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# International Technology Licensing, Intellectual Property Rights, and Tax Havens

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**Abstract**

This paper investigates the determinants of international technology licensing using data for 50 countries during 1996-2012. A multi-country model of innovation and international technology licensing yields a dynamic structural gravity equation for royalty payments as a function of fundamentals, including imperfect intellectual property protection and differences in corporate taxation. The gravity equation is estimated with nonlinear methods. The model's fundamentals account for about 60% of the variation in royalty payments. A quantitative analysis sheds light on the impact of global taxation reforms on both international technology licensing and innovation. The findings highlight the crucial role of taxation in shaping cross-border flows of technology and the potential consequences of profit-shifting strategies.

Keywords: Technology Diffusion; Royalty Payments; Intellectual Property Rights

JEL Classification: F12, O33, O41, O47

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# 1 Introduction

In the past few decades, intangibles have become increasingly important in international trade. Between 1995 and 2012, international technology licensing, which is a measure of trade in intellectual property (IP), increased by a factor of three. In contrast, merchandise trade only increased by a factor of 1.3. Trade in intangibles plays a crucial role in technology transfer, innovation, and economic growth. However, the lack of extensive data on intangibles has posed a challenge to empirical and theoretical research, which has traditionally focused on the study of trade in tangible goods.

This paper explores the determinants of international technology licensing, a crucial element of intangible trade. Technology licensing involves an agreement in which the proprietor of a patent sells intellectual property rights (IPRs) and the expertise necessary to exercise them to another entity. Although technology licensing accounts for only a small portion of total trade, it plays a significant role in pivotal sectors of the economy, including pharmaceuticals, computers and electronics, and transportation, which are also the most innovation-intensive industries (see Robbins, 2009). It is also a more direct method of transferring knowledge internationally than trade, foreign direct investment (FDI), or international patenting (see Keller, 2004, for a survey on the role for spillovers on international technology diffusion). Technology licensing transactions occur in a marketplace and are more readily measurable than other non-internalized technology transfer channels. However, taxation of these transactions has recently become a contentious issue, with concerns about multinational corporations' (MNCs) profit shifting and base erosion. Therefore, this study focuses on the impact of intellectual property rights and global taxation on international technology licensing determinants.

I provide an exhaustive longitudinal analysis of international technology licensing, using new data for bilateral royalty payments for 50 countries from 1995 to 2012. The data are recorded in the balance of payments of a country as a trade in services and include both intrafirm and arm's length transactions.[1] Recent theoretical papers point at technology licensing as a source of innovation and growth (Benhabib, Perla, and Tonetti, 2021; Monge-Naranjo, 2019). However, the empirical work on their main determinants is still limited, focusing on just one country or a small set of countries (Yang and Maskus, 2001; Branstetter, Fisman, and Foley, 2006).

I begin by documenting key patterns of international technology licensing over time, as well as its interrelation with innovation, global taxation, and IPRs. First, the available data highlight that only a select few countries account for the majority of technology exports. Among them are technologically advanced nations like the United States, Japan, and Germany, which exhibit positive net exports of technology. Second, countries in close proximity to each other tend to exchange more technology and participate in more bilateral royalty payments. Third, tax havens have gained greater prominence in cross-border licensing, particularly since the 2000s. Multinational corporations in countries with high taxes frequently use technology licensing to redistribute profits around the world in order to evade corporate taxes. Lastly, developing countries that have improved their IP protection over time have become significant recipients of technology from developed nations.

Next, I evaluate the main factors influencing cross-border technology licensing and the impact of corporate taxation disparities between nations. I develop an Armington trade model of innovation and international technology licensing. In this framework, innovators allocate their research efforts toward creating new ideas, a subset of which can be adopted by foreign firms to produce new intermediate goods. Due to imperfect IPRs, a fraction of these ideas may be subject to imitation. There are two ways for innovators to bring their remaining technologies to the international market—licensing or setting up a foreign affiliate. Under licensing, innovators receive royalty payments that are taxed at the domestic corporate tax rate. Alternatively, innovators can set up a foreign affiliate and transfer ownership of the technology at a discounted rate, potentially engaging in profit-shifting practices. The

[1] The data are reported in EBOPS 2012: Balanced International Trade in Services (1995-2012).

decision on the optimal licensing strategy depends on differences in corporate taxation, the cost of transferring technology, and the discount at which innovators sell the technology. The model yields a dynamic structural gravity equation of royalty payments that depends on various economic fundamentals, including the R&D intensity and productivity of the exporter, IPR protection and productivity of the importer, time-varying taxation disparities between countries, and a bilateral parameter that reflects geographic and cultural reasons for technology transfer.[2]

I then employ nonlinear methods to estimate the structural gravity equation, regressing royalty payments on various economic fundamentals.[3] The findings indicate that countries with higher innovation intensity and productivity tend to export more technology. Similarly, countries with greater productivity and stronger IPR enforcement tend to import more technology. Moreover, country pairs located closer to each other geographically tend to share more technology. Finally, the results demonstrate that countries with higher corporate income taxes relative to their trading partners tend to receive fewer royalty payments. This observation aligns with the notion that firms in high-tax jurisdictions may shift their IP ownership to low-tax jurisdictions. The model fundamentals exhibit strong predictive power of bilateral royalty payments, with a correlation of around 60% between the actual and predicted values of the regression.

The model is calibrated using data on innovation, royalty payments, trade flows, geography, corporate income taxes, and an index measuring IPR quality. I assume full depreciation of technologies so that the model can be solved as a sequence of static models (Anderson, Larch, and Yotov, 2020).[4] Two wedges are introduced to fully match data on bilateral royalties and R&D intensity in every period between 1996 and 2012.

Next, I evaluate the impact of corporate tax differences on international technology licens-

[2]This equation resembles the gravity equation derived by Eaton and Kortum (2002) for the case of international trade flows.

[3]For a comprehensive review of techniques to estimate gravity equations, see Head and Mayer (2014).

[4]This assumption is akin to assuming that innovators only get profits for one period, as in Desmet and Rossi-Hansberg (2014). It offers two advantages: (i) the structural gravity equation can be estimated dynamically, and (ii) the model can be solved as a sequence of static models.

ing and innovation through two quantitative exercises. Specifically, I introduce two policy reforms aimed at removing incentives for profit shifting. The first exercise is motivated by the Global Tax Deal negotiated at the OECD whereby more than 135 countries agreed to new rules in international taxation. The deal establishes a minimum effective corporate tax rate of 15%. The second exercise is motivated by the Tax Cuts and Jobs Act (TCJA), enacted at the end of 2017, which introduced a tax on IP being held in foreign tax countries—Global Intangible Low-Taxed Income (GILTI)—reducing the gap with foreign rates. I then ask the following question: How much would international technology licensing and innovation have been under the different tax schedules in each reform proposal?

The policy analysis shows that imposing additional taxes on foreign profits has a significant impact on international technology licensing and innovation. Specifically, it increases royalty payments to innovative countries that were previously engaging in profit-shifting, as removing these incentives leads to innovators retaining ownership of their technology and receiving royalties instead. Tax havens are the main source of the increased royalty payments. However, despite the rise in royalty payments, innovators invest less in R&D as the additional royalties are taxed at a higher rate. This suggests that levying taxes on foreign profits can have a negative effect on innovation.

Finally, in the appendix, I explore the role of the quality of IPR on international technology licensing. A limitation of the data on royalty payments in studying the role of IPR is that, in countries like China, technology misappropriation happens through FDI and quid-pro-quo practices, by which multinationals wanting to operate in China need to create a joint venture with a local firm and transfer their technology at no cost. Holmes, McGrattan, and Prescott (2015) study, through the lens of a quantitative model, the effect of quid-pro-quo practices on innovation and welfare and find significant effects. Due to these limitations, I relegate this exercise to the Appendix and focus, instead, on the role of global taxation.

