffitte and Toubal (2022), Samarakoon (2023) on U.S. multinational firms.

We proceed in two steps. First, we estimate a gravity model for direct investment income flows across countries, including the existence of tax havens as a predictor. We then use the estimated model to compute the counterfactual direct investment income flows without tax havens. The difference between the model and counterfactual predictions corresponds to the profits shifted to tax havens for each residence country. In the second step, we use a set of model-consistent relationships - which we refer to as "triangle identities" - between residence countries, source countries, and tax havens to recover the distribution of bilateral profit-shifting flows. Our methodology highlights the role of geography in determining bilateral profit-shifting flows.

Our framework allows us to quantify two important objects of interest. First, we estimate profit-shifting frictions and find them to be substantial: on average, shifting profits from a residence country to a tax haven through a source country generates an increase in the production cost of 23%, all else equal.[2] By comparison, the frictions associated with moving production across borders are found to raise costs by 40%. These costs can be decomposed into a bilateral component that depends on the source country-tax haven pair and on the unilateral ability of residence countries to reduce their firms' profit-shifting costs.[3] Our estimated bilateral frictions explain 27% of the variation in profit-shifting costs.

Second, our structural gravity framework allows the estimation of two distinct tax elasticities: one for the (reported) tax base and one for profit shifting. We find an elasticity of profit shifting approximately three times as large as that of the tax base.[4] We validate our calibration of the profit-shifting elasticity using estimations based on alternative datasets on i) profit shifting from Tørsløv et al. (2022) (TWZ hereafter); ii) country-by-country reporting from the OECD; iii) a new sample of bilateral reported pre-tax income and bilateral effective tax rates constructed using firm-level data.

Next, we use the model as a laboratory for counterfactual policy experiments in 40 countries, including seven tax havens (one of them being an aggregate of small tax havens). We start by showing that the closure of a tax haven has a negative impact on the real income of non-haven countries. We attribute this effect to profit-shifting frictions that shape the reallocation of profits across tax havens and, consequently, affect the location of multinational production through their interaction with multinational production (MP) frictions.

We then use our model to evaluate the impact of a global minimum tax, in line with the second pillar of the OECD agreement signed in October 2021. Implementing a minimum

[2]Anecdotal evidence confirms that these costs can be substantial. For example, according to the investigations of the U.S. Permanent Subcommittee on Investigations, Caterpillar paid more than $10 million annually to the consulting firm PwC to set up its Swiss tax planning strategy (Levin, 2014, p.42). Note that these consulting fees constitute a set-up cost and not the entirety of the expenses for tax planning in this case.

[3]We show that the U.S. and some European countries have better abilities to reduce their firms' profit-shifting costs than other residence countries. This finding echoes the recent literature that shows that U.S., European, or Chinese firms are more "aggressive" than firms from other countries (Garcia-Bernardo et al., 2021, Tørsløv et al., 2022).

[4]We also extend our model and allow for a variable elasticity of profit shifting. Profit shifting becomes more elastic when the tax rate differential between a non-haven and a tax haven decreases. This approach speaks to the recent results of Bilicka et al. (2022a).

tax increases the tax revenues from multinational firms' profits. For the U.S., it corresponds to an increase in corporate tax revenues by about 4%. While a response from tax havens reduces these gains by half, they do not fully eliminate them because the reform lowers the return on engaging in profit shifting: firms' endogenous response to the minimum rate leads to an increase in the corporate tax base of non-haven countries.[5] The reform's overall impact is best analyzed by disentangling its effect on private consumption from that on the provision of public goods. The latter unambiguously increases through a larger collection of tax revenues. The former, however, is more complex. While the reform would reduce the dispersion in tax rates across jurisdictions, allowing location decisions to better reflect countries' fundamentals, the overall effective tax rate increase may also encourage headquarters to exit non-havens and/or relocate to tax havens. Our results suggest that anti-abuse laws targeting corporate inversions can help mitigate the reform's adverse effects.

Combining private consumption and public-good provision in a welfare function informed by the data, we typically find a gain from a global minimum tax. We also examine whether non-haven countries would have an incentive to deviate from a global residence-based minimum tax, holding their preferences for public good provision constant. We find that a global minimum tax rate reduces the cost of increasing the statutory rate because such a reform would limit the erosion of the tax base through profit shifting. Consequently, countries are incentivized to increase their tax rates unilaterally.

Importantly, we find that a global minimum tax set at 15% does not eliminate profit shifting. Our estimates suggest that it would reduce profit shifting from the U.S. by at most 30-40%. This raises the question of whether more ambitious designs, such as the Destination-Based Cash Flow Tax (DBCFT hereafter), would be preferable. This proposal replaces the corporate income tax with a border-adjustment tax. Since firms' tax burden becomes entirely determined by the location of their sales, most standard profit-shifting strategies become inoperative. Our quantitative analysis of a unilateral adoption of DBCFT by the U.S. brings back a trade-off between private and public consumption. Compared to a global minimum tax, however, the most favorable parameters of such a policy increase real income at the expense of the provision of the public good, leading to a negative impact on welfare. We also find that the design of DBCFT is not immune to significant distortions, with low DBCFT rates generally preferable for private consumption.

Related Literature. First and foremost, our paper is related to the literature estimating profit shifting. To the best of our knowledge, Tørsløv et al. (2022) is the only paper that provides estimates of bilateral profit-shifting flows for several country pairs.[6] Their

[5] The expected response of tax havens to match the minimum rate has started to materialize, see, *e.g.*, the announcement of the Irish government (Irish Department of Finance, 2022), or of the Government of Bermuda (Government of Bermuda, 2023).

[6] A large literature focuses on the profit shifting of U.S. multinational firms (Hines and Rice, 1994, UNCTAD, 2015, Clausing, 2016, 2020, Wright and Zucman, 2018, Blouin and Robinson, 2021, Laffitte and Toubal, 2022,' Guvenen et al., 2022), or provide estimates at a global scale (Janský and Palanský, 2019, Garcia-Bernardo et al., 2021, Vicard, 2022). Note that Guvenen et al. (2022) estimates bilateral profit shifting to several tax havens, but only when the U.S. is the source country.

methodology infers profit shifting by comparing the profitability of domestic and multinational firms in tax havens. This profit premium of MNCs, representing profit shifting, is then allocated to country pairs using mainly bilateral excess trade in services between non-haven countries and tax havens. To compute bilateral profit shifting, we rely instead on bilateral excess FDI income and a model-consistent bilateral allocation of profits shaped by the tax base and profit-shifting elasticities. Our methodology allows us to remain agnostic on the channel through which profit shifting occurs.

Empirical studies have empirically documented significant real effects of corporate tax reforms beyond changes in tax revenues (see Suárez Serrato and Zidar, 2016 and Fuest et al., 2018 for analyses at the national level, and Grubert and Slemrod, 1998, Egger and Wamser, 2015, Suárez Serrato, 2018, de Mooij and Liu, 2020, 2021, Bilicka et al., 2022b for analyses of international tax reforms). In line with the results from this literature, our model allows firms to adjust their location and profit-shifting strategy after a tax reform. We also show that both of these margins of adjustment quantitatively matter to estimate reforms' impact on tax revenues and welfare.

A burgeoning literature evaluates international tax reforms (Hanappi and Cabral, 2020). The reforms of international taxation and their potential impacts are discussed, for instance, in Fuest et al. (2019), International Monetary Fund (2019), Clausing et al. (2021), and Devereux et al. (2021). Most of the literature evaluates the so-called Pillar II *i.e.* the introduction of minimum taxation. OECD (2020) and Baraké et al. (2021) propose estimations of the expected tax revenue gains from implementing Pillar II.[7] None of these contributions allows for real and profit-shifting responses from multinational firms, nor general equilibrium effects. Moreover, they focus on tax revenues only. Our model also allows us to quantify the impact of these reforms on welfare and on the incentive for countries to adjust their tax rate post-reform. To the best of our knowledge, this is also the first effort to benchmark the current reform against the DBCFT proposal (see Auerbach et al., 2017a for a description of DBCFT, and Barbiero et al., 2019 for a complementary analysis). We find that low tax rates for DBCFT (a border-adjusted tax - BAT - combined with a reduction in the corporate income tax rate) should be preferred to a pure BAT for production efficiency although it comes at the cost of low public good provision. This is because a pure BAT in the presence of multinational production violates Lerner symmetry (Costinot and Werning, 2019). Our results point to the quantitative importance of these distortions.

On the theoretical side, the mechanisms at play are reminiscent of the papers by Janeba and Schjelderup (2022), Johannesen (2022), and Hebous and Keen (2023) who build tax competition models to investigate the impact of minimum taxation. In line with these models, we take into account the potential policy reaction of tax havens to the global minimum tax. In our simulations, we find that a global minimum tax is welfare-improving for the majority of non-haven countries. Finally, we study the incentive of governments

[7] In addition to these revenue estimations, Bachas et al. (2023) explores the impact of Pillar II on developing countries, and Bilicka et al. (2023) discusses the effect of Pillar II on IP location incentives.

to change taxes after the implementation of minimum taxation. Contrary to Janeba and Schjelderup (2022), we find that the majority of them would gain by increasing their taxes.

Last, this paper makes use of the tools from the quantitative trade and economic geography literature. We build our model from a multi-country Krugman-type model à la Head and Mayer (2004) augmented with multinational firms and profit shifting. The patterns of trade and multinational production have received a lot of attention (Arkolakis et al., 2018, Head and Mayer, 2019) with applications to corporate tax reforms (Wang, 2020, Dyrda et al., 2023, Santacreu, forthcoming). Methodologically, however, the calibration of our model requires an estimation of worldwide bilateral profit-shifting flows and the elasticity of paper profits. The main contribution of our paper in this regards is to provide a model-consistent estimation of these profit-shifting flows as well as an estimate of paper-profit elasticity we find to be three times as large as the elasticity of the reported tax base. Our theoretical framework shares some features with Dyrda et al. (2023) who model the international spillovers from intangible investment that may be reduced when tax reforms curb profit shifting. In our model, high effective tax rates also have an efficiency cost but through a different mechanism: lower post-tax profits lead to a sub-optimal number of firms that can be mitigated through profit-shifting.

In relation to this literature, we add two important features. First, we add a public good whose contribution to welfare is disciplined by the data. This feature allows a trade-off for welfare between public and private consumption as in Johannesen (2022). Under minimum taxation, we find that an increase in public good provision dominates the reduction in consumption, while the opposite is true for DBCFT. Second, we introduce a set of tax havens whose geography is embedded in bilateral profit-shifting frictions. The introduction of tax havens endogenizes the intensity of profit-shifting: the share of shifted profits depends not only on the opportunity cost of engaging in profit-shifting but also on the cost of shifting to any other tax haven, conditional upon being a tax avoider. This gravity-based profit-shifting enriches the reduced-form set-up *à la* Hines and Rice (1994) used for instance in Wang (2020), in which bilateral profit-shifting abstracts from other tax havens' attributes and reallocation mechanisms across tax havens.

Last, the importance of geography for corporate taxation resonates with the work of Fajgelbaum et al. (2019). Our model shares the importance of market access and spatial distortions for firm location and welfare, respectively. We focus instead on profit shifting by multinationals. Furthermore, when implementing a global minimum tax, we find that the reduction in international spatial misallocation driven by the dispersion in the effective tax rates is typically dominated by the level effect of higher tax rates, reducing firm entry but increasing public-good consumption.

We proceed as follows: in Section 2, we present the model used for the counterfactual analysis. In Section 3, we show how the model guides the estimation of bilateral profit shifting and our elasticities. In Section 4, we estimate the two corporate tax elasticities that govern the location of real activities and profit shifting as well as profit-shifting frictions. In Section 5, we present the counterfactual results. We conclude in Section 6.

2 Model

This section describes the model we use for our counterfactual analysis. The model introduces tax havens and the ability of firms to shift profits. It guides the empirical estimation of both key elasticities that determine the responses of multinational corporations to corporate tax reforms.

2.1 Set-up

Structure of the Model. The world economy comprises $n = 1, \ldots, N$ countries, among which $h = 1, \ldots, H$ are labeled "tax havens". Each country is endowed with labor, the unique factor of production. The L_n workers are immobile across countries. They inelastically offer one unit of labor paid w_n. An endogenous number of corporations operate under monopolistic competition. Each corporation designs and produces a single variety that can be sold in any country. The set of varieties supplied in country n is Ω_n.

Demand. The demand for any variety in Ω_n at price p_n is given by $d_n(p_n) = Y_n \frac{p_n^{-\sigma}}{P_n^{1-\sigma}}$. The price-elasticity of demand is $\sigma > 1$; Y_n denotes total expenditures; P_n is the price index given by $P_n = \left(\int_{\Omega_n} p_n(\omega)^{1-\sigma} d\omega\right)^{\frac{1}{1-\sigma}}$. Real expenditure is given by Y_n/P_n. We postpone the definition of welfare to section 2.5 where we introduce a public good.

Pricing-rule. A firm with productivity φ sets its headquarter in a residence country i, sources its production in one source country l, and serves all destination markets n through local sales or exports. Under CES preferences and monopolistic competition, the profit-maximizing markup equals $\frac{\sigma}{\sigma-1}$ and is independent of the destination market. Labor costs in l and a set of frictions described below determine the firm's production costs and profitability.

Frictions and taxation. When the source country l and the residence country i differ, the cost to produce abroad involves a friction $\gamma_{il} \geq 1$, which reflects a technology transfer from the headquarter. Serving foreign destination markets $n \neq l$ comes with trade frictions $\tau_{ln} \geq 1$ for iceberg transport costs. Neither producing nor serving the destination market n requires the payment of a fixed cost. Therefore, firms serve all markets and $\Omega_n \equiv \Omega$. The geography of a source country l, its economic size, and that of its trade partners adjusted by trade frictions are summarized by the endogenous market potential of country l, $\Xi_l^{1-\sigma} = \sum_n \Xi_{ln}^{1-\sigma} = \sum_n \tau_{ln}^{1-\sigma} Y_n P_n^{\sigma-1}$ (Head & Mayer, 2004). In the absence of profit shifting, taxes are levied where production takes place, country l, at the rate t_{ll}, and the reported tax base reflects the location of the actual economic activities.

In our model, MNCs producing in a non-haven country l can book their profits in a tax haven h. We allow tax haven h to host and tax profits of foreign firms at the rate $t_{lh} < t_{ll}$ without requiring their physical presence, i.e., a production site. When shifting their profits, we assume that firms incur a bilateral cost α_{lh}. There are various reasons to expect these costs to be heterogeneous across production countries or tax havens. For example, these costs can subsume heterogeneity across production countries l, e.g., different sector composition and sectoral differences in profit-shifting abilities, which we do not model. Similarly, they can capture differences across tax havens h. Havens differ in characteristics that facilitate profit shifting, like communications infrastructures or the legal technologies they offer to foreign firms (e.g., reduced incorporation time and costs, opacity and secrecy, accounting rules, and treaty network). Our reduced-form friction α_{lh} goes further by allowing these determinants to be bilateral, so the cost of shifting profits to a tax haven differs whether they stem from production that is sourced in the U.S. or, for instance, in France.[8]

Profits. We denote the global post-tax profits of a corporation from i with productivity φ producing in l booking profits in h and selling its goods in all countries as

$$\pi_{ilh}(\varphi) = (1 - t_{ilh}) \frac{\iota_l}{\sigma} \left(\frac{\sigma}{\sigma - 1} \frac{\gamma_{il}\alpha_{lh}}{\varphi} w_l \Xi_l \right)^{1-\sigma}. \tag{1}$$

The term $\left(\frac{\sigma}{\sigma - 1} \frac{\gamma_{il}\alpha_{lh}}{\varphi} w_l \Xi_l \right)^{1-\sigma}$ denotes the global revenues of a firm in the triplet ilh. These revenues turn into pre-tax profits with the standard relationship that the sales-to-profit ratio is governed by the elasticity of demand σ. This parameter simultaneously governs profitability and the curvature of demand, meaning that all firms in the world have the same sales-to-profit ratio. As this is counterfactual, anticipating the calibration of the model, we separate these two by introducing a production-country-specific wedge $\iota_l \leq \sigma$ between sales and profits. Firms producing in l have a sales-to-profit ratio equal to ι_l/σ. We return to the calibration of ι_l and σ in Section 3.

Finally, we allow the tax rate t_{ilh} to be trilateral. For instance, taxing rights at the origin matter when discussing ongoing reforms, e.g., the global minimum tax reform, which gives taxing rights over the tax deficits in tax havens h to residence countries i.

Importantly, we assume that each firm books all its profits in a single tax domicile. This assumption implies that at the micro level tax avoiders' profits in l bunch at zero, consistent with Bilicka (2019). Aggregate bilateral profit-shifting flows then result from the aggregation of heterogeneous profit-shifting patterns across firms.

2.2 From micro to macro

Firm heterogeneity. We parametrize the distribution of φ and tax avoidance abilities α_{lh} to relate our model to bilateral macroeconomic flows, e.g., trade shares, multinational production shares, and profit shifting. We write the model with the understanding that further micro heterogeneity at the firm level would be subsumed in sufficient statistics as in Arkolakis et al. (2012). For instance, despite its simplicity, our model retains gravity

[8] This is consistent with recent evidence about the sectoral and geographical specialization of tax havens discussed, for instance, in Garcia-Bernardo et al. (2017), Bilicka et al. (2020) or Laffitte and Toubal (2022).

patterns for both trade and multinational production flows. We leverage this minimal structure to incorporate profit-shifting flows to tax havens.

We introduce firm heterogeneity as follows: in each residence country, firms decide whether to enter or not, i.e., to set up a headquarter in i upon the payment of a sunk cost $w_i f_E$.[9] Entrants find out how productive they would be when locating their production facility in any country l and recording their profits in any country h (where h is equal to l means that the firm does not shift profits abroad). We assume that firm productivity has two components. The first component, T_i, is deterministic and inherited from the residence country i. The second component φ_{lh} is idiosyncratic, specific to both the source country l and the location of profits h. A firm resident in i, sourcing production in l and booking profits in h, makes post-tax profits $\pi_{ilh}(T_i \varphi_{lh})$.

Parametrization. Building on Lind and Ramondo (2023), we consider a multivariate υ_1-Fréchet distribution of productivities with scale parameters A_l and a homogeneous correlation function $G_i(.)$ so that the φ_{lh} draws by country i are distributed according to the following c.d.f.:

$$\mathbb{P}\left(\varphi_{11} \leq z_{11}; \ldots; \varphi_{lh} \leq z_{lh}; \ldots; \varphi_{NH} \leq z_{NH}\right) = \qquad e^{-G_i\left(A_1 z_{11}^{-\upsilon_1} \ldots, A_l z_{lh}^{-\upsilon_1}, \ldots, A_N z_{NH}^{-\upsilon_1}\right)},$$

where

$$G_i(\mathbf{x}) = \sum_{l=1}^{N} x_{ll} + \theta_i^{-\upsilon_1} \left(\sum_{l=1}^{N} \sum_{h=1}^{H} x_{lh}^{\frac{\upsilon_2}{\upsilon_1}} \right)^{\frac{\upsilon_1}{\upsilon_2}},$$

with $\upsilon_2 \geq \upsilon_1$ and $\mathbf{x}$ denotes a matrix with generic entry x_{lh}.

The function G_i determines the substitutability across lh pairs and, therefore, the mobility of the tax base and paper profits. We make a technical assumption on the exact form of G_i to obtain two properties. First, the above expression assumes $\upsilon_2 \geq \upsilon_1$: it allows for a higher elasticity for paper profits vis-à-vis the elasticity of the tax base. As will become clear below, this assumption comes down to assuming that profits from tax-avoiding firms are more elastic to corporate taxes. The underlying idea is that it is harder to move production plants than P.O. boxes for profit booking. Second, we let the correlation functions be $i-$specific and governed by θ_i. This allows for different residence countries i to have different profit-shifting intensities. A lower θ_i increases the likelihood of a firm with residence-country i engaging in profit shifting. It can thus be interpreted as an inverse measure of a residence country's "aggressiveness" in profit shifting.[10] The tax "aggressiveness" parameter, θ_i, reflects the headquarters' i different abilities to reduce the costs of shifting profits.

[9] Sunk entry costs f_E can be country-specific. Note that T_i already absorbs such variations.

[10] Our theoretical definition of aggressiveness echoes the empirical strategy of Garcia-Bernardo and Jansky (2021) who test whether "MNCs differ in the aggressiveness of their tax planning depending on the country of their headquarters" (p.8).

Sourcing and profit-shifting decisions. After observing the φ_{lh} draws, firms from i select a unique pair lh that maximizes their profits. A firm from i chooses its profit-maximizing production site tax haven pair lh^*:

$$lh^*(i) = \arg\max_{lh} \left\{ (1 - t_{ilh})\, \iota_l \left(\frac{\gamma_{il}\alpha_{lh}}{\varphi_{lh}} w_l \Xi_l \right)^{1-\sigma} \right\}. \tag{2}$$

Formally, this choice depends on i) each firm's idiosyncratic profitability φ_{lh}, which reflects firms' production and tax-dodging technologies when operating through a source-haven pair lh, ii) bilateral frictions between the residence, source, destination, and tax havens such as γ_{il}, α_{lh}, and iii) country-specific variables such as the profitability wedge ι_l, labor costs w_l, market potentials Ξ_l, and iv) the trilateral tax rates t_{ilh}.

2.3 Equilibrium

The probability for a firm from country i to locate its production in l and book its profits in h is:

$$\mathbb{P}_{ilh} = \frac{\tilde{A}_{ilh} G_{i,lh}(\tilde{\mathbf{A}}_i, \mathbf{t}_i)}{G_i(\tilde{\mathbf{A}}_i, \mathbf{t}_i)} (1 - t_{ilh})^{\frac{\upsilon_1}{\sigma-1}}, \tag{3}$$

where $\mathbf{t}_i = (t_{ilh})_{1\le l\le N, 1\le h\le H}$ encompasses corporate income tax rates and other determinants of firms' location choices are contained in $\tilde{A}_{ilh} \coloneqq A_l \left(\gamma_{il}\alpha_{lh}\iota_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-\upsilon_1}$.

We denote by $G_{i,lh}$ the partial derivative of G_i with respect to the lh term and, with a slight abuse of notation, we denote by $G_i(\tilde{\mathbf{A}}_i, \mathbf{t_i})$ the correlation function evaluated at $\left(\tilde{A}_{ilh}(1 - t_{ilh})^{\frac{\upsilon_1}{\sigma-1}} \right)_{l\le N, h\le H}$.

Expression (3) results directly from McFadden (1978)'s discrete choice framework using Generalized Extreme Value distributions (GEV).[11] Using the properties of the GEV again, the expected post-tax profits $\bar{\pi}_i$ of a firm headquartered in i, taken across all possible pairs lh, are given by

$$\bar{\pi}_i = \frac{1}{\sigma T_i^{1-\sigma}} \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} G_i(\tilde{\mathbf{A}}_i, \mathbf{t}_i)^{\frac{\sigma-1}{\upsilon_1}} \Gamma \left(1 - \frac{\sigma - 1}{\upsilon_1} \right). \tag{4}$$

Given profits, we can build a government's tax revenue flow. Denote $\mathcal{N}_i$ the number of firms incorporated in country i, then aggregate post-tax profits of firms from i are $\mathcal{N}_i \bar{\pi}_i$. To compute pre-tax profits, we note that a firm headquartered in i, producing in l and booking profits in h is subject to the tax rate t_{ilh}. As a consequence, pre-tax profits correspond to $\frac{\bar{\pi}_i}{1-t_{ilh}}$. Firms from i choose the triplet ilh with probability $\mathbb{P}_{ilh}$, so the total pre-tax profits are given by $\mathcal{N}_i \mathbb{P}_{ilh} \frac{\bar{\pi}_i}{(1-t_{ilh})}$. Under a territorial tax regime and in the absence of profit shifting, the subscript i can be removed, and the relevant tax rate for country l's tax revenues is t_l if $l = h$ and zero otherwise. Hence, tax revenues of country l are given by

[11] To obtain the above formula, note that using (1), profits π_{ilh} from a residence country i follow a multivariate $\frac{\upsilon_1}{\sigma-1}$-Fréchet distribution with scale parameters $\tilde{A}_{ilh}(1 - t_{lh})^{\frac{\upsilon_1}{\sigma-1}}$ and the same correlation function $G_i(.)$.

$B_l = \sum_i t_l \mathcal{N}_i \mathbb{P}_{ill} \frac{\bar{\pi}_i}{1-t_l}$. In other words, if taxation is levied where production occurs (country l), then the tax revenues obtained by country l are the total pre-tax profits of firms from each country of incorporation i that are producing in l, multiplied by the tax rate t_l.

The exact shape of tax revenues depends on the taxation regime in the economy. For example, consider instead a minimum tax regime that allows country k to tax worldwide profits i) generated by firms from k, ii) shifted to tax havens, and iii) taxed at a rate smaller than t_k^{min}. Under this taxation regime, country k would raise tax revenues from firms producing in k and from firms headquartered in k paying taxes in a tax haven with a tax rate lower than t_k^{min}. Formally, tax revenues are given by $B_k = \sum_i t_k \mathcal{N}_i \mathbb{P}_{ikk} \frac{\bar{\pi}_i}{1-t_{ikk}} + \sum_{l \neq h,h} \max\{t_k^{min} - t_{lh}, 0\} \mathcal{N}_k \mathbb{P}_{klh} \frac{\bar{\pi}_k}{1-t_{klh}}$, where the first term describes the tax revenues generated by firms producing in k and the second term by firms headquartered in k booking profits in a tax haven for which the minimum tax rate binds. To encompass all these cases, we write compactly that tax revenues are described by

$$B_k = \sum_{i,l,h} t_{ilh}^{g_k} \mathcal{N}_i \mathbb{P}_{ilh} \frac{\bar{\pi}_i}{1 - t_{ilh}}, \tag{5}$$

where $t_{ilh}^{g_k}$ is the tax rate relevant for country's k tax authorities .

Production in country l aggregates multinational production from all origin countries. Under CES preferences, production Q_l is proportional to profits with a factor σ/ι_l, hence, we get:

$$Q_l = \frac{\sigma}{\iota_l} \sum_{i,h} \mathcal{N}_i \frac{\mathbb{P}_{ilh} \bar{\pi}_i}{(1 - t_{ilh})}. \tag{6}$$

Setting up a headquarter in country i involves a fixed entry cost $f_E w_i$ paid in labor. Wages clear the labor market in each country:

$$w_i L_i = \mathcal{N}_i f_E w_i + \frac{\sigma - 1}{\sigma} Q_i. \tag{7}$$

The first term corresponds to wages paid to labor used for firm entry, while the second reflects wages paid to workers in the production process. Last, the price index in country n can be simplified as follows:

$$P_n = \left(\sum_l \frac{\tau_{ln}^{1-\sigma} Q_l}{\Xi_l^{1-\sigma}} \right)^{\frac{1}{1-\sigma}}. \tag{8}$$

For example, the price index can be low thanks to large and close trade partners. Finally, aggregate expenditures in country i result from labor income and corporate income tax revenues:

$$Y_l = w_l L_l + B_l + \mathcal{N}_l (\bar{\pi}_l - f_E w_l) + \Delta_l, \tag{9}$$

where $\bar{\pi}_i - f_E w_i$ are the profits net of entry costs, and the residual imbalances are captured by Δ_l.[12] The system of equations (5)-(9) determines Q_l, Y_n, w_i, P_n with a numeraire con-

[12]Whether imbalances are considered to remain constant in absolute terms instead of relative terms does not make a difference for our quantification exercises.

dition such that $P_1 = 1$. The long-run monopolistically competitive equilibrium determines $\mathcal{N}_i$ through a free-entry condition imposing that

$$\bar{\pi}_i = f_E w_i. \tag{10}$$

2.4 Tax-base and profit-shifting elasticities

The max-stable property of the Fréchet distribution implies that $\mathbb{P}_{ilh}$ corresponds to the share of profits realized by firms from i in lh. Denote X_{ilh} the total sales of firms from i selecting the pair lh. The probability that firms from i select the pair lh is:

$$\mathbb{P}_{ilh} = \frac{X_{ilh}\iota_l\,(1-t_{ilh})}{\sum_{jk} X_{ijk}\iota_j\,(1-t_{ijk})}. \tag{11}$$

Denoting by $X_i = \sum_{lh} X_{ilh}$ the worldwide sales of firms from i, (11) implies:

$$\frac{X_{ilh}}{X_i} = \frac{\mathbb{P}_{ilh}/\left(\iota_l\,(1-t_{ilh})\right)}{\sum_{jk}\mathbb{P}_{ijk}/\left(\iota_j\,(1-t_{ijk})\right)}. \tag{12}$$

Combining our specific G_i function and equations (3), and (12), we obtain the following proposition.

