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► **To cite this version:**

Alessandro Ferrari, Sébastien Laffitte, Mathieu Parenti, Farid Toubal. Profit Shifting Frictions and the Geography of Multinational Activity. 2022. halshs-04103710

HAL Id: halshs-04103710

<https://shs.hal.science/halshs-04103710>

Preprint submitted on 23 May 2023

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**Profit Shifting
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December 2022

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PROFIT SHIFTING FRICTIONS AND THE GEOGRAPHY OF MULTINATIONAL ACTIVITY*

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October 2022

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.

*We wish to thank Pierre Boyer, Michael Devereux, Peter Egger, Clemens Fuest, Philipp Kircher, Marko Köthenbürger, Niels Johannesen, Julien Martin, Philippe Martin, Nora Paulus, Nadine Riedel, Juan Carlos Suarez-Serrato, Gabriel Zucman and seminar participants at Banque de France, City University of London, CESifo, CREST, ECARES, ETH Zurich, European University Institute, Geneva, Kiel, Moscow Higher School of Economics, Nottingham, OECD, Paris 1, Paris School of Economics and at the ERWIT conference, the Villars CEPR Workshop on International Trade, the Mannheim Taxation Conference, the National Tax Association Congress, the CESifo Area Conference on Public Economics, the 31st FIW Workshop (Firms and Workers in the Global Economy), the Mainz Shaping Globalization Workshop, the ECARES Workshop on International Corporate Taxation, and the NBER Business Taxation in a Federal System Conference for useful comments and discussions. We thank the Booster program of the ENS Paris-Saclay for financial support. We thank Baptiste Souillard for his contributions to earlier stages of this project. Felix Samy Soliman provided excellent research assistance.

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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 multinational corporations, 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 tax reforms is the estimation of bilateral profit shifting frictions (i.e, the cost to move profits from a production country to a low-tax jurisdiction) but also, the extent to which these profits are elastic to changes in corporate taxation. Current models of multinational production ignore the role of profit-shifting frictions 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 relocation of firms in general equilibrium.

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

1. A large literature has documented the use of low-tax jurisdictions and in particular tax havens by multinational firms. See for instance Hines and Rice (1994), Desai, Foley, and Hines (2006), Gumpert, Hines, and Schnitzer (2016), Bilicka (2019) or Tørsløv, Wier, and Zucman (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, de Mooij, and Liu (2020) for a meta-study, Dyreng and Lindsey (2009), Clausing (2016), Dowd, Landefeld, and Moore (2017), Wright and Zucman (2018), Laffitte and Toubal (2022), Blouin and Robinson (2021) on U.S. multinational firms.

2. Examples of these determinants include but are not limited to bilateral trade and investment frictions (Arkolakis, Ramondo, Rodríguez-Clare, and Yeaple, 2018, Head and Mayer, 2019) and corporate taxes (Grubert and Mutti, 1991, Grubert and Mutti, 2000, Altshuler, Grubert, and Newlon, 2000, Mutti and Ohrn, 2019).

shifting worldwide (Egger, Merlo, and Wamser, 2014, Grubert, 2003, Grubert and Slemrod, 1998). In particular, 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 excess profits between residence, source and haven triplets. These relationships imply that residence, source and haven triplets form a triangle in which profit shifting flows must be consistent. 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 and 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 and Riedel, 2011, Karkinsky and Riedel, 2012, Hebous and Johannesen, 2021), several works also suggest the importance of transfer mispricing of goods (Cristea and Nguyen, 2016, Davies, Martin, Parenti, and Toubal, 2018, Wier, 2020, and Laffitte and Toubal, 2022). We complement the TWZ methodology by developing an approach that relies on widely available data on bilateral foreign investment incomes 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) or Chinese firms (Garcia-Bernardo, Jansky, and Tørsløv, 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 the tax base and one for the shifted incomes. 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, Santomartino, and Acciari, 2021, Fuest, Hugger, and Neumeier, 2021, Garcia-Bernardo and 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 also introduce another source of non-linearity by allowing the elasticity of profit shifting to taxes to depend on the tax rate differential. When the tax rate differential between a non-haven and a tax haven decreases, profit shifting become more elastic, generating larger reallocations. This approach speaks to the recent results of Bilicka, Devereux, and Guçeri (2022).

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 and Rice (1994), and their degree of transparency. We use the list proposed by Hines and Rice (1994) and later used by Dharmapala and 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, 2020a, Baraké, Neef, Chouc, and Zucman, 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 and Grubert (2005), Hong and 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%.³ 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

3. While the global tax deal has generally been assessed as an important step forward (OECD, 2021), it has also received some criticism, in particular 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. Despite some improvements coming from the Pillar I that aims at allocating some taxing rights to destination countries, and the concept of digital permanent establishment, the current agreement maintains the concepts of source taxation and fiscal residence that are no longer adapted to modern multinational production (Auerbach, 2021). 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.

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 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 might thus generate positive welfare gains. It is worth stressing that these positive effects are particularly strong when firms cannot change their residence country.

Perhaps the more striking results concern 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 affect 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.

Finally, we close the paper by examining the incentives of countries to unilaterally change their statutory tax rate in response to the implementation of a global minimum tax rate. We find that most countries would be incentivized to raise their rates, highlighting a relative preference for real tax revenues over real income. This result brings a new view on how countries could react to the implementation of a global minimum tax.

Related Literature. We contribute to the literature that estimates profit shifting of multinational firms using macro-level data (focusing on U.S. multinationals, Blouin and Robinson, 2021, Wright and Zucman, 2018, Clausing, 2016, 2020, Guvenen, Mataloni, Rassier, and Ruhl, 2022, or at a global scale, Janský and 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 and Slemrod (1998) show that tax-free investment in Puerto Rico strongly impacts U.S. 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, Qi, and Xing (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 and 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 and 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 and 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 international tax reforms (Hanappi and Cabral, 2020). Detailed discussions of the reforms of international taxation and their potential impacts are discussed in Fuest, Parenti, and Toubal (2019), International Monetary Fund (2019) and Devereux, Auerbach, Keen, Oosterhuis, Schön, and Vella (2021). Most of the literature evaluates the so-called Pillar II *i.e.* the introduction of minimum taxation. OECD (2020a) 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 and 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 and Mayer, 2019) with applications to corporate taxation (Suárez Serrato and Zidar, 2016, Fajgelbaum, Morales, Serrato, and Zidar, 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 $k = 1, \dots, N$ countries, among which $h = 1, \dots, H$ 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 11).

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

4. We discuss alternative hypothesis in section 2.5.

5. Head and 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, Fichtner, Takes, and Heemskerk (2017), Bilicka, Qi, and Xing (2020) or Laffitte and Toubal (2022).

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 statistics as in Arkolakis, Costinot, and Rodriguez-Clare (2012), Arkolakis et al. (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:

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

\mathcal{F} is a multivariate Frechet distribution. Building on Lind and Ramondo (2018), we consider a multivariate v_1 -Frechet distribution of productivities with scale parameters A_{lh} and a homogenous correlation function $G_i(\cdot)$ so that:

$$\mathbb{P}(Z_{11} \leq z_{11}; \dots; Z_{lh} \leq z_{lh}; \dots; Z_{NH} \leq z_{NH}) = e^{-G_i(A_{11} z_{11}^{-v_1}, \dots, A_{lh} z_{lh}^{-v_1}, \dots, A_{NH} z_{NH}^{-v_1})}$$

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 $A_{lh} = A_{ll}, \forall h$ so that α_{lh} captures the bilateral variation in profit shifting. This means that for a given country l , α_{lh} measures the *net* profit-shifting friction from l to h , adjusted for potential synergies between the production

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 .

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:

$$G_i(\mathbf{x}) = \sum_{l=1}^N x_{ll} + \theta_i^{-v_1} \left(\sum_{l=1}^N \sum_{h=1}^H x_{lh}^{v_1} \right)^{\frac{v_1}{v_2}} \quad (1)$$

where $v_2 \geq v_1$.⁸ 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.⁹

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^* :

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

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.

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 v_1 recovers how substitutable the different source

8. Note that our set-up is easily adjusted to alternative nesting structures e.g. where there would be a larger substitutability among havens for a given source country. In this case, firms would decide first on where to produce before deciding on whether engaging in profit shifting. In our set-up instead, firms decide first on whether being a tax-avoider or not and, conditional upon this choice, they decide simultaneously on where to source their production and where to book their profits.

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

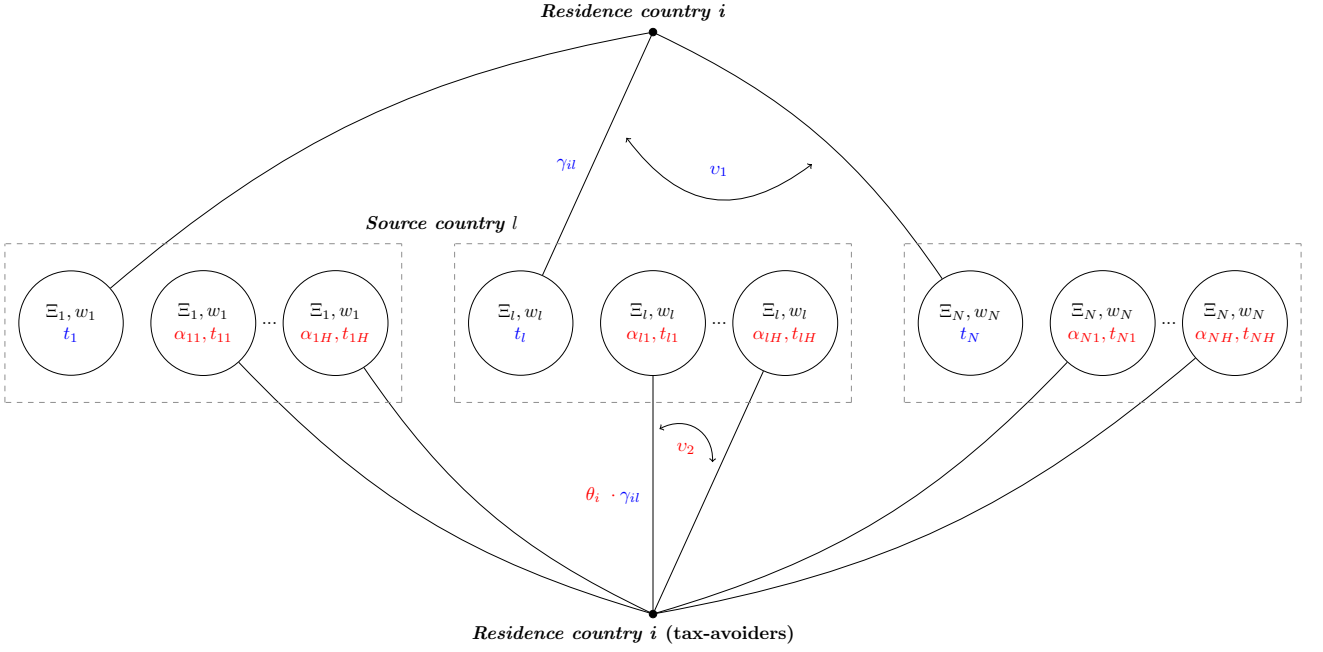


Figure 1 – Structure of the theoretical framework

countries are. The "profit shifting" elasticity v_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:

$$\mathbb{P}_{ilh} = \frac{\tilde{A}_{ilh} G_{i,lh}(\tilde{\mathbf{A}}_i, \mathbf{t}_i)}{G_i(\tilde{\mathbf{A}}_i, \mathbf{t}_i)} (1 - t_{ilh})^{\frac{v_1}{\sigma-1}} \quad (3)$$

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 $\tilde{A}_{ilh} = A_{ll} \left(\gamma_{il} \alpha_{lh} t_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_1}$.

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 $\left(\tilde{A}_{ilh} (1 - t_{ilh})^{\frac{v_1}{\sigma-1}} \right)_{l \leq N, h \leq H}$.

Expression (3) results directly from McFadden (1978)'s discrete choice framework using

GEV.¹⁰ Using again the properties of the GEV, the expected profits $\bar{\pi}_i$ of a firm headquartered in i - taken across all possible pairs lh - are given by

$$\bar{\pi}_i = \frac{1}{\sigma T_i^{1-\sigma}} \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} G_i(\tilde{\mathbf{A}}_i, \mathbf{t}_i)^{\frac{\sigma-1}{v_1}} \Gamma \left(1 - \frac{\sigma-1}{v_1} \right) \quad (4)$$

Given profits we can build a government's tax revenue flow. Aggregate pre-tax profits of firms from i producing in l which book their profits in h are given by $N_i \mathbb{P}_{ilh} \frac{\bar{\pi}_i}{(1-t_{ilh})}$. 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 $B_l = \sum_i t_l N_i \mathbb{P}_{ill} \frac{\bar{\pi}_i}{1-t_{ill}}$.

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 $B_k = \sum_i t_k N_i \mathbb{P}_{ikk} \frac{\bar{\pi}_i}{1-t_{ikk}} + \sum_{l \neq h, h} \max\{t_k^{min} - t_{lh}, 0\} N_k \mathbb{P}_{klh} \frac{\bar{\pi}_k}{1-t_{klh}}$, where the first term describes the tax revenues generated by firms headquartered in k and 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

$$B_k = \sum_{i,l,h} t_{ilh}^{gk} N_i \mathbb{P}_{ilh} \frac{\bar{\pi}_i}{1-t_{ilh}}, \quad (5)$$

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 , hence, we get:

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

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

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

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:

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

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:¹¹

$$Y_l = w_l L_l + B_l + N_l (\bar{\pi}_l - f_E w_l) + \Delta_l \quad (9)$$

10. To obtain the above formula, note that using (1), profits π_{ilh} from a residence country i follow a multivariate $\frac{v_1}{\sigma-1}$ -Fréchet distribution with scale parameters $\tilde{A}_{ilh} (1-t_{ilh})^{\frac{v_1}{\sigma-1}}$ and the same correlation function $G_i(\cdot)$.

11. 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-sum fashion. Our measure of welfare is thus better interpreted as an index of production efficiency rather than social welfare.

where $\bar{\pi}_i - f_E w_i$ are the profits net of entry costs and the residual imbalances are captured by Δ_l .¹² The system of equations (5)-(9) solves Q_l, Y_n, w_i, P_n with a numeraire condition such that $P_1 = 1$. The long-run monopolistically competitive equilibrium solves for N_i through a free-entry condition imposing that

$$\bar{\pi}_i = f_E w_i. \quad (10)$$

2.4 Tax-base and profit-shifting elasticities

As shown by Lind and 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 .¹³ 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:

$$\mathbb{P}_{ilh} = \frac{X_{ilh} \iota (1 - t_{ilh})}{\sum_{lh} X_{ilh} \iota (1 - t_{ilh})} \quad (11)$$

Denote $X_i = \sum_{l,h} X_{ilh}$ the worldwide sales of firms from i . Equation (11) implies:

$$\frac{X_{ilh}}{X_i} = \frac{\mathbb{P}_{ilh} / (\iota (1 - t_{ilh}))}{\sum_{l,h} \mathbb{P}_{ilh} / (\iota (1 - t_{ilh}))} \quad (12)$$

Equation (12) 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 (12), we obtain:

$$\frac{X_{ilh}}{X_i} = \frac{\tilde{A}_{ilh} (1 - t_{ilh})^{\frac{v_1}{\sigma-1} - 1} G_{lh}(\tilde{\mathbf{A}}_i, \mathbf{t})}{\sum_{l,h} \tilde{A}_{ilh} (1 - t_{ilh})^{\frac{v_1}{\sigma-1} - 1} G_{lh}(\tilde{\mathbf{A}}_i, \mathbf{t})} \quad (13)$$

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:

$$\frac{X_{ill}}{X_i} = \frac{\tilde{A}_{ill} (1 - t_{ill})^{\frac{v_1}{\sigma-1} - 1}}{\sum_{l,h} \tilde{A}_{ilh} (1 - t_{ilh})^{\frac{v_1}{\sigma-1} - 1} G_{lh}(\tilde{\mathbf{A}}_i, \mathbf{t})} \quad (14)$$

Note that the (partial) elasticity of the tax base in l to $1 - t_{ill}$ is then $\frac{v_1}{\sigma-1} - 1$. Moreover, the allocation of sales generated in l and moved toward tax havens is given by:

$$\frac{X_{ilh}}{\sum_{l,h,h \neq l} X_{ilh}} = \frac{\tilde{A}_{ilh}^{\frac{v_2}{v_1}} (1 - t_{ilh})^{\frac{v_2}{\sigma-1} - 1}}{\sum_{l,h,h \neq l} \tilde{A}_{ilh}^{\frac{v_2}{v_1}} (1 - t_{ilh})^{\frac{v_2}{\sigma-1} - 1}} \quad (15)$$

This time, the (partial) elasticity of profits shifted from l to $1 - t_{ilh}$ is equal to $\frac{v_2}{\sigma-1} - 1$. 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,

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

13. See Lind and Ramondo (2018), Lemma A.5. in the Online Appendix.

it increases the total share of profits shifted from l toward tax havens (see Equation 13). Second, it reshuffles these profits among tax havens (see Equation 15). 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 and Rice (1994), standard in the corporate tax avoidance literature, in which bilateral profit shifting abstracts from other tax havens' attributes and reallocation mechanisms across tax havens.¹⁴

2.5 Discussion and extensions

As in Hines and Rice (1994) or Huizinga and 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 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 paper profits $v_2(t_l - t_{lh})$ to effective tax rates that we estimate and use for our counterfactuals.

2.6 Welfare and efficiency

Following a change in corporate tax policy, be it a change in the current rate or a reallocation of taxing rights, firms will relocate their production and update their decision to shift profits. This, in equilibrium, will impact countries overall consumption, exports, tax revenues and number of firms. In general equilibrium, disentangling the channels that will impact welfare can be challenging. In this section, we stress a simple neutrality result of taxation that will guide the interpretation we offer in Section 5.

In our model and in the absence of public good, welfare at the country level measures the efficiency of production that is consumed. This, in turn, depends on the number of varieties available for consumption, the average per-variety consumption, and the allocation of consumption across goods with respect to their relative costs of production (see Dhingra and Morrow, 2019 for a general treatment under monopolistic competition and non-CES preferences). The number of varieties available in the economy is determined by a free-entry condition equating the sunk entry cost to the post-tax profits a firm can accrue in a given location. Therefore, taxes can distort entry directly by decreasing expected profits. Secondly, dispersion in taxes can distort the spatial allocation of production. Location choices are driven by profitability considerations: a firm with large productivity in country

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

i may choose to locate in country j , where it is less productive, for tax-related reasons. Thirdly, taxes affect welfare by changing the geography of sourcing. Firms may decide to locate far from their destination market to reduce their tax bill at the societal cost of higher trade costs. Finally, taxes affect both the level and distribution of tax revenues. As these are part of the income side of consumers' budget constraint this also indirectly distorts the location choices of firms by changing market potentials.