**Literature review** The paper is related to several strands of the literature. First, it contributes to the empirical literature on international technology diffusion. Several studies have focused on indirect forms of diffusion, such as international trade (Grossman and Helpman, 1991; Coe, Helpman, and Hoffmaister, 2009; Keller, 1998, 2002, 2004; Nishioka and Ripoll, 2012). In these studies, technology is embodied in a good and then diffused around the world whenever the good is traded internationally. More recently, several papers have studied trade as the vehicle of diffusion within general equilibrium models (see Santacreu, 2015; Aghion and Jaravel, 2015; Buera and Oberfield, 2019; Perla, Tonetti, and Waugh, 2021). Another channel of diffusion that has been studied in the literature is FDI, by which a domestic firm can open a foreign affiliate in a country of interest and transfer the ownership of the technology to produce the good there. Guadalupe, Kuzmina, and Thomas (2012) study how Spanish multinationals transfer superior technologies and organizational practices to their foreign subsidiaries. Fons-Rosen et al. (2021) quantify productivity gains from foreign investment and find that productivity of foreign-acquired affiliates increases modestly after four years, but only when majority stakes are acquired by foreigners. Keller and Yeaple (2009) analyze international technology spillovers to U.S. manufacturing firms via both imports and FDI and find that the latter leads to substantial productivity gains for domestic firms. Branstetter (2006) finds that FDI is a channel of knowledge spillovers for Japanese multinationals investing in the United States. Ramondo and Rodríguez-Clare (2013) study the gains from openness though trade and multinational production, using the latter as a form of international technology diffusion.

Second, it is related to recent studies that have emphasized the importance of international technology licensing in transferring technology (Branstetter, Fisman, and Foley, 2006; Mandelman and Waddle, 2019; Maskus, 2004). Yang and Maskus (2001) develop a theoretical model in which firms in industrial countries innovate products of higher quality levels and decide whether to transfer production rights to developing countries through licensing. Branstetter, Fisman, and Foley (2006) analyze, empirically, the response of technology transfer through licensing within U.S. multinational firms after IPR reforms in 16 countries receiving such transfers. Saggi (1999) studies the implications of licensing for innovative activity, whereas Glass and Saggi (2002) study the growth implications of licensing versus FDI. In a theoretical framework, Benhabib, Perla, and Tonetti (2021) find that licensing of excludable technologies is a direct channel through which adoption has an effect on long-term growth. Finally, using a quantitative model, Holmes, McGrattan, and Prescott (2015) find that quid-pro-quo practices, in which multinational firms were required to transfer technology in return for market access, had a significant impact on welfare and global innovation.

Third, the paper is related to recent work on the effect of differences in corporate taxation on transfers of technology ownership. Using firm-level data, Karkinsky and Riedel (2012); Dischinger and Riedel (2011); Griffith, Miller, and O'Connell (2014) find that differences in corporate taxation introduce profit-shifting motives through movements on IP. Specifically, they find that innovators in high-tax countries tend to transfer technology ownership to affiliates in low-tax countries. The counterpart of these transactions is reflected in cross-border royalty payments, which I analyze in this paper. Finally, Dyrda et al. (2022) explore, through the lens of a quantitative static model, the role of differences in corporate taxation on profit shifting, government tax revenues, and output. My model incorporates an endogenous decision to do R&D based on differences in corporate taxation.

Fourth, the paper lies at the intersection of technology diffusion through market and non-market channels. In my model, technology is both non-rival and partially excludable. It is non-rival in that ideas can be used in many markets. It is partially excludable in that the innovator receives royalty payments for those ideas that have been adopted. Monge-Naranjo (2019) builds a model to analyze the entry decisions of foreign firms sending their know-how to developing countries. Similarly to my paper, he considers both externalities and market decisions for technology transfer. His findings reinforce the importance of analyzing technology licensing as a vehicle of international technology transfer. Arqué-Castells and

Spulber (2022) also disentangle market channels of technology diffusion from pure knowledge spillovers.

Finally, this paper is related to a strand of literature analyzing distortions on international technology transfer. First, several studies study the role of the quality of IP rights enforcement in international technology transfer (Yang and Maskus, 2001; Maskus, 2004; Branstetter, Fisman, and Foley, 2006; Lin and Lincoln, 2017). In a very recent paper, Mandelman and Waddle (2019) study the strategic interaction of trade policy and the enforcement of IPR in the context of the current U.S.-China trade war. In their model, technology transfers happen in arms-length relationships. Second, several studies address the role of taxation and the legal system of the country receiving the technology (Guvenen et al., 2022; Bruner, Rassier, and Ruhl, 2018; Tørsløv, Wier, and Zucman, 2023). Different from all these approaches, my paper proposes a unified framework to study the role of different factors on the evolution of international technology licensing.

## 2 Empirical Evidence on the Patterns of International Technology Licensing

This section describes the data and documents salient features of international technology licensing.[5] I focus on three groups of countries—innovative, developing and tax havens— to emphasize the role of three key channels in driving international technology licensing: (i) innovation, (ii) global taxation, and (iii) intellectual property rights.

**The Data on International Technology Licensing** The data, reported in the OECD Balanced Trade in Services dataset (EBOPS) as bilateral royalty and license fees, are available for over 100 countries and the period 1995-2012. They are recorded in the balance of payments of a country as a trade in services and includes: (i) charges for the use of propri-

[5]Details on other data used throughout the paper are relegated to Appendix C.

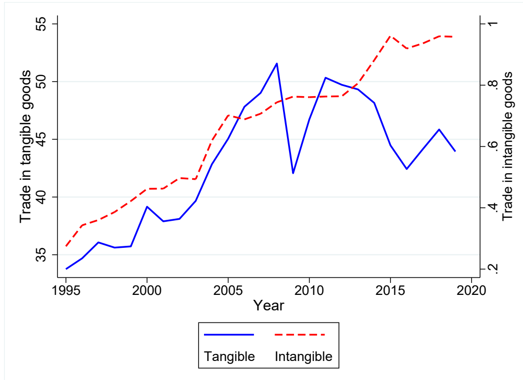
etary rights, such as patents, trademarks, copyrights, industrial processes and designs, trade secrets, and franchises, where rights arise from research and development; and (ii) charges for licenses to reproduce and distribute intellectual property embodied in produced originals or prototypes (copyrights on books and manuscripts, computer software, etc). Although it is not possible to decompose the EBOPS data into each of these components—patents, trademarks, franchising fees, and audiovisual licensing fees— according to Branstetter, Fisman, and Foley (2006), about 88% of royalty payments in 1989 consisted of technology licensing fees (see also Mandelman and Waddle, 2019). Moreover, data from the Bureau of Economic Analysis (BEA) on royalty payments between the United States and the world during 2002 and 2007 suggest that almost 80% of these payments were composed by the outcome of research and development and software, while the rest corresponded to franchising and entertainment. This is the most comprehensive longitudinal dataset on royalty and license fees, with the highest coverage in terms of the number of countries and time period.

International technology licensing, which is a type of intangibles trade, behaves differently than merchandise trade. Figure 1 shows that world royalty payments and receipts have increased at a faster pace than trade in merchandise goods, especially during the period after the Great Recession.[6] While merchandise trade (% world GDP) increased by a factor of 1.3 between 1996 and 2019 (from 33.7% in 1996 to 49.7% in 2012, and then 43.9% in 2019), international technology licensing (% world GDP) increased by a factor of 3 (from 0.15% in 1996 to 0.36% in 2012, and then 0.45% in 2019). As with other types of trade in services, technology licensing was less affected by the Great Recession than trade in goods. Moreover, while trade in merchandise decelerated after the Great Recession, trade in intangibles kept increasing continuously.

Next, I document patterns of the evolution of royalty payments with a focus on the role of global taxation and IPR. Throughout the paper, the technology exporter is the country receiving royalty payments; the technology importer is the country making royalty payments.

[6] After the Great Recession the world went through a period of de-globalization or slowbalization (see Antràs, 2020).

Figure 1: Trade in intangible vs trade in tangible



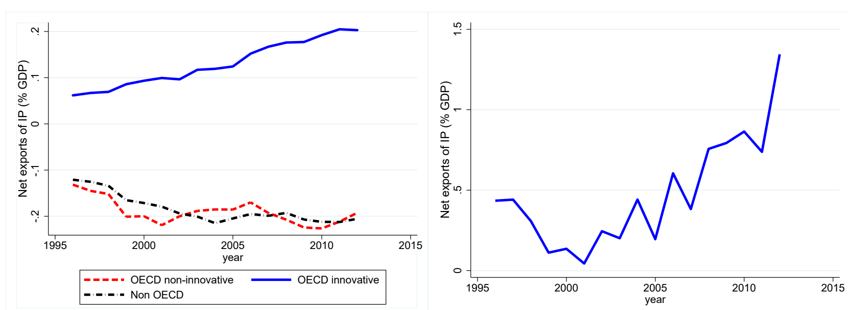

**Notes:** The figure plots the evolution of exports and imports of technology, using royalty payment data as a % of GDP (trade in intangible) and exports and imports of merchandise as a % of GDP (trade in tangible) between 1995 and 2019.

