A Macroeconomic Perspective on Taxing Multinational Enterprises*

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Abstract

We study the macroeconomic consequences of international profit shifting by multinational enterprises (MNEs) and tax reforms designed to curb this behavior. We develop a theory in which MNEs shift profits by exploiting intangible capital transfer pricing rules. We show that at the micro level, profit shifting increases MNEs' incentives to invest in intangible capital, increasing their output both at home and abroad. We then quantify the aggregate effects of the two reforms proposed by the OECD to reduce profit shifting: (i) reallocating the rights to tax MNEs' profits to the countries where they sell their products; and (ii) a minimum global corporate income tax. Both reforms would reduce profit shifting substantially, but (i) would reduce global output substantially whereas (ii) would have little macroeconomic impact. Both reforms would increase high-tax countries' national incomes, but would also reduce their wages and profits.

Keywords: Multinational enterprise; transfer pricing; profit shifting; base erosion; intangible capital; corporate tax.

JEL Codes: F23, H25, H26

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1 Introduction

Multinational enterprises (MNEs) shift large portions of their profits to foreign tax havens, costing governments in their home countries hundreds of billions of dollars per year in tax revenue. In October 2021, 136 countries signed onto a policy designed by the OECD and G20 governments to reduce profit shifting, making it the largest international tax reform in history. We analyze the macroeconomic consequences of OECD/G20 reform using a new model of profit shifting that emphasizes transfer pricing of intangible capital. We find that this reform would substantially reduce profit shifting and increase tax revenues in high-tax countries, but it would also cause global output to fall substantially.

Base erosion and profit shifting (BEPS) refers to MNEs' use of tax planning strategies to exploit gaps and mismatches in tax rules to artificially shift profits to low- or no-tax countries where they conduct little or no economic activity, or to erode tax bases through deductible payments such as interest or royalties. The scale of profit shifting is striking. For example, Tørsløv, Wier and Zucman (2022) estimate that 36 percent of worldwide multinational profits are shifted to tax havens, while Guvenen, Mataloni, Rassier and Ruhl (2022) find that 38 percent of foreign income reported by U.S. MNEs is actually generated at home in the United States. The implications for public finances are equally striking: Clausing (2020a) estimates that about a third of U.S. corporate income taxes are lost to profit shifting, which is equivalent to more than \$100 billion per year. According to the OECD, profit shifting reduces global corporate income tax revenues by as much as 10 percent per year, or \$240 billion (Johansson et al., 2017).

Addressing this issue is a top priority for policymakers in high-tax countries where many of the biggest MNEs are based. The OECD/G20 Inclusive Framework on BEPS outlines two major policy changes, or "pillars."[1] The first pillar is revenue-based profit allocation, which allocates the rights to tax some of an MNE's profits to the countries in which it operates in proportion to these countries' shares of the MNE's global sales. The second is a global minimum corporate income tax, which would require that all corporate income, regardless of where it is booked, be effectively taxed at no lower than 15 percent. The objective of this paper is to study how these two pillars would affect MNEs' production decisions and quantify the macroeconomic consequences of these effects.

MNEs can use a variety of strategies to shift profits, but the most important one centers around intangible capital.[2] U.S. Senator Carl Levin put it eloquently in a 2013 statement this issue: "More and more, intellectual property is the dominant source of value in the

[1]The press statement describing these pillars can be found here.

[2]Empirical evidence indicates that up to 80 percent of profit shifting is related to intangible capital and manipulating transfer prices. See the Appendix A for more details.

global economy. It is also highly mobile—unlike more tangible, physical assets, its value can be transferred around the globe, often with just a few keystrokes…The key to offshore tax avoidance is transferring the profit-generating potential of that valuable intellectual property offshore so that the profits are directed not to the United States, but to an offshore tax haven." One of the most prominent examples is Apple. Levin states that "95 percent of Apple's R&D... is conducted in the United States... [During] 2009 to 2012, [Apple Ireland, a.k.a. ASI] paid... $5 billion to [Apple USA] as its share of the R&D costs. Over that same time period, ASI received profits of $74 billion. The difference between ASI's costs and the profits, almost $70 billion, is how much taxable income [should] have flowed to the United States."[3] In addition to this anecdote, there is a wide variety of empirical evidence that intangible capital plays a central role in profit shifting. Guvenen et al. (2022) show that profit shifting is concentrated in the most intangible-intensive industries such as electronics manufacturing, pharmaceuticals, and information technology. Gumpert et al. (2016) and Delis et al. (2021) find similar relationships between intangible intensity and profit shifting at the firm level. Accoto et al. (2021) and Santacreu (2023a) document flows of intellectual property services between high-tax countries and recognized tax havens. Perhaps the most direct evidence comes from Dischinger and Riedel (2011), who show that MNEs transfer ownership of intangible capital to subsidiaries in low-tax countries.

Motivated by this evidence, we develop a theory that describes how MNEs shift profits by transferring the rights to intangible capital and how profit shifting affects MNEs' production decisions. As in McGrattan and Prescott (2010), intangible capital is nonrival: MNEs produce it by doing research and development at home, but use it to produce simultaneously in all of their foreign subsidiaries around the world.[4] According to transfer pricing rules, these subsidiaries pay licensing fees to use this capital. Normally, these fees are paid to the domestic parent corporation, but the rights to this capital can be transferred—at a cost—to subsidiaries in a tax haven. The end result is that the income generated by MNEs' intangible capital is taxed at a lower rate, which increases an MNE's optimal level of intangible investment. Because intangible capital is nonrival, this leads to higher output in all of an MNE's subsidiaries, both foreign and domestic. This illustrates a potential tradeoff that profit shifting presents to global policymakers: although it artificially redistributes MNEs' income to foreign tax havens, it also increases the amount of worldwide income that they actually generate. Moreover, we show that the size of this effect is increasing in the difference

[3] Levin's complete testimony can be found here.

[4] MNEs do some R&D in their foreign affiliates as well, but as Arkolakis et al. (2018) write, "most of the R&D is still done in the multinationals' home country. For example, according to BEA data for 2009, the parents of U.S. multinationals accounted for 85 percent of its total RD expenditure but only 70 percent of its value-added. See also Bilir and Morales (2020), which concludes that the parent RD is a substantially more important determinant of firm performance than affiliate R&D."

between the corporate tax rates in the MNE's home country and the tax haven. This has direct implications for the OECD/G20 BEPS pillars: the higher the minimum tax rate or sales-based profit reallocation share, the larger the reduction in intangible investment.

To quantify the macroeconomic effects of the OECD/G20 proposal, we embed our theory into a multi-country, general-equilibrium framework. Each country in our quantitative model is populated by a representative household, a government, and a measure of firms. Households spend all their income on the final good. Governments levy taxes on corporate profits to finance lump-sum transfers. Firms are heterogeneous in productivity and make four choices: where to export; where to establish foreign affiliates; intangible investment; and profit shifting. Exporting and FDI are subject to fixed costs, so only the most productive firms engage in multinational production in equilibrium as in Helpman et al. (2004). All firms invest in intangible capital, but its nonrival nature makes the return greater for MNEs, and so they account for the lion's share of intangible investment, consistent with the empirical evidence.[5] However, firms gain access to the profit-shifting technology only if they have an affiliate in a tax-haven country. Our quantitative model makes several methodological contributions in its own right: incorporating nonrival intangible capital into a heterogeneous-firm environment; allowing individual firms to make joint decisions about multinational production and innovation; and, of course, incorporating our theory of profit shifting.

In our calibration, we discipline the model's parameters so that it reproduces micro- and macroeconomic data on production, trade, multinational activity, and, most importantly, profit shifting. We split the world into five regions. The countries identified as tax havens make up two of these regions: the first is a productive low-tax region that includes Ireland, Switzerland, and other countries where most of the economy is not devoted to profit shifting; while the second is a "true" tax haven that includes the Caribbean, the Channel Islands, and other small countries whose economies rely heavily on profit shifting. The other three regions are North America, Europe (minus countries in the low-tax region), and the rest of the world. Firms in these three regions can shift profits to the low-tax region and/or the tax haven—provided they have paid the cost of establishing foreign affiliates there. We choose the costs of profit shifting to match Tørsløv et al. (2022)'s estimates lost profits at the country level. Our model also reproduces three other sets of facts about profit shifting that we do not target in our calibration: the share of low-tax countries' corporate income taxes that are paid by foreign MNEs; the aggregate compensation of employees hired by MNEs to engage in profit shifting; and the MNE-level relationship between profits reported by the domestic parent division and the tax differential between the home country and the tax haven.

[5]U.S. MNEs' parent companies account for about 75% of all R&D in the United States post 2000. See Foley et al., eds (2021) for an extensive discussion on the importance of the MNEs.

We use our calibrated model to simulate the effects of the two pillars of the OECD/G20 proposal, both together and in isolation. We find that this proposal would go a long way toward eliminating profit shifting: lost profits would fall by 74 percent in North America, 80 percent in Europe, and 88 percent in the rest of the world. However, it would also materially reduce intangible investment and overall macroeconomic performance around the world: GDP would fall by 0.09 percent in North America, 0.14 percent in Europe, 0.46 percent in the low-tax region, and 0.18 percent in the rest of the world. Our model predicts a decline in global GDP more than twice as large the OECD estimates (OECD, 2020), highlighting the quantitative importance of the intangible investment channel and general–equilibrium effects.

Further, we find that while both pillars of the OECD/G20 plan would reduce profit shifting, the first (sales-based profit reallocation) would have significantly larger macroeconomic consequences than the second (a global minimum corporate income tax). This is because the former affects firms that do not shift profits and even some firms that do not engage in multinational production at all. We find that the same reduction in profit shifting could be accomplished at a much smaller macroeconomic cost by scrapping the first pillar entirely and slightly increasing the minimum tax rate, and we recommend that policymakers seriously consider this alternative. We also find that although the OECD proposal would reduce output in high-tax countries, it would actually increase their gross national income. However, this aggregate increase masks a redistribution of income from the private sector to the public sector, indicating that the recouped corporate tax revenues should be redistributed or offset by reductions in other taxes to ensure that households in these countries benefit from the reforms.

2 Related Literature

This paper relates to two strands of literature on profit shifting. The first strand consists of empirical studies that provide motivation for our study, support for our modeling choices, and targets for our calibration. Several studies in this strand document the striking scope of profit shifting at the aggregate level. Guvenen et al. (2022) estimate that 38 percent of U.S. MNEs' foreign income is the result of profit shifting and should be re-attributed to domestic GDP, while Tørsløv et al. (2022) report a similar figure at the global level. Clausing (2020a) concludes that profit shifting reduces U.S. corporate tax revenues by as much as a third.[6] We draw on these estimates to discipline our quantitative model. Other empirical studies provide

[6]See Dowd et al. (2017), Clausing (2016), and OECD (2015) for extensive reviews of the empirical literature on profit shifting.

microeconomic evidence on profit shifting. Gumpert et al. (2016) and Delis et al. (2021) show that firms with high shares of intangible capital in total assets are more likely to shift profits, and Accoto et al. (2021) document that profit-shifting firms import intellectual property services from recognized tax-havens. Using cross-country data on bilateral royalty payments from 1995 to 2012, Santacreu (2023b) finds that differences in taxation impact international technology licensing. These studies provide support for our theory of profit shifting that centers around transfer pricing of intangible capital. Last, Schwab and Todtenhaupt (2021) find that reducing the tax rate on corporate income in one country increases R&D activities in other countries through the MNE networks. This provides empirical evidence for the key implication from our model that profit shifting increases the incentive for intangible investment.

The second strand focuses on the real economic consequences of profit shifting. Many studies in this literature are based on Hines and Rice (1994), who develop a theory in which MNEs can reduce their effective tax rates by paying a cost to shift profits to a tax haven. For example, Suárez Serrato (2018) use this theory to study how U.S. MNEs responded to a policy change that limited profit-shifting to Puerto Rico, and Bilicka et al. (2022) add a fixed cost of profit shifting to study the extensive margin of this phenomenon.[7] Our model has two advantages over these studies. First, we provide a micro-foundation for the role of intangible investment by explicitly spelling out the transfer-pricing transactions that MNEs use to engage in profit shifting.[8] Second, we embed our theory into a general-equilibrium framework, which allows us to study the macroeconomic effects of profit shifting as well as the microeconomic effects.[9] Some of our own subsequent work on this topic is also part of this strand. In Dyrda et al. (2024a), we use the framework developed herein to study optimal corporate taxation in the presence of profit shifting. In Dyrda et al. (2024b), we study how the OECD/G20 reforms would interact with other multinational-related provisions of the U.S. tax code, particularly the ones introduced by the Tax Cuts and Jobs Act on 2017.

More broadly, this paper contributes to the literature on globalization and multinational

[7]Other studies documenting real effects of profit shifting include Buettner et al. (2018), de Mooij and Liu (2020), and Schwab and Todtenhaupt (2021).

[8]In the Hines and Rice (1994) framework, the channel by which firms shift profits is left unspecified; firms can simply pay a cost to mechanically shift a portion of their profits abroad, which reduces the effective tax rate paid on these profits. Moreover, investment increases under profit shifting because it is not tax deductable, which means it is increasing in a firm's effective tax rate. However, intangible investment is tax deductable in most jurisdictions, including the United States.

[9]Ferrari et al. (2023) also build a general-equilibrium model of profit shifting based on Hines and Rice (1994). Aside from micro-founding the profit-shifting technology, our approach offers several advantages over theirs. First, our model features endogenous selection into profit shifting, which allows it to capture the fact that only a small number of the largest MNEs engage in this behavior and are therefore affected directly by anti-BEPS policies. Second, our approach allows profit shifting to alter the balance of payments in equilibrium, generating effects like those documented in Guvenen et al. (2022) and Hebous et al. (2021).

activity. One strand of this literature emphasizes the role of firm heterogeneity and selection. The seminal papers of Melitz (2003) and Chaney (2008) study selection into exporting. Helpman et al. (2004) develop a model of the "proximity-concentration tradeoff," in which firms can serve foreign markets by exporting, which requires a small fixed cost but larger variable costs, or by establishing foreign affiliates, which requires a large fixed cost but smaller variable costs. More recent work incorporates additional margins like export platforms (Tintelnot, 2017), endogenous product creation (Arkolakis et al., 2018), selection dynamics (Garetto et al., 2019), and offshoring (Spencer, 2021). Another strand emphasizes the role of nonrival intangible capital in shaping the aggregate effects of foreign direct investment (FDI). McGrattan and Prescott (2009) build a neoclassical growth model in which the representative multinational invests in intangible capital that can be used simultaneously to produce output at home and abroad, and show that this channel substantially increases the gains to openness to FDI. McGrattan and Waddle (2020) use a multi-country version of this model to study the macroeconomic consequences of FDI restrictions caused by Brexit. We synthesize these two approaches by developing a model in which heterogeneous firms choose where to export, where to establish foreign affiliates, and how much to invest in nonrival intangible capital. On top of this new framework, we incorporate our theory of profit shifting, allowing firms to additionally choose whether to establish affiliates in a tax haven and how much intangible capital to shift.

In terms of quantitative methodology, the most similar papers to ours are Arkolakis et al. (2018) and Wang (2020). Arkolakis et al. (2018) studies the relationship between innovation and multinational production. In their model, innovation is used to create new firms which then go on to make decisions about where to establish foreign affiliates. This innovation occurs at the aggregate level (it is pinned down in equilibrium by a sort of free-entry condition) and is separate from the firm's individual optimization problem.[10] In our model, each individual firm chooses its own level of intangible investment as well as where to establish foreign affiliates. Moreover, the nonrival nature of intangible capital creates an important interaction between these two decisions: the more foreign affiliates a firm establishes, the greater the return to intangible investment. Wang (2020) extends Arkolakis et al. (2018) to incorporate corporate taxes and profit shifting. Wang (2020)'s reduced-form approach to modeling profit shifting affects where firms choose to establish foreign affiliates, but it does not affect the scale of these operations. Our micro-founded approach to modeling profit shifting, which explicitly lays out the transfer pricing transactions that MNEs use to

[10] This is true even in the extension of their model described in their online appendix in which they allow for innovation that improves productivity. In this version of their model, entrants can augment the expected productivity of the firms they create, but cannot do any further productivity-enhancing innovation once these firms' productivities are drawn.

reallocate intangible income to tax havens, affects firms' incentives to invest in intangible capital, and thus affects their output both at home and abroad.

3 Model of multinational production and profit shifting

In this section, we present a theory of profit shifting integrated into a general equilibrium model with heterogeneous firms in the tradition of the international economics literature. With our profit-shifting theory, our quantitative framework synthesizes Helpman et al. (2004) and McGrattan and Prescott (2009). There are I "productive" regions, each populated by a representative household, a measure of heterogeneous firms, and a government. Indexed by i and j, regions differ in population, total factor productivity, trade costs, FDI costs, and corporate income taxes. Firms in each region decide the following: where to export and where to establish foreign subsidiaries; how much labor to hire in the parent division and each foreign subsidiary; and how much intangible capital to produce in the parent division. Importantly, intangible capital is *nonrival* in that it can used simultaneously in all of a firm's divisions.

Multinational firms (firms with foreign affiliates) use transfer pricing to allocate the costs of producing intangible capital across their foreign affiliates in proportion to the scale at which these affiliates use this capital. Affiliates license the right to use intangible capital from the division that owns this capital. MNEs can shift profits by selling their intangible capital to affiliates in lower-tax regions. We denote the "productive" region with the lowest corporate income tax rate by LT. Additionally, there is an "unproductive" tax haven populated by a representative household and a government, labeled as TH, where no economic activity occurs. MNEs based in high-tax regions can transfer their intangible capital rights to either (or both) of these regions, provided they have established subsidiaries there.

Representative households in each region choose consumption subject to budget constraint. The household receives income from labor, ownership of domestic firms, and lump-sum transfers. The government collects corporate income tax revenues and passes them to the household. We present the details of the model in what follows.

3.1 Households

Each region i has a population N_i of identical households that supply labor inelastically and have standard preferences over consumption, C_i, given by $u_i(C_i) = \log(C_i)$. The representative household's budget constraint is

$$P_i C_i = W_i N_i + D_i + T_i, \tag{1}$$

where W_i is the wage, D_i is the aggregate dividend payment from firms based in region i, and T_i is a transfer from the government.

Consumption is a constant-elasticity-of-substitution aggregate of products from different source countries,

$$C_i = \left[\sum_{j=1}^{J} \int_{\Omega_{ji}} q_{ji}(\omega)^{\frac{\rho-1}{\rho}} d\omega \right]^{\frac{\rho}{\rho-1}}, \tag{2}$$

where $q_{ji}(\omega)$ is the quantity of variety ω from region j, Ω_{ji} is the set of goods from j available in i, and ρ is the elasticity of substitution between varieties. The demand curve for each variety can be written as

$$p_{ji}(\omega) = P_i C_i^{\frac{1}{\rho}} q_{ji}(\omega)^{-\frac{1}{\rho}}. \tag{3}$$

The aggregate price index is

$$P_i = \left[\sum_{j=1}^{J} \int_{\Omega_{ji}} p_{ji}(\omega)^{1-\rho} d\omega \right]^{\frac{1}{1-\rho}}. \tag{4}$$

3.2 Firms: technology

Each productive region i has a unit measure Ω_i of firms that compete monopolistically as in Melitz (2003) and Chaney (2008). Firms are heterogeneous in productivity, a, which is drawn from a distribution $F_i(a)$. Firms produce their products using labor and intangible capital. Intangible capital, which we denote by z, is nonrival: it is produced in the home country but can be used to produce abroad as well, provided that a firm pays the cost of setting up a foreign affiliate in another productive region. We index firms by their productivities instead of their varieties to economize on notation; all firms from a given region with the same productivity make the same decisions.

Production. A firm from region i with productivity a and intangible capital z can produce its good in any productive region j, populated by N_j people, using the technology

$$y_{ij} = \sigma_{ij} A_j a \left(N_j z_i\right)^{\phi} \ell_j^{\gamma}. \tag{5}$$

where ℓ_j stands for labor hired locally in j. It also depends on the firm's idiosyncratic productivity as well as region j's aggregate productivity A_j; and the firm's ability to deploy its productivity and intangible capital abroad may be limited by FDI barriers, σ_{ij}, as in McGrattan and Waddle (2020). We assume that $\sigma_{ij} \in [0, 1]$ and that $\sigma_{ii} = 1$.

Intangible capital. Firms hire workers in their domestic parent corporations to produce intangible capital (R&D). We assume that firm from region i produces intangible capital according to the following technology:

$$z = A_i a l_i^z \tag{6}$$

In other words, it takes $1/(A_i a)$ workers in region i to produce one unit of intangible capital, i.e., the cost to produce z units of intangible capital is $W_i/(A_i a)$. This is similar to McGrattan and Prescott (2009), who assume that firms can transform their output one-for-one into intangible capital. We assume that R&D expenditures are tax-deductible, which is how they are treated under most countries' tax codes.

Trade and foreign direct investment. Firms can sell in the domestic market freely, but serving foreign markets is costly. There are two options for serving foreign markets: (i) pay a fixed cost κ_i^X to export domestically produced goods; and (ii) pay a fixed cost κ_i^F to open a foreign affiliate and produce locally. Fixed costs are denominated in units of the home country's labor. Each unit of goods shipped from region i to j incurs an iceberg transportation cost ξ_{ij}. As in Garetto et al. (2019) and McGrattan and Waddle (2020), we assume that exported and locally produced products are considered distinct varieties, so firms can simultaneously export to, and produce locally for, the same foreign country.[11] Let $J_X \subseteq I \setminus \{i\}$ denote the set of foreign regions to which a firm exports, and let $J_F \subseteq I \setminus \{i\}$ denote the set of regions in which it operates a foreign affiliate. The firm's resource constraints can then be written as follows:

$$y_{ii} = q_{ii} + \sum_{j \in J_X} \xi_{ij} q_{ij}^X, \tag{7}$$

$$y_{ij} = q_{ij}, \ j \in J_F, \tag{8}$$

where we distinguish exported goods, denoted as q_{ij}^X, from goods that are produced and consumed in the same location, q_{ij}. We refer to a multinational as a firm with $J_F \neq \emptyset$.

3.3 Firms: profit shifting

Multinationals' foreign affiliates are required to pay licensing fees to use intangible capital according to the rules of transfer pricing. The licensing fee of a subsidiary in region j is given

[11] In a version of the model where firms must choose whether to export or produce locally for each foreign market as in Helpman et al. (2004), the results of our experiments are similar to our baseline results, but non-MNEs' share of value added is too large relative to the data. While we do not explicitly allow for export platforms as in Arkolakis et al. (2018) and Wang (2020), our approach of aggregating the world into five regions can be interpreted as allowing foreign subsidiaries in a given region to "export" to all of the countries within that region costlessly.

by $\vartheta_{ij}(z)z$, where $\vartheta_{ij}(z) \equiv \gamma p_{ij} y_{ij}/z$ is the marginal revenue product of intangible capital, which captures the "arm's length" rule for how transactions between related parties are supposed to be priced. The total amount of licensing fees across the conglomerate is $\nu_i(z)z \equiv \sum_{j \in J_F \cup \{i\}} \vartheta_{ij}(z)z$. Note that this includes the licensing fee for the parent corporation's use of its own intangible capital, and thus captures the total value of an MNE's intangible capital.

A multinational based in a high-tax region can shift intangible capital licensing income to the low-tax region and/or the tax haven by transferring ownership of its intangible capital to its affiliates in these regions (provided that the fixed costs to establish these affiliates have been paid). To make this concrete, suppose an MNE sells a fraction λ_{LT} of its intangible capital to the former and a fraction λ_{TH} to the latter. Then, its affiliate in the LT region collects licensing fees of $\lambda_{LT} \sum_{j \in J_F \cup \{i\} \setminus \{LT\}} \vartheta_{ij}(z)z$, its affiliate in the TH region collects $\lambda_{TH} \sum_{j \in J_F \cup \{i\}} \vartheta_{ij}(z)z$, and the domestic parent corporation collects the remaining fees, $(1 - \lambda_{LT} - \lambda_{TH}) \sum_{j \in J_F} \vartheta_{ij}(z)z$. MNEs based in the low-tax region cannot shift profits.

The sale of intangible capital from an MNE's domestic parent in region i to its affiliate in region $j \in \{LT, TH\}$ is priced at markdown $\mu_{ij} < 1$ below the intangible capital's total market value per unit, $\nu_i(z)$. This captures the idea that profit shifting hinges on MNEs' ability to exploit the difficulty and lack of transparency involved in valuing intangible capital, as argued for example by Neubig and Wunsch-Vincent (2017).[12] Recall the figures from U.S. Senator Carl Levin's testimony cited in section 1: Apple's Irish affiliate paid \$5 billion for the rights to license Apple U.S.A's intellectual property and collected \$74 billion in income. These figures suggest that the purchase price for these licensing rights was far below the fair market value. It it important to emphasize that this markdown is what creates the incentive for MNEs to shift profits in the first place. If the sale of intangible capital occurred at fair market value ($\mu_{ij} = 1$), then an MNE's parent corporation would generate the same profits regardless how much intangible capital is transferred; the amount of profits shifted from the parent to the tax haven is precisely the difference between the price paid by the tax-haven affiliate to acquire the intangible capital and that capital's fair market value. We illustrate this formally in section 4 below.

While there is a benefit to profit shifting generated by the markdown, there is also a cost. We denote the cost (in units of home-country labor) to sell a fraction λ_j of intangible capital to country $j \in \{LT, TH\}$ by $\mathcal{C}_i(\lambda_{LT}, \lambda_{TH})$. We assume that this function satisfies several economically intuitive properties:

[12] We have explored an alternative formulation in which MNEs can "mark up" the licensing fees above the marginal product of intangible capital instead of marking down the price at which this capital can be sold. These two setups are mathematically isomorphic, provided that the markdown and markup are chosen appropriately. A proof of this equivalence is available upon request.

Assumption 1 *Let* $\boldsymbol{\lambda} = [\lambda_{LT}, \lambda_{TH}]$ *and*

$$\Gamma = \left\{ \boldsymbol{\lambda} \in [0,1]^2 : \lambda_{LT} + \lambda_{TH} \leq 1 \right\}. \tag{9}$$

The cost function $\mathcal{C}_i : \Gamma \to \mathbb{R}_+$ *has the following properties:*

1. *At least twice continuously differentiable.*
2. $\mathcal{C}_i^j \equiv \frac{\partial \mathcal{C}_i}{\partial \lambda_j} > 0$ *for* $j \in \{LT, TH\}$.
3. $\mathcal{C}_i^{jj} \equiv \frac{\partial^2 \mathcal{C}_i}{\partial {\lambda_j}^2} > 0$ *for* $j \in \{LT, TH\}$.
4. $\mathcal{C}_i(\mathbf{0}) = 0$. *Additionally, for every sequence* $\{\boldsymbol{\lambda}_n\} \subseteq \Gamma$ *with* $\boldsymbol{\lambda}_n \to \boldsymbol{\lambda}^*$ *and* $\lambda^*_{LT} + \lambda^*_{TH} = 1$, *it holds that* $\lim_{n\to\infty} \mathcal{C}_i^j(\boldsymbol{\lambda}_n) = \infty$ *for* $j \in \{LT, TH\}$.

