Profit Shifting Frictions and the Geography of Multinational Activity*

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Abstract

We develop a quantitative general equilibrium model of multinational activity embedding corporate taxation and profit shifting. In addition to trade and investment frictions, our model shows that profit-shifting frictions shape the geography of multinational production. Key to our model is the distinction between the corporate tax elasticity of real activity and profit shifting. The quantification of our model requires estimates of shifted profits flows. We provide a new, model-consistent methodology to calibrate bilateral profit-shifting frictions based on accounting identities. We simulate various tax reforms aimed at curbing tax-dodging practices of multinationals and their impact on a range of outcomes, including tax revenues and production. Our results show that the effects of the international relocation of firms across countries are of comparable magnitude as the direct gains in taxable income.

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

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

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1 Introduction

The current tax system has inherited the broad principles set out by the League of Nations in 1928. It treats multinational corporations (MNCs) as if they were a loose collection of legal entities across different host countries using separate accounting. Mounting empirical evidence shows that MNCs exploit the inadequacies of the international tax rules to shift profits to low or no-tax jurisdictions and avoid taxes. [1]

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 multinationals, both in terms of the location of their real activities and profit-shifting. Estimating the outcomes of such reforms requires weighting potential tax revenue gains or losses against changes in countries' attractiveness for firms to locate their activity. Key to understanding these international reallocation effects at stake in global reforms is the estimation of bilateral profit shifting frictions - the cost at which firms move profits from a country where they operate to a low-tax jurisdiction; but also, the extent to which these profits are elastic to effective changes in corporate taxation. Current models of multinational production ignore the role of profit-shifting frictions altogether and are therefore inadequate to study how firms' location choices optimally respond to changes in the international tax system.

In this paper, we propose a general equilibrium model of multinational production to study the consequences of changes in corporate tax rates and taxing rights allocation for the location and amounts of real resources and reported incomes of multinational corporations. In addition to (endogenous) country characteristics (market potential, production costs) and determinants to trade and investment, our model features profit-shifting frictions that impact the location choices of MNCs. [2] We discipline the model through a new, theory-consistent methodology to calibrate bilateral profit-shifting frictions based on accounting identities. Our framework is tractable and readily applies to a broad range of taxation scenarios using widely available data. Importantly, it allows us to evaluate the effect of international and domestic tax reforms on real activity, accounting for the general equilibrium relocation of firms.

Theoretically, we develop a model in which the location of multinationals' real activity also depends on the ability of firms to shift their profits to tax havens. Relative to the existing literature we allow firms to jointly choose production, investment and income shifting worldwide (Egger et al. 2014, Grubert 2003, Grubert & Slemrod 1998). In particular,

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

2. Examples of these determinants include but are not limited to bilateral trade and investment frictions (Arkolakis et al. 2018, Head & Mayer 2019) and corporate taxes (Grubert & Mutti 1991, Grubert & Mutti 2000, Altshuler et al. 2000, Mutti & Ohrn 2019).

firms choose their production location based on real forces (productivity of the production country, proximity to demand, wages) and profit-shifting forces (*e.g.*, proximity to tax havens). Profit-shifting frictions are bilateral and reflect different profit shifting abilities linked to many factors, including profit shifting technologies, bilateral communication costs, and compatibility between tax and legal systems of the source and tax haven countries. Our model delivers simple gravity equations of multinational production, bilateral profit shifting, and trade flows used to calibrate the model's key tax elasticities. Changes in the local or international tax system affect firms' profitability in a given location and therefore reshape the geography of international production. Importantly, the reallocation of profits and production across countries affects income in multiple ways. First, it directly impacts households' labor income. Second, it induces a reallocation of tax revenues across countries, which have both efficiency and distributional effects. At a macro-level, our model determines the winners and losers of corporate tax reforms.

The quantification of our model requires estimates of shifted profits flows. To this end, we provide a new, model-consistent methodology to estimate bilateral profit-shifting frictions based on accounting identities. In particular, an innovation of our methodology is to consider the ability of multinational firms headquartered in a country to shift profits to tax havens from each source country. We recover the distribution of profits shifted across pairs of source countries and tax havens and highlight the role of geography. We do so 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 direct investment income flows in absence of tax havens. The differences between predictions and data correspond to the profits shifted from residence countries to tax havens. In the second step, we use the model structural relationships to allocate these excessive profits between residence, source and haven triplets. The allocation of bilateral profit shifting depends on paper-profit and tax-base elasticities. A higher elasticity of paper profits compared to real profit implies that source countries with more multinational production attract disproportionately more tax avoiders.

The bilateral profit shifting equation improves on the reduced-form set-up à la Hines & Rice (1994), standard in the literature, in which profit shifting is modeled as a quadratic cost and abstracts from other tax havens' attributes. It also improves on existing literature which provides estimates of profit shifting using unilateral data on pre-tax profits of U.S. MNEs or at the global level. Tørsløv et al. (2022) (TWZ, hereafter) is the first paper to propose a measure of bilateral profit shifting across pairs of production countries and tax havens. It uses the global amounts of shifted profits and an allocation key based on trade in services and interest payments to determine profit shifting between production countries and tax havens. While transfer mispricing of services might contribute to profit shifting (Dischinger & Riedel 2011, Karkinsky & Riedel 2012, Hebous & Johannesen 2021), several works also suggest the importance of transfer mispricing of goods (Cristea & Nguyen 2016, Davies et al. 2018, Laffitte & Toubal 2021 and Wier 2020). We complement the TWZ methodology by developing an approach that relies on widely available data on foreign investment bilateral income and multinational production.

As predicted by our model, we find profit shifting to be subject to important costs. 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. We can decompose

the profit shifting costs into two components. First, it is linked to the ability of residence countries to reduce their firms' profit-shifting costs. We show that U.S. and some European countries have better abilities than other residence countries. This finding echoes the recent literature that shows U.S., European (Tørsløv et al. 2022, TWZ hereafter) or Chinese firms (Garcia-Bernardo et al. 2021) are more "aggressive" than firms from other countries. Second, the costs of shifting profits have a bilateral component. These bilateral frictions explain 26% of the variation of profit-shifting costs. We show that they are well explained by gravitational forces and correlate strongly and negatively with measures of tax avoidance technology.

Another key novelty of our approach is to allow for the distinction between profits generated by production activities and shifted incomes. Our structural (gravity) framework allows the estimation of two elasticities: one for tax base and one for income shifting. Recent empirical corporate taxation literature emphasizes the importance of considering the non-linear responses of incomes to corporate tax rates (e.g., Dowd et al. 2017, Bratta et al. 2021, Fuest et al. 2021, Garcia-Bernardo & Jansky 2021). These papers suggest that income tax sensitivity varies across high and low-tax jurisdictions. They use a methodology based on country-level data on profits that pool together tax havens – where observed profits include profits shifting, and high-tax countries – where profits only correspond to real activity. While the model cannot generate this non-linearity, we use our structural framework to disentangle both aspects of profits. We find the elasticity of profit shifting to be larger than the elasticity of real production. Since profits in tax havens result to a large extent in inward profit shifting, our finding thus rationalizes the observed non-linearity.

We use recent data on bilateral trade of goods and services, multinational sales, and profits for 40 countries to carefully calibrate the model. The quantification of profit shifting requires data on bilateral FDI income, multinational production, gravitational data, and country characteristics. Our sample includes seven major tax havens that differ markedly in terms of their economic weight and populations, as noted by Hines & Rice (1994), and their degree of transparency. We use the list proposed by Hines & Rice (1994) and later used by Dharmapala & Hines (2009). We follow Dowd et al. (2017), Clausing (2020), and Tørsløv et al. (2022) and add the Netherlands given the low amount of taxes paid by multinationals when operating there. The list of tax havens includes Hong Kong, Ireland, Luxembourg, Netherlands, Singapore, Switzerland, and Offshore Financial Centers (OFC, hereafter), an aggregate of small European, Caribbean, and Pacific islands.

We use the model as a laboratory for counterfactual policy experiments. To highlight the basic mechanisms of our framework, we start by studying the general equilibrium effects of a unilateral cut in the corporate tax rate in the US. This policy change brings about three main forces: i) a mechanical effect on tax revenues, which, for a given tax base, shrink; ii) a significant change in the tax base driven by firms relocating their production to the U.S. and by firms decreasing profit shifting to tax havens, therefore increasing the taxable profits; iii) as firms relocate, they demand more labor to both produce and potentially headquarter in the US, thereby increasing the equilibrium wage and households' income. These forces highlight the importance of considering the firm location problem in general equilibrium when assessing the effects of changes in international tax policy. In this sense, our analysis improves on the simulation exercises in static models (OECD 2020*a*, Baraké et al. 2021). In supplementary extensions of the model, we further explore the effect on

other macroeconomic variables such as production efficiency or income inequalities.

In a second counterfactual, we simulate the impact of ending profit shifting multilaterally. This has a negative impact on production in the U.S., highlighting that profit shifting opportunities participate to firms' location decisions. This result confirms earlier work by Altshuler & Grubert (2005), Hong & Smart (2010) and Dharmapala (2020) who show that non-haven countries might use lax enforcement of anti-abuse laws in order to attract mobile firms. Third, we predict the consequences of closing a tax haven. We examine the consequences of closing Singapore on the reallocation of production across non-haven countries and paper profits across tax havens. Our simulation shows that closing Singapore has negative consequences on the production of non-tax-haven countries, a result consistent with Suárez Serrato (2018). The effects are larger for countries that shifted more profits to Singapore. We also find a reallocation of paper profits in other tax havens, particularly in Hong Kong. Overall, our results underline the importance of bilateral profit shifting frictions and gravitational forces in explaining the reallocation of real and profit-shifting activities.

Next, we focus on the consequences of the implementation of a global minimum tax of 15%. The effects of minimum taxation depend on whether the reform is implemented unilaterally or globally and on which country, source or residence, has the taxing rights. It also hinges on whether the real activity is fully deductible. We assume a full substance-based carve-out so that our simulations deliver lower bounds of the impacts. A common objection to introducing a minimum effective tax rate is the possibility of corporate inversion. Corporations might move their headquarters to a country that does not apply an effective minimum tax rate. Our model addresses the effects of inversion by considering a set of short-run scenarios – assuming the number of firms headquartered in each country to be fixed – and long-run scenarios – where the number of firms adjusts endogenously. The short-run scenario is akin to a situation where headquarters cannot exit residence countries with more stringent anti-avoidance tax policies and enter low-tax jurisdictions. While focusing on the U.S. for brevity, the mechanisms described are easily extendable to any non-tax-haven country. Overall, implementing minimum taxation, whether in the short- or long-run, increases tax revenues and decreases profit shifting. Our model allows us to dissect the sources of tax revenue gains under alternative scenarios. Firms might continue to shift profits and be taxed at the minimum rate or stop their avoidance activities and be taxed at the U.S. statutory tax rate. This second effect is generally not taken into account in static simulations of minimum taxation. Foreign firms might also relocate away from the U.S. All these effects contribute to assessing the importance of tax revenue gains and profit-shifting losses. In the short-run, implementing a scenario comparable to the OECD/G20 global minimum tax generates, for instance, gains in tax revenues in the U.S. by 4.33% and reduces profit shifting by almost 29%. We observe a reduction in the dispersion of corporate tax rates and an increase in corporate taxes everywhere. The implementation of the global minimum tax reduces the firms' incentives to produce in source countries only because of their tax advantages. After the reform, the location of production across source countries is more likely to reflect their real activity fundamentals. The global minimum tax generates thus efficiency gains and positive welfare effects. It is worth stressing that these effects are particularly strong when firms cannot change their residence country.

Perhaps the more striking results concerns the negative effects of minimum taxation

on production and welfare in the long-run scenarios. Compared to the short-run cases, we now consider endogenous entry and exit. Changes in the tax environment affects now the firms' location across residence countries and also change the number of available varieties. We show that the OECD/G20 global minimum tax induces not only the reallocation of production across countries but also changes the likelihood of entry and exit of corporations whose presence is sensitive to the tax environment. The loss of production decreases the demand for labor, leading to a fall in workers' wages. In the long-run, the negative impact of a higher effective tax rate on firms' profits is magnified by the exit of firms which decreases the set of available products, contributing to a reduction in welfare. Minimum corporate taxation affects a country's efficiency by reshaping the geography of multinational production and changing the importance of real versus tax-related considerations in firms' location choices. Overall, our results show that the effects of the international relocation of firms across countries are of comparable magnitude as the direct gains in taxable income.

While the global tax deal has generally been assessed as an important step forward (OECD 2021), it has also received some criticism - from some signatories that find it unfair or unambitious but also from academics who underline that the global tax deal avoids the long-run challenges. Instead of reforming deeply the international tax system, the current agreement maintains the concepts of source taxation and fiscal residence that are no longer adapted to modern multinational production (Auerbach 2021). [3] In ongoing work, we also examine how alternative tax systems perform compared to the global tax deal. We focus on the implementation of a destination-based taxation regime and analyze its effects on tax revenues, production, welfare and efficiency.

Related Literature. We contribute to the literature that estimates profit shifting of multinational firms using macro-level data (focusing on U.S. multinationals, Blouin & Robinson 2021, Wright & Zucman 2018, Clausing 2020, 2016, Guvenen et al. 2022, or at a global scale, Janský & Palanský 2019, Garcia-Bernardo et al. 2021 and Tørsløv et al. 2022). The recent and important study by Tørsløv et al. (2022) proposes an estimation of bilateral "missing profits" from production countries to tax havens. Their new methodology infers profit shifting from the comparison of the profitability of domestic and multinational firms in tax havens. While having many advantages, this approach provides estimates of unilateral profit shifting, which are allocated to bilateral pairs using an allocation factor based mainly on excess trade in services. Gravitational forces are therefore at play since trade in services is well predicted by gravity. Our quantitative model provides useful guidance as it delivers a gravity equation of bilateral profit shifting. We rely on bilateral FDI income data to compute excessive profits for each pair of residence and tax haven countries. We then use a set of accounting equations to allocate this estimated profit shifting to production countries. The model also rationalizes empirical evidence that income shifting depends on the nationality of the headquarter. In TWZ, for instance, U.S. MNEs conduct more aggressive tax planning than European firms.

Many empirical studies have found significant real effects of international taxation. Grubert & Slemrod (1998) show that tax-free investment in Puerto Rico strongly impacts U.S.