Proposition 1 (Gravity Structure of Multinational Production and Profit Shifting)**.** *The fraction of profits that remain taxable in each source country l is given by:*

$$\frac{X_{ill}}{X_i} = \frac{\tilde{A}_{ill}(1-t_{ill})^{\frac{\upsilon_1}{\sigma-1}-1}\iota_l^{-1}}{\sum_{jk}\tilde{A}_{ijk}(1-t_{ijk})^{\frac{\upsilon_1}{\sigma-1}-1}\iota_j^{-1}G_{i,jk}(\tilde{\mathbf{A}}_i,\mathbf{t})}. \tag{13}$$

Moreover, the fraction of shifted income generated by firms from i that is produced in l and reported in tax haven h is given by:

$$\frac{X_{ilh}}{\sum_{jk,j\neq k} X_{ijk}} = \frac{\tilde{A}_{ilh}^{\frac{\upsilon_2}{\upsilon_1}}(1-t_{ilh})^{\frac{\upsilon_2}{\sigma-1}-1}\iota_l^{-1}}{\sum_{jk,j\neq k}\tilde{A}_{ijk}^{\frac{\upsilon_2}{\upsilon_1}}(1-t_{ijk})^{\frac{\upsilon_2}{\sigma-1}-1}\iota_j^{-1}}. \tag{14}$$

As a consequence, from (13), the partial elasticity of the tax base in l to $1-t_{ill}$ is $\tilde{\upsilon}_1 := \frac{\upsilon_1}{\sigma-1}-1$. Moreover, from (14), the partial elasticity of profits shifted from l to h w.r.t. $1-t_{ilh}$ is equal to $\tilde{\upsilon}_2 := \frac{\upsilon_2}{\sigma-1}-1$.

The proof is relegated to Appendix A.2. The model captures tax competition for paper profits across tax havens. Formally, the multilateral resistance terms in the denominator of (14) show that beyond the characteristics of tax haven h, those of the other tax havens also matter for bilateral profit shifting. A decrease in a tax haven's tax rate t_{ilh} triggers two main effects. First, it increases the total share of profits shifted from l toward tax havens (see Equation 3). Second, it reshuffles these profits among tax havens (see Equation 14). Some non-avoiding firms in l start shifting their profits to h and some firms producing in

$l' \neq l$ move their production site to l and engage in profit shifting. Moreover, some firms that were previously shifting their profits to $h' \neq h$ now switch to tax haven h.

This gravity-based profit-shifting enriches the reduced-form set-up *à la* Hines and Rice (1994), standard in the corporate tax avoidance literature, in which bilateral profit-shifting abstracts from other tax havens' attributes and reallocation mechanisms across tax havens.[13] We provide a schematic representation of the model in Appendix A (Figure A1).

2.5 Real Income and Welfare

Before turning to public-good consumption and welfare, we start by discussing the impact of corporate taxation on real income as a measure of the efficiency of production of the private consumption bundle. This, in turn, depends on the number of varieties available for consumption and the allocation of consumption across goods with respect to their relative costs of production (see Dhingra and Morrow, 2019 for a general treatment of efficiency under monopolistic competition with firm heterogeneity).

Corporate tax policy impacts real income through both these channels: a tax rate hike in one jurisdiction may lower the number of active firms by decreasing post-tax profits but it also distorts the spatial allocation of production across countries. In addition, tax-induced income effects will feed back into market potentials, distorting location probabilities further.

Disentangling quantitatively which channels impact real income is challenging in general equilibrium. For this reason, we start by stressing a simple neutrality result of taxation that will guide our interpretation in Section 5.

Proposition 2 (Residence-based top-up neutrality)**.** *Consider an equilibrium holding fixed the number of firms where* (5) − (9) *hold. A top-up residence-based unilateral tax in an otherwise territorial tax system is neutral on the market equilibrium and, thus, on real income.*

To build the intuition for this neutrality result, consider a short-run equilibrium response to a change in tax policy where the number and spatial allocation of headquarters across countries is fixed. Practically, $\mathcal{N}_i$ remains constant for all i and there is no level effect on the number of available varieties. Firms headquartered in country i can change their production location and where they book their profits. Consider a top-up residence-based corporate tax, defined as a residence-based tax t_i, which is levied on profits repatriated to the residence country once corporate taxes have been paid on a territorial basis, i.e., in the source or haven-country at rate t_{lh}. Thus, a firm from i, sourcing in l and booking its profits in h will have pre-tax profits given by $\frac{\bar{\pi}_i}{(1-t_{ilh})} \equiv \frac{\bar{\pi}_i}{(1-t_i)(1-t_{lh})}$. Since the top-up is applied to all firms headquartered in i, it does not directly change the relative profitability of different production and profit-booking locations. Formally, $\mathbb{P}_{ilh}$, as defined in (3), does

[13] In these models, bilateral profit shifting between l and h is proportional to the difference in tax rates between l and h. This implies that the elasticity of profit shifting is not constant. In section 4.2, we augment our model to allow for a varying profit-shifting elasticity.

not depend directly on t_i. It could, however, change the incentives to locate in a country l if it were to distort market access Ξ_l or the equilibrium labor costs w_l. For instance, market access depends on total expenditures and, thus, tax revenues. Plugging (5) into (9) shows that the budget constraint does not depend on t_i. Using (4), we note that pre-tax profits $\frac{\bar{\pi}_i}{(1-t_i)(1-t_{lh})}$ do not depend on t_i either. Moreover, since the top-up is unilateral, it does not change the income of countries $l \neq i$. We conclude that the solution of (5) – (9) is invariant to the top-up.

Two corollaries may be noted. First, it is immediate to see from this benchmark result that the effect of a unilateral residence-based top-up must be negative in the long run on real income when firms can re-optimize their headquarter entry decision. Such a reform will lead to a decrease in the number of headquarters in country i, thereby generating a negative real income effect in the long run.[14] Second, this result helps interpret a unilateral change in a source-based tax regime. Such change is identical to a unilateral residence-based tax change applied to domestic firms and a change in the tax rate applied to foreign producers. Proposition 2 implies that *the first-order effect of a source-based change in the tax rate is only driven by foreign firms.*

Public Goods Provision and Welfare. We conclude the model description by introducing a distinction between real income and welfare. The reason behind this extension is that the direction of real income and efficiency changes induced by any reform depends on the status quo level of taxes and, in particular, whether they are too high or too low to begin with. So far, tax rates are not optimized on, *i.e.*, the tax rates observed in the data are not an equilibrium of the "tax game", rather, the allocation defines an equilibrium given the observed tax rates. In principle, we could have a model in which taxes are too low and the reforms, by increasing the tax burden, would move the economy towards preferable outcomes. To discipline our comparison, we extend our model to rationalize the observed data as a Nash equilibrium. This allows us to pin down country-specific motives to obtain tax revenues. We think of this as a stand-in for heterogeneous preferences over public goods or political economy considerations. We remain agnostic on the deep rationales behind these preferences and include real tax revenues as a direct source of utility in our model, which does not distort the decisions of firms and consumers. We then ask what parametrization would reconcile the data as a Nash equilibrium.

Formally, we define the welfare of country n as:

$$U_n = (B_n/P_n)^{\beta_n} Y_n/P_n,$$

where, as before, Y_n/P_n is real income. From the data we back out the vector of β_n such that at the initial equilibrium, under territorial taxation, countries would not have an

[14]The intuition can be traced back from Dixit and Stiglitz (1977) and Dhingra and Morrow (2019) in a closed economy: since real income is maximized without any taxes, starting from an equilibrium with taxes features an inefficiently low number of firms. A decrease in the number of firms shifts the equilibrium further away from the first-best.

incentive to change their statutory rate. Namely, U_n must be maximized around the initial tax rates with $\beta_n : \frac{\partial U_n}{\partial t_n} = 0$. Note that, by definition, this pins down a Nash equilibrium. Under this specification of welfare, the vector of β_n implies that non-haven countries have no incentive to change their statutory rate unilaterally. Then, log changes in welfare are $\frac{dU_n}{U_n} = \frac{dY_n/P_n}{Y_n/P_n} + \beta_n \frac{dB_n/P_n}{B_n/P_n}$, namely a combination of private and public goods consumption.

3 Estimating Profit Shifting

Taking our model to the data requires estimating several parameters. An essential step in our procedure is estimating profit-shifting flows, from which we can back out $\mathbb{P}_{ilh}$ through a set of structural relations in the model.[15]

Our identification strategy rests on two pillars. The first is a decomposition implied by our model, which we formalize in Proposition 3. We start by noting that equation (3) describes the probability for a firm from i to select the pair lh to locate its production and book its post-tax profits. The firm can either report its profit in the source country ($h = l$) or shift profits from the source country to a tax haven ($h \neq l$). We denote by Π_{ill} the total post-tax profits declared in l by firms from i producing in l and by PS_{ilh} post-tax profits shifted to h by $i-$firms producing in l. Total profits - shifted or not - by firms from i are denoted $\Pi_i := \sum_l \Pi_{ill} + \sum_{lh} PS_{ilh}$, while $PS_i := \sum_{lh} PS_{ilh}$ (resp. $PS_{ih} := \sum_l PS_{ilh}$) represents total shifted profits by firms from i (resp. from i to h). We use the separability of $\mathbb{P}_{ilh}$ across country pairs to derive accounting equations determining bilateral profit shifting.

Proposition 3 (Decomposition of $\mathbb{P}_{ilh}$)**.** *The following decomposition holds*

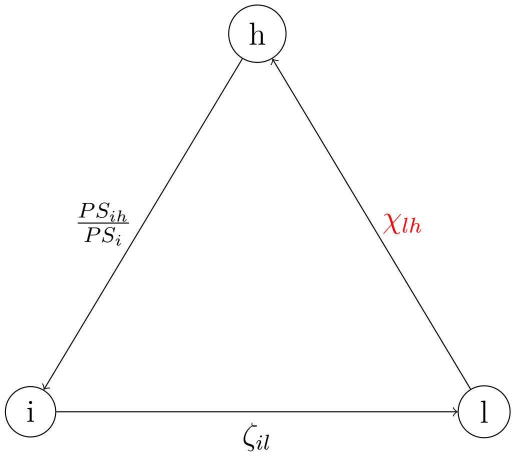
$$\mathbb{P}_{ilh} = \mathcal{P}_i \times \zeta_{il} \times \chi_{lh} \ , \textit{for } h \neq l, \tag{15}$$

where $\mathcal{P}_i = \frac{PS_i}{\Pi_i}$ is the probability that firms headquartered in i shift profits, ζ_{il} is the probability that a tax-avoiding firm headquartered in i locates production in l and χ_{lh} is the probability that a tax-avoiding firm producing in l books its profits in h.

The proof is provided in Appendix B.1. This proposition states that to infer $\mathbb{P}_{ilh}$, it is enough to observe three simpler objects: $\mathcal{P}_i$, ζ_{il} and χ_{lh}.

Our strategy's second pillar helps us identify these objects. First, we show that ζ_{il} can be recovered as a function of multinational production flows, of aggregated profit shifting in residence countries i and in source countries l, and of $\tilde{v}_1$ and $\tilde{v}_2$. Intuitively, for profits to be shifted from l, production must occur in l. However, because production and paper profits have different elasticities, the patterns of shifted profits are a distorted representation of real activity (captured by MP shares): our model implies that this distortion is shaped by $\frac{\tilde{v}_2+1}{\tilde{v}_1+1}$ (see in Appendix B.2). Second, to pin down χ_{lh}, we use the following "triangle identities": the profits from firms with residence in i that are booked in a tax haven h must

[15] As typical in the literature, we assume that no profit is shifted out of tax havens ($\alpha_{lh} \to \infty$, when $h = l$). Therefore, we back out the profit-shifting shares for the residence i and non-haven country l.



i: headquarter l: production h: haven

Note: $\frac{PS_{ih}}{PS_i}$ is estimated (section 3.2), ζ_{il} is a function of $MP_{il}, PS_i, PS_l, \frac{\tilde{\upsilon_1}+1}{\tilde{\upsilon_2}+1}$ (see the algorithm in Appendix B.2). MP_{il} is observed (see Appendix C), PS_i, *and* PS_l are estimated (see section 3.2 and Appendix B.2), $\tilde{\upsilon_1}$ and $\tilde{\upsilon_2}$ are estimated (section 4.2). χ_{lh} is recovered using the triangle identities.

Figure 1: Triangle of Profit Shifting

match the profits that they shift from any source country l where they operate to a given tax haven h. Since our data allows us to compute PS_{ih}, we can thus recover the share of profits shifted from l to any h, i.e., χ_{lh}.

The triangle identities are illustrated in Figure 1 and formalized in Proposition 4:

Proposition 4 (Triangle of Profit Shifting)**.** *The following holds*

$$\frac{PS_{ih}}{PS_i} = \sum_{l \neq h} \zeta_{il} \times \chi_{lh}. \tag{16}$$

The system shown in (16) gives a set of $(N - H) \times H$ equations, with $N - H$ the number of non-haven countries and H the number of tax havens. Equipped with our estimates of PS_{ih}/PS_i and ζ_{il}, we can solve for the set of χ_{lh}. Last, it should be noted that our estimates of PS_{ih} pin down PS_i and thus $\mathcal{P}_i$. Summarizing our methodology, as formalized in Propositions 3 and 4, $\mathbb{P}_{ilh}$ is readily obtained from $\mathcal{P}_i$, ζ_{il} and χ_{lh}.

3.1 Data

Our baseline sample consists of 40 countries from 2010-2014, which accounts for 84% of the world GDP in 2014. The sample includes seven major tax havens (Hong Kong, Ireland, Luxembourg, Netherlands, Singapore, Switzerland, and Offshore Financial Centers, an aggregate of smaller tax havens). Our methodology to estimate profit shifting, elasticities, and frictions uses information on bilateral FDI income and multinational production as building blocks. We also use other data sources in the analysis (tax rates, tax havens' policies, trade, profits, and other national accounts data). Details on the construction of the datasets and auxiliary sources of information are provided in the data Appendix C.

The bilateral FDI income dataset is the first source of information from which we compute profit shifting.[16] We collect it from bilateral balance of payment data issued by Eurostat and the OECD. It corresponds to the income of foreign affiliates returned to their residence country through dividends, interests, or reinvested earnings. The profits shifted to tax haven affiliates are either returned to the high-tax country as dividends or counted as reinvested earnings (interest income follows a different pattern in profit shifting schemes, see Wright and Zucman, 2018). To construct our FDI income series, we add up the flows of reinvested earnings in tax havens and dividends from tax havens.

The second important dataset is the multinational production (MP) dataset. This data allows us to construct X_{ill}, the sales resulting from the production in the country l by firms headquartered in the country i. We use data on country-level production to compute production by domestic firms (Q_l). We construct the MP data following Ramondo et al. (2015) using information on MNEs' bilateral sales from Eurostat, OECD, and the BEA.

In the following, we sketch our methodologies to calibrate profit shifting and the key elasticities. This procedure requires the calibration of σ and ι_l. We use administrative French firm-level data from the FARE dataset and follow the methodology provided by De Loecker and Warzynski (2012) to estimate firm-level markups. The results give a median markup equal to 17%, which corresponds to $\sigma = 6.88$.[17] With the estimation of σ, ι_l is then calibrated using the wedge between gross output and profits (corrected for profit shifting). Overall, ι_l absorbs any non-labor cost that impacts profits but not sales.

3.2 Estimation of PS_{ih}

We now evaluate profit shifting from each headquarter country i to each tax haven h, PS_{ih}. We define profit shifting as the difference between the predicted FDI income and the counterfactual FDI income that would have been generated if there were no tax haven in our sample. These counterfactual incomes are computed from an equation that regresses FDI income on factors related to gravitational forces, a tax haven indicator, and the effective average tax rate differential between pairs of countries:

$$\begin{aligned} FDI\ Income_{jk} &= exp(\beta_1 Haven_k + \beta_2 (ETR_j - ETR_k) \\ &\quad + \theta' \boldsymbol{X_{jk}} + r_k + \mu_j) + u_{jk}. \end{aligned} \tag{17}$$

$FDI\ Income_{jk}$ is the FDI income from an investment of country j in country k. $Haven_k$ an indicator variable equal to 1 if country k is a tax haven. $ETR_j - ETR_k$ is the effective average tax rate differential between country j and k. $\boldsymbol{X_{jk}}$ represents a set of gravity variables and θ the vector of coefficients associated. r_k are destination country's world region fixed effects, μ_j are investing country j fixed effects, and u_{jk} are the residuals. We estimate equation (17) using the Poisson pseudo-maximum likelihood (PPML) estimator

[16] See also UNCTAD, 2015, Janský and Palanský, 2019, or Vicard, 2022 for studies that use the FDI rate of returns in tax havens.

[17] This is in line with estimates found in the literature, e.g., Tintelnot (2017). Similarly, De Loecker et al. (2020) find a median markup of around 20 percent using Compustat data.

to take into account heteroskedasticity (Santos Silva and Tenreyro, 2006) and to allow us to work with predictions in levels, avoiding the (log) OLS prediction's transformation issue (Duan, 1983).

Profit shifting from residence i to a tax haven h, PS_{ih}, is defined as the difference between the predicted and counterfactual income that are predicted by muting the tax haven premium: $PS_{ih} = \widehat{FDI\ Income_{ih}} - \widehat{FDI\ Income^0_{ih}}$ with $\widehat{FDI\ Income_{ih}}$ the prediction of equation (17) on the sample of all pairs ih composed of non-haven countries i investing in tax havens h. $\widehat{FDI\ Income^0_{ih}}$ is defined on the same sample and corresponds to the predicted FDI income when the tax haven premium is set to 0 for all countries (i.e., $\beta_1 = 0$).

Table 1 presents the tax haven coefficients across different specifications (the complete estimation results are given in Appendix D.1). We aggregate the amount of bilateral profit shifted that we report along with the share of aggregate profit shifting in the sample's total profit. We use column (2) estimates to compute PS_{ih}. In particular, this specification includes Region × Tax Haven fixed effects to capture the geographical specialization of tax havens (Laffitte and Toubal, 2022). The amount of profit shifting could be overstated because some tax havens, like The Netherlands, are used as intermediate locations from where profit might be transferred. We follow Damgaard et al. (2019) to correct the profit-shifting series from conduit-tax havens (see appendix D.2).

Table 1: Estimation of PS_{ih}

	Dependent variable: $FDI\ income_{jk}$				
	(1)	(2)	(3)	(4)	(5)
$Haven_k$	1.565***	2.336***	2.767***	2.104***	1.677**
	(0.227)	(0.238)	(0.337)	(0.747)	(0.669)
Gravity Controls	Yes	Yes	Yes	Yes	Yes
HQ FE	Yes	Yes	Yes	Yes	Yes
HQ FE × Haven	No	No	No	Yes	Yes
Destination Region FE	Yes	Yes	Yes	Yes	Yes
Destination Region FE × Haven	No	Yes	Yes	Yes	Yes
Observations	1,444	1,444	1,444	1,444	1,212
Pseudo R2	0.819	0.836	0.861	0.884	0.898
Destination countries	52	52	52	52	52
Implied Aggregate Profit Shifting	**393551**	**397358**	**411327**	**408764**	**380954**
Share sample's profits	39%	40%	41%	41%	40%

Note: In column (1), we assume that the tax havens' impact on FDI income is the same for all tax havens. In column (2), we include Region × Haven fixed effects assuming that tax havens are used differently according to their geographic location (Laffitte and Toubal, 2022). Quadratic terms for distance and GDP are included in column (3). In column (4), we allow the origin countries to have a different propensity to use tax havens (Desai et al., 2006, Garcia-Bernardo et al., 2017) by including an interaction term between headquarter country fixed effects and the tax haven dummy variable. In column (5), we add a measure of the number of employees to account for labor inputs. Robust standard errors clustered at the destination country level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Once equipped with PS_{ih}, we can compute $PS^W := \sum_{i,h} PS_{ih}$, the total amount of profit shifting. We estimate it to $397bn, which corresponds to 39% of all profits in the sample. This is in line with TWZ, that report a share of profit shifting that amounts to 36% of global multinational profits. In Appendix D.3, we provide alternative quantifications based on the OECD's Country-by-Country reporting (CbCR) data. With this alternative source, we also evaluate this share to be about 40%.

3.3 Real activity and profit-shifting elasticities

Armed with the estimated profit-shifting flows, we can use a first set of model relations to estimate the tax elasticities. They will determine how changes in the global tax environment affect entry, production, and profit-shifting decisions. A novelty of our approach is to allow for, and calibrate, two tax elasticities: one for the tax base (governed by $\tilde{\upsilon}_1$) and one for profit shifting (governed by $\tilde{\upsilon}_2$). This allows corporate tax changes to induce different responses from real activities and profit shifting. In addition, the model restrictions impose $\tilde{\upsilon}_2 \geq \tilde{\upsilon}_1$, meaning that profit shifting is more elastic to taxes than real production (which is governed by both $\tilde{\upsilon}_1$ and $\tilde{\upsilon}_2$). This approach is motivated by the recent empirical corporate taxation literature, which emphasizes the non-linear responses of profits to corporate tax rates (e.g., Dowd et al., 2017, Bratta et al., 2021, Fuest et al., 2021, Garcia-Bernardo and Jansky, 2021). These papers, however, do not distinguish between profits generated by production activities and shifted incomes. Instead, the elasticity is estimated using data that pool together tax havens (where a large share of profits are shifted) and high-tax countries. Conditional on real activity, their results suggest a larger impact of corporate tax rates on profits for countries with low tax rates than for countries with higher tax rates. This finding is consistent with our setting, where the elasticity of profit shifting to taxes is larger than that of real activity.

To estimate the elasticities, we start by using Proposition 1, rewriting equations (13) and (14) in terms of observables and fixed effects.

Elasticity of the tax base. The elasticity of the tax base in country l, $\tilde{\upsilon}_1$, is obtained by rearranging and estimating the logarithm of equation (13) as:

$$\ln\left(\frac{X_{ill}}{\sum_l X_{ill}}\right) = \kappa_0 \ \ln(1-t_{ll}) + \kappa_1 \ \ln \tilde{A}_{ill} - \ln\left(\sum_l \tilde{A}_{ill}(1-t_{ll})^{\tilde{\upsilon}_1}\right), \tag{18}$$

where $\kappa_0 = \tilde{\upsilon}_1$ is our coefficient of interest. $\tilde{A}_{ill}$ includes bilateral frictions between residence and source countries and the production market's wage level and size. The regression analysis includes total and per capita GDP (in logs) and gravity-related control variables such as distance, contiguity, and indicators for colonial relationships. The headquarter country fixed effect is $FE_i = \ln\left(\sum_l \tilde{A}_{ill}(1-t_{ll})^{\tilde{\upsilon}_1}\right)$. We, therefore, use the variation across source countries to identify our coefficients.

Profit-shifting elasticity. Taking the logarithm of (14), we obtain:

$$\ln\left(\frac{X_{ilh}}{\sum_{l,h,h\neq l} X_{ilh}}\right) = \delta_0 \ln(1-t_{lh}) + \delta_1 \ln \tilde{A}_{ilh} - \ln\left(\sum_{l,h,h\neq l} \tilde{A}_{ilh}^{\frac{1+\tilde{v}_2}{1+\tilde{v}_1}} (1-t_{lh})^{\tilde{v}_2}\right), \quad (19)$$

where $\delta_0 = \tilde{v}_2$ is our coefficient of interest. t_{lh} is the tax rate applicable in tax haven h to tax-avoiding firms producing in country l. This tax rate is not observed as tax havens generally offer legal dispositions that allow effective tax rates to differ from the observed statutory tax rate. We use the OECD's Country-by-Country reporting (CbCR) data to compute it. This data aggregates (mandatory) firm-level reports informing on the country-by-country breakdown of firms' accounting information, including taxes paid, turnover and profits. It is gathered by the OECD as part of the Action 13 of the BEPS project and targets large MNEs (revenues larger than 750 million euros).[18] The CbCR dataset is publicly available for a limited sample of 25 reporting countries. We use this data to proxy the effective tax rate t_{lh} $(h \neq l)$ by the median effective tax rate observed in each tax haven, t_h. In further exercises reported in section 4.2, we show the robustness of the results using bilateral effective tax rates and alternative data sources.

In Equation (19), $\tilde{A}_{ilh}$ comprises information about technology A_l; bilateral frictions between residence and source countries γ_{il}; between source countries and the tax havens, α_{lh}; the source country's wage w_l and market potential Ξ_l. The last term on the RHS of (19) is a headquarter fixed effect. We add a set of headquarter $\times$ production country fixed effects, FE_{il} and we parametrize the frictions α_{lh} between the source country l and the tax haven h with gravity covariates. We also add an index of the tax haven aggressiveness, taken from the TJN's Corporate Tax Haven Index (Jansky et al., 2020), to proxy for the tax avoidance "technology" of tax havens.

As noted earlier, $\tilde{v}_2$ is needed to estimate profit shifting (see Section 3) while it is also estimated using profit-shifting data. To determine its value, we follow an iterative procedure.[19]

We summarize the methodology covered in this section before diving into the analysis of our empirical results. Given profit shifting and multinational production flows, we can i) estimate the elasticities $\tilde{v}_1$ and $\tilde{v}_2$, ii) compute the probability that a firm from i shifts profits $\mathcal{P}_i$, iii) use data on multinational production and the elasticity to compute the probability that a tax-avoiding firm from i locates production in l, ζ_{il}, iv) use our "triangle identities" to back out the probability that a firm, producing in l, shifts profits to h, χ_{lh}; and v) use our decomposition in (15) to compute $\mathbb{P}_{ilh}$.

[18] This data has been used in other studies on tax avoidance by multinationals (Garcia-Bernardo et al., 2021 at the macro level, Fuest et al., 2021 or Bratta et al., 2021 at the micro-level).

[19] We guess a value of $\tilde{v}_2$, compute ζ_{il} and PS_{ih}/PS_i and use (16) to back out χ_{lh} and (15) to compute $\mathbb{P}_{ilh}$. We then use the implied profit-shifting flows to update the guess on $\tilde{v}_2$ through (19) and iterate until convergence.