The first assumption is for mathematical convenience. The second assumption says that the cost of transferring intangible capital to each destination is increasing in the amount transferred. The third says that the marginal cost is also increasing, i.e., each additional unit of transferred intangible capital incurs a larger and larger cost. The fourth assumption says that firms that do not engage in profit shifting do not incur any costs, and that transferring the entire stock of intangible capital away from the parent location is prohibitively costly. It is important to note that $\mathcal{C}_i(\lambda)$ captures the direct costs of profit shifting (e.g., increased spending on lawyers, accountants, and transfer pricing consultants) but also, in a reduced-form way, the increased risk of penalization by the government (see, e.g., Allingham and Sandmo, 1972; Rotberg and Steinberg, 2022).

3.4 Firms: profit-maximization problem

The firm's objective is to maximize its dividend payout. The firm chooses where to export (J_X); where to open foreign affiliates (J_F); intangible investment (z); employment in each of its divisions (ℓ_{ij}); quantity sold in each of its markets (q_{ij}, q_{ij}^X); and how much intangible capital to transfer to the low-tax region (λ_{LT}) and the tax haven (λ_{TH}). We break this problem into two stages, working backward. In the second stage, the firm maximizes each division's gross operating profits taking $\{J_X, J_F, z, \lambda_{LT}, \lambda_{TH}\}$ as given. In the first stage, the firm maximizes its global after-tax profits by choosing these objects.

Stage 2: Operating profits. The domestic parent corporation's profits are

$$\pi_i^D(a,z;J_X) = \max_{q_{ii},\{q_{ij}^X\}_{j\in J_X},\ell_i} \left\{ p_{ii}(q_{ii})q_{ii} + \sum_{j\in J_X} p_{ij}(q_{ij}^X)q_{ij}^X - W_i\ell_i \right\}$$
$$\text{s.t} \quad q_{ii} + \sum_{j\in J_X} \xi_{ij}q_{ij} = y_i = A_i a (N_i z)^\gamma \ell_i^\phi. \tag{10}$$

Foreign subsidiaries' profits are

$$\pi_{ij}^F(a,z) = \max_{q_{ij},\ell_j} \; p_{ij}(q_{ij})q_{ij} - W_j\ell_j, \; j \in J_F. \tag{11}$$

Stage 1: Locations, intangible capital, and profit shifting. The firm's after-tax global profits are

$$d_i(a) = \max_{\substack{z,J_X,J_F,\\ \lambda_{TL},\lambda_{TH}\in\Gamma}} \left\{ (1-\tau_i)\pi_{ii} + (1-\tau_{LT})\pi_{i,LT}\mathbb{1}_{\{LT\in J_F\}} + (1-\tau_{TH})\pi_{i,TH}\mathbb{1}_{\{\lambda_{TH}>0\}} \right.$$
$$\left. + \sum_{j\in J_F\setminus\{LT\}} (1-\tau_j)\pi_{ij} \right\} \tag{12}$$

The first term in (12) represents the taxable profits of the parent division, π_{ii}. The second term represents the taxable profits of the low-tax affiliate, $\pi_{i,LT}$. The third represents the taxable profits of the tax-haven affiliate, $\pi_{i,TH}$. The fourth represents the taxable profits of affiliates in other high-tax regions, π_{ij}.[13] We now discuss the components of these terms in more detail.

[13] We abstract in our model from the Global Intangible Low Tax Income (GILTI), adopted by the U.S. government in 2017, for two reasons. First, once we take the model to the data (see next section) we treat North America as a single region. Second, according to the scarce literature on GILTI, see Clausing (2020b) and Garcia-Bernardo et al. (2022), it had limited impact on profit shifting of U.S. multinationals. We address these issues in Dyrda et al. (2024b).

The parent division's taxable profits are defined as

$$\pi_{ii} = \pi_i^D(a,z;J_X) - W_i \overbrace{\left(l_i^z + \sum_{j\in J_X}\kappa_{ij}^X + \sum_{j\in J_F}\kappa_{ij}^F + \kappa_{iTH}\mathbb{1}_{\{\lambda_{TH}>0\}}\right)}^{\text{Costs of intangible capital production and fixed costs}} \tag{13}$$
$$+ \overbrace{(\mu_{iLT}\lambda_{LT} + \mu_{iTH}\lambda_{TH})\,\nu_i(z)z}^{\text{Proceeds from selling } z} + \overbrace{\sum_{j\in J_F}(1-\lambda_{LT}-\lambda_{TH})\vartheta_{ij}(z)z}^{\text{Licensing fee receipts}} - \overbrace{(\lambda_{LT}+\lambda_{TH})\vartheta_{ii}(z)z}^{\text{Licensing fee payments}}$$
$$- \overbrace{W_i\mathcal{C}_i(\lambda_{LT},\lambda_{TH})\nu_i(z)z}^{\text{Cost of transferring } z}.$$

The first term represents the parent's operational profit as defined in (10). The second term captures the cost of producing intangible capital and the fixed costs of exporting and establishing foreign affiliates, both of which use domestic labor. The third term is the revenue from selling marked-down intangible capital to the two profit-shifting destinations. The fourth term represents the licensing fee income associated with intangible capital retained by the parent. The fifth term contains the associated licensing fees paid by the parent division on the transferred intangible capital. The sixth term shows the costs of profit shifting.

Taxable profit of a subsidiary in the low tax region is given by

$$\pi_{iLT} = \pi_{iLT}^F(a,z) + \overbrace{\sum_{j\in J_F\cup\{i\}\setminus\{LT\}}\lambda_{LT}\vartheta_{ij}(z)z}^{\text{Licensing fee receipts}} - \underbrace{\mu_{iLT}\lambda_{LT}\nu_i(z)z}_{\text{Cost of buying } z} - \underbrace{(1-\lambda_{LT})\vartheta_{iLT}(z)z}_{\text{Licensing fee payment}} \tag{14}$$

The first term is operating profit defined in (11). The second term represents the licensing fees collected on the fraction of intangible capital transferred to the LT region, λ_{LT}. The third term represents the marked-down cost of purchasing this intangible capital from the parent division. The last term represents the licensing fee the affiliate in this region pays on the fraction of intangible capital that it does not purchase, $1-\lambda_{LT}$.

Taxable profits of a subsidiary in the unproductive tax haven, are defined as

$$\pi_{iTH} = \underbrace{\sum_{j\in J_F\cup\{i\}}\lambda_{TH}\vartheta_{ij}(z)z}_{\text{Licensing fee receipts}} - \underbrace{\mu_{iTH}\lambda_{TH}\nu_i(z)z.}_{\text{Cost of buying } z} \tag{15}$$

The first term represents the licensing fees collected on the fraction of intangible capital transferred to the TH region, λ_{TH}. The second term represents the marked-down cost of purchasing this capital.

Finally, taxable profits of a subsidiary in another high-tax region j are

$$\pi_{ij} = \pi_{ij}^F(a,z) - \underbrace{\vartheta_{ij}(z)z.}_{\text{Licensing fee}} \tag{16}$$

The two terms are the operating profit defined in (11) and the licensing fees paid for the use of intangible capital, respectively.

3.5 Aggregation and accounting measures

Several national and international accounting measures are required to close the model and compare it to the data. Here, we revert to expressing firms' choices as functions of their varieties (ω) for notational brevity.

Gross domestic product. Nominal GDP is the total value of goods produced in a given region:

$$GDP_i = \sum_{j=1}^{I} \int_{\omega \in \Omega_j, i \in J_F(\omega)} p_{ji}(\omega) y_{ji}(\omega)\ d\omega. \tag{17}$$

We compute real GDP by deflating by the consumer price index P_i defined in (4).

Goods trade. Aggregate goods trade flows are given by

$$EX_i^G = \sum_{j \neq i} \int_{\Omega_i} p_{ij}^X(\omega)\,(1+\xi_{ij})\, q_{ij}^X(\omega)\ d\omega, \tag{18}$$

$$IM_i^G = \sum_{j \neq i} \int_{\Omega_j} p_{ji}^X(\omega)\,(1+\xi_{ji})\, q_{ji}^X(\omega)\ d\omega. \tag{19}$$

Services trade. Consistent with Guvenen et al. (2022) and Accoto et al. (2021), intangible capital licensing fees enter the national accounts as exports or imports of intellectual property services.[14] High-tax regions' services trade flows are given by

$$EX_i^S = \sum_{j \neq i} \int_{\Omega_i} \left[1 - \lambda_{LT}(\omega) - \lambda_{TH}(\omega)\right] \vartheta_{ij}(\omega) z(\omega)\ d\omega \qquad (20)$$

$$+ \int_{\Omega_i} [\mu_{i,LT} \lambda_{LT}(\omega) + \mu_{i,TH} \lambda_{TH}(\omega)] \nu_i(\omega) z(\omega)\ d\omega$$

$$IM_i^S = \sum_{j \neq i} \int_{\Omega_i} \left[\lambda_{LT}(\omega) + \lambda_{TH}(\omega)\right] \vartheta_{ij}(\omega) z(\omega)\ d\omega + \sum_{j \neq i} \int_{\Omega_j} \vartheta_{ji}(\omega) z(\omega)\ d\omega. \qquad (21)$$

The low-tax region's services trade flows are

$$EX_{LT}^S = \sum_{j \neq LT} \int_{\Omega_{LT}} \vartheta_{LT,j}(\omega) z(\omega)\ d\omega + \sum_{j \neq LT} \int_{\Omega_j} \lambda_{LT}(\omega) \sum_{k \neq LT} \vartheta_{j,k}(\omega) z(\omega)\ d\omega, \qquad (22)$$

$$IM_{LT}^S = \sum_{j \neq LT} \int_{\Omega_j} [1 - \lambda_{LT}(\omega)] \vartheta_{j,LT}(\omega) z(\omega)\ d\omega + \sum_{j \neq LT} \int_{\Omega_j} \mu_{j,LT} \lambda_{LT}(\omega) \nu_j(\omega) z(\omega)\ d\omega. \qquad (23)$$

The tax haven's services trade flows are

$$EX_{TH}^S = \sum_{j \neq TH} \int_{\Omega_j} \lambda_{TH}(\omega) \nu_j(\omega) z(\omega)\ d\omega, \qquad (24)$$

$$IM_{TH}^S = \sum_{j \neq TH} \int_{\Omega_j} \mu_{j,TH} \lambda_{TH}(\omega) \nu_j(\omega) z(\omega)\ d\omega. \qquad (25)$$

Net factor receipts and payments. Net factor receipts from (payments to) foreigners are the sum total of the dividends paid by foreign subsidiaries of domestic multinationals (domestic subsidiaries of foreign multinationals):

$$NFR_i = \sum_{j \neq i} \int_{\Omega_i} (1 - \tau_j) \pi_{ij}(\omega)\ d\omega, \qquad (26)$$

$$NFP_i = \sum_{j \neq i} \int_{\Omega_j} (1 - \tau_i) \pi_{ji}(\omega)\ d\omega. \qquad (27)$$

[14]For simplicity, we include marked-down transfers of intangible capital ownership as services trade as well as licensing fees. In reality, these transfers may actually enter the financial account depending on how they are structured. However, due to the balance of payments identity this does not affect the way these transfers affect the overall balance of payments. Our accounting allows us to avoid defining the financial account altogether.

3.6 Market clearing and equilibrium

In a general equilibrium of our model, the labor market must clear, the government's budget constraint must be satisfied, and the balance of payments must hold in each productive region.

Labor market. Labor demand comes from four sources: production of intermediate goods; production of intangible capital; fixed costs of exporting and setting up foreign affiliates; and the costs of transferring intangible capital. The labor market clearing condition can be written as

$$N_i = \overbrace{\sum_{j=1}^{I} \int_{\Omega_j} \ell_{ji}(\omega)\ d\omega}^{\text{goods production}} + \overbrace{\int_{\Omega_i} l_i^z\ d\omega}^{z \text{ production}} + \overbrace{\int_{\Omega_i} \left(\sum_{j \in J_X(\omega)} \kappa_i^X + \sum_{j \in J_F(\omega)} \kappa_i^F + \mathbb{1}_{\{\lambda_{TH}(\omega)>0\}} \kappa_i^{TH} \right) d\omega}^{\text{fixed costs}}$$
$$+ \underbrace{\int_{\Omega_i} \mathcal{C}_i(\lambda_{LT}, \lambda_{TH}) \nu(\omega) z(\omega)\ d\omega}_{\text{costs of shifting } z}. \tag{28}$$

Note that at the macro level, profit shifting diverts labor from goods production and R&D to wasteful administrative costs, potentially offsetting the positive macroeconomic effects of increased R&D at the micro level, and policies that reduce profit shifting such as the OECD/G20 proposal free up some of these wasted resources. We discuss the quantitative importance of this channel in section 5.3 below.

Government budget constraint. We assume that revenue from corporate income taxation is rebated lump-sum to households.[15] Lump-sum transfers are given by

$$T_i = \tau_i \sum_{j=1}^{I} \int_{\Omega_j} \pi_{ji}(\omega)\ d\omega. \tag{29}$$

Balance of payments. The balance of payments requires that each region's current account must be zero:

$$EX_i^G + EX_i^S - IM_i^G - IM_i^S + NFR_i - NFP_i = 0. \tag{30}$$

Note that several things happen to the balance of payments when a firm shifts profits away from its home region. First, that region's services trade balance worsens: the firm receives

[15]With a fixed supply of labor, this assumption is without loss of generality. We have also analyzed a version of the model with endogenous labor supply. In this model, the results are similar with lump-sum transfera and when labor income taxes adjust to clear the government's budget constraint.

fewer licensing fees from its foreign subsidiaries and makes more licensing payments. Second, net factor receipts rise: the firm's profits in the tax haven (or low-tax region) rise, and these increased profits are ultimately rebated back to the home country. These two effects offset one another, but not completely: some of the shifted profits are taxed and therefore remain in the tax haven and/or low-tax region. Thus, the net effect is that the current account worsens. The reduction in the services trade balance and the increase in net factor income are consistent with the accounting of Guvenen et al. (2022). The net negative effect on the balance of payments is consistent with the findings of Hebous et al. (2021). To regain equilibrium, that trade balance and/or net factor income balance must improve, which shows up in our model as a real exchange rate depreciation.

Competitive equilibrium. Given a set of parameters, an equilibrium in our model is defined as a set of aggregate prices and quantities $\{W_i, P_i, C_i\}$ and a set of firm decision rules $\{J_X(\omega), J_F(\omega), z(\omega), \boldsymbol{\ell}(\omega), \boldsymbol{q}(\omega), \lambda_{LT}(\omega), \lambda_{TH}(\omega)\}$ for each productive region $i \in I$ that satisfy the household's problem, the firm's problem, and the market-clearing conditions.

4 Theoretical properties of the model

In this section, we study a stripped-down version of the model outlined in Section 3 to formally characterize the real effects of profit shifting and the economic implications of the OECD/G20 proposal. We make five simplifying assumptions. First, we confine our analysis to a partial-equilibrium framework, concentrating on the firm's profit-maximization problem laid out in Section 3.4. Second, we assume that firms do not export and produce freely in an exogenous set of foreign locations J_F. Third, we assume perfect competition with decreasing returns to scale instead of monopolistic competition with constant returns. Fourth, we assume that MNEs do not internalize the impact of their intangible capital decisions on licensing fees, i.e.., they take $\vartheta_{ij}(z)$ as given.[16] Finally, we assume that there is a single destination for profit shifting, specifically the tax haven (TH). These assumptions allow us to isolate the key drivers of profit shifting and examine their impact on the allocation of intangible capital.

Under these simplifying assumption specified, the profit of the MNE becomes:

$$d_i(a) = \max_{z,\, \lambda\in[0,1]} \left\{ (1-\tau_i)\pi_{ii} + (1-\tau_{TH})\pi_{i,TH} + \sum_{j\in J_F} (1-\tau_j)\pi_{ij} \right\} \tag{31}$$

where $\pi_{ii}, \pi_{i,TH}$ and π_{ij} are adjusted accordingly to reflect our simplifying assumptions.[17] To economize on notation, we denote by λ the fraction of intangible capital sold to the tax

[16] This assumption simplifies formulas but does not change the economic message from our analysis. We relax this assumption in Appendix F.3.

[17] The details of all derivations are provided in the Appendix F.

haven. We impose the following profit-shifting cost function, which satisfies properties 1–3 of in Assumption 1.

$$\mathcal{C}(\lambda) \equiv \lambda + (1-\lambda)\log(1-\lambda) \tag{32}$$

4.1 Intangible investment without profit shifting

We begin by characterizing a scenario without profit shifting in which MNEs cannot sell intangible capital to the tax haven. The profit-maximizing level of intangible investment in this case is:

$$z^{NS} = \left(\frac{A_i a \sum_{j\in J_F\cup\{i\}} \Lambda_j}{W_i}\right)^{\frac{1-\gamma}{1-\phi-\gamma}}, \tag{33}$$

where $\Lambda_j \equiv \phi\gamma^{\frac{\gamma}{1-\gamma}} p_{ij}^{\frac{1}{1-\gamma}} A_j^{\frac{1}{1-\gamma}} \left(\frac{1}{W_j}\right)^{\frac{\gamma}{1-\gamma}} N_j^{\frac{\phi}{1-\gamma}}$. Several properties are obvious: intangible investment is increasing in an MNE's idiosyncratic productivity level a, as well as the aggregate productivity level A_j, the population N_j, and the price p_{ij} in each production location $j \in J_F \cup \{i\}$, and it is decreasing in the cost of R&D labor W_i and in the wage W_j in each production location.

There are two important properties worth highlighting. First, intangible investment is increasing in the number of foreign production locations $\#J_F$ due to nonrivalry, which means that, *ceteris paribus*, MNEs do more intangible investment than non-MNEs, and more-global MNEs do more than less-global ones.[18] Second, it does not depend on the corporate tax rate in the home country or in any of the foreign locations because both the costs and benefits are tax deductible in the home country due to transfer pricing, which implies that corporate taxes are not distortionary in the absence of profit shifting.

4.2 Optimal profit shifting

We now bring back the profit shifting margin into (31). We first study the MNE's choice of how much intangible capital to shift to tax haven, λ. The profit-maximizing solution for λ is

$$\lambda = 1 - \exp\left(-\frac{(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}\right). \tag{34}$$

The following lemma provides a formal characterization of how this solution depends on the profit shifting technology, which is governed by the markdown μ, and the potential gain from shifting profits, which is governed by the tax haven's tax rate τ_{TH}.

[18] Of course, all else is not equal in equilibrium. In the full quantitative model, where J_F is endogenous, higher-productivity firms choose to open more foreign affiliates, and which increases the elasticity of intangible investment to idiosyncratic productivity. This is one reason that firm heterogeneity matters for quantitative analysis in this context.

Lemma 2 *The share λ of intangible capital sold to the tax haven is:*

1. *decreasing in μ with elasticity*

$$\varepsilon_{\mu}^{\lambda} = -\left(\frac{\lambda - 1}{\lambda}\right)\log(1-\lambda)\frac{\mu}{1-\mu} < 0, \tag{35}$$

2. *decreasing in τ_{TH} with elasticity*

$$\varepsilon_{\tau_{TH}}^{\lambda} = -\left(\frac{\lambda - 1}{\lambda}\right)\log\left(1-\lambda\right)\frac{\tau_{TH}}{\tau_i - \tau_{TH}} < 0. \tag{36}$$

The first part of this lemma says that the smaller the markdown below the competitive price (i.e. the larger μ is), the smaller the fraction of intangible capital that is shifted to the tax haven. In particular, if the MNE has to sell the rights to intangible capital at the competitive price with no markdown (i.e., $\mu = 1$), then no profit shifting takes place at all. The second part says that λ is decreasing in the tax haven's tax rate, τ_{TH}. Specifically, the elasticity of λ with respect to τ_{TH} is larger when λ is closer to zero, when τ_{TH} is larger, and when τ_i is smaller.

4.3 Profit shifting and intangible investment

Having characterized the MNE's decision about how much intangible capital to transfer to the tax haven, we can now characterize the effect of this decision on the MNE's intangible investment choice.

$$z = z^{NS} \times \left(\underbrace{1 - W_i\mathcal{C}\left(\lambda\right) + \frac{\lambda\left(1-\mu\right)\left(\tau_i - \tau_{TH}\right)}{1-\tau_i}}_{\Omega(\lambda)}\right)^{\frac{1-\gamma}{1-\phi-\gamma}}, \tag{37}$$

The first term in (37) is the intangible investment without profit shifting as derived in (33). The second term, $\Omega(\lambda)$, represents the is the gain from profit shifting per unit of intangible capital, where λ is endogenous and given by (34).

Proposition 1 *The following hold if $\tau_{TH} < \tau_i$ and $\mu < 1$:*

1. *$z > z^{NS}$, i.e., profit shifting increases intangible investment.*

2. *z is decreasing in τ_{TH} with an elasticity given by:*

$$\varepsilon_{\tau_{TH}}^{z} = -\left(\frac{1-\gamma}{1-\phi-\gamma}\right)\left(\frac{\tau_{TH}}{\tau_i - \tau_{TH}}\right)\frac{1}{\left(1+\frac{1-W_i\mathcal{C}(\lambda)}{\lambda W_i\mathcal{C}'(\lambda)}\right)} < 0; \tag{38}$$

3. z is decreasing in μ with an elasticity given by:

$$\varepsilon_{\mu}^{z} = -\left(\frac{1-\gamma}{1-\phi-\gamma}\right)\left(\frac{\mu}{1-\mu}\right)\frac{1}{\left(1+\frac{1-W_i\mathcal{C}(\lambda)}{\lambda W_i\mathcal{C}'(\lambda)}\right)} < 0. \tag{39}$$

The first part of the proposition states that if the MNE chooses to shift profits, which happens when the tax haven's tax rate is lower than the home country's and the markdown is positive, then intangible investment is strictly higher than it would be in the absence of profit shifting. The intuition is that under these conditions, the net gain from profit shifting is positive, i.e., $\Omega(\lambda) > 1$, which increases the marginal return on intangible investment. The second and third parts characterize how changes in these conditions vary the magnitude of the effect described in the first part. As τ_{TH} or the markdown parameter μ increase, λ falls as shown in Lemma 2, and so does the gain from profit shifting, $\Omega(\lambda)$, reducing the return on intangible investment closer to what it would be without profit shifting.

These results highlight the central economic trade-off we uncover in this paper: profit shifting erodes high-tax countries' tax bases, but also boosts economic activity by increasing MNEs' intangible investment. This trade-off has important implications for the OECD/G20 BEPS framework. Specifically, a global minimum corporate income tax—which in this simple environment can be interpreted as an increase the tax haven's tax rate τ_{TH}—will reduce profit shifting, but this reduction will come at the cost of lower intangible investment.

4.4 Effects of sales-based profit allocation

We can also use our simplified model to illustrate the impact of the first pillar of the OECD/G20 framework, which allocates the rights to tax a portion of an MNE's global profits to the regions in which it operates in proportion to these regions' shares of the MNE's overall sales.

Under this rule, the tax base of a subsidiary in region j is the sum of local routine profit π_j^r, a share $(1-\theta)$ of local residual profit π_j^R, and a fraction of total global residual profit Π^R that is based on this region's share of the MNE's total global sales:

$$T_j = \pi_j^r + (1-\theta)\cdot\pi_j^R + \theta\cdot\frac{R_j}{\sum_{k\in J_F\cup\{i\}} R_k}\cdot\Pi^R. \tag{40}$$

Routine profit is defined as the fraction ι of the revenues R_j in jurisdiction j: $\pi_j^r = \iota R_j$. Residual profit is defined as the complementary fraction: $\pi_j^R = \pi_j - \pi_j^r$. Global residual profit is the sum of residual profits across regions: $\Pi^R = \sum_{j\in J_F\cup\{i\}} \pi_j^R$. The two key parameters of the rule are: (i) the fraction of residual profits that are allocated across regions based on sales, θ; and (ii) the routine profitability margin, ι. Under the OECD/G20 proposal, these are set to $\theta = 0.25$ and $\iota = 0.1$, but in what follows we will analyze comparative statics with respect to their values.

The MNE's profit-maximization problem under the sales-based profit allocation rule can be written as

$$\max_{z,\{\ell_j\}_{j\in J_F\cup\{i\}},\lambda} \sum_{j\in J_F\cup\{i\}} (\pi_j - \tau_j T_j). \tag{41}$$

We use hats to distinguish the solutions to this modified problem from the solutions to (31). The share of intangible capital sold to the tax haven under this rule is

$$\hat{\lambda} = 1 - \exp\left(-\frac{(1-\mu)(1-\theta)(\tau_i - \tau_{TH})}{W_i\left(1 - \left((1-\theta)\tau_i + \theta\widehat{\tau}\right)\right)}\right). \tag{42}$$

where $\widehat{\tau}$ is the sales-weighted average tax rate across regions:

$$\widehat{\tau} \equiv \sum_{j\in J_F\cup\{i\}} \tau_j \cdot \frac{R_j}{\sum_{k\in J_F\cup\{i\}} R_k}. \tag{43}$$

Intangible investment is given by

$$\hat{z} = z^{NS}\left(1 - W_i\mathcal{C}(\lambda) + \frac{\lambda(1-\theta)(1-\mu)(\tau_i - \tau_{TH})}{1 - \left((1-\theta)\tau_i + \theta\widehat{\tau}\right)}\right)^{\frac{1-\gamma}{1-\phi-\gamma}}. \tag{44}$$

The following lemma and proposition illustrate how the sales-based profit allocation rule affects profit shifting and intangible investment.[19]

Lemma 3 *The following hold if $\theta \in (0,1)$:*

1. *$\hat{\lambda} < \lambda$, i.e., sales-based profit allocation reduces profit shifting.*
2. *$\hat{\lambda}$ is decreasing in θ with elasticity*

$$\varepsilon_\theta^{\hat{\lambda}} = -\frac{\hat{\lambda}-1}{\hat{\lambda}}\log\left(1-\hat{\lambda}\right)\frac{1-\hat{\tau}}{1-((1-\theta)\tau_i + \theta\widehat{\tau})}\frac{\theta}{1-\theta} < 0. \tag{45}$$

3. *$\hat{\lambda}$ is decreasing in τ_{TH} with an elasticity that takes the same form as (36).*

Proposition 2 *The following hold if $\theta \in (0,1)$:*

1. *$\hat{z} < z$, i.e., sales-based profit allocation reduces intangible investment.*

[19]In Appendix F.2, we show that the profitability margin parameter ι does not affect profit shifting or intangible investment.