3. We can note however some improvements coming from the Pillar I that aims at allocating some taxing rights to destination countries. Besides, the concept of digital permanent establishment could help to deal with the taxation of the digital economy.

tax revenues because it incentivizes U.S. multinationals to invest and shift incomes. The income-shifting activity is itself affected by the pattern of real activity. In a recent paper, Suárez Serrato (2018) shows that the repeal of section 936 of the Internal Revenue Code, which prevents U.S. MNEs from shifting profits to affiliates in Puerto Rico, has substantial real effects on the U.S. economy. Exposed MNEs responded to the repeal by lowering domestic investment and employment, with persistent effects on local employment. Using data on UK MNEs Bilicka et al. (2021) show that introducing a worldwide debt cap in the U.K. in 2010 reduced total assets, fixed assets, and employment in the U.K. Other studies have investigated the impact of changes in regulations on MNEs' foreign investments. de Mooij & Liu (2020) find a strong negative effect of the introduction of transfer pricing regulations on investment of MNEs compared to observationally equivalent domestic firms. The introduction of regulations does not affect total investment suggesting a reallocation of investment within MNEs and across affiliates' locations. de Mooij & Liu (2021) also find a strong negative impact on foreign investments following the introduction of thin capitalization rules. The effect is particularly relevant in countries with high corporate tax rates. Egger & Wamser (2015) examines whether limitations to foreign income exemptions in Germany affect foreign affiliates' investments. It shows that the German CFC rules decreased foreign subsidiaries' real investments. We contribute to this literature by introducing profit-shifting frictions into a quantitative model that allows us to calibrate the elasticities that govern real impacts that go beyond tax revenues. We discuss how the reallocation of activities following a tax reform affects the measured outcomes.

There is a scarce but burgeoning literature on the evaluation of the international tax reform (Hanappi & Cabral 2020). Detailed discussions of the reforms of international taxation and potential impacts are discussed in Fuest et al. (2019), International Monetary Fund (2019) and Devereux et al. (2021). Most of the literature evaluates Pillar II, the effects of minimum taxation. OECD (2020*a*) and Baraké et al. (2021) propose estimations of the expected tax revenue gains from the implementation of Pillar II. None of these contributions allow for real and profit shifting responses of multinational firms. They moreover focus on tax revenues. We show the importance of variations in corporate taxation and the redistribution of taxing rights in countries' welfare. On the theoretical side, Johannesen (2022) provides an interesting contribution highlighting the importance of the minimum tax rate on welfare. When the minimum tax rate is sufficiently high to eliminate profit shifting, global minimum taxation leads to positive welfare gains for non-tax-haven countries. However, this tax competition model does not consider the real responses of multinational firms which might affect the welfare results.

Last, our quantitative analysis builds on recent advances from the quantitative trade and economic geography literature. We build our model from a multi-country Krugman-type model à la Head & Mayer (2004) that we augment with multinational firms and profit shifting. While the patterns of trade and multinational production have received a lot of attention (Arkolakis et al. 2018, Head & Mayer 2019) with applications to corporate taxation (Suárez Serrato & Zidar 2016, Fajgelbaum et al. 2019, Wang 2020), we focus instead on the geography of profit shifting frictions and how they affect the location of real activities. Contrary to trade flows or multinational production sales, the allocation of profit shifting across tax havens is unobserved. Therefore, the main input required for the calibration of our model needs to be estimated. Furthermore, by explicitly modeling

profit shifting, we can separate the elasticity of profits to taxes that result from aggressive tax planning from those that result from the mobility of multinational production. These two elasticities are key to determining the impact of a global corporate tax reform on real outcomes. Importantly, we find that the elasticity of profits shifted to tax havens is twice as large as the elasticity of multinational production. Calibrating our model with both these elasticities, we are thus able to disentangle the impact of global corporate tax reforms on profit shifting from its impact on multinationals' real activity.

We organize the paper as follows. In Section 2, we present the model used for the counterfactual analysis. The model guides the estimation of bilateral profit shifting and the tax base and profit shifting elasticities. In Section 3, we present the data, estimate bilateral profit shifting and calibrate the elasticity of substitution and the two corporate tax elasticities that govern the location of real activities and profit shifting. In Section 5, we present the counterfactual results.

2 Model

In this section we describe the model that we use for our counterfactual analysis. Importantly, the model introduces tax havens and the ability of firms to shift profits. The model guides the empirical estimation of the two key elasticities that determine the responses of multinational corporations to corporate tax reforms.

2.1 Set-up

Structure of the Model. The world economy is composed of $k = 1, \ldots, N$ countries, among which $h = 1, \ldots, H$ are labeled "tax havens". Each country is endowed with labor, the unique factor of production. The L_k workers are immobile across countries. They inelastically offer one unit of labor paid w_k. An endogenous number of corporations operate under monopolistic competition. Each corporate designs and produces a single variety which 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

$$P_n = \left(\int_{\Omega_n} p_n(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}$$

We use the term "welfare" to denote real expenditure $U_n = Y_n/P_n$ (see also footnote 9).

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 mark-up equals $\frac{\sigma}{\sigma-1}$ and is independent of the destination market. The elasticity σ governs the sales-to-profit ratio in each production country and the price elasticity of demand. Anticipating the calibration of the model, we separate them by introducing a production-country specific wedge $\iota_l \leq \sigma$ between sales and profits. We return to the (exact) calibration of ι_l and σ in Section 3.

Labor costs in l and a set of frictions described below determine the firm production costs and its profitability.

Frictions and taxation. When the source country l and the residence country i differ, the cost to produce abroad involves a friction $\gamma_{il} > 1$, 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 destination market n require the payment of a fixed cost. Therefore, firms serve all markets and $\Omega_n \equiv \Omega$.[4] 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, $\Xi_l^{1-\sigma} = \sum_n \Xi_{ln}^{1-\sigma} = \sum_n \tau_{ln}^{1-\sigma} Y_n P_n^{\sigma-1}$.[5] In the absence of tax optimization, all taxes are levied where production takes place, country l, at the rate t_{ll}, and the tax base's location mirrors the actual economic activities' location.

In our model, MNCs producing in non-haven countries have the opportunity to transfer their profits to a tax haven h. Compared to a low-tax jurisdiction, a tax haven h can also 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, firms incur a bilateral cost α_{lh}. There are various reasons to expect these costs to be heterogeneous across production countries or tax-havens. Indeed, the type and intensity of profit shifting itself are expected to vary across sectors, thereby reflecting countries' specialization. Tax havens, on the other hand, differ in the characteristics that may 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, 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 differ whether they stem from production that is sourced in the U.S. or in France.[6]

Profits We denote global post-tax profits as

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

We allow the tax rate t_{ilh} to be trilateral, acknowledging that even countries operating under a territorial regime may also partially levy taxes at the residence. Taxing rights at the origin also matter when discussing ongoing reforms e.g. the global minimum tax reform which gives taxing rights to residence countries.

2.2 From micro to macro

Firm heterogeneity. In this section, we parametrize the distribution of φ and tax avoidance abilities 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

4. We discuss alternative hypothesis in section 2.5.

5. Head & Mayer (2004) call it the "Krugman market potential" in reference to Krugman (1992).

6. 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 & Toubal (2021).

statistics as in Arkolakis et al. (2012, 2018) and therefore specify the minimal structure to provide us with trade, multinational production and profit-shifting shares.

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 $w_i f_E$.[7] 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 each productivity draw has two components. The first component, T_i is deterministic, inherited from the residence country. The second component φ_{lh} is idiosyncratic, specific to both the source country and the location of profits. A resident firm from i makes post-tax profits $\pi_{ilh}(T_i\varphi_{lh})$ if it chooses to source its production in l and book its profits in h.

Parametrization. The φ_{lh} draws by country i are distributed as follows:

$$(\varphi_{lh})_{l,h\in\mathcal{N}\times\mathcal{H}_l} \sim \mathcal{F}\left(\theta_i; (A_{lh})_{l,h\in\mathcal{N}\times\mathcal{H}_l}\right)$$

$\mathcal{F}$ is a multivariate Frechet distribution. Building on Lind & Ramondo (2018), we consider a multivariate υ_1-Frechet distribution of productivities with scale parameters A_{lh} and a homogenous correlation function $G_i(.)$ so that:

$$\mathbb{P}\left(Z_{11}\leq z_{11};\ldots;Z_{lh}\leq z_{lh};\ldots;Z_{NH}\leq z_{NH}\right) \quad = \quad e^{-G_i\left(A_{11}z_{11}^{-\upsilon_1}\ldots,A_{lh}z_{lh}^{-\upsilon_1},\ldots,A_{NH}z_{NH}^{-\upsilon_1}\right)}$$

When $h=l$, the $A_{lh}=A_{ll}$ parameters reflect the production technology of the source country. Instead when $l\neq h$, A_{lh} captures both the production technology of country l and the ease of tax planning in h for firms producing in l. Together with the α_{lh} frictions, the A_{lh} parameters determine the intensity of profit shifting between l and h. Since we cannot disentangle A_{lh} from α_{lh}, we set $A_{lh}=A_{ll}$, $forallh$ and therefore assume the bilateral variation in profit shifting to be captured by α_{lh}. This means that for a given country l, α_{lh} measures the *net* profit-shifing friction from l to h, adjusted for potential synergies between the production in l and tax avoidance in h. The function G_i gives the substitutability across lh pairs and, therefore, the mobility of the production and the tax base. In the baseline model, we parameterize G_i so that the implied elasticities governing the tax base are allowed to differ for tax-avoiding ($h\neq l$) and non-avoiding firms ($h=l$). Specifically, we assume for now that:

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

where $\upsilon_2\geq\upsilon_1$. We discuss alternative nesting structures in the Online Appendix. As will become clear below, this assumption comes down to assuming that profits from tax-avoiding firms are more elastic to corporate taxes. That correlation functions are i-specific allows for different residence countries i to have different profit-shifting intensities. A lower θ_i raises the likelihood of a firm with residence-country i to engage in profit shifting. It can thus be interpreted as an inverse measure of a residence country's "aggressiveness" in profit shifting.[8]

7. Sunk entry costs f_E could be country-specific. As they are irrelevant to predicting relative changes, we stick to the simple case $f_{Ei}=f_E$ for all i.

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

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^*:

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

Formally, this choice depends on i) each firm's idiosyncratic profitability, 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, and iii) country-specific variables such as labor costs, market potentials, and tax rates.

Structure of the theoretical framework. In Figure 1, we propose a schematic representation of the model in which we distinguish between real (in blue) and profit shifting parameters (in red). Parameters that are not discriminating for tax havens and non-tax-haven countries are left in black.

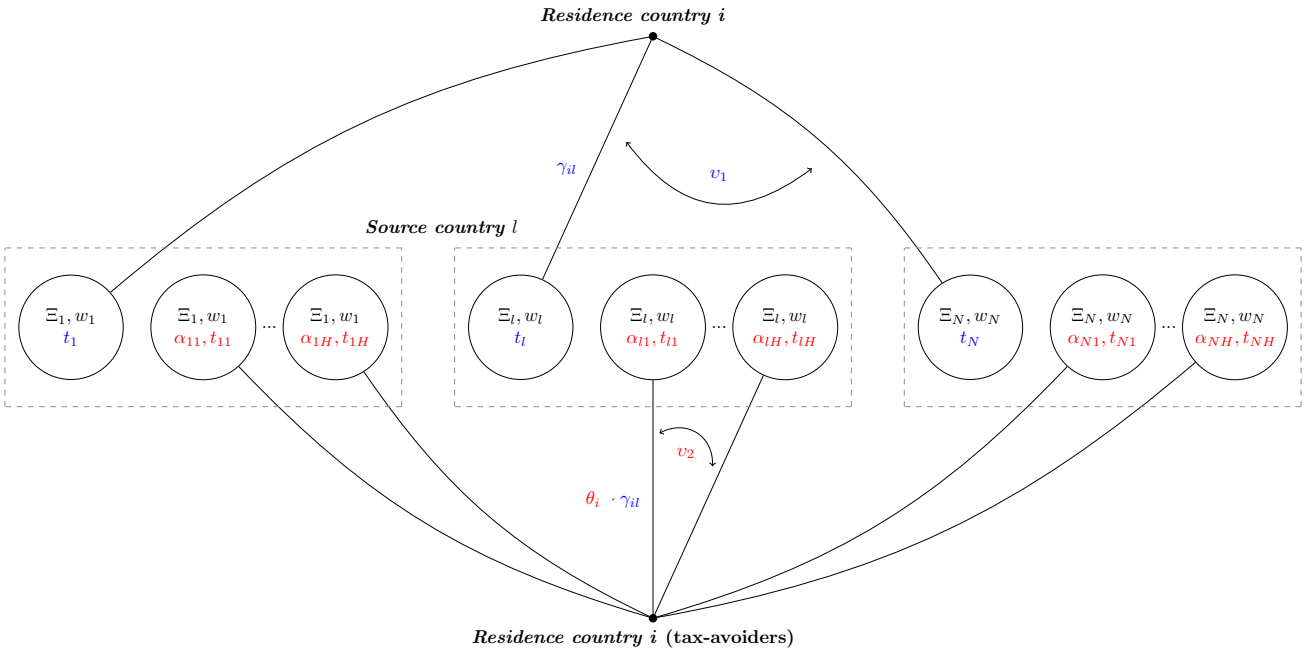


Figure 1 – Structure of the theoretical framework

For non tax avoiders, all taxes are levied where production takes place, country l, and the location of the tax base mirrors the location of actual economic activities. The location choice depends on corporate tax rates t_{ll}, market size and geography embedded in Ξ_l, and wages, w_l. Multinationals producing in non-haven countries can transfer their profits to a tax haven upon paying a marginal bilateral cost α_{lh}. The tax "*aggressiveness*" parameter, θ_i, reflects different abilities of headquarters i to reduce the costs of shifting profits. In the baseline model, we allow the tax base's elasticity to differ for tax-avoiding and non-avoiding firms. The tax base elasticity υ_1 recovers how substitutable the different source

their headquarters" (p.8).

countries are. The "*profit shifting*" elasticity υ_2 informs how substitutable are the different tax havens.

At the macro-level, the model determines the share of production in l undertaken by different countries i, the allocation of the production in l to different consumption markets n through trade, and the distribution of profits realized in l across tax jurisdictions h. A corporate tax reform will reallocate these three shares across countries that together determine the winners and losers of these reforms. Importantly, these changes are not zero-sum. The model also generates variations in overall profits and the number of firms operating in each country. These features allow us to discuss the efficiency of these reforms beyond their distributional impact.