In our setting these effects are all co-determined, making it hard to disentangle efficiency from distributional effects in general equilibrium. A short-run equilibrium response to a change in tax policy is one where firms do not relocate their headquarters. Practically, this implies that N_i remains fixed for all i so that there is no level effect on the number of available varieties. Firms headquartered in country i can still change their production location and where they book their profits. This special case yields an important benchmark result when we consider residence-based taxation:

Result *Consider an equilibrium holding fixed the number of firms where (5) – (9) hold. A top-up residence-based unilateral tax in an otherwise territorial tax system is neutral on the market equilibrium and thus welfare.*

A top-up residence-based corporate tax is defined as a residence-based tax t_i which is levied on profits repatriated to the residence country once corporate taxes have been paid on a territorial basis, i.e., in the source or haven-country at the rate t_{lh} . Thus, a firm from i , sourcing in l and booking its profits in h will have pre-tax profits given by $\frac{\bar{\pi}_i}{(1-t_{ilh})} \equiv \frac{\bar{\pi}_i}{(1-t_i)(1-t_{lh})}$.

To build the intuition for this neutrality result, consider first the effect of a residence-based top-up on firms' location choices. Since the top-up is applied to all firms headquartered in i , it does not change the relative profitability of different production and profit-booking locations directly. Formally, \mathbb{P}_{ilh} , as defined in (3), does not depend directly on t_i . It could however change the incentives to locate in a country l if it were to distort market access Ξ_l or the equilibrium labor costs w_l . For instance, market access depends on total expenditures and thus tax revenues. The unilateral introduction of the top-up however is neutral in the budget constraint of households living in country i and does not affect households located elsewhere. The top-up is tantamount to increasing tax revenues rebated to households via an identical reduction of the profits, which are also rebated to households. Moreover, since the top-up is unilateral, it does not change the income of countries $l \neq i$. Formally, plugging (5) into (9) shows that the budget constraint does not depend on t_i . Last, using (4), we note that pre-tax profits $\frac{\bar{\pi}_i}{(1-t_i)(1-t_{lh})}$ do not depend on t_i either. We conclude that the solution of (5) – (9) is invariant to the top-up.

Two corollaries may be noted. First, it is immediate to see from this benchmark result that the effect of a unilateral residence-based top-up must be negative in the long-run, when firms can re-optimize their headquarter location. Such a reform will lead to a decrease in the number of HQ in country i , thereby generating a negative welfare effect in the long-run.¹⁵ Second, this result helps interpreting a unilateral change in a source-based tax

15. Note that under labor-market clearing, this implies that more production is undertaken by surviving firms or new entrants from other countries. Quantitatively, we find that this negative effect dominates. The intuition can be traced back from Dixit and Stiglitz (1977) and Dhingra and Morrow (2019): since the first-best is typically

regime. Indeed, such a tax change is identical to a unilateral residence based tax change applied to domestic firms, as well as a change in the tax rate applied to foreign producers. The neutrality-result above implies that the first-order effect of a source-based change in the tax rate will be driven by foreign firms only.

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 heterogeneity of profit shifting across residence countries (*e.g.* European and U.S. firms in Tørsløv et al., 2022 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_{il} 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

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

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

obtained in an environment without any taxes, starting from an equilibrium with taxes features an inefficiently low number of firms. A decrease in the number of firms will shift the equilibrium further away from the first-best. At the country level, this implies a potentially small increase in welfare of j and a large decrease in i .

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

None of these probabilities are directly 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 ($\alpha_{lh} \rightarrow \infty$, 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:

$$s_{ih} = \sum_l s_{il} \times s_{lh}. \quad (16)$$

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 (16) 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 $\Gamma_{il} = \left(\frac{\gamma_{il}/\gamma_{i_0}}{\gamma_{i_0l}/\gamma_{i_0i_0}} \right)^{\frac{v_2}{v_1}}$ 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

$$s_{il} = \frac{\Gamma_{il} s_{i_0l}}{\sum_l \Gamma_{il} s_{i_0l}}. \quad (17)$$

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 $v_2 = v_1$, 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 (17), 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_{i0l} . 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 $PS_i \times s_{il}$.

$$PS_l = \sum_i PS_i \frac{\overbrace{\Gamma_{il} s_{i0l}}^{s_{il}}}{\sum_l \Gamma_{il} s_{i0l}}. \quad (18)$$

There are N equations and N unknowns (s_{i0l}). Consequently, the (non-linear) system in (18) is perfectly identified. We show below how we estimate PS_i and PS_l .

To summarize, we use equation (18) to back-out s_{i0l} . Equation (17) is used to recover s_{il} . Given s_{il} and s_{ih} , the set of equations (16) 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 that are a function of multinational production and the ratio of elasticities. Using these links and s_{ih} , we are able to find profit shifting shares s_{lh} .

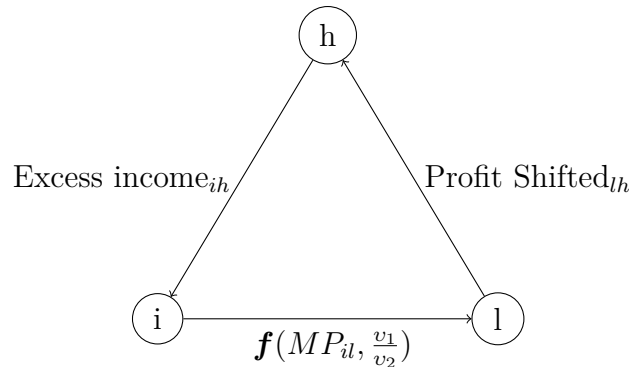


Figure 2 – The Triangle of Profit Shifting

Note: This figure illustrates the way we back-out $Profit Shifted_{lh}$. Country i represents a residence country, country l a source country, and country h a tax haven. MP_{il} is observed (described in Section 3.3.1), $Excess income_{ih}$ is estimated (described in Section 3.3.2), the function $f(\cdot)$ linking residence countries to source countries is given by equation 17. We solve for $Profit Shifted_{lh}$ conditional on $Excess income_{ih}$ and the adjusted MP share.

It is also important to note that the calibration of profit shifting requires observing the parameters v_1 and v_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.¹⁶ The FDI income data also contain information on interest payments. As noted by Wright and 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, Elkjaer, and Johannesen (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, Rodríguez-Clare, and Tintelnot (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 . Multinational production data is constructed using data from Eurostat’s *Foreign affiliate trade statistics* (FATS), OECD’s *Activities from Multinationals* (AMNE) and BEA’s *U.S. Direct Investment Activity* (USDIA) datasets. These datasets record multinational activity of parent country i in affiliate country l on an ultimate investor basis for majority-owned foreign affiliates. Following Ramondo et al. (2015), missing values are imputed based on the correlation between MP sales and mergers and acquisitions in the sample. More details and comparisons with similar existing datasets are presented in Appendix A.2. From multi-

16. 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.

national 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 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 and Tenreyro (2006). The estimated shifted profits are similar across specifications. The specification in column (1) does not include Region \times 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 and Toubal, 2022). 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 .¹⁷

We use the specification in column (2) to compute PS_{ih} , the estimated levels of bilateral

17. 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.

Table 1 – Estimating PS_{ih}

	Dependent variable: FDI income				
	(1)	(2)	(3)	(4)	(5)
$EATR_k - EATR_{k'}$	0.056*** (0.019)	0.036* (0.019)	0.091*** (0.017)	0.091*** (0.016)	0.033* (0.017)
$Haven_{k'}$	1.565*** (0.227)	2.336*** (0.238)	2.767*** (0.337)	2.104*** (0.747)	2.682*** (0.326)
$\ln(GDP_{k'})$	0.497*** (0.058)	0.574*** (0.080)	-4.472*** (0.737)	-4.392*** (0.722)	-3.395*** (0.607)
$\ln(GDP_{k'})^2$			0.095*** (0.014)	0.093*** (0.014)	0.069*** (0.012)
$\ln(GDPpc_{k'})$	0.355* (0.191)	0.372** (0.157)	0.337*** (0.111)	0.304*** (0.109)	0.537*** (0.100)
$\ln(Dist_{kk'})$	-0.645*** (0.089)	-0.501*** (0.073)	2.592*** (0.923)	2.163* (1.167)	2.617*** (0.985)
$\ln(Dist_{kk'})^2$			-0.198*** (0.057)	-0.173** (0.073)	-0.188*** (0.060)
Contiguity	-0.632** (0.246)	-0.358* (0.204)	0.115 (0.198)	0.279 (0.212)	-0.046 (0.182)
Common Language	1.309*** (0.412)	1.809*** (0.520)	1.340*** (0.514)	1.067*** (0.398)	1.039** (0.499)
Colonial Linkage	0.436 (0.294)	0.272 (0.302)	0.088 (0.248)	-0.227 (0.224)	-0.263 (0.245)
Common Colonizer	0.648** (0.322)	0.822* (0.476)	0.423 (0.594)	0.090 (0.475)	0.247 (0.478)
Com. Legal Origin	0.507 (0.365)	0.099 (0.458)	0.409 (0.424)	1.045*** (0.381)	0.578 (0.413)
$\ln(\# \text{ employees})$					0.393*** (0.080)
HQ FE	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes
Region \times Haven	No	Yes	Yes	Yes	Yes
HQ FE \times 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 and Tenreiro (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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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 ($\frac{\sum_i \Pi_{il}}{\sum_{i,l} \Pi_{il}}$) and the share of production reported ($\frac{X_{ll}}{\sum_l X_{ll}}$) 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, using 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 profit shifting PS_l by source countries. We use these amounts as inputs in our system as a robustness test. As shown in Figure A.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.

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.

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 and Palanský, 2019, Garcia-Bernardo and Jansky, 2021 and Tørsløv et al., 2022). Tørsløv et al. (2022) is the first paper to propose a methodology to compute bilateral profit shifting across pairs of source and tax haven countries that are comparable to ours. They use the global amounts of shifted profits and an allocation key based on trade in

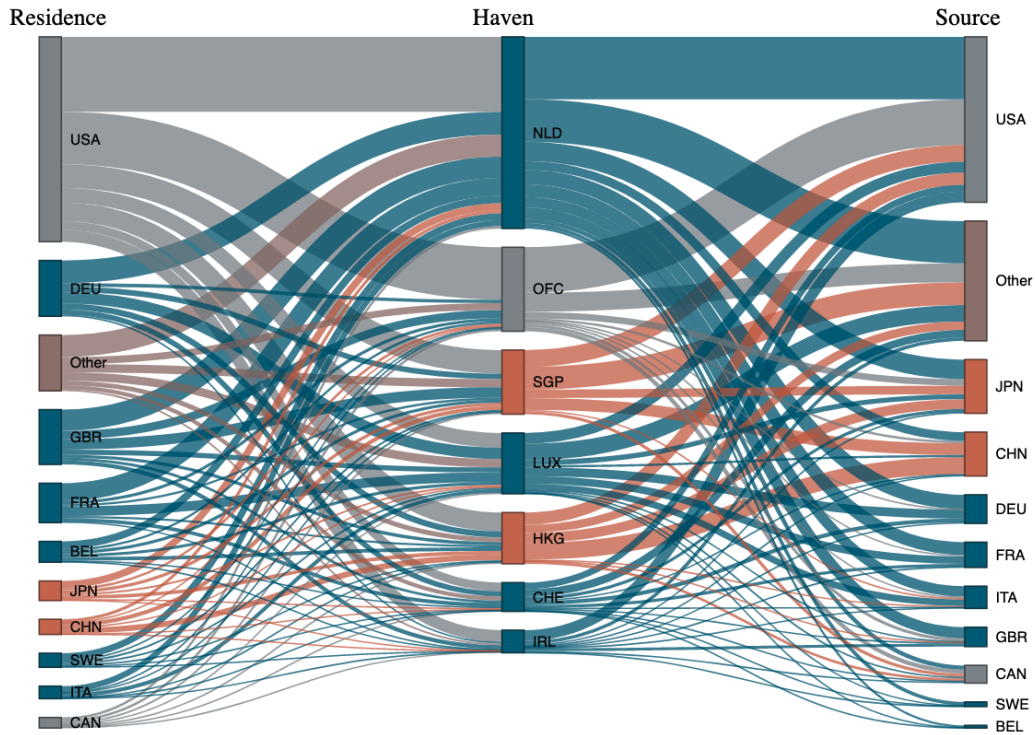


Figure 3 – Profit shifting from i to h and l to h .

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.

high-risk services to determine profit shifting between source countries and tax havens.¹⁸

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, Garcia-Bernardo, Palansky, and Bou Mansour, 2020), and the European Commission using the CORTAX 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.

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

18. Their approach is discussed in appendix B.

Table 2 – Spearman’s rank correlation

Source	Correlation	Obs.
Unilateral profit shifting:		
Tørsløv, Wier, and Zucman (2022)	0.90	33
Cobham, Garcia-Bernardo, Palansky, and Bou Mansour (2020)	0.92	33
Alvarez Martinez et al. (2016)	0.95	21
Bilateral profit shifting:		
Tørsløv, Wier, and Zucman (2022)	0.61	111

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 and Toubal, 2022).

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.¹⁹

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.

In appendix figure A.5, we explore the role of the parameters v_1 and v_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 17). In figure A.5, we plot the baseline estimation of s_{il} and alternative allocations obtained by i) setting v_1 equal to v_2 , and ii) increasing the ratio $\frac{v_2}{v_1}$ 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.

19. 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 Section 3. An advantage in the context of service data is that we can include exporting country \times year fixed effects. Therefore, the estimation of excesses is based on the excess exports of high-risk services compared to standard services in tax havens compared to this excess in non-tax-haven countries. We estimate $Service_{knst} = \beta_1 High-Risk_s \times Haven_k + \mu_{nst} + \mu_{kt} + \mu_{kn} + \mu_s + \epsilon_{knst}$

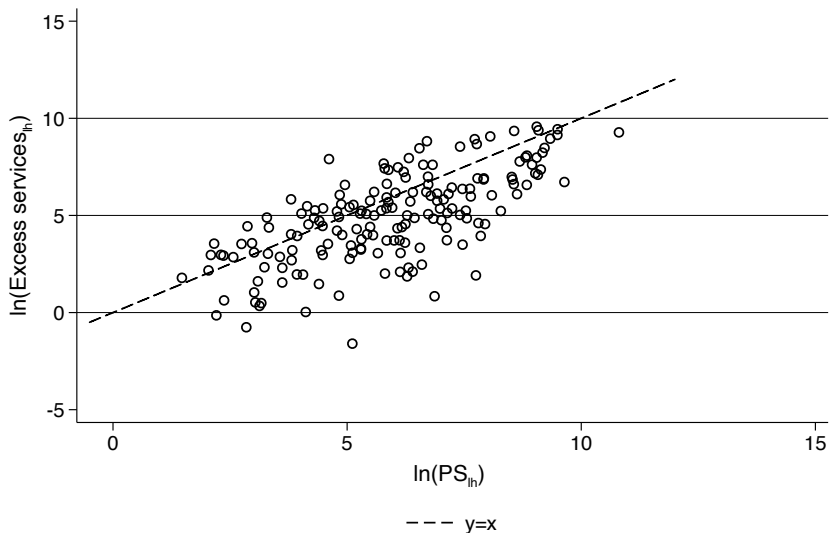


Figure 4 – Comparison between excessive high-risk services and our measure of bilateral profit shifting

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, Wier, and Zucman (2022) as insurance and pension services, financial services, charges for the use of intellectual property, telecommunications, computer, and information services and other business services.

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 v_1 and v_2 that govern the real and paper-profit elasticities. 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 and 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).²⁰

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%

20. Moreover, De Loecker, Eeckhout, and Unger (2020) find a median markup around 20 percent using CompuStat data.

based on OECD Corporate tax revenues data).

By using multinational gross output, a large part of u_l reflects expenditures on intermediate goods. In addition, u_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 v_1) and one for profit-shifting (governed by v_2). It reflects that corporate tax changes generate different responses from real activities and profit shifting. In addition, the model restrictions impose $v_2 \geq v_1$, 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 and 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 (14) and (15) that identify the corporate tax elasticities in an estimable way in terms of observed variables with associated coefficients and fixed effects.

Tax base elasticity. The parameter that governs the elasticity of the tax base in country l , v_1 , is obtained by rearranging Equation (14) as:

$$\frac{X_{ill}}{\sum_l X_{ill}} = \frac{\tilde{A}_{ill}(1-t_{ll})^{\frac{v_1}{\sigma-1}-1}}{\sum_l \tilde{A}_{ill}(1-t_{ll})^{\frac{v_1}{\sigma-1}-1}} \quad \forall(i, l) \quad (19)$$

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 $\frac{X_{ill}}{X_{il}} = 1 - \sum_{l,h,h \neq l} \beta_{ilh}$, MP shares $\frac{X_{il}}{X_i}$, and aggregated MP sales X_i – all of which are observable. We transform Equation (19) by taking its logarithm:

$$\ln \left(\frac{X_{ill}}{\sum_l X_{ill}} \right) = \delta_0^0 \ln(1-t_{ll}) + \delta_1^0 \ln \tilde{A}_{ill} - \ln \left(\sum_l \tilde{A}_{ill}(1-t_{ll})^{\frac{v_1}{\sigma-1}-1} \right) \quad (20)$$

where $\delta_0^0 = \frac{v_1}{\sigma-1} - 1$ 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 head-quarter country fixed effect is $FE_i = \ln \left(\sum_l \tilde{A}_{ill}(1-t_{ll})^{\frac{v_1}{\sigma-1}-1} \right)$. We, therefore, use the variation across production countries to identify our coefficients.

Table 3 reports the estimated coefficients and the corresponding parameter elasticities v_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 v_1 .

Table 3 – Tax base elasticity : v_1

	Dependent variable:	
	$\ln\left(\frac{X_{iil}}{\sum_i X_{iil}}\right)$	$\frac{X_{iil}}{\sum_i X_{iil}}$
$\ln(\tilde{t}_l)$	2.639*** (0.688)	3.047* (1.674)
Residence country FE	Yes	Yes
Technology controls	Yes	Yes
Gravity controls	Yes	Yes
Observations	1,256	1,600
Estimator	OLS	PPML
Implied v_1 ($\sigma = 4$)	10.90	12.10
Implied v_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 $v_1 = 21.40$ 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 and 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 v_1), multinational production frictions would be mostly irrelevant for our quantitative exercises.