2. $\hat{z}$ is decreasing in θ with elasticity

$$\varepsilon_{\theta}^{\hat{z}} = \varepsilon_{\theta}^{\hat{\lambda}} \left(\frac{1-\gamma}{1-\phi-\gamma} \right) \left(\frac{\hat{\lambda}}{\mathcal{C}(\hat{\lambda})(1-\hat{\lambda})} \right) \left(\frac{1}{1 + \frac{1 - W_i \mathcal{C}(\hat{\lambda})}{W_i \hat{\lambda} \mathcal{C}'(\hat{\lambda})}} \right) < 0; \tag{46}$$

3. $\hat{z}$ is decreasing in τ_{TH} with an elasticity that takes the same form as in (38).

In short, these results show that the sales-based profit reallocation rule has qualitatively similar effects as a global minimum tax (which can be captured in this setting as an increase in τ_{TH} as described above), and is thus subject to the same trade-off discussed above at the end of section 4.3. Both policies reduce the marginal gain from shifting profits, which reduces both profit shifting and intangible investment in equilibrium.

These results also show that increasing τ_{TH} has the same marginal effects under the profit reallocation rule as without it, but this does not mean that the two OECD/G20 pillars can be studied independently or that there would be no interaction between them. The key elasticities with respect to the two pillars' key parameters ($\varepsilon_{\tau_{TH}}^{\lambda}$, $\varepsilon_{\tau_{TH}}^{z}$, $\varepsilon_{\theta}^{\hat{\lambda}}$, and $\varepsilon_{\theta}^{\hat{z}}$) are all increasing in the current level of profit shifting, λ, which implies that the two pillars are, in a sense, substitutes. Introducing the first pillar in isolation would reduce profit shifting, and would thereby would reduce the marginal effects from subsequently introducing the second pillar (and vice versa). Quantifying the extent of this interaction and measuring which pillar would have a greater "bang for the buck"—how much it would reduce profit shifting relative to how much it affect the real economy—is one of the main goals of our quantitative analysis.

5 Calibration

We calibrate our model's parameters so that its equilibrium under the current international tax regime reproduces salient facts about production, international trade, foreign direct investment, and, most importantly, profit shifting. Some of the parameters, like elasticities of substitution, are assigned externally to standard values, while others, like population, can be set directly to exact data analogues. The remaining parameters are jointly calibrated by matching a set of target moments. These parameters influence all of the target moments to some degree, but there is one target that provides most of the identification for each parameter. Thus, in what follows, we describe each calibrated parameter alongside its main target. Table 1 lists target moments and calibrated parameter values for each region. Appendix B provides details on the data sources we use to discipline the model.

5.1 Technological parameters

Regions. We partition the world into five regions. The countries identified as tax havens by Tørsløv et al. (2022) are split into two regions: a low-tax productive region, LT, including Belgium, Ireland, Hong Kong, the Netherlands, Singapore, and Switzerland; and an unproductive tax-haven region, TH, including Luxembourg, small European countries and territories like Cyprus, Malta, and the Isle of Man, and a number of Caribbean countries. The other three regions are North America, Europe (except for the countries in the low-tax and tax-haven regions), and the rest of the world. Data for each region are obtained by aggregating or averaging country-level data. See Appendix B for more details.

Assigned parameters. The elasticity of substitution between varieties, ρ, is set to the standard value of 5. Each region's population, N_i, is set by aggregating country-level data from the World Bank's World Development Indicators database. Corporate income tax rates, τ_i, are set by averaging country-level estimates of effective corporate income tax rates from Tørsløv et al. (2022).

Technology capital share (ϕ). We set the technology capital share in the production function (5) to match the share of foreign-owned firms' income that accrues to intangible capital, which is estimated by Cadestin et al. (2021) to be 28%. Note that domestic-owned firms have lower intangible income shares, at around 22%. Although we do not target this moment in our calibration, our model is consistent with this fact. This is because technology capital is nonrival, which means that multinational firms have a greater incentive to invest in it than non-MNEs. Thus, our model captures the extent to which nonrivalry creates increasing returns at the MNE level.

Total factor productivity (A_i). Each region's TFP is set to match its aggregated real GDP based on PPP-adjusted data from the World Development Indicators database.

Productivity distribution ($F_i(a)$). We assume that firms' productivities are drawn from Pareto distributions with region-specific tail parameters η_i. We calibrate these tail parameters to match the share of aggregate employment that is accounted for by firms with fewer than 100 times the average number of employees, which is equal to 58.9% in data published by the U.S. Census Bureau. Although this is the only moment of the firm-size distribution that we target, our model's Lorenz curve is very close to its empirical counterpart.

Variable trade cost (ξ_{ij}). We set the iceberg trade barriers to match aggregate bilateral imports of goods (agriculture, resource extraction, and manufacturing) relative to nominal

GDP. Import data are from the World Input Output Database. Nominal GDP data are from the World Development Indicators. For both, we sum across the countries within each region.

Fixed export cost (κ_i^X). Each region's fixed cost of exporting is chosen so that 22.7% of firms export, as reported by Alessandria et al. (2021).

Variable FDI cost (σ_{ij}). We calibrate the parameters that govern the efficiency with which intangible capital can be deployed abroad to match the share of each region's gross value added that is accounted for by foreign multinationals. These data come from the OECD AMNE database. This share is equal to 11.12% in North America, 19.82% in Europe, 28.74% in the low-tax region, and 9.55% in the rest of the world.

Fixed FDI cost to productive regions (κ_i^F). The fixed costs of establishing foreign affiliates in other productive regions are set to match the average employment of multinational firms (i.e., firms with foreign affiliates) relative to the overall average employment of all firms. This ratio is equal to 444. The former is calculated using Compustat, while the latter is calculated using data from the U.S. Census.[20]

Fixed FDI cost to tax haven (κ_i^{TH}). The fixed costs of establishing affiliates in the tax haven region are set to match the average employment of firms that have affiliates in at least one country in our tax haven region. This ratio is equal to 981. It is also calculated using Compustat.

5.2 Profit-shifting costs

We discipline the profit-shifting cost function by matching estimates from Tørsløv et al. (2022) of the profits shifted out of high-tax regions. To compute these "lost profits" in the model, we first define $\pi_{ij}^{NS}(\omega)$ as the profits a firm would have reported in region j if it did not shift profits, holding fixed all of its other policy functions. Then, we can define the profits shifted out of region j by firm ω as

$$ps_{ij}(\omega) = \pi_{ij}^{NS}(\omega) - \pi_{ij}(\omega). \tag{47}$$

When $ps_{ijt}(\omega) > 0$, this indicates that the firm has shifted profits away from region j. Region-level lost profits are then given by:

$$PS_j = \sum_{i=1}^{I} \int_{\Omega_i} ps_{ij}(\omega)\; d\omega. \tag{48}$$

[20]Compustat contains data on public firms only. We do not have information on employment of private multinational firms. Our approach assumes that private multinationals are similar in size to public multinationals.

We impose the following functional form for the profit-shifting cost function, which satisfies the properties specified in Assumption 1:

$$\mathcal{C}_i(\lambda_{LT}, \lambda_{TH}) = \left[(\chi_{i,TH}\mathcal{C}(\lambda_{TH}))^{\epsilon} + (\chi_{i,LT}\mathcal{C}(\lambda_{LT}))^{\epsilon} \right]^{\frac{1}{\epsilon}}, \tag{49}$$

where with a slight abuse of notation, we denote $\mathcal{C}(\lambda_j) = \lambda_j + (1-\lambda_j)\log(1-\lambda_j), j \in \{TH, LT\}$. The parameter $\chi_{i,j}, j \in \{TH, LT\}$ controls the marginal cost of shifting profit from i to j. We calibrate these parameters by matching Tørsløv et al. (2022)'s estimates of (i) total lost profits, and (ii) the share of lost profits that are shifted to countries in our tax-haven region. As with production and trade data, we obtain region-level measures by summing the country-level estimates reported in this paper. Total lost profits are \$143bn for North America, \$216bn for Europe, and \$257bn for the rest of the world. The shares of these totals that are shifted to the tax-haven region are 66.39%, 44.50%, and 71.69%, respectively. We set the markdown parameters μ_{ij} to zero as they cannot be separately identified from the parameters controlling marginal costs $\chi_{i,j}$.[21]

The parameter ϵ governs the cross-derivative of the profit-shifting cost function, i.e. $\frac{\partial \mathcal{C}_i^2(\lambda_{TH},\lambda_{LT})}{\partial\lambda_{TH}\partial\lambda_{LT}}$. It is easy to show that $\frac{\partial \mathcal{C}_i^2(\lambda_{TH},\lambda_{LT})}{\partial\lambda_{TH}\partial\lambda_{LT}} > 0$ when $\epsilon < 1$. A positive cross-derivative implies that the marginal cost of shifting a share of z to TH increases with the share shifted to LT, and vice versa for the marginal cost of shifting to LT. It implies that it is costly to coordinate profit shifting endeavors to more than one destinations. On the other hand, we have $\frac{\partial \mathcal{C}_i^2(\lambda_{TH},\lambda_{LT})}{\partial\lambda_{TH}\partial\lambda_{LT}} < 0$ when $\epsilon > 1$. The negative cross-derivative happens if the headquarter of an MNE can economize resources that are used to shift profits to both LT and TH. An ideal empirical setting to discipline ϵ is to assess the degree to which λ shifted to one region changes in response to a change in corporate tax rate in another tax-haven region. However, we have not found such an empirical estimate from the literature. In the benchmark calibration, we set $\epsilon = 1$, but we conduct sensitivity analyses with different values of ϵ in Appendix D.

The flexibility of the cost function renders the firm's problem challenging to solve with a large number of regions. Specifically, the benefit of opening a tax haven subsidiary depends on the set of foreign subsidiaries it already establishes and the cost substitutability of shifting z to multiple regions. Recent developments in computational methods have advanced the resolution of large combinatorial problems, as evidenced by the works of Jia (2008), Fan and

[21] What matters from the MNE's perspective at the micro level is not the price the affiliate pays to acquire intangible capital per se, but the overall effect on the MNE's global after-tax profit relative to the cost of shifting, which is controlled by the parameter $\chi_{i,j}$. A lower markdown (smaller μ) and lower marginal cost (smaller χ) can both generate the same increase in λ and lost profits in equilibrium. As discussed above, this assumption is a reasonable approximation of reality; the figures for Apple taken from Senator Carl Levin's testimony imply a markdown of more than 93%.

Yang (2020), and Arkolakis et al. (2023). Arkolakis et al. (2023) highlight that applying these methods necessitates the complementarities among locations to be consistently either weakly positive or weakly negative. As we discuss in Appendix F.4, a positive cross-derivative of the profit-shifting cost function disrupts the global complementarity property, so we opt for a brute-force approach, which is feasible with our limited number of regions. See Appendix F.4 for a more detailed discussion.

5.3 External validation

We have calibrated the key parameters of our model—the profit-shifting costs, $\chi_{i,j}$—to match macroeconomic estimates of aggregate lost profits. However, our calibrated model also matches very closely several other facts about profit shifting that we did not target in our calibration. This indicates that it is well suited to measuring the macroeconomic effects of profit shifting and the OECD/G20 reform.

One way to validate our calibration is to measure the share of corporate income tax revenues in each region that are paid by local affiliates of foreign MNEs. The idea is that foreign MNEs should pay a large share of taxes in the low-tax region because the profits they report in this region have been artificially increased. Panel (a) of Table 2 reports the share of corporate income tax revenues paid by foreign MNEs in each region in our model according to the OECD's Corporate Tax Statistics Database (OECD, 2022a). The rest of the world has the lowest share (16.3%), followed closely by North America (16.6%). Europe has a higher share (41.6%), but, as one expects, the low-tax region has the highest share by a large margin (72.4%). Our model matches the data for Europe, the rest of the world, and the low-tax region very closely, although it overshoots the data for North America. The low-tax region's share is the most informative moment about the suitability of our calibration, however, and we reproduce this figure almost exactly.

Another way to validate our calibration is to measure MNEs' spending on profit shifting costs. Although MNEs do not report this spending in reality for obvious reasons, Tørsløv et al. (2022) argue that it can be inferred by estimating the salaries earned by transfer pricing specialists. Using data from LinkedIn and Glassdoor, they estimate that transfer pricing specialists employed in the private sector earned \$25 billion in base salary income worldwide in 2020. We compute the model counterpart of this figure by summing profit shifting costs, $W_i \mathcal{C}_i(\lambda_{TH}, \lambda_{LT})$, across all firms in all regions, which yields a value of \$82 billion. Both figures are reported in panel (b) of Table 2. Although our model's figure is about three times larger than Tørsløv et al. (2022)'s estimate, the latter is likely to be biased downward for several reasons. First, it does not include benefits, bonuses, and other components of transfer pricing specialists' compensation. Second, it excludes salaries earned by lawyers, accountants, compliance officers, executives in tax-haven affiliates, and other workers that facilitate transfer pricing but are not classified as transfer pricing specialists. Finally, it also excludes non-salary profit shifting costs such as transfer pricing software.[22] The fact that our model produces a figure of the same magnitude as Tørsløv et al. (2022)'s estimate indicates that our calibrated profit shifting costs are empirically reasonable.

Yet another way to validate our calibration is to analyze the determinants of profit shifting at the firm level. One of the key objects of interest in the empirical literature on profit shifting is the semi-elasticity of reported pre-tax profits in a MNE's domestic parent division to the tax differential between the home country and a foreign tax haven. Panel (c) of Table 2 reports three estimates of this elasticity. They range from 0.8 to 1.1, which means that one-percentage-point increase in the tax differential is associated with a 0.8% to 1.1% increase in profits reported at home.[23] We estimate this elasticity in our model by solving for counterfactual equilibria with different tax rates, constructing simulated datasets from these equilibria, and running the following regression:

$$\log \pi_i^{k,PS}(\omega) = \beta_0 + \beta_\ell \log \ell_i^k(\omega) + \beta_z \log z^k(\omega) - \beta_\tau \hat{\tau}_i^k + \epsilon_i^k(\omega), \tag{50}$$

where k denotes the index of the counterfactual economy and $\hat{\tau}_i^k$ denotes the tax differential between an MNE's home region and the profit-shifting destination region (either the low-tax region or the tax haven).[24] The parameter of interest is β_τ. We obtain an estimate of $\beta_\tau = 0.90$, which lies comfortably within the narrow bounds of the empirical estimates.

6 Quantitative Results

We now use our calibrated model to conduct four experiments to analyze the macroeconomic consequences of the policies proposed in the OECD/G20 Inclusive Framework on BEPS. First, we focus on the first pillar of this framework, which allocates a portion of an MNE's overall global profit to its subsidiaries based on these subsidiaries' revenues. Second, we focus on the second pillar, which imposes a global minimum corporate income tax. Third, we analyze the combined effects of these two pillars together. In the last experiment (which is really a set of sub-experiments), we study the combined effects of both pillars under different values for the profit reallocation share and global minimum tax rate. In all four experiments, we restrict

[22]See, for example, the specialized transfer pricing solutions offered by Thomson Reuters, Workiva, and Insight Software.

[23]Appendix C provides a detailed discussion of this literature and the methodology employed in the three studies cited in the table.

[24]Appendix C.3 contains more details on how we produce the model-generated data and specify the empirical regression.

attention to long-run analysis, comparing the steady state under the current regime to the steady state after the policy is implemented. Tables 3–4 and Figure 1 show the results of these experiments, which we will explain in detail below. Appendix D shows that our results are robust to a wide range of alternative setups and calibrations, such as different intangible capital shares and profit-shifting costs.

6.1 OECD pillar one: sales-based profit allocation

The first pillar of the OECD BEPS project allocates, for the purposes of taxation, a fraction of a firm's global profits to the countries in which the firm sells its products. Following the OECD proposal, this allocation is based on these countries' shares of the firm's overall global sales. Importantly, it is independent of whether the firm has a physical presence in these countries, which implies that non-MNE exporters are also subject to this rule.[25] Recall from Section 4.4 that under pillar one, the tax liability faced by an MNE from i in a region j is:

$$T_{ij}^{P1}(a,z) = \pi_{ij}^{r}(a,z) + (1-\theta)\cdot\pi_{ij}^{R}(a,z) + \theta\cdot\hat{S}_{ij}(a,z)\cdot\Pi_{i}^{R}(a,z),$$

where π_{ij}^{r} is a subsidiary's routine profit, which is a fraction ι of its revenue; π_{ij}^{R} is a its residual profit, which is its revenue net of routine profit; Π_{i}^{R} is the MNE's total worldwide residual profit; $\hat{S}_{ij}$ is a region's share of the firm's total global sales; and θ is the fraction of residual profits that are reallocated. Note that under this pillar, an MNE pays corporate income taxes to each of its export destinations even if it does not produce any its goods there. The firm's problem under this rule can be written as

$$d_i^{P1}(a) = \max_{\substack{z,J_X,J_F,\\ \lambda_{TL},\lambda_{TH}\in\Gamma}} \Big\{\pi_{ii} + \pi_{i,LT}\mathbb{1}_{\{LT\in J_F\}} + \pi_{i,TH}\mathbb{1}_{\{\lambda_{TH}>0\}} + \sum_{j\in J_F\setminus\{LT\}}\pi_{ij} - \sum_{j\in J_F\cup J_X\cup\{i\}}\tau_j T_{ij}^{P1}(a,z)\Big\}, \tag{51}$$

with the profit terms defined by equations (13)-(15).

Panel (a) of Table 3 shows the effects of this pillar. It would indeed make a large dent in international profit shifting and materially raise high-tax countries' corporate income tax revenues. Lost profits would fall by 27–32% in North America, Europe, and the rest of the world, and tax revenues would increase by 1.6–2.3%. In the low-tax region, profits shifted inward would fall by 24% and tax revenues would fall by 10.9%. At the same time, however,

[25] According to the current implementation timeline of pillar one, its scope will be initially limited to the largest MNEs. However, the OECD intends to extend the coverage in future years. Our approach reflects these long-term policy goals.

pillar one would reduce output in all regions of the world economy. This would be driven by a reduction in intangible investment by MNEs based in the high-tax regions, especially in North America. In these regions, these effects would be partially, but not entirely, offset by an increase in non-MNEs' intangible investment caused by a decline in labor costs. This highlights the importance of accounting for general-equilibrium forces and redistribution of resources across firms. In the low-tax region, all domestic firms would increase their intangible investment, but the decline in foreign MNEs' output would be large enough to ultimately drag overall output downward as well. This highlights the macroeconomic importance of foreign MNEs' intangible investments for profit-shifting destinations.

6.2 OECD pillar two: Global minimum corporate income tax

The second pillar is a global minimum corporate income tax. Following the OECD guidance, we implement this policy through top-up taxes levied by the governments of MNEs' home countries. Specifically, if a firm based in jurisdiction i reports profits in a jurisdiction j where the tax rate is below the global minimum tax rate $\underline{\tau} = 15\%$, such profits are taxed in jurisdiction i at a rate equal to the tax differential, $\underline{\tau} - \tau_j$. Thus under pillar two, the headquarter of an MNE's additional tax liability is

$$T_i^{P2}(a, z) = \sum_{j \in J_F} \max\left(\underline{\tau} - \tau_j, 0\right) \cdot \pi_{ij}(a, z). \tag{52}$$

The firm's problem is then

$$\begin{aligned} d_i^{P2}(a) = \max_{\substack{z, J_X, J_F, \\ \lambda_{TL}, \lambda_{TH} \in \Gamma}} \Big\{ & (1-\tau_i)\pi_{ii}(a,z) + (1-\tau_{LT})\pi_{i,LT}(a,z)\mathbb{1}_{\{LT \in J_F\}} + (1-\tau_{TH})\pi_{i,TH}(a,z)\mathbb{1}_{\{\lambda_{TH}>0\}} \\ & + \sum_{j \in J_F \setminus \{LT\}} (1-\tau_j)\pi_{ij}(a,z) - T_i^{P2}(a,z) \Big\}. \end{aligned} \tag{53}$$

Panel (b) of Table 3 shows the effects of the second pillar. This policy would have even larger effects on profiy shifting than the first pillar. Lost profits in North America, Europe, and the rest of the world would fall by 62–84% and tax revenues would rise by 2.7–5.0%. On the other hand, the macroeconomic effects would be smaller, and in some regions they would even be positive. MNEs based in Europe and the rest of the world would reduce intangible investment by more than under the first pillar (0.39% vs. 0.18% for Europe and 0.22% vs. 0.09% for the rest of the world), whereas North American MNEs' R&D would fall much less (0.29% vs. 0.80%). As with the first pillar, non-MNEs would expand as MNEs contract, and in North America and Europe this general-equilibrium reallocation would be large enough to push output slightly upward. This reinforces the importance of accounting for general-equilibrium responses and firm heterogeneity. In the low-tax region, while tax revenues would fall further than under pillar one due to the larger drop in profit shifting, the macroeconomic response would be smaller due to the more muted effects on foreign MNEs' intangible investment.

6.3 Both pillars combined

Separately, the two pillars of the OECD/G20 BEPS Framework would both work to reduce profit shifting, but pillar two would be more effective in achieving this goal and would have smaller macroeconomic consequences. What would happen if and when both pillars are implemented together?

Panel (c) of Table 3 shows the results of this third experiment. Consistent with lemma 3 and proposition 2 and the discussion at the end of section 4.4, the effects of the full policy framework would be larger than the effects of each pillar in isolation, but the effects would not be additive; each pillar would have smaller marginal effects when combined with the other. The full policy framework would indeed reduce profit shifting and increase high-tax countries' corporate tax revenues substantially, but not much more than under pillar two alone. Conversely, the macroeconomic effects of the combined framework would be only slightly larger than the effects of pillar one in isolation. This reinforces our finding that pillar one is a less efficient way to reduce profit shifting than pillar two.

Figure 1 shows the effects of the combined framework under alternative values of the two pillars' parameters. The x-axis in each plot is pillar one's profit reallocation share and the y-axis is pillar two's global minimum tax rate. The first column of plots in the figure shows how the effects on lost profits change and the second column shows how the effects on output change. In both columns, darker shades of red indicate "worse" outcomes (smaller reductions in lost profits in the first column and larger output losses in the second column). Clearly, a global minimum tax rate is better policy than profit reallocation. Both pillars are effective at reducing profit shifting, but profit reallocation causes much larger output losses. A 20 percent minimum tax rate would essentially eliminate profit shifting entirely but would not reduce output much more than the benchmark 15 percent rate. It would take a profit reallocation share of at least 90 percent to achieve the same reduction in lost profits, but the output losses from this policy would be an order of magnitude greater.

6.4 Why does pillar one have larger macroeconomic consequences?

Our results show that either pillar of the OECD/G20 Framework would reduce profit shifting substantially, but pillar one would have larger effects on output. The explanation for this is that pillar one affects firms that do not shift profits—and even some firms that do not engage in multinational production at all—while pillar two only affects MNEs that actually shift profits. Specifically, pillar one allocates taxation rights based on where firms make their sales, including export markets. This aspect of the rule increases effective tax rates for firms in Europe, the low-tax region, and the rest of the world because North America, the largest, richest export market, has the highest tax rate. In Appendix D, we show that a version of pillar one that allocates taxation rights based on production instead of sales would achieve the same reduction in profit shifting at a lower macroeconomic cost in these regions. In the case of North America, pillar one has larger macroeconomic effects because the home share of revenue is larger than the home share of profits for firms based in this region, as intangible investment expenses (as well as the fixed costs of selling abroad) are incurred at home.

6.5 Comparison with the OECD's estimates

The OECD predicts that implementing the two pillars will increase global corporate income tax revenue by 3.0%–5.1% and reduce global GDP by about 0.07% (OECD, 2020).[26] They arrive at these figures by combining a formulaic application of the pillars to pre-reform corporate profits with a partial-equilibrium, reduced-form estimate of how profit shifting and tangible investment will change based on relevant elasticities from the empirical literature. In comparison, our results indicate a 3.20% increase in global corporate income tax revenue and a 0.17% decrease in global GDP. Thus, while our estimate of the revenue effect is similar to the OECD's, our estimate of the macroeconomic effect is more than twice as large. The main reason for this difference is the nonrival nature of intangible capital, which OECD (2020) do not take into account. When an MNE's intangible investment declines, its output falls both at home and abroad. Our results show that this channel is particularly important for low-tax countries, where foreign MNEs account for a large fraction of economic activity.

6.6 Effects on components of national income

We have focused our analysis thus far on the effects of the OECD/G20 BEPS Framework on profit shifting and aggregate economic activity. Here, we ask how this framework would affect different components of national income to dig deeper into how it might affect different groups of economic agents.[27] Table 4 shows how each of our three main experiments would affect labor compensation, dividends, and overall tax revenue.

[26]Note that the OECD's headline figure for the global tax revenue effect of the policy, reported in Table 1.1 of OECD (2020), is 2.3%-4.0%. However, this number is calculated using a 12.5% minimum tax rate in Pillar. Panel B of Table 3.15 reports results for a minimum tax rate of 15%.

[27]In our model, we assume that dividends and tax revenues are rebated to consumers. Since we do not explicitly model heterogeneity across households in terms of income, taxation, or firm ownership, we hesitate to draw strong conclusions from our results about welfare implications.

There are several important differences relative to the macroeconomic results. First, labor income falls in all regions in each of the three experiments, even under pillar two which raises GDP slightly in North America and Europe. Thus, these policies could make consumers worse off even if they do not materially shrink the economy. Second, while pillar one has larger macroeconomic effects, pillar two actually has larger effects on dividends in high-tax countries (note that this result is closely related to the fact that pillar two generates more corporate income tax revenue). Third, the increase in high-tax regions' tax revenue would be larger than the decreases in their labor income and dividends, which implies that while these regions' output would generally fall, their gross national income (which is the sum of labor income, dividends, and tax revenue) would actually rise. Fourth, the effects of these policies on labor income and dividends in the low-tax region would be much smaller than the effects on output; in fact, dividends of firms based in this region would rise. Thus, while these policies would significantly hurt public finances in profit-shifting destinations, the private sector in these countries may be relatively insulated.

Overall, this portion of the analysis paints a more subtle picture of the framework's consequences. On the one hand, it highlights that multinational production can lead to differences in the effects on gross national income versus gross domestic product, which implies that GDP may not tell the whole story about whether these policies are desirable to implement. At the same time, it indicates that any potential welfare gains in high-tax countries from reducing profit shifting are only likely to be realized if the increased tax revenues find their way into consumers' pockets.

7 Conclusion

We have developed a model of multinational profit shifting to study the macroeconomic implications of this phenomenon. In our model, MNEs invest in nonrival intangible capital which they can use simultaneously in all of their divisions around the world. MNEs charge their foreign affiliates licensing fees to use intangible capital according to transfer pricing rules, and they can shift profits by transferring the rights to this capital to affiliates in low-tax jurisdictions.