4 Profit-Shifting Flows, Elasticities and Frictions

In this section, we discuss our empirical results. We start by describing the estimated profit-shifting flows and their implied elasticities. Finally, we illustrate our estimates of the profit-shifting frictions.

4.1 Profit-Shifting Flows

The diagram in Figure 2 displays the estimated profit that has been shifted to tax havens (in the center) according to the residence country (on the left) and the source country (on the right). For visualization, we display the top 10 countries and aggregate the bilateral shares for others.

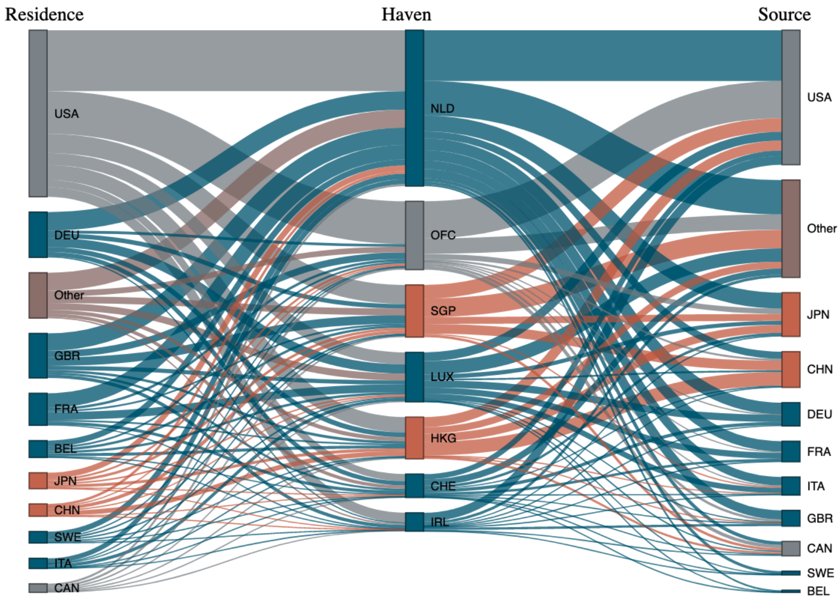


Figure 2: Profit shifting shares from residence-country i to h (PS_{ih}/PS_i) and from source-country l to h (χ_{lh}).

The figure shows the predominance of residence countries such as the U.S. and, to a lesser extent, Germany, the UK, and France in shifting profits to tax havens. It also shows the importance of European tax havens and, in particular, the Netherlands as a major destination for profit shifting. Furthermore, Figure 2 suggests larger shares of profit shifted from the U.S. as a residence country than as a source. This is also the case for France, Germany, and the United Kingdom but not Japan and China. The pattern displayed in Figure 2 confirms that gravitational frictions shape profit shifting. European tax havens prominently host profits from non-haven countries in the E.U. and the U.S., while China and Japan shift most of their profits to Hong Kong and Singapore.

Comparisons. Several papers provide estimates of profit shifting at the production country or tax haven level (Zucman, 2014, Clausing, 2016, 2020, Janský and Palanský, 2019, Garcia-Bernardo and Jansky, 2021 and Tørsløv et al., 2022). Tørsløv et al. (2022)

is the first paper to propose a methodology to compute bilateral profit shifting across pairs of source and tax haven countries. They use the global amounts of shifted profits and an allocation key based on trade in high-risk services to determine profit-shifting between source countries and tax havens.[20] While the relative rank of source countries using different methodologies proves to be similar, we find the relative position of country pairs regarding profit shifting to be less correlated.

We benchmark our shifted profit flows with these previous estimates. Table 2 reports Spearman's rank correlations of our vector of estimated profit shifting with different estimates from the literature. In Panel A, we aggregate our bilateral measure of profit shifting for each production country and display the correlations of this vector with unilateral profit-shifting measures constructed by TWZ, the Tax Justice Network (Cobham et al., 2020), and the European Commission using the CORTAX model (Alvarez Martinez et al., 2016). We find large positive rank correlations at the unilateral level, suggesting a stable relative position of each source country in profit shifting irrespective of the methodology used.

Table 2: Spearman's rank correlation

Source	Correlation	Obs.
A. Unilateral profit shifting:		
Tørsløv et al. (2022)	0.90	33
Cobham et al. (2020)	0.92	33
Alvarez Martinez et al. (2016)	0.95	21
B. Bilateral profit shifting:		
Tørsløv et al. (2022)	0.61	111

In Panel B, we compare our estimations with the bilateral estimates of Tørsløv et al. (2022). We restrict our comparison to bilateral estimates for European tax havens as TWZ reports an aggregate for non-European tax havens. We find a strong rank correlation between our bilateral measure and the one of TWZ, slightly above 60%. TWZ's bilateral allocation of profit shifting mainly relies on exports of services by tax havens. In contrast, we are agnostic about the channels of profit shifting (see section D.4 of our Appendix for a discussion). In our Appendix's section D.5, we provide additional material that compares our profit-shifting estimates with other sources found in the literature.

Finally, we propose different robustness exercises in our Appendix's section D.6. We assess the correlation between our profit-shifting allocation and an allocation based on excess trade in services with tax havens only. We find a positive and significant correlation between excessive high-risk services and our theoretically consistent measure of bilateral

[20] In Appendix's section D.4, we briefly discuss the approach followed so far by the literature and, especially TWZ. We argue that profit shifting in goods, tax-havens deflated imports and non-"high-risk" services are three additional sources that come on top of the excess of "high-risk" services exports and intra-firm interest payments considered in TWZ. We also discuss the robustness of our calibration using inputs from TWZ in Appendix's section D.6.

profit shifting. The Spearman rank correlation coefficient of 0.6 indicates a relatively high correlation between both series but the PS_{lh} estimated in this paper is generally larger than the excess of services trade. This result suggests that services trade is an important driver of profit shifting between source countries and tax havens but shall not be considered its unique determinant.[21]

4.2 Tax Base and Profit-Shifting Elasticities

Table 3 reports the estimated coefficients and the corresponding parameter elasticities $\tilde{\upsilon}_1$ and $\tilde{\upsilon}_2$. In columns (1) and (2), we use the statutory tax rates as the corporate tax variable, while we use the median effective tax rate in columns (3) and (4). We report the result using OLS in columns (1) and (3), and PPML in columns (2) and (4).

Table 3: Estimation of elasticities $\tilde{\upsilon}_1$ and $\tilde{\upsilon}_2$

	Estimation $\tilde{\upsilon}_1$		Estimation $\tilde{\upsilon}_2$	
Dep. Var.	$ln\left(\frac{X_{ill}}{\sum_i X_{ill}}\right)$	$\frac{X_{ill}}{\sum_i X_{ill}}$	$ln\left(\frac{X_{ilh}}{\sum_i X_{ilh}}\right)$	$\frac{X_{ilh}}{\sum_i X_{ilh}}$
	(1)	(2)	(3)	(4)
$ln(\tilde{t}_{ll})$	2.639***	3.047*		
	(0.688)	(1.674)		
$ln(\tilde{t}_{lh})$ (Med.)			7.869***	8.625***
			(0.191)	(1.295)
Observations	1,256	1,600	6,561	7,091
Estimator	OLS	PPML	OLS	PPML
Gravity controls	Yes	Yes	Yes	Yes
i country FE	Yes	Yes	No	No
i-l pair FE	–	–	Yes	Yes
Technology controls	Yes	Yes	–	–

Note: Robust standard errors clustered at the $i \times l$ level in parentheses. Gravity controls include bilateral distance (in logarithm), a contiguity dummy, colonial linkages dummies, common legal origin dummies, and common language dummies. Technology controls include GDP and GDP per capita (both in logarithm). Our main estimate of $\tilde{\upsilon}_2$ (column (3)) is estimated following an iterative procedure where we first guess a value of $\tilde{\upsilon}_2$, compute ζ_{il} and PS_{ih}/PS_i and use (16) to back out χ_{lh} and (15) to compute $\mathbb{P}_{ilh}$. We then use the implied profit-shifting flows to update the guess on $\tilde{\upsilon}_2$ through (19) and iterate until convergence. *** p<0.01, ** p<0.05, * p<0.1.

We find a profit-shifting elasticity, $\tilde{\upsilon}_2 = 7.9$, three times the tax base elasticity, $\tilde{\upsilon}_1 = 2.6$. Our estimate suggests that multinational production - which is governed by both elasticities - is relatively mobile across countries.[22]

[21] In Appendix Figure D6, we explore the role of the parameters $\tilde{\upsilon}_1$ and $\tilde{\upsilon}_2$ on the allocation of profit shifting and find that the estimated profit shifting is robust to different calibrations of these elasticities.

[22] The elasticity of production to MP-frictions υ_1 would have been 10.9 assuming $\sigma = 4$. It is somewhat larger than the elasticity found in the literature. For comparison, Head and Mayer (2019) and Wang (2020) estimate an

Profit-shifting elasticity: Robustness. Overall, there is no direct comparison between our estimate of the profit-shifting elasticities and the literature. Beer et al. (2020) show in their meta-analysis that, all else equal, a 1-point decrease in the tax rate corresponds to an increase in reported profits by 1%. In addition, a few studies have estimated the *elasticity* of reported profits to corporate taxes using country-level data. Gruber and Rauh (2007) find a moderate elasticity of the corporate tax base with respect to current effective tax rates (equivalent to 0.2). Using administrative data on U.S. tax filings, a recent study by Coles et al. (2022) decomposes the corporate tax elasticity of taxable income into a tax base and a paper profit elasticity. In line with our findings, their results suggest larger profit-shifting reactions to corporate tax than tax-base responses.

So far, our estimation relies on the profit-shifting flows we estimated following the methodology of section 3. To assess the sensitivity of our implied elasticities, we use alternative data sources of income and profit shifting, effective tax rates, and different methodologies. First, we reproduce the results shown in column (4) of Table 3 by using direct information on profit shifting from source to haven countries from Wier and Zucman (2022). Second, we reproduce the results of Table 3 by using the information on bilateral effective tax rates for the 25 countries reporting in the OECD CbCR dataset. Third, we construct a new sample of bilateral reported pre-tax income and bilateral effective tax rates using micro-level data from the Refinitiv Thomson Reuters *Eikon* database – hereafter, the Eikon dataset. The dataset allows us to use high-dimensional fixed effects and control for unobserved bilateral frictions determining excess profits. It has, however, the drawback of covering only a few countries, particularly tax havens. Details on sample construction are provided in Appendix D.3.

Using data from Tørsløv et al. (2022) allows a direct estimation of $\tilde{v}_2$ while the other two sources require us to estimate shifted profits. Therefore, we proceed in two steps using the CbCR and Eikon datasets. In the first step, we estimate the amounts of profit shifted to tax havens. The empirical specification includes bilateral ETRs, gravity controls, and a set of origin × year and destination × year fixed effects, removing country-specific and time-varying unobserved heterogeneity. Under this fixed effect specification, we cannot identify excess profits based on the tax haven dummy. We follow the methodology proposed by Garcia-Bernardo and Jansky (2021), who compute profit shifting to tax havens based on the hypothetical case that tax havens would have had an effective tax rate (ETR) of

elasticity of 7.7. This implies that the impact of multinational firms' production and profit-shifting frictions will be downplayed in our quantitative exercises compared to these estimates. For comparability purposes, in table H6 of Appendix H.5, we also compute the semi-elasticity of the tax base to taxes and of profit shifting to taxes using the same specification as in Table 3. We find a semi-elasticity of the tax base of 3.6 and of profit shifting of 8.3. In their meta-study, Beer et al. (2020) find that the average semi-elasticity of profits to taxes estimated in studies that use aggregate data is between 2.5 (Table 2, column 3) and 2.9 (Table 2, column 2). Our semi-elasticity of the tax base to taxes, despite being slightly higher than this average, lies in the same range. In their estimation of a non-linear elasticity of profit to taxes using micro-level country-by-country reporting data, Fuest et al. (2021) find a semi-elasticity of profits to taxes between -10 and -13 when the effective tax rate is close to zero, a situation which typically corresponds to tax haven affiliates. This result confirms large elasticities for profits (essentially paper profits) located in tax havens. We assess the sensitivity of our counterfactual experiments to alternative calibrations of $\tilde{v}_1$ and $\tilde{v}_2$ in section H.6 of the Appendix.

25%. Profit shifting is computed as the difference between the predicted profits and those predicted with the counterfactual tax rates of 25%. In the second step, we regress profit shifting on the $\log(1 - t_l^{ETR})$, gravity controls, and a set of origin × year and destination × year fixed effects following the specification of equation (14). When time variation allows, we include pair-fixed effects in both steps.

Table 4 reports a summary of our results. The complete estimation table is reported in Appendix D.3.

Table 4: Alternative identification of $\tilde{\upsilon}_2$

	(1)	(2)	(3)	(4)
Data Source	WZ	CBCR	Eikon	Eikon
Implied $\tilde{\upsilon}_2$	10.5	8.2	8.4	5.4
Controls and FE in first and second steps				
Gravity Controls	Yes	Yes	Yes	No
Origin × Year FE		Yes	Yes	Yes
Destination × Year FE		Yes	Yes	Yes
Pair FE		No	No	Yes

Note: This table displays alternative estimations of profit shifting and corresponding estimation of $\tilde{\upsilon}_2$. In column (1), we directly use profit-shifting data from Wier and Zucman (2022) (WZ). In column (2), we estimate profit shifting using data from Country-by-country reports (CbCR), and in columns (3) and (4), we use the Eikon dataset. Details on the estimation procedure, additional results, and full tables are provided in Appendix D.3.

In column (1), we use the TWZ estimate of profit shifting to compute $\tilde{\upsilon}_2$ following the specification of table 3. In column (2), we use the bilateral ETR computed from the CbCR dataset and assume a constant profit elasticity to the effective tax rate.[23] We report the results using the Eikon dataset in columns (3) and (4). Compared to column (3), column (4) reports results using pair fixed effects in addition to origin × year and destination × year fixed effects. Using alternative samples and calibration, we find that $\tilde{\upsilon}_2$ varies between 5.4 and 10.5 compared to $\tilde{\upsilon}_2 = 7.9$ in the baseline estimation.

In additional results shown in Appendix D.3, we find that the ratio of profit shifting to total incomes in most samples matches our previous estimates at around 40% of total incomes. We find lower estimates using the aggregated micro-level dataset because it is composed of fewer tax havens. Moreover, only a few firms report profits in tax-haven countries.

Extension: varying profit-shifting elasticity. Our calibration of $\tilde{\upsilon}_2$ rests on the assumption that the share of profits shifted to tax havens is a constant elasticity function of the corporate tax rate. While this assumption is reasonable for small changes in

[23] In Appendix D.3, we follow Hines and Rice (1994), Dowd et al. (2017) Garcia-Bernardo and Jansky (2021) and allow for non-linearities. The results are qualitatively the same.

corporate tax rates, policies like a minimum taxation reform could generate large variations in effective tax rates and tax rate differentials. We refine our parametrization of the profit-shifting elasticity and allow for an additional variable profit-shifting elasticity. We augment our profit-shifting friction α_{lh} with $(t_l - t_{lh})^k$ where k is a shape parameter. The partial elasticity of profit shifting then becomes $\tilde{\upsilon}_2 + \frac{k(1+\tilde{\upsilon}_2)}{1+\tilde{\upsilon}_1}\frac{(1-t_{lh})}{(t_l-t_{lh})}$. The shape parameter k is recovered from the data (see results in Table E1). The estimated k is such that the elasticity is below $\tilde{\upsilon}_2$ for tax rate differentials above 20 percentage points. This property will have implications for the implementation of the minimum tax rate.[24] We implement this varying profit-shifting elasticity to simulate minimum taxation policy scenarios.

4.3 Profit-shifting frictions

Bilateral profit-shifting frictions are a key new ingredient of our framework. They govern how multinational firms make decisions about where to shift profits and where to produce. In this subsection, we back out these frictions, consistently with the observed flows of shifted profits by firms in residence i to tax haven h from source country l. We first detail the procedure and then explore the magnitude and determinants of these frictions.

Identifying Profit-shifting frictions. We start by noting that, at the calibrated equilibrium, we know profit-shifting probabilities $\mathbb{P}_{ilh}$; taxes t_{ll} and t_{lh}; frictions γ_{il}; wages w_l; market potential Ξ_l; and our estimated elasticities $\tilde{\upsilon}_1, \tilde{\upsilon}_2$ (see Appendix F for details). We group these in a set of observables denoted $\mathcal{O}$. We formalize an important result for the identification of profit-shifting frictions in the next Proposition.

Proposition 5 (Identifying Profit-Shifting Frictions)**.**
At the calibrated equilibrium the following holds

$$\frac{\mathbb{P}_{ilh}}{\mathbb{P}_{ill}} = \left(\bar{\theta}\tilde{\theta}_i \alpha_{lh}\right)^{-\upsilon_1} \times f(\mathcal{O}), \tag{20}$$

where $f(\cdot)$ is a known function of observables and $\bar{\theta}$ is a normalizing constant such that $\theta_i = \bar{\theta}\tilde{\theta}_i$. We specify both $f(\cdot)$ and $\bar{\theta}$ in Appendix F.

This important result allows us to recover the set of profit-shifting frictions up to a normalization constant $\bar{\theta}$. We define $\bar{\theta}$ as such that when $\theta_i = \bar{\theta}$ and absent profit-shifting frictions, firms would have an equal probability of engaging in tax avoidance and booking their profits domestically *ceteris paribus*.

We note that $\tilde{\theta}_i = \theta_i/\bar{\theta}$ and α_{lh} can be mapped into a marginal cost equivalent $Cost_{ilh} \coloneqq \tilde{\theta}_i\alpha_{lh}$. This is the marginal cost increment associated with profit shifting from any l to any h by firms from i *if all profit-shifting frictions were such that* $\alpha_{l'h'} = \alpha_{lh}$. In contrast with trade or multinational production frictions, the interaction of the tax base and profit-shifting elasticities implies that bilateral profit-shifting flows do not verify the irrelevance

[24] A higher rate would reduce profit shifting more than proportionally. We observe large elasticities for tax differentials that are smaller than 10%. This result suggests larger responses of profit shifting when the tax differential is small.

of independent alternatives. The cost of shifting profits from l to h depends on the profit-shifting frictions between other $l' - h'$ pairs.

Average profit-shifting costs. We start by describing the distribution of average $Cost_{ilh}$ between l and h in Figure 3. We plot the distribution of the profit-shifting cost averaged over (non-haven) i countries: $Cost_{lh} = \frac{1}{33}\sum_i Cost_{ilh}$.

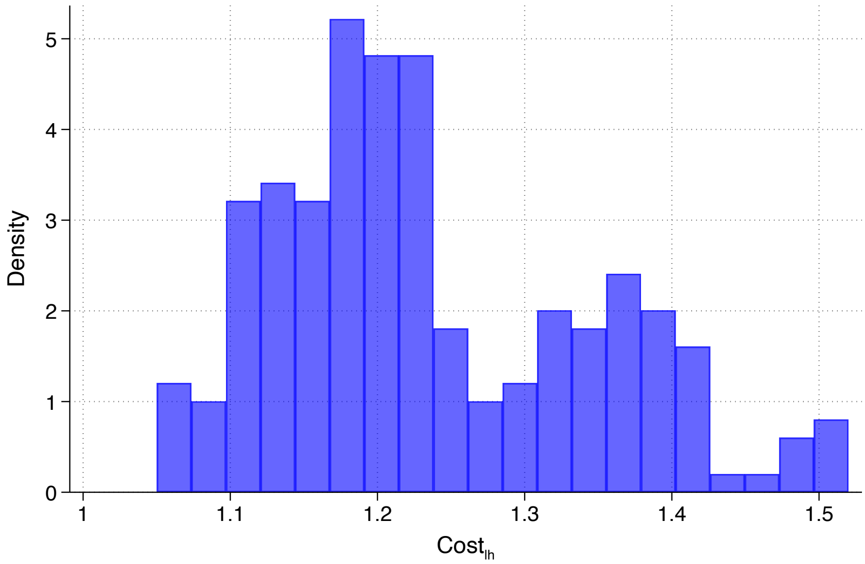


Figure 3: Average cost of profit shifting ($Cost_{lh}$)

Conditional on observing profit shifting, the median value of profit-shifting costs calculated in our sample is 1.23. It can be up to 1.5I update for some pairs. A profit-shifting cost of 1.23 means that shifting from a residence country i to a tax haven h through a production affiliate l generates an increase in the cost of production of 23%, all other things being equal. The friction can be compared to the variable friction γ_{il}, which represents the costs of separating the location of production from headquarters. We find a median value of γ_{il} of 1.40, similar to the multinational production costs of 1.31 provided by Head and Mayer (2019) for the car industry.

Components of profit-shifting costs: $\tilde{\theta}_i$ and α_{lh}. The profit-shifting cost has two components: the tax aggressiveness of the residence country $\tilde{\theta}_i$ and the bilateral friction α_{lh}. Our model suggests that the costs are separable via a fixed effect for i and one for lh pairs: $ln(Cost_{ilh}) = ln(\tilde{\theta}_i) + ln(\alpha_{lh})$. The residence country fixed effects correspond to the log of $\tilde{\theta}_i$. The source and tax haven dyadic fixed effects capture the bilateral profit-shifting frictions α_{lh}. About 27% of the variation in profit-shifting costs is explained by the (log) bilateral frictions, α_{lh}. [25]

[25]Note that the different abilities of each residence country to reduce the costs of shifting profits should be interpreted as deviations from the tax aggressiveness of one reference country that we choose to be the U.S.

In Figure 4, we show the cross-country distribution of $\ln \theta_i$. Compared to U.S. MNCs, Turkish firms experience a profit-shifting cost penalty of 35%. Belgian MNCs benefit from a 13% reduction in profit-shifting costs compared to U.S. MNCs. The differences in tax aggressiveness across residence countries in Figure 4 show the key role of headquarters in firms' profit-shifting practices.

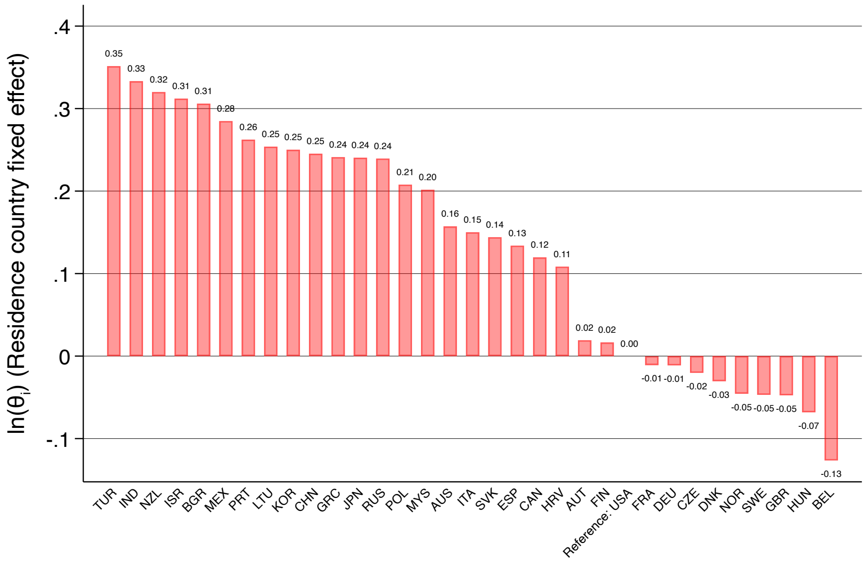


Figure 4: Distribution of $ln(\theta_i)$

Finally, we regress the log of α_{lh} on gravitational variables, tax rates, and the TJN's Corporate Tax Haven index (CTHI). This last variable corresponds to an index computed by the TJN that aggregates 20 *de jure* and *de facto* indicators of the aggressiveness of tax havens' policies. We see it as a proxy for tax avoidance technology provided by tax havens (see Appendix C.6 for details). We show in the Appendix Table F1 that the distance between the source and tax haven countries, and other gravitational forces affect α_{lh}. In other words, profit shifting frictions shape the geographic incidence of international tax reforms. Moreover, profit-shifting frictions are negatively correlated with the TJN's Corporate Tax Haven Index and with the corporate tax rate difference between the source and the havens. We also find a negative correlation between the difference in tax rates of the source and haven countries and the profit-shifting friction, controlling for source and haven fixed effects. This points to the importance of introducing a varying profit-shifting elasticity as done in Section 4.2.

5 Policy Simulations

This section discusses policy simulations regarding tax policy changes in various countries, including their effects on tax revenues, GDP levels, profit shifting, real income, and welfare. It starts by demonstrating the effects of simple tax policy changes to illustrate the model's key mechanisms. Then, it quantifies different scenarios of minimum taxation and discusses these policies' short- and long-term effects. Finally, it evaluates the introduction of a border-adjustment tax in the spirit of the DBCFT proposal.

To simulate counterfactual tax reforms, we follow the exact hat algebra methodology popularized by Dekle et al. (2007) and Costinot and Rodriguez-Clare (2014), which consists in writing the new equilibrium in proportional changes with respect to the baseline one (see Appendix G for details). We mainly focus on the U.S. as an example throughout the discussion, but our model generates counterfactual outcomes for the 40 countries of our sample. The findings are derived using calibrated parameters summarized in Table H1. We assess the external validity of the calibration in Figure H1, and we analyze the sensitivity of the results to different elasticities in the Appendix (section H.6).

5.1 Preliminaries: Model mechanism

Unilateral tax reforms. *What are the effects of a 5% unilateral reduction of U.S. statutory tax rate (from 40% to 38%)?* We illustrate our findings in Appendix Table H2. The reduction in the U.S. tax rate has a modest positive impact on GDP (+0.33%). All else equal, the U.S. becomes a more attractive production location after the reform. The policy decreases profit-shifting activities (-9.95%) because some U.S.-based firms book their profits in the U.S. after the reform. The cross-country reallocation of production and profit-shifting activities dampens the negative effect on tax revenues. We find a reduction of tax revenue by 3.9%, which also reduces consumers' income because of lower lump-sum transfers. In this scenario, U.S. production and labor demand increase, raising workers' wages. We find a positive effect of the policy on real income (+0.33%) and a slight negative impact on welfare (-0.02%), driven by the loss of tax revenues. The effect on real income can be decomposed between the effect of a significant positive response of wages (increasing welfare by +0.39%) that is not offset by the negative response of tax revenues (decreasing welfare by 0.08%). The rest of the effect (+0.03%) is driven by imbalances. The net effect on welfare is driven by the lower provision of public goods as tax revenues decline.

Benchmarking: Closing a tax haven. *What are the tax revenues and real effects of closing a tax haven*? We choose Singapore and illustrate the effects on the U.S. We implement this by setting $t_{lSGP} = 1$, $\forall l \notin \mathcal{H}$.

The results are presented in the second line of Table H2. Profit shifting reduces by 3.3%. This result comes from the increased costs for some firms to shift their profits to other tax havens. As they face considerable bilateral profit-shifting frictions α_{lh}, $h \neq SGP$, they stop shifting profits to tax havens. Tax revenues increase by 0.27%. Consistent with Suárez Serrato (2018), we find additional effects beyond tax revenues. The U.S. GDP loss (-0.01%) is due to the relative increase in the effective tax rate for tax-avoiding U.S. firms. In this scenario, some firms would leave the U.S. leading to a net loss in real income (-0.02%).