Profit shifting elasticity. We start by taking the logarithm of Equation (15):

$$\ln\left(\frac{X_{ilh}}{\sum_{l,h,h \neq l} X_{ilh}}\right) = \delta_0^1 \ln(1 - t_{lh}) + \delta_1^1 \ln \tilde{A}_{ilh} - \ln\left(\sum_{l,h,h \neq l} \tilde{A}_{ilh}^{\frac{v_2}{v_1}} (1 - t_{lh})^{\frac{v_2}{\sigma-1}-1}\right) \quad (21)$$

where $\delta_0^1 = \frac{v_2}{\sigma-1} - 1$ 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.²¹ 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.²² 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 (21), \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 colinear 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 $FE_i = -\ln \left(\sum_{l,h,h \neq l} \tilde{A}_{ilh}^{\frac{v_2}{\sigma-1}} (1 - t_{lh})^{\frac{v_2}{\sigma-1} - 1} \right)$. 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.²³ Further

21. 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).

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

23. 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.

discussion on data sources and the details of the data treatment are provided in Appendix A.4.

As noted earlier, v_2 is needed to estimate profit shifting (see Section 3) while it is also estimated using profit shifting data. To determine its value we follow an iterative procedure.²⁴

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 $v_2 = 52.1$, 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.

Table 4 – Profit shifting elasticity : v_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*** (0.191)	8.625*** (1.295)
<i>il</i> FE	Yes	Yes
Gravity controls	Yes	Yes
Observations	6,561	7,091
Estimator	OLS	PPML
Implied v_2 ($\sigma = 4$)	26.60	28.90
Implied v_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

Profit shifting elasticity and the existing literature. How does the profit shifting elasticity derived here compare with estimates in the current literature? The parameter v_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 v_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 v_1 and v_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).

24. We solve equations (16) to (18) by setting up an initial value of v_2 . We estimate 21 to determine a new value of v_2 . We replicate the steps until the same value is obtained in the output of two following iterations.

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 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 and Rauh (2007) report an elasticity of 0.2. A recent study by Coles, Patel, Seegert, and Smith (2022) finds an elasticity of profits of 0.9 which is 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 and 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.²⁵ The elasticity of taxable income implied by our estimates appears close to the one estimated by Gruber and 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 frictions, i.e., when $\tilde{\theta}_i = \alpha_{lh} = 1$, $\forall i, l, h \in \mathcal{N} \times \mathcal{N} \times \mathcal{H}$ then

$$\sum_{l \neq h} A_{ll} = \bar{\theta} \left(H \sum_{l \neq h} A_{ll}^{\frac{v_2}{v_1}} \right)^{\frac{v_1}{v_2}}$$

or, equivalently

$$\bar{\theta} = \frac{\sum_l A_{ll}}{\left(H \sum_l A_{ll}^{\frac{v_2}{v_1}} \right)^{\frac{v_1}{v_2}}}$$

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.

25. 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.

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:

$$\frac{\sum_{l \neq h, h} \mathbb{P}_{ilh}}{\sum_{l \neq h} \mathbb{P}_{ill}} = \frac{\sum_{l \neq h, h} A_{ll}^{\frac{v_2}{v_1}} (\theta_i \alpha_{lh})^{-v_2}}{\sum_{l, h, h \neq l} A_{ll}^{\frac{v_2}{v_1}} (\theta_i \alpha_{lh})^{-v_2}} \times \frac{\left(\sum_{l, h, h \neq l} A_{ll}^{\frac{v_2}{v_1}} (\theta_i \alpha_{lh})^{-v_2} \right)^{\frac{v_1}{v_2}}}{\sum A_{ll}}$$

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

$$\frac{\sum_{l \neq h, h} \mathbb{P}_{ilh}}{\sum_{l \neq h} \mathbb{P}_{ill}} = \left(\frac{\theta_i}{\bar{\theta}} \alpha_{lh} \right)^{-v_1}$$

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.

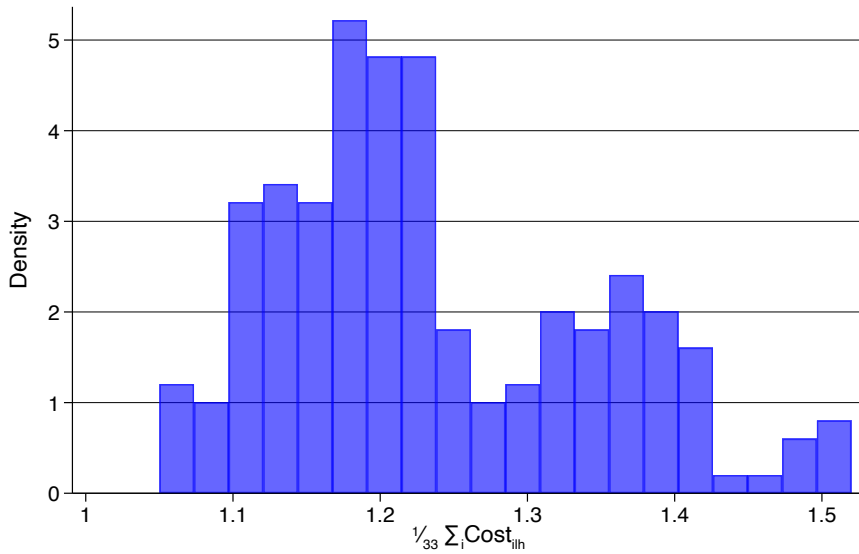


Figure 5 – Average cost of profit shifting ($cost_{ilh}$)

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

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 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 and 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:

$$\ln(\text{cost}_{ilh}) = \ln(\tilde{\theta}_i) + \ln(\alpha_{lh}) + \epsilon_{ilh} \quad (22)$$

with $\ln(\text{Cost}_{ilh})$, 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

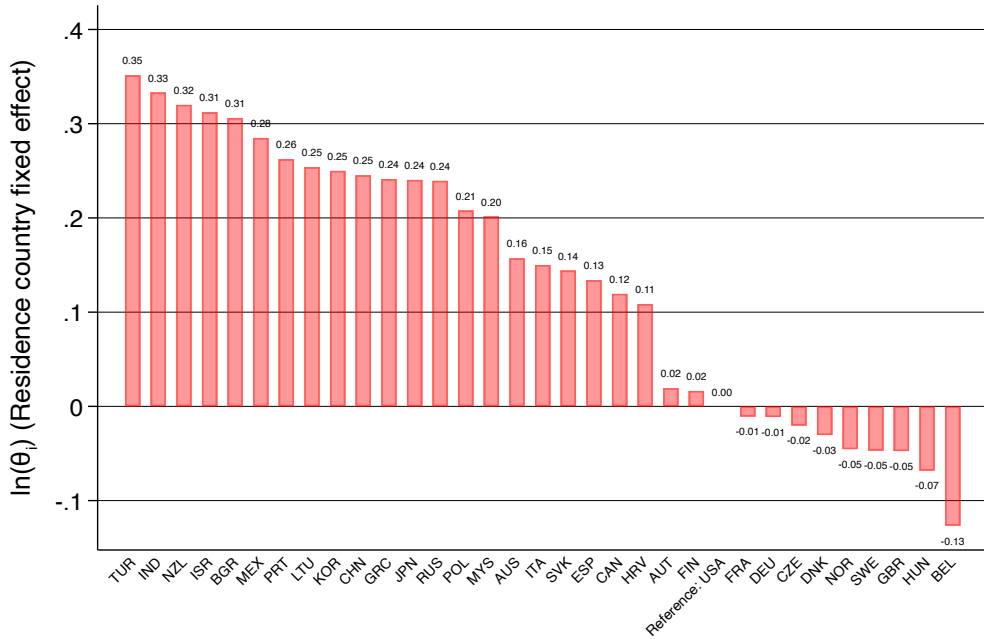


Figure 6 – Distribution of $\ln(\theta_i)$

Note: This figure plots the residence country fixed effect obtained by estimating equation 22. It theoretically corresponds to $\ln(\theta_i)$.

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 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 and Mayer, 2013).

Table 5 – Gravitational determinants of profit-shifting frictions

	(1)	(2)	(3)	(4)	(5)
			$\ln(\alpha_{lh})$		
$\ln(\text{distance}_{lh})$	0.0117*** (0.00250)	0.00962*** (0.00213)	0.0114*** (0.00206)	0.00957*** (0.00207)	0.0129*** (0.00238)
Ever colony $_{lh}$	-0.00989* (0.00513)	-0.0157*** (0.00553)	-0.0173** (0.00654)	-0.0163** (0.00681)	-0.0176*** (0.00569)
Common colonizer $_{lh}$	-0.00951** (0.00452)	-0.0178*** (0.00440)	-0.0122** (0.00448)	-0.0151*** (0.00460)	-0.0116** (0.00452)
Common legal origin $_{lh}$	-0.00343 (0.00499)	-0.000954 (0.00554)	-0.00559 (0.00537)	-0.00671 (0.00563)	-0.00154 (0.00522)
Contiguity $_{lh}$	-0.00222 (0.00702)	-0.00371 (0.00957)	0.00133 (0.00979)	-0.00239 (0.00970)	0.00360 (0.00982)
$\ln(GDP_h)$		-0.00697*** (0.00110)	-0.00423** (0.00179)	-0.00792*** (0.00147)	-0.00221 (0.00241)
$\ln(GDPpc_h)$		-0.00191 (0.00212)	-0.0108*** (0.00310)	-0.00749** (0.00312)	-0.00442 (0.00335)
$\ln(t_l - t_{lh})$			-0.0124** (0.00584)	-0.00553** (0.00267)	-0.0209* (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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

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.

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. Using the tax-neutrality result developed in Section 2.6, 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 Section 5.4 we also consider alternative criteria for welfare by introducing tax-driven externalities. This allows us to rationalize the data as a Nash equilibrium and study the individual incentives to deviate from a global minimum tax.²⁶

To simulate counterfactual tax reforms, we follow the exact hat algebra (EHA) methodology popularized by Dekle, Eaton, and Kortum (2007) and Costinot and 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 G for details about the algorithm. We focus below 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. Lower taxes would increase the U.S. tax base by

26. In ongoing work, we study the impact of a Destination-Based Cash Flow Tax (Auerbach, Devereux, Keen, and Vella, 2017) as an alternative tax system that we compare to minimum taxation.

Table 6 – Calibration overview

Variables	Definition/Source/Methodology/Reference	Section
<i>Endogenous variables</i>		
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, Rodríguez-Clare, and Tintelnot (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.4
<i>Parameters</i>		
t_l	Statutory tax rate. KPMG Statutory Corporate tax rate tables.	Appendix A.3
t_{lh}	Tax havens' tax rate. OECD's Country-by-Country reporting.	Appendix A.3
Π_l	Profits recorded in l . National Accounts, methodology from Tørsløv, Wier, and Zucman (2022).	Appendix A.5
ι_l	Profits-sales gap. Computed using: $\iota_l = \sigma \frac{\Pi_l}{\sum_i X_{iil}}$.	Section 4.1
σ	Elasticity of substitution. Set to 6.88 following a 17% mark-up in French firm level data (De Loecker, Eeckhout, and Unger, 2020 methodology).	Section 4.1
v_1	Elasticity of the tax base. Estimated following equation 20. Set to 21.4	Section 4.2
v_2	Elasticity of profit shifting. Estimated following equation 21. Set to 52.1	Section 4.2
<i>Frictions</i>		
γ_{il}	Multinational production frictions. Backed-out from X_{iil} shares.	Appendix F
τ_{ln}	Trade frictions. Backed-out from X_{ln} shares.	Appendix F
α_{ilh}	Profit shifting frictions. Backed-out from X_{ilh} .	Section 4.3, Appendix F

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 A.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 lower lump-sum transfers. The unilateral reduction of the U.S. statutory tax rate would increase U.S. attractiveness, production, and labor demand, raising thereby workers' wages. A reduction in the price index leads to a small positive effect on real trade imbalances. In Figure A.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 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 A.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 (-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 A.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.²⁷ Lax enforcement of anti-abuse laws might therefore be used by non-haven countries in order to attract mobile firms (for instance Altshuler and Grubert, 2005, Hong and Smart, 2010 or Dharmapala, 2020).

27. 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.

Closing a tax haven. *What are the tax revenues and real effects of closing a tax haven?* Equation 15 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 A.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%).²⁸ 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 A.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 relative attractiveness. Given the gravitational structure of profit shifting, the impact is smaller for source countries that 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 A.15, we show tax revenues changes across non tax haven countries after closing Singapore. Countries close to Singapore such as India, New Zealand, Australia or Japan, appear more affected than countries further away, such as European countries, underlining again the important role of bilateral frictions.

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: v_1 and v_2 . In the first scenario, the profit shifting elasticity (v_2) is equal to the tax base elasticity (v_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 v_2 constant, and we consider a lower value of v_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 v_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

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

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 A.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 v_2 is lowered, profit shifting is less sensible to taxes, which explains this result. In the second scenario, decreasing v_1 while keeping v_2 constant means that production is less mobile internationally. Therefore the decrease in shifted profits relative to the tax base is lower for a lower v_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 A.17 to A.19). In the first alternative scenario, where v_1 is fixed and v_2 decreased, there is no effect on any outcome. This is expected since when profit shifting stops, there is no room for v_2 . When the elasticity of real profits is 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 v_1 is decreased. Indeed, a lower v_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.²⁹ 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.³⁰ In this case, minimum taxation should not strongly affect tax competition for real activities but tackle directly profit-shifting incentives. It is, however,

29. 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 and Becker (2019).

30. 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.

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.³¹ 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.

Minimum taxation operationalized. 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 $\sum_{l,h,l \neq h} (\Pi_{ill} + PS_{ilh})$ (a version without carve-outs), as long as they are taxed under the minimum tax rate. Here, we implement an idealized OECD’s BEPS version where the real activity is fully deductible for the minimum taxation (full substance-based carve-out). The simulations thus 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 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 v_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 $\left(\frac{v_2}{\sigma-1} - 1\right) + \frac{kv_2}{v_1} \frac{(1-t_{lh})}{(t_l-t_{lh})}$. We recover the shape parameter k from the data. This alternative calibration yields a profit shifting elasticity $v_2 = 43.6$ (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

31. 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.

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.

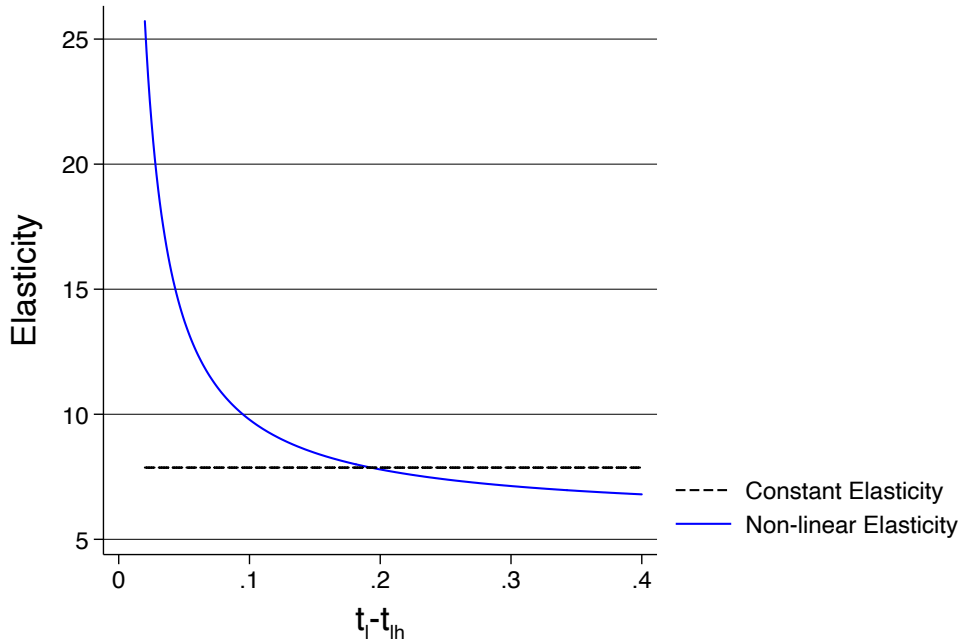


Figure 7 – Implied elasticities of profit shifting at equilibrium

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 v_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.

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

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

Minimum Taxation	Percent change in ...			
	Tax revenues	Profit Shifting	Production	Consumer Welfare
A. Short Run Effects				
Unilateral				
– Residence	4.18	-28.38	0.05	0.08
– Source	4.45	-38.68	-0.01	-0.001
Multilateral				
– Residence	4.33	-29.37	0.11	0.11
– Source	3.98	-29.37	0.09	0.11
B. Long Run Effects				
Unilateral				
– Residence	3.86	-27.77	-0.18	-0.14
– Source	4.34	-38.58	-0.11	-0.09
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 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 a priori. Compared to a top-up residence-based tax applied on all repatriated profits as considered in section 3, a residence-based minimum tax raises the effective tax rate only for tax-avoiders. Compared to the neutral impact on welfare, minimum taxation distorts firms' sourcing and profit-booking location choices. Under a minimum tax-regime, firms now give more importance to the US fundamentals captured by A_{US} and less to the effective tax rate. Overall, we find a positive effect on production (+0.05%), larger workers' wages and a positive impact on welfare (+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 but very small (-0.001%).

The multilateral implementation of minimum taxation reduces the dispersion of corporate tax rates and increases effective corporate taxes from all avoiding firms wherever they are headquartered. 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_{it} . 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. However, the allocation of taxing rights is 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 producing in the U.S. 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 12% more revenues than the unilateral residence-based scenario. Profit shifting by the U.S. and foreign multinationals in the U.S. reduces by 38.60%, almost 40% more than in the source-based 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 channels through which firms adjust to a change in the tax environment. Firms reallocate their real activities ("real effects") and paper profits ("profit shifting effects"). Consequently, both effects make the general equilibrium results different from what we denote as partial effects (PE): a situation where firms do not adjust. The PE are often computed to assess the first-order impact of tax reforms on tax revenues. The quantification of the PE assumes that the location and amount of production and profit shifting found in the initial equilibrium remain fixed.³² In table 8, we decompose the impact of each effect and choose to explain the change in tax revenues. In table 9, we show the results for welfare.

The strategy to isolate the PE from the general equilibrium effects is as follows. Considering tax revenues, we assume a change in the tax environment to compute the PE. We do not allow for a change in the allocation of profit shifting found in the initial equilibrium. By contrast, the general equilibrium results include real and paper profit reallocation.

32. See for instance International Monetary Fund, 2019 or OECD, 2020a.

Formally, for country k , the counterfactual tax revenues are written (see equation (5))

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

while the PE change in tax revenues is

$$B_k{}^{PE} = \sum_{i,l,h} t'_{ilh}{}^{gk} N_i \mathbb{P}_{ilh} \frac{w_i f_E}{1 - t'_{ilh}}.$$

The difference between these tax revenues combines profit shifting and real effects. The “profit shifting effect” indicates a change in tax revenues due to the change in the profit shifting strategy of MNEs (keeping production constant) with respect to the PE. The “real effect” indicates a change in tax revenues due to the change in the location of MNEs with respect to the PE.