We make two substantive contributions in addition to our methodological contribution. First, we prove that profit shifting presents a trade-off at the firm level between economic performance and tax revenues. On the one hand, profit shifting erodes the corporate income tax base in an MNE's home country. On the other hand, it incentivizes MNEs to do more intangible investment, which boosts output at home as well as abroad. Second, we calibrate our model to match empirical facts about profit shifting under the current international tax regime and use it to quantify the aggregate impact of the OECD's plan to eliminate profit shifting. This plan features two pillars: taxing MNEs in the countries in which they sell their products rather than the countries in which they book their profits; and a global minimum corporate income tax rate. We find that this reform would indeed largely eliminate profit shifting and boost tax revenues in high-tax jurisdictions, but it would also reduce capital investment and shrink the global economy. However, while both pillars would contribute to the decline in profit shifting, the adverse macroeconomic consequences would be driven entirely by the first pillar; the second pillar would have little macroeconomic effect on its own. Thus, we encourage policymakers to abandon the former and focus their attention on the latter.

To put our quantitative results in context, it is helpful to compare them to the effects of other major international policy changes that have been analyzed elsewhere in the literature. Caliendo and Parro (2014) estimate that the North American Free Trade Agreement increased welfare by 0.08% in the United States and reduced it by 0.06% in Canada, while di Giovanni et al. (2014) find that the average country gained 0.13% from liberalizing trade with China. Caliendo et al. (2021) find that the 2004 EU enlargement, which liberalized international labor markets as well as trade, increased welfare in the original EU member states by 0.04%. Despite the small number of firms involved in profit-shifting—far fewer firms engage in multinational production than trade, and only a small fraction of the former shift profits—we find that the macroeconomic effects of the OECD/G20 BEPS framework would be even larger than these examples.

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Table 1: Calibration

Statistic or parameter value	North America	Europe	Low-tax	RoW	Tax haven
(a) Assigned parameters and target moments					
Population (NA = 100)	100	92	11	1,323	–
Real GDP (NA = 100)	100	80.78	14.57	297.10	–
Corporate tax rate (%)	22.5	17.3	11.4	17.4	3.3
Labor tax rate (%)	22.4	22.4	22.4	22.4	–
Foreign MNEs' VA share (%)	11.12	19.82	28.73	9.55	–
Total lost profits ($B)	143	216	–	257	–
Lost profits to TH (%)	66.4	44.5	–	71.1	–
Imports from... (% GDP)					
North America	–	1.28	1.77	1.74	–
Europe	1.70	–	12.39	3.78	–
Low tax	0.35	2.98	–	0.59	–
Row	6.15	7.96	6.78	–	–
(b) Calibrated parameter values					
TFP (A_i)	1.00	0.89	1.58	0.20	–
Prod. dispersion (η_i)	4.28	4.31	4.83	4.12	–
Fixed export cost (κ_i^X)	1.7e-3	3.5e-3	1.0e-3	1.4e-2	–
Variable FDI cost (σ_i)	0.47	0.56	0.52	0.53	–
Fixed FDI cost (κ_i^F)	1.80	1.59	0.46	8.75	–
Cost of shifting profits to LT (ψ_{iLT})	3.40	0.38	–	2.35	–
Cost of shifting profits to TH (ψ_{iTH})	2.25	1.25	–	1.76	–
Fixed FDI cost to TH (κ_i^{TH})	0.09	0.06	–	0.59	–
Variable export cost (ξ_{ij}) from ...					
North America	–	3.21	3.41	2.07	–
Europe	1.89	–	1.69	1.33	–
Low tax	2.04	1.59	–	1.56	–
RoW	2.26	2.59	3.01	–	–

Notes: Population and real GDP from World Bank WDI. Corporate tax rate from Tørsløv et al. (2022). Foreign MNEs' VA share from OECD AMNE database. Fractions of firms with foreign affiliates from Compustat. Lost profits from Tørsløv et al. (2022). Imports/GDP from WIOD. Dashes (–) represent "not applicable."

Table 2: Validation

(a) Share of corporate taxes paid by foreign MNEs (%)

Source	North America	Europe	Low tax	RoW
OECD (2022a)	16.65	41.58	72.40	16.32
Model	24.44	40.13	73.62	18.35

(b) Global profit-shifting costs ($bn)

Source	Estimate
Tørsløv et al. (2022)	25
Model	82

(c) Firm-level semi-elasticity of profit shifting

Source	Estimate
Johansson et al. (2017)	1.11
Heckemeyer and Overesch (2017)	0.79
Beer et al. (2020)	0.98
Model	0.90

Notes: Panel (a): Data source is OECD Corporate Tax Statistics Database (OECD, 2022a). Shares are first calculated at the country level, and then aggregated to the region level by averaging, weighting by total corporate tax revenues. Panel (b): Model value calculated by summing $C(\lambda)$ across all firms, dividing by world GDP in the model, and multiplying by 2020 world GDP in the data from the World Bank ($84.91 tn). Panel (c): See Appendix C.2 for empirical estimates and Appendix C.3 for model estimate.

Table 3: Macroeconomic effects of profit shifting and OECD BEPS pillars

Region	Lost profits (benchmark = 1)	Corp. tax rev. (% chg.)	Value added (% chg.) Total	Non MNEs	Domestic MNEs	Foreign MNEs	Tech. capital (% chg.) Total	Non MNEs	Domestic MNEs
(a) Pillar 1: Profit reallocation									
North America	0.68	2.27	-0.09	0.04	-0.27	0.02	-0.70	0.19	-0.80
Europe	0.73	2.15	-0.15	-0.11	-0.19	-0.18	-0.15	0.09	-0.18
Low tax	0.76	-10.92	-0.37	-0.39	0.15	-0.75	1.06	0.08	1.21
Rest of world	0.70	1.55	-0.17	-0.15	-0.18	-0.21	-0.08	0.04	-0.09
(b) Pillar 2: Global minimum tax rate									
North America	0.38	3.27	0.01	0.07	-0.05	-0.03	-0.25	0.16	-0.29
Europe	0.27	4.95	0.02	0.09	-0.07	0.03	-0.33	0.16	-0.39
Low tax	0.49	-9.80	-0.16	0.01	0.03	-0.59	0.18	0.17	0.19
Rest of world	0.16	2.65	-0.04	0.00	-0.08	-0.06	-0.19	0.07	-0.22
(c) Pillars 1 & 2 together									
North America	0.26	4.30	-0.09	0.07	-0.29	0.01	-0.81	0.26	-0.92
Europe	0.20	5.27	-0.14	-0.06	-0.22	-0.16	-0.31	0.16	-0.36
Low tax	0.37	-16.52	-0.46	-0.34	0.20	-1.21	1.18	0.23	1.33
Rest of world	0.12	3.25	-0.18	-0.14	-0.21	-0.23	-0.17	0.07	-0.20

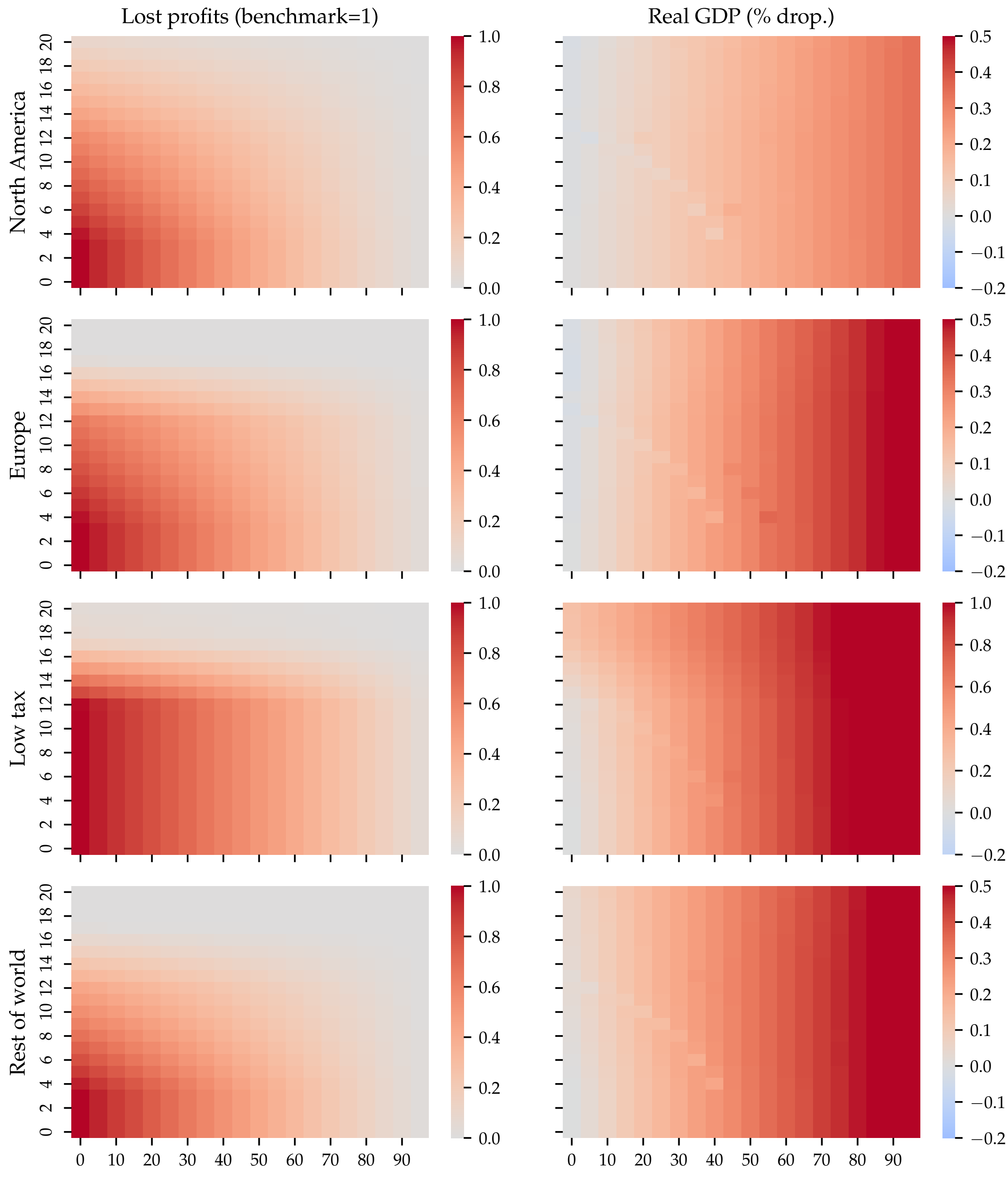
Notes: Lost profits are measured relative to the benchmark. Note that for the low-tax region, lost profits are negative in both the benchmark equilibrium and in the policy counterfactuals, i.e., profits are shifted inward to the low-tax region. However, the magnitude of these lost profits are smaller in the counterfactuals. For example, in panel (b), the amount of profits shifted into the low-tax region under pillar 2 is about half of the amount in the benchmark.

Table 4: Effects of profit shifting and OECD BEPS pillars on components of national income

Region	Labor income	Dividends	Tax revenue	Labor income +Dividends	Labor income +Tax revenue	All three
(a) Pillar 1: Profit reallocation						
North America	-0.03	0.02	2.27	-0.02	0.08	0.07
Europe	-0.01	-0.06	2.19	-0.02	0.07	0.05
Low tax	-0.03	-0.20	-10.81	-0.06	-0.37	-0.34
Rest of world	-0.00	-0.04	1.57	-0.01	0.06	0.04
(b) Pillar 2: Global minimum tax rate						
North America	-0.02	-0.09	3.27	-0.03	0.14	0.10
Europe	-0.01	-0.09	4.94	-0.02	0.17	0.13
Low tax	-0.05	0.10	-9.78	-0.03	-0.35	-0.28
Rest of world	-0.01	-0.13	2.64	-0.03	0.09	0.06
(c) Pillars 1 & 2 together						
North America	-0.04	-0.03	4.30	-0.04	0.17	0.14
Europe	-0.02	-0.11	5.30	-0.03	0.18	0.14
Low tax	-0.07	-0.12	-16.42	-0.08	-0.58	-0.51
Rest of world	-0.01	-0.17	3.27	-0.04	0.12	0.07

Notes: Table reports percent changes in outcomes adjusted for purchasing power parity.

Figure 1: Varying the sizes of the pillars



Notes: Each column reports effects on one variable for each region. First column: Lost profits (reported relative to the benchmark equilibrium). Second column: real GDP (reported as a percent change from the benchmark equilibrium). X-axis in each plot represents the reallocation share for Pillar 1. Y-axis in each plot represents the global minimum corporate income tax rate for Pillar 2.

Appendix (For Online Publication)

A Institutional Background

In this section we provide a brief overview of the current international tax regime and describe the main features of the two-pillar reform proposed by the OECD. We aim here to deliver an executive summary, rather than an exhaustive discussion, of these immensely complex issues.[28] Understanding the main components of the international tax architecture is crucial since they largely dictate the setup of our theory and impose restrictions on what any reform proposal can achieve.

A.1 The Current International Tax Regime

Existing international law entitles a country to tax persons, either natural or legal, with which it has sufficient ties. In practice, taxing rights are a product of multiple national laws and international treaties that often contradict one another. The following are the most important characteristics of the current regime.

Legal separation of entities. The current regime treats subsidiaries within one MNE as separate legal entities. Thus, any transaction between parts of an MNE in different tax jurisdictions, such as for example an asset purchase, has real tax consequences. This characteristic coupled with heterogeneity of the tax systems across jurisdictions and manipulation of transfer prices gives rise to profit-shifting opportunities.

Allocation of taxing rights. There are at least four possible locations where a multinational company might in principle be taxed: the location of its shareholders, parent companies, affiliates, or customers. According to the current regime MNEs are taxed primarily in the third location (affiliates' location), but sometimes also in the second. This is achieved by a combination of legal rules allowing the countries concerned to tax on to a source or residence basis.[29]

Transfer prices. Within-MNE transactions occur at transfer prices, which are disciplined by the so-called *arm's length principle (ALP)*. The basic idea behind the ALP is that within-MNE prices should reflect the market prices that would have been charged by two independent parties of transactions. There are five core methods to achieve the ALP standard: the comparable uncontrolled price (CUP), resale price minus, cost plus, profit split, and transactional net margin methods. The practical implementation of this principle is challenging and requires complex guidelines published regularly by the OECD which member countries should obey—see OECD (2022b) for the latest guide.

Treatment of intangibles. The method preferred by the OECD to implement ALP is CUP, which simply employs the price charged on comparable transactions between independent parties. CUP however is hard to implement in case of trading intangibles, since most of the time a comparable transaction is non-existent. In such cases the preferred method is the profit split method, which essentially inspects the relative financial or other contributions made by the two companies entering into a transaction. A profit split is then determined

[28] Our summary is largely based on Devereux et al. (2021), OECD (2015), OECD (2017), and OECD (2022b).

[29] From a legal perspective, a country taxes on a residence basis when it taxes companies that are resident in that country for tax purposes on income arising in that or in another country. A country taxes on a source basis when it taxes companies that are not resident in that country for tax purposes on income deemed to arise in that country. For a thorough discussion of these concepts see Devereux et al. (2021).

based on these contributions. OECD (2014) provides extensive guidelines on pricing transactions involving intangibles.

A.2 Tax Avoidance and Profit Shifting Channels

Tax avoidance and profit shifting is conducted by MNEs using variety of channels. In what follows we briefly discuss the most important ones.[30]

1. *Transfer Pricing Manipulations.* The global allocation of tax base between source and residence countries is impacted by the valuation of intracompany transactions within an MNE. The arm's length principle, which requires that internal prices between related parties be similar to prices that would exist between independent parties, is used by most countries. However, this principle can be subject to significant subjective interpretation and may not have a "correct" arm's length price if there are no comparable third-party transactions. MNEs can manipulate transfer pricing by charging lower prices for exports from high-tax to low-tax countries or higher prices for inputs from low-tax countries, thus reducing their global tax liability.

2. *Strategic Location of IP.* The global tax of an MNE can also be reduced through the strategic location of IPs. A company may carry out R&D in one country and then transfer ownership of the resulting patent to a subsidiary in a low-tax jurisdiction, where the income generated from it will be taxed at a lower rate. Determining the arm's length price for intangible transactions within a company can be difficult, as there are often no comparable transactions between unrelated parties. This creates room for transfer pricing manipulation for tax purposes.

3. *International Debt Shifting.* Intracompany loans can also serve as a tool for reducing the tax bill of an MNE. The variation in corporate tax rates across countries creates the possibility of lending from low-tax countries to high-tax affiliates or borrowing from external sources in high-tax countries. The deductibility of interest payments on debt from taxable income results in a reduced tax bill for the group, without affecting its overall debt exposure and hence, bankruptcy risk.

4. *Tax Treaty Shopping.* Considerable variation in the withholding taxes (WHT) in more than 3000 bilateral double tax treaties creates opportunities of treaty shopping. This enables MNCs to link different treaties and divert cross-border payments through the country with the lowest WHT rate.

5. *Tax Treaty Shopping.* The presence of the withholding taxes (WHT) disparities in 3000-plus bilateral double tax agreements produces prospects for treaty shopping. This gives MNEs the capability to tie together varied pacts and divert cross-border payments through the nation with the least possible WHT rate.

A.2.1 The importance of intangible capital and strategic IP location.

In an influential paper Grubert (2003) examines the links between intangible income, income shifting, intercompany transactions, and location choices by utilizing data from U.S. parent corporations and their manufacturing subsidiaries. He finds that income from R&D-based intangible assets makes up roughly half of the income that is shifted from high-tax to low-tax jurisdictions. Heckemeyer and Overesch (2017) distinguish between the tax response through financial planning, such as inter-company debt financing, and the response through transfer pricing and licensing. They specifically compare the tax sensitivity of pre-tax

[30] This discussion is largely based on Johansson et al. (2017) and Beer et al. (2020).

profits, which encompasses shifting through various means, with the tax sensitivity of earnings before interest and taxes (EBIT), which only captures non-financial shifting mechanisms. The results of their stylized calculations indicate that transfer pricing and licensing, not inter-company debt financing, is the principal channel for profit shifting. The overall semi-elasticity of pre-tax profits is estimated to be 0.786, and the non-financial component of this response accounts for 82% of the total response. In their headline analysis OECD (Johansson et al., 2017) concludes that a comprehensive analysis of the allocation of third-party debt, among MNEs presents evidence of debt manipulation, accounting for 20% of profit shifting. Thus the rest, the vast majority, is accounted for by mispricing and strategic location of intangible capital. Moreover OECD finds that tax sensitivity of profit is almost twice as high among patenting MNEs than other MNEs (see Table A5.4 in their study). Beer, de Mooij and Liu (2020) extend the meta analysis conducted by Heckemeyer and Overesch (2017) by almost doubling the sample size of primary estimates. They conclude that debt-shifting channel plays, on average, a minor role.

A.3 OECD Base Erosion and Profit Shifting Project

In what follows we briefly summarize the key provisions of reform proposed by OECD/G20 Inclusive Framework on BEPS, as they were at the time of the writing of this paper.[31]

A.3.1 Pillar 1: Profit allocation and nexus

The general principle behind Pillar 1 is to allocate taxing rights more closely where the customers and users of the in-scope MNEs are located. The key elements of Pillar 1 are as follows.

Scope. The new profit allocation rule will apply to groups with greater than €20 billion in worldwide revenues and a profitability before tax margin of at least 10 percent. There are some exclusions for extractive industries and regulated financial services.

Nexus. The allocation key is based on the revenue that is sourced to each jurisdiction. It will be sourced to the end-market jurisdictions, where goods or services are used or consumed, permitting allocation to a market jurisdiction from which the in-scope MNE derives at least €1 million in revenues.

Quantum. For in-scope MNEs, 25% of residual profit (i.e. profit in excess of 10% of revenue) will be allocated to market jurisdictions with nexus using a revenue-based allocation key.

Elimination of double taxation. Profit allocated to a market jurisdiction will be dispensed from double taxation through direct exemption of credit method.

Unilateral Measures. The agreement requires all parties to remove all digital services taxes and other relevant, similar measures with respect to all companies and to commit not to introduce such measures in the future.

A.3.2 Pillar 2: Global minimum taxation

The second pillar consists of two sets of rules granting jurisdictions additional taxing rights: (i) interlocking domestic rules termed Global anti-Base Erosion (GloBE) rules, and (ii) a treaty-based Subject to Tax Rule (STTR). Their key features are as follows.

[31] The details of both pillars as well as the exact implementation plan are very much a work in progress at the time of writing this paper. Since November 2021 the OECD has been organizing a series of public consultation meetings in order to work out technical details and parameters of the reform.

Scope. GloBe rules apply to multinational enterprise groups with a total consolidated group revenue above €750 million in at least two of the four preceding years.

Minimum tax rate. GloBE rules apply a system of top-up taxes that brings the total amount of taxes paid on an MNE's profit in a jurisdiction up to the minimum rate of 15%.

Exclusions. GloBe rules will also provide for an exclusion for those jurisdictions where the MNE has revenues of less than EUR 10 million and profits of less than EUR 1 million.

Subject to Tax Rule (STTR). This complements the GloBE rules by targeting intra-MNE payments exploiting certain provisions of the treaty to shift profits from source countries to payee jurisdictions where those payments are subject to no or low rates of nominal taxation. In such cases, it reallocates taxing rights to source jurisdictions. It applies to such payments as covered payments—interest, royalties, brokerage, marketing, procurement, agency or other intermediary services, and so on. The minimum rate for the STTR will be 9 percent.

B Data sources

Region definitions. We take the list of tax havens from Tørsløv et al. (2022). The complete list of countries in the tax-haven region is: Andorra, Anguilla, Antigua, Aruba, the Bahamas, Bahrain, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Curacao, Cyprus, Gibraltar, Grenada, Guernsey, the Isle of Man, Jersey, Lebanon, Liechtenstein, Luxembourg, Malta, Marshall Islands, Mauritius, Monaco, the Netherlands Antilles, Panama, Puerto Rico, Samoa, Seychelles, Sint Maartin, St. Kitts & Nevis, St. Vincent & the Grenadines, St. Lucia, the Turks & Caicos, and Vanuatu.

World Development Indicators. Data on population and output come from the World Bank's World Development Indicators database. The specific series that we use are total population (SP.POP.TOTL), GDP in current US dollars (NY.GDP.MKTP.CD), and GDP at purchasing power parity in constant 2011 international dollars (NY.GDP.MKTP.PP.KD). For each of these variables, when constructing regional aggregates, we sum across countries within a region following McGrattan and Waddle (2020), and then average over the period 2014–2017.

World Input-Output Database. International goods trade data are taken from the World Input-Output Database (Timmer et al., 2015). For each bilateral import relationship, we sum all intermediate inputs and final uses of goods (industries 1–23, which represent agriculture, resource extraction, and manufacturing) from countries in the source region by countries in the destination region. We use data from 2014, the most recent year available.

OECD AMNE Database. This is a new dataset provided by the OECD which distinguishes between three types of firms: foreign affiliates (firms with at least 50% foreign ownership), domestic MNEs (domestic firms with foreign affiliates), and domestic firms not involved in international investment. It includes a full matrix of the output of foreign affiliates in 59 countries plus the rest of the world (in the host country, industry, parent country dimension), as well as matrices for value-added and for exports and imports of intermediate inputs (host country and industry). A second set of matrices in the database provides information on output, value-added, and exports and imports of intermediate inputs of domestic MNEs and non-MNE domestic firms (from 2008 onwards). In addition, split Inter-Country Input-Output tables are provided distinguishing for all countries the transactions of domestic-owned and foreign-owned firms. These tables can be used to analyze multinational production in value-added terms. We exploit them to discipline our model and make sure it replicates the share of each region's gross value added that is accounted for by foreign multinationals. We first map the set of 59 countries from the AMNE dataset to our five regions and then compute the average value-added shares for three types of firms (foreign affiliates, domestic MNES, and domestic non-MNEs) in each region over the time period 2008–2016. The data can be accessed at OECD AMNE Database.

Compustat. Data on sales, employment, and country of origin of parent companies come from the Compustat North America Fundamentals Annual database. This database contains data of North American companies parsed from SEC filings. Data on subsidiaries come from the Wharton Research and Data Services (WRDS) Subsidiary Data. These data also come from SEC filing, particularly Exhibit 21, in which firms filing with the SEC must list the names of all existing Significant Subsidiaries. For a detailed, legal definition of Significant Subsidiaries, see here. Roughly, if the parent company controls at least 10% of the subsidiary, it is considered Significant. The WRDS data are available from 1995 to 2019, and contain identifying information for the parent company, as well as the name and country of residence of all Significant Subsidiaries. These two datasets were linked using a common identifier of the parent company, the `gvkey`. Mean and median sales and employment statistics were computed for the years 2010-2019. The unit of observation was parent company-year.

U.S. Census Data. To discipline the firm size distribution we exploit data from the Statistics of U.S. Businesses (SUSB). SUSB is an annual series that provides national and subnational data on the distribution of economic data by establishment industry and enterprise size. SUSB covers most of the country's economic activity. The series excludes data on nonemployer businesses, private households, railroads, agricultural production, and most government entities. We construct a Lorenz employment curve for the U.S. at the firm level using two Excel spreadsheets available at the Census website. We combine the table with detailed employment sizes with the table with larger employment sizes (20,000+ employees), both from 2019 SUSB. This allows us to account for a long right tail of the firm size distribution in our model, which is crucial given that average MNE is three orders of magnitude larger than the average firm in the U.S. economy. Both Excel files can be downloaded from the SUSB website.

OECD Corporate Tax Statistics Database. To compute the share of corporate income tax revenue in each region that is paid by local affiliates of foreign MNEs, we use data from the OECD Corporate Tax Statistics Database (OECD, 2022a). First, for each country in the database, we compute two numbers from Table 1: (i) corporate income taxes paid by domestic MNEs' affiliates; and (ii) corporate income taxes paid by foreign MNEs' affiliates. Second, we compute (i) as a share of (ii). Third, for each region in our model, we compute the average of these shares across the countries in that region, weighting by (i) + (ii). The data can be accessed here.

Tørsløv et al. (2022). Two kinds of data are taken from this paper: lost profits and effective corporate income tax rates. Total lost profits are from sheet Table3 of the Main Data Excel file. We first sum across all countries within the North America and Europe regions, and then set the rest of the world's lost profits by subtracting the North America and Europe totals from the overall world total. The share of lost profits that are shifted to the tax haven region is constructed in the same way using sheet TableC2 in the Replication Guide Tables Excel file. The effective corporate income tax rates come from sheet DataF2 in the Main Tables Excel file. Here, we take the average across countries within each region. Both Excel files can be downloaded from `https://missingprofits.world/`.