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 $\mathbf{t}_i = (t_{ilh})_{1 \leq l \leq N, 1 \leq h \leq H}$ encompasses corporate income tax rates; all the other determinants of firms' location decisions are contained in $\tilde{A}_{ilh}$, with $\tilde{A}_{ilh} = A_{ll} \left(\gamma_{il} \alpha_{lh} \iota_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-\upsilon_1}$.

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

Expression (3) results directly from McFadden (1978)'s discrete choice framework using GEV.[9] In the long-run monopolistically competitive equilibrium, the free-entry condition holds $\mathbb{E}\left[\pi_{i\{lh\}^*}\right] = w_i f_E$ so that aggregate profits cover the sunk entry cost. Using again the properties of the GEV, we get:

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

Given profits we can build a government's tax revenue flow. Using the free-entry condition above, aggregate pre-tax profits of firms from i producing in l which book their profits in h are given by $N_i \mathbb{P}_{ilh} \frac{w_i f_E}{(1 - t_{ilh})}$. Under a territorial taxation 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 $B_l = \sum_i t_l N_i \mathbb{P}_{ill} \frac{w_i f_E}{1 - t_{ill}}$.

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 inferior to t_k^{min}, we would have that the tax rate is equal to the "normal" statutory tax rate in k if $l = h = k$, equal to $\max\{t_k^{min} - t_{lh}, 0\}$ if $i = k$ and $l \neq h$, and zero otherwise. In this case the tax revenue is given by $B_k = \sum_i t_k N_i \mathbb{P}_{ikk} \frac{w_i f_E}{1 - t_{ikk}} + \sum_{l \neq h, h} \max\{t_k^{min} - t_{lh}, 0\} N_k \mathbb{P}_{klh} \frac{w_k f_E}{1 - t_{klh}}$, where the first term describes the tax revenues generated by firms headquartered in k and

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

the second term by firms located elsewhere whenever the mintax binds. To encompass all these cases we write compactly that tax revenues are described by

$$B_k = \sum_{i,l,h} t_{ilh}^{gk} N_i \mathbb{P}_{ilh} \frac{w_i f_E}{1 - t_{ilh}}, \tag{5}$$

where t_{ilh}^{gk} is the tax rate which is relevant for the tax authorities of country k.

The production in the country l aggregates multinational production from all origin countries. Under CES preferences, production Q is proportional to profits with a factor σ/ι_l. Using the free-entry condition, we get:

$$Q_l = \sigma \sum_{i,h} N_i \frac{\mathbb{P}_{ilh} w_i f_E}{(1 - t_{ilh})\iota_l} \tag{6}$$

Wages clear the labor market in each country, hence:

$$w_i L_i = N_i w_i f_E + \frac{\sigma - 1}{\sigma} Q_i \tag{7}$$

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. Summing-up across all origin-source country pairs that sell in n, we can show that the country n price index verifies:

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

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: [10]

$$Y_l = w_l L_l + B_l + \Delta_l \tag{9}$$

where the imbalances Δ_l. [11] The system of equations (4)-(9) solves Q_l, Y_n, w_i, N_i, P_n with a numeraire condition such that $P_1 = 1$.

2.4 Tax-base and profit-shifting elasticities

As shown by Lind & Ramondo (2018), the max-stable property of the Frechet distribution implies that $\mathbb{P}_{ilh}$ corresponds to the share of profits realized by firms from i in lh. [12] Denote X_{ilh} the overall sales of firms from i selecting the pair lh. The probability for a firm from i to select the pair lh is:

$$\mathbb{P}_{ilh} = \frac{X_{ilh} \iota_l (1 - t_{ilh})}{\sum_{lh} X_{ilh} \iota_l (1 - t_{ilh})} \tag{10}$$

Denote $X_i = \sum_{l,h} X_{ilh}$ the worldwide sales of firms from i. Equation (10) implies:

$$\frac{X_{ilh}}{X_i} = \frac{\mathbb{P}_{ilh} / (\iota_l (1 - t_{ilh}))}{\sum_{l,h} \mathbb{P}_{ilh} / (\iota_l (1 - t_{ilh}))} \tag{11}$$

10. There are several rationales for collecting corporate tax revenues that may differ across countries. We avoid taking a stand on country's heterogeneous preferences over the provision of a public good by assuming that tax revenues are redistributed in a lump-sump fashion. Our measure of welfare is thus better interpreted as an index of production efficiency rather than social welfare.

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

12. See Lind & Ramondo (2018), Lemma A.5. in the Online Appendix.

Equation (11) means that tax rates influence firms' location choices, but they do not affect their sales conditional on the location of their production site. After combining equations (1), (3), and (11), we obtain:

$$\frac{X_{ilh}}{X_i} = \frac{\tilde{A}_{ilh}(1-t_{ilh})^{\frac{\upsilon_1}{\sigma-1}-1}G_{lh}(\tilde{\mathbf{A}}_i,\mathbf{t})}{\sum_{l,h}\tilde{A}_{ilh}(1-t_{ilh})^{\frac{\upsilon_1}{\sigma-1}-1}G_{lh}(\tilde{\mathbf{A}}_i,\mathbf{t})} \tag{12}$$

This yields a gravity-type equation for multinational production sales. In particular, the fraction of the taxable base that remains in each production location is given by:

$$\frac{X_{ill}}{X_i} = \frac{\tilde{A}_{ill}(1-t_{ill})^{\frac{\upsilon_1}{\sigma-1}-1}}{\sum_{l,h}\tilde{A}_{ilh}(1-t_{ilh})^{\frac{\upsilon_1}{\sigma-1}-1}G_{lh}(\tilde{\mathbf{A}}_i,\mathbf{t})} \tag{13}$$

Note that the (partial) elasticity of the tax base in l to $1-t_{ill}$ is then $\frac{\upsilon_1}{\sigma-1}-1$. Moreover, the allocation of sales generated in l and moved toward tax havens is given by:

$$\frac{X_{ilh}}{\sum_{l,h,h\neq l}X_{ilh}} = \frac{\tilde{A}_{ilh}^{\frac{\upsilon_2}{\upsilon_1}}(1-t_{ilh})^{\frac{\upsilon_2}{\sigma-1}-1}}{\sum_{l,h,h\neq l}\tilde{A}_{ilh}^{\frac{\upsilon_2}{\upsilon_1}}(1-t_{ilh})^{\frac{\upsilon_2}{\sigma-1}-1}} \tag{14}$$

This time, the (partial) elasticity of profits shifted from l to $1-t_{ilh}$ is equal to $\frac{\upsilon_2}{\sigma-1}-1$. We thus allow for two distinct elasticities. In addition, the above equation delivers a gravity equation for bilateral profit shifting. The multilateral resistance terms in the denominator show that beyond the characteristics of tax haven h, those of the other tax havens also matter for bilateral profit shifting. The model captures tax competition across tax havens. To see this, note that 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 12). 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 for tax haven h instead of h'. This gravity-based profit shifting enriches the reduced-form set-up *à la* Hines & 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]

2.5 Discussion and extensions

As in Hines & Rice (1994) or Huizinga & Laeven (2008), we may also assume that for a bilateral pair, the marginal cost of shifting profits increases linearly with the ratio of shifted profits to true profits. This functional form would lead to a variable elasticity of shifted profits to tax rates, and would predict exactly zero shifted profit when tax rates are aligned across the pair. Instead, our framework implies that some residual profits would be located in h even without a lower tax rate, implying that tax havens would still get a profit "premium". This distinction makes little difference when exploring small changes in corporate tax policy. However, they could turn out to be important when investigating the impact of more ambitious reforms. In section 5, we explore in detail this

13. In these models, bilateral profit shifting between l and h is proportional to the difference in tax rates between l and h.

question when turning to counterfactuals of implementing a global minimum tax rate with a redistribution of taxing rights to the residence country. Specifically, we extend our model to a non-constant elasticity of profits to effective tax rates that we estimate and use for our counterfactuals.

3 Estimating profit shifting

A preliminary step to calibration is the estimation of profit shifting, which is not directly observable. This section describes the estimation procedure. The calibration of the model parameters, including elasticities, is addressed in section 4.

Our baseline model assumes a territorial tax system in which firms are taxed where production takes place. Its calibration requires quantifying the profits shifted from source countries to tax havens. Our model also shows that the probability and amounts of income shifting vary across residence countries. Some residence countries might have better abilities to reduce the costs of shifting profits. Their firms are thus more aggressive in profit shifting than in other countries. Consequently, we need to estimate the probability for firms headquartered in i to shift profits in tax haven h from source country l, and the distribution of profits shifted for all $i-l-h$ triplets.

This section proposes a structural quantification of profit shifting, consistent with our model. The probability and amounts of profits shifted from the source country to the tax haven depends on other tax havens' tax rate opportunities and factors in other production locations. The structural approach emphasizes the importance of disentangling real from paper-profit elasticities. It also rationalizes the variation of profit shifting across residence countries (e.g. European and U.S. firms in TWZ and Chinese firms in Garcia-Bernardo et al. 2021).

3.1 The structural approach

Our methodology. 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} and PS_{ilh} respectively the absolute value of post-tax profits declared in l and shifted to h by $i-$firms sourcing in l. Total profits - shifted or not - by firms from i are denoted Π_i, while PS_i represent total shifted profits by firms from i. We use the separability of $\mathbb{P}_{ilh}$ across country pairs to derive a set of accounting equations that determine bilateral profit shifting. For $h \neq l$ equation (3) boils down to

$$\mathbb{P}_{ilh} = s_i \times s_{il} \times s_{lh} \; for \; h \neq l$$

where $s_i = \frac{PS_i}{\Pi_i}$ is the probability that firms headquartered in i shift profits;

$$s_{il} = \frac{\sum_{h,h\neq l} \tilde{A}_{ilh}^{\frac{\upsilon_2}{\upsilon_1}} (1-t_{lh})^{\frac{\upsilon_2}{\sigma-1}}}{\sum_{l,h,h\neq l} \tilde{A}_{ilh}^{\frac{\upsilon_2}{\upsilon_1}} (1-t_{lh})^{\frac{\upsilon_2}{\sigma-1}}} \quad \text{and} \quad s_{lh} = \frac{A_{ll}^{\frac{\upsilon_2}{\upsilon_1}} \left(\alpha_{lh} \left((1-t_{lh})\,\iota_l\right)^{\frac{1}{1-\sigma}}\right)^{-\upsilon_2}}{\sum_{l,h,h\neq l} A_{ll}^{\frac{\upsilon_2}{\upsilon_1}} \left(\alpha_{lh} \left((1-t_{lh})\,\iota_l\right)^{\frac{1}{1-\sigma}}\right)^{-\upsilon_2}}.$$

None of these probabilities are observed in the data. In the next subsection, we show that conditional upon the overall profits shifted by firms from i to a country h, i.e. $PS_{ih} =$

$\sum_l PS_{ilh}$, as well as PS_l, the overall amount of profits shifted from source country l, the model structure can be used to back-out all s_{il} and s_{lh}. Subsection 3.3 addresses the estimation of PS_{ih} and PS_l.

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

3.2 Bilateral profit shifting shares s_{il} and s_{lh}

We proceed in 3 steps.

1. In a first step, we compute the probability $s_{ih} = PS_{ih}/PS_i$ that a firm headquartered in i shifts its profits to country h conditional on being a tax avoider. We note that:

$$s_{ih} \quad = \quad \sum_l s_{il} \times s_{lh}. \tag{15}$$

   Compared to s_{il} or s_{lh}, the share s_{ih} can be more easily estimated because databases about MNCs' profits inform in general on ownership link (who owns profits) rather than on value-added links (who generates the value embedded in the profits). The system shown in (15) gives a set of $N \times H$ equations, with N the number of non-haven countries and H the number of tax havens. In steps 2 and 3, we show how to derive s_{il}, which will leave us with a perfectly-identified linear system in s_{lh}.

2. In step 2, we further use the model's structure to determine s_{il}. We denote by $\Gamma_{il} = \left(\frac{\gamma_{il}/\gamma_{il_0}}{\gamma_{i_0 l}/\gamma_{i_0 l_0}}\right)^{\frac{\upsilon_2}{\upsilon_1}}$ the attractiveness of country l when i shifts its profits to a tax haven (relative to a reference country denoted by i_0). It is easily verified that

$$s_{il} \quad = \quad \frac{\Gamma_{il} s_{i_0 l}}{\sum_l \Gamma_{il} s_{i_0 l}}. \tag{16}$$

   To interpret the equation above, first, note that the share of profits generated in l should be positive to observe a positive share of profits shifted from l. The share of profits that can be shifted from country l depends on the amounts of multinational production located in the country l and on the ability to shift part of the profits stemming from this production to tax havens. The attractiveness of source country l for tax avoiders is therefore intrinsically linked to the tax base and profit-shifting elasticities. A higher elasticity of paper profits relative to real profits implies that differences in attractiveness for multinational production - governed by γ_{il} - are magnified when it comes to attracting tax avoiders, as shown by Γ_{il}. In other words, source countries with more multinational production activity tend to attract disproportionately more tax avoiders, all else being equal.

   Instead, whenever $\upsilon_2 = \upsilon_1$, the share of profits shifted from l is proportional to the share of profits reported in l. While simple heuristics might assume that doubling profits doubles profit-shifting, our model shows the importance of correcting for the differential in tax elasticities between real activity and paper profits.

   From Equation (16), we can recover all s_{il} from the reference country s_{i0l} and the frictions γ_{il}.

3. In a third step, we use an accounting identity to back out s_{i_0l}. Profits shifted by multinational firms from source country l to tax havens are equal to the sum of the amounts of profits shifted from headquarters countries $PS_i \times s_{il}$.

$$PS_l = \sum_i PS_i \overbrace{\frac{\Gamma_{il} s_{i_0l}}{\sum_l \Gamma_{il} s_{i_0l}}}^{s_{il}}. \tag{17}$$

There are N equations and N unknowns (s_{i0l}). Consequently, the (non-linear) system in (17) is perfectly identified. We show below how we estimate PS_i and PS_l.

To summarize, we use equation (17) to back-out s_{i_0l}. Equation (16) is used to recover s_{il}. Given s_{il} and s_{ih}, the set of equations (15) is a linear system which solves for s_{lh}.

Our methodology can be summed up by figure 2. It proposes a schematic representation of profit shifting in our model: firms with residence in i make profits in source countries l. These firms may shift some profits to tax havens h. Profit shifting in h can finally be attributed to their owners from country i (they are either kept undistributed in the tax haven or distributed through dividends). Our goal is to triangulate profit shifting. By observing PS_i and PS_l, we can recover all production links between i and l. Using these links and s_{ih}, we are able to find profit shifting shares s_{lh}.