**Comparative advantage in IP: The role of innovation and global taxation** The data on technology licensing indicate that only a few countries have a comparative advantage in IP, as measured by their net exports of technology (i.e., the difference between the amount of royalty payments they receive from foreigners and royalty payments they make to foreigners.) As a percentage of their GDP, the main exporters in 2012 were Bermuda (156%), Luxembourg (20%), Cyprus (4.8%), the Netherlands (4%), Ireland (3.97%), and Switzerland (3.1%). All these countries are characterized by their special tax regimes and considered tax havens. Among non-tax haven countries, Sweden (1.14%), Denmark (0.81%), the United States (0.73%), the United Kingdom (0.70%), Finland (0.65%) and Japan (0.53%) were the main exporters of IP in 2012. These are countries that spend large amount of resources into R&D. While it is not surprising that highly innovative countries like the United States, Japan, and the United Kingdom are among the main exporters of technology, the cases of Bermuda, Luxembourg, Ireland, and the Netherlands deserve special attention. As Bruner, Rassier, and Ruhl (2018); Zucman (2014); Guvenen et al. (2022) have argued, multinational corporations in high-tax countries engage in profit-shifting activities to avoid paying taxes. These practices typically involve firms transferring their IP's ownership to affiliates in low-tax countries, which then receive royalty payments from the parent company. Thus, countries may get large royalty payments from abroad (i.e., export large amounts of technology) either because they create IP and then license it internationally or because they get the technology ownership from other innovative countries for tax reasons.

Figure 2 shows the evolution of net exports (as a percentage of GDP) for 4 groups of countries: innovative OECD, non-innovative OECD, non-OECD, and tax havens (excluding Ireland).[7] The left panel focuses on the evolution of net exports of technology in non-tax havens, whereas the right panel looks at tax havens. The figure shows that innovative OECD countries and tax havens have a comparative advantage in technology—i.e., they are net exporters of technology. In both cases, net exports have been growing over time. Ireland is an exception, as it is a large net importer of technology despite being considered a tax haven. Throughout this section, I leave Ireland out of the analysis and I go into more detail later.

Figure 2: Net exports of technology (as % GDP)

(a) Non-tax havens (b) Tax havens




**Notes:** The figure shows net exports of IP—the difference between royalties received from the world and royalties paid to the world—for non-tax haven countries in panel (a) and tax havens in panel (b) for the period 1996-2012. Non-tax haven countries are further decomposed into OECD innovative countries, other OECD countries, and non-OECD countries.

Innovative countries are expected to be technology exporters, since they have a comparative advantage in producing IP. However, we observe that tax havens tend to have a net surplus of technology. What is even more striking is that, despite OECD innovative countries

[7] Countries are classified as innovative OECD if their average GDP per capita over the sample period is above the cross-country OECD average during that period. A list of countries in each group is reported in Appendix B.

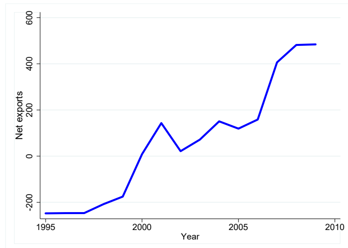
having net surpluses overall, they have deficits with many tax havens. For instance, if we focus on the United States, Germany, the United Kingdom, and France—which, as Zucman (2014) documents, are the countries that engage in more profit shifting—we observe that, in 2012, the United States had a technology deficit with Antigua, Malta, Cyprus, and Barbados; Germany was a net importer from Luxembourg, Ireland, Cyprus and Antigua; the United Kingdom had a deficit with Antigua, Cyprus, Luxembourg, and the Netherlands; and France was a net importer from Bermuda, Luxembourg, and the Netherlands. These findings suggest that differences in corporate taxation may be an important driver of bilateral royalty flows. Finally, Figure 3 shows the evolution of bilateral net exports of technology from several tax havens to a few OECD innovative countries. The patterns in the figure suggest that innovative countries tend to engage in profit-shifting practices with countries that have special tax regimes.

To generalize these findings, Figure 4 shows the evolution of cross-country average bilateral net exports of technology from unproductive tax havens to OECD innovative countries. The findings are consistent with those in Figure 3: innovative countries tend to pay more royalties to unproductive countries than the other way around. These findings are consistent with firms in high-tax countries engaging in profit-shifting practices with tax havens.

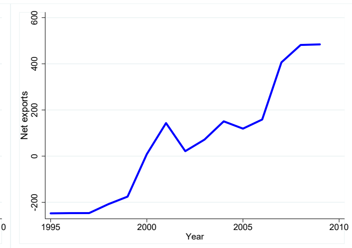
Ireland's unique tax regime makes it a complex case and stand out as an outlier. Despite being one of the largest exporters of technology globally, it is the biggest net importer of technology, paying more royalties abroad than it receives. The Netherlands is the primary recipient of Irish royalty outflows, followed by the United States, Luxembourg, and Bermuda. Ireland's status as the largest net importer of technology, makes it unique among other recognized tax havens in that it pays more royalties internationally than it receives. One explanation lies in the "double Irish" and the "double Irish with a Dutch sandwich" tax avoidance techniques, which allow royalties received by Ireland to be channeled to offshore financial centers to be taxed at lower rates. For more details about this case, see Appendix H.

Figure 3: Bilateral next exports between tax havens and OECD innovative countries for a selected sample of countries (in millions of US Dollars)

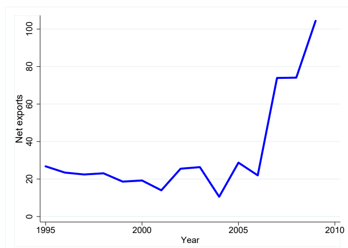
(a) Singapore and Japan



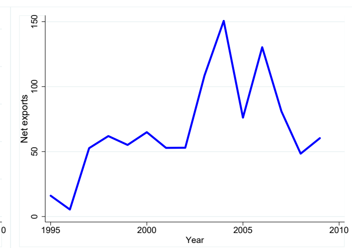

(b) Netherlands and Germany




(c) Luxembourg and Germany

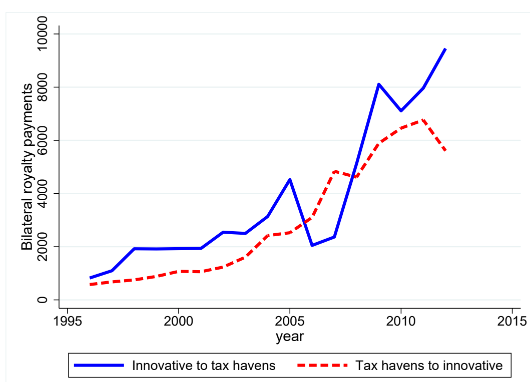



(d) Luxembourg and USA




**Notes:** The figure shows net exports of IP—the difference between royalties paid by the innovative country to the tax haven—for the period 1996-2012. A positive number means that the tax haven is receiving more than what is paying. Net exports are in millions of US Dollars.

Figure 4: Bilateral next exports between unproductive tax havens and OECD innovative countries (in millions of US Dollars)




**Notes:** The figure shows net exports of IP—the difference between royalties paid by innovative countries to the tax haven (solid blue line) and the difference between royalties paid by the tax haven to innovative countries—for the period 1996-2012. Net exports are in millions of US Dollars.