C Firm-level profit shifting estimates

In this section we briefly discuss the empirical literature on profit shifting, which aims to estimate the elasticity of reported profits with respect to the tax rate differentials across jurisdictions. We begin with an overview of the empirical strategy adopted in this line of research, then move to the discussion of the headline, consensus estimates emerging from the literature. Finally we link our structural modelling approach to the empirical strategy.

C.1 Empirical strategy

Most of the empirical literature on elasticity of the profit shifting margin follows the concept presented by Grubert and Mutti (1991) and Hines and Rice (1994) that the reported pre-tax profit of a multinational entity, Π_i^R, is a sum of the "true" profit, Π_i^T, and the profit shifted for tax reasons, Π_i^S

$$\Pi_i^R = \Pi_i^T + \Pi_i^S. \tag{C.1}$$

This shifted profit would be positive in low-tax countries and negative in high-tax countries. The idea here is that the actual profitability of multinational enterprises with similar characteristics (e.g. size, industry, country etc.) is similar. However, the opportunities to shift profits differ since they depend on such characteristics as locations of the other subsidiaries and statutory tax rates in these locations. Thus, the entities linked to low-tax jurisdictions are more likely to shift profits and the entities linked to high-tax jurisdictions are more likely to receive profits. The fundamental challenge for estimating the elasticity of profit shifting margin is that neither "true" profits nor shifted ones are directly observable in the firm-level data. To tackle this problem the literature usually assumes that "true" profits are equal to output minus the wage bill, with the wage being equal to marginal product of labor (see for example Huizinga and Laeven (2008)). As for the shifted profits, the literature typically specifies some stylized framework that allows linking shifted profits to tax differentials between jurisdiction j and other operating jurisdictions. This strategy leads to the following generic equation to identify shifting profits:

$$\pi_{i,j,t}^R = \beta X_{i,j,t} - \gamma C_{i,j,t} + \delta_t + \varepsilon \tag{C.2}$$

where $\pi_{i,j,t}^R = \ln \Pi_{i,j,t}^R$ are log reported profits of a multinational i located in jurisdiction j at time t, $X_{i,j,t}$ is a vector of determinants of true profitability, which includes capital and labor inputs among others. It may also include a number of macroeconomic variables, such as GDP growth, exchange rate, or inflation. $C_{i,j,t}$ is a composite variable that summarizes the tax differentials between jurisdiction j and other jurisdictions in which the MNE located in jurisdiction i has subsidiaries. The specific formula for $C_{i,j,t}$ differs across papers but in all of them it reflects the tax incentives to shift profits away from or into jurisdiction j. Finally δ_t denotes time fixed-effect and ε denotes the residual term. The coefficient of interest is then γ which reflects the extent to which the multinational shifts profits into or out of affiliate i. It is important to note that this estimate represents a marginal effect – i.e. the change in reported profits associated with a small change in tax rates, *holding all else constant*. We can interpret γ in equation (C.2) as the semi-elasticity of observed profits π_i^O with respect to the composite tax variable $C_{i,j,t}$. The *semi-elasticity* indicates the percentage change of reported profit in response to a one percentage point change in the tax differential vis-a-vis other international locations, reflecting the incentive to shift profits abroad.

C.2 Empirical estimates

A number of papers estimate different versions of equation (C.2) for a variety of datasets and time periods. A thorough and detailed review of this literature is beyond the scope of this paper.[32] Instead, we focus here on the two most recent survey papers, which conduct meta analyses of existing estimates, and on the main OECD estimate, all of which report the headline semi-elasticity number.

Johansson et al. (2017) provide the main estimate of the magnitude of the profit shifting used by the OECD. They conduct a comprehensive study using firm-level data from the ORBIS database to assess international tax planning by multinational enterprises (MNEs). Their results are based on an impressively large sample of firms (1.2 million observations of MNE accounts) in 46 OECD and G20 countries and a sophisticated procedure to identify MNE groups. Their headline estimate of the semi-elasticity of the profit shifting margin with respect to the tax differential is **1.11** (see Table 1, column 1 and footnote 31 in their paper). Hence, reported profits decrease by about 1.1% if the international tax rate differential increases by one percentage point. The estimated elasticities combined with a number of assumptions are then used to estimate the effect of international tax planning on corporate tax revenues: the estimated net tax revenue loss ranges from 4% to 10% of global corporate tax revenues.

Heckemeyer and Overesch (2017) construct a meta-database containing 203 primary estimates sampled from 27 empirical studies identified by means of article search engines. All of the included studies estimate the empirical relationship between reported parent and subsidiary profitability and the tax incentive to shift profits abroad. Therefore, this meta-analysis reviews the literature, providing indirect evidence for profit shifting without specifying directly the shifting methods. They find a tax semi-elasticity of pre-tax profit of about **0.79**, in absolute terms. They conclude that across all specifications the predicted semi-elasticities turn out to be statistically significant and rather robust in magnitude. They also provide a 95% confidence interval in addition to the point estimate and conclude that conditional on a hypothetical state-of-the-art study design, the set of semi-elasticities that should not be rejected at the 5% significance level ranges from 0.546 to 1.026.

Beer, de Mooij and Liu (2020) extend the analysis conducted by Heckemeyer and Overesch (2017) and include 11 additional studies and 199 additional primary estimates. They also reduce specification bias, and adopt an enhanced estimation method that corrects for within-study correlation of primary estimates. Their results indicate that a semielasticity of reported pretax profits with respect to international tax differentials equal to **0.98** is a good reflection of the literature. This means that a one-percentage-point larger tax rate differential reduces reported pretax profits of an affiliate by 1%.

C.3 Model counterpart of semi-elasticity

We now describe how we estimate the model counterpart of the semi-elasticity summarized above. We view this as a validation exercise of the cost function $C(\lambda)$ upon which the extent of profit shifting in the presence of tax differentials between jurisdictions heavily depends. Since our parsimonious model of only four productive regions does not provide sufficient variation in cross-jurisdiction differences in corporate tax rates (regressor $C_{i,j,t}$ in equation (C.2)), we conduct a simulation exercise as follows.

We simulate 200 counterfactual economies, raising the corporate tax rate of the LT region incrementally for the first 100 economies and the rate of the TH region for the latter 100. We set the highest counterfactual corporate tax rate to 11.9%, which is the corporate tax rate of LT. In each of these counterfactual economies,

[32] See Dharmapala (2014), Heckemeyer and Overesch (2017), Johansson et al. (2017) and Beer et al. (2020) for extensive reviews of this line of research.

we hold fixed the set of firms' FDI and exporting destinations, J_F and J_X, as well as the final good price and wage rate of each region, P_i and W_i. We allow firms to solve for their optimal choices of labor $\boldsymbol{\ell}$, intangible capital z and shifting shares λ_{LT} and λ_{TH}. In other words, the firms' problem is re-solved in a partial equilibrium setting, which allows us to isolate the relationship of reported profits in home divisions to tax rate differentials relative to the profit-shifting destination.

Denote k as the index of a counterfactual economy. We follow the empirical specification of equation (C.2) and run the regression using the model-simulated dataset:

$$\log \pi_i^{k,PS}(\omega) = \beta_0 + \beta_\ell \log \ell_i^k(\omega) + \beta_z \log z^k(\omega) - \beta_\tau \hat{\tau}_i^k + \epsilon_i^k(\omega) \tag{C.3}$$

where we denote by τ_i^k the counterfactual tax differential defined as $\hat{\tau}_i^k = \tau_i - \tau_{LT}^k$ for $k \leq 100$ and $\hat{\tau}_i^k = \tau_i - \tau_{TH}^k$ otherwise. For each experiment k, we include in the regression only home divisions of firms doing FDI in the region for which we change the corporate tax rate. We only include home divisions of profit-shifting MNEs because we do not model profit shifting originating from a foreign subsidiary. Nonetheless, such regression informs us of how reported profit responds to changes in profit-shifting relevant tax differentials, which is captured by the coefficient of interest β_τ. We report the coefficient estimate of β_τ in Table 2.

D Sensitivity Analysis

Our quantitative results are robust to a variety of alternative assumptions and calibrations. Here, we describe the results of three sensitivity analyses that illustrate the impact of some of the most important elements of our model and policy experiments. Tables D.1–D.2 show the results of these sensitivity analyses.

Alternative profit reallocation rules. The first pillar of the OECD's BEPS project reallocates the rights to tax a portion of a firm's global profits to the regions in which it operates in accordance with these regions' shares of the firm's global sales. Importantly, some of these rights are allocated to a firm's export markets, even if the firm does not operate foreign affiliates in these markets. This aspect of the rule increases effective tax rates for firms based in Europe, the low-tax region, and the rest of the world because North America, which is a large, rich export market, has the highest corporate income tax rate. This reduces these firms' incentives to invest in intangible capital, even if they do not shift profits at all. This partly explains why Pillar 1 has larger macroeoconomic consequences than Pillar 2, despite having smaller effects on profit shifting. To explore the importance of this aspect of Pillar 1, we have analyzed the effects of alternative versions in which profit taxation rights are allocated for MNEs only, or are based on output shares instead of sales shares. Panel (a) of Table D.1 shows the effects of a profit allocation rule that applies only to MNEs, as opposed to firms that export but do not operate foreign affiliates. The effects on profit shifting are the same as the OECD's version but the macroeconomic consequences are smaller, especially outside of North America. Panel (b) of Table D.1 shows what happens when profit-taxation rights are allocated based on output rather than sales. Under this version of the pillar, export destinations do not receive any taxation rights at all. The results are almost identical to panel (a). These results indicate that allocating taxation rights based on export sales should be avoided.

Intangible share. We have set the share of intangible capital in production, ϕ, to match the share of income that accrues to intangible capital in MNEs' foreign affiliates. This approach ensures that our model captures the extent to which nonrivalry governs MNEs' incentives to invest in intangible capital. This share is the key determinant of the potential scope for profit shifting; a greater intangible share means more licensing fee income that can be transferred to the low-tax region and/or the tax haven. Of course, it is also the key determinant of the macroeconomic impact of policies that affect incentives to invest in intangible capital, including the policies designed to reduce profit shifting that we study. Panels (c) and (d) of Table D.1 show the results of our experiments under alternative calibrations with different intangible shares. In each, we recalibrate all model parameters except for those that govern profit shifting. This allows us to explore how the intangible share affects profit shifting under the current international tax system as well as the effects of changes to this system. The results of these analyses show that a lower intangible share reduces macroeconomic effects of transfer pricing and profit shifting, reduces the amount of profit shifting under the current tax code, and reduces the macroeconomic consequences of the OECD BEPS pillars; the reverse is true for a higher intangible share. However, the extent to which the BEPS pillars reduce profit shifting is about the same as in the baseline model. For example, with a lower intangible share, lost profits in North America fall by 1 - 0.27/0.41 = 34% under Pillar 1, which is similar to the decline of 32% reported in Table 3.

Endogenous labor supply. In our baseline model we assume that labor supply is fixed, which means that the only way for the labor market to clear is for wages to adjust. Here we explore how allowing households to endogenously choose labor supply changes the results. Panel (e) of Table D.1 shows the results when preferences are assumed to be log-separable in consumption and leisure as in McGrattan and Waddle (2020), and panel (f) shows results in a model with GHH preferences where there is no wealth effect on labor supply. The main difference between these models and the baseline is that the effects on GDP are larger, which is driven by the fact that households reduce labor supply for two reasons: (i) wages fall due to reduced labor demand from MNEs; and (ii) in the case of log-separable preferences, lump-sum transfers rise due to the increase in tax revenue. Now, output falls in all regions in all three experiments. One interesting result aspect of the results is that the macro effects of profit shifting and pillar 2 are much smaller for the low-tax region in the model with log-separable preferences. This highlights that profit shifting may cause a kind of Dutch disease, whereby low-tax regions' labor supply is depressed by the increase in income from foreign MNEs. This is kind of funny, since the Netherlands is in our low-tax region).

Variable profit-shifting costs. We have set the costs of profit shifting, $\chi_{i,LT}$ and $\chi_{i,TH}$, to match estimates in the literature about the amount of profit shifting and the extent to which profits are shifted to low-tax "productive" regions versus "unproductive" tax havens. These estimates are inferred from information about the profitability and labor shares of MNEs' foreign affiliates in these regions—it is impossible to measure lost profits directly without access to detailed information about intra-MNE transactions—so there is some uncertainty about how much profit shifting truly occurs. To determine the sensitivity of our results to these key parameters, we have conducted our experiments in alternative calibrations within which these parameters are set to higher or lower values. Panel (g) of Table D.2 shows the results when $\chi_{i,LT}$ and $\chi_{i,TH}$ are halved, while panel (h) shows the results when they are doubled. With lower profit-shifting costs, there is more profit shifting under the current tax system and the OECD BEPS pillars have larger macroeconomic effects; the reverse holds with higher costs. As in the previous exercise, the BEPS pillars reduce profit shifting by about the same amount as in the baseline. For example, with lower shifting costs, lost profits in North America fall by 1 - 1.43/2.02 = 29% under Pillar 1, which is again quite similar to the result of the benchmark model.

Separability of profit shifting costs across destinations. In the benchmark model, we set $\epsilon = 1$ with the lack of a relevant empirical moment to discipline this cost parameter. This implies that profit-shifting cost function is additively separable in the two components, that is $\frac{\partial \mathcal{C}_i^2(\lambda_{TH},\lambda_{LT})}{\partial\lambda_{TH}\partial\lambda_{LT}} = 0$ and $C_i(\lambda_{LT}, \lambda_{TH}) =$

$C_i(0, \lambda_{TH}) + C_i(\lambda_{LT}, 0)$. To gauge how the substitution parameter ϵ affects our results, we perform two sensitivity tests where we set $\epsilon = 0.75$ and $\epsilon = 1.25$. All other model parameters are re-calibrated. The results are shown in Panels (g) and (h) of Table D.2. The effects of Pillar 1 are quite similar to the benchmark model. For Pillar 2, however, there is greater reductions of lost profits in the case with positive cross-derivatives (Panel (g)) than with the negative cross-derivatives (Panel (h)). The results of the two pillars together are thus also different. As expected, the effects in the benchmark model is in between of these two panels. This is because, with a positive cross-derivative cost function, the return of shifting to both LT and TH is smaller. In response to Pillar 2, more firms that used to operate in both LT and TH will exit from one of them when there is a positive cross-derivative than a negative cross-derivative. This generates a greater reduction in lost profits in Panel (g). This differential impact is absent with Pillar 1. This is because Pillar 1 increases the effective tax rate of TH more than LT. With a positive cross-derivative, fewer firms shift to both TH and LT. However, the firms which still shift to both will have greater relatively λ_{LT} than in the case with a negative cross-derivative, as $\frac{\partial \mathcal{C}_i(\lambda_{LT}, \lambda_{TH})}{\partial \lambda_{LT}}$ decreases by more. These two effects happen to cancel out. The policy effects on GDP across the world is insensitive to choosing different values of ϵ.

Exogenously restricting some firms from profit shifting. In the benchmark model, we assume that all firms have access to the profit shifting technology. In reality, profit shifting is concentrated in certain sectors, suggesting that not all sectors have the same kind of profit shifting opportunities. Barrios and d'Andria (2019) document significant sectoral differences in profit shifting which cannot be fully attributed to heterogeneity in intangible intensity. One naive way to assess the importance of this assumption is to assume that only 50% of firms in the model are allowed to shift profits, while continuing to use the baseline parameterization. Panel (k) of Table D.2 shows the results of this experiment. The macroeconomic consequences of profit shifting and the two OECD pillars are smaller than in the baseline model, but the aggregate amount of profit shifting in this model is too low (about 50% of the observed values). This should not be surprising, since the costs of profit shifting have not changed but only half of the firms in the model can shift profits. This suggests that a more appropriate way to assess the importance of this assumption is to recalibrate the profit shifting costs so that even though fewer firms can shift profits, the model still matches the aggregate amount of profit shifting observed in the data. Panel (l) of Table D.2 shows the results of this version of the experiment. The aggregate results are extremely similar to the baseline results in all respects, but of course the profit shifting costs must be lower and the amount of profit shifting per firm (conditional on engaging in this activity) must be higher to rationalize the aggregate amount of profit shifting.

Table D.1: Sensitivity analysis

Experiment	Lost profits (benchmark = 1) North America	Europe	Low tax	Rest of World	GDP (% chg.) North America	Europe	Low tax	Rest of World
Baseline model								
Effects of profit shifting	1.00	1.00	1.00	1.00	0.01	0.02	0.29	0.08
Pillar 1	0.68	0.73	0.76	0.70	-0.09	-0.15	-0.37	-0.17
Pillar 2	0.38	0.27	0.49	0.16	0.01	0.02	-0.16	-0.04
Pillars 1 & 2 together	0.26	0.20	0.37	0.12	-0.09	-0.14	-0.46	-0.18
(a) Profit reallocation rule applies to MNEs only								
Pillar 1	0.69	0.73	0.76	0.70	-0.07	-0.09	-0.23	-0.12
Pillars 1 & 2 together	0.26	0.20	0.37	0.12	-0.06	-0.08	-0.33	-0.14
(b) Production-based profit reallocation rule								
Pillar 1	0.69	0.73	0.76	0.70	-0.07	-0.08	-0.22	-0.11
Pillars 1 & 2 together	0.27	0.20	0.37	0.12	-0.07	-0.07	-0.31	-0.13
(c) Low intangible share								
Effects of profit shifting	0.41	0.39	0.40	0.39	-0.01	-0.01	0.10	0.02
Pillar 1	0.27	0.28	0.31	0.27	-0.06	-0.12	-0.27	-0.12
Pillar 2	0.15	0.10	0.20	0.06	0.01	0.02	-0.06	-0.01
Pillars 1 & 2 together	0.11	0.08	0.15	0.04	-0.05	-0.11	-0.31	-0.13
(d) High intangible share								
Effects of profit shifting	1.76	1.81	1.75	1.84	0.05	0.07	0.56	0.17
Pillar 1	1.21	1.32	1.34	1.31	-0.13	-0.19	-0.50	-0.23
Pillar 2	0.67	0.49	0.87	0.30	-0.01	0.00	-0.30	-0.09
Pillars 1 & 2 together	0.47	0.36	0.65	0.21	-0.13	-0.19	-0.67	-0.27
(e) Endogenous labor supply (log-separable preferences)								
Effects of profit shifting	1.00	1.00	1.00	1.00	0.09	0.12	0.02	0.11
Pillar 1	0.68	0.73	0.76	0.70	-0.15	-0.19	-0.19	-0.19
Pillar 2	0.38	0.27	0.49	0.16	-0.06	-0.06	-0.02	-0.07
Pillars 1 & 2 together	0.26	0.20	0.37	0.12	-0.18	-0.22	-0.21	-0.22
(f) Endogenous labor supply (GHH preferences)								
Effects of profit shifting	1.00	1.00	1.00	1.00	0.03	0.03	0.36	0.09
Pillar 1	0.68	0.73	0.76	0.70	-0.12	-0.16	-0.39	-0.17
Pillar 2	0.38	0.27	0.49	0.16	-0.01	0.00	-0.20	-0.05
Pillars 1 & 2 together	0.26	0.20	0.37	0.12	-0.12	-0.16	-0.52	-0.20

Notes: Panel (a): profit-reallocation rule for pillar 1 applies only to MNEs (not firms that export but do not operate foreign affiliates). Panel (b): rule is based on value added rather than sales; profits are not reallocated to export destinations. Panels (c) and (d): intangible share is changed and all parameters except for profit-shifting costs are recalibrated. Panel (e): households have GHH preferences (no income effects on labor supply). Panel (f): labor supply is fixed. Lost profits measured relative to benchmark equilibrium in baseline calibration. Baseline results shown at top of table for ease of comparison.

Table D.2: Sensitivity analysis, continued

Experiment	Lost profits (benchmark = 1) North America	Europe	Low tax	Rest of World	GDP (% chg.) North America	Europe	Low tax	Rest of World
Baseline model								
Effects of profit shifting	1.00	1.00	1.00	1.00	0.01	0.02	0.29	0.08
Pillar 1	0.68	0.73	0.76	0.70	-0.09	-0.15	-0.37	-0.17
Pillar 2	0.38	0.27	0.49	0.16	0.01	0.02	-0.16	-0.04
Pillars 1 & 2 together	0.26	0.20	0.37	0.12	-0.09	-0.14	-0.46	-0.18
(g) Low variable profit-shifting costs								
Effects of profit shifting	2.02	1.95	1.90	2.04	-0.00	0.03	0.56	0.14
Pillar 1	1.43	1.44	1.46	1.46	-0.09	-0.16	-0.48	-0.20
Pillar 2	0.80	0.54	0.96	0.35	0.02	0.03	-0.29	-0.07
Pillars 1 & 2 together	0.56	0.40	0.73	0.25	-0.07	-0.14	-0.65	-0.23
(h) High variable profit-shifting costs								
Effects of profit shifting	0.48	0.50	0.51	0.48	0.01	0.01	0.15	0.04
Pillar 1	0.32	0.36	0.39	0.33	-0.09	-0.15	-0.31	-0.15
Pillar 2	0.18	0.13	0.25	0.08	0.00	0.01	-0.08	-0.02
Pillars 1 & 2 together	0.12	0.10	0.19	0.05	-0.09	-0.14	-0.36	-0.16
(i) Positive cross-destination effects on marginal profit shifting costs								
Effects of profit shifting	1.00	1.00	1.00	1.00	0.01	0.03	0.36	0.09
Pillar 1	0.69	0.73	0.76	0.71	-0.09	-0.15	-0.37	-0.17
Pillar 2	0.38	0.25	0.40	0.15	0.01	0.01	-0.18	-0.04
Pillars 1 & 2 together	0.26	0.18	0.30	0.10	-0.09	-0.14	-0.47	-0.18
(j) Negative cross-destination effects on marginal profit-shifting costs								
Effects of profit shifting	1.00	1.00	1.00	1.00	0.01	0.02	0.28	0.08
Pillar 1	0.67	0.72	0.78	0.70	-0.09	-0.15	-0.36	-0.17
Pillar 2	0.41	0.33	0.78	0.23	0.01	0.02	-0.09	-0.04
Pillars 1 & 2 together	0.29	0.25	0.60	0.17	-0.09	-0.13	-0.42	-0.18
(k) Some firms exogenously restricted from profit shifting, baseline profit shifting costs								
Effects of profit shifting	0.50	0.50	0.50	0.50	0.00	0.00	0.15	0.04
Pillar 1	0.34	0.36	0.38	0.35	-0.08	-0.13	-0.29	-0.13
Pillar 2	0.19	0.13	0.25	0.08	0.01	0.02	-0.08	-0.01
Pillars 1 & 2 together	0.13	0.10	0.19	0.06	-0.08	-0.13	-0.35	-0.15
(l) Some firms exogenously restricted from profit shifting, recalibrated profit shifting costs								
Effects of profit shifting	1.00	1.00	0.99	1.00	-0.00	0.02	0.36	0.08
Pillar 1	0.69	0.74	0.77	0.71	-0.09	-0.14	-0.37	-0.16
Pillar 2	0.39	0.28	0.50	0.17	0.01	0.02	-0.16	-0.04
Pillars 1 & 2 together	0.27	0.21	0.38	0.12	-0.08	-0.13	-0.46	-0.18

Notes: Panel (g): parameters that govern marginal cost of profit shifting, ψ_{ij}, are halved. Panel (h): ψ_{ij} are doubled. Panel (i): $\epsilon_i = 0.75$. Panel (j): $\epsilon_i = 1.25$. Panel (k): 50% of firms exogenously restricted from profit shifting, using values for profit-shifting cost parameters from baseline calibration. Panel (l): 50% of firms exogenously restricted from profit shifting, using recalibrated profit-shifting cost parameters. Lost profits measured relative to benchmark equilibrium in baseline calibration. Baseline results shown at top of table for ease of comparison.