In Figure H2, we illustrate the importance of bilateral profit-shifting frictions and gravitational forces in explaining profit shifting to tax havens. In panel (a), we find that closing

Singapore induces a larger reallocation of profits to Hong Kong than to Luxembourg or Ireland. In panel (b), we observe that fewer firms engage in profit-shifting activities, which broadens the tax base of countries geographically close to Singapore, such as India, New Zealand, Australia, or Japan. On the other hand, European countries, which are more distant, benefit less from this reallocation.[26]

5.2 Minimum taxation

We now study the effects of minimum taxation. The general principle of minimum taxation implies that no foreign affiliate can escape a minimum rate of taxation t^{min} by declaring its operations in a low-tax jurisdiction. However, implementing minimum taxation poses several challenges, including the allocation of taxing rights. Determining which jurisdictions should have the right to enforce the minimum tax is delicate since it requires taking a stance on whether the value is created in the location of headquarters, the location of research and development, or the place of production of physical output (see Devereux et al., 2021). Therefore, the taxing rights could be either allocated to the source or to the residence countries.[27] Moreover, minimum taxation can be implemented unilaterally or multilaterally.

We implement a 15% minimum tax reform where real activities are fully deductible from the minimum tax. In this version, the minimum tax applies to shifted profits only, $\sum_{l,h,l\neq h} PS_{ilh}$. This captures the OECD/G20 Inclusive Framework agenda, which aims to tackle the erosion of the tax base through profit shifting and not through tax competition for real resources.

A common objection to introducing a minimum effective tax rate is the possibility of corporations to move their headquarters to a country that does not apply an effective minimum tax rate. Our model allows us to dissect the effect of minimum taxation in the short-run (assuming a fixed number and a fixed location of headquarters) and in the long-run (once the number and location of headquarters adjust endogenously). By assumption, the short-run scenario does not allow for corporate inversions. However, multinational firms may relocate their production across countries in both scenarios. Table 5 reports the results of the short-run (Panel A) and long-run (Panel B) scenarios.

Unilateral minimum taxation. Under a residence-based minimum tax rate t^{min}, the U.S. taxes U.S. MNCs that continue to shift profits to tax havens at a rate that is equal to the difference between the minimum rate and their effective tax rate $(t^{min} - t_{ilh})$, regardless of the source countries where they operate. Additionally, the reform also directly increases the U.S. tax base as some U.S. firms operating in the U.S. no longer find it profitable to engage in profit shifting. As a result, corporate tax revenues in the U.S.

[26] In Appendix H.2, we also discuss the scenario in which countries implement effective anti-abuse policies, de facto eliminating profit shifting.

[27] The recent reform of international taxation allocates the residual taxing right on foreign profits to residence countries (see OECD, 2021). Allocating taxing rights to residence countries rather than source countries is still debated (see Englisch and Becker, 2019).

Table 5: Impact of minimum taxation for the U.S. (rate: 15%)

Minimum Taxation	% change in ... Tax revenues	Profit Shifting	Real Production	Consumer Real Income	Welfare
			A. Short Run		
Unilateral					
– Residence	4.20	-28.38	0.06	0.08	0.45
– Source	4.40	-38.68	-0.06	-0.001	0.38
Multilateral					
– Residence	4.33	-29.37	0.11	0.11	0.49
– Source	3.99	-29.37	0.11	0.11	0.46
			B. Long Run		
Unilateral					
– Residence	4.00	-27.77	-0.04	-0.14	0.21
– Source	4.33	-38.58	-0.12	-0.09	0.29
Multilateral					
– Residence	4.09	-28.94	-0.06	-0.12	0.24
– Source	3.79	-28.95	-0.06	-0.13	0.20
– Tax havens' adjustment	2.33	-28.95	-0.06	-0.16	0.05

increase (+4.20% in the short run) because of both the reduction in profit shifting (-28.38%) and the implementation of the minimum tax. Ex-ante, the impact of residence-based minimum taxation on production is ambiguous. In comparison to a top-up residence-based tax that applies to all repatriated profits, a minimum tax raises the ETR only for those firms engaging in tax avoidance. In contrast to the neutral impact of a top-up residence-based tax, discussed in Proposition 2, we show that a residence-based minimum tax distorts firms' production and profit-booking location decisions. Specifically, under the minimum tax regime, U.S. firms give more weight to U.S. fundamentals ($A_{U.S.}$) and less weight to the effective tax rate when deciding where to book profits and allocate production. Our simulations reveal that the minimum tax positively affects production (+0.06%), increases workers' wages, and positively impacts real income (+0.08%). Additionally, the effect on welfare is positive and sizeable (+0.45%), which is primarily driven by increased tax revenues.[28]

Our findings suggest that the effects of implementing a *unilateral source-based minimum tax* would differ from those described above. Under this scenario, the effective tax rate of all profit-shifting firms operating in the U.S. increases, resulting in a decrease in production by 0.06%. Although tax revenues increase, the overall real income effect is negative but minimal, with a decrease of 0.001%. The impact on welfare is smaller than in the residence-

[28]Recall that our status quo that define the preference for public-good consumption is a Nash equilibrium where the instruments are the unilateral statutory rates. Instead, the minimum tax is another instrument that induces changes to the tax rates applied to shifted profits t_{ilh} for $h \neq l$, not to the statutory tax rates. Hence deviations from the status quo with minimum taxation can be welfare improving.

based scenario, with an increase of 0.38%.

The exit of headquarters can diminish the positive impact on welfare in the long run by reducing private consumption. This negative effect on real income is particularly pronounced when a residence-based minimum tax targets all U.S.-headquartered firms, as opposed to a source-based minimum tax that applies to firms operating in the U.S.. In fact, a unilateral source-based minimum tax is found to be more beneficial for welfare in the long run, resulting in a 0.29% increase.

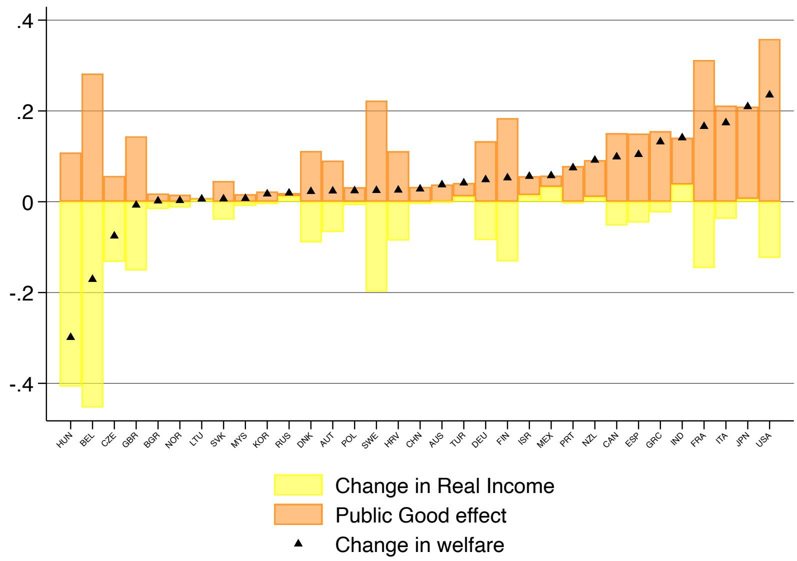
A global minimum tax. Implementing a multilateral minimum tax reduces the dispersion of the effective tax rates across countries and increases their level for all avoiding firms, regardless of where they are headquartered. Note that the distribution of corporate tax rates across countries is the same in both the residence and source scenarios. This is because firms face the same minimum tax, irrespective of whether it is levied by countries where they operate or where they are headquartered. As a result, the direct effects on profit shifting and production are identical. However, in general equilibrium, these effects differ since the two reforms allocate tax revenues differently across countries.

From a global efficiency standpoint, the effect of the reform, in the long run, is ambiguous, as it increases the effective tax rate while reducing the dispersion of tax rates across countries. The increase in the ETR has two opposite implications on welfare through public and private good consumption. First, it raises tax revenues which increases public good provision and, therefore, welfare. At the same time, it also leads to the exit of headquarters (as discussed in Section 2), which negatively affects private consumption. Importantly, recall that this effect is only present in the long-run scenarios. Lastly, the reform also reduces the dispersion of tax rates across countries so that corporate-tax determinants are less binding and firms' choices increasingly reflect countries' fundamentals, e.g., source-countries' technologies. The latter effect has an unambiguous impact on welfare through an increase in real income.

To sum up, in the short run, public good provision increases without dampening product variety, and the dispersion in tax rates decreases: the reform benefits both public and private consumption. Instead, in the long run, the exit of firms has a negative impact on real income. Panel B of Table 5 shows that this channel dominates the reduction in tax dispersion. Nevertheless, we note that welfare increases in all scenarios, as higher public good consumption more than offsets the reduction in private consumption.

Tax havens' response to the minimum tax. In addition to the impact of minimum taxation on global efficiency, the implementation of minimum taxation also has to consider the tax havens' incentive to adjust their corporate tax regime (see, e.g., Janeba and Schjelderup, 2022, Johannesen, 2022, and Hebous and Keen, 2023). We let tax havens respond to the reform by adjusting their tax systems to collect the tax revenues that would otherwise go to source or residence countries. Through the lens of our model, it means that tax havens h set $t_{lh} = t^{min}$.[29] It is important to note again that the ETR at the firm level does not depend on the allocation of taxing rights: whether the additional revenues brought by the minimum tax are collected by the tax havens or by other countries is irrelevant from a firm's perspective. This implies that after a minimum-tax reform, the decision of tax havens to match the minimum rate will not deter investment further. Instead, it will unambiguously increase tax havens' tax revenues. We consider this case in the last row of Table 5. The responses of tax havens do not impact profit-shifting decisions, only public good provision and welfare are lower in non-havens. Nevertheless, the response of tax havens to the reform does not eliminate the gains from a global minimum tax. Compared to the status-quo, non-haven countries still benefit from the reduction in profit-shifting, as the reform broadens their tax base.

To further illustrate the effects of the reform, we provide Figure 5, which displays the welfare changes induced by a residence-based multilateral minimum tax for each non-haven country. The figure shows that, in general, most countries experience a net welfare increase after the reform, with only a few countries displaying significant losses in real income that are not compensated by public good provision effects. These results suggest that, overall, a residence-based multilateral minimum tax can lead to significant welfare gains for most countries.



Note: Real income of country n is defined as its real income Y_n/P_n. Welfare of country n is defined as $\tilde{U}_n = (B_n/P_n)^{\beta_n} Y_n/P_n$. The public good effect denotes the change in $(B_n/P_n)^{\beta_n}$. The change in welfare corresponds to the sum of the change in real income and the public good effect. Bars are stacked. See Section 2.5 for details on the calibration of β_n.

Figure 5: Effect of a 15% multilateral residence-based minimum tax.

[29]Note that this does not imply that tax havens increase their statutory tax rate. See for instance the case of Ireland cited in Footnote 5.

Profit-shifting and general equilibrium effects. We show in this paragraph the quantitative relevance of our policy simulations within a framework that allows for profit-shifting in general equilibrium. We consider a scenario where the U.S. implements a unilateral residence-based minimum tax rate of 15%. Our focus is on the long-term impact of this reform, and we provide a formal decomposition of the results in Appendix H.3. Introducing the minimum tax rate has a mechanical tax rate effect that increases tax revenues by 2.59% ceteris paribus. However, in general equilibrium, the total increase in tax revenues is 4%. This additional effect is driven by the reduction in profit shifting, which broadens the tax base. We find that this effect is substantial and raises tax revenues by 1.49%, representing 57.4% of the mechanical tax rate effect.[30] However, firms facing higher effective tax rates, after the reform, adjust the location and scale of their activity, resulting in a decrease in initial tax revenues by 0.07% ceteris paribus. These results underline the importance of considering the endogenous profit-shifting decision of firms when evaluating the impact of tax policy reforms.

We can also disentangle the impact of GE forces on the changes in real income. The tax rate effect induces a mechanical increase in tax revenues, positively impacting real income (+0.06%). However, the full counterfactual effect on real income is negative (-0.14%). In general equilibrium, the positive impact of the reform on tax revenues is more than offset by the negative effect on wages when we allow free entry (-0.25% in wages).

Responses after a minimum-tax reform. We conclude this section by asking whether non-haven countries would have an incentive to adjust their statutory corporate tax rate after the implementation of a global minimum tax, i.e. when the number of firms has adjusted, and tax havens have matched the minimum-tax rate. To answer this question, we start from the Nash equilibrium induced by the vector of β_n discussed above; we implement the minimum-tax reform and, finally, let countries unilaterally change their statutory rate after a global minimum tax to understand who benefits from such deviation.[31]

We start from the counterfactual equilibrium considered in the last row of Table 5. From here, we let countries unilaterally deviate by changing their statutory rate at the margin (0.1 percentage point increase). In other words, we compute $\frac{\partial U_n}{\partial t_n}$ starting from a world where the minimum tax has already been implemented. This informs us about which country would have the incentive to increase or decrease its statutory rate in response to the global minimum tax. Figure 6 plots the change in welfare implied by a marginal increase in the statutory rate. As shown in the figure, most countries would benefit from a unilateral increase in their statutory rate. Intuitively they would trade off a loss in real income with an increase in real tax revenues. The introduction of the global minimum tax reduces the

[30] In Appendix H.3, we decompose the effect of the policy on the CIT base and on the minimum tax base. This increase of 1.49% is the sum of the effect on each base. Indeed, the reduction of profit shifting increases the CIT base (increasing revenues by 2.28%) but decreases the minimum tax base (decreasing revenues by 0.79%).

[31] We leave the resolution of the new Nash equilibrium for future work. Although the broad approach of Ossa (2014) and Wang (2020) could be applied to our framework, a policy-relevant exercise should carefully examine all the instruments at the disposal of various countries from subsidies (as announced by Switzerland following the global tax deal) to domestic minimum taxes (e.g., the U.K.).

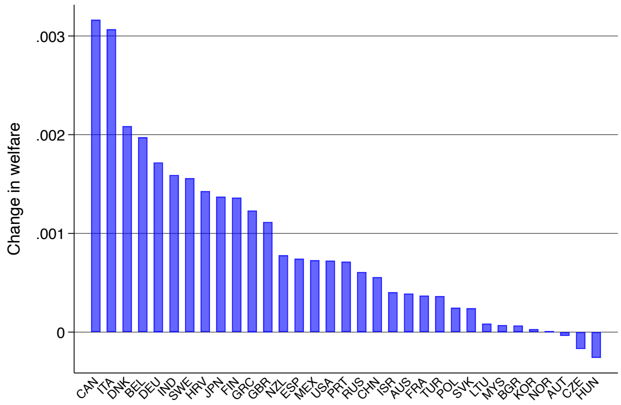


Figure 6: Marginal effect of the statutory tax rate after a global minimum tax.

cost of increasing the statutory rate as it limits the erosion of the tax base through profit shifting. This, in turn, implies that countries are incentivized to increase their statutory tax rate and suggests a positive impact of the global minimum tax on non-havens' tax policies.

5.3 Destination-Based Cash Flow Tax (DBCFT)

We conclude by examining the effects of the implementation of a reform in the spirit of a destination-based cash flow tax by the U.S. The fact that a global minimum tax at 15% would reduce profit shifting from the U.S. by at most 30-40% raises the question of whether more ambitious designs, such as the DBCFT, would be preferable. This proposal replaces the corporate income tax with a border adjustment tax. Under this regime, most standard profit-shifting strategies become inoperative (Auerbach et al., 2017b) because it is indifferent to the place where profits are located.

We implement this policy via three main changes to the tax system: i) a sales tax tr_n levied on all domestic consumption, ii) a production cost subsidy s_l on all domestic production, and iii) elimination of the corporate income tax (CIT). Profits are still given by (1), but taxation now distorts market potentials:

$$\Xi_l^{1-\sigma} = (1+s_l)^{\sigma-1} \sum_n \frac{\tau_{ln}^{1-\sigma}}{(1+tr_n)^{\sigma}} \frac{Y_n}{P_n^{1-\sigma}}.$$

Under a unilateral DBCFT proposal with $s_{U.S.} = tr_{U.S.} \equiv tr$, the above expression implies that profits arising from domestic sales by domestic producers are effectively taxed at rate $(1+tr)^{-1}$ instead of $(1-t_{ilh})$. Generally, the tax revenues for country l are given by

$$B_l = (1+tr_l)^{-1} \sum_i \mathcal{N}_i \mathbb{P}_{ill} \tilde{\pi}_{il}^D + tr_l \sum_{i,k \neq l} X_{ikl} - s_l \frac{\sigma-1}{\sigma} \sum_{i,n} X_{iln},$$

where $\tilde{\pi}_{il}^D$ are the average profits associated with domestic sales in l by firms producing in

l.[32] The first term represents the revenues from taxing domestic firms' profits, the second term is the sales tax levied on imports, and the final term is the cost of subsidizing domestic firms' exports. We relegate the rest of the derivations to Appendix H.4.

In the special case where $(1 + tr_{U.S.})^{-1} = 1 - t_{U.S.}$, DBCFT boils down to a border-adjusted-tax: the tax rate on profits from domestic sales is unchanged, imports are taxed and exports subsidized. Outside this case, the DBCFT proposal combines a border-adjusted tax with a (potentially large) reduction in the corporate tax rate. As such, in any environment where the corporate tax rate is expected to have some effect on economic activity, such a proposal will not be neutral on real income or on trade patterns. In addition, it should be noted that even if the reform was a pure BAT, it would not be neutral on trade either, be it for the presence of multinational firms under imperfect competition (Costinot and Werning, 2019), or the income effects arising from curbing profit shifting.

We present our results for different values of the DBCFT rate in Table 6. Table H5 in the Appendix breaks down government revenues after the reform between revenues coming from domestic sales and revenues coming from the border adjustment. It also decomposes the change in GDP between the activity of U.S. firms and the activity of foreign firms in the U.S.

To build intuition, consider the introduction of a 5% DBCFT. This is tantamount to taxing the profits accruing from domestic sales of domestic firms at $(1 + 5\%)^{-1} \approx 1 - 5\%$. This is equivalent to an 87.5% reduction of the corporate tax rate, from 40% to 5%. The government revenues from domestic firms fall by 87% as some firms move into the U.S. As the U.S. starts with a trade deficit, the border adjustment yields net revenues so that the overall fall in revenues is -82%. Firm entry in the U.S. boosts the demand for labor, which, in turn, generates increases in wages and income. These gains are approximately halved by the almost full pass-through of the border tax, in line with Barbiero et al. (2019). As a consequence of the reform, the terms of trade undergo a significant appreciation, with the U.S. price index increasing by 4%. Finally, the net gain in real income is undone by the large drop in tax revenues, which translates into an overall large negative welfare effect of -11%.

The insights of this relatively small policy carry through to higher rates with the important caveat that larger policy interventions significantly affect the trade balance. In particular, the trade deficit turns into a surplus around a DBCFT rate of 20%, which further contributes to the decline in tax revenues. Higher DBCFT rates generate smaller revenue drops from domestic firms but reduce the contribution of the border adjustment and, importantly, generate a strong appreciation of the terms of trade. The border-adjusted tax (BAT) case maintains a taxation of profits from domestic sales at 40%. Far from neutral, the impact is largely negative, driven by quantitatively important distortions in the allocation of production in the US between domestic vs. foreign firms: as shown in Table H5, a border-adjusted tax that subsidizes exports *de facto* has a much larger impact on the

[32] Formally, average profits from domestic sales are given by $\pi_{il}^{D} = \mathbb{E}\left[(1+tr)^{-1}\frac{\iota_l}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{\gamma_{il}\alpha_{lh}}{\varphi_{il}}w_l\right)^{1-\sigma}\frac{Y_l}{P_l^{1-\sigma}}\right]$.

international location of multinational production than it has on the expansion of US-firms operating in the U.S. The U.S. becomes a net importer of multinational production and features a trade surplus. This, in turn, implies that the tax revenue contribution of the border adjustment component turns negative since the US now has to subsidize a net trade surplus. A lower DBCFT rate leads to the expansion of domestic profits from domestic sales, triggering entry of U.S. firms and benefiting less - on average - foreign multinationals.

Table 6: Implementation of DBCFT

	% change in ...								
	Real			Nominal					
DBCFT Rate tr_{US}	Tax Rev.	GDP	Income	Tax Rev.	GDP	Income	P	Welfare	$\frac{NX'}{GDP'}$
5%	-82.82	-0.23	4.39	-82.08	4.09	8.91	4.33	-10.82	-1.05
10%	-69.04	-4.86	3.84	-66.32	3.51	12.97	8.8	-6.5	-0.61
20%	-49.61	-13.04	2.7	-40.69	2.36	20.88	17.71	-3.41	0.2
30%	-39.05	-19.98	1.54	-22.9	1.23	28.44	26.5	-2.86	1.02
BAT ($t_{US} = 40\%$)	-64.04	-38	-3.05	-43.61	-2.79	52.01	56.8	-11.52	4.87

In general, our quantitative analysis suggests that fiscal reforms featuring the introduction of DBCFT and the elimination of the statutory rate trade-off private versus public consumption. As a consequence, if a government cares solely about private consumption (formally, $\beta_n = 0$), then abolishing corporate taxes and implementing DBCFT around 5% can generate sizeable gains. On the other hand, if households value public good consumption, then none of the reforms we consider generates a welfare gain, and the status quo is preferable.

Finally, we note a broader point highlighted by our simulations. The design of a DBCFT reform is crucial. The tax revenue shortfall could be limited by introducing DBCFT on top of, rather than instead of, the current statutory tax rate (Becker and Englisch, 2020). While this is likely to generate a smaller drop in public good provision, it carries two potentially negative consequences. The first is the introduction of further distortions generated by the general equilibrium interplay between sales tax, production cost subsidy, and corporate profit tax. The second is the inability of such a policy to eliminate incentives to shift incomes to more lenient tax jurisdictions. We leave to future research a more detailed analysis of these open questions regarding alternative designs and their general equilibrium efficiency and welfare effects.

6 Conclusion

The current international corporate tax system is outdated because it is not robust to a variety of tax avoidance strategies used by firms to shift their profits to tax havens. The ongoing reform of international taxation discussed in the OECD/G20 Inclusive Framework is meant to crowd out profit shifting by implementing a multilateral residence-based minimum taxation. This paper examines this tax policy proposal against alternative reforms such as Destination-Based Cash-Flow Taxation (DBCFT).

We use a general equilibrium model of multinational production augmented with corporate taxation and profit shifting to assess the short- and long-run consequences of different scenarios of domestic and international corporate taxation reforms. Our focus is on real activity and welfare, in addition to tax revenues and profit shifting. The model delivers a set of simple equations to recover the distribution of profits shifted across source-haven country pairs. Exploiting our theoretical framework, we derive profit-shifting frictions and the tax-base and profit-shifting elasticities, which are key determinants of how changes in the tax environment affect entry, production, and profit-shifting decisions. We highlight the importance of profit-shifting frictions and the role of geography in shaping profit shifting and production locations.

Our findings indicate that a global minimum tax improves welfare in most countries. In contrast with some critics of the proposal, we find little support for a "race to the minimum tax". Instead, we find that a global minimum tax reduces the cost for countries to increase their corporate tax rate. We benchmark this reform against a border-adjustment tax that eliminates profit shifting: the efficiency gains of a DBCFT proposal are obtained under an important decline in tax revenues, penalizing thereby public good provision.

References

Alvarez Martinez, M. T., Barrios, S., Bettendorf, L., d'Andria, D., Gesualdo, M., Loretz, S., Pontikakis, D., & Pycroft, J. (2016). *A new calibration for cortax: A computable general equilibrium model for simulating corporate tax reforms.* JRC Working Papers on Taxation and Structural Reforms.

Arkolakis, C., Costinot, A., & Rodriguez-Clare, A. (2012). New trade models, same old gains? *American Economic Review*, *102*(1), 94–130.

Arkolakis, C., Ramondo, N., Rodríguez-Clare, A., & Yeaple, S. (2018). Innovation and production in the global economy. *American Economic Review*, *108*(8), 2128–73.

Auerbach, A. J., Devereux, M. P., Keen, M., & Vella, J. (2017a). *Destination-based cash flow taxation* (CBT Working Papers WP 17/01). Oxford University.

Auerbach, A. J., Devereux, M. P., Keen, M., & Vella, J. (2017b). International tax planning under the detination-based cash flow tax. *National Tax Journal*, *70*(4), 783–802.

Bachas, P., Brockmeyer, A., & Semelet, C. (2023). *Effective Tax Rates and Firm Size* (DP17985).

Baraké, M., Neef, T., Chouc, P.-E., & Zucman, G. (2021). *Collecting the tax deficit of multinational companies simulations for the European Union* (Report No. 1). EU Tax Observatory.

Barbiero, O., Farhi, E., Gopinath, G., & Itskhoki, O. (2019). The macroeconomics of border taxes. *NBER Macroeconomics Annual*, *33*(1), 395–457.

Becker, J., & Englisch, J. (2020). Unilateral introduction of destination-based cash-flow taxation. *International Tax and Public Finance*, *27*(3), 495–513.

Beer, S., de Mooij, R., & Liu, L. (2020). International Corporate Tax Avoidance: A Review Of The Channels, Magnitudes, And Blind Spots. *Journal of Economic Surveys*, *34*(3), 660–688.

Bilicka, K. (2019). Comparing uk tax returns of foreign multinationals to matched domestic firms. *American Economic Review*, *109*(8), 2921–53.

Bilicka, K., Devereux, M., & Guçeri, I. (2022a). *Tax policy, investment and profit-shifting.* mimeo.

Bilicka, K., Devereux, M., & Güçeri, I. (2023). Tax-Avoidance Networks and the Push for a "Historic" Global Tax Reform. *Tax Policy and the Economy*, *37*, 57–108.

Bilicka, K., Qi, Y., & Xing, J. (2020). *Geographical Diversification of Tax Havens: How Did the Use of Tax Haven Subsidiaries Change in Recent Years?* (mimeo).

Bilicka, K., Qi, Y., & Xing, J. (2022b). Real Responses to Anti-Tax Avoidance: Evidence from the UK Worldwide Debt Cap. *Journal of Public Economics*, *214*(104742).

Blouin, J., & Robinson, L. A. (2021). *Double counting accounting: How much profit of multinational enterprises is really in tax havens?* (SSRN Working Paper).

Bratta, B., Santomartino, V., & Acciari, P. (2021). *Assessing profit shifting using Country-by-Country Reports: a non-linear response to tax rate differentials* (Working Papers wp2021-11). Ministry of Economy and Finance.

Clausing, K. A. (2016). The Effect of Profit Shifting on the Corporate Tax Base in the United States and Beyond. *National Tax Journal*, *69*(4), 905–934.

Clausing, K. A. (2020). Profit Shifting before and after the Tax Cuts and Jobs Act. *National Tax Journal*, *73*(4), 1233–1266.

Clausing, K. A., Saez, E., & Zucman, G. (2021). Ending Corporate Tax Avoidance and Tax Competition: A Plan to Collect the Tax Deficit of Multinationals.

Cobham, A., Garcia-Bernardo, J., Palansky, M., & Bou Mansour, M. (2020). *The state of tax justice 2020*. Tax Justice Network.

Coles, J. L., Patel, E., Seegert, N., & Smith, M. (2022). How do firms respond to corporate taxes? *Journal of Accounting Research*, *60*(3), 965–1006.

Costinot, A., & Rodriguez-Clare, A. (2014). Trade theory with numbers: Quantifying the consequences of globalization. In *Handbook of international economics* (pp. 197–261). Elsevier.