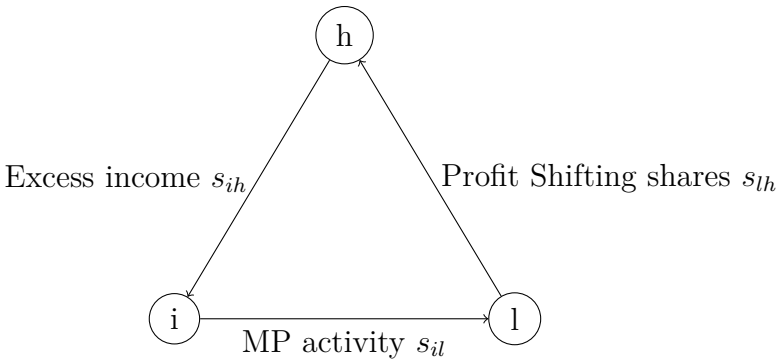


Figure 2 – A schematic representation of profit shifting

It is also important to note that the calibration of profit shifting requires observing the parameters υ_1 and υ_2. The latter can only be calibrated using the information on profit shifting. We will thus use an iterative procedure to quantify bilateral profit shifting. The next section will describe the calibration of these two elasticities at length.

3.3 Estimation of PS_{ih} and PS_l

We start with evaluating the amount of profits shifted from each headquarter country to each tax haven, PS_{ih} which will determine s_{ih} and PS_i.

3.3.1 Data: FDI and multinational production

We use data from a sample of 40 countries from 2010-2014. These countries account 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 29 small Caribbean and Pacific islands). As building blocks, we use the information on bilateral multinational production and FDI income from the OECD's direct investment statistics and Eurostat's balance of payment data. The construction of both datasets and all the related data sources are described in the Online Appendix. The FDI income dataset is the core statistical source from which we can observe the flows of reinvested earnings in tax havens and dividends from tax havens.[14] The FDI income data also contain information on interest payments. As noted by Wright & Zucman (2018), these differ from the two other income components. In a tax avoidance scheme, they would be paid from the parent company to the tax haven foreign affiliates. FDI income flows are presented on a *direct* ownership basis rather than on an *ultimate* ownership basis. The former definition gives more weight to conduit tax havens in the estimation of profits shifting. Damgaard et al. (2019), present an interesting contribution that we use later on to account for the use of tax havens as conduits. Moreover, we need to evaluate the *excessive* amount of income booked in tax havens as only a fraction of FDI income is associated with profit-shifting. The quantification of excess income requires defining a benchmark (normal) income that we present below.

We follow the methodology of Ramondo et al. (2015) to construct data on bilateral multinational production (MP). This methodology is now common in the literature related to multinational production. We construct X_{ill}, the sales resulting from the production in country l by firms headquartered in the country i. More details and comparisons with similar existing datasets are presented in Appendix A.2. From multinational production, we can deduct bilateral multinational production shares and thus bilateral multinational production frictions γ_{il} (see Appendix F). Last, we compute production by domestic firms (X_{iii}) for which we use data on country-level production (see Appendix A).

3.3.2 Bilateral profit shifting as excess profits

The quantification of PS_{ih} requires the definition of a benchmark level of *normal* profit. We construct several benchmark levels, whose specifications are detailed in Table 1 and then predict the level of profits that would be observed if there were no tax haven among the sending countries k. The difference between the "*benchmark*" predicted profits and the predicted profits without tax havens is our measure of profit shifting from any country i to any tax haven h, PS_{ih}. We evaluate total profit shifting to range from \$379bn to \$411bn depending on the benchmark level.

Controlled Foreign Corporation (CFC) rules, employed to counteract the allocation of passive income to low-tax jurisdictions, are unlikely to be a concern for evaluating the amount of profit shifting. According to Clifford (2019), firms react to CFC rules by reducing the revenues they locate in locations that enter the scope of CFC rules. Moreover, within the European Union, CFC rules are only applied to wholly artificial structures following the Cadbury-Schweppes judgment (see Schenkelberg 2020). This limits the potential bias

14. The literature which focuses on U.S. multinational firms shows large estimates of permanently reinvested earnings in tax havens. These funds are often held in U.S. financial institutions and are thus available to the U.S. capital market. Consequently, they constitute leverage for U.S. multinationals. Until the tax reform of 2018, they could not be returned as dividends to the U.S. parent company without incurring U.S. corporate taxation upon repatriation. See Kleinbard (2011) and Murphy (2013), "Indefinitely Reinvested Foreign Earnings on the Rise", *The Wall Street Journal*, 7 May 2013.

Table 1 – Estimating PS_{ih}

	Dependent variable: FDI income				
	(1)	(2)	(3)	(4)	(5)
$EATR_k - EATR_{k'}$	0.056***	0.036*	0.091***	0.091***	0.033*
	(0.019)	(0.019)	(0.017)	(0.016)	(0.017)
$Haven_{k'}$	1.565***	2.336***	2.767***	2.104***	2.682***
	(0.227)	(0.238)	(0.337)	(0.747)	(0.326)
$ln(GDP_{k'})$	0.497***	0.574***	-4.472***	-4.392***	-3.395***
	(0.058)	(0.080)	(0.737)	(0.722)	(0.607)
$ln(GDP_{k'})^2$			0.095***	0.093***	0.069***
			(0.014)	(0.014)	(0.012)
$ln(GDPpc_{k'})$	0.355*	0.372**	0.337***	0.304***	0.537***
	(0.191)	(0.157)	(0.111)	(0.109)	(0.100)
$ln(Dist_{kk'})$	-0.645***	-0.501***	2.592***	2.163*	2.617***
	(0.089)	(0.073)	(0.923)	(1.167)	(0.985)
$ln(Dist_{kk'})^2$			-0.198***	-0.173**	-0.188***
			(0.057)	(0.073)	(0.060)
Contiguity	-0.632**	-0.358*	0.115	0.279	-0.046
	(0.246)	(0.204)	(0.198)	(0.212)	(0.182)
Common Language	1.309***	1.809***	1.340***	1.067***	1.039**
	(0.412)	(0.520)	(0.514)	(0.398)	(0.499)
Colonial Linkage	0.436	0.272	0.088	-0.227	-0.263
	(0.294)	(0.302)	(0.248)	(0.224)	(0.245)
Common Colonizer	0.648**	0.822*	0.423	0.090	0.247
	(0.322)	(0.476)	(0.594)	(0.475)	(0.478)
Com. Legal Origin	0.507	0.099	0.409	1.045***	0.578
	(0.365)	(0.458)	(0.424)	(0.381)	(0.413)
ln(# employees)					0.393***
					(0.080)
HQ FE	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes
Region × Haven	No	Yes	Yes	Yes	Yes
HQ FE × Haven	No	No	No	Yes	Yes
Observations	1,444	1,444	1,444	1,444	1,216
Pseudo R2	0.819	0.836	0.861	0.884	0.873
Number of destination countries	52	52	52	52	52
Implied Aggregate Profit Shifting	**393551**	**397358**	**411327**	**408764**	**379089**

Dependent variable: FDI income that excludes income from interests. Poisson maximum likelihood (PPML) estimator as proposed by Santos Silva & Tenreyro (2006). The PPML estimator successfully handles the heteroskedasticity in FDI income data and enables us to take advantage of the information contained in the zero FDI income series due to its multiplicative form. Robust standard errors clustered at the destination country level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

for pairs of i and h in E.U. countries.

Our estimation sample includes 33 origin (investing) countries and 52- destination countries – 33 non-haven countries, Hong Kong, Ireland, Luxembourg, Netherlands, Singapore, Switzerland, and 13 tax havens that are later aggregated to form a composite country (named "Offshore Financial Centers"). We also correct conduit FDI using data on bilateral FDI recorded on an ultimate investor basis rather than on a direct investor basis from Damgaard et al. (2019). This correction does not affect the aggregate amount of PS_{ih}. Details on the construction of the sample and the methodology are given in Appendix B.

Results are reported in Table 1 where each specification is estimated using Poisson pseudo-maximum likelihood (PPML) following Santos Silva & Tenreyro (2006). The estimated shifted profits are similar across specifications. The specification in column (1) does not include Region × Haven fixed effects. The impact of tax havens on FDI income is assumed to be the same for all tax havens. By using these specific effects from column (2) onward, we follow the recent literature that shows that tax havens are used differently according to their geographic location (Laffitte & Toubal 2021). In column (3), we add quadratic terms for distance and GDP. In this specification, the contiguity dummy now has a positive impact, and the tax haven dummy coefficient appears larger than in column (2). In column (4), we interact each headquarter country fixed effect with the tax haven dummy. We therefore allow the origin countries to have a different propensity to use tax havens (Desai et al. 2006, Garcia-Bernardo et al. 2017). In column (5), we add a measure of the number of employees in k working for a firm from i. This control is useful to consider the productive capacity of firms from i to k. [15]

We use the specification in column (2) to compute PS_{ih}, the estimated levels of bilateral profits that are shifted from residences to tax havens. From this, we can compute s_{ih} and PS^W the total amount of profits shifting. Total profit shifting is estimated at $397bn.

3.3.3 Quantification of PS_l

We quantify the total amounts of profit shifted from production country l to solve our system. Knowing total profit shifting, we only need to compute the share of profits shifted from l i.e. $s_l = PS_l/PS^W$. Our estimation of the relative profit shifting made from l relies on the differences between the share of profits reported ($\frac{\Pi_{ll}}{\sum_l \Pi_{ll}}$) and the share of production reported ($\frac{X_{l\iota_l}}{\sum_l X_{l\iota_l}}$) in countries l. To get an idea about s_l, we compare both shares. The ratio of production to profits can be seen as a measure of profit-shifting intensity in country l independently of the origin of FDI. For instance, usinh this measure, the U.S. as a source country has a profit-shifting intensity of 1.5, while it is equal to one for Germany. It suggests that firms that produce in the U.S. shift more profits than those that produce in Germany, all other things being equal. We then weight the size of each economy by this ratio to obtain s_l.

Alternatively, TWZ. also provides data on the amounts of profit shifting PS_l by source countries. We use these amounts as inputs in our system as a robustness test. As shown in Figure 4 in Appendix, the level of bilateral profit shifting using both inputs is qualitatively similar for the sample of countries available in both TWZ. and our datasets.

15. Note that this variable is partially interpolated following the same procedure as for the MP sales and leads to a decrease in the number of observations. See Appendix A for more details.

3.4 Results and comparisons

Results. The Sankey diagram in Figure 3 shows the shares of profits shifted from residence (s_{ih}) and source countries (s_{lh}) to tax havens. For visualization, we display the top 10 countries and aggregate the bilateral shares for others.

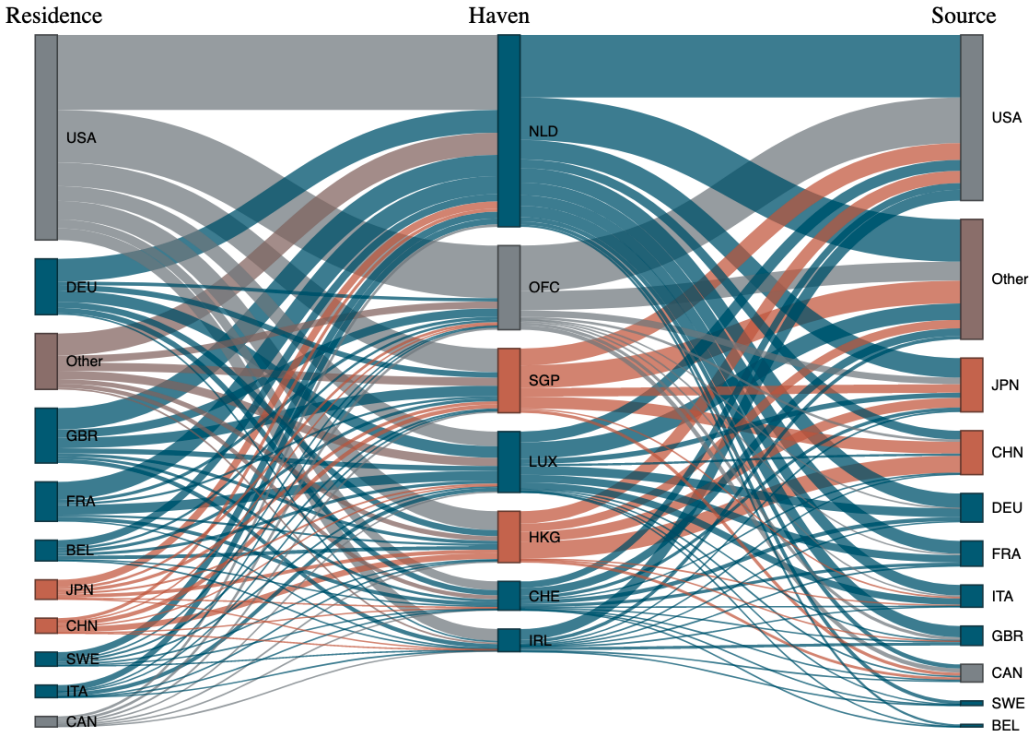


Figure 3 – Profit shifting from i to h and l to h.

Note: This figure plots the estimated profit shifting from residence countries i (on the left), to tax haven h (in the center) and from source country l (on the right) to tax haven h. Details on the computation of profit shifting are given in section 3.

The figure shows the predominance of residence countries such as the U.S. and, to a lesser extent, Germany, the United Kingdom, 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 of profit shifting. The Netherlands is also a major destination of profit shifted from source countries such as the U.S., Japan, and China. Furthermore, Figure 3 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 3 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. Important papers based on macro-level generally provide estimates of profit shifting at the production country or tax haven level (Zucman 2014, Clausing 2016, 2020, Janský & Palanský 2019, Garcia-Bernardo & 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 that are comparable to ours. 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. [16]

Table 2 reports the Spearman's rank correlation of our vector of estimated profit shifting with different estimates from the literature. 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 CORTEX model (Alvarez Martinez et al. 2016). We find positive and larger rank correlations at the unilateral level suggesting a stable relative position of each source country in profit shifting irrespective of the methodology used. In Appendix C, we provide additional materials that compare our profit shifting estimates with other sources found in the literature. The estimates are rather similar on aggregate and for a vast majority of countries.