E Quantitative Model Derivations

E.1 Firm's problem

E.1.1 Scale choice: the parent division

We start from the parent division of a firm $\omega \in \Omega_i$'s scale choice here. A parent division that produces for the domestic market and exports to a set of J_X regions chooses its scale and how to allocate its output across its markets. Note that this problem nests the problem for firms only producing for the domestic markets when $J_X = \emptyset$. The parent division's problem can then be written as

$$\pi_i^D(a, z; J_X) = \max_{q_{ii}, (q_{ij})_{j \in J_X}, \ell} \left\{ p_{ii}(q_{ii}) q_{ii} + \sum_{j \in J_X} p_{ij}(q_{ij}^X) q_{ij}^X - W_i \ell \right\},$$

$$\text{s.t} \quad q_{ii} + \sum_{j \in J_X} \xi_{ij} q_{ij}^X = y_i = A_i a (N_i z)^\gamma \ell^\phi.$$

The first-order conditions are

$$[q_{ij}] \quad \frac{\rho - 1}{\rho} P_j Q_j^{\frac{1}{\rho}} q_{ij}^{-\frac{1}{\rho}} = \lambda \xi_{ij},$$

$$[\ell] \quad W_i = \lambda \phi A_i a (N_i z)^\gamma \ell^{\phi - 1},$$

where $\xi_{ii} = 1$. Rearrange to get

$$\frac{\rho - 1}{\rho} P_j Q_j^{\frac{1}{\rho}} q_{ij}^{-\frac{1}{\rho}} = \frac{\tau_{ij} W_i}{\phi A_i a (N_i z)^\gamma \ell^{\phi - 1}}.$$

The solution is

$$q_{ij} = \left[\frac{\phi(\rho - 1)}{\rho} \right]^\rho \left[\frac{P_j Q_j^{\frac{1}{\rho}} A_i a (N_i z)^\gamma \ell^{\phi - 1}}{\xi_{ij} W_i} \right]^\rho = \left[\frac{P_j Q_j^{\frac{1}{\rho}}}{\xi_{ij}} \right]^\rho \left[\frac{\phi(\rho - 1)}{\rho} \right]^\rho \left[\frac{A_i a (N_i z)^\gamma \ell^{\phi - 1}}{W_i} \right]^\rho.$$

Plugging this back into the resource constraint, can solve for labor as

$$\ell = \left\{ \left[P_i^\rho Q_i + \sum_{j \in J_X} P_j^\rho \tau_j^{1 - \rho} Q_j \right] \left[\frac{\phi(\rho - 1)}{\rho} \right]^\rho W_i^{-\rho} (A_i a)^{\rho - 1} (N_i z)^{\gamma(\rho - 1)} \right\}^{\frac{1}{\phi + \rho - \rho\phi}}. \tag{E.1}$$

We can use the equations above to compute q_{ij}, p_{ij}, and $\pi_i^D(a, z; J_X)$. It is convenient to express domestic parent revenues as

$$
\begin{aligned}
p_{ii}q_{ii} + \sum_{j\in J_X} p_{ij}q_{ij} &= P_i Q_i^{\frac{1}{\rho}} q_{ii}^{\frac{\rho-1}{\rho}} + \sum_{j\in J_X} P_j Q_j^{\frac{1}{\rho}} q_{ij}^{\frac{\rho-1}{\rho}} \\
&= \left[P_i Q_i^{\frac{1}{\rho}} \bar{Q}_{ii}^{\frac{\rho-1}{\rho}} + \sum_{j\in J_X} P_j Q_j^{\frac{1}{\rho}} \bar{Q}_{ij}^{\frac{\rho-1}{\rho}} \right] \\
&\qquad \times \left\{ \left[P_i^{\rho} Q_i + \sum_{j\in J_X} P_j^{\rho} \tau_j^{1-\rho} Q_j \right] \left[\frac{\phi(\rho-1)}{\rho} \right]^{\rho} W^{-\rho} \right\}^{\frac{\rho-1}{\rho}\frac{\phi}{\phi+\rho-\rho\phi}} \\
&\qquad \times (A_i a)^{\frac{\rho-1}{\phi+\rho-\phi\rho}} N_i^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}} z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}} \\
&= \bar{R}_{ii} z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}.
\end{aligned} \tag{E.2}
$$

Similarly, domestic parent costs can be expressed as

$$
\begin{aligned}
W_i\ell + W_i z/(A_i a) &= W_i \left\{ \left[P_i^{\rho} Q_i + \sum_{j\in J_X} P_j^{\rho} \tau_j^{1-\rho} Q_j \right] \left[\frac{\phi(\rho-1)}{\rho} \right]^{\rho} W^{-\rho} (A_i a)^{\rho-1} (N_i z)^{\gamma(\rho-1)} \right\}^{\frac{1}{\phi+\rho-\rho\phi}} + W_i z/(A_i a) \\
&= \bar{C}_{ii} z^{\frac{\gamma(\rho-1)}{\phi+\rho-\rho\phi}} + W_i z/(A_i a).
\end{aligned} \tag{E.3}
$$

E.1.2 Scale choice: foreign subsidiaries

Foreign subsidiaries are similar to domestic-only firms. They just choose scale to maximize profits from selling to the host market given the demand curve and production technology. The only difference is the presence of the FDI barrier σ_{ij}. The foreign subsidiary's problem is

$$
\begin{aligned}
\pi_{ij}^F(a,z) &= \max_{q,\ell}\ p_{ij}(q)q - W_i\ell \\
&= \max_{\ell}\ P_j Q_j^{\frac{1}{\rho}} (\sigma_{ij} A_j a)^{\frac{\rho-1}{\rho}} (N_j z)^{\gamma\frac{\rho-1}{\rho}} \ell^{\phi\frac{\rho-1}{\rho}} - W_j \ell.
\end{aligned}
$$

The optimal ℓ, which yields all the other quantities immediately, is

$$
\ell = \left\{ \left[\frac{\phi(\rho-1)}{\rho} \right]^{\rho} (P_j/W_j)^{\rho} Q_j \left(\sigma_{ij} A_j a\right)^{\rho-1} \left(N_j z\right)^{\gamma(\rho-1)} \right\}^{\frac{1}{\phi+\rho-\phi\rho}}. \tag{E.4}
$$

We can use this to compute $q_{ij} = y_{ij} = \sigma_{ij} A_j a (N_j z)^{\gamma} \ell^{\phi}$, $p_{ij} = P_j Q_j^{\frac{1}{\rho}} q_{ij}^{-\frac{1}{\rho}}$, and $\pi_j^F(a,z)$. It is convenient to express foreign affiliate revenues as

$$
\begin{aligned}
p_{ij}q_{ij} &= P_j Q_j^{\frac{1}{\rho}} q_{ij}^{\frac{\rho-1}{\rho}} \\
&= \left[P_j Q_j^{\frac{1}{\rho}} \right] \left[(P_j/W_j) \frac{\phi(\rho-1)}{\rho} \right]^{\frac{\phi(\rho-1)}{\phi+\rho-\phi\rho}} Q_j^{\frac{\rho-1}{\rho}\frac{\phi}{\phi+\rho-\phi\rho}} (A_j \sigma_{ij} a)^{\frac{\rho-1}{\phi+\rho-\phi\rho}} N_j^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}} z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}} \\
&= \bar{R}_{ij} z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}},
\end{aligned} \tag{E.5}
$$

and express foreign affiliate costs as

$$W_j \ell = W_j \left\{ \left[\frac{\phi(\rho-1)}{\rho} \right]^{\rho} (P_j/W_j)^{\rho} Q_j \left(A_j \sigma_{ij} a \right)^{\rho-1} \left(N_j z \right)^{\gamma(\rho-1)} \right\}^{\frac{1}{\phi+\rho-\phi\rho}} \tag{E.6}$$

$$= \bar{C}_{ij} z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}. \tag{E.7}$$

E.1.3 Technology and Profit Shfiting Choice

Here, we solve the optimal nonrival technology allocation z and profit shifting shares λ_{TH} and λ_{LT} in the environment with transfer pricing and profit shifting, taking J_X and J_F as given. Letting $\Pi_i(a; J_X, J_F)$ be the maximized dividend for a firm in region i, given productivity a and the sets of exporting and FDI destinations J_X and J_F, we have

$$\begin{aligned}
\Pi_i(a; J_X, J_F) = \max_{z, \lambda_{LT}, \lambda_{TH}} \Bigg\{ & (1-\tau_i) \Bigg[\pi_i^D(a, z; J_X) + \Bigg(-(\lambda_{LT} + \lambda_{TH}) \vartheta_{ii}(z) + (1 - \lambda_{LT} - \lambda_{TH}) \sum_{j \in J_F} \vartheta_{ij}(z) \\
& - \frac{W_i}{A_i a} - W_i \mathcal{C}_i \left(\lambda_{TH}, \lambda_{LT} \right) \nu_i(z) + (\mu_{iTH} \lambda_{TH} + \mu_{iLT} \lambda_{LT}) \nu_i(z) \Bigg) z \Bigg] \\
& + (1 - \tau_{LT}) \Bigg[\pi_{i,LT}^F(a, z) + \Bigg(\lambda_{LT} \sum_{j \in J_F \cup \{i\} \setminus \{LT\}} \vartheta_{ij}(z) - (1 - \lambda_{LT}) \vartheta_{iLT}(z) - \mu_{iLT} \lambda_{LT} \nu_i(z) \Bigg) z \Bigg] \\
& + (1 - \tau_{TH}) \Bigg[\Bigg(\lambda_{TH} \sum_{j \in J_F \cup \{i\}} \vartheta_{ij}(z) - \mu_{iTH} \lambda_{TH} \nu_i(z) \Bigg) z \Bigg] \\
& + \sum_{j \in J_F \setminus \{LT\}} (1 - \tau_j) \left[\pi_{ij}^F(a, z) - \vartheta_{ij}(z) z \right] \Bigg\}.
\end{aligned}$$

Here, we solve the full problem where the firm operates in both LT and TH. The optimal choices of z and λ could be derived similarly for firms only operate in fewer than two profit-shifting destinations. Substituting in the optimal scale choices specified in equation (E.1) and (E.4) and letting $\lambda = \lambda_{TH} + \lambda_{LT}$, we can write

$\Pi_i(a; J_X, J_F)$ as

$$\max_{z,\lambda_{TH},\lambda_{LT}} \Bigg\{(1-\tau_i)\left[\left(1-\lambda\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)\right)(\bar{R}_{ii}-\bar{C}_{ii})+(1-\lambda)\sum_{j\in J_F}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\right]$$
$$-(1-\tau_i)\left[(W_i\mathcal{C}_i(\lambda_{TH},\lambda_{LT})-(\mu_{iTH}\lambda_{TH}+\mu_{iLT}\lambda_{LT}))\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\right]$$
$$+(1-\tau_{LT})\Bigg[\left(1-(1-\lambda_{LT})\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)\right)(\bar{R}_{i,LT}-\bar{C}_{i,LT})+$$
$$\lambda_{LT}\sum_{j\in J_F\cup\{i\}\setminus\{LT\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})-\mu_{iLT}\lambda_{LT}\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\Bigg]$$
$$+(1-\tau_{TH})\left[(1-\mu_{iTH})\lambda_{TH}\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\right]$$
$$+\sum_{j\in J_F\setminus\{LT\}}(1-\tau_j)\left[\left(1-\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\right]\Bigg\}z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}-(1-\tau_i)W_i z/(A_i a).$$

And further simplifying

$$\max_{z,\lambda_{TH},\lambda_{LT}}\Bigg\{\sum_{j\in J_F\cup\{i\}}(1-\tau_j)(\bar{R}_{ij}-\bar{C}_{ij})-\sum_{j\in J_F\cup\{i\}}(\tau_i-\tau_j)\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})$$
$$+(1-\mu_{iLT})(\tau_i-\tau_{LT})\lambda_{LT}\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})$$
$$+(1-\mu_{iTH})(\tau_i-\tau_{TH})\lambda_{TH}\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})$$
$$-(1-\tau_i)W_i\mathcal{C}_i(\lambda_{TH},\lambda_{LT})\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\Bigg\}z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}-(1-\tau_i)W_i z/(A_i a).$$

With the functional form assumption of $\mathcal{C}$ specified by equation (49), the optimal λ values can be solved independent of z from the following two first-order conditions:

$$(1-\tau_i)W_i\left[(\chi_{i,TH}\mathcal{C}(\lambda_{TH}))^\epsilon+(\chi_{i,LT}\mathcal{C}(\lambda_{LT}))^\epsilon\right]^{\frac{1}{\epsilon}-1}\cdot\chi_{i,TH}^\epsilon\mathcal{C}(\lambda_{TH})^{\epsilon-1}\cdot\mathcal{C}'(\lambda_{TH})=(1-\mu_{iTH})(\tau_i-\tau_{TH})$$
$$(1-\tau_i)W_i\left[(\chi_{i,TH}\mathcal{C}(\lambda_{TH}))^\epsilon+(\chi_{i,LT}\mathcal{C}(\lambda_{LT}))^\epsilon\right]^{\frac{1}{\epsilon}-1}\cdot\chi_{i,LT}^\epsilon\mathcal{C}(\lambda_{LT})^{\epsilon-1}\cdot\mathcal{C}'(\lambda_{LT})=(1-\mu_{iLT})(\tau_i-\tau_{LT}).$$

The FOC for z is

$$
\begin{aligned}
(1-\tau_i)W_i/(A_i a) = \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right) z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}-1} \Bigg\{ & \sum_{j\in J_F\cup\{i\}} (1-\tau_j)(\bar{R}_{ij}-\bar{C}_{ij}) \\
& - \sum_{j\in J_F\cup\{i\}} (\tau_i-\tau_j)\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij}) \\
& +(1-\mu_{iLT})(\tau_i-\tau_{LT})\lambda_{LT} \sum_{j\in J_F\cup\{i\}} \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij}) \\
& +(1-\mu_{iTH})(\tau_i-\tau_{TH})\lambda_{TH} \sum_{j\in J_F\cup\{i\}} \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij}) \\
& -(1-\tau_i)W_i\mathcal{C}_i\left(\lambda_{TH},\lambda_{LT}\right) \sum_{j\in J_F\cup\{i\}} \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij}) \Bigg\}.
\end{aligned}
$$

We can solve the optimal z as:

$$
z = \left\{ \left(\frac{\phi+\rho-\phi\rho}{\gamma(\rho-1)}\right) \left[\frac{(1-\tau_i)\,W_i/(A_i a)}{DENOM^{PS}}\right] \right\}^{\frac{\phi+\rho-\phi\rho}{\gamma\rho+\phi\rho-\gamma-\phi-\rho}}, \tag{E.8}
$$

where $DENOM^{PS}$ is the sum of terms inside the big brackets above.

E.1.4 Market choice

Given $\Pi_i(a; J_X, J_F), \forall J_X, J_F$, firms decide where to export and where to operate foreign subsidiaries, according to the following problem

$$
d_i(a) = \max_{J_X, J_F} \left\{ \Pi_i(a; J_X, J_F) - W_i \left(\sum_{j\in J_X} \kappa_{jX} - \sum_{j\in J_F} \kappa_{jF} - \kappa_{iTH}\mathbb{1}(\lambda_{TH}>0) \right) \right\}. \tag{E.9}
$$

where d denotes the optimal firm dividend. This is a combinatorial discrete choice problem as a firm's exporting and FDI choices are interdependent across regions. This problem is hard to solve since the number of potential decision sets grows exponentially in the number of regions. We limit the number of regions in the quantitative model to ease the computational burden. See Appendix F.4 for more discussions on the combinatorial problem.

E.2 Firm's problem under sales-based profit allocation

Under sales-based profit allocation, the scale and market choices can be solved in the same way as in Appendix E.1. The only difference of the firm's problem is the technology and profit shifting choices. As before, we solve for the full problem where $\lambda_{LT} > 0$ and $\lambda_{TH} > 0$. It's easier to state the firm's problem as:

$$
\hat{d}_i(a; J_X, J_F) = \max_{z, J_X, J_F, \lambda_{TL}, \lambda_{TH}} \left\{ \hat{\Pi}_i(a; J_X, J_F) - W_i \left(\sum_{j\in J_X} \kappa_{jX} - \sum_{j\in J_F} \kappa_{jF} - \kappa_{iTH}\mathbb{1}(\lambda_{TH}>0) \right) \right\}.
$$

Each firm, taking J_X and J_F as given, chooses z and λ to maximize

$$\hat{\Pi}_i(a; J_X, J_F) = \max_{z,\lambda_{TH},\lambda_{LT}} \left\{ \sum_{j\in\{i\}\cup J_X\cup J_F} \left(\pi_{ij}(a,z) - \tau_j T_{ij}^{P1}\right) \right\}, \tag{E.10}$$

where

$$\begin{aligned}
\hat{\Pi}_i(a; J_X, J_F) = \max_{z,\lambda_{LT},\lambda_{TH}} \Bigg\{ & \Bigg[\pi_i^D(a,z;J_X) + \Bigg(-(\lambda_{LT}+\lambda_{TH})\vartheta_{ii}(z) + (1-\lambda_{LT}-\lambda_{TH}) \sum_{j\in J_F} \vartheta_{ij}(z) \\
& \qquad - \frac{W_i}{A_i a} - W_i \mathcal{C}_i\left(\lambda_{TH}, \lambda_{LT}\right)\nu_i(z) + (\mu_{iLT}\lambda_{LT} + \mu_{iTH}\lambda_{TH})\nu_i(z)\Bigg) z - \tau_i T_i\Bigg] \\
& + \Bigg[\pi_{i,LT}^F(a,z) + \Bigg(\lambda_{LT} \sum_{j\in J_F\cup\{i\}\setminus\{LT\}} \vartheta_{ij}(z) - (1-\lambda_{LT})\vartheta_{iLT}(z) - \mu_{iLT}\lambda_{LT}\nu_i(z)\Bigg) z - \tau_{LT}T_{LT}\Bigg] \\
& + \Bigg[\Bigg(\lambda_{TH} \sum_{j\in J_F\cup\{i\}} \vartheta_{ij}(z) - \mu_{iTH}\lambda_{TH}\nu_i(z)\Bigg) z - \tau_{TH}T_{TH}\Bigg] \\
& + \sum_{j\in J_F\setminus\{LT\}} \left[\pi_{ij}^F(a,z) - \vartheta_{ij}(z)z - \tau_j T_j\right] + \sum_{j\in J_X\setminus J_F} \left[-\tau_j T_{ij}^{P1}\right] \Bigg\}.
\end{aligned}$$

The term T_{ij}^{P1} is the tax base in region j, which consists of local firms' routine profit, a proportion of local firms' residual profits and reallocated residual profits to this region:

$$\begin{aligned}
T_{ij}^{P1} &= \pi_j^r + (1-\theta)\cdot\pi_j^R + \theta\cdot\frac{R_j}{\sum_k R_k}\cdot\Pi_i^R \\
&= \iota R_j + (1-\theta)\cdot(\pi_j - \iota R_j) + \theta\cdot\frac{R_j}{\sum_k R_k}\cdot\sum_{k\in\{i\}\cup J_X\cup J_F}(\pi_k - \iota R_k) \\
&= (1-\theta)\cdot\pi_j + \theta\cdot\frac{R_j}{\sum_k R_k}\cdot\sum_{k\in\{i\}\cup J_X\cup J_F}\pi_k.
\end{aligned}$$

Profit π_j is the profit earned in region j and it is zero if the firm does not operate in the region. Revenue earned in region j, denoted as R_j, include sales of both goods produced locally (by parent division or FDI) and goods exported to the region. Formally:

$$\begin{aligned}
R_i &= p_{ii}\left(q_{ii}\right)q_{ii}, \\
R_j &= p_{ij}^F\left(q_{ij}\right)q_{ij}, j\in J_F, j\notin J_X, \\
R_j &= p_{ij}^X\left(q_{ij}^X\right)q_{ij}^X, j\in J_X, j\notin J_F, \\
R_j &= p_{ij}^F\left(q_{ij}\right)q_{ij} + p_{ij}^X\left(q_{ij}^X\right)q_{ij}^X, j\in J_X\cap J_F, \\
R_j &= 0, \quad j\notin\{i\}\cup J_F\cup J_X.
\end{aligned}$$

We can rewrite firm's problem as:

$$\hat{\Pi}_i(a; J_X, J_F) = \max_{z,\lambda_{TH},\lambda_{LT}} \left\{ \sum_{j\in\{i\}\cup J_X\cup J_F} \left(\left(1-\tau_j(1-\theta)\right)\pi_j(a,z;J_X) - \tau_j\theta\cdot\frac{R_j}{\sum_j R_j}\cdot\sum_k \pi_k(a,z;J_X)\right) \right\}.$$

Further, substituting in π_i and denoting $\lambda = \lambda_{TH} + \lambda_{LT}$, we get

$$
\begin{aligned}
\max_{z,\lambda_{TH},\lambda_{LT}} \Bigg\{ & (1-(1-\theta)\tau_i) \left[\left(1 - \lambda \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)\right) (\bar{R}_{ii} - \bar{C}_{ii}) + (1-\lambda) \sum_{j \in J_F} \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right) (\bar{R}_{ij} - \bar{C}_{ij}) \right] \\
& -(1-(1-\theta)\tau_i) \left[(W_i \mathcal{C}_i (\lambda_{TH}, \lambda_{LT}) - (\mu_{iLT}\lambda_{LT} + \mu_{iTH}\lambda_{TH})) \sum_{j \in J_F \cup \{i\}} \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right) (\bar{R}_{ij} - \bar{C}_{ij}) \right] \\
& +(1-(1-\theta)\tau_{LT}) \Bigg[\left(1 - (1-\lambda_{LT}) \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)\right) (\bar{R}_{i,LT} - \bar{C}_{i,LT}) + \\
& \qquad \lambda_{LT} \sum_{j \in J_F \cup \{i\} \setminus \{LT\}} \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right) (\bar{R}_{ij} - \bar{C}_{ij}) - \mu_{iLT}\lambda_{LT} \sum_{j \in J_F \cup i} \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right) (\bar{R}_{ij} - \bar{C}_{ij}) \Bigg] \\
& +(1-(1-\theta)\tau_{TH}) \left[(1-\mu_{iTH})\lambda_{TH} \sum_j \left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right) (\bar{R}_{ij} - \bar{C}_{ij}) \right] \\
& + \sum_{j \in J_F \setminus \{LT\}} (1-\tau_j) \left[\left(1 - \frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right) (\bar{R}_{ij} - \bar{C}_{ij}) \right] \Bigg\} z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}} - (1-(1-\theta)\tau_i) W_i z/(A_i a) \\
& - \sum_{j \in \{i\} \cup J_X \cup J_F} \tau_j \theta \cdot \frac{R_j}{\sum_j R_j} \cdot \sum_k \pi_k(a, z; J_X).
\end{aligned}
$$

Here we define $\tilde{R}_{ij}$ as the revenue shifter in region j for firms from region i, depending on region j is served. These terms are defined analogously of $\bar{R}_{ij}$ in equations (E.2) and (E.5):

$$
\begin{aligned}
\tilde{R}_{ii} &= P_i Q_i^{\frac{1}{\rho}} \bar{Q}_{ii}^{\frac{\rho-1}{\rho}} \left\{ \left[P_i^\rho Q_i + \sum_{j \in J_X} P_j^\rho \tau_j^{1-\rho} Q_j \right] \left[\frac{\phi(\rho-1)}{\rho}\right]^\rho W_i^{-\rho} \right\}^{\frac{\rho-1}{\rho} \frac{\phi}{\phi+\rho-\rho\phi}} (A_i)^{\frac{\rho-1}{\phi+\rho-\phi\rho}} N_i^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}, \\
\tilde{R}_{ij} &= P_j Q_j^{\frac{1}{\rho}} \bar{Q}_{ij}^{\frac{\rho-1}{\rho}} \left\{ \left[P_i^\rho Q_i + \sum_{j \in J_X} P_j^\rho \tau_j^{1-\rho} Q_j \right] \left[\frac{\phi(\rho-1)}{\rho}\right]^\rho W_i^{-\rho} \right\}^{\frac{\rho-1}{\rho} \frac{\phi}{\phi+\rho-\rho\phi}} (A_i)^{\frac{\rho-1}{\phi+\rho-\phi\rho}} N_i^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}, \quad j \in J_X, j \notin J_F, \\
\tilde{R}_{ij} &= \left[P_j Q_j^{\frac{1}{\rho}} \right] \left[(P_j/W_j) \frac{\phi(\rho-1)}{\rho} \right]^{\frac{\phi(\rho-1)}{\phi+\rho-\phi\rho}} Q_j^{\frac{\rho-1}{\rho} \frac{\phi}{\phi+\rho-\phi\rho}} (A_j \sigma_{ij})^{\frac{\rho-1}{\phi+\rho-\phi\rho}} N_j^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}, \quad j \in J_F, j \notin J_X, \\
\tilde{R}_{ij} &= \left[P_j Q_j^{\frac{1}{\rho}} \right] \left[(P_j/W_j) \frac{\phi(\rho-1)}{\rho} \right]^{\frac{\phi(\rho-1)}{\phi+\rho-\phi\rho}} Q_j^{\frac{\rho-1}{\rho} \frac{\phi}{\phi+\rho-\phi\rho}} (A_j \sigma_{ij})^{\frac{\rho-1}{\phi+\rho-\phi\rho}} N_j^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}} \\
&\quad + P_j Q_j^{\frac{1}{\rho}} \bar{Q}_{ij}^{\frac{\rho-1}{\rho}} \left\{ \left[P_i^\rho Q_i + \sum_{j \in J_X} P_j^\rho \tau_j^{1-\rho} Q_j \right] \left[\frac{\phi(\rho-1)}{\rho}\right]^\rho W_i^{-\rho} \right\}^{\frac{\rho-1}{\rho} \frac{\phi}{\phi+\rho-\rho\phi}} (A_i)^{\frac{\rho-1}{\phi+\rho-\phi\rho}} N_i^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}, \quad j \in J_X \cap J_F, \\
\tilde{R}_{ij} &= 0, \quad j \notin \{i\} \cup J_F \cup J_X.
\end{aligned}
$$

With these definitions, it's straightforward to show that the revenue share $\frac{R_j}{\sum_j R_j} = \frac{\tilde{R}_{ij}}{\sum_j \tilde{R}_{ij}}$. We can further simplify the problem to

$$\max_{z,\lambda_{TH},\lambda_{LT}} \Bigg\{(1-(1-\theta)\tau_i)\left[\left(1-\lambda\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)\right)(\bar{R}_{ii}-\bar{C}_{ii})+(1-\lambda)\sum_{j\in J_F}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\right]$$

$$-(1-(1-\theta)\tau_i)\left[\left(W_i\mathcal{C}_i\left(\lambda_{TH},\lambda_{LT}\right)-(\mu_{iLT}\lambda_{LT}+\mu_{iTH}\lambda_{TH})\right)\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\right]$$

$$+(1-(1-\theta)\tau_{LT})\Bigg[\left(1-(1-\lambda_{LT})\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)\right)(\bar{R}_{i,LT}-\bar{C}_{i,LT})+$$

$$\lambda_{LT}\sum_{j\in J_F\cup\{i\}\setminus\{LT\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})-\mu_{iLT}\lambda_{LT}\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\Bigg]$$

$$+(1-(1-\theta)\tau_{TH})\left[(1-\mu_{iTH})\lambda_{TH}\sum_{j}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\right]$$

$$+\sum_{j\in J_F\setminus\{LT\}}(1-\tau_j)\left[\left(1-\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\right]\Bigg\}z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}-(1-(1-\theta)\tau_i)W_iz/(A_ia)$$

$$-\sum_{j\in\{i\}\cup J_X\cup J_F}\tau_j\theta\cdot\frac{\tilde{R}_{ij}}{\sum_j\tilde{R}_{ij}}\cdot\Bigg\{\sum_k\left(\bar{R}_{ik}-\bar{C}_{ik}\right)z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}-W_iz/(A_ia)-$$

$$W_i\mathcal{C}_i\left(\lambda_{TH},\lambda_{LT}\right)\cdot\sum_j\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})z^{\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}}\Bigg\}.$$

As before, the shift shares λ_{TH} and λ_{LT} can be solved from the first-order conditions:

$$\left[\left(\chi_{i,TH}\mathcal{C}\left(\lambda_{TH}\right)\right)^{\epsilon}+\left(\chi_{i,LT}\mathcal{C}\left(\lambda_{LT}\right)\right)^{\epsilon}\right]^{\frac{1}{\epsilon}-1}\cdot\chi_{i,TH}^{\epsilon}\mathcal{C}\left(\lambda_{TH}\right)^{\epsilon-1}\cdot\mathcal{C}'\left(\lambda_{TH}\right)=\frac{1}{W_i}\frac{(1-\mu_{iTH})(1-\theta)\left(\tau_i-\tau_{TH}\right)}{1-(1-\theta)\tau_i-\theta\sum_k\tau_k\cdot\frac{\tilde{R}_{ik}}{\sum_j\tilde{R}_{ij}}}$$

$$\left[\left(\chi_{i,TH}\mathcal{C}\left(\lambda_{TH}\right)\right)^{\epsilon}+\left(\chi_{i,LT}\mathcal{C}\left(\lambda_{LT}\right)\right)^{\epsilon}\right]^{\frac{1}{\epsilon}-1}\cdot\chi_{i,LT}^{\epsilon}\mathcal{C}\left(\lambda_{LT}\right)^{\epsilon-1}\cdot\mathcal{C}'\left(\lambda_{LT}\right)=\frac{1}{W_i}\frac{(1-\mu_{iLT})(1-\theta)\left(\tau_i-\tau_{LT}\right)}{1-(1-\theta)\tau_i-\theta\sum_k\tau_k\cdot\frac{\tilde{R}_{ik}}{\sum_j\tilde{R}_{ij}}}$$

The optimal z is given by

$$z=\left\{\left(\frac{\phi+\rho-\phi\rho}{\gamma(\rho-1)}\right)\left[\frac{\left(1-(1-\theta)\tau_i-\theta\sum_j\tau_j\frac{\tilde{R}_{ij}}{\sum_k\tilde{R}_{ik}}\right)W_i/(A_ia)}{DENOM^{P1}}\right]\right\}^{\frac{\phi+\rho-\phi\rho}{\gamma\rho+\phi\rho-\gamma-\phi-\rho}},$$

where $DENOM^{P1}$ is defined as

$$\Bigg\{ \sum_{j\in J_F\cup\{i\}} (1-(1-\theta)\tau_j)(\bar{R}_{ij}-\bar{C}_{ij}) - \sum_{j\in J_F\cup\{i\}} (1-\theta)(\tau_i-\tau_j)\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})$$

$$+(1-\theta)\left[(1-\mu_{iLT})(\tau_i-\tau_{LT})\lambda_{LT}\ +(1-\mu_{iTH})(\tau_i-\tau_{TH})\lambda_{TH}\right]\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})$$

$$-(1-(1-\theta)\tau_i)W_i\mathcal{C}_i\left(\lambda_{TH},\lambda_{LT}\right)\cdot \sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})$$

$$-\sum_{j\in\{i\}\cup J_X\cup J_F}\tau_j\theta\cdot\frac{\tilde{R}_{ij}}{\sum_k\tilde{R}_{ik}}\cdot\left[\sum_{k\in J_F\cup\{i\}}\left(\bar{R}_{ik}-\bar{C}_{ik}\right)-W_i\mathcal{C}_i\left(\lambda_{TH},\lambda_{LT}\right)\sum_{j\in J_F\cup\{i\}}\left(\frac{\gamma(\rho-1)}{\phi+\rho-\phi\rho}\right)(\bar{R}_{ij}-\bar{C}_{ij})\right]\Bigg\}.$$

F Proofs of Theoretical Results

This Appendix contains the proofs of the lemmas and propositions from the main body of the paper.