Costinot, A., & Werning, I. (2019). Lerner symmetry: A modern treatment. *American Economic Review: Insights*, *1*(1), 13–26.

Damgaard, J., Elkjaer, T., & Johannesen, N. (2019). *What is real and what is not in the global fdi network?* (IMF Working Paper). International Monetary Fund.

De Loecker, J., Eeckhout, J., & Unger, G. (2020). The rise of market power and the macroeconomic implications. *The Quarterly Journal of Economics*, *135*(2), 561–644.

De Loecker, J., & Warzynski, F. (2012). Markups and firm-level export status. *American economic review*, *102*(6), 2437–71.

de Mooij, R., & Liu, L. (2020). At a Cost: The Real Effects of Transfer Pricing Regulations. *IMF Economic Review*, *68*(1), 268–306.

de Mooij, R., & Liu, L. (2021). At a cost: The real effects of thin capitalization rules. *Economics Letters*, *200*, 109745.

Dekle, R., Eaton, J., & Kortum, S. (2007). Unbalanced trade. *American Economic Review*, *97*(2), 351–355.

Desai, M. A., Foley, C. F., & Hines, J. R. (2006). The demand for tax haven operations. *Journal of Public Economics*, *90*(3), 513–531.

Devereux, M. P., Auerbach, A. J., Keen, M., Oosterhuis, P., Schön, W., & Vella, J. (2021). *Taxing Profit in a Global Economy*. Oxford University Press.

Dhingra, S., & Morrow, J. (2019). Monopolistic competition and optimum product diversity under firm heterogeneity. *Journal of Political Economy*, *127*(1), 196–232.

Dixit, A. K., & Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. *The American Economic Review*, *67*(3), 297–308.

Dowd, T., Landefeld, P., & Moore, A. (2017). Profit shifting of U.S. multinationals. *Journal of Public Economics*, *148*, 1–13.

Duan, N. (1983). Smearing estimate: A nonparametric retransformation method. *Journal of the American Statistical Association*, *78*(383), 605–610.

Dyrda, S., Hong, G., & Steinberg, J. (2023). *A macroeconomic perspective on taxing multinational enterprises* (SSRN Working Paper).

Dyreng, S. D., & Lindsey, B. P. (2009). Using financial accounting data to examine the effect of foreign operations located in tax havens and other countries on u. s. multinational firms' tax rates. *Journal of Accounting Research*, *47*(5), 1283–1316.

Egger, P. H., & Wamser, G. (2015). The impact of controlled foreign company legislation on real investments abroad. a multi-dimensional regression discontinuity design. *Journal of Public Economics*, *129*, 77–91.

Englisch, J., & Becker, J. (2019). International effective minimum taxation – the GLOBE proposal. *World tax journal : WTJ*, *11*(4), 483–529.

Fajgelbaum, P. D., Morales, E., Serrato, J. C. S., & Zidar, O. (2019). State Taxes and Spatial Misallocation. *Review of Economic Studies*, *86*(1), 333–376.

Fuest, C., Hugger, F., & Neumeier, F. (2021). *Corporate profit shifting and the role of tax havens: Evidence from German Country-By-Country Reporting data* (CESifo Working Paper). CESifo.

Fuest, C., Parenti, M., & Toubal, F. (2019). International corporate taxation: What reforms? what impact? *Notes du conseil danalyse economique*, (6), 1–12.

Fuest, C., Peichl, A., & Siegloch, S. (2018). Do Higher Corporate Taxes Reduce Wages? Micro Evidence from Germany. *American Economic Review*, *108*(2), 393–418.

Garcia-Bernardo, J., Fichtner, J., Takes, F. W., & Heemskerk, E. M. (2017). Uncovering Offshore Financial Centers: Conduits and Sinks in the Global Corporate Ownership Network. *Scientific Reports*, *7*(1), 6246.

Garcia-Bernardo, J., & Jansky, P. (2021). *Profit Shifting of Multinational Corporations Worldwide* (Working Papers IES No. 2021/14). Charles University Prague.

Garcia-Bernardo, J., Janskỳ, P., & Tørsløv, T. (2021). Multinational corporations and tax havens: Evidence from country-by-country reporting. *International Tax and Public Finance*, 1–43.

Government of Bermuda. (2023). *Bermuda considers introducing a corporate income tax.* Tax Division of the Department of Finance.

Gravelle, J. G. (2015). *Tax Havens: International Tax Avoidance and Evasion.* Congressional Research Service.

Gruber, J., & Rauh, J. (2007). How elastic is the corporate income tax base? In A. J. Auerbach, J. R. Hines Jr., & J. Slemrod (Eds.), *Taxing corporate income in the 21st century* (pp. 140–163). Cambridge University Press.

Grubert, H., & Slemrod, J. (1998). The Effect of Taxes on Investment and Income Shifting to Puerto Rico. *The Review of Economics and Statistics*, *80*(3), 365–373.

Gumpert, A., Hines, J. R., & Schnitzer, M. (2016). Multinational Firms and Tax Havens. *The Review of Economics and Statistics*, *98*(4), 713–727.

Guvenen, F., Mataloni, J., Raymond J., Rassier, D. G., & Ruhl, K. J. (2022). Offshore profit shifting and aggregate measurement: Balance of payments, foreign investment, productivity, and the labor share. *American Economic Review*, *112*(6), 1848–84.

Hanappi, T., & Cabral, A. C. G. (2020). *The impact of the pillar one and pillar two proposals on mne's investment costs: An analysis using forward-looking effective tax rates* (OECD Taxation Working Papers No. 50). OECD. OECD publishing.

Head, K., & Mayer, T. (2004). Market Potential and the Location of Japanese Investment in the European Union. *The Review of Economics and Statistics*, *86*(4), 959–972.

Head, K., & Mayer, T. (2019). Brands in motion: How frictions shape multinational production. *American Economic Review*, *109*(9), 3073–3124.

Hebous, S., & Keen, M. (2023). Pareto-Improving Minimum Corporate Taxation. *Journal of Public Economics*, *225*(104952).

Hines, J., & Rice, E. M. (1994). Fiscal Paradise: Foreign Tax Havens and American Business. *The Quarterly Journal of Economics*, *109*(1), 149–182.

International Monetary Fund. (2019). *Corporate taxation in the global economy*. IMF.

Irish Department of Finance. (2022). *Consultation on Pillar Two Minimum Tax Rate Implementation*. Tax Division of the Department of Finance.

Janeba, E., & Schjelderup, G. (2022). *The Global Minimum Tax Raises More Revenues than You Think, or Much Less* (CESifo Working Paper Series No. 9623).

Jansky, P., Meinzer, M., Palansky, M., Ates, L., Cobham, A., Harari, M., & Millan-Narotzky, L. (2020). *The Corporate Tax Haven Index: A New Geography of Profit Shifting* (Working Papers IES No. 2020/38). Charles University Prague.

Janský, P., & Palanský, M. (2019). Estimating the scale of profit shifting and tax revenue losses related to foreign direct investment. *International Tax and Public Finance*, *26*(5), 1048–1103.

Johannesen, N. (2022). The global minimum tax. *Journal of Public Economics*, *212*, 104709.

Laffitte, S., & Toubal, F. (2022). Multinationals' sales and profit shifting in tax havens. *American Economic Journal: Economic Policy*, *14*(4), 371–393.

Levin, C. (2014). *Caterpillar's Offshore Tax Strategy*. Permanent Subcommittee on Investigations, U.S. Senate.

Lind, N., & Ramondo, N. (2023). Trade with correlation. *American Economic Review*, *113*(2), 317–53.

McFadden, D. (1978). Modelling the choice of residential location. In *Spatial Interaction Theory and Planning Models* (pp. 75–96). North Holland.

OECD. (2020). *Tax challenges arising from digitalisation – economic impact assessment*.

OECD. (2021). *Statement on a two-pillar solution to address the tax challenges arising from the digitalization of the economy ?*

Ossa, R. (2014). Trade Wars and Trade Talks with Data. *American Economic Review*, *104*(12), 4104–4146.

Ramondo, N., Rodríguez-Clare, A., & Tintelnot, F. (2015). Multinational production: Data and stylized facts. *American Economic Review*, *105*(5), 530–36.

Samarakoon, N. (2023). The Effect of the Closure of the Double Irish Arrangement on the Location of U.S. Multinational Companies' Profits.

Santacreu, A. M. (forthcoming). International Technology Licensing, Intellectual Property Rights, and Tax Havens. *Review of Economics and Statistics*.

Santos Silva, J., & Tenreyro, S. (2006). The Log of Gravity. *The Review of Economics and Statistics*, *88*(4), 641–658.

Suárez Serrato, J. C. (2018). *Unintended consequences of eliminating tax havens*. NBER.

Suárez Serrato, J. C., & Zidar, O. (2016). Who benefits from state corporate tax cuts? a local labor markets approach with heterogeneous firms. *American Economic Review*, *106*(9), 2582–2624.

Tintelnot, F. (2017). Global production with export platforms. *The Quarterly Journal of Economics*, *132*(1), 157–209.

Tørsløv, T., Wier, L., & Zucman, G. (2022). The Missing Profits of Nations. *Review of Economic Studies*.

UNCTAD. (2015). *World investment report 2015—reforming international investment governance*. United Nations.

Vicard, V. (2022). Profit shifting, returns on foreign direct investments and investment income imbalances. *IMF Economic Review*.

Wang, Z. (2020). Multinational production and corporate taxes: A quantitative assessment. *Journal of International Economics*, *126*, 103353.

Wier, L., & Zucman, G. (2022). *Global profit shifting, 1975-2019* (NBER Working Papers No. 30673). NBER.

Wright, T., & Zucman, G. (2018). *The Exorbitant Tax Privilege* (NBER Working Paper). NBER.

Zucman, G. (2014). Taxing across Borders: Tracking Personal Wealth and Corporate Profits. *Journal of Economic Perspectives*, *28*(4), 121–48.

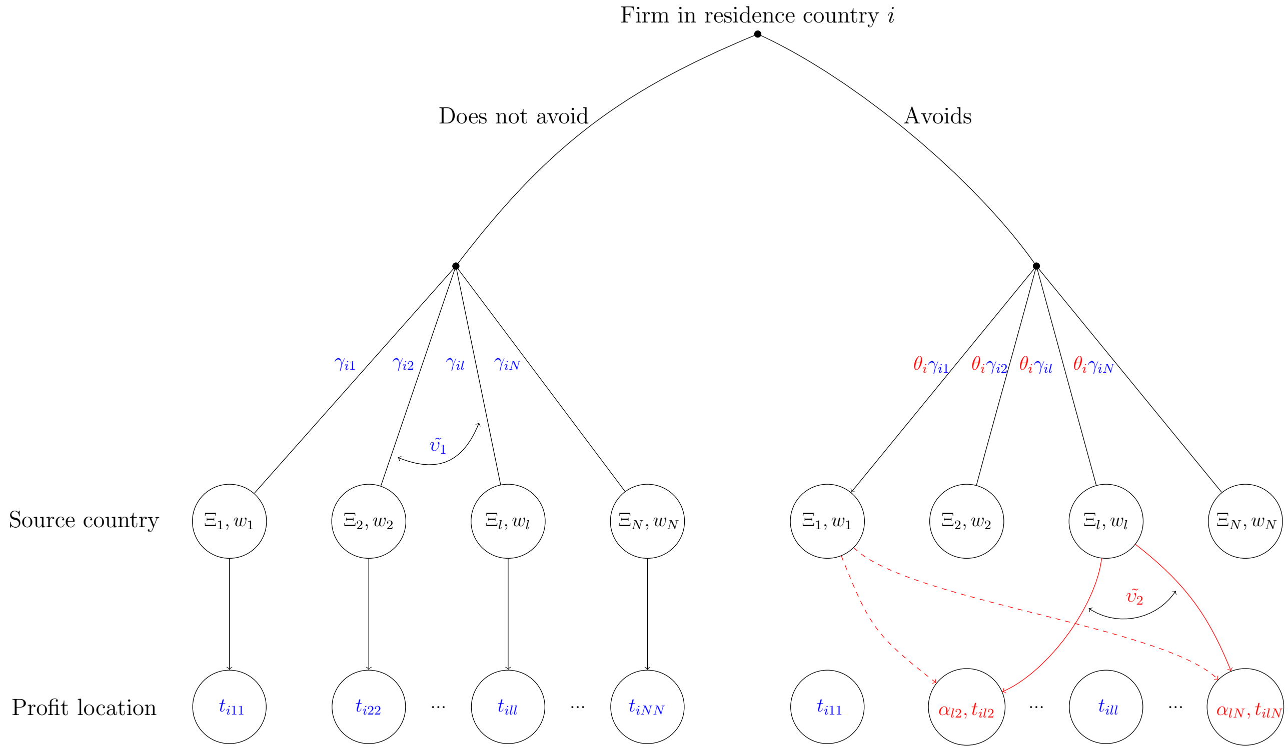
Online Appendix

Table of Contents

A Model

A.1 Representation of the model

Figure A1 shows a schematic representation of the model under a territorial taxation regime. For non-tax avoiders, all taxes are levied where production takes place, in country l. The location choice depends on corporate tax rates t_{ill}, market size and geography embedded in Ξ_l, and wages, w_l. For tax avoiders, multinationals producing in non-haven countries can transfer their profits to a tax haven (countries 2 and N) upon paying the cost α_{lh}.



Note : The red color refers to the profit shifting activity of the firms and the blue color to their real activity. Countries 2 and N are tax havens.

Figure A1: Structure of the theoretical framework

A.2 Proof of proposition 1

Taking equations (3) and (4) together, we have:

$$\frac{X_{ilh}}{X_i} = \frac{\tilde{A}_{ilh}(1-t_{ilh})^{\frac{\upsilon_1}{\sigma-1}-1}\iota_l^{-1}G_{i,lh}(\tilde{\mathbf{A}}_i, \mathbf{t})}{\sum_{jk}\tilde{A}_{ijk}(1-t_{ijk})^{\frac{\upsilon_1}{\sigma-1}-1}\iota_j^{-1}G_{i,jk}(\tilde{\mathbf{A}}_i, \mathbf{t})}$$

Thus, we can deduct easily:

$$\frac{X_{ilh}}{\sum_{l,h,h\neq l} X_{ilh}} = \frac{\tilde{A}_{ilh}^{\frac{v_2}{v_1}}(1-t_{lh})^{\frac{v_2}{\sigma-1}-1}}{\sum_{l,h,h\neq l}\tilde{A}_{ilh}^{\frac{v_2}{v_1}}(1-t_{lh})^{\frac{v_2}{\sigma-1}-1}}$$

B Estimation of profit shifting: Theory

B.1 Proof of Proposition 3

Proof. Using equation (3) and the specific $G(\cdot)$ function, the statement follows by defining ζ_{il} and χ_{lh} that are given are given by

$$\zeta_{il} = \frac{\sum_{h,h\neq l}\tilde{A}_{ilh}^{\frac{v_2}{v_1}}(1-t_{lh})^{\frac{v_2}{\sigma-1}}}{\sum_{l,h,h\neq l}\tilde{A}_{ilh}^{\frac{v_2}{v_1}}(1-t_{lh})^{\frac{v_2}{\sigma-1}}} \quad \text{and} \quad \chi_{lh} = \frac{A_{ll}^{\frac{v_2}{v_1}}\left(\alpha_{lh}\left((1-t_{lh})\,\iota_l\right)^{\frac{1}{1-\sigma}}\right)^{-v_2}}{\sum_{h,h\neq l}A_{ll}^{\frac{v_2}{v_1}}\left(\alpha_{lh}\left((1-t_{lh})\,\iota_l\right)^{\frac{1}{1-\sigma}}\right)^{-v_2}}.$$

□

B.2 Computing ζ_{il}

We describe how ζ_{il} can be backed-out from the data using the model's equations. We proceed in three steps.

1. Denote 0 as a reference country, such that i_0 and l_0 denote the reference country for the location of the HQ and as a source country respectively. We write $\Gamma_{il} = \left(\frac{\gamma_{il}/\gamma_{il_0}}{\gamma_{i_0l}/\gamma_{i_0l_0}}\right)^{\frac{v_2}{v_1}}$ the propensity of country i to shift profits out of source country l, relative to the reference country. Then

$$\zeta_{il} = \frac{\Gamma_{il}\zeta_{i_0l}}{\sum_k \Gamma_{ik}\zeta_{i_0k}}. \tag{21}$$

A higher elasticity of paper profits relative to the tax base implies that differences in attractiveness for multinational production (governed by γ_{il}) are magnified when attracting tax avoiders, as shown by Γ_{il}. From Equation (21), we can recover all ζ_{il} from the reference country ζ_{i0l} and the frictions γ_{il}.

2. We use an accounting identity to back out ζ_{i_0l}. Profits shifted by multinational firms from source country l to tax havens, PS_l, are equal to the sum of profits shifted from headquarters countries, PS_i, times ζ_{il}.

$$PS_l = \sum_i PS_i \overbrace{\frac{\Gamma_{il}\zeta_{i_0l}}{\sum_l \Gamma_{il}\zeta_{i_0l}}}^{\zeta_{il}}. \tag{22}$$

Conditional on observing PS_i and PS_l, there are 33 equations and 33 unknowns (ζ_{i0l}). Consequently, the system described in equation (22) is perfectly identified.

3. Solving equation (22) implies to observe PS_i and PS_l. PS_i is recovered in section 3.2.

To compute the share of profits shifted from l, i.e., PS_l/PS^W, we rely on the differences between the share of profits reported $\frac{\sum_i \Pi_{ill}}{\sum_{i,l} \Pi_{ill}}$ and the share of production $\frac{X_{l\iota_l}}{\sum_l X_{l\iota_l}}$. We use the ratio between these shares, weighted by the size of country l, as a proxy for PS_l/PS^W.

This allows us to obtain $\zeta_{i_0 l}$ from PS_l and PS_i and thereby ζ_{il}.

C Data

C.1 FDI Income

We collect information on bilateral FDI income from 2010 to 2014 using the bilateral balance of payments data from Eurostat and the OECD.

FDI income has three components: reinvested earnings, dividends, and interest payments. We add the data on reinvested earnings and dividends to construct the FDI income data because interest payments in a tax avoidance scheme would be paid from the parent company to the tax haven affiliates (Wright and Zucman, 2018). We impute some values in the FDI income series because some countries are poorly covered by the Eurostat and the OECD datasets.

1. We use a two-step methodology to impute the data for small countries, usually tax havens. First, we use the unilateral balance of payment from the IMF, which informs on inward FDI income, inward FDI stock, outward FDI income and outward FDI stock. This dataset helps us compute the unilateral rates of return on inward and outward investments. We apply the unilateral rates of returns on bilateral FDI stock data from the *Financial Flows Dataset* (see Nardo et al., 2017, https://finflows.jrc.ec.europa.eu). Second, we use the outward rates of return only in the case of missing information on the inward rate. This strategy allows us to recover 31% of our estimation sample. The correlation between imputed bilateral rates of return and observed rates of return in our dataset is 0.79.

2. In very few cases, we only have information on aggregated FDI income, including interest payments. In these cases, we apply a conservative imputation by assuming that the value of FDI income excluding debt instruments is equal to 75% of the aggregated amount.

We average the bilateral data to obtain a single cross-section. The dataset includes 33 investing (non-haven) countries and 68 destination countries (33 non-haven countries plus Hong Kong, Ireland, Luxembourg, Netherlands, Singapore, Switzerland, and 29 countries later aggregated to form the Offshore Financial Centers, a composite tax haven).

C.2 Multinational Production Sales

Multinational production (MP) sales corresponds to the sales made in the production country l by firms headquartered in the country i and reported in l (country l may be identical to country i). It corresponds to X_{ill} in model's notations. We build a 40×40 matrix of MP sales that covers the period 2010-2014. We follow the methodology of Ramondo et al. (2015) to construct the MP series.

To obtain information on MNEs' bilateral sales, we combine different sources of Foreign Affiliates Trade Statistics (FATS), including Eurostat, OECD, and BEA. When different sources provide different values, we select the highest one. The data is complemented with information on Mergers and Acquisitions (M&A) from Thomson Reuters.

We follow the methodology of Ramondo et al. (2015) to deal with zero or Tableing MP sales. We leverage information on M&A from 2001 to 2014 to distinguish between true zeros and Tableing values. If we observe zero or Tableing MP sales nor M&A transactions, we assign a zero value. If we have a positive number of M&A transactions and no MP data, we impute the observations. The imputation is based on the conditional correlation between MP sales and M&A, that Ramondo et al. (2015) find to be large. We run the following regression:

$$ln(MP_{ij}) = \beta ln(\#M\&A) + \mu_i + \mu_j + \epsilon_{ij}. \tag{23}$$

We estimate $\beta = 0.508$ (standard error of 0.0710, $R^2 = 0.75$). Of 1560, 178 values are extrapolated using this procedure and 148 are true zeros. We follow the same procedure to interpolate the Tableing values for the number of employees in the country l by firms headquartered in the country i – a control variable in some of our regressions.

Our MP series correlates well with other MP sales series such as those provided by Ramondo et al. (2015) (Corr=0.91) , Alviarez (2019) (Corr=0.94), the CBCR data released by the OECD in 2020 for the year 2016 (Corr=0.84), and the Analytical AMNE dataset developed by Cadestin et al. (2018) at OECD (Corr=0.92).

We then compute intra-national MP sales. It corresponds to the domestic sales made by domestic firms: X_{lll}. They are obtained by summing the exports of country l and its intra-national trade ($\sum_{i,n} X_{iln}$) and subtracting the MP sales made in l by other countries i, with $i \neq l$ ($\sum_{i,i\neq l} X_{ill}$).

C.3 Trade

Trade is computed as the sum of trade in goods (UN Comtrade database) and trade in services (EBOPS database). Own trade is constructed using OECD's TiVA database as a difference between the total production of a country and its total exports. Production data is Tableing for "Offshore Financial Centers", our composite tax haven. Consequently, we impute it by regressing production on GDP, which is observed for all countries and predicting the production level in OFCs ($R^2 = 0.98$).

C.4 Tax rates

Statutory tax rates. We use the KPMG Corporate Tax Rate Table accessed through the Tax Foundation's "Corporate Tax Rates Around the World" database(Tax Foundation, 2022).

Tax havens' tax rates. The model needs the tax rate available to tax-avoiding firms in tax havens, which is not directly observable. Tax havens offer legal provisions that can make the effective tax rate differ greatly from the statutory tax rate. We use the OECD CbCR dataset to calculate effective tax rates based on taxes paid and profits. It consists in the aggregation of firm-level country-by-country reports at the (residence country × source country) level. Only large firms with a turnover larger than EUR 750 million fill the reports. This restriction allows us to concentrate on the firms that are the most likely to engage in profit shifting activities. The aggregation distinguishes profit-making from loss-making firms. We focus on profit-making firms to avoid an aggregation bias. We use the reports from the year 2016 that are filled by firms from 25 different residence countries.

We calculate effective tax rates (ETR) as tax paid divided by pre-tax profits, and remove negative and outlier values. For each tax haven in our sample, we observe the ETR paid by firms from each headquarter country reporting activity in the tax haven. It corresponds to 12 origin countries for Switzerland, 14 for Hong Kong, 8 for Ireland, 10 for Luxembourg, 15 for the Netherlands, 14 for OFCs, and 11 for Singapore. We define t_{lh} as the median effective tax rate observed in each tax haven. Therefore, t_{lh} does not vary with country l for $l \neq h$.

Notice that Tørsløv et al. (2022) provides data on the effective tax rate for many countries. However, this would measure t_{lh} with a bias induced by firms having a real activity in tax havens and then paying a different tax rate than tax-avoiding firms. This is especially the case in large tax havens.

C.5 Profits

The calibration of the model requires information on profits in each country of the sample. Profits are composed of three components. It is computed as: gross operating surplus minus depreciation less net interest paid. The main data source is the UN National Accounts (United Nations, n.d.). The data is complemented with data gathered from Australia's official statistics and Singapore's National Accounts. When Tableing, we impute the profits' component using the ratio of the component to the Gross Operating Surplus of other countries in the sample. The information is Tableing for Honk-Kong and OFCs. We impute their profits by predicting their value based on a regression of profits on GNI (adjusted R^2 of 0.88).

C.6 Tax haven policies

We proxy tax havens' tax avoidance "technologies" using the TJN's Corporate Tax Haven Index (Jansky et al., 2020) for 2019 (the first available year). The index aggregates 20 *de jure* and *de facto* indicators from 5 categories of policies: Lowest available corporate income tax, Loopholes and gaps, Transparency, Anti-avoidance, and Double tax treaty aggressiveness. Out of the 20, we select 13 indicators that inform on the profit-shifting technology and take their average for each tax haven in our database (Foreign investment income treatment, Loss utilization, Capital gains taxation, Sectoral exemptions, Tax holidays and Economic zones, Fictional interest deduction, Public company accounts, Tax court secrecy, Interest deduction, Royalties deduction, Service payment deduction, CFC rules, and Tax treaties).

D Estimation of profit shifting: Empirics

D.1 Estimation of excess profits in tax havens

Table D1 presents the full table of the estimation of β_1 across different specifications.

Table D1: Estimating PS_{ih}

	Dependent variable: $FDI\ income_{jk}$				
	(1)	(2)	(3)	(4)	(5)
$Haven_k$	1.565***	2.336***	2.767***	2.104***	1.677**
	(0.227)	(0.238)	(0.337)	(0.747)	(0.669)
$ETR_j - ETR_k$	0.056***	0.036*	0.091***	0.091***	0.031**
	(0.019)	(0.019)	(0.017)	(0.016)	(0.015)
$\ln(GDP_k)$	0.497***	0.574***	-4.472***	-4.392***	-3.086***
	(0.058)	(0.080)	(0.737)	(0.722)	(0.577)
$\ln(GDP_k)^2$			0.095***	0.093***	0.064***
			(0.014)	(0.014)	(0.011)
$\ln(GDPpc_k)$	0.355*	0.372**	0.337***	0.304***	0.478***
	(0.191)	(0.157)	(0.111)	(0.109)	(0.098)
$\ln(Dist_{jk})$	-0.645***	-0.501***	2.592***	2.163*	2.257**
	(0.089)	(0.073)	(0.923)	(1.167)	(1.136)
$\ln(Dist_{jk})^2$			-0.198***	-0.173**	-0.168**
			(0.057)	(0.073)	(0.069)
ln(# Employees+1)					0.381***
					(0.071)
Gravity Controls	Yes	Yes	Yes	Yes	Yes
HQ FE	Yes	Yes	Yes	Yes	Yes
HQ FE × Haven	No	No	No	Yes	Yes
Destination Region FE	Yes	Yes	Yes	Yes	Yes
Destination Region FE × Haven	No	Yes	Yes	Yes	Yes
Observations	1,444	1,444	1,444	1,444	1,212
Pseudo R2	0.819	0.836	0.861	0.884	0.898
Destination countries	52	52	52	52	52
Implied Aggregate Profit Shifting	**393551**	**397358**	**411327**	**408764**	**380954**
Share sample's profits	39%	40%	41%	41%	40%

Note: Dependent variable: $FDI\ income_{jk}$ that excludes income from interests. Poisson maximum likelihood (PPML) estimator. Robust standard errors clustered at the destination country level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

D.2 Correcting profit shifting from conduit-tax havens

Our estimates of PS_{ih} may be biased if h is used as a conduit tax haven. Damgaard et al. (2019) propose a method to determine the distribution of ultimate investors in bilateral FDI statistics. Using their data, we assume the share of excess income that has to be reallocated from one tax haven to another to be the same as the share of FDI that transits from this tax haven to the other.