**Developing Countries: The role of IPR** Restricting attention to developing countries, China has become the main destination for international technology licensing, especially from the United States and Japan. After joining the World Trade Organization (WTO) in 2001, China improved its IPR substantially, according to the Ginarte-Park index (see Ginarte and Park, 1997)).[8]

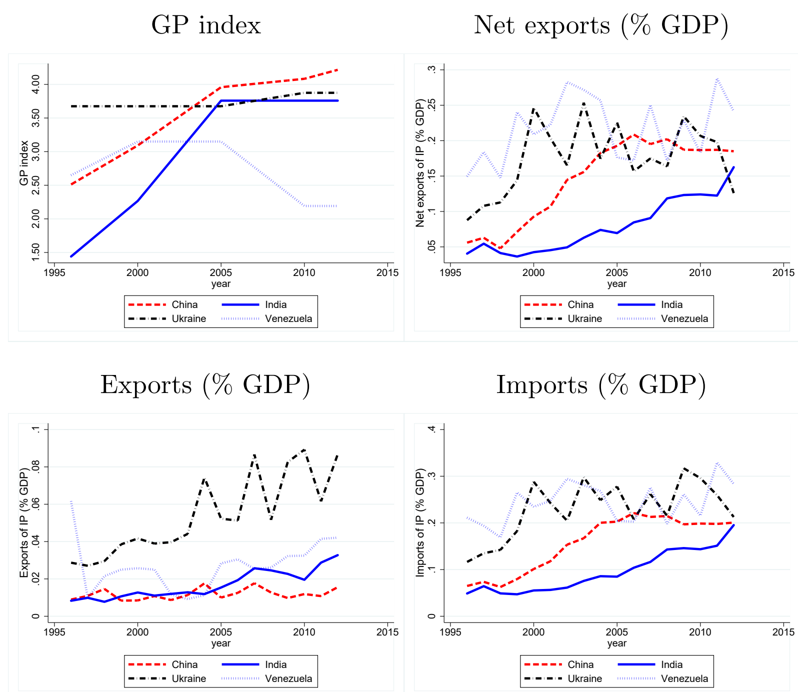
More generally, I find that countries that experienced substantial improvements in their IP enforcement became recipients of technology and started paying more royalties abroad. Figure 5 shows the evolution of the GP index (left panel) and of net exports as a % GDP (right panel) for a few developing countries in the sample: two countries that improved their IPR substantially, according to the Ginarte-Park index (China and India), and two countries that either maintained or experienced declines in their quality of IP protection (Ukraine and Venezuela). The right panel shows that China and India experienced an increase in net royalty payments made abroad, whereas in Ukraine and Venezuela payments remained unchanged. These trends are explained by the dynamic patterns of imports of technology.

**International technology licensing and fundamentals** Figure 6 displays the relationship between royalty payments and various economic fundamentals that provide insight into observed patterns. The results indicate that countries with higher R&D intensity and productivity tend to receive more royalty payments from around the world (top panel). Additionally, countries with stronger IPR enforcement and greater productivity tend to make more royalty payments to other countries (middle panel). Moreover, countries that are geographically closer tend to exchange more technology, while those with higher corporate taxes relative to their trading partners in tax havens tend to receive less technology (bottom panel).

To summarize, the patterns described so far reflect that innovative countries are net exporters of technology, as they have a comparative advantage in R&D, whereas developing

[8]As the Ginarte-Park index is calculated every five years, I linearly extrapolate it to retrieve missing values.

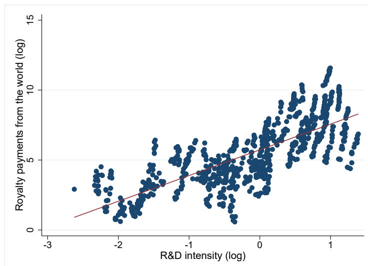
Figure 5: The rise of China and India as technology recipients



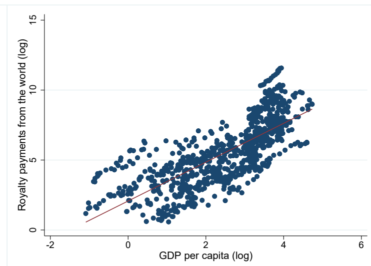

**Notes:** The figure plots the evolution of the GP index, net exports, exports and imports of technology for China, India, Ukraine and Venezuela between 1995 and 2012

Figure 6: Royalty payments and economic fundamentals

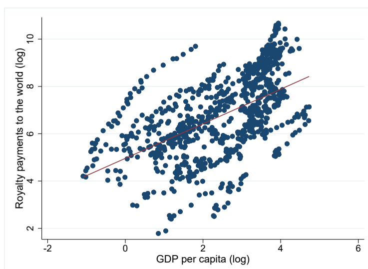
(a) Royalties received and R&D intensity



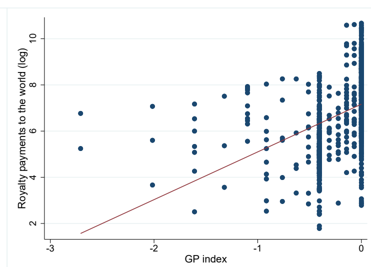

(b) Royalties received and GDP pc



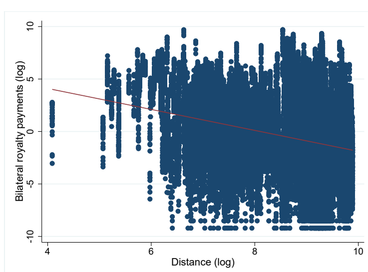

(c) Royalties paid and GDP pc



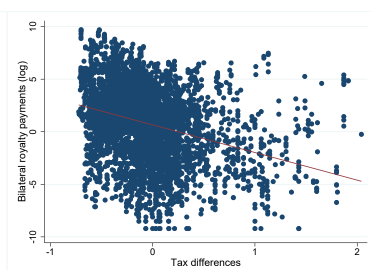

(d) Royalties paid and IPR




(e) Bilateral royalties and distance




(f) Bilateral royalties and tax differences




**Notes:** The figure shows the relationship between royalties received (top panel), royalties paid (middle panel), bilateral royalties (bottom panel), and several economic fundamentals.

countries, especially those with good IPR, are net importers of technology. Tax havens are also net exporters of technology even if they do not invest in R&D. These patterns are consistent with multinational corporations in high-tax countries shifting the ownership of their IP to affiliates in low-tax countries. The rest of the paper develops a methodology to investigate the main determinants of international technology licensing, with emphasis on the role of global taxation and the quality of IP protection in explaining some of the features of the data.

# 3 The Model

I develop an Armington model of trade in which productivity evolves endogenously through innovation and adoption. There are $M$ countries indexed by $i$ and $n$, and time is discrete and indexed by $t$. There are five agents in each country: consumers, final producers, intermediate producers, innovators, and adopters. The consumption and production sides of the economy are standard. Innovation and adoption are less standard. Innovators invest resources to introduce new technologies, a fraction of which diffuses to the foreign market. There are imperfect intellectual property rights: an exogenous fraction of diffused technologies is imitated and those innovators are not compensated for their effort. A fraction of the remaining technologies can be adopted by foreign firms to produce intermediate goods. A technology can be adopted internationally through licensing or by transferring ownership to an affiliate abroad. Different corporate tax laws in different countries influence the decision of each mode of adoption. Adopters then produce an intermediate good as monopolistic competitive firms and pay royalties or a transfer price to innovators. The model yields a dynamic structural gravity equation of royalty payments as a function of several economic fundamentals, including differences in corporate taxes and the quality of intellectual property rights.

## 3.1 Final Production

In each country $n$, a perfectly competitive final producer demands intermediate inputs to produce a non-traded good according to a constant elasticity of substitution production function

$$Y_{nt} = \left( \sum_{i=1}^{M} \int_{j=1}^{T_{it}} x_{ni,t}(j)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where $x_{ni,t}(j)$ is the amount of intermediate input $j$ demanded by the final producer in country $n$ from country $i$ at time $t$; $T_{it}$ is the number of intermediate goods produced in country $i$; and $\sigma > 1$ is the elasticity of substitution across intermediate products.

The demand for intermediate goods is given by

$$x_{ni,t}(j) = \left( \frac{p_{ni,t}(j)}{P_{nt}} \right)^{-\sigma} Y_{nt}. \tag{2}$$

**Intermediate Producers** In each country $n$, a continuum of monopolistic competitive intermediate producers indexed by $j$ hire labor to produce a traded good according to the CRS production function

$$y_{nt}(j) = \Omega_{nt} l_{nt}(j). \tag{3}$$

where $y_{nt}(j)$ is the amount of intermediate good $j$ produced at time $t$, $\Omega_{nt}$ is the fundamental productivity in country $n$, and $l_{nt}(j)$ is the amount of labor hired by producer $j$ in country $n$ at time $t$.

Intermediate producers take the demand of final producers as given and choose the price and the amount of labor to hire to maximize profits subject to equation (2). Pre-tax profits are given by

$$\pi_{nt}(j) = \sum_{i=1}^{M} p_{in,t}(j) x_{in,t}(j) - W_{nt} l_{nt}(j). \tag{4}$$

**International trade** Intermediate products are traded internationally. Trade is costly with iceberg transport costs: in order to sell one unit of the intermediate good from country $n$ to country $i$, country $n$ must ship $d_{in}$ units of the good. That means that, in equilibrium, $y_{nt}(j) = \sum_{i=1}^{M} x_{in,t}(j) d_{in}$.