F.1 Optimal Profit-Shifting and Effect on Intangible Investment

Proof of Lemma 2. Let $\nu_i \equiv \sum_{j\in J_F\cup\{i\}}\vartheta_{ij}$. The MNE's profit maximization problem can be written as

$$\begin{aligned}\max_{z,\lambda,\{l_j\}_{j=1}^{I}} &(1-\tau_i)\left(p_{ii}A_ia\left(N_iz_i\right)^{\phi}l_i^{\gamma}-W_i\left(\frac{z}{A_ia}\right)+z\left[\mu\lambda\nu_i+\sum_{j\in J_F}(1-\lambda)\vartheta_{ij}-\lambda\vartheta_{ii}-W_i\mathcal{C}_i(\lambda)\nu_i\right]\right)\\ &+(1-\tau_{TH})\,z\left(\lambda\nu_i-\mu\lambda\nu_i\right) \qquad\qquad (F.1)\\ &+\sum_{j\in J_F}(1-\tau_j)\left(p_{ij}A_j\left(N_jz\right)^{\phi}l_j^{\gamma}-W_jl_j-\vartheta_{ij}z\right)\end{aligned}$$

where we subsumed the subscripts of μ and λ. The FOCs are then:

$$l_i: 0=\gamma p_{ii}A_i\left(N_iz\right)^{\phi}l_i^{\gamma-1}-W_i \qquad (F.2)$$

$$\begin{aligned}z: 0=&\sum_{j\neq TH}(1-\tau_j)\,\phi N_jp_{ij}A_j\left(N_jz\right)^{\phi-1}l_j^{\gamma}+(1-\tau_i)\left(\mu\lambda\nu_i+\sum_{j\in J_F}(1-\lambda)\vartheta_{ij}-\lambda\vartheta_{ii}-W_i\mathcal{C}_i(\lambda)\nu_i\right)+\\ &+(1-\tau_{TH})\left(\lambda\nu_i-\mu\lambda\nu_i\right)-\sum_{j\in J_F}(1-\tau_j)\,\vartheta_{ij} \qquad (F.3)\end{aligned}$$

$$\begin{aligned}\lambda: 0=&(1-\tau_i)\,z\left(\mu\nu_i-\sum_{j\in J_F}\vartheta_{ij}-\vartheta_{ii}-W_i\mathcal{C}_i'(\lambda)\,\nu_i\right) \qquad (F.4)\\ &+(1-\tau_{TH})\,z\left(\nu_i-\mu\nu_i\right).\end{aligned}$$

From the FOC wrt to λ, we can get

$$\mathcal{C}'(\lambda)=\frac{(1-\mu)\left(\tau_i-\tau_{TH}\right)}{W_i\left(1-\tau_i\right)}$$

and under our assumption of the profit-shifting cost function by equation (32), this can be written as

$$\lambda = 1 - \exp\left(-\frac{(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}\right).$$

Now towards proving the lemma, we have

$$\frac{\partial \lambda}{\partial \mu} = -\exp\left(-\frac{(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}\right)\left(\frac{\tau_i - \tau_{TH}}{W_i(1-\tau_i)}\right) < 0$$
$$\frac{\partial \lambda}{\partial \tau_{TH}} = -\exp\left(-\frac{(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}\right)\left(\frac{1-\mu}{W_i(1-\tau_i)}\right) < 0$$

and therefore the elasticities are

$$\varepsilon^{\lambda}_{\mu} = \frac{\partial \lambda}{\partial \mu}\frac{\mu}{1-\exp\left(-\frac{(1-\mu)(\tau_i-\tau_{TH})}{W_i(1-\tau_i)}\right)} = -\exp\left(-\frac{(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}\right)\left(\frac{\tau_i - \tau_{TH}}{W_i(1-\tau_i)}\right)\frac{\mu}{1-\exp\left(-\frac{(1-\mu)(\tau_i-\tau_{TH})}{W_i(1-\tau_i)}\right)}$$
$$= -\left(\frac{\lambda-1}{\lambda}\right)\log(1-\lambda)\frac{\mu}{1-\mu} < 0$$

$$\varepsilon^{\lambda}_{\tau_{TH}} = \frac{\partial \lambda}{\partial \tau_{TH}}\frac{\tau_{i^*}}{1-\exp\left(-\frac{(1-\mu)(\tau_i-\tau_{TH})}{W_i(1-\tau_i)}\right)} = -\exp\left(-\frac{(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}\right)\left(\frac{1-\mu}{W_i(1-\tau_i)}\right)\frac{\tau_{TH}}{1-\exp\left(-\frac{(1-\mu)(\tau_i-\tau_{TH})}{W_i(1-\tau_i)}\right)}$$
$$= -\left(\frac{\lambda-1}{\lambda}\right)\log(1-\lambda)\frac{\tau_{TH}}{\tau_i - \tau_{TH}} < 0$$

which proves 1. and 2. ∎

Proof of Proposition 1. To prove this proposition, we start by deriving optimal z^{NS} of the MNE in the no-shifting case, and optimal z in the profit-shifting case. Inspecting the FOC for z, equation (F.3), we can get in the no-shifting case ($\lambda = 0$):

$$0 = \sum_{j \in J_F \cup \{i\}} (1-\tau_j)\Lambda_j z^{\frac{\phi+\gamma-1}{1-\gamma}} - (1-\tau_i)\left(\frac{W_i}{A_i a} + \sum_{j \in J_F}\vartheta_{ij}\right) - \sum_{j \in J_F}(1-\tau_j)\vartheta_{ij}.$$

Note we have

$$\vartheta_{ij}(z) = \phi p_{ij} N_j \left(A_j (N_j z)^{\phi-1} l_j^{\gamma}\right)$$
$$= \phi p_{ij} N_j \left(A_j (N_j z)^{\phi-1}\left(\frac{\gamma p_{ij} A_j (N_j z)^{\phi}}{W_j}\right)^{\frac{\gamma}{1-\gamma}}\right)$$
$$= \phi \gamma^{\frac{\gamma}{1-\gamma}} p_{ij}^{\frac{1}{1-\gamma}} A_j^{\frac{1}{1-\gamma}}\left(\frac{1}{W_j}\right)^{\frac{\gamma}{1-\gamma}} N_j^{\frac{\phi}{1-\gamma}}(z)^{\frac{\phi+\gamma-1}{1-\gamma}} = \Lambda_j (z)^{\frac{\phi+\gamma-1}{1-\gamma}},$$

where we define $\Lambda_j \equiv \phi \gamma^{\frac{\gamma}{1-\gamma}} p_{ij}^{\frac{1}{1-\gamma}} A_j^{\frac{1}{1-\gamma}}\left(\frac{1}{W_j}\right)^{\frac{\gamma}{1-\gamma}} N_j^{\frac{\phi}{1-\gamma}}$. Then, we can rewrite the FOC as

$$0 = \sum_{j \in J_F \cup \{i\}} (1-\tau_j)\Lambda_j z^{\frac{\phi+\gamma-1}{1-\gamma}} - (1-\tau_i)\frac{W_i}{A_i a} + \sum_{j \in J_F \cup \{i\}} \Lambda_j z^{\frac{\phi+\gamma-1}{1-\gamma}}\left((1-\tau_i) - (1-\tau_j)\right).$$

We can solve for the optimal z as

$$z^{NS} = \left(\frac{A_i a \sum_{j \in J_F \cup \{i\}} \Lambda_j}{W_i} \right)^{\frac{1-\gamma}{1-\phi-\gamma}}.$$

Now turn into the profit-shifting case, the FOC of z can be rewritten as

$$0 = \sum_{j \in J_F \cup \{i\}} (1-\tau_j) \Lambda_j z^{\frac{\phi+\gamma-1}{1-\gamma}} - (1-\tau_i) \frac{W_i}{A_i a} + \lambda \nu_i (1-\mu)(\tau_i - \tau_{TH}) + \sum_{j \in J_F} \vartheta_{ij} (\tau_j - \tau_i) - (1-\tau_i) W_i \mathcal{C}_i(\lambda) \nu_i.$$

Following the same steps as before, we can obtain,

$$z = \left(\frac{A_i a \sum_{j \in J_F \cup \{i\}} \Lambda_j \left(1 - W_i \mathcal{C}_i(\lambda) + \frac{\lambda(1-\mu)(\tau_i - \tau_{TH})}{(1-\tau_i)} \right)}{W_i} \right)^{\frac{1-\gamma}{1-\phi-\gamma}},$$

hence we have

$$z = z^{NS} \left(1 - W_i \mathcal{C}_i(\lambda) + \frac{\lambda(1-\mu)(\tau_i - \tau_{TH})}{(1-\tau_i)} \right)^{\frac{1-\gamma}{1-\phi-\gamma}}.$$

Now, to show 1, that is $z > z^{NS}$, we would need to prove that

$$1 - W_i \mathcal{C}_i(\lambda) + \frac{\lambda(1-\mu)(\tau_i - \tau_{TH})}{(1-\tau_i)} > 1$$

which can be rewritten as

$$\mathcal{C}(\lambda) < \frac{\lambda(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}. \tag{F.5}$$

We have already shown that

$$\mathcal{C}'(\lambda) = \frac{(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}.$$

Thus, to prove (F.5), it suffices to show that

$$\mathcal{C}(\lambda) < \lambda \mathcal{C}'(\lambda).$$

Let $G(\lambda) = \mathcal{C}(\lambda) - \lambda \mathcal{C}'(\lambda)$, we know that $G(0) = 0$, and

$$G'(\lambda) = \mathcal{C}'(\lambda) - \mathcal{C}'(\lambda) - \lambda \mathcal{C}''(\lambda) = -\lambda \mathcal{C}''(\lambda) < 0, \ \forall \lambda \in (0,1]$$

hence

$$G(\lambda) = \mathcal{C}(\lambda) - \lambda \mathcal{C}'(\lambda) < 0, \ \forall \lambda \in (0,1].$$

and

$$\mathcal{C}(\lambda) < \lambda \mathcal{C}'(\lambda) = \frac{\lambda(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}$$

which proves (F.5) and hence establishes $z > z^{NS}$. To show 2. and 3. we can derive the elasticity with respect to the tax rate as

$$
\begin{aligned}
\varepsilon^z_{\tau_{TH}} &= \frac{\partial z}{\partial \tau_{TH}} \frac{\tau_{TH}}{z} \\
&= \frac{1-\gamma}{1-\phi-\gamma}\left(1 - W_i \mathcal{C}_i(\lambda) + \frac{\lambda(1-\mu)(\tau_i - \tau_{TH})}{(1-\tau_i)}\right)^{-1}\left(-\lambda \frac{\tau_{TH}(1-\mu)}{1-\tau_i}\right) \\
&= -\frac{1-\gamma}{1-\phi-\gamma}\left(\frac{\tau_{TH}}{\tau_i - \tau_{TH}}\right)\frac{1}{\left(1 + \frac{1-W_i\mathcal{C}_i(\lambda)}{\lambda W_i \mathcal{C}'(\lambda)}\right)}
\end{aligned}
$$

Now note that for this to be negative we have to show that

$$
\begin{aligned}
\frac{1}{\left(1 + \frac{1-W_i\mathcal{C}_i(\lambda)}{\lambda W_i \mathcal{C}'(\lambda)}\right)} &> 0 \\
\frac{1 - W_i\mathcal{C}_i(\lambda)}{\lambda W_i \mathcal{C}'(\lambda)} &> -1 \\
\frac{W_i\mathcal{C}_i(\lambda) - 1}{\lambda W_i \mathcal{C}'(\lambda)} &< 1
\end{aligned}
$$

what we have shown already is

$$
\mathcal{C}(\lambda) < \lambda \mathcal{C}'(\lambda)
$$

implying

$$
\frac{W_i\mathcal{C}_i(\lambda) - 1}{\lambda W_i \mathcal{C}'(\lambda)} < \frac{\lambda W_i \mathcal{C}'(\lambda) - 1}{\lambda W_i \mathcal{C}'(\lambda)} = 1 - \frac{1}{\lambda W_i \mathcal{C}'(\lambda)} < 1
$$

where the last inequality comes from the fact that

$$
\begin{aligned}
\lim_{\lambda \to 0}\left(1 - \frac{1}{\lambda W_i \mathcal{C}'(\lambda)}\right) &= -\infty \\
\lim_{\lambda \to 1}\left(1 - \frac{1}{\lambda W_i \mathcal{C}'(\lambda)}\right) &= 1
\end{aligned}
$$

and the fact that the function $1 - \frac{1}{\lambda W_i(\log(1-\lambda))}$ is strictly increasing for $\lambda \in [0,1)$. This proves 2. Now to prove 3., we can derive the elasticity with respect to μ as

$$
\begin{aligned}
\varepsilon^z_{\mu} &= \frac{\partial z}{\partial \mu} \frac{\mu}{z} \\
&= \frac{1-\gamma}{1-\phi-\gamma}\left(1 - W_i \mathcal{C}_i(\lambda) + \frac{\lambda(1-\mu)(\tau_i - \tau_{TH})}{(1-\tau_i)}\right)^{-1}\left(-\lambda \frac{\mu(\tau_i - \tau_{TH})}{1-\tau_i}\right) \\
&= -\frac{1-\gamma}{1-\phi-\gamma}\left(\frac{\mu}{1-\mu}\right)\frac{1}{\left(1 + \frac{1-W_i\mathcal{C}_i(\lambda)}{\lambda W_i \mathcal{C}'(\lambda)}\right)}.
\end{aligned}
$$

By the same argument as above we conclude that $\varepsilon^z_{\tau_{TH}} < 0$.

■

F.2 Effects of Sales-Based Profit Allocation (OECD/G20 Pillar 1)

We first establish the following lemma characterizing how $\hat{\lambda}$ depends on the parameters of the profit allocation rule and how it differs from the share λ that is transferred under the existing tax regime.

Proof of Lemma 3. We start with the tax liability faced by a subsidiary in region j under pillar 1,

$$\begin{aligned} T_j &= \pi_j^r + (1-\theta)\cdot\pi_j^R + \theta\cdot\frac{R_j}{\sum_k R_k}\cdot\Pi^R \\ &= \iota R_j + (1-\theta)\cdot(\pi_j - \iota R_j) + \theta\cdot\frac{R_j}{\sum_k R_k}\cdot\sum_{k\in\{i\}\cup J_F}(\pi_k - \iota R_k) \\ &= (1-\theta)\cdot\pi_j + \theta\cdot\frac{R_j}{\sum_k R_k}\cdot\sum_{k\in\{i\}\cup J_F}\pi_k. \end{aligned}$$

We can see that the profitability margin parameter ι does not affect into T_j, so it will not affect any firm decision under pillar 2. Plugging the tax liabilities in to the profit maximization problem of the MNE specified by equation (51), we have

$$\begin{aligned} \max_{z,\lambda,\{\ell_i\}_{i=1}^I} & (1-\tau_i(1-\theta))\Bigg(p_{ii}\left(A_i(N_i z)^\phi \ell_i^\gamma\right) - W_i\ell_i - \frac{W_i z}{A_i a} \\ & + z\left[\mu\lambda\sum_{k\in J_F\cup\{i\}}\vartheta_k(z) - \lambda\vartheta_{ii}(z) + (1-\lambda)\sum_{k\in J_F}\vartheta_k(z) - W_i\mathcal{C}(\lambda)\sum_{k\in J_F\cup\{i\}}\vartheta_k(z)\right]\Bigg) \\ & + (1-\tau_{TH}(1-\theta))\,z\left[\lambda\sum_{k\in J_F}\vartheta_k(z) - \mu\lambda\sum_{k\in J_F}\vartheta_k(z)\right] \\ & + \sum_{k\in J_F}(1-\tau_k(1-\theta))\left(p_{ik}\left(A_k(N_k z)^\phi\ell_k^\gamma\right) - w_k\ell_k - \vartheta_k(z)\,z\right) \\ & - \theta\sum_{j\in J_F\cup\{i\}}\tau_j\cdot\frac{p_{ij}y_{ij}}{\sum_{k\in J_F\cup\{i\}}p_{ik}y_{ik}}\cdot\left[\sum_{k\in J_F\cup\{i\}}\left(p_{ik}\left(A_k(N_k z)^\phi\ell_k^\gamma\right) - w_k\ell_k\right) - \frac{W_i z}{A_i a} - W_i\mathcal{C}(\lambda)\sum_{k\in J_F\cup\{i\}}\vartheta_k(z)\right]. \end{aligned}$$

We can derive the following from the FOC with respect to λ:

$$\hat{\lambda} = 1 - \exp\left(-\frac{(1-\mu)(1-\theta)(\tau_i - \tau_{TH})}{W_i(1-((1-\theta)\tau_i + \theta\widehat{\tau}))}\right) \tag{F.6}$$

where

$$\begin{aligned} \widehat{\tau} &= \sum_{j\in J_F\cup\{i\}}\tau_j\cdot\frac{R_j}{\sum_{k\in J_F\cup\{i\}}R_k} \\ &= \sum_{j\in J_F\cup\{i\}}\tau_j\cdot\frac{p_{ij}q_{ij}}{\sum_{k\in J_F\cup\{i\}}p_{ik}q_{ik}} \end{aligned}$$

Towards proving 1., with equation (34) we have that the following sequence of inequalities holds for any

$0 < \theta < 1$:

$$
\begin{aligned}
1 - \exp\left(-\frac{(1-\mu)(\tau_i - \tau_{TH})}{W_i(1-\tau_i)}\right) &> 1 - \exp\left(-\frac{(1-\mu)(1-\theta)(\tau_i - \tau_{TH})}{W_i(1-((1-\theta)\tau_i + \theta\widehat{\tau}))}\right) \\
\frac{1}{1-\tau_i} &> \frac{1-\theta}{1-(1-\theta)\tau_i - \theta\widehat{\tau}} \\
\sum_j \tau_j \cdot \frac{p_{ij}y_{ij}}{\sum_{k\in J_F\cup\{i\}} p_{ik}y_{ik}} &< 1.
\end{aligned}
$$

The last inequality holds, since $\tau_k < 1 \ \forall k$ and all sales shares are by construction less than one. This proves that $\hat{\lambda} < \lambda$. Now, towards showing 2, inspect how θ affects $\hat{\lambda}$

$$
\frac{\partial\hat{\lambda}}{\partial\theta} = -\exp\left(-\frac{(1-\mu)(1-\theta)(\tau_i - \tau_{TH})}{W_i(1-((1-\theta)\tau_i + \theta\widehat{\tau}))}\right) \cdot (1-\mu)(\tau_i - \tau_{TH}) \frac{1-\hat{\tau}}{\left[(1-((1-\theta)\tau_i + \theta\widehat{\tau}))\right]^2} < 0
$$

and the elasticity is given by

$$
\begin{aligned}
\varepsilon_\theta^{\hat{\lambda}} &= -\exp\left(-\frac{(1-\mu)(1-\theta)(\tau_i - \tau_{TH})}{W_i(1-((1-\theta)\tau_i + \theta\widehat{\tau}))}\right) \cdot (1-\mu)(\tau_i - \tau_{TH}) \frac{1-\hat{\tau}}{\left[(1-((1-\theta)\tau_i + \theta\widehat{\tau}))\right]^2} \frac{\theta}{\hat{\lambda}} \\
&= -\frac{\hat{\lambda}-1}{\hat{\lambda}} \cdot \log\left(1-\hat{\lambda}\right) \cdot \frac{1-\hat{\tau}}{1-((1-\theta)\tau_i + \theta\widehat{\tau})} \frac{\theta}{1-\theta} < 0,
\end{aligned}
$$

where we used the FOC of the profit function with respect to $\hat{\lambda}$. Hence, we have established 2. Now, inspect how τ_{TH} affects $\hat{\lambda}$ to prove 3. First, compute the relevant partial derivative

$$
\frac{\partial\hat{\lambda}}{\partial\tau_{TH}} = -\exp\left(-\frac{(1-\mu)(1-\theta)(\tau_i - \tau_{TH})}{W_i(1-((1-\theta)\tau_i + \theta\widehat{\tau}))}\right) \cdot \frac{(1-\mu)(1-\theta)}{W_i(1-((1-\theta)\tau_i + \theta\widehat{\tau}))} < 0,
$$

and hence the elasticity

$$
\begin{aligned}
\varepsilon_{\tau_{TH}}^{\hat{\lambda}} &= -\exp\left(-\frac{(1-\mu)(1-\theta)(\tau_i - \tau_{TH})}{W_i(1-((1-\theta)\tau_i + \theta\widehat{\tau}))}\right) \cdot \frac{(1-\mu)(1-\theta)(\tau_i - \tau_{TH})}{W_i(1-((1-\theta)\tau_i + \theta\widehat{\tau}))} \frac{1}{\tau_i - \tau_{TH}} \frac{\tau_{TH}}{\hat{\lambda}} \\
&= -\frac{\hat{\lambda}-1}{\hat{\lambda}} \cdot \log\left(1-\hat{\lambda}\right) \frac{\tau_{TH}}{\tau_i - \tau_{TH}} < 0.
\end{aligned}
$$

■

Proof of Proposition 2. Following the same procedure as in the first part of the proof for Proposition 1, we can first show that

$$
\hat{z} = z^{NS}\left(1 - W_i\mathcal{C}\left(\hat{\lambda}\right) + \frac{\lambda(1-\theta)(1-\mu)(\tau_i - \tau_{TH})}{1-((1-\theta)\tau_i + \theta\widehat{\tau})}\right)^{\frac{1-\gamma}{1-\phi-\gamma}}.
$$

With the optimal allocation of intangible capital, the proof for 1. relies on the following sequence of iff inequalities:

$$
\begin{aligned}
&\hat{z} < z \\
1 - W_i \mathcal{C}\left(\hat{\lambda}\right) + \hat{\lambda}\left[\frac{(1-\mu)(\tau_i - \tau_{TH})}{1-\tau_i}\right]\frac{(1-\tau_i)(1-\theta)}{1-((1-\theta)\tau_i + \theta\widehat{\tau})} &< 1 - W_i\mathcal{C}(\lambda) + \frac{\lambda(1-\mu)(\tau_i-\tau_{TH})}{1-\tau_i} \\
\lambda\frac{(1-\mu)(\tau_i-\tau_{TH})}{W_i(1-\tau_i)} - \hat{\lambda}\frac{(1-\mu)(1-\theta)(\tau_i-\tau_{TH})}{W_i(1-((1-\theta)\tau_i+\theta\widehat{\tau}))} &> \mathcal{C}(\lambda) - \mathcal{C}\left(\hat{\lambda}\right),
\end{aligned}
$$

To simplify notation, let's denote:

$$
\begin{aligned}
\hat{A} &= \frac{(1-\mu)(1-\theta)(\tau_i-\tau_{TH})}{W_i(1-((1-\theta)\tau_i+\theta\widehat{\tau}))}, \\
A &= \frac{(1-\mu)(\tau_i-\tau_{TH})}{W_i(1-\tau_i)}.
\end{aligned}
$$

Plugging equations (42) and equation (32) to the inequality we want to show, we have

$$
\begin{aligned}
1 - \exp(-A) + \exp(-A)(-A) - 1 + \exp\left(-\hat{A}\right) - \exp\left(-\hat{A}\right)\left(-\hat{A}\right) &< (1-\exp(-A))A - \left(1 - \exp\left(-\hat{A}\right)\right)\hat{A} \\
\hat{A} + \exp\left(-\hat{A}\right) &< A + \exp(-A).
\end{aligned}
$$

We have shown that $0 < \hat{A} < A,\ \forall\theta > 0$, thus proving the inequality above amounts to proving that function $f(x) = x + \exp(-x)$ is monotonically increasing when $x > 0$. Taking its derivative we get:

$$
f'(x) = 1 - \exp(-x) > 0,\ x > 0.
$$

To prove 2., we start with the partial derivative with respect to θ:

$$
\begin{aligned}
\frac{\partial\hat{z}}{\partial\theta} = \left(\frac{1-\gamma}{1-\phi-\gamma}\right)\hat{z}\left(1 - W_i\mathcal{C}\left(\hat{\lambda}\right) + \frac{(1-\theta)\hat{\lambda}(1-\mu)(\tau_i-\tau_{TH})}{1-((1-\theta)\tau_i+\theta\widehat{\tau})}\right)^{-1} \cdot \left\{\frac{\partial\hat{\lambda}}{\partial\theta}\left[\frac{(1-\theta)(1-\mu)(\tau_i-\tau_{TH})}{1-((1-\theta)\tau_i+\theta\widehat{\tau})} - W_i\mathcal{C}'\left(\hat{\lambda}\right)\right] + \right. \\
\left. \frac{-\hat{\lambda}(1-\mu)(\tau_i-\tau_{TH})(1-((1-\theta)\tau_i+\theta\widehat{\tau})) - (\tau_i-\hat{\tau})(1-\theta)\hat{\lambda}(1-\mu)(\tau_i-\tau_{TH})}{\left[(1-((1-\theta)\tau_i+\theta\widehat{\tau}))\right]^2}\right\},
\end{aligned}
$$

and notice that the FOC w.r.t. $\hat{\lambda}$ is given by

$$
W_i\mathcal{C}'\left(\hat{\lambda}\right) = \frac{(1-\theta)(1-\mu)(\tau_i-\tau_{TH})}{(1-((1-\theta)\tau_i+\theta\widehat{\tau}))}.
$$