We define conduit FDI as FDI into Special Purposed Entites (SPE) going from a non-haven country to a tax haven as $Conduit_{ih'} = FDI^{SPE}_{ih'}$. We proceed in two steps to correct profit shifting.

1. We compute an allocation key that corresponds to the ratio of conduit FDI from country i to country h' to all FDI from i to h':

$$\Theta_{ih'} = \frac{Conduit_{ih'}}{FDI_{ih'}}$$

$\Theta_{ih'}$ informs on the share of total FDI (conduit FDI and non-conduit FDI) by non-haven country i in tax haven h' that needs to be reallocated to another tax haven h because haven h' is not the ultimate investment destination but a conduit tax haven.

2. We reallocate a share $\Theta_{ih'}$ of excessive income between i and h' to h countries. We allocate it to h countries according to h' non-SPE investment in tax havens h:

$$Total\ Reallocation_{ih'h} = \Theta_{ih'} \times \frac{FDI^{Non-SPEs}_{h'h}}{\sum_k FDI^{Non-SPEs}_{h'k}}.$$

Figure D1 summarizes our correction for each tax haven.

The United Kingdom and Belgium on a smaller scale are generally identified as conduit countries (see e.g., Garcia-Bernardo et al., 2017). Our sample does not consider them as tax havens, but we compute another reallocation factor $\gamma_{ii'}$ where i' is either U.K. or Belgium: $\gamma_{ii'} = \frac{Conduit_{ii'}}{\sum_i FDI_{ii'}}$ We obtain that 8.9% of excess FDI income in the United Kingdom and 7.1% of excess FDI income in Belgium are reallocated to other non-haven headquarter countries.

D.3 Alternative estimation of PS_{lh} and $\tilde{v}_2$

We first use the data on profit shifting from source countries to tax havens from Wier and Zucman (2022) for the year 2017, which are constructed based on the methodology of Tørsløv et al. (2022). Second, we use the OECD CbCR data to compute bilateral effective tax rates that we match with FDI income data for 2016 and 2017. The matched dataset allows us to use the bilateral variation across pairs of countries to identify the profit-shifting elasticity. Third, we construct a new sample of bilateral reported pre-tax income and bilateral effective tax rates using micro-level data from the Eikon dataset. The constructed dataset provides cross-sectional and time variation.

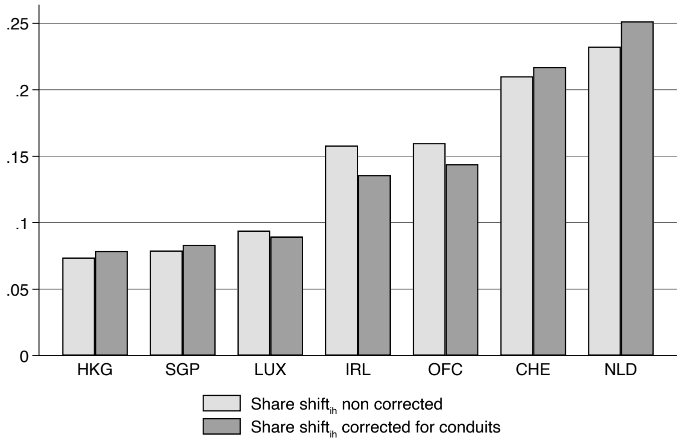


Figure D1: Profit shifting estimates before and after the correction for conduits.

Estimation of $\tilde{v}_2$ using data on profit shifting from Wier and Zucman (2022). To estimate $\tilde{v}_2$ using Wier and Zucman (2022) data, we only use information on profit shifting to European tax havens since other tax havens are aggregated in a single entity as in Tørsløv et al. (2022)'s files. We estimate $\tilde{v}_2$ following the main specification in table 3. Results in Table D2 of the main paper reveal an estimation of $\tilde{v}_2$ slightly higher than in our baseline exercise but in the range of the upper bound of our robustness exercise in Table D3.

Table D2: Estimation of $\tilde{v}_2$ using Wier and Zucman (2022) dataset

	(1)
$ln(\tilde{t}_h)$ (Med.)	11.48*
	(6.186)
Observations	111
R-squared	0.851
Source country FE	Yes
Gravity controls	Yes
Implied $\tilde{v}_2$	10.48

Estimation of $\tilde{v}_2$ using the OECD's CbCR data. We compute bilateral ETR from OECD's CbCR data for 2016-2017 and update the bilateral income data. Outliers and errors are avoided by constraining the ETR to be lower or equal to the statutory rate.

Contrary to our baseline methodology, we estimate profit shifting using the elasticity of profits to the effective tax rate, following a recent literature in public finance (Beer et al., 2020, Garcia-Bernardo and Jansky, 2021). This approach allows for the use of richer fixed effects (both origin × year and destination × year) and bilateral ETR, as opposed to indicator variables for tax havens (interacted with region-level dummies in our baseline estimation). Profit shifting is estimated by setting a counterfactual effective tax rate to 25%, as in Garcia-Bernardo and Jansky (2021), and compute profit shifting as the difference between predicted profits and predicted profits in the counterfactual world where tax havens set their ETR to 25%. We model the elasticity of income to the bilateral ETR in three ways. First, we estimate a simple constant elasticity, reported in Table 4. Second, we estimate non-constant elasticities using a squared term to model non-linearity (Dowd et al., 2017; Hines and Rice, 1994). Finally, we use a logarithmic transformation to model stronger non-linearities when the ETR is close to zero (Garcia-Bernardo and Jansky, 2021).

To estimate profit shifting between residence countries i and tax havens h, we estimate the following equation using a PPML estimator.

$$\Pi_{ilt} = exp\left[\beta_1 ETR_{ilt} + \beta_2 f\left(ETR_{ilt}\right) + \zeta Gravity_{il} + \nu_{jt} + \nu_{it}\right] + \epsilon_{ilt} \tag{24}$$

where Π_{ilt} are the bilateral FDI income excluding interest income at date t, ETR_{ilt} is the bilateral ETR at date t taken from the CbCR, $f\left(ETR_{ilt}\right)$ is a non-linear function of the effective tax rate that we use to model non-linearities. In this exercise we will use both $f\left(ETR_{ilt}\right) = ETR^2_{ilt}$ and $f\left(ETR_{ilt}\right) = ln(ETR_{ilt})$. $Gravity_{il}$ is a set of gravity variables and ζ the vector of coefficients associated. ν_{jt} are a set of destination country $\times$ year fixed effects. ν_{it} are investing country $\times$ year fixed effects and ϵ_{ilt} are the residuals. Our richer set of fixed effects includes origin-year and destination-year fixed effects, controlling for other factors that make a country a tax haven beyond low tax rates. The inclusion of these fixed effects yields a lower estimate of profit shifting since they are assumed constant in the counterfactual world with no tax havens, where only the effective tax rate is affected.

We follow the methodology of section D.1 to compute profit shifting. It is calculated as the difference between the profits predicted using equation 24 and the profit predicted when the variable ETR_{ilt} is set to 25% for all destination countries l that are tax havens.

Results are displayed in Table D3. Importantly the aggregate estimates of profit shifting align with our previous estimates when compared to the sample's profits. Profit shifting is around 37% of the profits in the estimation sample, while it corresponds to 40% of the estimation sample's profits in our main estimate.

These new estimates of profit shifting also allow us to estimate a new $\tilde{\upsilon}_2$ following equation (14). In all specifications, we find that $\tilde{\upsilon}_2$ is in the same range as the baseline $\tilde{\upsilon}_2$ calibrated in the model. In the baseline model, we have $\tilde{\upsilon}_2 = 7.9$ while it varies here between 8.2 and 13.5 according to the specification.

Estimation of $\tilde{\upsilon}_2$ using the Eikon dataset. Eikon is a commercial database that provides financial, accounting, and ownership information about listed companies worldwide. It includes pre-tax income and cash tax paid, as well as firm and ultimate beneficial owner location data. Using this information, we construct a dataset of reported income and bilateral ETR that aggregates the data coming from 41,672 affiliates from 2010 to 2018. To reduce volatility, we compute the ETR of a firm in a period as the ratio of cash tax paid to pre-tax financial income summed over three years, following the methodology provided by Dyreng et al. (2008): $ETR_{is} \equiv \frac{\sum_{t=1}^{S}(CTP_{it})}{\sum_{t=1}^{S} PTI_{it}}$.

In each cell, that is composed of a country-pair observed during a given period, we

Table D3: Estimation of $\tilde{\upsilon}_2$ using the CbCR dataset

	(1)	(2)	(3)
	$FDIincome_{ijt}$		
ETR CbCR	-6.054***	-13.07***	-3.436
	(1.345)	(4.621)	(2.250)
ETR CbCR^2		21.27	
		(13.74)	
ln(ETR CbCR)			-0.294*
			(0.165)
$ln(Dist_{kk'})$	-0.447**	-0.416**	-0.358*
	(0.200)	(0.203)	(0.189)
Contig.	-0.0897	-0.0806	-0.0733
	(0.356)	(0.341)	(0.340)
Com. Lang. index	1.521***	1.723***	1.837***
	(0.491)	(0.427)	(0.459)
Colony	-0.120	-0.232	-0.111
	(0.255)	(0.254)	(0.247)
Common Colonizer	1.447*	1.457	2.031*
	(0.861)	(0.957)	(1.191)
Com. Legal origin	-0.0496	-0.0335	-0.221
	(0.364)	(0.357)	(0.350)
Implied $\tilde{\upsilon}_2$	8.2	13.5	12.9
Observations	435	435	424
Origin x year FE	Yes	Yes	Yes
Destination x year FE	Yes	Yes	Yes
Profits in sample (2017)	605	605	604
Profits in tax havens (2017)	335	335	333
Implied PS (2017)	222	228	216

Robust standard errors clustered at the pair level in parentheses. In columns (1) and (2), the estimations include 14 origin countries, 43 destination countries, 308 country pairs, including 56 with a tax haven as the destination of investment. In column (3), the estimation includes 13 origin countries, 42 destination countries, 298 country pairs, including 53 with a tax haven as the destination of investment. *** p<0.01, ** p<0.05, * p<0.1

observe several firm-level ETRs. This allows us to compute the aggregate effective tax rate of the cell in different ways by looking at different moments of the distribution of firm-level ETRs. We compute the minimum, average, and 5th percentile ETRs for each country pair and period. Our estimation sample is composed with 3 periods, 46 residences, and 57 source countries (including 7 tax havens). However, the dataset has two limitations: there are only few links between non-tax haven countries and tax havens (only 13% of country pairs in the sample), and reported income in tax havens is limited (about 20% of the total reported income).

We use the same methodology as with the CbCR data to compute profit shifting. The results of the profit shifting estimations and the associated estimation of $\tilde{v}_2$ are reported in Table D4. Columns (1) to (3) report the estimates using gravity controls and alternative

Table D4: Estimation of $\tilde{v}_2$ using the Eikon dataset.

	(1)	(2)	(3)	(4)	(5)	(6)
ETR (Eikon)	-6.565***	-4.608**	-7.714***	-2.231**	-2.396**	-1.863
	(2.385)	(2.027)	(2.654)	(0.929)	(0.933)	(3.108)
$\ln(\text{Dist}_{kk'})$	-0.049	-0.071	-0.106			
	(0.144)	(0.148)	(0.159)			
Contig.	0.549*	0.547*	0.541*			
	(0.282)	(0.287)	(0.290)			
Com. Lang. index	1.169**	1.240**	1.327**			
	(0.593)	(0.606)	(0.614)			
Colony	1.002***	1.043***	1.067***			
	(0.297)	(0.304)	(0.301)			
Common Colonizer	1.459**	1.445**	1.402**			
	(0.575)	(0.594)	(0.622)			
Com. Legal origin	-1.178**	-1.216***	-1.256***			
	(0.459)	(0.468)	(0.482)			
Type of ETR	Minimum	5^{th} percentile	Average	Minimum	5^{th} percentile	Average
Implied $\tilde{v}_2$	8.4	7.3	12.2	5.4	5.4	9.8
Observations	202	202	202	188	188	188
Origin x year FE	Yes	Yes	Yes	Yes	Yes	Yes
Destination x year FE	Yes	Yes	Yes	Yes	Yes	Yes
Pair FE	No	No	No	Yes	Yes	Yes
Profits in Sample	953	953	953	947	947	947
Profits in Tax Havens	220	220	220	216	216	216
Implied PS	169	136	113	91	90	37

Note: PPML estimators with clustered robust standard errors at the level of country pairs in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

definitions of ETRs. Likewise, columns (4) to (6) display the results using alternative definitions of ETRs, but the estimations use pair fixed effects. The pair fixed effects are perfectly collinear with the time-invariant gravity controls. They also imply a more constrained estimation since they absorb much more variation that in the previous specifications. We find $\tilde{\upsilon}_2$ to vary between 5.4 to 12.2. Notice that the amount of profit shifted is much lower than in previous regressions using the CbCR or TWZ data, because of sample limitations. However, the ratio of profit shifted to total profits in tax havens is in line with previous findings.

D.4 Bilateral profit-shifting flows

Unilateral profit-shifting flows The measurement of aggregate profit shifting at the country level is challenging. Most of the literature follows, in spirit, the approach pioneered by Hines and Rice (1994), which delivers estimated amounts of unilateral profit shifting. The premise of their methodology is that the observed pre-tax profits of a firm correspond to the sum of *normal* profits and *shifted* profits. The combination of inputs and technology in production countries determines normal profits. Shifted profits are generated thanks to the fiscal environment and the incentives offered to foreign firms to shift profits out of production countries. Profit shifting is then estimated as the difference between total profits and estimated normal profits. When the countries of interest are tax havens, these are "excess profits"; when the countries of interest are non-havens these are "missing profits". Papers based on macro-level data estimate the amount of profit shifted to tax havens for the U.S. or at the global level (Zucman, 2014, Clausing, 2016, 2020, Janský and Palanský, 2019, Garcia-Bernardo and Jansky, 2021, or Tørsløv et al., 2022).

The methodology from Tørsløv et al. (2022) Unilateral profit-shifting estimates may be allocated to bilateral pairs using an allocation key. TWZ are the first to propose a bilateral allocation of profit shifting across pairs of production countries and tax havens.

To estimate profit shifting, TWZ collect data on the geography of profits by local and foreign companies. They proceed in two independent steps. They first compute a benchmark level of *normal* profitability level from national account data. This benchmark is defined as the ratio of pre-tax profits to wages of domestic-controlled firms. The methodology assumes that, in the absence of profit shifting, the average ratio of pre-tax profits to wages of foreign-controlled firms is the same as that of domestic-controlled firms. They show that the ratio of foreign-owned firms in tax havens is an order of magnitude larger than the one of local firms. In tax havens, profits that are above the benchmark level of profitability are considered as "excessive". The difference between the excessive level of profits and the benchmark level is the amount of shifted profits. TWZ provide estimates of profit shifting to each tax haven and then aggregate it to obtain a worldwide estimate of $616bn in 2015. The estimation is extended to subsequent years in Wier and Zucman (2022).

In the second step, the profits shifted to tax havens are allocated across non-haven origin countries. Their methodology relies on the assumption that multinational corporations in high-tax countries use intra-firm interest payments and services imports to shift profits. Following Hebous and Johannesen (2021), TWZ identify "high-risk" services categories such as royalties and headquarter services (information and communication technologies, insurance, financial and management). TWZ define as a benchmark level of trade in "high-risk" services and intra-firm interest payment the average share of high-risk services exports and intra-firm interest received in the GNI of non-haven EU countries. These shares are then computed for each tax haven and their difference with respect to the benchmark informs on excessive flows going to tax havens.

Profit shifting and "high-risk" services exports. The approach of TWZ has many advantages, one of which is that it relies on available trade in services data, arguably having a broader coverage than FDI income data. Nevertheless, our approach, developed in section 3 of the paper for our baseline calibration, is agnostic about the sources of profit shifting. We do not rely on specific information about the methods used to shift profits to tax havens.

One important advantage of our methodology is that it does not require intra-firm transactions and prices. Take trade in "high-risk" services, for instance. Profit shifting is due to the manipulation or mispricing of high-risk services transactions between entities of the multinational firm. Quantifying profit shifting at the aggregate level requires information on intra-firm services transactions. These flows could be approximated by service trade if they constituted a non-negligible share of it. Hebous and Johannesen (2021) note that less than half of "high-risk" services imports from tax havens in Germany are intra-firm. A back-of-the-envelope calculation implies that around \$26bn of "high-risk" services are imported intra-firm by German firms from tax havens in 2015 (50% of \$51.5bn, as reported in TWZ replication guide, table C1). In comparison, TWZ find \$44bn in excess services imported by German firms from tax havens (replication guide, table C2).

To illustrate this point from a different angle, we compare in appendix D.6 the bilateral excess exports of "high-risk" services by tax havens (computed using a gravity equation) with our estimated distribution of bilateral profit shifting. The figure shows a good correlation (in line with TWZ assumptions) but also that the implied estimates of profit shifting are generally larger than those from excess trade in "high-risk" services only.

The gap between these two suggests that while high-risk services are an important channel for profit shifting, they may not fully account for profit-shifting practices.

Missing profit shifting. We see at least three possible explanations for this gap: i) profit-shifting estimates through trade in goods are admittedly small in the academic literature. Yet, it is backed out by a lot of anecdotal evidence and even dispute settlements with large fines that go beyond the rather conservative econometric approaches; ii) while profits can be shifted by inflating firms' exports from tax havens, it is also possible for firms to symmetrically deflate their imports; iii) other services, not considered as high-risk, can account for an important share of profit shifting.

The case study of Caterpillar provided by the U.S. Subcommittee in investigations (Levin, 2014) illustrates ii) and iii). The tax avoidance strategy of Caterpillar allowed them to shift more than \$8bn to Switzerland between 2000 and 2012. A part of this strategy was based on the fact that Caterpillar's Swiss affiliate entered into tolling agreements that require the French and Belgian affiliates to provide manufacturing services at a reduced margin of 7% (see Levin, 2014, page 51). This strategy, which relies on an under-priced import of a manufacturing service, allowed Caterpillar to shift its profits from France and Belgium to Switzerland. The case of Procter and Gamble (Bensoussan, 2019) provides a similar narrative. Procter and Gamble's Swiss affiliate contracts with French affiliates to provide a manufacturing service. Once the production is done, the goods are owned by the Swiss affiliate against the payment of a margin to the manufacturing affiliate. Procter and Gamble has been accused of shifting its profits to Switzerland by under-pricing this margin compared to similar production activities that would have been conducted with a non-related entity. Both case studies highlight that the under-evaluation of imports of "manufacturing services" (that are not considered as "high-risk" services) by firms located in tax havens is not an uncommon tax avoidance practice.

D.5 Comparing PS_{lh} to other estimations

Comparison with TWZ. To our knowledge Tørsløv et al. (2022) (TWZ) is the only other paper in the literature that proposes a bilateral measure of profit shifting. We compare our measure of bilateral profit shifting to the one of TWZ. We also compare our estimates of profit shifting aggregated at the country level with other estimates from the literature.

In Figure D2, we show for European tax havens the correlation between TWZ estimation of profit shifting and ours (in naperian logarithm).[1]

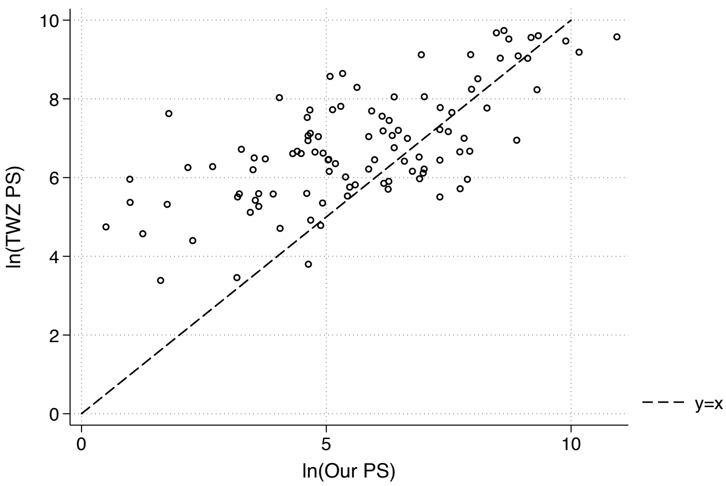


Figure D2: Comparison between Tørsløv et al. (2022) estimation of PS and our for European tax havens.

Note: This figure compares the logarithms of the bilateral profit shifting from source countries l to tax havens h in this paper and in Tørsløv et al. (2022).

[1]Due to aggregation of OFC, Hong-Kong and Singapore in TWZ files, we are not able to display a similar graph that separately includes these countries.

Figure D2 displays a positive relationship between the two variables. The Pearson correlation between both variables is 0.63 and the Spearman rank correlation is 0.61. In Figure D3, we focus on large profit-shifting flows (profit-shifting flows larger than \$5bn). We show bigger differences for larger values of profit-shifting flows.

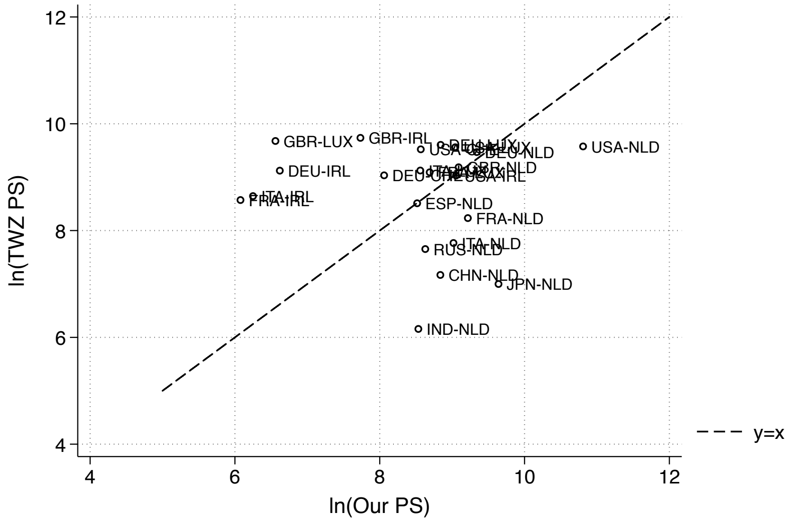


Figure D3: Comparison between TWZ estimation of PS and ours for large profit shifting.

Note: This figure compares the logarithms of the bilateral profit shifting from source countries l to tax havens h in this paper and in Tørsløv et al. (2022). It corresponds to a focus on large values of bilateral profit shifting.

While a few country pairs are close to the $y = x$ line, some pairs that include Ireland as a tax haven are systematically associated with more bilateral profit shifting in TWZ estimates than ours. On the contrary, profit shifting to the Netherlands is generally larger in our estimates.

Comparison with unilateral estimations. We now compare our estimates aggregated at the source-country level with other estimates in the literature. These estimates are taken from TWZ, the Tax Justice Network report (Cobham et al., 2020) and CORTAX, the model of the European Commission (Alvarez Martinez et al., 2016). To match with CORTAX data, we transform estimates of profit shifting into tax losses by multiplying them by the statutory tax rate. Figure D4 displays tax losses in selected source countries based on the available data in the CORTAX estimations– the study with the smallest sample of countries.

This graph first reveals that the estimates of profit shifting are sensitive to methodologies and data. However, these studies find a similar order of magnitude for many countries. The CORTAX estimation is particularly high for the U.S while our estimation, despite being higher than others, is close to the ones of the Tax Justice Network and TWZ. Overall, our quantification is in the range of the other studies.

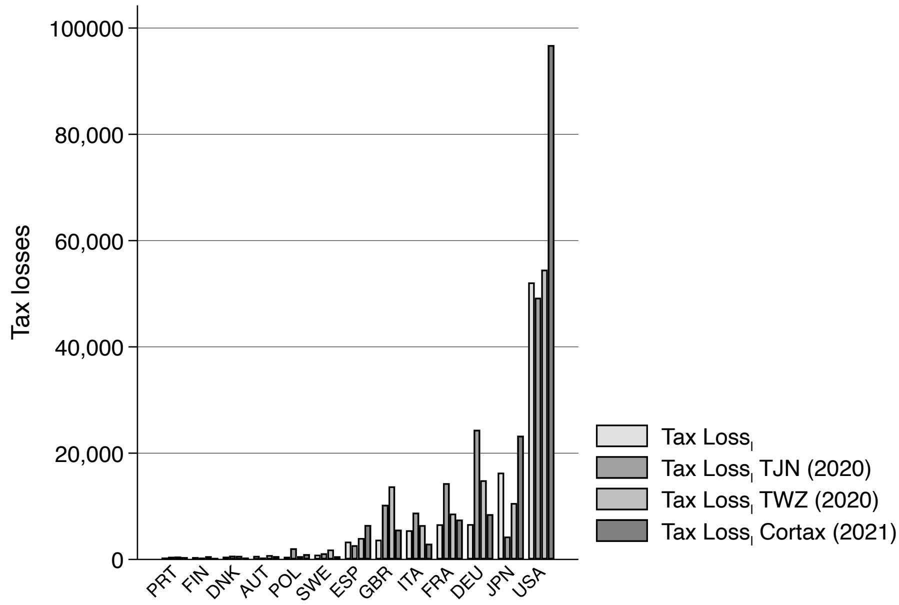


Figure D4: Comparison with other estimations.

Note: This figure compares the (unilateral) tax losses from profit shifting with Cobham et al. (2020), Tørsløv et al. (2022) and Alvarez Martinez et al. (2016). Tax losses are obtained by multiplying profit shifting out of source countries l by their statutory tax rate.

D.6 Robustness of profit-shifting estimates

This section explores the robustness of our bilateral profit-shifting estimates.

Comparing PS_{lh} with excess trade in services in tax havens. In Figure D5, we assess the correlation between our profit-shifting allocation and an allocation based on excess imports of services from tax havens. We use a reduced-form methodology to directly approximate PS_{lh} from the observations of bilateral services flows. For each pair of countries l and h, we estimate the amount of bilateral profit shifting as excessive "high-risk" services computed from a gravity equation. We regress the trade values in services exported from country k to the country n for the service category s at date t on a dummy equal to one when a "high-risk" service s is exported by a tax haven k. "High-risk" services are defined following Tørsløv et al. (2022) as insurance and pension services, financial services, charges for using intellectual property, telecommunications, computer and information services, and other business services. The methodology that is used to estimate excesses follows the one used to estimate profit shifting in Section 3 of the paper. An advantage in the context of service data is that we can include exporting country × year fixed effects. Therefore, the estimation of excesses is based on the excess exports of high-risk services compared to standard services in tax havens compared to this excess in non-tax-haven countries. We estimate $Service_{knst} = \beta_1 High - Risk_s \times Haven_k + \mu_{nst} + \mu_{kt} + \mu_{kn} + \mu_s + \epsilon_{knst}$. We compute the excess high-risk services exported by tax havens as the difference between the prediction of this equation and its prediction assuming that $\beta_1 = 0$.

Figure D5 shows a positive and significant correlation between excessive high-risk services and the theoretically consistent measure of bilateral profit shifting.