Country $n$'s import share of goods produced by country $i$ is given by

$$\frac{X_{ni,t}}{\sum_{n=1}^{M} X_{ni,t}} = \frac{\Omega_{it}^{\sigma-1} T_{it} \left(W_{it} d_{ni}\right)^{1-\sigma}}{\sum_{m=1}^{M} \Omega_{mt}^{\sigma-1} T_{mt} \left(W_{mt} d_{nm}\right)^{1-\sigma}}. \tag{5}$$

where $X_{ni,t}$ is the spending by country $n$ on intermediate goods from country $i$, and $W_{it}$ is the wage.

In this model, $T_{nt}$ is endogenously determined by innovation and adoption, as I describe in detail next.

## 3.2 Innovation and International Adoption

The number of technologies that are used to produce intermediate goods, $T_{nt}$, evolves endogenously through domestic innovation and international adoption.

**Innovation** In each country $n$ an innovator invests final output, $H_{nt}^{r}$, to create a new prototype or technology. The number of new technologies invented in country $n$ is given by

$$Z_{nt} = \kappa_{nt} T_{nt} \left(\frac{H_{nt}^{r}}{Y_{nt}}\right)^{\beta_r}. \tag{6}$$

where $\kappa_{nt} T_{nt}$ represents the innovation efficiency, and is composed of two terms: $\kappa_{nt}$ is a country-specific time-varying parameter and $T_{nt}$ is the stock of knowledge available in country $n$ at time $t$. The parameter $\beta_r$ represents diminishing returns to adding one extra unit of final output into the innovation process.[9]

[9]Equation (6) derives from a more general law of motion of new technologies $Z_{nt} = \kappa_{nt} T_{nt} \left(\frac{H_{nt}^{r}}{Y_{nt}}\right)^{\beta_r} + Z_{n,t-1}(1-\delta)$, where I assume full depreciation. This assumption converts the dynamic model into a sequence of static models, as in Anderson, Larch, and Yotov (2020).

Innovators have a monopoly over their technology. In the domestic country, innovators use the technology to produce an intermediate good and get all the profits through licensing. However, innovators can commercialize their technology in a foreign country through a process of adoption that consists of either licensing the technology or selling it to foreign adopters that then use it to produce an intermediate good.

**International Technology Adoption: The Role of Profit Shifting and Imperfect IPR** A technology developed by an innovator must be adopted in order to be used in the production of intermediate goods. I assume all new technologies are adopted domestically every period. Firms in a foreign country, however, can adopt only a fraction of these technologies. It reflects the idea that not all innovations are available to or are usable by foreign countries, for reasons such as distance, culture, or frictions that prevent countries from exchanging technologies. Denote $\varepsilon_{in}$ as the fraction of ideas developed in country $n$ that can be adopted by country $i$ (i.e., the number of diffused ideas). Thus, a mass $\varepsilon_{in}Z_{nt}$ of new technologies can potentially be adopted by firms in country $i$. I assume that all ideas can be adopted domestically, i.e., $\varepsilon_{ii} = 1$.

A fraction of new technologies that diffuse internationally is imitated. The remaining technologies can be adopted through licensing or through transfers of IP ownership to a foreign firm. While the probability of imitation is taken as exogenous, the probability of licensing and ownership transfers is determined endogenously by differences in corporate taxation. I elaborate more on these processes next.

**Imitation: The quality of IPR** International adoption is subject to imperfect intellectual property rights by which a fraction of the diffused technologies is imitated and innovators receive no compensation. I assume that innovators do not internalize this possibility when choosing whether to license or transfer the technology.[10]

[10]This assumption could be relaxed in a more realistic setting where the probability of licensing internationally could depend on the risk of imitation (Holmes, McGrattan, and Prescott, 2015).

Specifically, a fraction $1 - \phi_{in}$ of ideas invented in country $n$ and diffused to country $i$ is imitated. Thus, the innovator in country $n$ can only capture profits from a fraction $\phi_{it}$ of technologies that have been diffused to country $i$. In this case, the mass of adopted technologies from country $n$ by country $i$ is

$$A_{in,t} = \varepsilon_{in}\phi_{it}Z_{nt}. \tag{7}$$

I assume that there is perfect enforcement of IPR domestically, i.e., $\phi_{ii} = 1$. In this case, $A_{ii,t} = Z_{it}$.

**Adoption: Technology licensing vs profit shifting** Innovators receive profits from both domestic producers and foreign firms that adopt their technology. Domestically, they receive royalty payments from all domestic adopters. Abroad, innovators choose whether to license their technology to a foreign firm, or whether to open an affiliate to transfer the technology ownership, at a cost. These transfers are related to profit-shifting practices. Foreign affiliates then license the technology in that country.[11] As a result, a fraction of domestic technologies is licensed abroad and a fraction is transferred. Royalty payments received by the innovator through licensing are taxed at the domestic rate, whereas royalty payments received by the affiliates that own the technology are taxed at the corporate tax rate of the affiliate country. By transferring the technology ownership, multinationals reallocate profits from high-tax jurisdictions to low-tax ones.

Denote $\lambda_{in,t}$ as the fraction of technologies of which innovators in country $n$ transfer ownership to country $i$. In this case, innovators receive $TR_{in,t}$, and pay a cost $C(\lambda_{in,t})$, for every unit transferred. This cost can include the cost of opening an affiliate in a new country or litigation costs for engaging in profit-shifting practices (the modeling choice follows a

[11] Alternatively, one could consider the case in which the foreign affiliate can also license the technology abroad. For simplicity, I only allow for domestic royalties. The underlying assumption is that these decisions are taken country by country, and the same technology can be transferred to multiple countries that can only license it domestically.

simplified version of Dyrda et al., 2022).[12] Furthermore, when the multinational headquarters transfers a fraction $\lambda_{in}$ of technologies developed in country $n$ to its affiliate in country $i$, this portion of technologies is no longer available in country $n$. Instead, the headquarters in $n$ licenses them back from its affiliate in country $i$. Hence, innovators in $n$ pay royalties to $i$ for the technologies that were transferred through profit shifting, as they are now licensing back technology that was previously owned. A fraction $1-\lambda_{in,t}$ is then licensed to a foreign firm in country $i$. Thus, the profits that the $n$'s headquarter (i.e., the innovator) generates in that country, $\pi^{mn}_{nt}$, are given by

$$\pi^{mn}_{nt} = \underbrace{\left(A_{nnt} - \sum_{i\neq n} A_{in,t}\lambda_{in,t}\right) rp_{nn,t}}_{\text{Licenses received from domestically-owned technologies}} - \underbrace{\sum_{i\neq n} A_{in,t}\lambda_{in,t}\left(\frac{\Pi_{nt}}{T_{nt}} - rp_{ni,t}\right)}_{\text{Licensing back from } n \text{ transferred technology}}$$
$$+ \sum_{i\neq n} A_{in,t}\left[\underbrace{(1-\lambda_{in,t})rp_{in,t}}_{\text{Licensing to } i} + \underbrace{\lambda_{in,t}TR_{in,t} - C(\lambda_{in,t})TR_{in,t}}_{\text{Ownership transfer}}\right]. \tag{8}$$

where $rp_{in,t}$ represents royalty payments from each firm in country $i$ producing with a technology being licensed from country $n$, and $TR_{in,t}$ is the transfer price.

The profits generated by an affiliate of that innovator in country $i$, $\pi^{aff}_{in,t}$, are given by

$$\pi^{aff}_{int} = A_{in,t}\phi_{it}\left[\underbrace{(1-\lambda_{in,t})(\Pi_{it}/T_{it} - rp_{in,t})}_{\text{Licensing from } n} + \underbrace{\lambda_{in,t}(rp_{ii,t} - TR_{in,t})}_{\text{Ownership transfer}} + \underbrace{\lambda_{in,t}rp_{ni,t}}_{\text{Licensing back to } n}\right] \tag{9}$$

The affiliate receives royalties, both domestically and from the headquarters, which is licensing back technology it previously owned. Subsequently, it pays the transfer price to the headquarters. This represents the portion of profits accounted for by profit-shifting. For

[12]One difference with Dyrda et al. (2022) is that, in my model, affiliates only license their technology to local firms and back to the headquarter, excluding licensing to third countries.

the technologies that have not been transferred, royalties are also paid to the headquarters.