We now turn to welfare. Following equation (9), the economy k ' welfare in the counterfactual equilibrium writes as $W'_k = \frac{Y'_k}{P'_k} = \frac{w'_k L_k + B'_k + \Delta'_k}{P'_k}$. The PE of a reform on welfare is entirely driven by the PE on tax revenues, i.e. ($B'_k = B_k{}^{PE}$), whereas the number of firms (no free entry), the price index and the imbalances are all kept constant. As shown in column (3) of table 9, these hypotheses imply that reforms do not affect wages ($w'_k = w_k$). The PE of tax reforms on welfare boils down to $W_k{}^{PE} = \frac{w_k L_k + B_k{}^{PE} + \Delta_k}{P_k}$.

Results We consider a residence-based minimum tax rate at 15% implemented by the U.S. only. We observe a positive PE on tax revenues which amounts to 2.59%. The total increase in tax revenues, however, is 3.86%, because some U.S. companies stop shifting profits once the reform is implemented. This channel raises tax revenues by increasing the U.S. tax base. Notice that the profit-shifting effect is significant and amounts to 57.4% of the PE. The PE underestimate the impact of minimum taxation on tax revenues. Firms that face larger effective tax rates also adjust their location and the scale of their activity. These real effects decrease tax revenues by 8.49% compared to the PE.

The increase in tax revenues positively impacts welfare (+0.06%). However, the full counterfactual effect on welfare is negative (-0.14%). In general equilibrium, the positive impact of the reform on tax revenues is more than compensated by the negative effect on wages when we allow free entry (-0.39% in wages). These results shed light on the importance of accounting for real effects to quantify the effects of corporate tax reforms on tax revenues and welfare.

In other scenarios, profit-shifting effects on tax revenues are significant and amount to 60% of the first-order PE under residence-based minimum taxation and 80% under source-based minimum taxation. The role of the profit shifting effect in the change in tax revenues in the U.S. is more important for source minimum taxation because this scenario applies to both U.S MNEs and foreign MNEs producing in the U.S., while residence-based scenarios do not affect those foreign MNEs.

By reducing profit shifting, all reforms have a positive partial effect on tax revenues, increasing welfare, everything else being equal. However, a change in firms' location reverses the finding because the decrease in labor income more than offsets the increase in tax revenues.³³

33. Note that in general equilibrium, imbalance and price effects also affect welfare, which is measured in real terms.

Table 8 – Quantification of real and shifting effects on tax revenues

Counterfactual	Change in tax revenues (in %)		Contribution w.r.t. the PE (in %)	
	Partial Effect (no reallocation)	GE effect (reallocation)	PS effect (change in PS)	Real effect (reallocation)
	(1)	(2)	(3)	(4)
<i>15% min. tax</i>				
Unil. Residence	+2.59	+3.86	57.40	-8.49
Unil. Source	+2.12	+4.34	109.62	-4.47
Multi. Residence	+2.59	+3.95	60.56	-7.96
Multi. Source	+2.12	+3.64	80.51	-8.46
TH adjustment	0	+2.18	–	–

Note: Results in this table are provided for the United States. "PE effect" in column (1) indicates the reform's effect as computed 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 PE effect. 57.4% means that there are 57.4% more tax revenues than the PE 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 PE effect. -8.49% means that there are 8.49% fewer tax revenues than the PE effect because firms have adapted their location following the reform.

Table 9 – Quantification of real effects on welfare

Counterfactual	Change in welfare (in %)		Change in wages (in %)	
	Partial Effect (no reallocation)	GE effect (reallocation)	Partial Effect (no reallocation)	GE effect (reallocation)
	(1)	(2)	(3)	(4)
<i>15% min. tax</i>				
Unil. Residence	0.06	-0.14	0	-0.39
Unil. Source	0.05	-0.09	0	-0.19
Multi. Residence	0.06	-0.12	0	-0.36
Multi. Source	0.05	-0.13	0	-0.38
TH adjustment	0	-0.16	0	-0.39

Note: Results in this table are provided for the United States. "Partial effect" in columns (1) and (3) indicates the reform's effect as computed by assuming no change in profit-shifting activity or production location and no free entry. "GE effect" in columns (2) and (4) corresponds to the effect computed using our quantitative model.

The last scenario, where tax havens adjust their tax rate to the minimum tax rate, increases tax revenues in the U.S. by 2.18%. In contrast, There are no partial effects concerning tax revenues and welfare since production and profit shifting do not adjust. The minimum tax is not collected. However, in general equilibrium, entry is affected by the larger effective tax rate, which negatively affects wages and welfare.

The above tables show the critical importance of quantifying profit-shifting effects and real effects to predict the impact of international tax reforms on tax revenues and welfare. It is also worth mentioning that unilateral and multilateral scenarios lead to identical results concerning the change in tax revenues and welfare in estimation that do not consider the reallocation of real and paper profits. These tables highlight quantitatively-relevant channels that studies based on partial equilibrium cannot capture.

5.4 Responses after a minimum-tax reform

We conclude by asking which country would have an incentive to deviate from a global residence-based minimum tax in the long-run. To answer this question, we extend our model to rationalize the observed data as a Nash equilibrium. Indeed, in the absence of public good and as we have illustrated for the US, non-haven countries would typically deviate from the observed allocation. Several explanations may explain this gap such as (heterogeneous) preferences over public goods or political economy considerations. We remain agnostic on the deep rationales behind deviation and include instead real tax revenues as a direct source of utility in our model, which does not distort the decisions of firms and consumers. We then ask what parametrization would reconcile the observed data as a Nash equilibrium. Last, we let countries unilaterally change their statutory rate after a global minimum tax to understand who benefits from such deviation.³⁴

Formally, we define the welfare of a country as $\tilde{U}_n = (B_n/P_n)^{\alpha_n} U_n$, where, as before, $U_n = Y_n/P_n$ is real income. From the data we back out the vector of α_n such that at the initial equilibrium, under territorial taxation, countries would not have an incentive to change their statutory rate. Namely, U_n must be locally quasi-concave around the initial tax rates with $\alpha_n := \frac{\partial \tilde{U}_n}{\partial t_n} = 0$. Note that, by definition, this pins down a local Nash equilibrium. Under this specification of welfare, this vector of α_n implies that non-haven countries have no incentive to change their statutory rate unilaterally. Next, fixing the vector of α_n , we compute the counterfactual for the long run residence-based minimum tax at 15%. This is the scenario in which the number of firms is endogenously determined and tax havens react to the introduction of the minimum tax by increasing their tax rate on paper profits to match the minimum tax. From here we let countries unilaterally deviate by changing their statutory rate at the margin (.1 percentage point increase). In other words we compute $\frac{\partial \tilde{U}_n}{\partial t_n}$ starting from a world in which the minimum tax has already been implemented. This informs us about which country would have an incentive to increase or decrease their statutory rate in response to the global minimum tax. Figure 8 plots the change in welfare implied by a marginal increase of the statutory rate.

34. We leave the resolution of the new Nash equilibrium for future work. Although it is easily done within our framework, a policy-relevant exercise should examine carefully all the instruments at the disposal of various countries from subsidies (as announced by Switzerland following the global deal) to domestic minimum taxes (e.g. the U.K.).

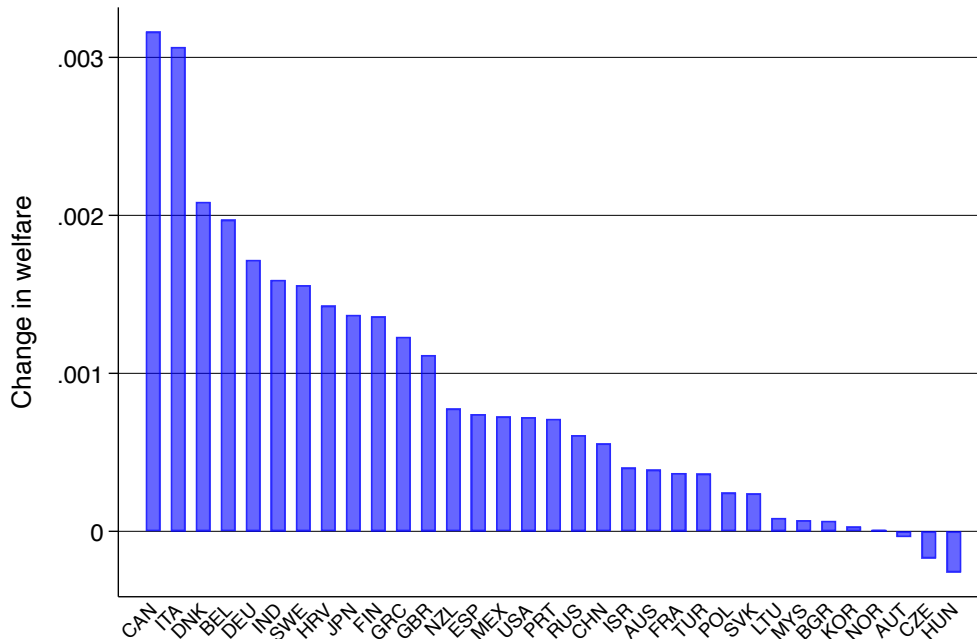


Figure 8 – Incentive to change the statutory tax rate in response to the global minimum tax.

As shown in the figure, the vast majority of countries would benefit from a unilateral increase in their statutory rate. Intuitively they would trade off a loss in real income with an increase in real tax revenues. The introduction of the global minimum tax reduces the cost of increasing the statutory rate as it reduces tax competition. This, in turn, implies that countries are incentivized to increase their tax rate further.

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 elasticities 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, 2020b). Our approach takes 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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Appendix

A Data

A.1 Trade

Our trade data covers both trade in goods and trade in services. Trade in goods comes from the UN Comtrade database. Trade in services comes from the EBOPS database. Own trade is constructed using OECD's TiVA database as a difference between the total production of a country and its total exports.

Production data is missing for "Offshore Financial Centers", our composite tax haven. Consequently we simply impute it by regressing production on GDP (GDP is observed for all countries). The R^2 of the regression is equal to 0.98, confirming the precision of the imputation.

A.2 Multinational Production Sales

Multinational production sales (MP sales) correspond to the sales made in the production country l by firms headquartered in country i and reported in l (country l may be identical to country i). It corresponds to X_{il} . We build a 40×40 matrix of MP sales that are averaged over the period between 2010 and 2014. We follow recent methodologies and sources used to create similar databases (Alviarez, 2019; Ramondo, Rodríguez-Clare, and Tintelnot, 2015).

Our dataset is constructed using various sources of Foreign Affiliate Trade Statistics (FATS) including Eurostat FATS (inward and outward), OECD AMNE (inward and outward) statistics and the BEA USDIA statistics on majority-owned U.S. foreign affiliates as well as information on Merger and Acquisition (M&A) using the Thomson Reuters dataset. The FATS datasets provide information at the country level on the affiliates sales of multinational firms by nationality of the ultimate controlling owner. We use *Turnover* as the variable to construct our MP sales matrix.

These different datasets may overlap. When the information on bilateral multinational production is available in different datasets, we choose the highest value. When all MP sales are recorded as zero or missing, we rely on the number of M&A during the period 2001-2014 to differentiate between true zeros and missing values. We follow Ramondo et al. (2015) by assigning value of zero to the cell when we observe zero or missing MP sales and zero M&A transactions. We impute the observations when we observe a strictly positive number of M&A and no MP data. As in Ramondo et al. (2015), our main extrapolation is based on the conditional correlation between MP sales and mergers and acquisitions. As argued by Ramondo et al. (2015) there is a "tight correlation between the number of cross-M&A deals and [...] affiliate sales" (Data documentation of Ramondo et al., 2015, p.4). Following their strategy, we run the following regression:

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

We estimate $\beta = 0.508$ (standard error of 0.0710, $R^2 = 0.75$). Out of 1560, 178 values are extrapolated using this procedure and 148 are true zeros. We follow the same

procedure to interpolate the missing values for the number of employees in country l by firms headquartered in country i .

In Figure A.1, we compare our MP sales matrix with the data from Ramondo et al. (2015), Alvarez (2019), from the Country-by-country reports (CbCR) data released by the OECD in 2020 for the year 2016 and from the Analytical AMNE dataset developed by the OECD (Cadestin, Backer, Desnoyers-James, Miroudot, Rigo, and Ye, 2018). The Figure visualizes a large correlation between MP sales found in different datasets. We show, moreover, that the average MP sales for the period 2010-2014 appear, as expected, larger than the average MP sales between 1996 and 2001 (top-left panel) and than the average MP sales between 2003 and 2012 (top-right panel). They appear to be lower than the MP sales computed from revenue data from the CbCR of 2016 (bottom-left panel). In this later case the correlation is somewhat lower than with previous dataset. This may be due to the different variable definitions and threshold of the CbCR data.³⁵ Our MP sales appear lower than those from analytical AMNE dataset for the same period as ours. This difference may come from different sources: different industry coverages, different imputation procedures.³⁶

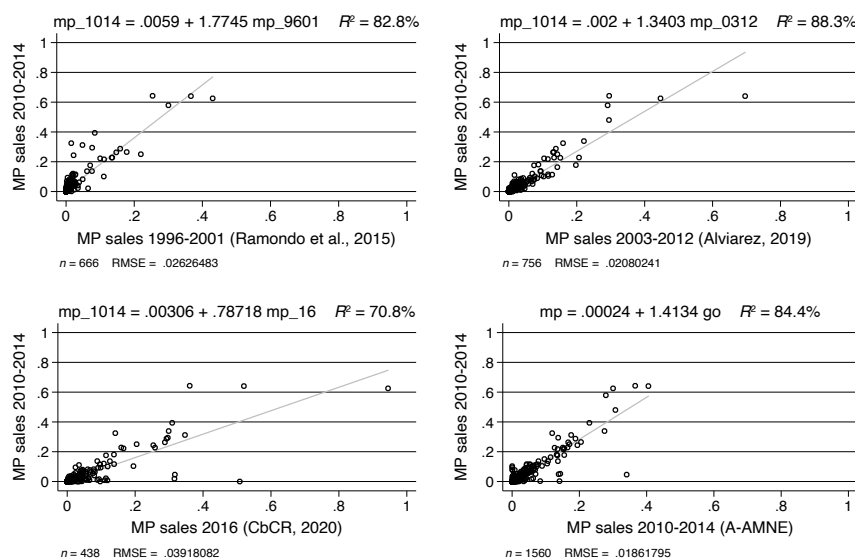


Figure A.1 – Comparison of MP sales with other datasets.

Note: This figure compares the MP sales used in this paper with other measures in the literature: Ramondo, Rodríguez-Clare, and Tintelnot (2015) (top-left corner), Alvarez (2019) (top-right corner), OECD’s Country-by-Country reporting (bottom-left corner) and OECD’s Analytical AMNE, Cadestin, Backer, Desnoyers-James, Miroudot, Rigo, and Ye (2018) (bottom-right corner).

We then compute intra-national MP sales. It corresponds to the domestic sales made by domestic firms. We use a key accounting equation, that is that total production in a country must equal total exports (included intra-national exports). Intra-national MP sales correspond to the part of trade, including intra-national trade, that is not explained

35. In a disclaimer released with the data, the OECD describes the limitations of the 2020 release of CbCR: <https://www.oecd.org/tax/tax-policy/anonymised-and-aggregated-cbcr-statistics-disclaimer.pdf>.

36. In particular, the Analytical AMNE dataset is constructed at the industry level, with a large share of values being imputed from a gravity-like equation.

by the MP sales made by foreign countries. Therefore, we obtain intra-national MP sales made by country l in country l by summing the exports of country l and its intra-national trade and subtracting the MP sales made in l by other countries i , with $i \neq l$.

A.3 Tax rates

Statutory tax rates The calibration of the model requires data on statutory corporate tax rates. We use the KPMG Corporate Tax Rate Table.³⁷

A.4 FDI Income

We collect information on bilateral FDI incomes from 2010 to 2014 using bilateral balance of payments data from Eurostat and the OECD. As we show later on, we impute values of FDI incomes for countries that are poorly covered by the Eurostat and the OECD datasets. FDI income has three components: reinvested earnings, dividends and interest payments. As noted by Wright and Zucman (2018), interest payments differ from the two other income components as in a tax avoidance scheme they would be paid from the parent company to the foreign affiliates in the tax haven. Therefore, we focus on FDI income coming from reinvested earnings and dividends.

We assume that tax havens do not shift profit.³⁸ The information is averaged to get a single cross-section. The dataset includes 33 investing (non-haven) countries and 68 destination countries – 33 non-haven countries, Hong-Kong, Ireland, Luxembourg, Netherlands, Singapore, Switzerland and 29 countries that are latter aggregated to form the OFC a composite tax haven.

The information from Eurostat and OECD does not cover the full sample. For small countries, usually tax havens, we develop a two-step methodology to impute the data. First, we use the unilateral balance of payment from the IMF, which informs on inward FDI income, inward FDI stock, outward FDI income and outward FDI stock. This datasets help us to compute the unilateral rates of return of inward and outward investments. Second, we apply the unilateral rates of returns of bilateral FDI stock data from the *Financial Flows Dataset* produced by the ECFIN and JRC (see Nardo, Ndayayisenga, Pagano, and Zeugner, 2017).³⁹ We use the outward rate of return only in the case of missing information on the inward rate. This strategy allows us to recover 31% of our estimation sample. The correlation between imputed bilateral rates of return and observed rates of return in our dataset is 0.79.

Finally, it happens for a very few cases that we have information on total income but no information on FDI income excluding debt instruments. In this case, we apply a conservative imputation by assuming that the value of FDI income excluding debts instrument is equal to 75% of the total flow.

Tax havens tax rates An essential parameter of the model is the tax rate available to tax-avoiding firms in tax havens, t_{lh} . This parameter is not observed as tax havens

37. <https://home.kpmg/xx/en/home/services/tax/tax-tools-and-resources/tax-rates-online/corporate-tax-rates-table.html>

38. This further allows us to reduce any noise created by cross-border investment positions between tax havens

39. <https://finflows.jrc.ec.europa.eu/>.

generally offer legal dispositions that allow the effective tax rate of a firm to differ strongly from the observed statutory tax rate (except for the rare tax havens where the statutory tax rate is 0%). The ideal measure would be the effective tax rate paid by tax-avoiding firms. It can be proxied by various effective tax rate measures.

The forward-looking effective tax rate corresponds to the average tax rate that will apply to a hypothetical investment considering available tax credits. It is generally viewed in the literature as the rate that determines incentives to invest because it represents the actual tax cost a firm will incur. It is not adapted to our setting as we are interested in the profit-shifting behavior of firms in tax havens, which is generally not covered by available measures of forward-looking effective tax rates.