Table 2 – Spearman's rank correlation

Source	Correlation	Obs.
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
Bilateral profit shifting:		
Tørsløv et al. (2022)	0.61	111

We also 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 positive and significant rank correlation between our bilateral measure and the one of TWZ., slightly above 60%. While the relative rank of source countries using different profit shifting methodologies proves to be similar, we find the relative position of country pairs regarding profit shifting to be dissimilar. Indeed, TWZ's bilateral allocation of profit shifting relies mainly on bilateral trade in services. As found by Davies et al. (2018) and Wier (2020), not all source countries use services trade to shift profit to tax havens. The use of services transactions may also depend on the MNC's sector of activities (Laffitte & Toubal 2021).

We assess the correlation between our profit shifting allocation and an allocation based on excess trade in services with tax havens only. 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. [17]

16. Their approach is discussed in appendix B.

17. We regress the value of trade in services exported from country k to country n for the service category s at date t on a dummy that is 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 the use of intellectual property, telecommunications, computer and information services, and other business services. The methodology to estimate excesses follows the one used to estimate profit shifting in

Figure 4 shows a positive and significant correlation between excessive high-risk services and the theoretically consistent measure of bilateral profit shifting. 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 cannot explain all profit shifting.

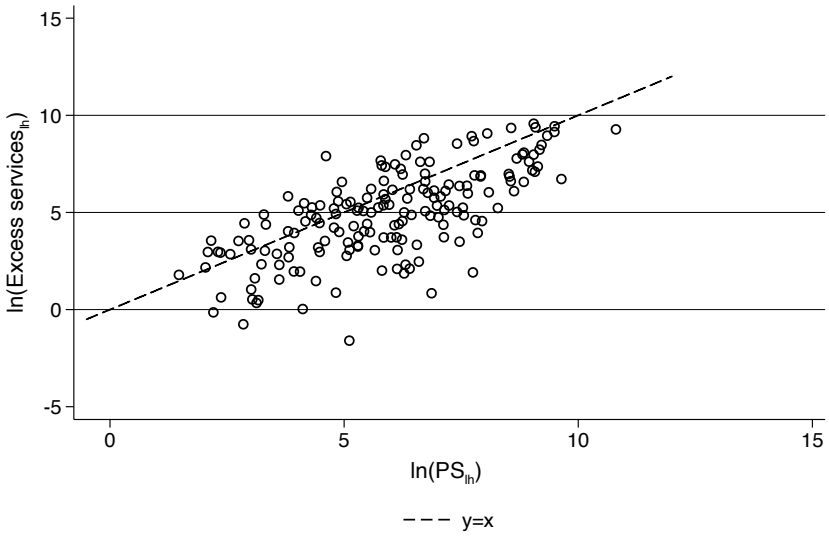


Figure 4 – Comparison between excessive high-risk services and our measure of bilateral profit shifting

Note: This figure compares the estimation of profit shifting between production countries l to tax havens h, as detailed in section 3, 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.

In appendix figure 5, we explore the role of the parameters υ_1 and υ_2 on the allocation of profit shifting. Only the ratio, and not the level, of these elasticities matters. This ratio enters the calibration of profit shifting through Γ_{il}. As such, the ratio will mainly affect the determination of s_{il} (see equation 16). In figure 5, we plot the baseline estimation of s_{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 s_{il} is similar to the baseline allocation and displays a Spearman correlation coefficient larger than 0.95.

4 Elasticities and bilateral frictions

This section describes the rest of the calibration exercise. We first set the elasticity of substitution σ, we then estimate υ_1 and υ_2 that govern the real and paper-profit elasticities.

section 3. 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 $Service_{knst} = \beta_1 High\text{-}Risk_s \times Haven_k + \mu_{nst} + \mu_{kt} + \mu_{kn} + \mu_s + \epsilon_{knst}$

Finally we back-out profit shifting frictions and explore their determinants.

4.1 Elasticity of substitution and implication for profits

The CES monopolistic competition set-up implies a mark up equal to $\frac{\sigma}{\sigma-1}$. We use administrative French firm-level data from the FARE administrative dataset and follow the methodology provided by De Loecker & Warzynski (2012) to calculate firm-level mark-ups. The results give a median mark-up equal to 17% which corresponds to $\sigma = 6.88$. This is in line with estimates found in the literature, e.g. Tintelnot (2017). [18]

However, using a single parameter to map sales to profits in all countries is problematic. It does not allow for matching multinational production and profits for all countries and biases the counterfactuals concerning the real impact of tax reforms on production or tax revenues. This is why we have introduced a country-specific wedge ι_l. Recall that $\iota_l = \sigma\Pi_l/\sum_i X_{il}$, with Π_l being the observed profits generated in country l after correcting for profit-shifting. Profits are computed using National Accounts data (see Appendix A for details). Since profits depend on σ/ι_l, these parameters indirectly determine the tax-GDP ratio. In this regard, it is worth noting that the average model-based tax-GDP ratio at the equilibrium is equal to 2.38%, which is similar to what is observed in our data (2.27% based on OECD Corporate tax revenues data).

By using multinational gross output, a large part of ι_l reflects expenditures on intermediate goods. In addition, ι_l can also absorb a gap stemming from fixed costs (or subsidies) that would impact net profits but not sales. We also ignore heterogeneous mark-ups across firms and, therefore, across countries.

4.2 Real and paper-profit elasticities

Tax elasticities are key for our counterfactual exercises. They 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 real activity (governed by υ_1) and one for profit-shifting (governed by υ_2). It reflects that corporate tax changes generate different responses from real activities and profit shifting. In addition, the model restrictions impose $\upsilon_2 \geq \upsilon_1$, meaning that profit shifting is more elastic to taxes than real production. This approach speaks to 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 & Jansky 2021). These papers, however, do not distinguish between profits generated by production activities and shifted incomes. Rather, 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 very 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 the elasticity of real activity, as shown below.

We now express equations (13) and (14) that identify the corporate tax elasticities in an estimable way in terms of observed variables with associated coefficients and fixed effects.

18. Moreover, De Loecker et al. (2020) find a median markup around 20 percent using Compustat data.

Tax base elasticity. The parameter that governs the elasticity of the tax base in country l, υ_1, is obtained by rearranging Equation (13) as:

$$\frac{X_{ill}}{\sum_l X_{ill}} = \frac{\tilde{A}_{ill}(1-t_{ll})^{\frac{\upsilon_1}{\sigma-1}-1}}{\sum_l \tilde{A}_{ill}(1-t_{ll})^{\frac{\upsilon_1}{\sigma-1}-1}} \quad \forall(i,l) \tag{18}$$

X_{ill} represents sales of firms from i generated and taxed in l. Because $X_{ill} = \frac{X_{ill}}{X_{il}}\frac{X_{il}}{X_i}X_i$, these sales can be recovered using data on PS shares $\frac{X_{ill}}{X_{il}} = 1 - \sum_{l,h,h\neq h}\beta_{ilh}$, MP shares $\frac{X_{il}}{X_i}$, and aggregated MP sales X_i – all of which are observable. We transform Equation (18) by taking its logarithm:

$$ln\left(\frac{X_{ill}}{\sum_l X_{ill}}\right) = \delta_0^0\, ln\,(1-t_{ll}) + \delta_1^0\, ln\tilde{A}_{ill} - ln\left(\sum_l \tilde{A}_{ill}(1-t_{ll})^{\frac{\upsilon_1}{\sigma-1}-1}\right) \tag{19}$$

where $\delta_0^0 = \frac{\upsilon_1}{\sigma-1} - 1$ 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 $FE_i = ln\left(\sum_l \tilde{A}_{ill}(1-t_{ll})^{\frac{\upsilon_1}{\sigma-1}-1}\right)$. We, therefore, use the variation across production countries to identify our coefficients.

Table 3 reports the estimated coefficients and the corresponding parameter elasticities υ_1 for two values of $\sigma \in \{4; 6.88\}$. We use O.L.S. in column (1). In column (2), we show the validity of the results using the PPML estimator. Both estimations lead to similar positive coefficients for the corporate tax rates and thus similar values for υ_1.

Table 3 – Tax base elasticity : υ_1

	Dependent variable:	
	$ln\left(\frac{X_{ill}}{\sum_i X_{ill}}\right)$	$\frac{X_{ill}}{\sum_i X_{ill}}$
$ln(\tilde{t}_l)$	2.639***	3.047*
	(0.688)	(1.674)
Residence country FE	Yes	Yes
Technology controls	Yes	Yes
Gravity controls	Yes	Yes
Observations	1,256	1,600
Estimator	OLS	PPML
Implied υ_1 ($\sigma = 4$)	10.90	12.10
Implied υ_1 ($\sigma = 6.88$)	21.40	23.80

Notes: 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.

Our preferred elasticity is the one presented in column (1) that uses the statutory tax rate as a proxy for corporate tax. We find a parameter $\upsilon_1 = 21.40$ using $\sigma = 6.88$,

thereby suggesting that multinational production is relatively mobile across countries or, equivalently, that foreign and domestic production are close substitutes. The tax base elasticity would have been 10.9 assuming $\sigma = 4$. It is somewhat larger than the elasticity of multinational production to variable production costs found in the literature. Head & Mayer (2019) estimate an elasticity of 7.7 exploiting variation in car tariffs. Assuming the same elasticity of substitution, Wang (2020) also finds a tax base elasticity of 7.7 using cross-section variation in corporate tax rates on aggregated MP sales. This implies that the impact of multinational firms' production and profit-shifting frictions tend to be downplayed in our quantitative exercises compared to these estimates. In the event where domestic and foreign production are perfect substitutes (large υ_1), multinational production frictions would be mostly irrelevant for our quantitative exercises.

Profit shifting elasticity. We start by taking the logarithm of Equation (14):

$$ln\left(\frac{X_{ilh}}{\sum_{l,h,h\neq l} X_{ilh}}\right) = \delta_0^1 ln(1-t_{lh}) + \delta_1^1 ln\tilde{A}_{ilh} - ln\left(\sum_{l,h,h\neq l} \tilde{A}_{ilh}^{\frac{\upsilon_2}{\upsilon_1}}(1-t_{lh})^{\frac{\upsilon_2}{\sigma-1}-1}\right) \quad (20)$$

where $\delta_0^1 = \frac{\upsilon_2}{\sigma-1} - 1$ 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 strongly differ from the observed statutory tax rate (except for the rare tax havens where the statutory tax rate is 0%). The average effective tax rates are computed as the ratio of tax paid to pre-tax profits using the OECD's Country-by-Country reporting (CbC-R) data. [19] The OECD collects this data as part of the Action 13 of the BEPS Project. It consists of the aggregation of firm-level country-by-country reports for 2016. Firms with over EUR 750 million in turnovers must report their files, including information on taxes paid and profits. [20] An interesting and unique feature of the CbC-R is that the aggregation distinguishes profit-making from loss-making firms. We keep profit-making firms in tax havens to avoid aggregating different types of firms. Unfortunately, the CbC-R data set is available for firms from only 25 reporting countries. There is not enough bilateral data to compute an effective tax rate, which would be specific to each pair between the 40 production countries in our sample and each tax haven. We therefore proxy the effective tax rate t_{lh} by the median effective tax rate observed in each tax haven, t_h. We use alternative proxies by computing the average effective tax rate or the lower quartile. The first quartile is representative of the lowest effective tax rates paid in tax havens. It is therefore likely to represent the effective tax rates of large avoiders. We, however, use the median effective tax rate as our main measure to be more conservative and the alternative rates in robustness exercises.

In Equation (22), $\tilde{A}_{ilh}$ comprises information about technologies A_{lh}, bilateral friction between headquarters and production countries γ_{il} and between production countries and the tax havens, α_{lh}. It also includes information on the source country's wage level and market potential. We add a set of headquarter $\times$ production country fixed effects, FE_{il}, which absorb the multinational production costs γ_{il}. These fixed effects are perfectly collinear

19. This data have been used in other studies evaluating tax avoidance by multinational firms (Garcia-Bernardo et al. 2021 at the macro level, Fuest et al. 2021 or Bratta et al. 2021 at the micro-level).

20. The dataset covers, therefore, large firms that are more likely to avoid taxes than smaller firms.

with source countries' specific factors such as wages and market potential. They also absorb the production technology and ease of tax planning in l. Moreover, the headquarter $\times$ production country specific effects confounds with $FE_i = -ln\left(\sum_{l,h,h\neq l} \tilde{A}_{ilh}^{\frac{\upsilon_2}{\upsilon_1}}(1-t_{lh})^{\frac{\upsilon_2}{\sigma-1}-1}\right)$. We parametrize the frictions and technological parameters between the production country l and the tax haven h with gravity covariates. Importantly, we also add an index of the tax haven aggressiveness to proxy for the tax avoidance 'technology' of tax havens. It is taken from the TJN's Corporate Tax Haven Index (Jansky et al. 2020). We construct our index using the information on different regulations and laws in tax havens that inform on the profit-shifting technology. Different loopholes and legislative gaps are reviewed as well as policies regarding transparency, anti-tax avoidance, tax rulings, and treaties. This index is mainly based on the legal features of tax havens, which makes it a good proxy for our understanding of how profits are booked in tax havens. We select the 13 out of 20 most relevant sub-indexes concerning our variable of interest and take their average. [21] Further discussion on data sources and the details of the data treatment are provided in Appendix A.4.

As noted earlier, υ_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. [22]

Table 4 reports the estimation results of the last iteration. Our baseline specification uses the median effective tax rate. We find a coefficient of 7.8 which implies an elasticity $\upsilon_2 = 52.1$, when assuming $\sigma = 6.88$. The coefficient is precisely estimated and is approximately twice as large as $upsilon_1$, the elasticity of the real activity to taxes.

Profit shifting elasticity and the existing literature. How does the profit shifting elasticity derived here compare with estimates in the current literature? The parameter υ_2 governs the elasticity of profit shifting, conditional on shifting profits. It governs the allocation of profits shifted to tax haven h by firms producing in l. Associated with υ_1, that governs the international allocation of the tax base, it informs on how reported profits move with changes in tax rates.

To get a sense of the elasticities of corporate revenues that υ_1 and υ_2 imply, we simulate the effect of a unilateral 5% decrease in the statutory corporate tax rate in the U.S. (see below in section 5 for details on the implementation of counterfactual scenarios). We find that the profits reported in the U.S. increase by 1.14% while production increases by 0.31%. Normalized to a 1% change in the tax rate, we obtain an elasticity of profits of 0.22, which can be decomposed between real activity responses (0.06) and profit shifting responses (0.16).