Also, we can show that

$$
\begin{aligned}
&\frac{-\hat{\lambda}(1-\mu)(\tau_i-\tau_{TH})(1-\hat{\tau}_i(\theta)) - (\tau_i-\hat{\tau})(1-\theta)\hat{\lambda}(1-\mu)(\tau_i-\tau_{TH})}{\left[(1-((1-\theta)\tau_i+\theta\widehat{\tau}))\right]^2} \\
=&\frac{\hat{\lambda}(1-\mu)(\tau_i-\tau_{TH})(\hat{\tau}-1)}{\left[(1-((1-\theta)\tau_i+\theta\widehat{\tau}))\right]^2} < 0.
\end{aligned}
$$

Thus we have established that

$$
\frac{\partial\hat{z}}{\partial\theta} < 0.
$$

And the elasticity is

$$\varepsilon_{\theta}^{\hat{z}} = \left(\frac{1-\gamma}{1-\phi-\gamma}\right)\hat{z}\left(1 - W_i\mathcal{C}\left(\hat{\lambda}\right) + \frac{(1-\theta)\,\hat{\lambda}\,(1-\mu)\,(\tau_i-\tau_{TH})}{1-((1-\theta)\,\tau_i+\theta\widehat{\tau})}\right)^{-1}\left[\frac{\hat{\lambda}\,(1-\mu)\,(\tau_i-\tau_{TH})\,(\hat{\tau}-1)}{[1-((1-\theta)\,\tau_i+\theta\widehat{\tau})]^2}\right]\frac{\theta}{\hat{z}}$$

$$= \varepsilon_{\theta}^{\hat{\lambda}}\left(\frac{1-\gamma}{1-\phi-\gamma}\right)\left(\frac{\hat{\lambda}}{\mathcal{C}(\hat{\lambda})(1-\hat{\lambda})}\right)\left(\frac{1}{1+\frac{1-W_i\mathcal{C}(\hat{\lambda})}{W_i\hat{\lambda}\mathcal{C}'(\hat{\lambda})}}\right) < 0.$$

Now, to show 3. consider the partial derivative of $\hat{z}$ with respect to τ_{TH},

$$\frac{\partial\hat{z}}{\partial\tau_{TH}} = \left(\frac{1-\gamma}{1-\phi-\gamma}\right)\hat{z}\left(1 - W_i\mathcal{C}\left(\hat{\lambda}\right) + \frac{(1-\theta)\,\hat{\lambda}\,(1-\mu)\,(\tau_i-\tau_{TH})}{[1-((1-\theta)\,\tau_i+\theta\widehat{\tau})]}\right)^{-1}\cdot$$
$$\left[\frac{\partial\hat{\lambda}}{\partial\tau_{TH}}\left(\frac{(1-\mu)\,(\tau_i-\tau_{TH})\,(1-\theta)}{1-((1-\theta)\,\tau_i+\theta\widehat{\tau})} - W_i\mathcal{C}'\left(\hat{\lambda}\right)\right) - \frac{(1-\theta)\,\hat{\lambda}\,(1-\mu)}{1-((1-\theta)\,\tau_i+\theta\widehat{\tau})}\right].$$

Plugging in the optimality condition of $\hat{\lambda}$, the elasticity becomes

$$\varepsilon_{\tau_{TH}}^{\hat{z}} = \left(\frac{-\tau_{TH}}{\tau_i-\tau_{TH}}\right)\left(\frac{1-\gamma}{1-\phi-\gamma}\right)\frac{1}{\left[1+\frac{1-W_i\mathcal{C}(\hat{\lambda})}{W_i\hat{\lambda}\mathcal{C}'(\hat{\lambda})}\right]}.$$

F.3 Analytical Results when MNEs Take $\vartheta'_{ik}(z)$ into Account

Here, we assume that MNEs internalize the effect of changing z on the licensing fee $\vartheta_{ik}(z)$ and solve for optimal z under different scenarios. We then prove Proposition 2 under this assumption.[33] As before, we start from the optimal z.

Proof of Proposition 2 under alternative assumption. We can first derive the allocations of intangible capital are as follows if firms internalize the effect of changing z on the licensing fee $\vartheta_k(z)$ when deciding intangible capital $\tilde{z}$:

$$\tilde{z}^{NS} = \left(\frac{\sum_k\left(1-\hat{\tau}_k(\theta)\right)\Lambda_k - \frac{\phi}{1-\gamma}\sum_k(1-\theta)\,(\tau_i-\tau_k)\,\Lambda_k}{(1-\hat{\tau}_i(\theta))\,W_i/(A_ia)}\right)^{\frac{1-\gamma}{1-\phi-\gamma}}, \tag{F.7}$$

$$\tilde{z} = \left(\frac{-\frac{\phi}{1-\gamma}\mathcal{C}\left(\hat{\lambda}\right)\sum_k\Lambda_k}{W_i/(A_ia)}\right.$$
$$\left.+\frac{\sum_k\left(1-\hat{\tau}_k(\theta)\right)\Lambda_k - \frac{\phi}{1-\gamma}\sum_k(1-\theta)\,(\tau_i-\tau_k)\,\Lambda_k + \hat{\lambda}\frac{\phi}{1-\gamma}(1-\theta)\,(\tau_i-\tau_{TH})\,(1-\mu)\sum_k\Lambda_k}{(1-\hat{\tau}_i(\theta))\,W_i/(A_ia)}\right)^{\frac{1-\gamma}{1-\phi-\gamma}} \tag{F.8}$$

where with a slight abuse of notation, we denote in this section

$$\hat{\tau}_i(\theta) = (1-\theta)\,\tau_j + \theta\sum_{j\in J_F\cup\{i\}}\tau_j\cdot\frac{p_{ij}q_{ij}}{\sum_{k\in J_F\cup\{i\}}p_{ik}q_{ik}}.$$

[33] Proposition 1 can be proved similarly by setting $\theta = \iota = 0$.

We start from proving 1 from deriving a set of iff inequalities:

$$\frac{\sum_k \Lambda_k}{W_i/(A_i a)} - \frac{\phi+\gamma-1}{1-\gamma}\frac{\sum_k (1-\theta)(\tau_i-\tau_k)\Lambda_k}{(1-\hat{\tau}_i(\theta))W_i/(A_i a)} - \left(1+\frac{\phi+\gamma-1}{1-\gamma}\right)\frac{\sum_k \Lambda_k}{W_i/(A_i a)}\left[W_i\mathcal{C}\left(\hat{\lambda}\right) - \frac{\hat{\lambda}(1-\theta)(\tau_i-\tau_{TH})(1-\mu)}{(1-\hat{\tau}_i(\theta))}\right]$$
$$< \frac{\sum_k \Lambda_k}{W_i/(A_i a)} - \frac{\phi+\gamma-1}{1-\gamma}\frac{\sum_k (\tau_i-\tau_k)\Lambda_k}{(1-\tau_i)W_i/(A_i a)} - \left(1+\frac{\phi+\gamma-1}{1-\gamma}\right)\frac{\sum_k \Lambda_k}{W_i/(A_i a)}\left[W_i\mathcal{C}(\lambda) - \frac{\lambda(\tau_i-\tau_{TH})(1-\mu)}{(1-\tau_i)}\right]$$
$$-\frac{1-\phi-\gamma}{1-\gamma}\frac{\sum_k (\tau_i-\tau_k)\Lambda_k}{(1-\tau_i)W_i/(A_i a)} + \frac{\phi}{1-\gamma}\frac{\sum_k \Lambda_k}{W_i/(A_i a)}\left[W_i\mathcal{C}(\lambda) - \frac{\lambda(\tau_i-\tau_{TH})(1-\mu)}{(1-\tau_i)}\right]$$
$$< -\frac{1-\phi-\gamma}{1-\gamma}\frac{\sum_k (1-\theta)(\tau_i-\tau_k)\Lambda_k}{(1-\hat{\tau}_i(\theta))W_i/(A_i a)} + \frac{\phi}{1-\gamma}\frac{\sum_k \Lambda_k}{W_i/(A_i a)}\left[W_i\mathcal{C}\left(\hat{\lambda}\right) - \frac{\hat{\lambda}(1-\theta)(\tau_i-\tau_{TH})(1-\mu)}{(1-\hat{\tau}_i(\theta))}\right].$$

We have proven before that $W_i\mathcal{C}(\lambda) - \frac{\lambda(\tau_i-\tau_{TH})(1-\mu)}{(1-\tau_i)} < W_i\mathcal{C}\left(\hat{\lambda}\right) - \frac{\hat{\lambda}(1-\theta)(\tau_i-\tau_{TH})(1-\mu)}{(1-\hat{\tau}_i(\theta))}$. It suffices to prove that

$$-\frac{1-\phi-\gamma}{1-\gamma}\frac{\sum_k (\tau_i-\tau_k)\Lambda_k}{(1-\tau_i)W_i/(A_i a)} < -\frac{1-\phi-\gamma}{1-\gamma}\frac{\sum_k (1-\theta)(\tau_i-\tau_k)\Lambda_k}{(1-\hat{\tau}_i(\theta))W_i/(A_i a)},$$

which simplifies to $1 > \sum_k \tau_k \frac{\Lambda_k}{\sum_i \Lambda_i}$. Thus, we have proven 1. We now prove 2:

$$\frac{d\tilde{z}}{d\theta} = \frac{1-\gamma}{1-\phi-\gamma}(\tilde{z})^{\frac{\phi}{1-\gamma}}\frac{A_i a}{W_i}\left(\frac{\sum_k \tau_k \frac{\Lambda_k}{\sum_i \Lambda_i} - 1}{(1-\hat{\tau}_i(\theta))^2}\right)\left(\frac{\phi}{1-\gamma}\lambda(\tau_i-\tau_{TH})(1-\mu) + \frac{1-\phi-\gamma}{1-\gamma}\sum_k (\tau_i-\tau_k)\Lambda_k\right).$$

We have shown that

$$\sum_k \tau_k \frac{\Lambda_k}{\sum_i \Lambda_i} - 1 < 0.$$

The other terms are all positive, thus we have proven 2. Now to prove 3 we can show that

$$\frac{\partial \tilde{z}}{\partial \tau_{TH}} = \left(\frac{1-\gamma}{1-\phi-\gamma}\right)(\tilde{z})^{\frac{\phi}{1-\gamma}}\frac{A_i a}{W_i}\Bigg\{-\frac{\phi}{1-\gamma}W_i\mathcal{C}'\left(\hat{\lambda}\right)\frac{\partial\hat{\lambda}}{\partial\tau_{TH}}\sum_k \Lambda_k + \frac{\phi}{1-\gamma}\frac{\sum_k \Lambda_k}{(1-\hat{\tau}_i(\theta))^2}\cdot$$
$$\left[\left(\frac{\partial\hat{\lambda}}{\partial\tau_{TH}}(1-\mu)(\tau_i-\tau_{TH})(1-\theta)\sum_k \Lambda_k - (1-\theta)\hat{\lambda}(1-\mu)\right)(1-\hat{\tau}_i(\theta)) + \left(\theta\frac{\Lambda_{TH}}{\sum_k \Lambda_k}\right)(1-\theta)\hat{\lambda}(1-\mu)(\tau_i-\tau_{TH})\right]$$
$$-\frac{1-\phi-\gamma}{1-\gamma}(1-\theta)\Lambda_{TH}\frac{1-\tau_i}{(1-\hat{\tau}_i(\theta))^2}\Bigg\}.$$

We have shown in previous proof that the sum of first two terms in the big bracket is negative. It is obvious that the last term is also negative. Hence we have proven 3, that is $\frac{\partial\tilde{z}}{\partial\tau_{TH}} < 0$. ■

F.4 Discussions on the Combinatorial Choice Problem

Arkolakis et al. (2023) (hereinafter AES) develop a computational method, namely a squeezing procedure, to solve combinatorial problems of location decisions for MNEs. As discussed in Theorem 1 of AES, applying the squeezing procedure requires the return function to obey the single crossing in differences in choices (SCD-C) property, from either above or below. In what follows, we discuss whether the squeezing procedure is suitable for our model.

In our model, we assume that each foreign subsidiary produces a different variety than the headquarter, so the location choice problem in productive locations satisfies positive complementarities. However, In our model, the role of TH and LT as profit-shifting destinations may break this complementarity, if it is marginally more costly to shift profits to multiple regions. We proceed with the following two arguments, focusing on how the decisions of intangible investment and profit shifting affects solving the combinatorial problem of J_F:

1. Fixing intangible capital z, the profit function of the firm does not satisfy SCD-C if the profit shifting cost function $\mathcal{C}\left(\lambda_{TH}, \lambda_{LT}\right)$ has positive cross-derivatives, that is $\frac{\partial^2 \mathcal{C}(\lambda_{TH}, \lambda_{LT})}{\partial \lambda_{TH} \partial \lambda_{LT}} > 0$.
2. The interdependence of intangible capital z and the set of foreign subsidiary locations J_F makes the firm's problem hard to solve with many countries.

F.4.1 Cross-derivative of profit-shifting cost

In this section, we discuss how the cross-derivative of the profit-shifting function affects the SCD-C property of the profit function. To isolate the issue of choosing J_F, we hereby assume that the intangible capital z and the set of exporting destinations J_X for each firm are fixed. We start by defining the marginal value from adding a subsidiary location, as in Definition 1 of AES.

Definition 1 *Marginal value from adding location l is defined as*

$$D_l \Pi_i(a; J_F) \equiv \Pi_i(a; J_F \cup \{l\}) - \Pi_i(a; J_F \backslash \{l\})$$

where $\Pi_i(a; J_F)$ is the optimal after-tax dividend of a country i firm with productivity a and FDI destinations J_F.

In line with Definition 4 in AES we define the SCD-C properties as follows.

Definition 2 *The return function obeys SCD-C from above if for all $l \in I$ and sets of locations $J_F^1 \subset J_F^2 \subseteq I$,*

$$D_l \Pi_i\left(a; J_F^2\right) \geq 0 \Rightarrow D_l \Pi_i\left(a; J_F^1\right) \geq 0,$$

Analogously, the return function obeys SCD-C from below if for all $l \in I$ and sets of locations $J_F^1 \subset J_F^2 \subseteq I$,

$$D_l \Pi_i\left(a; J_F^1\right) \geq 0 \Rightarrow D_l \Pi_i\left(a; J_F^2\right) \geq 0.$$

We first show that the profit function, $\Pi_i(a; J_F)$, does not satisfy SCD-C from above.

Lemma 4 (SCD-C from above) *The profit function does not satisfy SCD-C from above.*

Proof. Suppose a firm HQed in NA maximizes its profit by setting up subsidiaries in EU, RW and TH. Let $J_F^1 = \emptyset$ and $J_F^2 = \{EU, RW\}$. It is straightforward to show that the profit function does not satisfy SCD-C from above that requires

$$D_{TH} \Pi_i\left(a; J_F^2\right) \geq 0$$

which can be written as

$$(\tau_{NA}-\tau_{TH})\,\lambda_{TH}\sum_{j\in J_F^2\cup\{NA\}}\vartheta_{ij}(z)z-(1-\tau_{NA})\,W_{NA}\mathcal{C}_{NA}\,(\lambda_{TH},0)\sum_{j\in J_F^2\cup\{NA\}}\vartheta_{ij}(z)z\geq\kappa_{NA,TH,F}$$

$$\sum_{j\in J_F^2\cup\{NA\}}\vartheta_{ij}(z)z\cdot\left[(\tau_{NA}-\tau_{TH})\,\lambda_{TH}-(1-\tau_{NA})\,W_{NA}\mathcal{C}_{NA}\,(\lambda_{TH},0)\right]\geq\kappa_{NA,TH,F}.$$

We now show it does not imply that for $J_F^1=\emptyset$, we have $D_{TH}\left(J_F^1;a\right)\geq 0$. To satisfy this inequality, we need

$$(\tau_{NA}-\tau_{TH})\,\lambda_{TH}\sum_{j\in\{NA\}}\vartheta_{ij}(z)z-(1-\tau_{NA})\,W_{NA}\mathcal{C}_{NA}\,(\lambda_{TH},0)\sum_{j\in\{NA\}}\vartheta_{ij}(z)z\geq\kappa_{NA,TH,F}$$

$$\sum_{j\in\{NA\}}\vartheta_{ij}(z)z\cdot\left[(\tau_{NA}-\tau_{TH})\,\lambda_{TH}-(1-\tau_{NA})\,W_{NA}\mathcal{C}_{NA}\,(\lambda_{TH},0)\right]\geq\kappa_{NA,TH,F},$$

which is not necessarily true since $\sum_{j\in\{NA\}}\vartheta_{ij}(z)z<\sum_{j\in J_F^2\cup\{NA\}}\vartheta_{ij}(z)z$. ■

The relevant case for us is when the MNE's problem satisfies SCD-C from below. It is straightforward to show that this property is satisfied for productive regions, excluding LT. That is for $J_F^1\subset J_F^2\subseteq I$

$$D_l\Pi_i\left(a;J_F^1\right)\geq 0\Rightarrow D_l\Pi_i\left(a;J_F^2\right)\geq 0$$

where $l\in\{NA,EU,RW\}$. This is because $D_l\Pi_i\left(a;J_F\right)=(1-\tau_l)\left(\pi_{il}^F(a,z)-\vartheta_{il}(z)z\right)$ does not vary by J_F conditional on z. Hence, $D_l\Pi_i\left(a;J_F^1\right)=D_l\Pi_i\left(a;J_F^2\right),\forall J_F^1,J_F^2$. Now, we want to discuss whether the SCD-C from below property is satisfied for the profit shifting destinations, $\{LT,TH\}$. In other words, we want to investigate whether for $l\in\{LT,TH\}$ and $J_F^1\subset J_F^2\subseteq I$, $D_l\Pi_i\left(a;J_F^1\right)\geq 0$ implies $D_l\Pi_i\left(a;J_F^2\right)\geq 0$.

Lemma 5 *If the profit-shifting cost function satisfies Assumption 1 and $\frac{\partial^2\mathcal{C}_i(\lambda_{TH},\lambda_{LT})}{\partial\lambda_{TH}\partial\lambda_{LT}}>0$, then the profit function does not satisfy SCD-C from below for the profit-shifting destinations. That is, for $l\in\{LT,TH\}$ and $J_F^1\subset J_F^2\subseteq I$, $D_l\Pi_i\left(a;J_F^1\right)\geq 0\nRightarrow D_l\Pi_i\left(a;J_F^2\right)\geq 0$.*

Proof. Suppose $J_F^1\cap\{LT,TH\}=\emptyset$, $J_F^2\cap\{LT,TH\}=\{m\}\neq\emptyset$, $l\notin J_F^2$, and $l\in\{LT,TH\}$, then $D_l\Pi_i\left(a;J_F^1\right)\geq 0$ implies

$$D_l\Pi_i\left(a;J_F^1\right)=\sum_{j\in J_F^1\cup\{i\}}\vartheta_{ij}(z)z\cdot\left[(1-\mu_{il})\,(\tau_i-\tau_l)\,\lambda_l^0-(1-\tau_i)\,W_i\mathcal{C}_{i,l}\left(\lambda_l^0\right)\right]\geq\kappa_{i,l,F}\tag{F.9}$$

where λ_l^0 represents the optimal profit shifting share when the MNE operates in $J_F^1\cup\{i\}\cup\{l\}$, and $\mathcal{C}_{i,l}\left(\lambda_l\right):=\mathcal{C}_i\left(\lambda_l,\lambda_{-l}=0\right)$. Then, $D_l\Pi_i\left(a;J_F^2\right)\geq 0$ requires

$$\begin{aligned}D_l\Pi_i\left(a;J_F^2\right)=&\sum_{j\in J_F^2\cup\{i\}}\vartheta_{ij}(z)z\cdot\left\{(1-\mu_{iTH})\left(\left[(\tau_{NA}-\tau_{TH})\,\lambda_{TH}^1\right]+\left[(\tau_{NA}-\tau_{LT})\,\lambda_{LT}^1\right]\right)-(1-\tau_i)\,W_i\mathcal{C}_i\left(\lambda_{TH}^1,\lambda_{LT}^1\right)\right\}\\&-\sum_{j\in J_F^2\cup\{i\}}\vartheta_{ij}(z)z\cdot\left[(\tau_i-\tau_m)\,\lambda_m^0-(1-\tau_i)\,W_i\mathcal{C}_{i,m}\left(\lambda_m^0\right)\right]\geq\kappa_{i,l,F}\end{aligned}\tag{F.10}$$

where λ_l^1 represents the optimal profit shifting share to l when the MNE operates in $J_F^1\cup\{i\}\cup\{LT,TH\}$.

The profit function thus does not necessarily satisfy SCD-C from below if

$$D_l\Pi_i\left(a; J_F^2\right) < D_l\Pi_i\left(a; J_F^1\right) \tag{F.11}$$

For simplicity, we assume

$$\sum_{j\in J_F^2\cup\{i\}} \vartheta_{ij}(z)z = \sum_{j\in J_F^1\cup\{i\}} \vartheta_{ij}(z)z$$

which is true when $l = TH$ or when $l = LT$ and $L_{LT} \to 0$. The inequality can then be written as

$$(1-\mu_{iTH})\left(\left[\left(\tau_{NA}-\tau_{TH}\right)\lambda_{TH}^1\right] + \left[(\tau_{NA}-\tau_{LT})\,\lambda_{LT}^1\right]\right) - (1-\tau_i)\,W_i\mathcal{C}_i\left(\lambda_{TH}^1,\lambda_{LT}^1\right) <$$
$$\left[(1-\mu_{im})\,(\tau_i-\tau_m)\,\lambda_m^0 - (1-\tau_i)\,W_i\mathcal{C}_{i,m}\left(\lambda_m^0\right)\right] + \left[(1-\mu_{il})\,(\tau_i-\tau_l)\,\lambda_l^0 - (1-\tau_i)\,W_i\mathcal{C}_{i,l}\left(\lambda_l^0\right)\right],$$

and

$$\left[(1-\mu_{iTH})\,(\tau_i-\tau_{TH})\,\lambda_{TH}^1 - (1-\tau_i)\,W_i\mathcal{C}_i\left(\lambda_{TH}^1,0\right)\right] + \left[(1-\mu_{iLT})\,(\tau_i-\tau_{LT})\,\lambda_{LT}^1 - (1-\tau_i)\,W_i\mathcal{C}_i\left(\lambda_{LT}^1,0\right)\right] <$$
$$\left[(1-\mu_{iTH})\,(\tau_i-\tau_{TH})\,\lambda_{TH}^0 - (1-\tau_i)\,W_i\mathcal{C}_i\left(\lambda_{TH}^0,0\right)\right] + \left[(1-\mu_{iLT})\,(\tau_i-\tau_{LT})\,\lambda_{LT}^0 - (1-\tau_i)\,W_i\mathcal{C}_i\left(0,\lambda_{LT}^0\right)\right].$$

One can show that $D_l\Pi_i\left(a; J_F^2\right) < D_l\Pi_i\left(a; J_F^1\right)$ if the following two conditions are both satisfied:

1. $\lambda_l^1 < \lambda_l^0$, $l \in \{TH, LT\}$,
2. $f_l(\lambda) = (\tau_i - \tau_l)\,\lambda - (1-\tau_i)\,W_i\mathcal{C}_{i,l}(\lambda)$ increases in $\lambda \in [0, \lambda_l^0]$.

We can show that both two conditions are met if $\frac{\partial^2\mathcal{C}(\lambda_{TH},\lambda_{LT})}{\partial\lambda_{TH}\partial\lambda_{LT}} > 0$. For 1, we know from the FOC of the firm's problem that

$$\frac{\partial\mathcal{C}_i\left(\lambda_{TH},\lambda_{LT}^1\right)}{\partial\lambda_{TH}} = \frac{1}{W_i}\frac{(1-\mu_{iTH})(\tau_i-\tau_{TH})}{1-\tau_i}$$

and

$$\frac{\partial\mathcal{C}_i\left(\lambda_{TH},0\right)}{\partial\lambda_{TH}} = \frac{1}{W_i}\frac{(1-\mu_{iTH})(\tau_i-\tau_{TH})}{1-\tau_i}$$

Then to show $\lambda_{TH}^1 < \lambda_{TH}^0$ it suffices to show that

$$\frac{\partial\mathcal{C}_i\left(\lambda_{TH},\lambda_{LT}^1\right)}{\partial\lambda_{TH}} > \frac{\partial\mathcal{C}_i\left(\lambda_{TH},0\right)}{\partial\lambda_{TH}} > 0, \forall\ \lambda_{LT}^1 > 0$$

which is true when

$$\frac{\partial^2\mathcal{C}_i(\lambda_{TH},\lambda_{LT})}{\partial\lambda_{TH}\partial\lambda_{LT}} > 0, \forall\lambda_{TH},\lambda_{LT} > 0.$$

We can show in the same way that $\lambda_{LT}^1 < \lambda_{LT}^0$, when $\frac{\partial^2\mathcal{C}_i(\lambda_{TH},\lambda_{LT})}{\partial\lambda_{TH}\partial\lambda_{LT}} > 0$. For 2, we need to show that

$$f_l^{'}(\lambda) = (\tau_i-\tau_l) - (1-\tau_i)\,W_i\frac{\partial\mathcal{C}_{i,l}(\lambda)}{\partial\lambda} \geq 0,\ \ \lambda \leq \lambda_l^0.$$

From the FOC of the firm's problem, we know that

$$(\tau_i-\tau_l) - (1-\tau_i)\,W_i\left.\frac{\partial\mathcal{C}_{i,l}(\lambda)}{\partial\lambda}\right|_{\lambda=\lambda_l^0} = 0.$$

By Assumption 1, $\frac{\partial^2 \mathcal{C}_{i,l}(\lambda)}{\partial \lambda^2} > 0$. Therefore, we have $f_l^{'}(\lambda) \geq 0,\ \lambda \leq \lambda_l^0$. ■

F.4.2 Interdependence of intangible capital and subsidiary locations

One key result of the model is that the optimal choice of intangible capital is a function of the set of foreign subsidiaries. Suppose the profit function satisfies SCD-C from below. Then we can utilize the squeezing procedure to solve for the optimal J_F with a fixed amount of z, and obtain the corresponding firm profit. However, in order to fully solve the firm's problem, we would need to solve for location choice problem for different amounts of z and compute the largest profit. Therefore, the interdependence between intangible capital z and the subsidiary locations J_F makes the firm's problem hard to solve, even when the profit function satisfies SCD-C. We instead assume a small number of locations, compute the optimal z for different combinations of J_F, and compare the associated profits.