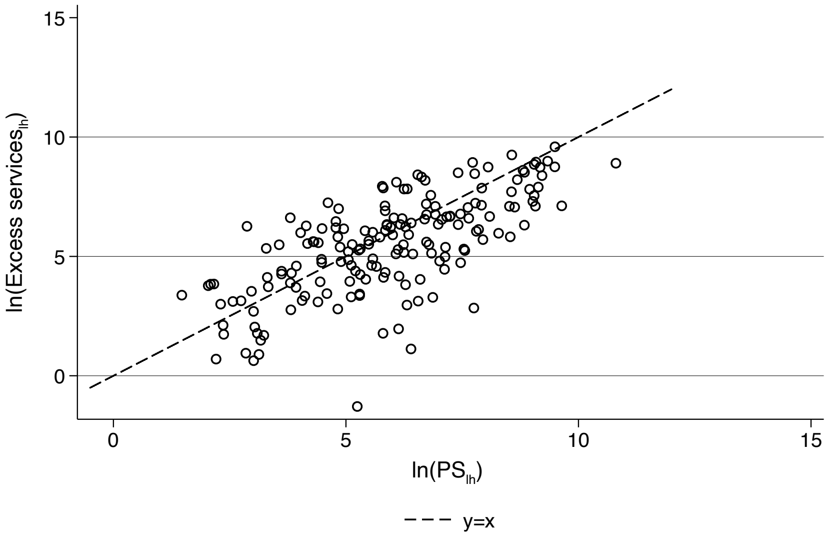


Figure D5: Comparison between excessive high-risk services and our measure of bilateral profit shifting

Note: This figure compares the estimation of profit shifting between production countries l to tax havens h, as detailed in Section 3 of the paper, to the excess of high-risk services exported by tax havens. High-risk services are defined following Tørsløv et al. (2022) as insurance and pension services, financial services, charges for the use of intellectual property, telecommunications, computer, and information services and other business services.

The Spearman rank correlation coefficient of 0.6 indicates a relatively high correlation between both series. This result suggests that services trade is an important driver of profit shifting between source countries and tax havens but shall not be considered its unique determinant. In particular, the PS_{lh} estimated in this paper is generally larger than the excess of services, suggesting that services does not explain the aggregate amounts of bilateral profit shifting.

Sensitivity to $\tilde{\upsilon}_1$ and $\tilde{\upsilon}_2$. In our methodology to estimate profit shifting, the value of ζ_{il} depends on $\Gamma_{il} = \left(\frac{\gamma_{il}/\gamma_{il_0}}{\gamma_{i_0 l}/\gamma_{i_0 l_0}}\right)^{\frac{\upsilon_2}{\upsilon_1}}$, that itself depends on the elasticities υ_1 and υ_2. We explore the sensitivity of our estimates to the values of these elasticities. Note that only the ratio of these elasticities, not their level, matters for estimating profit shifting. In Figure D6, we plot the baseline estimation of ζ_{il} and alternative allocations obtained by i) setting υ_1 equal to υ_2, and ii) increasing the ratio $\frac{\upsilon_2}{\upsilon_1}$ to 3.5. In both cases, the allocation of ζ_{il} is similar to the baseline allocation and displays a Spearman correlation coefficient larger than 0.95.

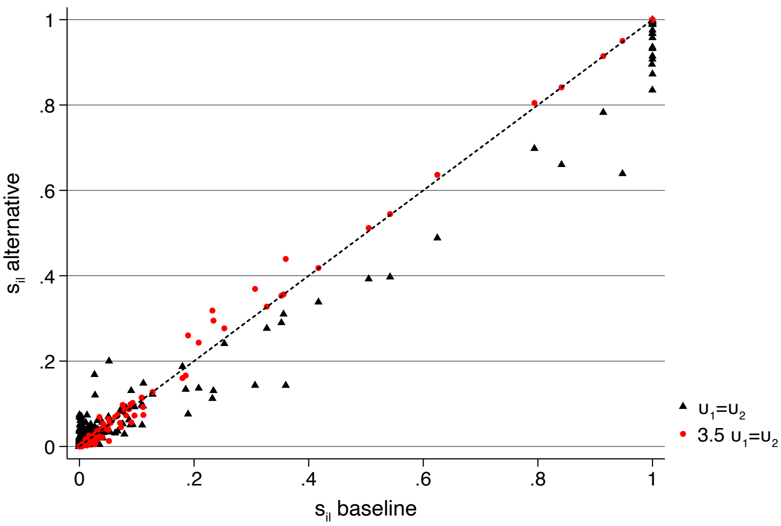


Figure D6: Profit shifting: sensitivity to elasticities calibration

Note: This figure plots ζ_{il} as obtained in the baseline exercise (horizontal axis) and compares it to alternative ζ_{il} obtained with a different calibration of the ratio $\frac{\upsilon_2}{\upsilon_1}$.

Sensitivity to PS_l calibration. As detailed in section 3 of the paper, the share of world profits shifted from production countries l needs to be calibrated to recover ζ_{il}. We use the share provided in Tørsløv et al. (2022) data to assess the sensitivity of our estimates to this assumption. In figure D7, we observe a large correlation between both PS_{lh} measures, showing the robustness of our estimates to the calibration of PS_l.

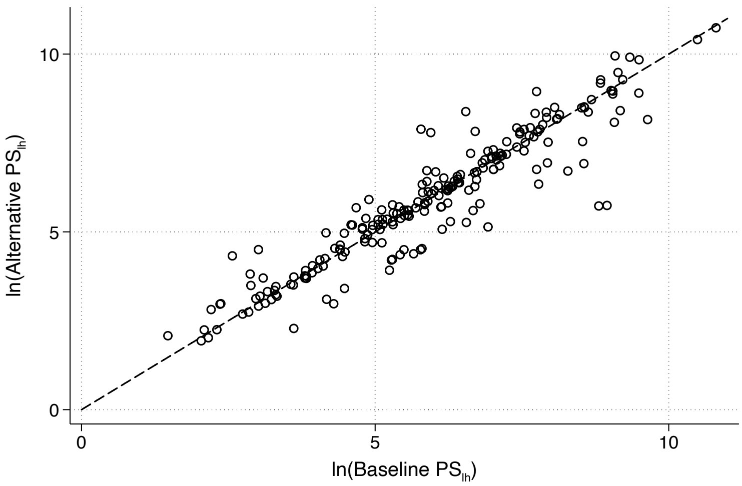


Figure D7: Profit shifting: sensitivity to s_l calibration

Note: This figure plots the log value of PS_{lh} obtained in the baseline exercise and the log value of PS_{lh} obtained when we calibrate PS_l using TWZ data.

E Varying elasticity of profit shifting

Table E1 displays the estimation of (19) with a varying elasticity of profit shifting.

Table E1: Varying Elasticity: Estimation of $\tilde{\upsilon}_2$ and k

Dep. Var.	$ln\left(\frac{X_{ilh}}{\sum_i X_{ilh}}\right)$ (1)	$\frac{X_{ilh}}{\sum_i X_{ilh}}$ (2)
$ln(\tilde{t}_h)$ (Med.)	6.412***	5.610***
	(0.230)	(1.570)
$ln(t_l - t_h)$ (Med.)	0.235***	0.483***
	(0.0103)	(0.142)
Observations	6,561	7,091
Estimator	OLS	PPML

Note: Robust standard errors clustered at the $i \times l$ level in parentheses. Both regressions include gravity controls and *i-l* pair fixed effects. Gravity controls include bilateral distance (in logarithm), a contiguity dummy, colonial linkages dummies, common legal origin dummies and common language dummies. Technology controls include GDP and GDP per capita (both in logarithm). The coefficient on $ln(\tilde{t}_h)$ gives $\tilde{\upsilon}_2$ and the coefficient on $ln(t_l - t_h)$ gives k.*** p<0.01, ** p<0.05, * p<0.1.

F Profit-shifting frictions

Normalisation of θ_i. We define our normalization as the value of θ_i such that, absent profit-shifting frictions, firms from non-havens would have an equal probability of engaging in tax avoidance *vs.* booking their profits domestically, everything else being equal (i.e., when all location-decision variables, whether endogenous or exogenous, are equal across countries). Formally, we have

$$\bar{\theta} = \frac{\sum_l A_l}{\left(H \sum_l A_l^{\frac{\upsilon_2}{\upsilon_1}}\right)^{\frac{\upsilon_1}{\upsilon_2}}}$$

To recover profit-shifting frictions α_{lh}, we use that $Cost_{ilh} = \tilde{\theta}_i \times \alpha_{lh} = \left(\frac{\tilde{\theta}_i^{-\upsilon_1} A_l \alpha_{lh}^{-\upsilon_1}}{A_l}\right)^{\frac{-1}{\upsilon_1}}$, and we proceed in 3 steps to recover $\tilde{\theta}_i^{-\upsilon_1} A_l \alpha_{lh}^{-\upsilon_1}$ and A_l. We denote $\breve{A}_{lh} = A_l \alpha_{lh}^{-\upsilon_1}$.

Step 1: Wages, trade frictions and market potential. At the calibrated equilibrium, wages w_l are directly recovered from the labor market constraint, while Ξ_l depends on the (unobserved) price index and trade frictions.

Price indices in the initial equilibrium are not identified as they cannot be recovered separately from asymmetric trade costs. While the symmetric trade costs assumption is common place in the literature (Head and Mayer, 2014), asymmetric trade costs are required to match exactly the observed trade shares. We start by normalizing $\tau_{ll} = 1$ so that

$$\tau_{ln} = \left(\frac{X_{ln}Y_l P_l^{\sigma-1}}{X_{ll}Y_n P_n^{\sigma-1}}\right)^{\frac{1}{1-\sigma}}.$$

Then, observing Y_n and X_{ln} for all l, n, we solve for P_l (and thus Ξ_l) by minimizing the asymmetry in trade costs between countries i.e., $\sum_{l,n}(\tau_{ln} - \tau_{nl})^2$. MP frictions γ_{il} are recovered using equation (13).

Step 2: Recovering $\breve{A}_{ll}$. We compute all the $\breve{A}_{ll}$ relative to a reference country, $l' = US$, whose technology is normalized to 1. We obtain:

$$\frac{\breve{A}_{ll}}{\breve{A}_{l'l'}} = \breve{A}_{ll} = \frac{\mathbb{P}_{ill}}{\mathbb{P}_{il'l'}}\left(\frac{\iota_l^{\frac{1}{1-\sigma}}\gamma_{il}\breve{t}_l\Xi_l w_l}{\iota_{l'}^{\frac{1}{1-\sigma}}\gamma_{il'}\breve{t}_{l'}\Xi_{l'}w_{l'}}\right)^{\upsilon_1}$$

Note that this also pins down the normalization constant $\bar{\theta}$ defined at the beginning of this section.

Step 3: Recovering $\breve{A}_{lh}\tilde{\theta}^{-\upsilon_1}$. Likewise, we can express all $\breve{A}_{lh}$ using a reference tax haven h' by simply expressing $\frac{\mathbb{P}_{ilh}}{\mathbb{P}_{il'h'}}$. Last, using and simplifying the ratio $\frac{\mathbb{P}_{il'h'}}{\mathbb{P}_{il'l'}}$, we can obtain

$$\breve{A}_{l'h'}\tilde{\theta}_i^{-\upsilon_1} = \frac{\mathbb{P}_{il'h'}}{\mathbb{P}_{il'l'}}\frac{\left(\iota_{l'}^{\frac{1}{1-\sigma}}\gamma_{il'}\breve{t}_{l'h'}w_{l'}\Xi_{l'}\right)^{\upsilon_2}}{\left(\iota_{l'}^{\frac{1}{1-\sigma}}\gamma_{il'}\breve{t}_{l'}w_{l'}\Xi_{l'}\right)^{\upsilon_1}}\left(\sum_{l,h,h\neq l}\left(\frac{\breve{A}_{lh}}{\breve{A}_{l'h'}}\right)^{\frac{\upsilon_2}{\upsilon_1}}\left(\iota_l^{\frac{1}{1-\sigma}}\gamma_{il}\breve{t}_{lh}w_l\Xi_l\right)^{-\upsilon_2}\right)^{1-\frac{\upsilon_1}{\upsilon_2}}\bar{\theta}^{\upsilon_1}$$

where all variables on the right-hand side are observed.

To link it with Proposition 5, note that this last equation can also be written:

$$\frac{\mathbb{P}_{ilh}}{\mathbb{P}_{ill}} = \breve{A}_{lh}\left(\tilde{\theta}_i\bar{\theta}\right)^{-\upsilon_1}\frac{\left(\iota_l^{\frac{1}{1-\sigma}}\gamma_{il}\breve{t}_{lh}w_l\Xi_l\right)^{-\upsilon_2}}{\left(\iota_l^{\frac{1}{1-\sigma}}\gamma_{il}\breve{t}_l w_l\Xi_l\right)^{-\upsilon_1}}\left(\sum_{l,h,h\neq l}\left(\frac{\breve{A}_{lh}}{\breve{A}_{lh}}\right)^{\frac{\upsilon_2}{\upsilon_1}}\left(\iota_l^{\frac{1}{1-\sigma}}\gamma_{il}\breve{t}_{lh}w_l\Xi_l\right)^{-\upsilon_2}\right)^{\frac{\upsilon_1}{\upsilon_2}-1}$$

Determinants of profit shifting costs α_{lh}. In Table F1, we show the results of estimations of the log of α_{lh} on gravitational variables, tax rates' differentials, and the TJN's Corporate Tax Haven index (CTHI).

We show that the gravitational variables correlate well with the profit-shifting costs. We find a negative correlation between the corporate tax haven indexes, as proxies for the country-specific tax avoidance technology, and the bilateral profit-shifting frictions.

The corporate tax rate difference between the source and the tax haven countries negatively correlates with the bilateral profit-shifting costs. This finding has important consequences for minimum taxation. Consider a tax haven with a tax rate of 0% and a non-haven country with a tax rate of 20%. Introducing a minimum tax of 15% decreases the tax rate differential by 75%. All other things being equal, this would increase profit-shifting costs by 0.9% (estimate in column 3). This finding motivates our extension to a non-constant elasticity of profit shifting, discussed in Section 4.2.

Table F1: Gravitational determinants of profit-shifting frictions

	(1)	(2)	(3) $ln(\alpha_{lh})$	(4)	(5)
$ln(distance_{lh})$	0.0117***	0.00962***	0.0114***	0.00957***	0.0129***
	(0.00250)	(0.00213)	(0.00206)	(0.00207)	(0.00238)
Ever colony $_{lh}$	-0.00989*	-0.0157***	-0.0173**	-0.0163**	-0.0176***
	(0.00513)	(0.00553)	(0.00654)	(0.00681)	(0.00569)
Common colonizer $_{lh}$	-0.00951**	-0.0178***	-0.0122**	-0.0151***	-0.0116**
	(0.00452)	(0.00440)	(0.00448)	(0.00460)	(0.00452)
Common legal origin $_{lh}$	-0.00343	-0.000954	-0.00559	-0.00671	-0.00154
	(0.00499)	(0.00554)	(0.00537)	(0.00563)	(0.00522)
Contiguity $_{lh}$	-0.00222	-0.00371	0.00133	-0.00239	0.00360
	(0.00702)	(0.00957)	(0.00979)	(0.00970)	(0.00982)
$ln(GDP_h)$		-0.00697***	-0.00423**	-0.00792***	-0.00221
		(0.00110)	(0.00179)	(0.00147)	(0.00241)
$ln(GDPpc_h)$		-0.00191	-0.0108***	-0.00749**	-0.00442
		(0.00212)	(0.00310)	(0.00312)	(0.00335)
$ln(t_l - t_{lh})$			-0.0124**	-0.00553**	-0.0209*
			(0.00584)	(0.00267)	(0.0112)
Corporate tax haven index $_h$			-0.000979***		
			(0.000154)		
Loopholes and exemptions $_h$				-0.000311***	
				(7.87e-05)	
Transparency $_h$					-0.000796***
					(0.000138)
Observations	212	212	212	212	212
R-squared	0.983	0.963	0.966	0.966	0.967
Source Fixed Effects	Yes	Yes	Yes	Yes	Yes
Haven Fixed Effects	Yes	No	No	No	No

Robust standard errors clustered at the l level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

G Exact hat algebra

This section describes the Exact Hat Algebra algorithm used in the paper.

G.1 Relative changes in probabilities $\hat{\mathbb{P}}_{ilh}$

Non-haven residence countries $i \notin \mathcal{H}$. We introduce N_{ill} and N_{ilh} to denote the numerator of $\mathbb{P}_{ill}$ and $\mathbb{P}_{ilh}$ respectively and $\mathcal{D}_i = \sum_l N_{ill} + \left(\sum_{l \notin \mathcal{H},h,h \neq l} N_{ilh}\right)^{\frac{v_1}{v_2}}$ their denominator so that:

$h \neq l \Rightarrow \mathbb{P}_{ilh} = \frac{N_{ilh}\left(\sum_{l \notin \mathcal{H},h,h \neq l} N_{ilh}\right)^{\frac{v_1}{v_2}-1}}{\mathcal{D}_i}$ and $h = l \Rightarrow \mathbb{P}_{ill} = \frac{N_{ill}}{\mathcal{D}_i}$.

Relative changes in $\mathbb{P}_{ill}$ and $\mathbb{P}_{ilh}$ are given by

$$\widehat{\mathbb{P}}_{ill} \equiv \frac{\hat{N}_{ill}}{\sum_l \hat{N}_{ill}\mathbb{P}_{ill} + (1 - \sum_l \mathbb{P}_{ill})^{1-\frac{v_1}{v_2}} \left(\sum_{l \notin \mathcal{H},h,h \neq l} \hat{N}_{ilh}\mathbb{P}_{ilh}\right)^{\frac{v_1}{v_2}}}$$

and

$$\widehat{\mathbb{P}}_{ilh} \equiv \frac{\hat{N}_{ilh}\left(1-\sum_l \mathbb{P}_{ill}\right)^{1-\frac{\upsilon_1}{\upsilon_2}}\left(\sum_{l\notin\mathcal{H},h,h\neq l}\hat{N}_{ilh}\mathbb{P}_{ilh}\right)^{\frac{\upsilon_1}{\upsilon_2}-1}}{\sum_l \hat{N}_{ill}\mathbb{P}_{ill}+\left(1-\sum_l \mathbb{P}_{ill}\right)^{1-\frac{\upsilon_1}{\upsilon_2}}\left(\sum_{l\notin\mathcal{H},h,h\neq l}\hat{N}_{ilh}\mathbb{P}_{ilh}\right)^{\frac{\upsilon_1}{\upsilon_2}}}$$

where

$$\hat{N}_{ill} = \widehat{w_l \Xi_l \tilde{t}_{ill}}^{-\upsilon_1} \qquad \hat{N}_{ilh} = \widehat{w_l \Xi_l \tilde{t}_{ilh}}^{-\upsilon_2}$$

Haven-residence countries $i \in \mathcal{H}$. Relative changes in the probability to locate in l are given by $\widehat{\mathbb{P}}_{ill} = \frac{\hat{N}_{ill}}{\sum_l \mathbb{P}_{ill}\hat{N}_{ill}}$.

G.2 Computing counterfactual equilibria

Notations: we introduce the share of sales by firms from i, sourcing in l, booking their profits in h: $\eta_{ilh} = \frac{X_{ilh}}{\sum_{l,h} X_{ilh}}$. From equation (10), we obtain

$$\eta_{ilh} = \frac{\mathbb{P}_{ilh}/\left((1-t_{ilh})\iota_l\right)}{\sum \mathbb{P}_{ilh}/\left((1-t_{ilh})\iota_l\right)}.$$

We denote by μ_{ln} the share of sales to country n by firms producing in l. This share does not depend on firm's residence:

$$\mu_{ln} = \frac{\tau_{ln}^{1-\sigma} Y_n P_n^{\sigma-1}}{\sum_n \tau_{ln}^{1-\sigma} Y_n P_n^{\sigma-1}} \equiv \left(\frac{\Xi_{ln}}{\Xi_l}\right)^{1-\sigma}.$$

The sales of firms from i producing in l is denoted by $X_{il} = \sum_{h=l;h\in\mathcal{H}} X_{ilh}$ and their sales in market n by $X_{iln} = \mu_{ln} X_{il}$.

Endogenous variables z are denoted z, and z', respectively the initial and the new equilibrium so that $\hat{z} = z'/z$. Following Dekle et al. (2007), we look for a fixed point in changes $\hat{\mathbf{w}} = (\hat{w}_l)_{l\in[[1,N]]}, \hat{\mathbf{Y}} = (\hat{Y}_n)_{n\in[[1,N]]}, \hat{\mathbf{P}} = (\hat{P}_n)_{n\in[[1,N]]}, \hat{\mathbf{N}} = (\hat{\mathcal{N}}_i)_{i\in[[1,N]]}$. Given $\hat{\mathbf{w}}, \hat{\mathbf{Y}}, \hat{\mathbf{N}}, \hat{\mathbf{P}}$ and the change in policy, we can compute the implied change in market potential $\hat{\Xi}_l$. This pins down the change in $\hat{\mathbb{P}}_{ilh}$ (see next subsection) and thereby the changes $\hat{\eta}_{ilh}$ and $\hat{\mu}_{ln}$. The output in l produced by l firms is then obtained as

$$X'_{il} = \frac{\mathcal{N}'_i}{T_i^{1-\sigma}}\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\sum_h\left(\mathbb{P}'_{ilh}\iota_l^{-1}(1-t_{lh})^{-1}\right)\mathcal{D}_i'^{\frac{\sigma-1}{\upsilon_1}}\Gamma\left(1-\frac{\sigma-1}{\upsilon_1}\right)$$

We thus get $X'_{iln} = \mu'_{ln}X'_{il}$ and $X'_{ilh} = \eta'_{ilh}\left(\sum_n X'_{iln}\right)$. A fixed point in changes is obtained when:

- wages satisfy the labor-market clearing

$$w'_k = \frac{1}{\sigma L_k}\sum_{l,h,n}\eta'_{klh}\left(1-t'_{klh}\right)\iota_l X'_{kln} + \frac{\sigma-1}{\sigma L_k}\sum_i X'_{ik};$$

- total expenditures are equal to labor income, tax revenues, adjusted for the friction ι_l

and imbalances

$$Y'_k = w'_k L_k + \frac{1}{\sigma}\left(\sum_{i,n} t'_k \eta'_{ikk} \iota_k X'_{ikn} + \sum_{i,l,n,l\neq k} t'_{ilk}\eta'_{ilk}\iota_l X'_{iln}\right) + \frac{1}{\sigma}\sum_{i,n}(1-\iota_k)X'_{ikn} + \Delta_k;$$

- price indices for all countries but the numeraire verify

$$P_n'^{1-\sigma} = \sum_l \tau_{ln}^{1-\sigma}\Xi_l'^{\sigma-1}\sum_i X'_{il};$$

- and the number of firms satisfies the free-entry condition

$$\mathcal{N}'_i = \frac{\frac{1}{\sigma}\sum_{l,h,n}\left(1-t'_{ilh}\right)\iota_l X'_{ilh}}{w'_i f_E}.$$

H Supplements to section 5

H.1 Calibration overview and validation

Table H1: Calibration overview

Variables	**Definition/Source/Methodology/Reference**	**Section**
Endogenous variables		
X_{ln}	Trade. Trade in goods from Comtrade, Trade in services from EBOPS, Own trade from OECD's TiVA.	Appendix C.3
X_{ill}	Multinational Production Sales. Methodology from Ramondo et al. (2015). Data: OECD's AMNE, Eurostat's FATS, BEA's USDIA, Thomson Reuters' Merger and Acquisition.	Appendix C.2
X_{ilh}	Profit shifting. Estimated using accounting models' equations and using data from OECD and Eurostat bilateral balance of payments, IMF Balance of payments data, ECFIN's Financial Flows Dataset.	Section 4.1, Appendix C.1
Parameters		
t_l	Statutory tax rate. KPMG Statutory Corporate tax rate tables.	Appendix C.4
t_{lh}	Tax havens' tax rate. OECD's Country-by-Country reporting.	Appendix C.4
Π_l	Profits recorded in l. National Accounts, methodology from Tørsløv et al. (2022).	Appendix C.5
ι_l	Profits-sales gap. Computed using: $\iota_l = \sigma \frac{\Pi_l}{\sum_i X_{ill}}$.	Section 3.1
σ	Elasticity of substitution. Set to 6.88 following a 17% markup in French firm-level data (De Loecker and Warzynski, 2012 methodology).	Section 3.1
$\tilde{\upsilon}_1$	Elasticity of the tax base. Estimated following equation (18). Set to 21.4	Section 4.2
$\tilde{\upsilon}_2$	Elasticity of profit shifting. Estimated following equation (19). Set to 52.1	Section 4.2
Frictions		
γ_{il}	Multinational production frictions. Backed out from X_{ill} shares.	Appendix F
τ_{ln}	Trade frictions. Backed out from X_{ln} shares.	Appendix F
α_{lh}	Profit shifting frictions. Backed-out from X_{ilh}.	Section 4.3, Appendix F

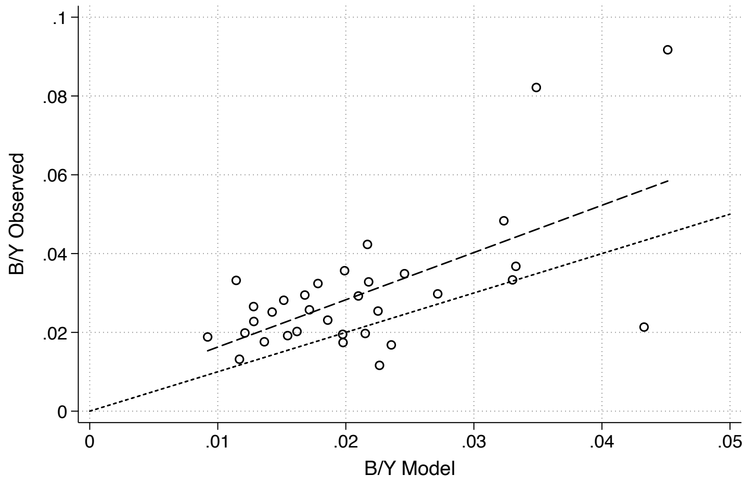


Figure H1: External validity: comparing the observed ratio of tax revenues over GDP (B/Y) to the model ones

Note: Data on corporate tax revenues over GDP is obtained from UNU-WIDER's Government Revenue Dataset. We select the variable "Taxes on income, profits and capital gains from corporation" (corresponding to OECD item 1200). The figure is drawn for the sample of non-haven countries.

H.2 Illustrating model mechanisms

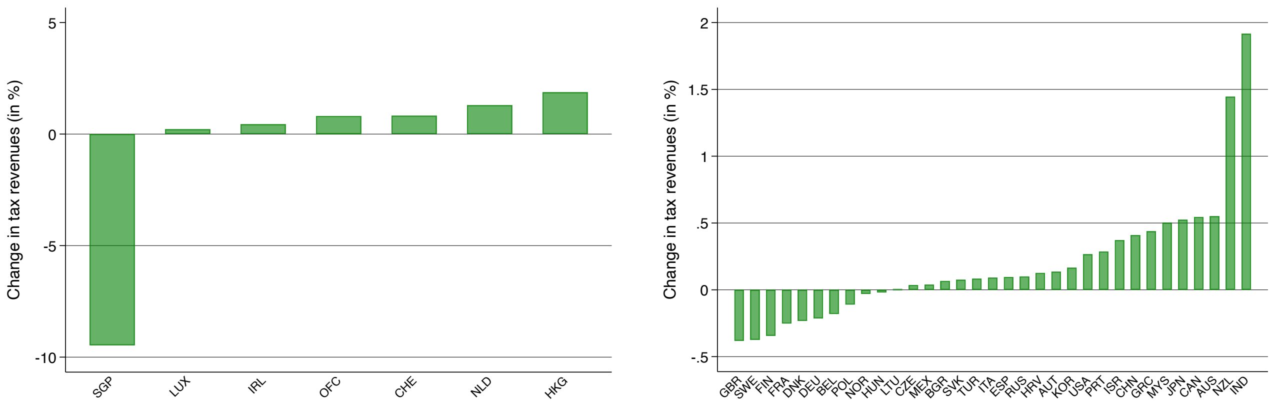
Table H2 illustrates the impact of different scenarios on tax revenues, profit shifting, real production, real income and welfare.