Innovators choose $\lambda_{in,t}$ to maximize global profits, $\Pi_{nt}^{\text{global}}$. Global profits are composed of profits received by the headquarters located in the country of innovation, which are taxed at the domestic corporate tax rate, and of those obtained by foreign affiliates, which are taxed at the foreign corporate tax rate. That is,

$$\Pi_{nt}^{\text{global}} = (1-\tau_{nt})\pi_{nt}^{mn} + \sum_{i\neq n}(1-\tau_{it})\pi_{in,t}^{aff}. \tag{10}$$

**Royalty payments and transfer price of a technology** I assume that innovators choose royalties as a Nash-bargaining equilibrium between the innovator and the foreign adopter. Here, they chose $rp_{in,t}$ to maximize

$$(rp_{in,t})^{\rho}\left(\frac{\Pi_{it}}{T_{it}} - rp_{in,t}\right)^{1-\rho}.$$

with $\rho$ the bargaining power of the innovator.

In this case:

$$rp_{in,t} = \rho\frac{\Pi_{it}}{T_{it}}.$$

with $\Pi_{it} = \frac{1}{\sigma}W_{it}L_{it}$ Second, I assume that innovators transfer their IP to a foreign affiliate at a discount, in order to take advantage of lower tax rates. Denote $\psi < 1$ as the discount at which they sell their technology. In that case

$$TR_{in,t} = \psi(rp_{ii,t} + rp_{ni,t}/\psi)$$

Two remarks are in order. First, the transfer price includes both domestic royalty payments received by the subsidiary from its local operations and royalty payments received from the headquarters, which involve licensing back the transferred IP. Second, the discount only applies to domestic royalties. This reflects adherence to the arm's length principle, which not only aligns with international tax guidelines but also introduces a layer of complexity that may make it more challenging for tax authorities in high-tax countries to readily identify profit-shifting practices.

**Optimal profit shifting** Substituting equations (8) and (9) into equation (10), we obtain an expression for ex-post global profits. Innovators choose $\lambda_{in,t}$ to maximize these profits. Assuming $\rho = 1$, the first order condition of equation (10) with respect to $\lambda_{in}$ is

$$(1-\tau_{nt})(-rp_{in,t}+\psi rp_{ii,t}-C'(\lambda)\psi rp_{ii,t})+(1-\tau_{it})(-\Pi_{it}/T_{it}+rp_{in,t}+rp_{ii,t}-TR_{in,t}) = 0. \quad (11)$$

Following Dyrda et al. (2022), I assume a functional form for the cost of transferring the ownership of $C(\lambda) = \lambda + (1-\lambda)\log(1-\lambda)$. This functional form implies that the cost is increasing in $\lambda$, is bounded between 0 and 1, and ensures that the fraction of licensed technologies is between 0 and 1. Then, substituting $C'(\lambda) = -log(1-\lambda)$, $rp_{ii,t} = \Pi_{it}/T_{it}$, $rp_{in,t} = \Pi_{it}/T_{it}$ and $TR_{in,t} = \psi\Pi_{it}/T_{it}$, into equation (11), the fraction of technologies being transferred through profit-shifting practices is

$$\lambda_{in,t} = 1 - \exp\left(-\frac{1-\psi}{\psi}\frac{\tau_{nt}-\tau_{it}}{1-\tau_{nt}}\right). \quad (12)$$

if $\tau_{nt} > \tau_{it}$, and 0 otherwise. Hence, the share of technologies transferred to a foreign affiliate depends on three factors: (i) the difference in corporate taxation between the exporter and importer of technology, (ii) the discount $\psi$, and (iii) the transfer cost. First, when tax rates are identical, there is no incentive to engage in profit shifting and the innovator keeps ownership of the IP. Using firm-level data, several empirical papers document that differences in corporate income taxation have a positive impact on transfers of IP ownership from high-tax jurisdictions to low-tax jurisdictions (see Karkinsky and Riedel, 2012; Griffith, Miller, and O'Connell, 2014; Dischinger and Riedel, 2011). Second, if $\psi = 1$ there is no incentive to relocate IP overseas. Selling technology at a discount allows innovators in high-tax countries to increase their global post-tax profits, as profits are reallocated from high-tax countries to low-tax countries. Third, the costly technology transfer prevents corner solutions. This means that firms will not transfer 100% of their new technologies abroad. This is consistent with the observation that highly innovative countries also pay some royalties to tax havens.[13]

**The value of an innovation** Absent any profit shifting, the return to innovation would be given by the total amount of royalties paid by foreign firms. With profit shifting, the innovator receives profits domestically—from the technologies it licenses and from the IP it transfers—and profits abroad—from the licenses received by the foreign affiliates.

The value of innovation, taking into account profit-shifting motives, is given by

$$V_{nt} = (1 - \tau_{nt})\pi_{nt}^{mn} + \sum_{i \neq n}(1 - \tau_{it})\pi_{int}^{aff}. \tag{13}$$

This assumption has several policy implications. Profit-shifting practices lower the return to innovation since (i) there is a cost of transferring the IP, and (ii) there is a discount at which the IP is sold to the foreign affiliate. However, as foreign profits are taxed at a lower rate, the return to innovation increases.

Innovators choose R&D investment, $H_{nt}^r$, to maximize

$$V_{nt} - P_{nt}H_{nt}^r,$$

subject to equation (6).

**Royalty payments** Royalty payments from country $i$ to country $n$ are then given by

[13] In the model, technologies are non-rival and can be used across multiple locations. However, the Armington assumption implies that these technologies are used in the production of differentiated goods. Innovators have the option of licensing the technology themselves or establishing an affiliate in a foreign country to license the technology and enjoy lower taxes. This reflects the idea of profit-shifting serving a foreign market not with the same product, but with the same technology.

$$R_{in,t} = A_{in,t} \exp\left(-\frac{1-\psi}{\psi}\frac{\tau_{nt}-\tau_{it}}{1-\tau_{nt}}\right)\frac{\Pi_{it}}{T_{it}}. \tag{14}$$

Combining equation (14), together with the law of motion of innovation and adoption in equations (6) and (7), the model delivers a dynamic structural gravity equation for bilateral royalty payments as a function of economic fundamentals that takes the following expression:

$$R_{in,t} = \varepsilon_{in}\kappa_{nt}T_{nt}\left(\frac{H^r_{nt}}{Y_{nt}}\right)^{\beta_r}\phi_{it}\frac{\Pi_{it}}{T_{it}}\exp\left(-\frac{1-\psi}{\psi}\frac{\tau_{nt}-\tau_{it}}{1-\tau_{nt}}\right). \tag{15}$$

Royalty payments depend on: (i) R&D intensity and productivity of the technology exporter; (ii) the profitability and quality of IPR of the technology importer; (iii) country-pair characteristics capturing geography and cultural variables, as well as other barriers to exchange technology; and (iv) differences in corporate income taxation between the importer and exporter of technology.

## 3.3 Preferences

In each country $n$, a representative consumer chooses $C_{nt}$ to maximize

$$U\left(C_{nt}\right) = \log\left(C_{nt}\right) \tag{16}$$

subject to the budget constraint

$$P_{nt}C_{nt} = W_{nt}L_{nt} + \Pi^{\mathrm{T}}_{nt} + IBT_{nt} \tag{17}$$

where $W_{nt}$ is the wage, $L_{nt}$ is population, $\Pi^{\mathrm{T}}_{nt}$ are the profits of all the firms in the economy, and $IBT_{nt}$ represent tax revenues collected by the government and rebated lump-sum to the consumers.