There is no direct comparison available in the literature. Indeed, the profit shifting literature computes *semi-elasticities* of reported profits to taxes using cross-country variations while our exercise highlights a within-country elasticity. This literature shows that

21. We select the following variables: 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.

22. We solve equations 15 to 17 by setting up an initial value of υ_2. We estimate to determine a new value of υ_2. We replicate the steps until the same value is obtained in the output of two following iterations.

Table 4 – Profit shifting elasticity : υ_2

	Dependent variable:	
	$ln\left(\frac{X_{ilh}}{\sum_i X_{ilh}}\right)$	$\frac{X_{ilh}}{\sum_i X_{ilh}}$
$ln(\tilde{t}_h)$ (Med.)	7.869***	8.625***
	(0.191)	(1.295)
il FE	Yes	Yes
Gravity controls	Yes	Yes
Observations	6,561	7,091
Estimator	OLS	PPML
Implied υ_2 ($\sigma = 4$)	26.60	28.90
Implied υ_2 ($\sigma = 6.88$)	52.10	56.60

Notes: Robust standard errors clustered at the *il* level in parentheses. Gravity controls include bilateral distance (in logarithm), a contiguity dummy, colonial linkages dummies, common legal origin and common language. *** p<0.01, ** p<0.05, * p<0.1

keeping production constant, a 1-point decrease in the tax rate corresponds to 1% more reported profits (see the meta-study of Beer et al. 2020). At the country level, a few studies have estimated the *elasticity* of reported profits to corporate taxes in the U.S.. Gruber & Rauh (2007) report an elasticity of 0.2. A recent study by Coles et al. (2022) finds an elasticity of profits of 0.9 which in decomposed between real responses (0.3) and optimization responses (0.6). This last study uses marginal tax rates and identifies its effects using small firms while the firms covered by Gruber & Rauh (2007) are larger. Due to their methodologies and coverage, in both cases the optimization responses of firms are likely to be different from ours.[23] The elasticity of taxable income implied by our estimates appears close to the one estimated by Gruber & Rauh (2007) and like Coles et al. (2022) we find that optimization responses drive the larger part of this elasticity.

4.3 Profit shifting frictions

In this subsection, we back out the profit-shifting frictions consistent 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.

Normalisation. The likelihood that firms shift their profits from l and h is specific to their residence country i. The country of residence may alleviate or dampen bilateral profit-shifting frictions α_{lh} through θ_i. In order to interpret θ_i, we first need to normalize it. We introduce $\bar{\theta}$ so that $\theta_i = \tilde{\theta}_i\bar{\theta}$ where $\bar{\theta}$ is defined such that in the absence of profit-shifting

23. Coles et al. (2022) uses corporate tax bracket thresholds to identify their elasticities. These thresholds generally apply to small firms that are unlikely to shift profits in tax havens. The optimization responses correspond to income shifting between the corporate and the individual tax bases, or to inter-temporal optimization responses.

frictions, i.e., when $\tilde{\theta}_i = \alpha_{lh} = 1, \quad \forall i, l, h \in \mathcal{N} \times \mathcal{N} \times \mathcal{H}$ then

$$\sum_{l \neq h} A_{ll} = \bar{\theta} \left(H \sum_{l \neq h} A_{ll}^{\frac{\upsilon_2}{\upsilon_1}} \right)^{\frac{\upsilon_1}{\upsilon_2}}$$

or, equivalently

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

The normalization of $\bar{\theta}$ implies that everything else being equal, in the absence of frictions between any non-haven country l and any haven $h \in \mathcal{H}$, the probability of shifting and not shifting conditional on producing in a non-haven country are equal.

Profit-shifting frictions and interpretation. Backing-out $\tilde{\theta}_i$ and α_{lh} requires estimates of A_{ll}, γ_{il}, τ_{ln} and the endogenous variables w, Ξ in the initial equilibrium – the one that is consistent with the profit-shifting probabilities $\mathbb{P}_{ilh}$. The procedure is detailed in appendix F.

We now turn to mapping these profit-shifting frictions and countries' tax aggressiveness into a trilateral cost of profit shifting. In the absence of all non-profit-shifting frictions and when endogenous variables are equal across all countries, the probability that firms from i engage in profit shifting over the probability that they do not reads as:

$$\frac{\sum_{l \neq h,h} \mathbb{P}_{ilh}}{\sum_{l \neq h} \mathbb{P}_{ill}} = \frac{\sum_{l \neq h,h} A_{ll}^{\frac{\upsilon_2}{\upsilon_1}} (\theta_i \alpha_{lh})^{-\upsilon_2}}{\sum_{l,h,h \neq l} A_{ll}^{\frac{\upsilon_2}{\upsilon_1}} (\theta_i \alpha_{lh})^{-\upsilon_2}} \times \frac{\left(\sum_{l,h,h \neq l} A_{ll}^{\frac{\upsilon_2}{\upsilon_1}} (\theta_i \alpha_{lh})^{-\upsilon_2} \right)^{\frac{\upsilon_1}{\upsilon_2}}}{\sum A_{ll}}$$

Setting $\alpha_{l'h'} = \alpha_{lh}$ and rearranging, the above equation simplifies as

$$\frac{\sum_{l \neq h,h} \mathbb{P}_{ilh}}{\sum_{l \neq h} \mathbb{P}_{ill}} = \left(\frac{\theta_i}{\bar{\theta}} \alpha_{lh} \right)^{-\upsilon_1}$$

This expression shows that θ_i and α_{lh} can be mapped into a marginal cost equivalent $Cost_{ilh} := \tilde{\theta}_i \alpha_{lh}$. It is the marginal cost increment associated with profit shifting from any l to any h by i *would all profit shifting frictions be such that* $\alpha_{l'h'} = \alpha_{lh}$. Note that in contrast with the trade τ_{ln} or multinational production frictions γ_{il}, the interaction of real production and profit-shifting elasticities implies that bilateral profit-shifting flows do not verify the irrelevance of independent alternatives. The cost of shifting profits from l to h depends on the frictions to engage in profit shifting between other $l' - h'$ pairs.

Determinants of profit shifting costs. In Figure 5, we represent the distribution of average profit shifting costs between l and h. Conditional on observing profit shifting, the median value of profits shifting costs calculated in our sample is 1.23 – the average value of profits shifting costs is 1.24. 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. Given our sample, we find

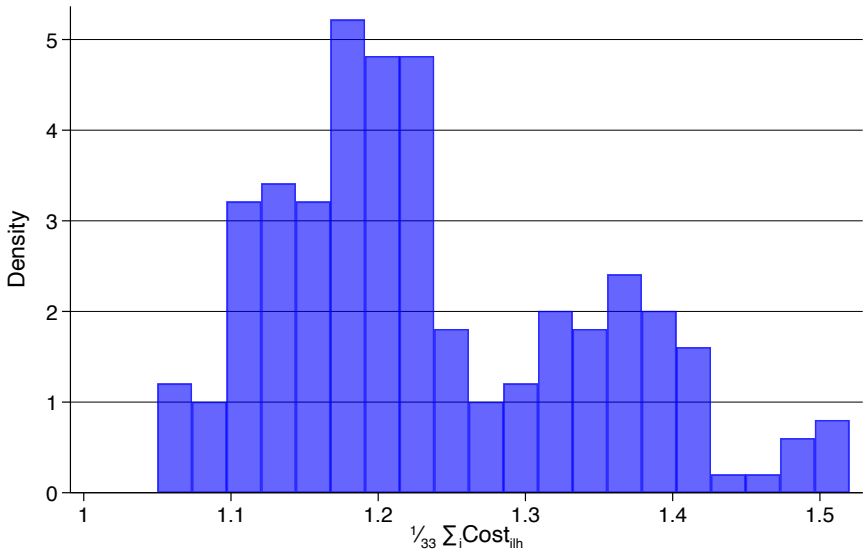


Figure 5 – Average cost of profit shifting ($cost_{ilh}$)

Note: This figure plot the distribution of the profit shifting cost $cost_{ilh}$ averaged over i countries.

a median value of γ_{il} on the same sample is 1.40, slightly more than the multinational production costs figure of 1.31 provided by Head & Mayer (2019) for the car industry.

The profit shifting cost has two components: the tax aggressiveness of the residence country $\tilde{\theta}_i$ and the bilateral friction α_{lh}. We decompose them using a simple fixed effects regression. We estimate the following equation:

$$ln(cost_{ilh}) = ln(\tilde{\theta}_i) + ln(\alpha_{lh}) + \epsilon_{ilh} \tag{21}$$

with $ln(Cost_{ilh})$, the logarithm of the profit-shifting costs. The residence country fixed effects correspond to the log of θ_i. The source and tax haven dyadic fixed effects capture the bilateral profit shifting frictions α_{lh}. 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. We choose the U.S.A. About 26% of the variation in the profit-shifting costs is explained by the (log) bilateral frictions, α_{lh}.

In Figure 6, we display the cross-country distribution of the log of θ_i. Compared to U.S. MNCs, Turkish firms experience a profit-shifting cost penalty of 41%. Belgian MNCs benefit from a 14% reduction of profit-shifting costs. The differences in tax aggressiveness across residence countries highlighted by figure 6 show the key role of headquarters in firms' profit-shifting behavior.

We turn to the examination of bilateral profit-shifting frictions. In Table 5, we show the results of estimations of the log of α_{lh} on gravitational variables, tax rates, and the TJN's Corporate Tax Haven index (CTHI). The CTHI ranks tax havens by combining information on the scope for corporate tax abuse allowed by the jurisdiction's tax and financial systems and the amount of financial activity from MNCs.

Distance and colonial linkages coefficients have the expected signs. Institutional and cultural linkages lower profit-shifting costs while higher bilateral distances increase them. Moving Switzerland, the closest tax haven to France, to the same location as Singapore, the

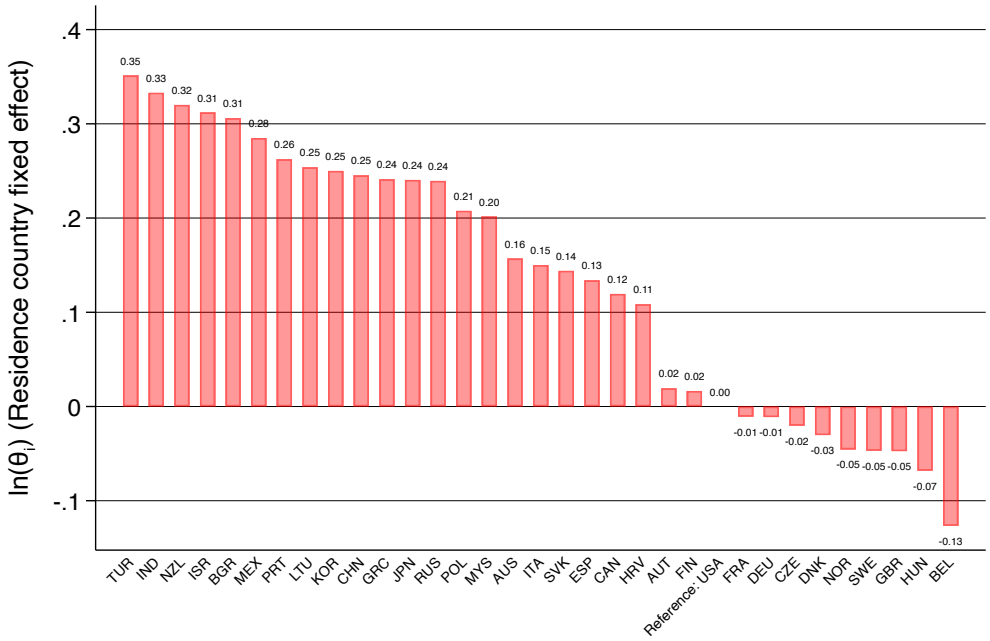


Figure 6 – Distribution of $ln(\theta_i)$

Note: This figure plots the residence country fixed effect obtained by estimating equation 21. It theoretically corresponds to $ln(\theta_i)$.

most remote tax haven from France, would increase the costs of shifting profits from France to Switzerland by about 17%– based on the distance elasticity in column (1). Interestingly, the distance elasticities vary between 0.01 to 0.013 and are comparable to the bottom estimate of the distance elasticities of trade costs which generally range between 0.01 and 0.07 (Head & Mayer 2013).

We find a negative correlation between the composite corporate tax haven index, which we can see as a proxy for the country-specific tax avoidance technology, and the bilateral profit-shifting frictions. We find similar results using the information on the extent of transparency or tax loopholes and exemptions introduced by tax havens. Moving the CTHI ladder from Luxembourg (62 points over 100) to OFCs (92 points over 100) would decrease the costs of profit shifting by 0.03% (estimate in column (3)).

The corporate tax rate difference between the source and the tax haven countries negatively correlates with the bilateral profit-shifting costs. However, we find a larger difference in inducing lower costs, all other things equal. 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%. The introduction of 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)).

All other things being equal, we find weak evidence that tax haven size and level of development negatively correlate with bilateral profit-shifting frictions. The GDP and per-capita GDP variables become insignificant once we include an indicator of the level of transparency. This result suggests that less transparent havens, mostly of larger size and a higher level of development, have lower bilateral profit-shifting costs.

Table 5 – Gravitational determinants of profit-shifting frictions

	(1)	(2)	(3)	(4)	(5)
			$ln(\alpha_{lh})$		
$ln(distance_{lh})$	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

5 Counterfactual Results

In this section, we use calibrated parameters from the previous section combined with estimates of bilateral profit shifting and other inputs to investigate counterfactual tax policies (see table 6 for an overview). Beyond tax revenues, the model allows us to study tax policy changes in each country's GDP level, profit shifting, and welfare. We start by presenting the effects of simple tax policy changes in order to illustrate the model's key mechanisms. We then discuss the principle of minimum taxation and investigate its impact for a fixed and endogenous number of corporations. This distinction allows us to discuss both short and long-run effects from tax policies.

In ongoing work, we also consider alternative criteria for welfare – by introducing a public good to finance and disentangle consumer welfare from production efficiency. We also examine the level of welfare-maximizing minimum tax rates when minimum taxation is implemented multilaterally or unilaterally. We finally study the impact of the implementation of a Destination-Based Cash Flow Tax (Auerbach et al. 2017) as an alternative

tax system that we compare to minimum taxation.