Backward-looking effective tax rates are more adapted to our needs. It corresponds to ex-post measures of tax rates over pre-tax profits. In particular, Tørsløv, Wier, and Zucman (2022) compute the effective tax rate for many countries based on national accounts data. However, in our perspective, this would measure t_{lh} with a bias induced by firms having a real activity in tax havens and then paying a different tax rate than tax-avoiding firms. This is especially the case in large tax havens.

Alternatively, the OECD CbC-R provides data closer to our ideal one. The OECD has collected this data as part of the Action 13 of the BEPS Project. It consists in the aggregation of firm-level country-by-country reports at the (origin country \times destination country) level. These reports are available for 2016 and filled by firms from 25 different headquarter countries.

Importantly, these reports contain information on taxes paid and profits. Only large firms, with turnover larger than EUR 750 million, are required to submit CbC-R. This feature prevents the data from being contaminated by smaller firms that are likely to be non-avoiding firms. This data have been used in other studies evaluating the tax avoidance of multinational firms (Garcia-Bernardo and Jansky, 2021 at the macro level, Fuest, Hugger, and Neumeier, 2021, Fuest et al., 2021 or Delpeuch and Laffitte, 2019 at the micro-level). Another interesting and unique feature of the CbC-R is that the aggregation distinguishes profit-making from loss-making firms. We concentrate on profit-making firms in tax havens to avoid an aggregation bias and exclude firms realizing negative profits in tax havens.

We apply a minimal treatment to the raw data. We compute effective tax rates as the ratio of tax paid to pre-tax profits. We then delete observations with negative effective tax rates and with effective tax rates larger than the statutory tax rate, thus eliminating outliers probably caused by unprecise reporting. At this stage, we observe for each tax haven in our sample, the effective tax rate paid by firms from each headquarter country reporting activity in the tax haven. We observe the effective tax rate from 12 origin countries for Switzerland, 14 for Hong Kong, 8 for Ireland, 10 for Luxembourg, 15 for the Netherlands, 14 for OFCs, and 11 for Singapore. We define t_{lh} as the median effective tax rate observed in each tax haven.

A.5 Profits

For each country of the sample, we need to compute its profits. For this we follow the methodology of Tørsløv et al. (2022) presented in the appendix of their paper. We use

national accounts data. Profit correspond to gross operating surplus minus depreciation minus net interest paid. The main data source is the UN National Accounts (United Nations, [n.d.](#)). The data is complemented with data gathered from Australian's official statistics. The information on one of the component may be missing for a limited number of countries. In this case, we impute it using the ratio of the component to the Gross Operating Surplus of other countries in the sample. This allows us to construct a complete database of the components of profits for the majority of countries. The data on profits in Singapore is directly taken from Singapore's National Accounts. At this stage, information is missing for Honk-Kong and OFCs. We impute their profits by predicting their value based on a regression of profits on GNI (adjusted R^2 of 0.88).

B Estimation of profit shifting

B.1 Bilateral profit shifting: State of the art

A large amount of information on various cases and techniques of tax avoidance has been released in the press, leading to a number of papers on different aspects of corporate tax avoidance (see for instance Clausing, 2003, 2006, 2020, Cristea and Nguyen, 2016 and Davies, Martin, Parenti, and Toubal, 2018 for transfer mispricing of goods, Hebous and Johannesen, 2015 for transfer mispricing of services, Laffitte and Toubal, 2022 for sales shifting). In essence, the basic strategy multinational corporations use to shift profit is to shift sales from high-tax to low-tax jurisdictions, while moving expenses in the opposite direction. The measurement of profit shifting is challenging because it is not directly observable. Most of the literature follows the approach pioneered by Hines and Rice (1994), which delivers estimated amounts of profit shifting that are unilateral. The premise of their methodology is that the observed pre-tax profits of a firm correspond to the sum of *normal* profits and *shifted* profits. Normal profits are determined by the combination of inputs and technology in production countries. Shifted profits are generated thanks to the fiscal environment and the incentives to shift profits out of production countries. Profit shifting is then estimated as the difference between total profits and estimated normal profits (excess profits). When the countries of interest are tax havens these are "excess profits" and when the countries of interest are non-haven these are "missing profits". Important papers based on macro-level data estimate the amount of profit shifted to tax havens for the U.S. or at the global level (Zucman, 2014, Clausing, 2016, 2020, Tørsløv et al., 2022, Janský and Palanský, 2019 or Garcia-Bernardo and Jansky, 2021). They generally provide estimates of unilateral profit shifting (either excess profits or missing profits). This amount might then be allocated to bilateral pairs using an allocation key. Tørsløv et al. (2022) (TWZ hereafter) is the first paper to propose a bilateral allocation of profit shifting across production countries-tax havens pairs. However, while having many advantages, their approach is not suited to consistently estimate bilateral profit shifting in our framework.

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

In a second step, the profit shifted to tax havens is allocated across non-haven countries. It relies on the assumption that multinational corporations in high-tax countries use intra-firm interest payments I_{lh} from production countries l to tax havens h and services imports S_{lh} from these countries to shift profits. Following Hebous and Johannesen (2021),

TWZ identify "high-risk" services categories such as royalties and headquarter services (information and communication technologies, insurance, financial and management) which are generally used to shift profits in tax havens using transfer pricing. Hebus and Johannesen (2021) note however that even within these categories, not all services imported from tax haven are traded intra-firm (it corresponds to less than 50% of them), and not all intra-firm flows to tax havens reflect profit shifting. Given the quality of the data, TWZ focus on European countries and define as a benchmark, the share of high-risk services and intra-firm interest in the Gross National Income (GNI) of non-haven EU countries. Similar shares are computed for each tax haven. The ratios of these shares to the benchmark inform on excessive flows. They are computed for each tax haven and can be written as: $s_h^{Y_k} = 1 - \frac{\sum_{l,l \neq h} Y_l / GNI_{EU 22}}{Y_h / GNI_h}$ where Y_k is country k 's amounts of total interest received or its exports of high-risk services. TWZ determine a allocation matrix of bilateral interest payments and service flows that allows to allocate the aggregate worldwide estimate of profit shifting across production and tax haven countries: $PS_{lh}^{TWZ} = 616 \times \frac{I_{lh} \times s_h^I + S_{lh} \times s_h^S}{\sum_{l,h} I_{lh} \times s_h^I + \sum_{l,h} S_{lh} \times s_h^S}$.

This allocation methodology implies that the total amount of profits shifted in a tax haven ($\sum_l PS_{lh}^{TWZ}$) is not necessarily equal to the ones computed in the first step. While this gap is not necessarily important, it prevents a direct use of profit shifting shares as an input to calibrate our model. Figure A.2 illustrates the distribution of bilateral profit shifting in TWZ.

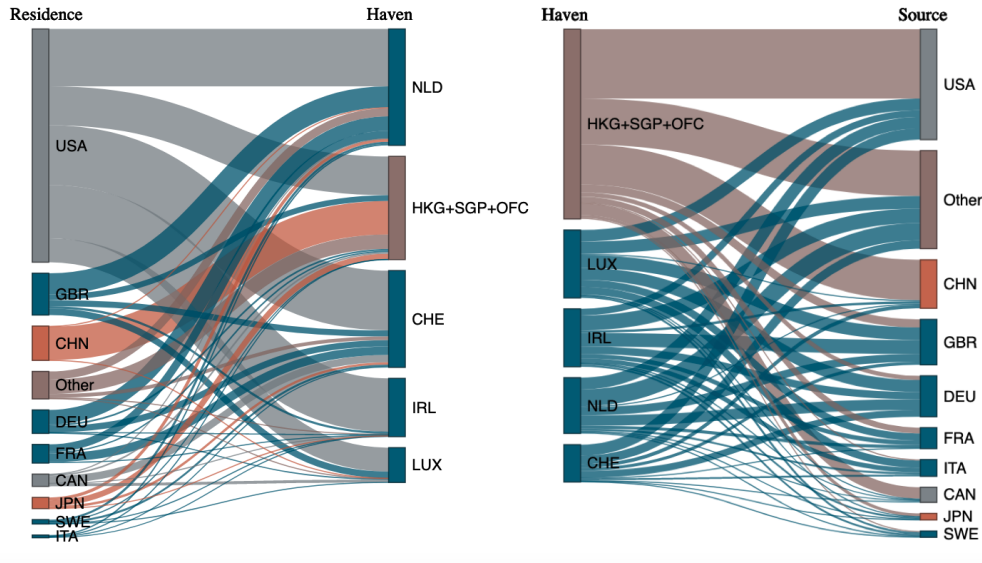


Figure A.2 – Profit shifting from i to h and l to h in Tørsløv, Wier, and Zucman (2022)

Note: This figure shows the profit shifting estimates in Tørsløv, Wier, and Zucman (2022). The residence country i is located on the left, the tax haven country h in the middle and the source country l on the right. Data from Tørsløv, Wier, and Zucman (2022), Appendix table C4.

B.2 Estimation of excessive incomes: PS_{ih}

The excessive income in some tax havens may be inflated due to the geographical breakdowns of FDI incomes which are made according to the immediate counterparts country. Damgaard, Elkjaer, and Johannesen (2019), construct a FDI dataset which combines the

detailed information of the OECD and the IMFs Coordinated Direct Investment Survey (CDIS) datasets. They propose bilateral direct investment statistics on an ultimate ownership basis rather than on a direct ownership basis.

They also breakdown total inward FDI between inward FDI in Special Purpose Entities (henceforth SPEs) used as conduit between two other countries, and inward FDI in non-SPEs. By comparing the bilateral FDI positions recorded in each tax haven on an ultimate ownership basis and on a direct ownership basis, we can compute the proportion of FDI that transit through a tax haven to reach another one. Assuming proportionality, we then reallocate the share of income to the ultimate owner of the transaction. In the schematic representation of Figure 2, we reallocate the profit shifted in h' to h when h' is the conduit tax haven. It means that we do not correct for all conduit FDI. For instance an FDI between two non-haven countries channelled through a conduit tax haven need not to be reallocated. We only reallocate excessive income that are mistakenly attributed to a tax haven h' instead of a tax haven h .

Using Damgaard et al. (2019) data, we define conduit FDI as FDI in SPE going from a non-haven country to a tax haven as $Conduit_{ih'} = FDI_{ih'}^{SPE}$. We compute an allocation key which corresponds to the share of conduit FDI from country i to country h' :

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

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

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

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

The United Kingdom, and on a smaller scale, Belgium are generally identified as conduit countries too (see for instance Garcia-Bernardo, Fichtner, Takes, and Heemskerk, 2017). We account for both countries by computing another reallocation factor $\gamma_{ii'}$ where i' is either U.K. or Belgium.

$$\gamma_{ii'} = \frac{Conduit_{ii'}}{\sum_i FDI_{ii'}}$$

We obtain that 8.9% of excess FDI income in the United Kingdom and 7.1% of excess FDI income in Belgium are reallocated to other non-haven headquarter countries.

In figure A.3, we display the share of profit shifting in each tax haven before and after correction for conduit investment using DEJ data. It indicates how much a country is used as a conduit between a non-haven country and an other tax haven (it is then a subset of total conduit investment). We see that the correction is generally small. The nature of the data currently available for such corrections does not allow us to proceed to large reallocation. Figure A.3 shows that Ireland and OFC seem to be used as conduit to reach other tax havens (their share decrease after correction). Switzerland's and Netherlands' share increase after correction, indicating that they are reached through other tax havens.

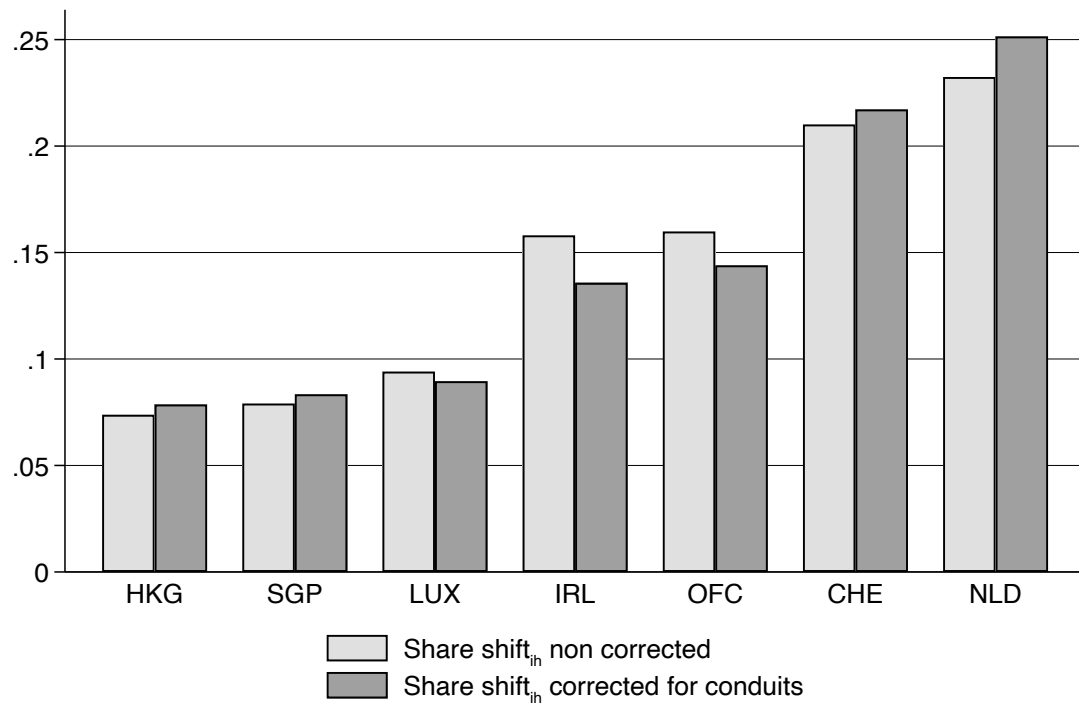


Figure A.3 – Profit shifting before and after taking conduits into account

Note: This figure shows the world share of profit shifting located in each tax haven before and after correcting it for conduit use.

B.3 Robustness figures

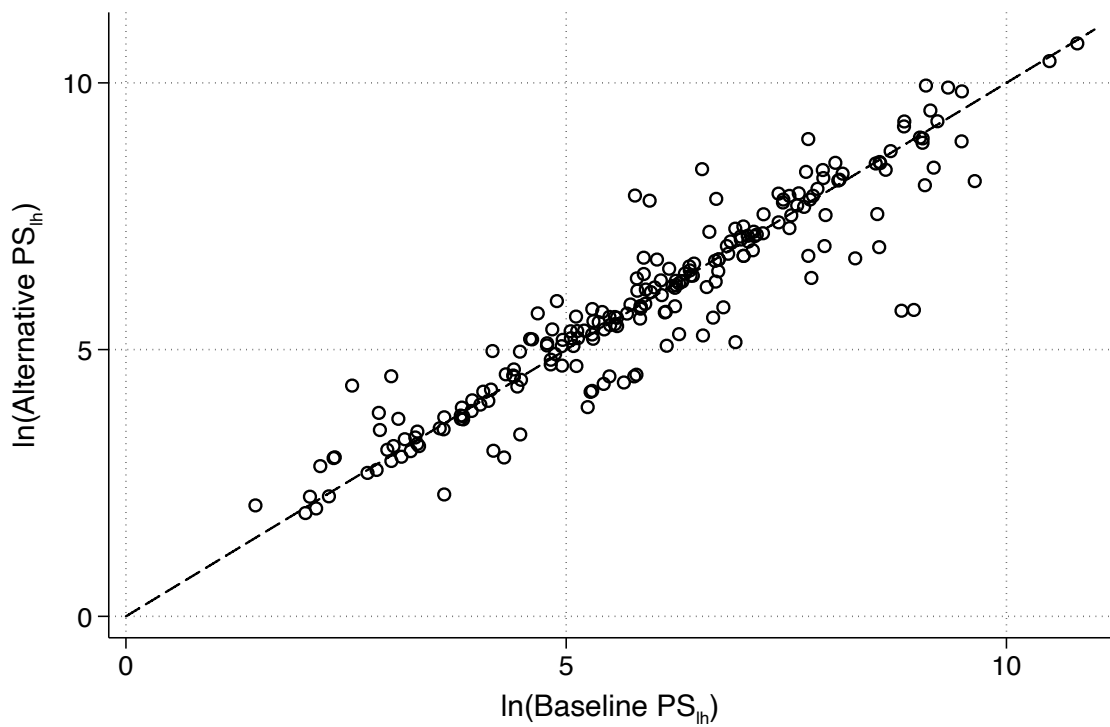


Figure A.4 – Profit shifting: sensitivity to s_l calibration

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

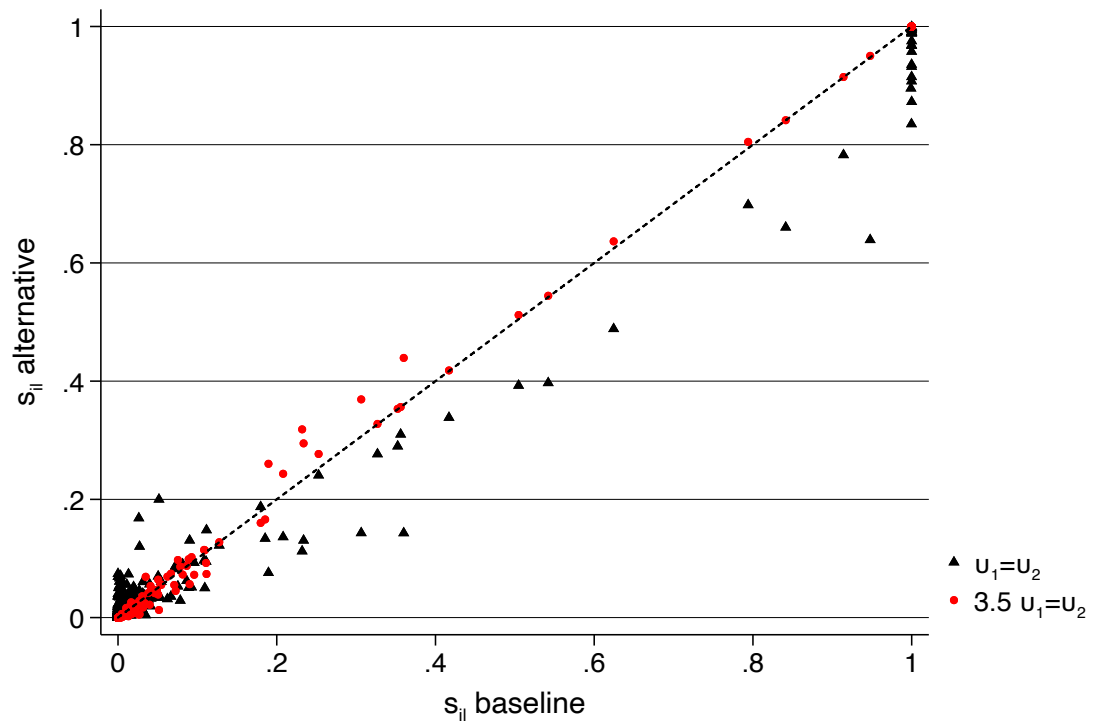


Figure A.5 – Profit shifting: sensitivity to elasticities calibration

This figure plots s_{il} as obtained in the baseline exercise (horizontal axis) and compares it to alternative s_{il} obtained with a different calibration of the ratio $\frac{v_2}{v_1}$.