### 3.4 Closing the Model

The model is closed with the following market clearing conditions. Output is used for consumption and innovation:

$$P_{nt}Y_{nt} = P_{nt}C_{nt} + P_{nt}H^{r}_{nt}. \tag{18}$$

Labor is used for the production of intermediate goods that are sold to the domestic and foreign market:

$$W_{nt}L_{nt} = \sum_{i=1}^{M} T_{nt}W_{nt}l_{in,t} = \sum_{i=1}^{M} A_{in,t}W_{nt}x_{in,t}d_{in} = \sum_{i=1}^{M} T_{nt}\Omega_{nt}^{\sigma-1}\left(\frac{W_{nt}d_{in}}{P_{it}}\right)^{1-\sigma} P_{it}Y_{it}. \tag{19}$$

The number of varieties being produced in each country $n$ is

$$T_{nt} = \sum_{i=1}^{M} \varepsilon_{ni}Z_{it} \tag{20}$$

From the budget constraint of the consumers,

$$P_{nt}C_{nt} = W_{nt}L_{nt} + \Pi^{T}_{nt} + IBT_{nt}. \tag{21}$$

Finally, tax revenues in country $n$ are

$$IBT_{nt} = \tau_{nt}\left(\pi^{mn}_{nt} + \sum_{i\neq n} \pi^{aff}_{ni,t}\right).$$

# 4 Empirical strategy: The structural gravity equation

The model yields a structural gravity equation of bilateral royalty payments as a function of economic fundamentals, including global taxation and the quality of IPR. This equation can be estimated with non-linear methods.

From the expression for royalty payments in equation (15), the structural gravity equation can be expressed as follows:

$$R_{in,t} = \underbrace{\varepsilon_{in}}_{\text{Country-pair FE}} \underbrace{\kappa_{nt} T_{nt} \left(\frac{H^r_{nt}}{Y_{nt}}\right)^{\beta_r}}_{\text{Exporter FE}} \underbrace{\phi_{it} \frac{\Pi_{it}}{T_{it}}}_{\text{Importer FE}} \underbrace{\exp\left(-\frac{1-\psi}{\psi} \frac{\tau_{nt}-\tau_{it}}{1-\tau_{nt}}\right)}_{\text{Profit shifting}} \tag{22}$$

Royalty payments depend on (i) time-varying characteristics of the technology exporter, such as the R&D intensity, productivity, and the quality of IP protection; (ii) time-varying characteristics of the technology importer, such as their profits and the quality of IP protection; (iii) time-invariant country-pair characteristics that capture geography and cultural variables; and (iv) time-varying differences in corporate income taxation.[14]

The structural gravity equation reveals the role of global taxation and imperfect IPR on international technology licensing. The term $\exp\left(-\frac{1-\psi}{\psi} \frac{\tau_{nt}-\tau_{it}}{1-\tau_{nt}}\right)$ captures the role of profit shifting on royalty payments. Absent any differences in corporate taxation across countries (i.e., $\tau_{nt} = \tau_{it}$) innovators keep the technology ownership and license the right to use it internationally in exchange for royalty payments. Instead, with differences in corporate taxation, innovators in high-tax countries have an incentive to transfer their technology's ownership to a low-tax country that then licenses it domestically in exchange for a royalty payments. The share of technologies that is transferred abroad increases with differences in corporate taxation. Similarly, the discount, $\psi$, at which countries transfer the technology impacts the extent of profit-shifting. By selling the technology at a discount, countries reallocate government revenues from high-tax countries to low-tax ones. Finally, the term $\chi_{it}$ captures the role of imperfect IPR on international technology licensing. Lower enforcement of IPR implies that the country imitates a larger fraction of technologies from the innovator's country. As a result, some intermediate goods in the foreign country are produced with imitated technology and the domestic innovators of those technologies are not compensated

[14] The term $\kappa_{nt}$ can be decomposed into $\kappa_n me_{nt}$ where $\kappa_n$ is part of the constant and $me_{nt}$ is part of the error term in the regression. That term will be calibrated to match data on R&D intensity exactly in the quantitative analysis.

for their efforts. I assume that the share of imitated technologies can be expressed as $\chi_{it} = \text{GP}_{it}^{\epsilon}$, where $\text{GP}_{it}$ is the quality of IP enforcement as measured by the Ginarte-Part index.

I then estimate equation (15) by regressing royalty payments on economic fundamentals using PPML methods. The results are reported in Table 1. Column 1 reports the estimated coefficients when all 50 countries are included in the estimation. Column 2 restricts attention to royalty payments among OECD countries.[15] All coefficients have the expected signs and are statistically and economically significant. The economic fundamentals from the model have a good predictive power of bilateral royalty payments—the correlation between the data and the predicted value of this regression is around 63%.

Specifically, distance has the expected sign and is statistically significant– more distant countries share less technology, with a coefficient of $-0.157$. Countries that do more innovation and are more productive tend to export more technology on average. R&D intensity and GDP per capita of the exporter have a positive and statistically significant impact on royalty payments. The elasticity of royalty payments with respect to the R&D intensity of the technology exporter is 0.57, which captures an elasticity of innovation in the model of $\beta_r = 0.57$. This value is consistent with recent estimates of these parameters in the literature (Cai, Li, and Santacreu, 2022; Kucheryavyy, Lyn, and Rodríguez-Clare, 2023). More productive destinations as measured by GDP per capita and those with better IPR quality tend to receive more royalty payments. The elasticity of the quality of the destination's IPR is 1.75, which implies that, on average, 25% of technologies have been imitated over the period of analysis. These results are robust to restricting attention to OECD countries.

Finally, countries with high corporate taxes relative to those of their partners tend to receive less royalties. The elasticity of corporate tax differences on royalty payments is negative: Increases in corporate tax differences that make the innovator country more taxing than the destination decrease the amount of royalties received by the innovator. An estimate

[15] OECD countries in the sample are: Australia, Austria, Belgium, Canada, Chile, Colombia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Lithuania, Luxembourg, Mexico, Netherlands, Norway, New Zealand, Poland, Portugal, Slovak Republic, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

of $-2$ (i.e., an elasticity of $-0.86$) translates into a discount, $\psi$, of one-third. Hence, the average country engaging in profit shifting tends to sell the technology at 33% of what its value would be if it were fully licensed. This is consistent with profit-shifting practices. We can use these estimates to compute $\lambda_{in,t}$—i.e., the fraction of newly invented technologies in $n$ that are transferred to affiliates in $i$ for a few groups of countries in the sample. Using equation (12) and data on corporate taxation, the estimation results imply that about one-third of Japan's, Germany's, and the United States' technologies are transferred to foreign affiliates as part of profit shifting. Japan and the United States each transferred about 60% of their technologies to Ireland in 2012, while France transferred about 50%.

Next, I look at two groups of countries: tax havens versus non-tax havens as technology destinations, and innovative countries that are well known for using IP to shift profits abroad versus other countries.[16] Innovative countries transfer almost 40% of their technologies to tax havens and about one-fourth to non-tax havens. The rest of the countries transfer about 13% of their technologies to tax havens and about 6% to non-tax havens. Hence, through the lens of the model, profit-shifting practices are more prevalent between innovative, high corporate-tax countries and tax havens. This result is consistent with previous findings in the literature that use differences in corporate taxation as inductive to profit-shifting through IP (Karkinsky and Riedel, 2012; Griffith, Miller, and O'Connell, 2014; Dischinger and Riedel, 2011).[17]

[16] The list of tax havens is composed of Belgium, Hong Kong, Hungary, Ireland, Luxembourg, Malta, Netherlands, Panama, Singapore, and Switzerland. The list of innovative countries more prone to profit shifting is composed of Canada, France, Germany, Japan, and United States, following the results in Tørsløv, Wier, and Zucman (2023).

[17] In the online appendix E, I estimate a reduced-form gravity equation of royalty payments on bilateral fixed effects, differences in corporate taxation, and exporter-time and importer-time fixed effects. This allows me to evaluate the importance of the model's fundamentals in capturing the dynamic patterns of international technology licensing.