We adopt the exact hat algebra (EHA) methodology popularized by Dekle et al. (2007) and Costinot & Rodríguez-Clare (2014) to provide the results of our hypothetical scenarios. This technique consists of writing the new equilibrium in proportional changes to obtain counterfactual predictions. We refer the reader to Appendix **??** for details on the algorithm.

We focus on the U.S. as an example throughout the discussion for clarity and simplicity. However, the concepts expressed can readily be generalized to all non-haven countries in our sample.

5.1 Preliminary counterfactuals: Model mechanisms

Unilateral tax reforms. *What are the effects of a 5% unilateral reduction of U.S. statutory tax rate on tax revenues, profit shifting, production, and consumer welfare*? In our model, the cross-country reallocation of production affects tax revenues. The hypothetical scenario of reducing the U.S. statutory tax rate would directly impact U.S. GDP, and the amounts of profits shifted to tax havens. Reducing production costs would increase the U.S. tax base by raising its attractiveness. Additionally, profit shifting decreases because it would not be profitable for some firms to continue to shift profits to tax havens at a lower U.S. tax rate. In Figure 9 in the appendix, we illustrate the effects of an unilateral reduction of the U.S. statutory tax rate by 5%. Tax revenues decrease by 3.91%. The static effect of the unilateral tax reduction on tax revenues is compensated by the reduction in profit-shifting activities (-9.95%) and by a modest increase in U.S. GDP (+0.31%). Overall, welfare measured by real expenditures increases by 0.33%.

The impact of unilateral tax reform on U.S. consumers' welfare depends on the effects of the reform on the components of real expenditure U_n (aggregate expenditure deflated by the price index). From equation (9), U.S. aggregate expenditures result from corporate income tax revenues and labor income. All else being equal, a 5% unilateral reduction of the U.S. statutory tax rate would reduce corporate income tax revenues and thus consumers' income because of lesser lump-sum transfers. The unilateral reduction of the U.S. statutory tax rate would increase U.S. attractiveness, production, and labor demand. Workers would therefore enjoy higher wages from this channel. A reduction in the price index drives a slight positive effect on real trade imbalances. In Figure 10, we illustrate the effects of a 5% unilateral reduction of U.S. statutory tax rate on consumer welfare. A unilateral decrease of the tax rate by 5% generates an increase in welfare by 0.33%. This positive effect stems from a large and positive response of wages (+0.39%) that is not offset by the effect of the unilateral reform on the redistribution of tax revenues (-0.08%). The impact of trade imbalances on consumer welfare remains negligible (+0.03%).

Effective anti-abuse laws. *What are the effects of implementing multilateral effective anti-abuse laws in non-haven countries*? Implementing multilateral effective anti-abuse laws would eliminate profit shifting to tax havens. The hypothetical scenario shows how profit shifting might benefit non-haven countries. For the sake of clarity, we consider that this implementation is costless. Figure 11 shows the effects on the U.S. economy of the multilateral implementation of effective anti-abuse laws. The policy increases the U.S. effective tax rate, increasing U.S. tax revenues (+7.64%) at the expense of production

Table 6 – 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 A.1
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 A.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 3, Appendix A.3
Parameters		
t_l	Statutory tax rate. KPMG Statutory Corporate tax rate tables.	Appendix A.4
t_{lh}	Tax havens' tax rate. OECD's Country-by-Country reporting.	Appendix A.4
Π_l	Profits recorded in l. National Accounts, methodology from Tørsløv et al. (2022).	Appendix A.5
ι_l	Profits-sales gap. Computed using: $\iota_l = \sigma \frac{\Pi_l}{\sum_i X_{ill}}$.	Section 4.1
σ	Elasticity of substitution. Set to 6.88 following a 17% mark-up in French firm level data (De Loecker et al. 2020 methodology).	Section 4.1
υ_1	Elasticity of the tax base. Estimated following equation 19. Set to 21.4	Section 4.2
υ_2	Elasticity of profit shifting. Estimated following equation 22. 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

(-0.61%). The net effect on consumer welfare depends on whether the potential loss of production due to the reduction of the level of attractiveness is more than compensated by the increase in tax revenues due to the elimination of profit shifting. We find a net welfare loss of 0.42%. All else equal, firms that would have found it beneficial to locate their production in the U.S. and shift their profits to a tax haven may relocate their activities elsewhere. In Figure 12, we break down the increase in U.S. tax revenues into the part stemming from the reduction in profit shifting and the part coming from the reallocation of production. As shown, the reform would lead to higher tax revenues (+8.31%) if production would not reallocate (-0.66%). This finding, which can be generalized to all non-haven countries, illustrates that high-tax countries benefit from tax havens to attract foreign production. [24] Lax enforcement of anti-abuse laws might therefore be used by non-haven countries in order to attract mobile firms (for instance Altshuler & Grubert 2005, Hong & Smart 2010 or Dharmapala 2020).

Closing a tax haven. *What are the tax revenues and real effects of closing a tax haven?* Equation 14 shows that bilateral profit shifting depends on the tax haven's characteristics and those of other tax havens. The hypothetical scenario of closing a tax haven would have important consequences on reallocating profits, production, and tax revenues. We choose Singapore and continue to illustrate the effects on the U.S.

First, some firms would not find it advantageous to shift profits to other tax havens because of larger bilateral profit shifting frictions α_{lh}. These firms stop shifting profits to tax havens generating more tax revenues in source countries. We illustrate these effects by shutting down profit shifting to Singapore and examining the changes in U.S. tax revenues, GDP, profit shifting, and consumer welfare. Appendix figure 13 illustrates the results. We find a positive effect on tax revenues (+0.21%) mostly due to profit-shifting reduction (-3.30%). The U.S. loses GDP (-0.07%) because its effective tax rate increases relatively and slightly more than in other countries. Eliminating the possibility of shifting profit in Singapore would lead some firms to leave the U.S. – leading to a net welfare loss. The negative effect on welfare is relatively small (-0.02%). [25] These findings are consistent with Suárez Serrato (2018) who shows that eliminating a tax haven generates real effects beyond those on tax revenues.

Second, a share of profits would be reallocated to other tax havens following bilateral profit shifting frictions α_{lh}: more "aggressive" and closer tax havens would gain more. We consider the hypothetical scenario of closing Singapore and show in appendix Figure 14 the changes in tax revenues across tax havens. Our findings suggest a substitution of profit shifting across tax-havens. Shutting down Singapore induces a larger reallocation of profits to Hong Kong than Luxembourg or Ireland. This result underlines the importance of bilateral profit shifting frictions and gravitational forces in explaining profit shifting to tax havens.

Third, closing a tax haven would increase the effective tax rate in all source countries that previously shifted profits. It would therefore affect their attractiveness. Given the gravitational structure of profit shifting, the impact is smaller for source countries that

24. Source countries that are relatively more attractive in production because of easier access to tax havens are also likely to lose more once the reform is implemented.

25. For comparison, 5% statutory tax rate increase in the U.S. decreases welfare by 0.34%.

shifted few profits to the closed tax haven. Following this increase in the effective tax rate, some firms may relocate their production and profit shifting activities. In appendix Figure 15, we show tax revenues changes across non tax haven countries after closing Singapore.

Sensitivity and extensions. In appendix D, we propose two different scenarios to analyze the sensitivity of our results. In each scenario, we modify one or several key calibrated parameters: υ_1 and υ_2. In the first scenario, the profit shifting elasticity (υ_2) is equal to the tax base elasticity (υ_1). This scenario reflects a hypothetical case in which profit shifting is less sensible to changes in corporate taxes. In the second scenario, we keep υ_2 constant, and we consider a lower value of υ_1, that we set to 15. Under this scenario, the tax base elasticity would be lower and firms' location more responsive to their costs. Intuitively, the lower υ_1, the higher the real effects from tax reforms. These scenarios are implemented when simulating an 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 on the statutory tax rate are displayed in figure 16. We observe slightly less tax revenues in both alternative scenarios, driven by a lower decrease in profit shifting than in the baseline scenario. When υ_2 is lowered, profit shifting is less sensible to taxes, which explains this result. In the second scenario, decreasing υ_1 while keeping υ_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 υ_1. Production and welfare are almost unaffected. This is expected given the small shock we are imposing on the equilibrium.

We repeat the same sensitivity exercise in the case where the profit shifting is multilaterally stopped (figures 17 to 19). In the first alternative scenario, where υ_1 is fixed and υ_2 decreased, there is no effect on any outcome. This is expected since when profit shifting stops, there is no room for υ_2. When the elasticity of real profits in lowered to 15, 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 υ_1 is decreased. Indeed, a lower υ_1 means that the costs faced by MNEs becomes more important in their decision. Countries which relied on profit shifting to attract MNE activity are now hardly affected. This is for instance the case of Belgium, France or the U.S. This effect also translates in more negative changes in welfare.

5.2 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. Minimum taxation gives the countries which own the taxing rights the ability to tax foreign profits of corporations that would have been taxed at a lower rate than the minimum tax rate. Addressing which jurisdictions should have the taxing rights is delicate since, in effect, value creation stems from the joint location of headquarters, the location of research and development, and 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.[26] Moreover, minimum taxation can be implemented unilaterally or multilaterally. Notice that the implementation of the minimum rate could also include a substance-based carve-out.[27] In this case, minimum taxation should not strongly affect tax competition for real activities but tackle directly profit-shifting incentives. It is, however, conceivable to apply minimum taxation broadly on any activities, meaning that all firms will be taxed at least at the minimum rate on all their foreign profits. In this case, it impacts tax competition directly by moving the tax rate floor from zero to the chosen minimum tax rate.

A common objection to introducing a minimum effective tax rate is the possibility of corporations moving their headquarters to a country that does not apply an effective minimum tax rate.[28] Our model allows dissecting the effect of minimum taxation in the short-run (assuming a fixed number of firms) and in the long-run (once the number of firms adjusts endogenously). In both cases, multinational firms may relocate their production across countries. In the longer run, headquarters may also enter or exit markets. The short-run scenarios correspond to situations where headquarters cannot exit or enter following a tax-policy change. In particular, the short-run scenario does not allow for corporate inversions - the relocation of HQ to low-tax jurisdictions.

Model's implementation. We operationalize the implementation of the reform by applying minimum taxation either to shifted profits only, $\sum_{l,h,l\neq h} PS_{ilh}$ (a version with carve-outs), or to total profits $\sum_{l,h} PS_{ilh}$ (a version without carve-outs), as long as they are taxed under the minimum tax rate. Here, we implement a polar version where the real activity is fully deductible for the minimum taxation (full substance-based carve-out). The simulations deliver lower bounds of the impacts.

The profit shifting response varies according to tax rate differentials between the source and the tax haven countries. We expect larger responses of profit shifting when the tax

26. The recent reform of international taxation allocates the residual taxing right on foreign profits to residence countries (see OECD 2021). Taxing rights to residence countries rather than source countries is still hotly debated. This is discussed for instance in Englisch & Becker (2019).

27. The initial proposal of the Biden Administration in 2020 specified that the profits of U.S. corporations made even by real activity in low-tax countries would no longer be deductible from their U.S. tax base (as it is the case with the QBAI exemption). The idea was, among other things, to counteract the decline in tax revenues following the implementation of the "GILTI" (Global Intangible Low-taxed Income) taxation system, which provides an exemption for income generated by tangible assets abroad (labeled "QBAI" for Qualified Business Asset Investment). Whereas this exemption was intended not to penalize productive investment, the U.S. administration notes that it has encouraged U.S. corporations to invest more abroad to reduce their tax base via GILTI. This is a reminder that tangible investment is indeed affected by the tax policy.

28. This issue has been a concern of the U.S. administration for many years because of its tax regime. Effective tools such as "*BEAT*", recently replaced by "*SHIELD*", have therefore been put in place, limiting the legal possibilities of this type of arrangement. The BEAT (Base Erosion Anti-Abuse Tax) clause is an anti-abuse clause introduced to stem the erosion of the tax base due to so-called "erosive" payments made to a group's foreign entities. The SHIELD (Stopping Harmful Inversions and Ending Low-tax Developments) clause, proposed by the Biden Administration, concerns payments leaving the U.S. to countries where the effective rate is less than the U.S. effective rate. It provides for the elimination of deductions on such payments. As noted by Fuest et al. (2019), the implementation of minimum taxation relies on two legal instruments, the income inclusion rule (IIR) and the tax on the base erosion payment. These two rules make it possible to reduce the occurrence of inversion significantly.

differential is small. It has implications for implementing the minimum tax rate as a higher rate would reduce profit shifting more than proportionally.

The calibration of υ_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 corporate tax rates, 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 $\left(\frac{\upsilon_2}{\sigma-1} - 1\right) + \frac{k\upsilon_2}{\upsilon_1}\frac{(1-t_{lh})}{(t_l-t_{lh})}$. We recover the shape parameter k from the data.This alternative calibration yields a profit shifting elasticity $\upsilon_2 = 43.6$ (estimated parameter of 6.41 with a standard error of 0.23) and $k = 0.23$ (estimated parameter of 0.23 with a standard error of 0.01).

Figure 7 below visualizes the implied elasticities of profit shifting when the elasticity of profit shifting to corporate tax rate differentials is constant and when it is allowed to vary with tax rate differentials. The figure shows that the constant elasticity is above the non-linear elasticity for large tax differentials. It is largely below when the tax differential gets closer to zero.

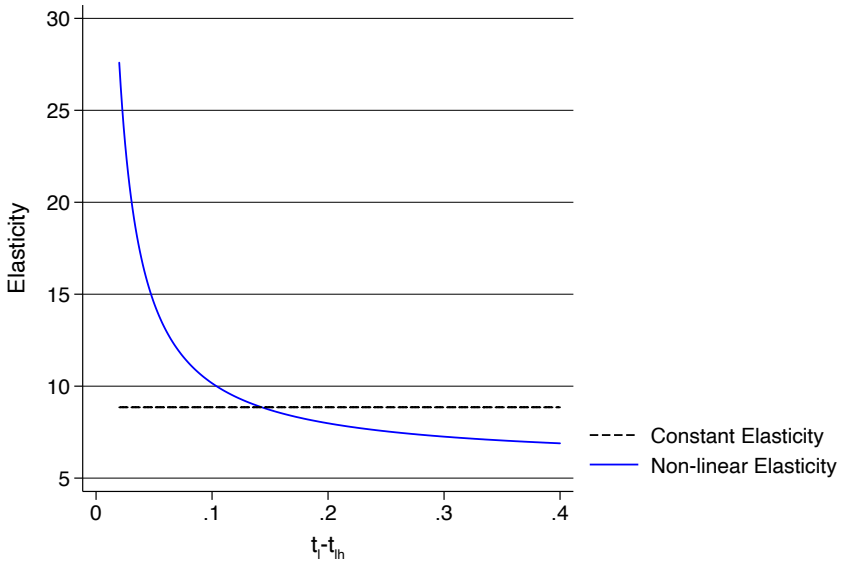


Figure 7 – Implied elasticities of profit shifting at equilibrium

This result has implications for the implementation of the minimum tax rate. 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. We implement this non-linear specification of the profit-shifting elasticity throughout this section.