Table H2: Impact of different counterfactual scenarios

Scenario	% change in ... Tax revenues	Profit Shifting	Real Production	Consumer Real Income	Welfare
5% decrease statutory tax rate	-3.9	-9.95	0.33	0.33	-0.02
Closing Singapore	0.27	-3.3	-0.01	-0.02	0.003
Effective anti-abuse regulations	8.02	-100	-0.26	-0.43	0.26

Unilateral tax reform. We illustrate the percentage change of a unilateral reduction of 5% in the U.S. corporate tax rate (from 40% to 38%) on five outcomes in Table H2. The effect on real income (+0.33%) can be decomposed between the effect coming from the decrease in tax revenues (-0.08%), the effect coming from the increase in wages (+0.39%) and the imbalances effect (+0.03%).

Closing a tax haven. In Table H2, we examine the impact of closing Singapore on U.S. tax revenues, GDP, profit shifting, consumers' real income, and welfare. Figure H2 shows the impact of this reform on i) tax revenues across tax havens (Panel a) and on ii) tax revenues across non-tax havens (Panel b).



(a) Impact on tax revenues in tax havens

(b) Impact on tax revenues in non-havens

Figure H2: Effect of closing Singapore as a tax haven

Note: These two histograms illustrate the impact of closing the access to Singapore as a tax haven. Panel (a) shows how this reform would impact tax revenues in tax havens. Panel (b) shows how this reform would impact tax revenues in non-havens

Effective anti-abuse laws. *What are the effects of implementing multilateral effective anti-abuse laws in non-haven countries*?

Assuming costless implementation, Table H2 shows the results for the U.S. policy. The policy raises the U.S. effective tax rate and generates an 8.02% increase in tax revenues while reducing production by 0.26%. Consumers' real income decreases by 0.43%, but the welfare effect is positive (0.26%) due to a large increase in corporate tax revenues.

The increase in tax revenues is due to reduced profit shifting and reallocation of production. If production does not reallocate, the tax revenues increase by 8.31%. High-tax countries benefit from tax havens, and non-haven countries might use lax enforcement of anti-abuse laws to attract mobile firms (for instance Altshuler and Grubert, 2005, Hong and Smart, 2010 or Dharmapala, 2020).

H.3 Quantification of equilibrium effects

This subsection illustrates the quantification of equilibrium effects in long-run minimum taxation scenarios. We compute what would have been the effect of these reforms if we did not allow the tax base to adjust. This is tantamount to forcing production choices, including location and profit shifting to remain unchanged after the introduction of a minimum tax. The goal of this exercise is to quantify the mismeasurement of the reforms' impact if we were just considering the mechanical tax rate effects.

Post-reform tax revenues of country k are given by

$$B'_k = \sum_{i,l,h} t'^{g_k}_{ilh} \mathcal{N}'_i \mathbb{P}'_{ilh} \frac{w'_i f_E}{1 - t'_{ilh}}.$$

This includes a mechanical adjustment of the tax rate $t'^{g_k}_{ilh}$ and an equilibrium response of the tax base $\mathcal{N}_i'\mathbb{P}_{ilh}'\frac{w_i' f_E}{1-t_{ilh}'}$. We define a counterfactual tax revenue stream in which we force the tax base not to move. Formally

$$B_k'^{TRE} = \sum_{i,l,h} t_{ilh}'^{g_k} \mathcal{N}_i \mathbb{P}_{ilh} \frac{w_i f_E}{1 - t_{ilh}'},$$

where we use the superscript TRE to denote the tax rate effect. For clarity, we separate the change in tax revenues between those coming from the corporate income tax base and those coming from the minimum tax base.

Along similar lines, we note that the real income of country k post-reform is given by $\frac{Y_k'}{P_k'} = \frac{w_k' L_k + B_k' + \Delta_k'}{P_k'}$. This is clearly driven by a tax revenues effect, B_k', as well as the rest of the equilibrium adjustment, for example, the changes in wages and prices. We can then define a mechanical real income response as $\frac{w_k L_k + B_k'^{TRE} + \Delta_k}{P_k}$, where only the tax revenues are allowed to move and only through mechanical tax rates effects.

Results Table H3 decomposes the change in tax revenues for different scenarios of a 15% minimum tax rate. We illustrate the results for the implementation of an unilateral residence-based minimum tax by the U.S. In this case, our model predicts an increase in tax revenues of 4%. Because the corporate tax rate does not change, the tax rate effect on the CIT base is zero. However, because profit shifting decreases, tax revenues by 2.28% , all other things being equal. This effect is counteracted by a small real effect on the CIT base of -0.01%. After the reform, new revenues are collected on the minimum tax base. The mechanical tax rate effect increases revenues by 2.59%. Because profit shifting decreases after the reform, this mechanical effect is lowered (-0.79%). Finally, the adjustment of production choices also reduces the tax revenues levied on this base (-0.06%). When a source-based minimum taxation is implemented, additional tax revenues come from the profit shifting effect, that is larger than in the previous case.

When tax havens adjust their tax rate in response to the implementation of the minimum tax, no MNE is taxed below the minimum rate and then no minimum tax is levied. The change in tax revenues only comes from changes in the profit shifting behavior and in the production choices of MNEs. This change is similar to those in other scenarios (+2.33%) as the world distribution of tax rates is the same (the world distribution of tax revenues if different though).

Table H4 decomposes the change in real income. All reforms have a positive tax rate effect on tax revenues as demonstrated by column (5) of table H3, increasing real income, everything else being equal. However, a change in firms' location choices reverses the finding as the decrease in labor income more than offsets the increase in tax revenues. Notice that, in general equilibrium, imbalance and price effects also affect real income.

Table H3: Profit-shifting and GE effects of a 15% minimum tax on tax revenues

Counterfactual	Change in real tax revenues (in %)	CIT Base - Contribution (in %)			Min. tax Base - Contribution (in %)		
		Tax Rate Effect	PS effect	Real effect	Tax Rate Effect	PS effect	Real effect
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
15% min. tax							
Unil. Residence	4.00	0	2.28	-0.01	2.59	-0.79	-0.06
Unil. Source	4.33	0	3.18	-0.10	2.12	-0.86	-0.01
Multi. Residence	4.09	0	2.36	-0.02	2.59	-0.79	-0.06
Multi. Source	3.79	0	2.36	-0.02	2.12	-0.65	-0.01
TH adjustment	2.33	0	2.36	-0.03	0	0	0

Note: Results in this table are provided for the United States. Column (1) corresponds to the effect computed using our quantitative model."Tax Rate Effect" in columns (2), and (5) indicates the reform's effect as computed assuming no change in profit-shifting activity or production location. "PS effect" in columns (3), and (6) indicates the change in tax revenues due to the change in the profit-shifting strategy of MNEs all other things being equal. "Real effect" in column (4), and (7) indicates the change in tax revenues due to the change in the location strategy of MNEs all other things being equal.

Table H4: Profit-shifting and GE effects of a 15% minimum tax on real income

	Change in real income (in %)		Change in real wages (in %)	
	Tax Rate Effect (no reallocation)	Total effect	Tax Rate Effect (no reallocation)	Total effect (reallocation)
	(1)	(2)	(3)	(4)
15% min. tax				
Unil. Residence	0.06	-0.14	0	-0.25
Unil. Source	0.05	-0.09	0	-0.20
Multi. Residence	0.06	-0.12	0	-0.23
Multi. Source	0.05	-0.13	0	-0.23
TH adjustment	0	-0.16	0	-0.23

Note: Results in this table are provided for the United States. "Tax Rate Effect" in columns (1), and (2) indicates the reform's effect as computed assuming no change in profit-shifting activity or production location. "Total effect" in columns (2), and (4) corresponds to the effect computed using our quantitative model.

The tables highlight the importance of considering profit-shifting and real effects when predicting the impact of tax reforms on tax revenues and real income. It is also worth mentioning that unilateral and multilateral scenarios lead to identical results concerning the change in tax revenues and real income in estimation that do not consider the reallocation of real and paper profits. These tables capture relevant channels that a pure "accounting" exercise would miss.

H.4 DBCFT

Implementation We first modify the market market access as follows:

$$\Xi_l^{1-\sigma} = \sum_n \Xi_{ln}^{1-\sigma} = \sum_n \tau_{ln}^{1-\sigma} (1+s_{ln})^{\sigma-1} \left(\frac{1}{1+tr_{ln}}\right)^{\sigma} Y_n P_n^{\sigma-1}$$

Simplify with

$$\Xi_l^{1-\sigma} = \sum_n \Xi_{ln}^{1-\sigma} = \sum_n \tau_{ln}^{1-\sigma} (1+s_l)^{\sigma-1} \left(\frac{1}{1+tr_n}\right)^{\sigma} Y_n P_n^{\sigma-1}$$

$$(1-t_{ilh}) \frac{\iota_l}{\sigma} \left(\frac{\sigma}{\sigma-1} \frac{\gamma_{il}\alpha_{lh}}{\varphi} w_l \Xi_l\right)^{1-\sigma} \qquad \Xi_l := \sum_n \frac{\tau_{ln}^{1-\sigma}(1+s_l)^{\sigma-1}}{(1+tr_n)^{\sigma}} \frac{Y_n}{P_n^{1-\sigma}}$$

where $n = l \Rightarrow tr_n = s_n$.

The change in trade costs here are given by $\hat{\tau}_{ln} = \frac{1}{1+s_l}\left(\frac{1}{1+tr_n}\right)^{\frac{\sigma}{1-\sigma}}$. It determines the new $\mathbb{P}_{ilh}$ as a function of Y_n,P_n, w_l.

The share of production by firms from i in l shifting in h is undistorted with regards to $\mathbb{P}_{ilh}$:

$$\beta_{ilh} = \frac{\mathbb{P}_{ilh}/(\iota_l(1-t_{ilh}))}{\mathbb{P}_{ilh}/(\iota_l(1-t_{ilh}))}$$

In the labor market, we have

$$w_i L_i = N_i w_i f_E + \frac{\sigma-1}{\sigma}(1+s_i) Q_i$$

Using:

$$\frac{X_{ln}}{X_l} = \frac{(1+tr_n)^{-\sigma}(1+s_l)^{\sigma-1}\tau_{ln}^{1-\sigma}\left(Y_n/P_n^{1-\sigma}\right)}{\Xi_l^{1-\sigma}}$$

The price index is (implicitly) given by:

$$P_n^{1-\sigma} = (1+tr_n)^{1-\sigma} \sum_l \frac{X_l}{\Xi_l^{1-\sigma}} \tau_{ln}^{1-\sigma} (1+s_l)^{\sigma-1}$$

where the value of production in k is

$$Q_l = \sigma \sum_{k,h} N_k \frac{\mathbb{P}_{klh} w_k f_E}{(1-t_{klh})\,\iota_l}$$

Additional results Table H5 decomposes the change in real tax revenues (column 1) and the change in real GDP (column 4) when DBCFT is implemented.

The change in real tax revenues is separated between the taxation of domestic sales (when $l = n$) and the border adjustment. The border adjustment corresponds to the difference between additional tax revenues from taxing imports and tax expenses from subsidizing exports. Columns (2) and (3) add up to the change in tax revenues in column (1).

The change in real GDP is decomposed between the contribution of domestic sales, and the contribution of foreign multinationals' sales to real GDP. Columns (5) and (6) add up to the change in GDP in column (4).

Table H5: Breakdown of the increase in real tax revenues

DBCFT rate (tr_{US})	% Change real tax rev. (1)	Contrib. domestic tax (2)	Contrib. Border Adjustment (3)	% Change real GDP (4)	Contrib. domestic sales (5)	Contrib. Foreign MP (6)
5%	-82.82	-87.37	4.55	-0.23	-1.69	1.46
10%	-69.04	-75.97	6.93	-4.86	-8.63	3.77
20%	-49.61	-56.27	6.66	-13.04	-21.93	8.89
30%	-39.05	-39.94	0.89	-19.98	-34.73	14.75
BAT ($t_{US} = 40\%$)	-64.04	0.75	-64.79	-38	-81.81	43.81

Note: This table breaks down the change in real tax revenues and in real GDP. The change in tax revenues is broken down between the contribution of domestic revenues (as compared with B, the tax revenues collected at the initial equilibrium) and the contribution of the border adjustment. The later is presented as the net effect between the revenues coming from the taxation of imports and the revenues spent by subsidizing exports. Columns (2) and (3) add up to the change in tax revenues in column (1). The change in GDP is broken down between the contribution of domestic sales and the contribution of foreign multinationals' sales. Columns (5) and (6) add up to the change in GDP in column (4).

H.5 Estimation of semi-elasticities

In this section, we estimate the semi-elasticity of the tax base and of profit shifting to the tax rates. This estimation is done for comparison purposes with the literature. While our set-up requires us to estimate elasticities, the literature generally relies on semi-elasticities. We run the same regression as in Table 3 columns (1) and (2) but use as regressor the level of the tax rate instead of the log of (one minus) the tax rate.

Table H6: Estimation of semi-elasticities of the tax base and profit hsifting to taxes

	Semi-elasticity of the tax base	Semi-elasticity of profit shifting
Dep. Var.	$ln\left(\frac{X_{ill}}{\sum_i X_{ill}}\right)$ (1)	$ln\left(\frac{X_{ilh}}{\sum_i X_{ilh}}\right)$ (2)
t_{ll}	-3.626***	
	(0.929)	
t_{lh}		-8.253***
		(0.204)
Observations	1,256	6,561
Estimator	OLS	OLS
Gravity controls	Yes	Yes
i country FE	Yes	No
i-l pair FE	–	Yes
Technology controls	Yes	–

Note: Robust standard errors clustered at the $i \times l$ level in parentheses. Gravity controls include bilateral distance (in logarithm), a contiguity dummy, colonial linkages dummies, common legal origin dummies, and common language dummies. Technology controls include GDP and GDP per capita (both in logarithm). *** p<0.01, ** p<0.05, * p<0.1.

H.6 Sensitivity of counterfactual simulations

Sensitivity and extensions. We propose two different scenarios to analyze the sensitivity of our results. In each scenario, we modify one or both of our key calibrated elasticities: $\tilde{\upsilon}_1$ and $\tilde{\upsilon}_2$. In the first scenario, the profit shifting elasticity ($\tilde{\upsilon}_2$) is equal to the tax base elasticity ($\tilde{\upsilon}_1$). This scenario reflects a hypothetical case in which profit shifting is less sensitive to changes in corporate taxes. In the second scenario, we keep $\tilde{\upsilon}_2$ constant, and we consider a lower value of $\tilde{\upsilon}_1$, which we set to 1.55 (which corresponds to $\upsilon_1 = 15$). Under this scenario, the tax base elasticity would be lower and firms less mobile internationally. These scenarios are implemented when simulating a unilateral 5% decrease in the corporate tax rate in the U.S. and when ending profit shifting at the world level.

Results for the unilateral decrease in the statutory tax rate are displayed in Figure H3. We observe slightly fewer tax revenues in both alternative scenarios, driven by a lower

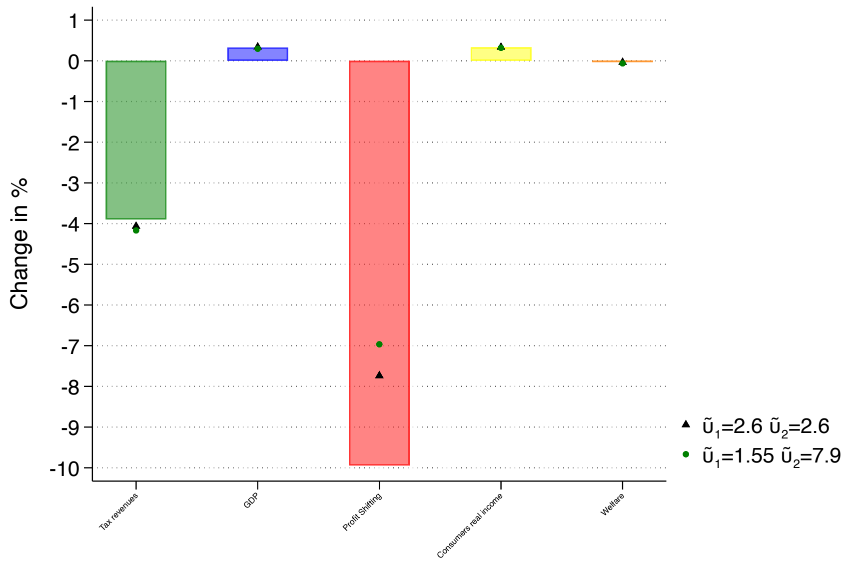


Figure H3: Unilateral tax decrease of 5% in the U.S.: sensitivity to calibration

decrease in profit shifting than in the baseline scenario. When $\tilde{v}_2$ is lowered, profit shifting is less sensitive to taxes, which explains this result. In the second scenario, decreasing $\tilde{v}_1$ while keeping $\tilde{v}_2$ constant means that production is less mobile internationally. Therefore the decrease in shifted profits relative to the tax base is lower for a lower $\tilde{v}_1$. Production and real income are almost unaffected, and welfare slightly decreases in both cases, mimicking the results on tax revenues. This is expected given the small shock we are imposing on the equilibrium.

We repeat the same sensitivity exercise in the case where profit shifting is multilaterally stopped (Figure H4). In the first alternative scenario, where $\tilde{v}_1$ is fixed, and $\tilde{v}_2$ is decreased, there is no effect on any outcome. This is expected since when profit shifting stops, there is no room for $\tilde{v}_2$ to play a role. When the elasticity of real profits is lowered to 1.55, keeping the elasticity of profit shifting constant, we observe systematically (slightly) lower tax revenues from ending profit shifting than in the baseline parametrization. This is explained by the effect of the reform on production. Production appears more negatively affected when $\tilde{v}_1$ is decreased. Indeed, a lower $\tilde{v}_1$ means that the costs faced by MNEs become more important in their decision. Countries that relied on profit shifting to attract MNE activity are now hardly affected. This is for instance the case of Belgium, France, and the U.S. This effect also translates in more negative changes in consumers' real income and welfare.

References

Altshuler, R., & Grubert, H. (2005). The three parties in the race to the bottom: Host governments, home governments and multinational companies. *Fla. Tax Rev.*, *7*, 153.

Alvarez Martinez, M. T., Barrios, S., Bettendorf, L., d'Andria, D., Gesualdo, M., Loretz, S., Pontikakis, D., & Pycroft, J. (2016). *A new calibration for cortax: A computable general equilibrium*

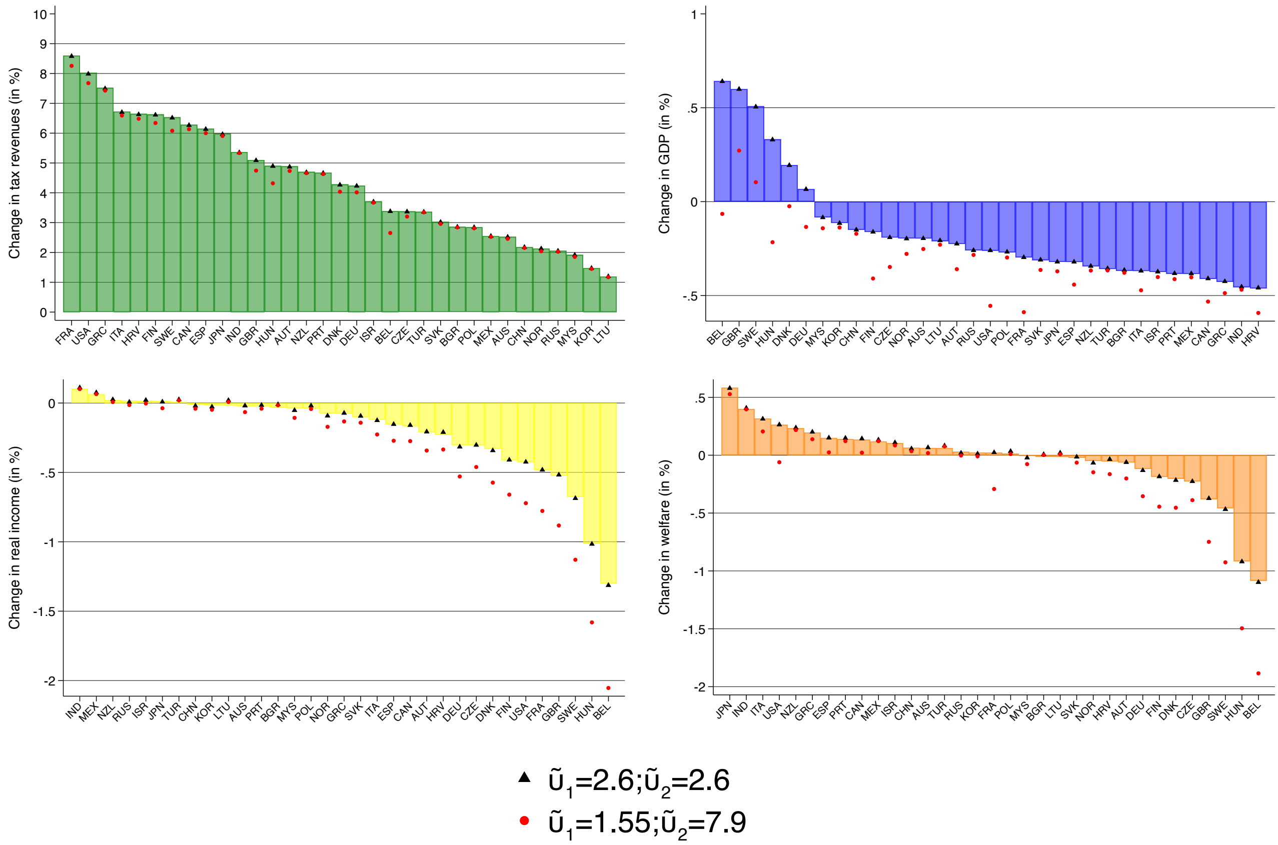


Figure H4: Effect of multilaterally ending profit shifting: sensitivity to parameters calibration

model for simulating corporate tax reforms. JRC Working Papers on Taxation and Structural Reforms.

Alviarez, V. (2019). Multinational production and comparative advantage. *Journal of International Economics*, *119*, 1–54.

Beer, S., de Mooij, R., & Liu, L. (2020). International Corporate Tax Avoidance: A Review Of The Channels, Magnitudes, And Blind Spots. *Journal of Economic Surveys*, *34*(3), 660–688.

Bensoussan, D. (2019). Bras de fer entre Procter & Gamble et ses syndicats. *Challenges*.

Cadestin, C., Backer, K. D., Desnoyers-James, I., Miroudot, S., Rigo, D., & Ye, M. (2018). *Multinational enterprises and global value chains: The OECD Analytical AMNE database* (OECD Trade Policy Papers No. 211). OECD.

Clausing, K. A. (2016). The Effect of Profit Shifting on the Corporate Tax Base in the United States and Beyond. *National Tax Journal*, *69*(4), 905–934.

Clausing, K. A. (2020). Profit Shifting before and after the Tax Cuts and Jobs Act. *National Tax Journal*, *73*(4), 1233–1266.

Cobham, A., Garcia-Bernardo, J., Palansky, M., & Bou Mansour, M. (2020). *The state of tax justice 2020*. Tax Justice Network.

Damgaard, J., Elkjaer, T., & Johannesen, N. (2019). *What is real and what is not in the global fdi network?* (IMF Working Paper). International Monetary Fund.

De Loecker, J., & Warzynski, F. (2012). Markups and firm-level export status. *American economic review*, *102*(6), 2437–71.

Dekle, R., Eaton, J., & Kortum, S. (2007). Unbalanced trade. *American Economic Review*, *97*(2), 351–355.

Dharmapala, D. (2020). *Do Multinational Firms Use Tax Havens to the Detriment of Other Countries?* (CESifo Working Paper Series No. 8275). CESifo.

Dowd, T., Landefeld, P., & Moore, A. (2017). Profit shifting of U.S. multinationals. *Journal of Public Economics*, *148*, 1–13.

Dyreng, S. D., Hanlon, M., & Maydew, E. L. (2008). Long-run corporate tax avoidance. *The Accounting Review*, *83*(1), 61–82.

Garcia-Bernardo, J., Fichtner, J., Takes, F. W., & Heemskerk, E. M. (2017). Uncovering Offshore Financial Centers: Conduits and Sinks in the Global Corporate Ownership Network. *Scientific Reports*, *7*(1), 6246.

Garcia-Bernardo, J., & Jansky, P. (2021). *Profit Shifting of Multinational Corporations Worldwide* (Working Papers IES No. 2021/14). Charles University Prague.

Head, K., & Mayer, T. (2014). Gravity equations: Workhorse, toolkit, and cookbook. In G. Gopinath, E. Helpman, & K. Rogoff (Eds.), *Handbook of international economics* (pp. 131–195). North-Holland.

Hebous, S., & Johannesen, N. (2021). At your service! the role of tax havens in international trade with services. *European Economic Review*, *135*, 103737.

Hines, J., & Rice, E. M. (1994). Fiscal Paradise: Foreign Tax Havens and American Business. *The Quarterly Journal of Economics*, *109*(1), 149–182.

Hong, Q., & Smart, M. (2010). In praise of tax havens: International tax planning and foreign direct investment. *European Economic Review*, *54*(1), 82–95.

Jansky, P., Meinzer, M., Palansky, M., Ates, L., Cobham, A., Harari, M., & Millan-Narotzky, L. (2020). *The Corporate Tax Haven Index: A New Geography of Profit Shifting* (Working Papers IES No. 2020/38). Charles University Prague.

Janský, P., & Palanský, M. (2019). Estimating the scale of profit shifting and tax revenue losses related to foreign direct investment. *International Tax and Public Finance*, *26*(5), 1048–1103.

Levin, C. (2014). *Caterpillar's Offshore Tax Strategy.* Permanent Subcommittee on Investigations, U.S. Senate.

Nardo, M., Ndacyayisenga, N., Pagano, A., & Zeugner, S. (2017). *Finflows: Database for bilateral-financial investment stocks and flows* (JRC Technical Report). European Commission.

Ramondo, N., Rodríguez-Clare, A., & Tintelnot, F. (2015). Multinational production: Data and stylized facts. *American Economic Review*, *105*(5), 530–36.

Tax Foundation. (2022). Corporate Tax Rates around the World.

Tørsløv, T., Wier, L., & Zucman, G. (2022). The Missing Profits of Nations. *Review of Economic Studies.*

United Nations. (n.d.). National accounts data.

Wier, L., & Zucman, G. (2022). *Global profit shifting, 1975-2019* (NBER Working Papers No. 30673). NBER.

Wright, T., & Zucman, G. (2018). *The Exorbitant Tax Privilege* (NBER Working Paper). NBER.

Zucman, G. (2014). Taxing across Borders: Tracking Personal Wealth and Corporate Profits. *Journal of Economic Perspectives*, *28*(4), 121–48.