C Comparing PS_{lh} to other estimations

Comparison with TWZ To our knowledge Tørsløv et al. (2022) is the only other paper in the literature that proposes a bilateral measure of profit shifting. As described earlier our approach is different to their, making both estimates complementary.

In this appendix section we compare our measure of bilateral profit shifting to the one of TWZ. We also compare our estimates of profit shifting aggregated at the country level with other estimates from the literature. First note that our measure concentrates on years 2013-2014 while TWZ estimates concern year 2015. This may explain some deviations of the values as we expect profit shifting to increase over time.

In figure A.6, we show for European tax havens the correlation between TWZ estimation of profit shifting and ours (in neperian logarithm).⁴⁰ Figure A.6 overall displays a positive relationship between the two variables. The Pearson correlation between both variables is 0.63 and the Spearman rank correlation is 0.61. It reveals both similarities and differences between our approaches.

In particular when we concentrate on large values of profit shifting in figure A.7 we observe large differences. While few pair of countries are located close to the $y = x$ line, some pairs that include Ireland as tax haven imply systematically more bilateral profit shifting in TWZ estimates than in ours. On the contrary, profit shifting to Netherlands is generally larger in our estimates.

Comparison with unilateral estimations We now compare our estimates aggregated at the production-country level with other estimates available in the literature. These estimates are taken from TWZ, the Tax Justice Network report (Cobham, Garcia-Bernardo, Palansky, and Bou Mansour, 2020) and CORTAX, the model of the European Commission (Alvarez Martinez et al., 2016). To match with CORTAX data, we transform estimates of profit shifting into tax losses by multiplying them by the statutory tax rate.

Figure A.8 displays the comparison from each l countries available in the CORTAX estimations, the study with the smallest sample of countries. This graph first reveal that the estimations of profit shifting are sensitive to methodologies and data. However, these studies may converge on the order of magnitude for some countries.

The CORTAX estimation is particularly high for the U.S while our estimation, despite being higher than others is close from the one from the Tax Justice Network and the ones from TWZ. Overall, the numbers that we estimate are in the range of the other studies and no pattern is identifiable.

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

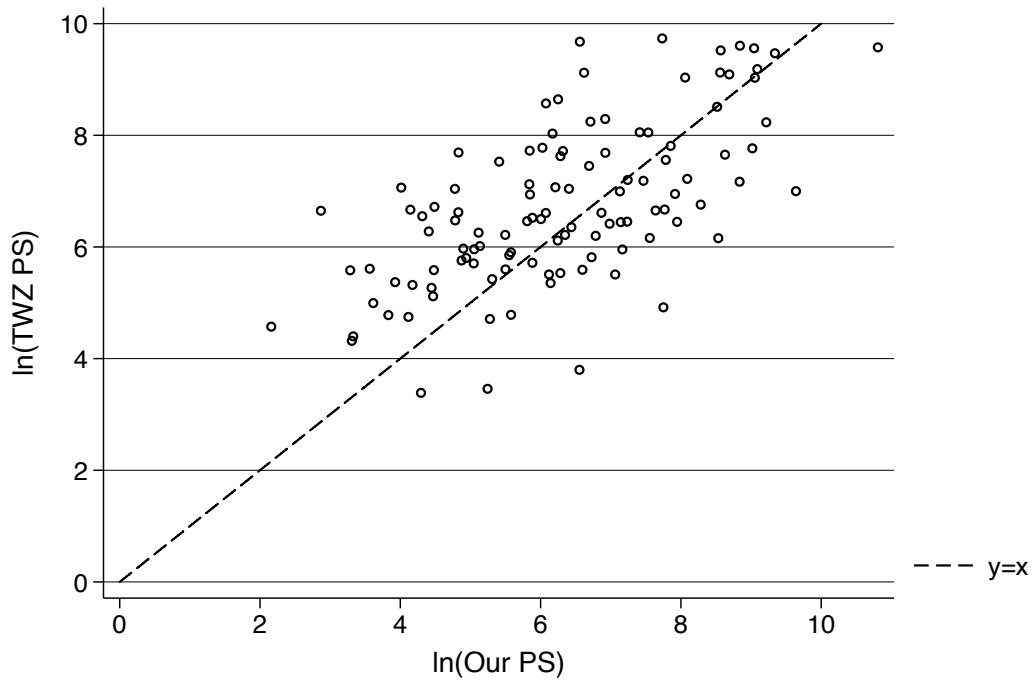


Figure A.6 – Comparison between Tørsløv, Wier, and Zucman (2022) estimation of PS and our for European tax havens.

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

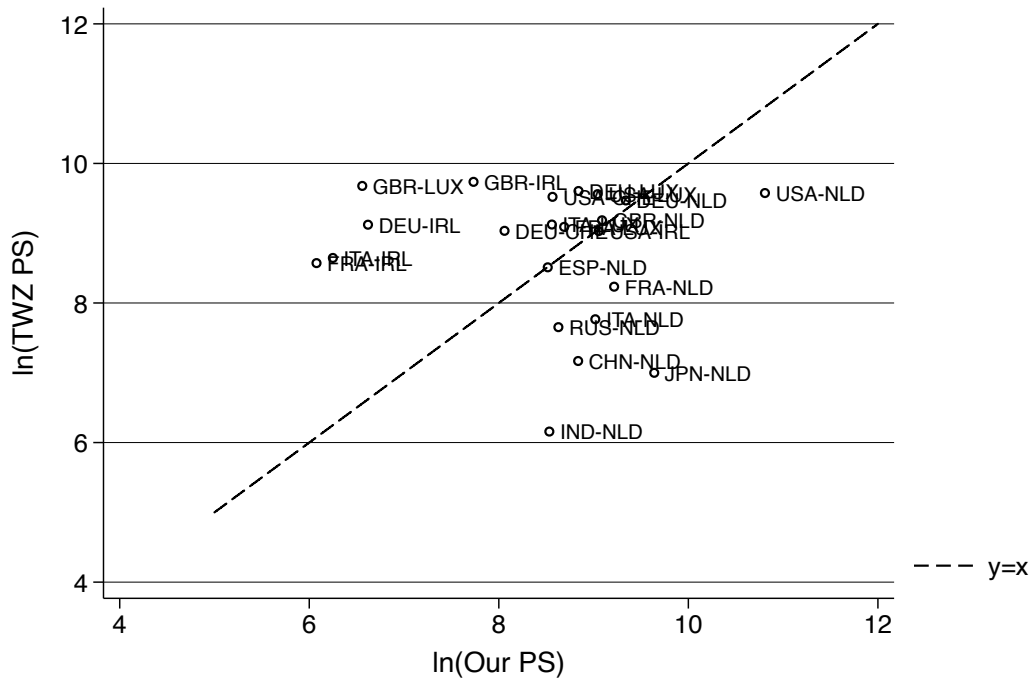


Figure A.7 – Comparison between TWZ estimation of PS and ours for large profit shifting.

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

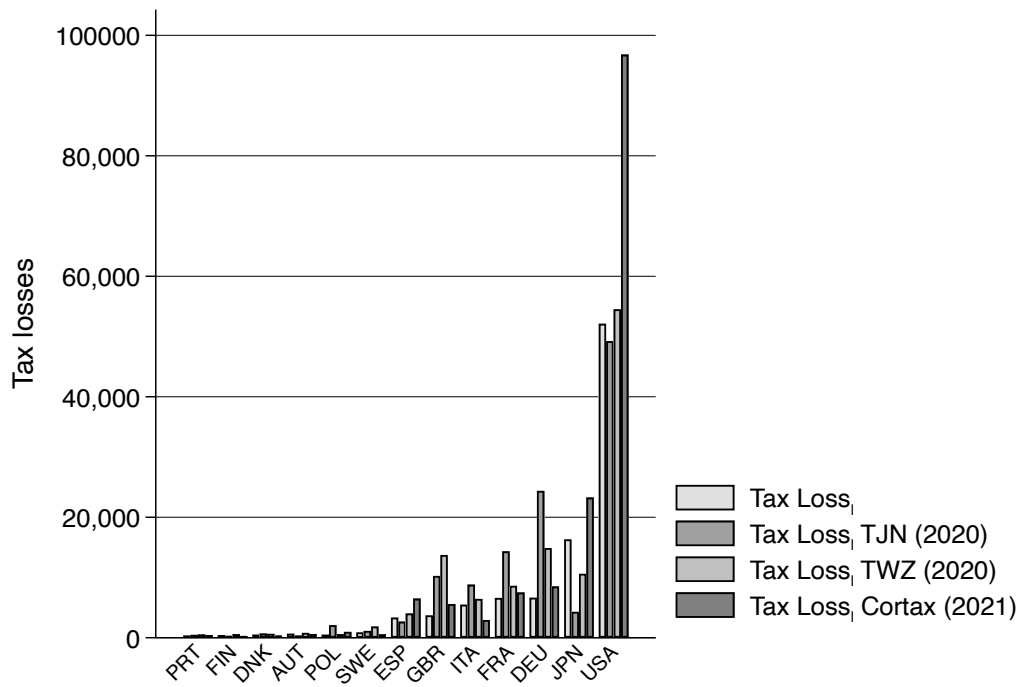


Figure A.8 – Comparison with other estimations.

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

D Supplementary figures

D.1 Illustrating model mechanisms

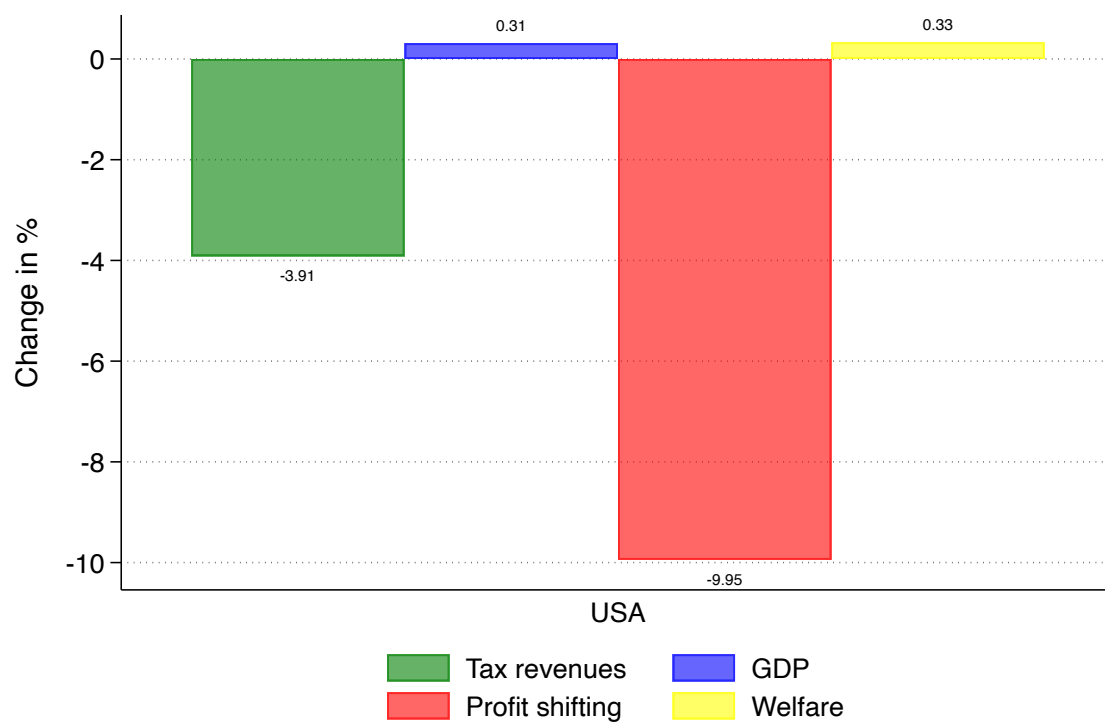


Figure A.9 – Unilateral tax decrease of 5% in the U.S.

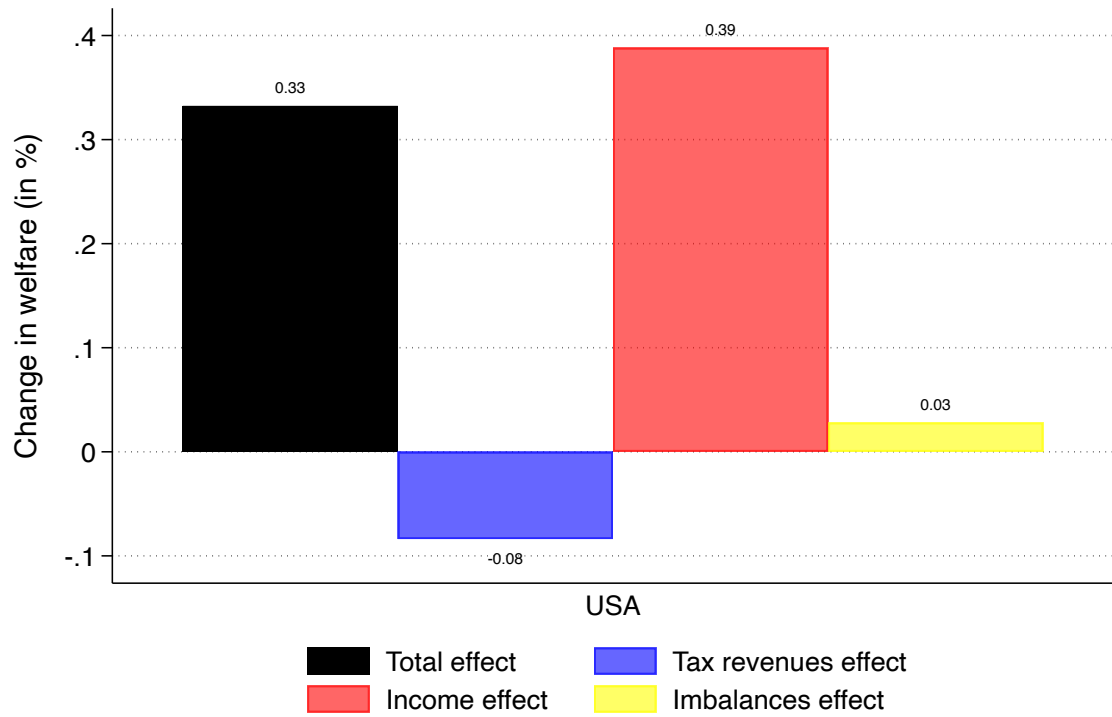


Figure A.10 – Unilateral tax decrease of 5% in the U.S.: decomposition of welfare effects

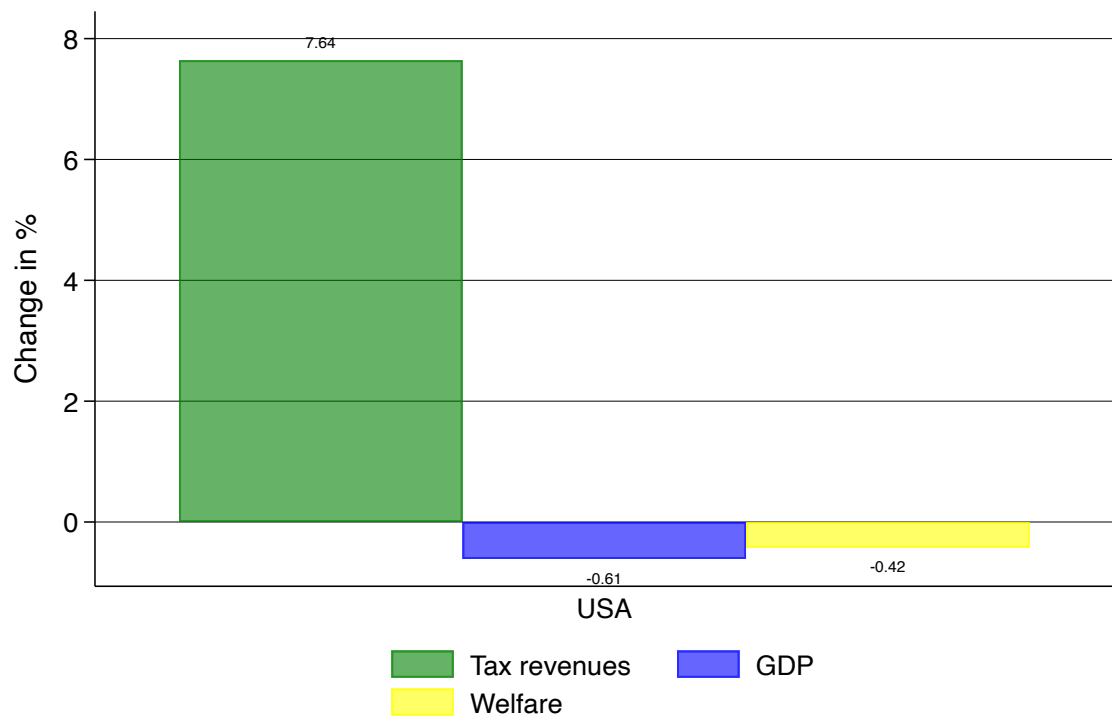


Figure A.11 – Effect of multilaterally ending profit shifting on tax revenues GDP and welfare in the U.S.

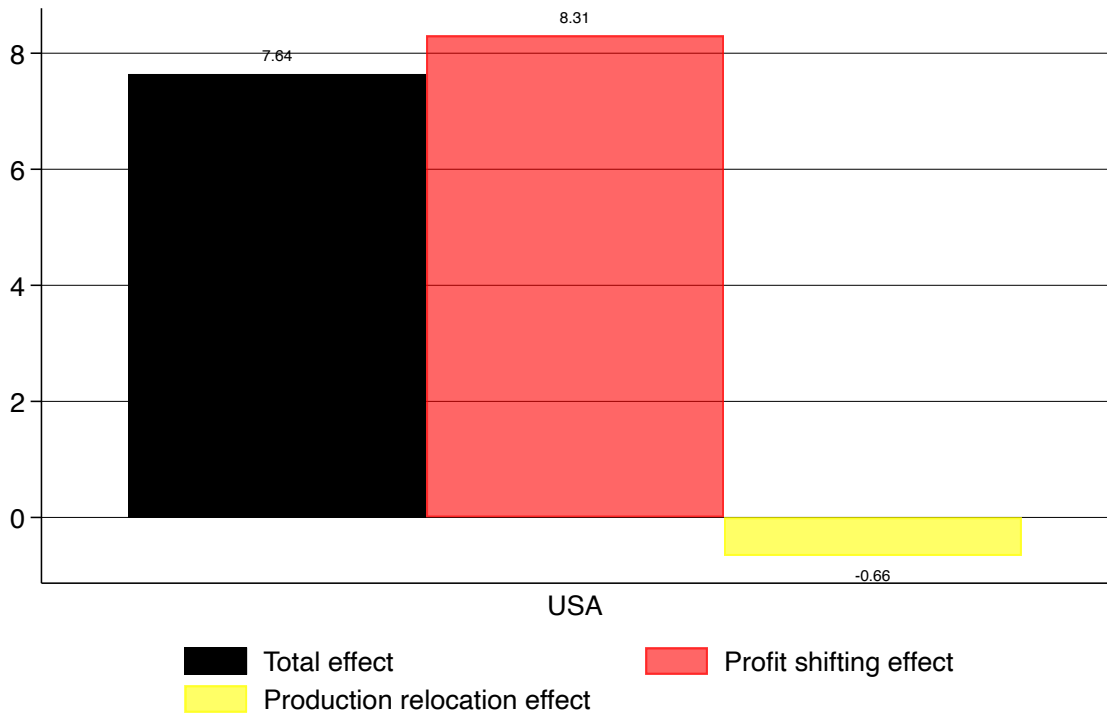


Figure A.12 – Effect of multilaterally ending profit shifting: decomposition of tax revenues effects in the U.S.