Results. The effects of minimum taxation depend on whether the reform is implemented unilaterally or globally. They also rest on which source or residence country has the taxing rights. We assume a full substance-based carve-out and variable-elasticity υ_2. We summarize the results in Table 7 which distinguishes two panels. In panel A, we present the results of short-run scenarios where the number of firms (and therefore Ω_n) is fixed.

Minimum taxation induces a cross-country reallocation of production. In panel B, we present the results of long-run scenarios when we allow the model to endogenously adjust the number of firms. These latter scenarios consider entry and exit in addition to real reallocation effects.

Table 7 – Impact of minimum taxation for the U.S. (Minimum taxation rate: 15%)

Minimum Taxation	Tax revenues	Percent change in ... Profit Shifting	Production	Consumer Welfare
		A. Short Run Effects		
Unilateral				
– Residence	4.18	-28.37	0.05	0.04
– Source	4.45	-38.68	-0.01	-0.03
Multilateral				
– Residence	4.33	-29.37	0.09	0.13
– Source	3.98	-29.37	0.09	0.07
		B. Long Run Effects		
Unilateral				
– Residence	3.85	-27.77	-0.18	-0.17
– Source	4.31	-38.60	-0.14	-0.12
Multilateral				
– Residence	3.95	-28.94	-0.19	-0.12
– Source	3.64	-28.95	-0.20	-0.13
– Tax havens' adjustment	2.18	-28.95	-0.22	-0.16

The U.S. implements *unilaterally residence-based minimum taxation.* The reform raises the effective tax rate of U.S. firms which increases corporate tax revenues in the U.S. (+4.18%). The increase in tax revenues is due to two effects. The "profit shifting" effect is an increase in the U.S. tax base because of the reduction of profit-shifting activities. Each dollar of profit not shifted anymore generates t_l additional dollars of tax revenues. Profit shifting decreases by -28.37%. The "minimum taxation effect" corresponds to a gain in tax revenues on the activities of U.S. multinationals, which continue to shift profits to tax havens. The U.S. (their residence country) can now tax them at a rate that equals the difference between the minimum rate and their effective tax rate. Each dollar of profit taxed at the minimum rate adds $t^{min} - t_{ilh}$ dollar of tax revenues. Note that the marginal gains of tax revenues of the "profit shifting effect" are larger than those of the "minimum taxation effect." The effect on production is ambiguous. U.S. foreign affiliates which do not find it profitable to shift taxes from their foreign location after the introduction of minimum taxation might reallocate production in the U.S. This reallocation has a positive

effect on production. The effective tax rate of firms increases leading to a potential drop in production. Overall, we find a positive effect on production (+0.05%). The demand for labor increases, leading to larger workers' wages. We find a positive welfare effect (+0.04%).

The results of a scenario where the U.S. implements a *unilateral source-based minimum tax* are different. Minimum taxation does not apply to the profits of U.S. MNEs that produce in foreign countries. Compared to the previous scenario, the U.S. now applies minimum taxation to the profits from firms producing in the U.S. These firms might continue to shift profits and be taxed at the minimum rate or stop their avoidance activities and be taxed at the U.S. statutory tax rate. Moreover, foreign firms might relocate their production to foreign countries. This scenario unambiguously increases the effective tax rate of firms shifting profits out of the U.S. by decreasing their profit-shifting incentives. Overall, the impact on production is negative (-0.01%). Despite the tax revenues increase, the overall welfare effect is negative (-0.03%).

The multilateral implementation of minimum taxation reduces the dispersion of corporate tax rates and increases corporate taxes everywhere. Therefore, the corporate-tax determinants of location are less binding, and the location of firm production increasingly reflects countries' fundamentals, e.g., source countries' technology A_{ll}. The distribution of corporate tax rates across countries is the same in both residence and source scenarios. The effects on profit shifting and production are therefore the same. The allocation of taxing rights is, however, different. Minimum taxation reduces firms' incentives to choose a source country only because it offers tax advantages. Therefore, its implementation generates efficiency gains. This effect should be particularly important in the short-run scenario because firms cannot exit the residence country – as they might in the long run. The multilateral residence-based implementation of minimum taxation generates more revenues than the source-based implementation because foreign-owned firms might reallocate their production to other countries. Welfare effects are smaller in the source-based scenario because labor demand decreases more. Notice that the effects of minimum taxation might differ across countries because of different non-tax frictions. For instance, in the multilateral implementation of minimum taxation, production in Bulgaria, Greece, Turkey, or Portugal decreases compared to the U.S., Germany or Denmark where production increases.

Compared to the short-run cases, we now allow endogenous entry and exit. Corporate taxes might affect firms' location across residence country and can also change the number of varieties. Panel B of Table 7 presents the results. Compared to the short-run results, we add a case in which tax havens adjust their corporate tax rates to the minimum tax rate in the long run.

Implementing the long-run scenario generates similar effects on tax revenues and profit shifting than in the short-run scenarios. Tax revenues are lower due to more firms exiting the market following the increase in effective tax rates. As previously mentioned, the reforms reduce profit shifting. Notice that the unilateral source-based scenario raises 8% more revenues than the unilateral residence-based scenario. Profit shifting by the U.S. and foreign multinationals in the U.S. reduces by 36.11%, almost 30% more than in the previous scenario. The source-based scenario applies minimum taxation to all firms producing in the U.S., while the residence-based scenario only applies to U.S.-headquartered firms producing in the U.S. and does not affect their amounts of profit-shifting. In long-run

scenarios, implementing a minimum tax induces not only the reallocation of production across countries but also changes the likelihood of entry and exit of corporations whose presence is sensitive to the tax environment. The loss of production decreases the demand for labor, leading to a fall in workers' wages and firms' profits. The decrease in product variety magnifies the negative impact of the reform on profits in the short-run, contributing to reducing welfare.

The quantification of the implementation of minimum taxation also has to consider the tax havens' incentive to adjust their corporate tax rates to the minimum tax rate (Johannesen 2022). Under residence-based minimum taxation, the residence country taxes under-taxed profits of tax haven affiliates so that their effective tax rates reach the minimum. If tax havens maintain their corporate tax rate t_{lh}, the headquarter country applies a tax rate equal to the difference $t^{min} - t_{lh}$. This mechanism might incentivize tax havens to set their tax rate at the minimum tax rate: $t_{lh} = t^{min}$. As a first-order effect, compared to the situation where tax havens do not change their rates, such adjustment would only affect the distribution of tax revenues without affecting the effective tax rate of firms. In both cases, firms make decisions based on the minimum tax rate and the corporate tax rates of tax havens. Consequently, when tax havens adjust, no minimum tax is levied, and it does not matter if taxing rights are allocated to source or residence countries. Because no minimum tax is levied, the "minimum taxation effect" disappears reducing revenue gains in non-haven countries compared to the scenario where tax havens do not adjust.

5.3 Quantification of equilibrium effects

Our model proposes two key channels of firm's adjustment to corporate tax reforms. In response to changes in the corporate tax environment, firms adjust their location strategy ("real effects") and their profit shifting strategy ("profit shifting effects") to maximize their profits in the new environment. Consequently, these two effects make the general equilibrium results differ from a mechanical effect of tax reforms where firms do not adjust. These mechanical effects are those often computed to assess the impact of tax reforms. [29]

In table 8, we quantify the size of these equilibrium effects relative to the mechanical effect when the U.S. implement a reform. The mechanical effect (column 1) is computed by assuming that only the tax rate changes keeping the amount and allocation of profits and profit shifting constant. The GE effect (column 2) is the effect predicted by our model. The "profit shifting effect" (column 3) indicates the change in tax revenues due to the change in the profit shifting strategy of MNEs with respect to the mechanical effect. The "real effect" (column 4) indicates the change in tax revenues due to the change in the location strategy of MNEs with respect to the mechanical effect.

When the U.S. decrease its statutory tax rate by 5%, the associated mechanical effect is that tax revenues decrease by 5%. However, the final effect is a decrease in tax revenues by 3.91%. Profit shifting effects represent 15.6% of the mechanical effect, and real effects represent 6% of the mechanical effect. Similarly, when ending profit shifting at the world level, the final effect is 7.98% lower than the mechanical effect due to changes in MNEs location strategies. Real effects are therefore substantial.

Turning to minimum taxation scenarios, we observe a significant profit shifting effect:

29. See for instance OECD 2020*a* or International Monetary Fund 2019.

around 60% for residence-based minimum taxation and larger than 80% for source-based minimum taxation. While all additional tax revenues in the mechanical effect comes from minimum tax revenues, in equilibrium a lot of firms adjust their profit shifting strategy by decreasing tax avoidance. This ends up in larger effects on tax revenues in equilibrium. The role of the profit shifting effect in the change in tax revenues in the U.S. is larger for source minimum taxation because this scenario is applied to both U.S MNEs and foreign MNEs producing in the U.S., while residence-based scenarios do not affect foreign MNEs producing in the U.S. Real effects are also substantial, from -4.47% for unilateral source minimum taxation to -8.49% for unilateral residence minimum taxation.

This table shows the critical importance of quantifying profit shifting effects and real effects to predict the impact of international tax reforms. It is also worth mentioning that unilateral and multilateral scenarios lead to the same mechanical estimation of the change in tax revenues in the U.S. This is because policies of other countries do not matter to compute this effect since firms do not move. Similarly, the scenario where tax havens adjust their tax rate to the minimum tax rate leads to a rise in tax revenues in the U.S. of 2.18%. However, it would lead to a mechanical effect of 0% since production and profit shifting do not change, and no minimum tax is collected. Therefore, this table highlights differences between different scenarios that mechanical effects cannot capture.

6 Conclusion

We develop a quantitative general equilibrium model of multinational production to analyze reforms of international corporate taxation. In addition to bilateral trade and investment frictions, our model incorporates profit-shifting frictions. These frictions determine the intensity of profit shifting, shaping thereby the impact of international taxation reforms across countries. We show that profit-shifting frictions are sizeable: their magnitude is comparable to other frictions that determine the geography of multinational production.

We provide a new, model-consistent methodology to calibrate profit-shifting between source and tax haven country pairs. We highlight the role of gravitational forces in determining profit shifting from residence and source countries to tax havens. For instance, we shed light on the importance of European tax havens for the U.S. and European source countries, and Singapore and Hong Kong for China and Japan. Examining profit-shifting, we show the predominance of some residence countries – such as the U.S., France, Germany, and the U.K. Firms from these countries benefit from a cost advantage when it comes to shifting their profits to offshore havens.

Our approach allows to disentangle real activities from profit-shifting activities. Profit shifting estimates depend on the interaction between elasticties that govern the mobility of multinational production and paper profits respectively. These elasticities are also key determinants of how changes in the tax environment affect entry, production, and profit-shifting decisions. A higher elasticity of paper profits relative to real profits implies that source countries with more production attract disproportionately more tax avoiders.

We simulate various tax reforms aimed at curbing the tax-dodging practices of multinationals and their impact on a range of outcomes, including tax revenues, profit-shifting, production, and consumer welfare. We estimate the impact of minimum taxation, the Pillar II of the tax reform promoted by the OECD (OECD 2020*b*). Our approach takes

Table 8 – Quantification of real and shifting effects

Counterfactual	Change in tax revenues		Contribution relative to the mechanical effect	
	Mechanical Effect (no reallocation) (1)	GE effect (with reallocation) (2)	PS effect (change in PS) (3)	Real effect (change in location) (4)
5% Statutory decrease	-5%	-3.91%	15.6%	6%
End of profit shifting	+8.31%	+7.64%	–	-7.98%
15 % min. tax				
Unil. Source	+2.12%	+4.34%	109.61%	-4.47%
Unil. Residence	+2.59%	+3.85%	57.40%	-8.49%
Multi. Source	+2.12%	+3.64%	80.51%	-8.46%
Multi. Residence	+2.59%	+3.95%	60.56%	-7.96%
TH adjustment	0%	+2.18%	–	–

Results in this table are provided for the United States. "Mechanical effect" in column (1) indicates the reform's effect as computed by assuming no change in profit-shifting activity or production location. "GE effect" in column (2) corresponds to the effect computed using our quantitative model. "PS effect" in column (3) indicates the change in tax revenues due to the change in the profit shifting strategy of MNEs with respect to the mechanical effect. 15.6% means that there are 15.6% more tax revenues compared to the mechanical effect because firms have adapted their profit-shifting strategy following the reform. "Real effect" in column (4) indicates the change in tax revenues due to the change in the location strategy of MNEs with respect to the mechanical effect. 6% means that there are 6% more tax revenues compared to the mechanical effect because firms have adapted their location following the reform.

into account two mechanisms that have been overlooked so far by the empirical literature estimating the effects of minimum taxation. First, firms react to minimum taxation by adapting their profit shifting behavior. After the implementation of the reform, profit shifting decreases, which generates additional tax revenues. Second, firms react to minimum taxation by reallocating their activity across residence and source countries. We show that these channels are quantitatively relevant to assess the macroeconomic impact of international tax reforms. Minimum corporate taxation affects a country's efficiency by reshaping the geography of multinational production and changing the importance of real versus tax-related considerations in firms' location choices.

The effect of minimum taxation on consumer's welfare depends mostly on which from the tax revenues or labor income dominate for a given minimum tax rate. In ongoing work, we simulate the optimal level of minimum taxation. We also analyze alternative reforms such as the Destination-Based Cash Flow Taxation (see Auerbach et al. 2017). Under a DBCFT regime, corporate income taxes would be paid in the place of final consumption. This is in contrast with the current international system that aims at taxing profits where corporate activity generates value. A consequence of the destination-based tax system is that exports are not taxed by the country of production, while imports are. This proposition has the advantage of curbing profit shifting incentives when implemented multilaterally. DBCFT can be implemented in our current setting through a broad-base VAT combined with a labor subsidy. Our model allows to simulate the quantitative impact of such a reform taking into account its effect on real activity and profit shifting. Future work will compare the efficiency and welfare gains of DBCFT to those of minimum taxation.

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