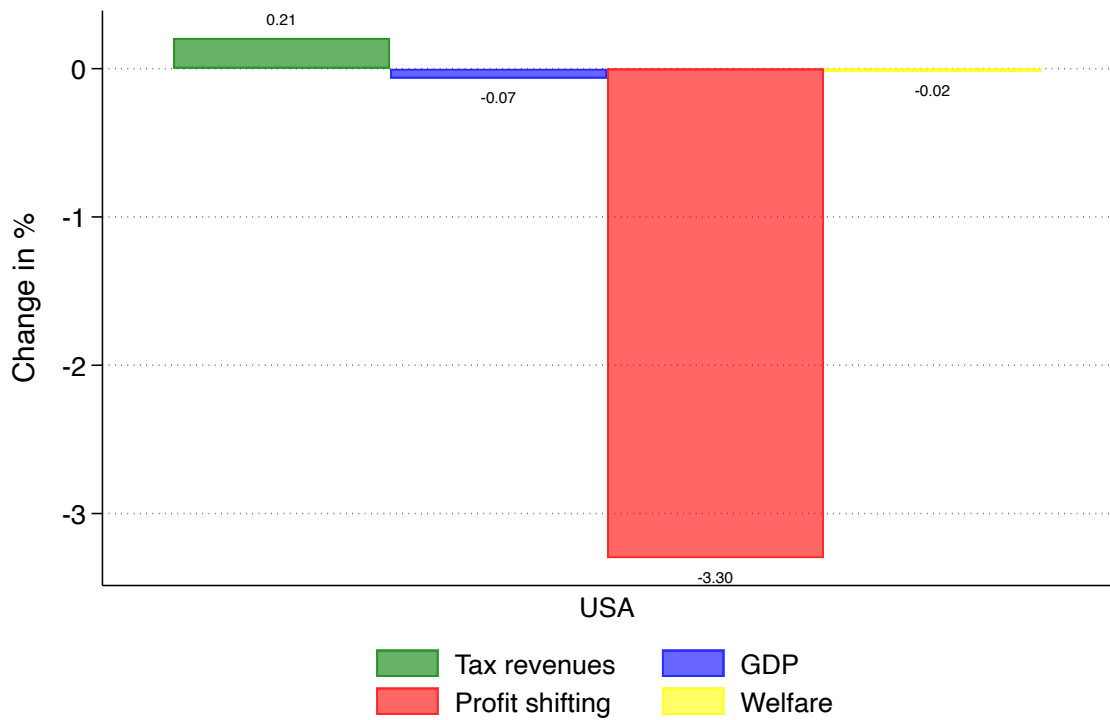


Figure A.13 – Effect of closing Singapore on the U.S.

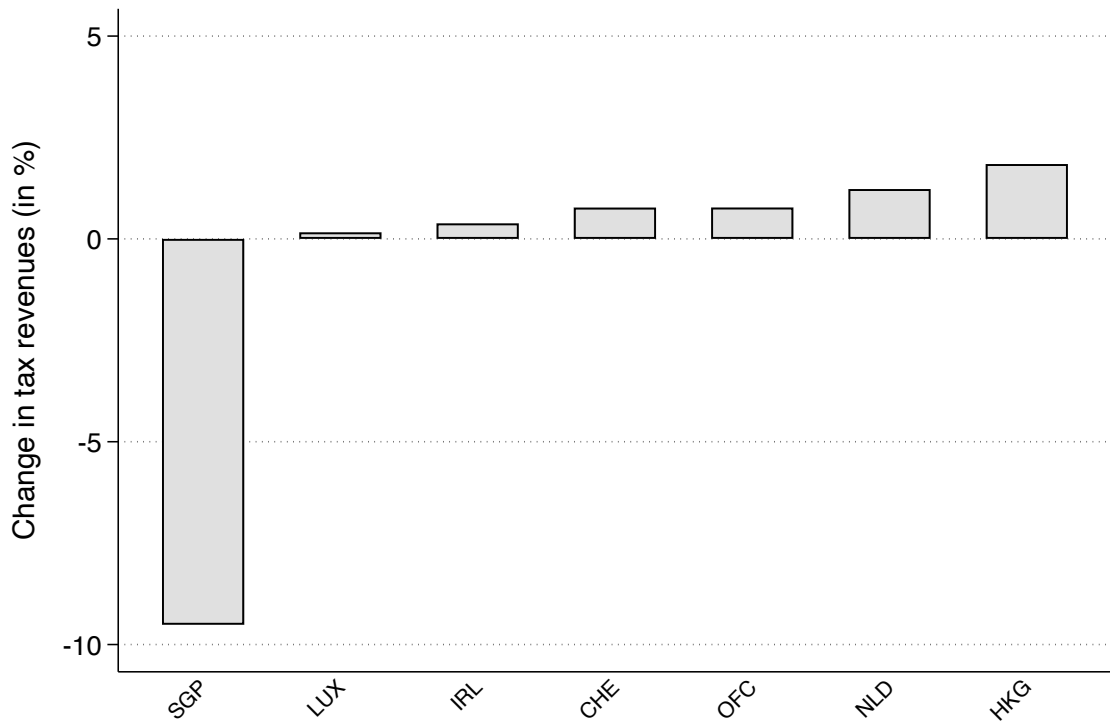


Figure A.14 – Effect of closing Singapore on tax revenues in tax havens

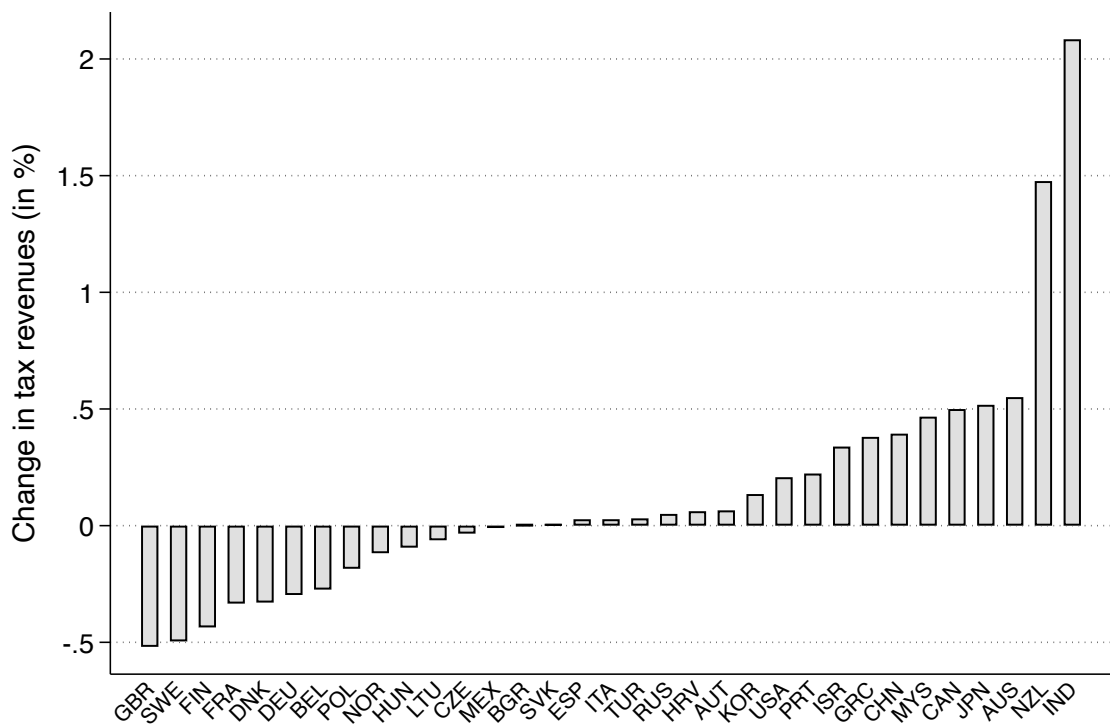


Figure A.15 – Effect of closing Singapore on tax revenues in non-havens

D.2 Sensitivity

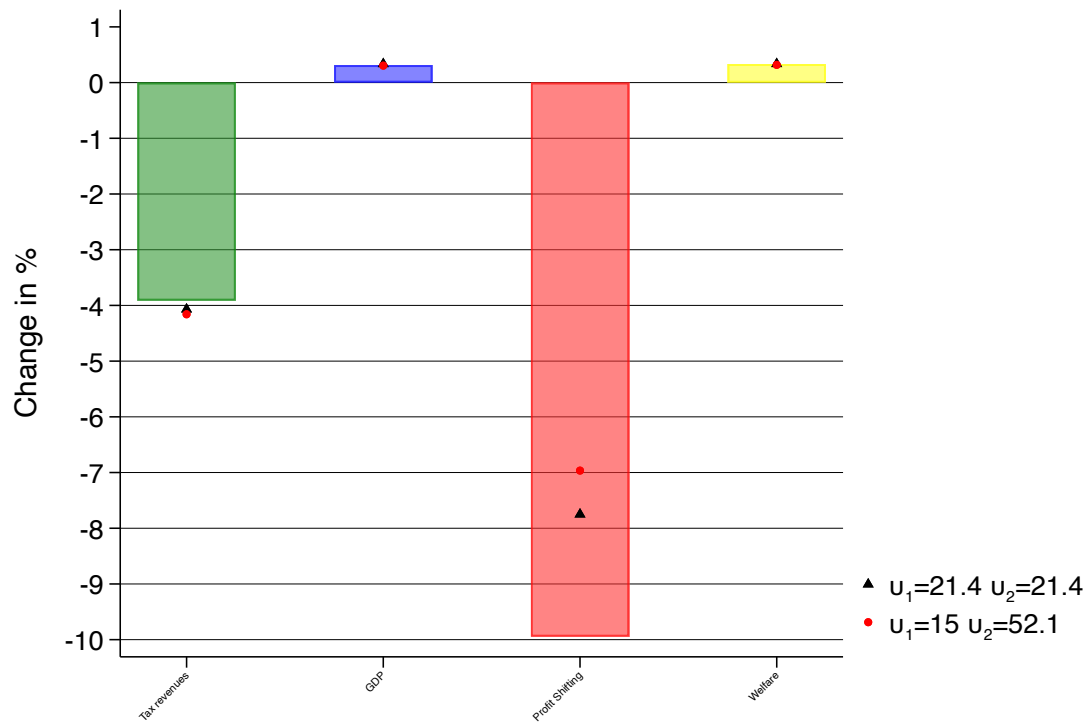


Figure A.16 – Unilateral tax decrease of 5% in the U.S.: sensitivity to parameters calibration

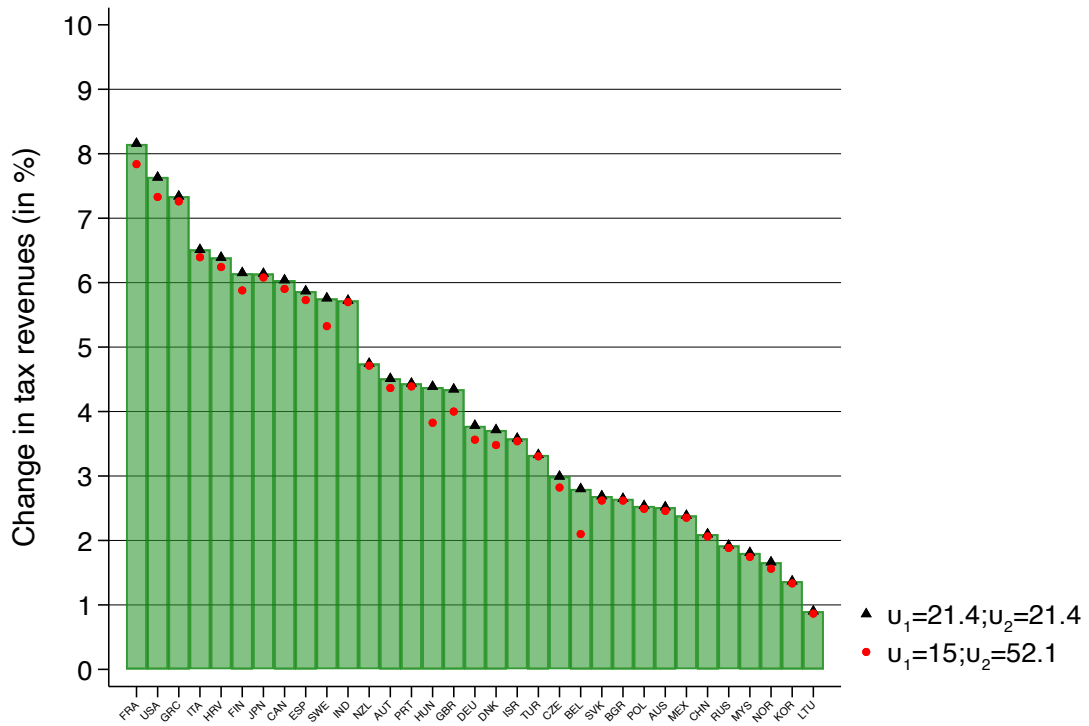


Figure A.17 – Effect of multilaterally ending profit shifting on tax revenues: sensitivity to parameters calibration

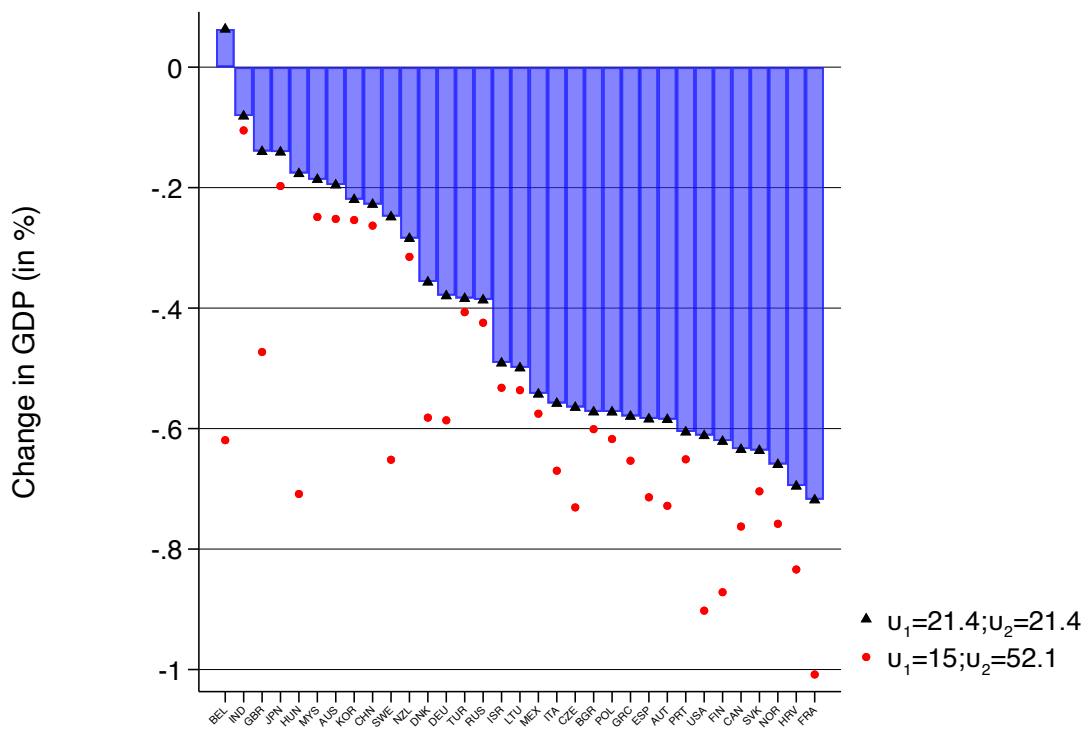


Figure A.18 – Effect of multilaterally ending profit shifting on production: sensitivity to parameters calibration

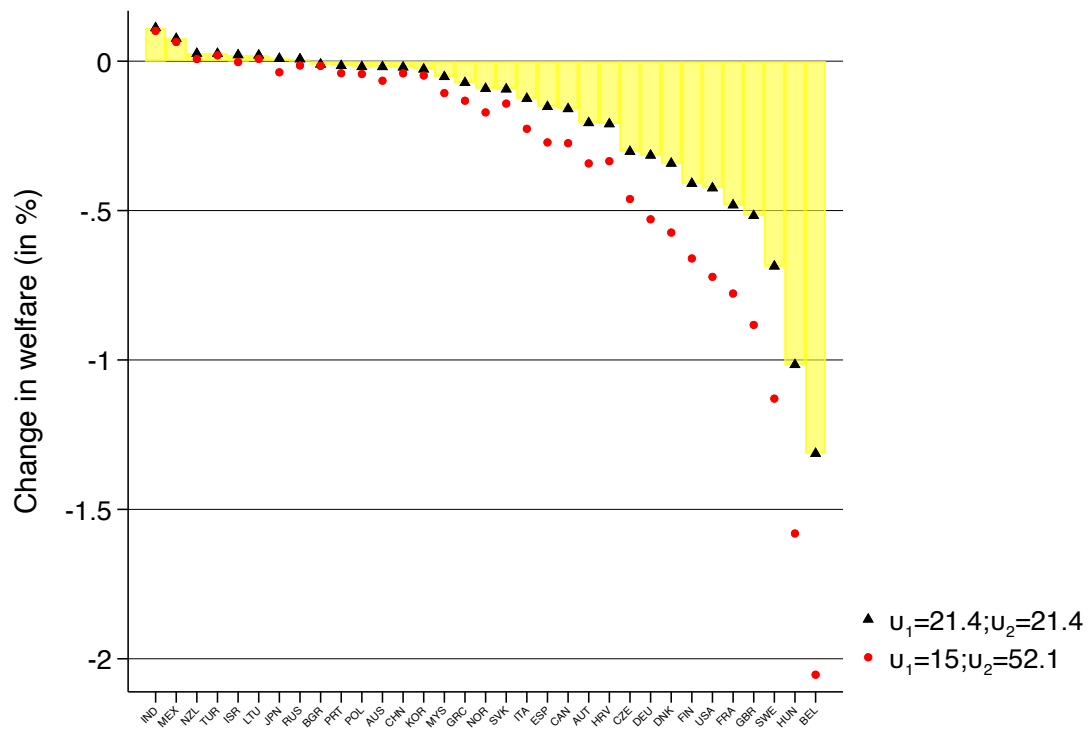


Figure A.19 – Effect of multilaterally ending profit shifting on welfare: sensitivity to parameters calibration

E Theory (baseline model)

Proof of equation (17) Taking equations (3) and (4) together, we have:

$$\begin{aligned}
\frac{X_{ilh}}{\sum_{l,h,h \neq l} X_{ilh}} &= \frac{\tilde{A}_{ilh}(1-t_{lh})^{\frac{v_1}{\sigma-1}-1} G_{i,lh}(\tilde{\mathbf{A}}_i, \mathbf{t})}{\sum_{l,h,h \neq l} \tilde{A}_{ilh}(1-t_{lh})^{\frac{v_1}{\sigma-1}-1} G_{i,lh}(\tilde{\mathbf{A}}_i, \mathbf{t})} \\
&= \frac{\tilde{A}_{ilh}(1-t_{lh})^{\frac{v_1}{\sigma-1}-1} \tilde{A}_{ilh}^{\frac{v_2}{v_1}-1} (1-t_{lh})^{\frac{v_2-v_1}{\sigma-1}}}{\sum_{l,h,h \neq l} \tilde{A}_{ilh}(1-t_{lh})^{\frac{v_1}{\sigma-1}-1} \tilde{A}_{ilh}^{\frac{v_2}{v_1}} (1-t_{lh})^{\frac{v_2-v_1}{\sigma-1}}} \\
&= \frac{\tilde{A}_{ilh}^{\frac{v_2}{v_1}} (1-t_{lh})^{\frac{v_2}{\sigma-1}-1}}{\sum_{l,h,h \neq l} \tilde{A}_{ilh}^{\frac{v_2}{v_1}} (1-t_{lh})^{\frac{v_2}{\sigma-1}-1}}
\end{aligned}$$

Equation (16) is derived along the same logic.

Notice that this second term, by construction, is always null for non-haven countries. Again, summing the two equations above gives equation (5).

Price index The price-index can be computed directly decomposing the set of varieties Ω_n across origin country i and production country l :

$$P_n^{1-\sigma} = \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \sum_i \sum_{lh} N_i \mathbb{P}_{ilh} \tau_{ln}^{1-\sigma} \mathbb{E} \left[\left(\frac{\gamma_{il} w_l \alpha_{lh}}{T_i \varphi_{lh}} \right)^{1-\sigma} \mid lh = lh^* \right]$$

where $\frac{\gamma_{il} w_l \alpha_{lh}}{T_i \varphi_{lh}}$ is the marginal cost of production of one variety by a firm from i , sourcing in l , shifting its profits to h . The mass of firms - and thus varieties - produced at this cost is $N_i \mathbb{P}_{ilh}$. Re-arranging the above expression so as to use the free-entry condition in each country i , we obtain that

$$P_n^{1-\sigma} = \sum_l \tau_{ln}^{1-\sigma} \Xi_l^{\sigma-1} Q_l$$

F Profit shifting, trade and multinational production frictions

Profit shares We start by computing \mathbb{P}_{ill} the probability that a firm from country i produces in l and locates its profits in l .

$$\mathbb{P}_{ill} = \frac{A_{ll} (\gamma_{il} \tilde{t}_{ll} w_l \Xi_l)^{-v_1}}{\sum_l A_{ll} (\gamma_{il} \tilde{t}_{ll} w_l \Xi_l)^{-v_1} + \theta_i^{-v_1} \left(\sum_{l,h,h \neq l} A_{ll} \alpha_{lh}^{\frac{v_2}{v_1}} \left(\gamma_{il} \tilde{t}_{ilh} \alpha_{lh} \tau_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2} \right)^{\frac{v_1}{v_2}}} \quad (24)$$

and \mathbb{P}_{ilh} , the probability that a firm from country i produces in l and shifts its profits in h .

$$\mathbb{P}_{ilh} = \frac{A_{ll}^{\frac{v_2}{v_1}} \left(\gamma_{il} \tilde{t}_{ilh} \alpha_{lh} \tau_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2}}{\sum_{l,h,h \neq l} A_{ll}^{\frac{v_2}{v_1}} \left(\gamma_{il} \tilde{t}_{ilh} \alpha_{lh} \tau_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2}} \times \frac{\theta_i^{-v_1} \left(\sum_{l,h,h \neq l} A_{ll}^{\frac{v_2}{v_1}} \left(\gamma_{il} \tilde{t}_{ilh} \alpha_{lh} \tau_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2} \right)^{\frac{v_1}{v_2}}}{\sum_l A_{ll} (\gamma_{il} \tilde{t}_{ll} w_l \Xi_l)^{-v_1} + \theta_i^{-v_1} \left(\sum_{l,h,h \neq l} A_{ll}^{\frac{v_2}{v_1}} \left(\gamma_{il} \tilde{t}_{ilh} \alpha_{lh} \tau_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2} \right)^{\frac{v_1}{v_2}}} \quad (25)$$

Or, equivalently

$$\mathbb{P}_{ilh} = \frac{A_{ll}^{\frac{v_2}{v_1}} \left(\gamma_{il} \tilde{t}_{ilh} \theta_i \alpha_{lh} \tau_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2}}{\sum_{l,h,h \neq l} A_{ll}^{\frac{v_2}{v_1}} \left(\gamma_{il} \tilde{t}_{ilh} \theta_i \alpha_{lh} \tau_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2}} \times \frac{\left(\sum_{l,h,h \neq l} A_{ll}^{\frac{v_2}{v_1}} \left(\gamma_{il} \tilde{t}_{ilh} \theta_i \alpha_{lh} \tau_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2} \right)^{\frac{v_1}{v_2}}}{\sum_l A_{ll} (\gamma_{il} \tilde{t}_{ll} w_l \Xi_l)^{-v_1} + \left(\sum_{l,h,h \neq l} A_{ll}^{\frac{v_2}{v_1}} \left(\gamma_{il} \tilde{t}_{ilh} \theta_i \alpha_{lh} \tau_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2} \right)^{\frac{v_1}{v_2}}}$$

Observing equations (24) and (25), we notice that backing-out profit shifting frictions and thereby computing $Cost_{ilh}$ requires a series of parameters A_{ll} , γ_{il} , τ_{ilh} and the endogenous variables w , Ξ in the initial equilibrium - the one that is consistent with all the \mathbb{P}_{ilh} .

Backing-out price indices, trade frictions and market potential The endogenous variables w are easily recovered from the labor market constraint, while Ξ depends on the (unobserved) price index and trade frictions.

Price indices in the initial equilibrium are not themselves identified as they cannot be disentangled from trade costs. Intuitively, their combination matters to replicate the observed trade shares from a source country l to a market n :

$$\frac{\tau_{ln}^{1-\sigma} P_n^{\sigma-1}}{\tau_{ll}^{1-\sigma} P_l^{\sigma-1}} = \frac{X_{ln} Y_l}{X_{ll} Y_n}$$

We thus look for a matrix of trade costs that departs as little as possible from the symmetry assumption often made in the literature (Head and Mayer, 2014). This, in turn, pins down market potentials Ξ_l across countries and perfectly replicates the observed trade shares at the same time.

We normalize domestic trade frictions, i.e., $\tau_{ll} = 1$ for all l . We obtain:

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

We look for a matrix of trade costs that departs as little as possible from the symmetry assumption both to (i) perfectly reproduce observed trade shares and (ii) have variation in

market potentials across countries.

In practice, trade shares and imports are observed. We thus treat the vector of price indexes P as a vector of unknowns and search for values minimizing $\sum_{l,n} (\tau_{ln} - \tau_{nl})^2$. Figure A.20 plots the results: the price indexes, the corresponding asymmetric trade costs (comparing the latter with what symmetric trade costs would look like in our model, i.e., $\tau_{ln} = (X_{ln}/Y_l) / (X_{nl}/Y_n)$), and the market potentials.

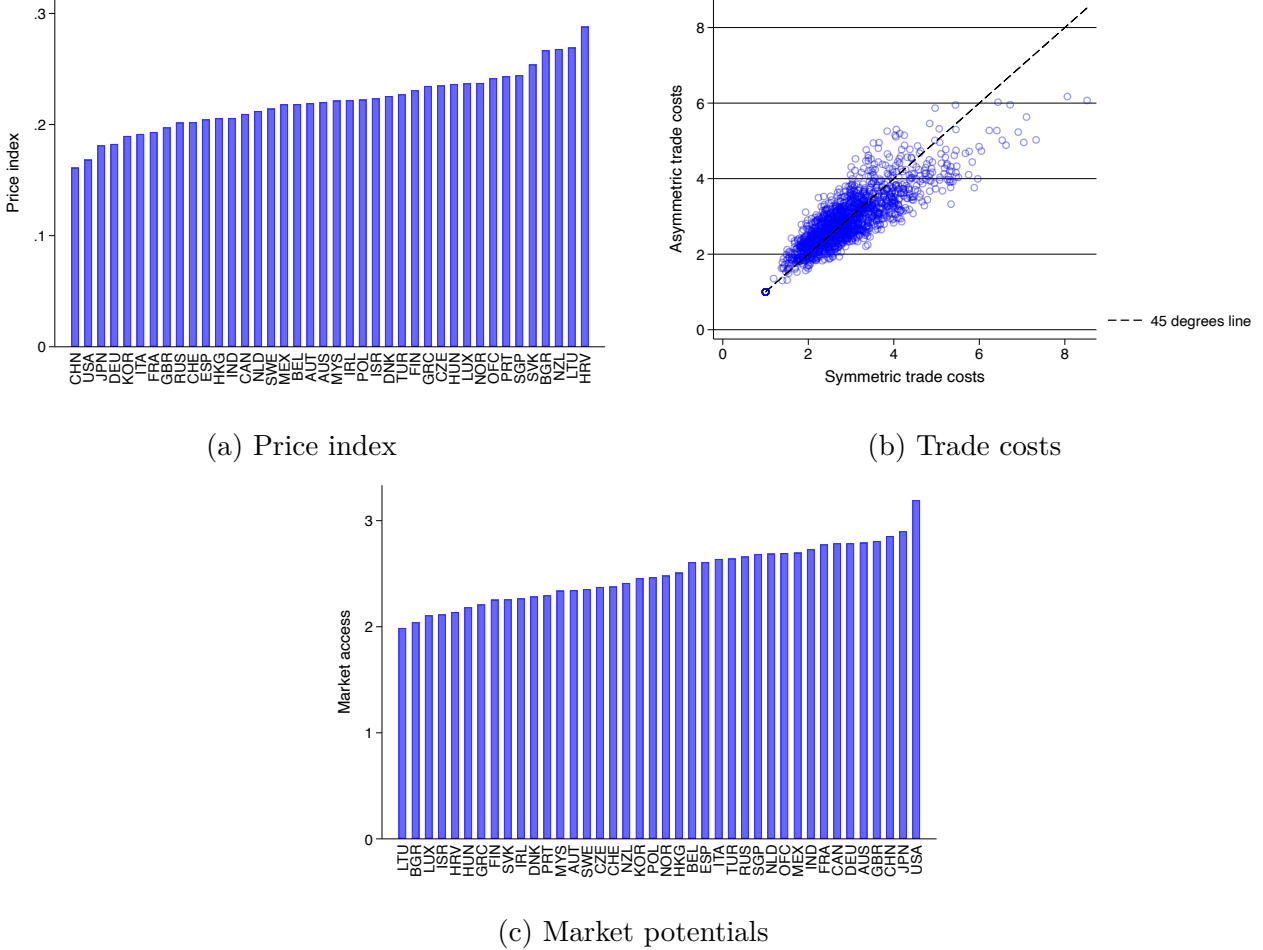
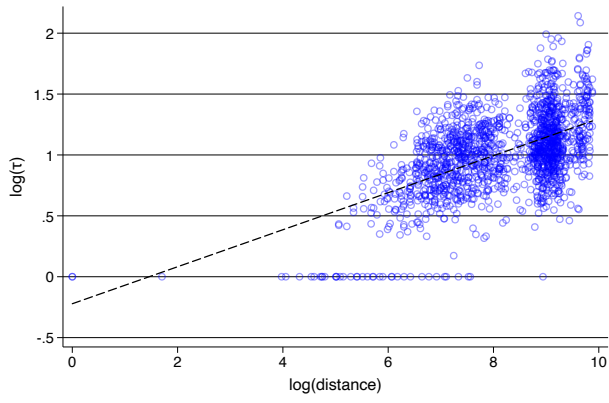


Figure A.20 – Price indexes, market potentials, and trade costs

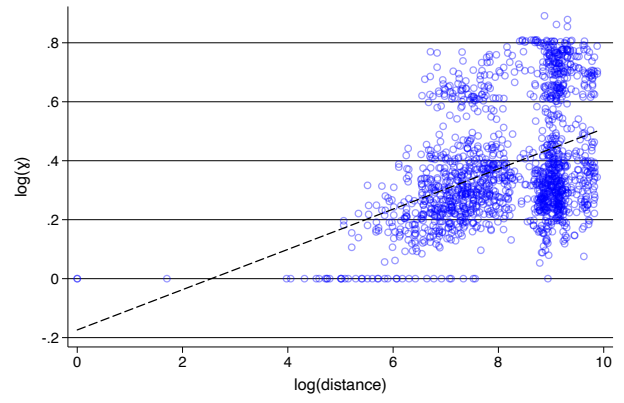
Asymmetric HQ frictions γ_{il} are also recovered using 24. Trade frictions τ_{ln} and HQ frictions γ_{il} are plotted against distance in figure A.21.

Knowing w, Ξ and γ , we can back out country-level technology parameters A_{ll} (relative to a reference country that we take to be the U.S.) from equation 24. Intuitively, productivity differences are the residual explanatory factor for multinational activity once we control for differences in the cost of production, market potential, and gravity determinants of MP sourcing.

Last, equation 25 allows us to back-out profit shifting frictions. Intuitively, variations in profits shifted to different h from a given l given by 25 pin down the relative frictions $\alpha_{lh'}/\alpha_{lh}$. In turn, the comparison of the intensity of profit shifting from different l to the same h informs on the relative friction from other source countries after controlling for the “attractiveness” of source countries l , which depends on the market potential Ξ , wages w and technology A_{ll} .



(a) Trade costs (τ_n)



(b) Multinational activity costs (γ_{il})

Figure A.21 – Trade and MNE activity bilateral frictions

G Exact hat algebra

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

G.1 Computing counterfactual equilibria

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

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

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

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

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

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

$$X'_{il} = \frac{N'_i}{T_i^{1-\sigma}} \left(\frac{\sigma}{\sigma-1} \right)^{-\sigma} \sum_h \left(\mathbb{P}'_{ilh} \iota_l^{-1} (1 - t_{lh})^{-1} \right) \mathcal{D}'_i \frac{\sigma-1}{v_1} \Gamma \left(1 - \frac{\sigma-1}{v_1} \right)$$

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

wages satisfy the labor-market clearing

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

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

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

price indices for all countries but the numeraire verify

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

and the number of firms satisfies the free-entry condition

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

G.2 Relative changes in probabilities $\hat{\mathbb{P}}_{ilh}$

Non-haven residence countries $i \notin \mathcal{H}$. The unconditional probabilities \mathbb{P}_{ilh} for $h \neq l$ are given by

$$\mathbb{P}_{ilh} = \frac{A_{lh}^{\frac{v_2}{v_1}} \left(\gamma_{il} \theta_i \alpha_{lh} \tilde{t}_{ilh} \iota_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2} \times \left(\sum_{l,h,h \neq l} A_{lh}^{\frac{v_2}{v_1}} \left(\gamma_{il} \theta_i \alpha_{lh} \tilde{t}_{ilh} \iota_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2} \right)^{\frac{v_1}{v_2} - 1}}{\sum_l A_{ll} \left(\gamma_{il} \tilde{t}_{ll} \iota_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_1} + \left(\sum_{l,h,h \neq l} A_{lh}^{\frac{v_2}{v_1}} \left(\gamma_{il} \theta_i \alpha_{lh} \tilde{t}_{ilh} \iota_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_2} \right)^{\frac{v_1}{v_2}}}$$

while for $h = l$, we get

$$\mathbb{P}_{ill} = \frac{A_{ll} \left(\gamma_{il} \iota_l^{\frac{1}{1-\sigma}} \tilde{t}_{ll} w_l \Xi_l \right)^{-v_1}}{\theta_i \sum_l A_{ll} \left(\gamma_{il} \tilde{t}_{ll} \iota_l^{\frac{1}{1-\sigma}} w_l \Xi_l \right)^{-v_1} + \left(\sum_{l,h,h \neq l} A_{lh}^{\frac{v_2}{v_1}} \left(\gamma_{il} \theta_i \alpha_{lh} \iota_l^{\frac{1}{1-\sigma}} \tilde{t}_{ilh} w_l \Xi_l \right)^{-v_2} \right)^{\frac{v_1}{v_2}}}$$

Since tax havens do not shift to other tax havens, l is a haven implies that $A_{lh} = 0$ for $l \neq h$.

We introduce N_{ill} and N_{ilh} to denote the numerator of \mathbb{P}_{ill} and \mathbb{P}_{ilh} respectively and \mathcal{D}_i their denominator so that for $h \neq l$

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

$$h = l \Rightarrow \mathbb{P}_{ill} = \frac{N_{ill}}{\sum_l N_{ill} + \left(\sum_{l \notin \mathcal{H}, h, h \neq l} N_{ilh} \right)^{\frac{v_1}{v_2}}}$$

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

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

and

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

where

$$\hat{N}_{ill} = \widehat{w_l \Xi_l \tilde{t}_{ll}}^{-v_1} \quad \hat{N}_{ilh} = \widehat{w_l \Xi_l \tilde{t}_{ilh}}^{-v_2}$$

Haven-residence countries $i \in \mathcal{H}$ The probability to locate in l is simply given by

$$\mathbb{P}_{ill} = \frac{N_{ill}}{\sum_l N_{ill}}$$

and relative changes are given by

$$\hat{\mathbb{P}}_{ill} = \frac{\hat{N}_{ill}}{\sum_l \mathbb{P}_{ill} \hat{N}_{ill}}$$

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