Table 1: Bilateral royalty payments and economic fundamentals: This table reports PPML estimation results of the regression of bilateral royalty payments for 50 countries for the period 1996-2012 on economic fundamentals.

| | All | OECD |
|---|---|---|
| Differences in taxation | -2.009*** | -2.350*** |
| | (0.426) | (0.544) |
| log(Distance) | -0.157*** | -0.151*** |
| | (0.0225) | (0.0233) |
| log(R&D intensity exporter) | 0.567*** | 0.564*** |
| | (0.0765) | (0.0913) |
| log(GDP exporter) | 1.335*** | 1.453*** |
| | (0.0767) | (0.110) |
| log(GDP pc exporter) | 0.507*** | 0.518*** |
| | (0.0311) | (0.0462) |
| log(GDP pc importer) | 0.507*** | 0.518*** |
| | (0.0311) | (0.0462) |
| GP index importer | 1.750*** | 1.679*** |
| | (0.208) | (0.272) |
| GP index exporter | 0.272 | 0.338 |
| | (0.297) | (0.465) |
| $N$ | 42,703 | 17,570 |
| pseudo. $R^2$ | 0.63 | 0.57 |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

# 5 Quantitative Analysis

I quantify the model to study the role of profit shifting on international technology licensing. I calibrate the model to data on trade flows, R&D intensity, royalty payments, corporate income taxation, and an index measuring the quality of IP enforcement (i.e, the Ginarte-Park index) for each year in 1996-2012. I introduce two wedges in the model that allow me to fully match data on R&D intensity and bilateral royalty payments in every period. The model is solved as a sequence of static models since I am assuming full depreciation of technologies every period.[18]

I then perform two exercises to study the role of tax differences on international technology licensing and innovation. The first exercise is motivated by the Global Tax Deal negotiated at the OECD whereby more than 135 countries agreed to new rules in international taxation. The deal establishes a minimum effective corporate tax rate of 15%. The second exercise is motivated by the Tax Cuts and Jobs Act (TCJA), enacted at the end of 2017, which, among other things, introduced a tax on IP being held in foreign tax countries (GILTI), reducing the gap with foreign rates. The aim of these two policies was to reduce incentives for multinationals in high-tax countries to book profits in tax havens. Looking at US firms' profits booked in the United States versus abroad, as well as the fraction of their non-US profits booked in tax havens, Clausing (2020) and Garcia-Bernardo, Janskỳ, and Zucman (2022) find that these policies had limited impact on US profit-shifting practices. However, Garcia-Bernardo, Janskỳ, and Zucman (2022) still find that big tech corporations changed the location of their IP based on these policies. As they state in their paper, regarding an Alphabet statement in 2020, *"As of December 31, 2019, we have simplified our corporate legal entity structure and now license intellectual property from the U.S. that was previously licensed from Bermuda resulting in an increase in the portion of our income earned*

[18]This assumption is akin to assuming that profits of innovation last only for one period, as in Desmet and Rossi-Hansberg (2014). Alternatively, one could consider an scenario with partial depreciation of technologies in which innovators get profits for an infinite period of time. In this case, the functional form of the structural gravity equation (15) would only hold exactly on the balanced growth path (BGP), and we would lose the time dimension when doing the estimation.

*in the U.S."*

I study the impact of these policies on royalty payments and innovation. In particular, I ask the following question: What would R&D spending and international technology licensing have been had those policies been in place during the period of analysis?[19]

## 5.1 Calibration

I start by describing the calibration strategy for the main parameters of the model. Then, I explain how wedges are estimated to fully match data on R&D intensity and royalty payments in each year between 1996 and 2012.

**Parameter calibration** The Armington elasticity $\sigma$ is calibrated to 5, which implies a trade elasticity of 4, as is common in the trade literature (see Waugh, 2010). The parameters related to iceberg transport costs and productivity are calibrated using data on trade flows and geography, together with gravity methods. Specifically, I estimate a gravity equation of bilateral trade flows, following Waugh (2010). Finally, the parameters that govern the innovation and diffusion processes are calibrated following the empirical methodology developed in Section 4.

**Trade costs and relative productivity** Using data on bilateral trade flows, geography and GDP per capita from CEPII for the period 1996-2012 , I calibrate iceberg transport costs, $d_{in}$, and productivity, $\Omega_{nt}^{\sigma-1}T_{nt}$, by running the following reduced-form equation, derived from manipulating equation (5):

$$\left(\frac{X_{in,t}}{X_{ii,t}}\right) = \exp\left(-(\sigma-1)\sum_{p=1}^{6} d_{in,p} - (\sigma-1)B_{in} + \log(S_{nt}) - \log(S_{it}) + u_{in,t}\right),$$

[19] In Appendix F, I study the role of IPR in international technology licensing. I ask the following question: What would have been royalty payments from China to the United States if China had the same quality of enforcement as the United States?

where $X_{in,t}$ represents the expenditures by country $i$ of goods coming from country $n$, $X_{ii,t}$ is computed as the difference between GDP and absorption, and, following Eaton and Kortum (2002), $d_{in,p}$ is the contribution to trade costs of the distance between country $n$ and $i$ falling into the $p^{th}$ interval (in miles), defined as [0,350], [350, 750], [750, 1500], [1500, 3000], [3000, 6000], [6000, maximum). The other control variables are in $B_{in}$, and include common border effect, common currency effect, and regional trade agreement, between country $i$ and country $n$. From $S_{nt} = \Omega_{nt}^{\sigma-1} T_{nt} \left(\frac{\omega_{nt}}{P_{nt}}\right)^{1-\sigma}$, and using the estimated value for $S_{nt}$, data on GDP per capita, and $\sigma = 5$, I recover $\Omega_{nt}^{\sigma-1} T_{nt}$. Finally, I obtain trade costs from the following expression:

$$-(\sigma-1)\tau_{in} = -(\sigma-1)\sum_{p=1}^{6} d_{in,p} - (\sigma-1)B_{in}.$$

The correlation between the estimated relative productivity from the gravity regression, and relative GDP per capita in the data, is about 0.93 (see Figure 9); the correlation between trade shares in the data and in the model is about 0.80.

**Innovation and adoption parameters** The parameters that govern the innovation and adoption processes are calibrated following the empirical methodology developed in Section 4. First, I recover $\varepsilon_{i,n}$ from regressing the bilateral fixed effects in the reduced-form gravity equation (E.2) (see Appendix E) on the log of distance, contiguity and common language, including exporter and importer fixed effects. The remaining parameters are obtained from the regressions in Table 1. The elasticity of royalty payments with respect to differences in corporate income taxes is set to $-2$, which implies a discount of one-third of the value of patents transferred to low tax havens. The elasticity of innovation $\beta_r$ is set to 0.57. The elasticity of IPR for the importer is set to 1.75, which implies that on average one-fourth of technologies are imitated abroad.

The calibrated parameters that are common across countries are reported in Table 2.

Table 2: Calibrated parameters

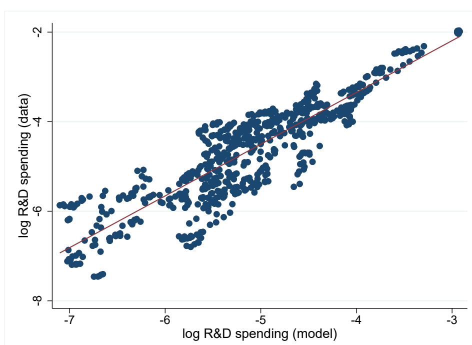
| Parameter | Value | Interpretation | Source |
|---|---|---|---|
| $\sigma$ | 5 | Armington elasticity | Waugh (2010) |
| $\frac{1-\psi}{\psi}$ | -2 | Tax differences | Table 1 |
| $\beta_r$ | 0.57 | Elasticity of innovation | Table 1 |
| $\epsilon$ | 1.75 | IP rights importer | Table 1 |

**Wedges calibration** I introduce two wedges in the model so that it fully matches data on R&D intensity and royalty payments every period. Specifically, I calibrate $\kappa_{nt}$ in equation (6) so that the variable $\frac{H^r_{nt}}{Y_{nt}}$ in the model follows the same evolution as that of observed R&D intensity. Then, I introduce a wedge $me_{nt}$ in equation (14) so that the model's variable $RP_{in,t}$ exactly fits data on bilateral royalty payments every period.

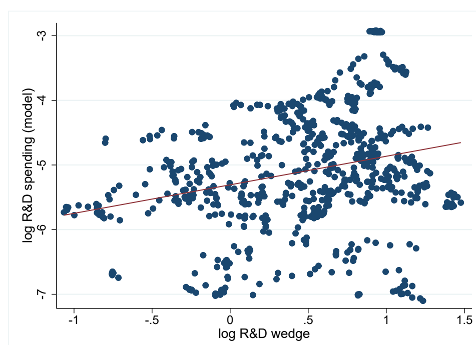
I find that R&D spending from the model explains 70% of the variation of R&D spending from the data; $\kappa_{nt}$ explains the remaining 30%. Figure 7 shows a strong correlation between R&D spending in the model (without the wedge) and in the data. Figure 7b shows that there is a slightly positive correlation between the model R&D spending and the wedge that is introduced to fully match R&D spending from the data.

Figure 7: R&D spending in the model and in the data

(a) R&D spending: Model vs Data




(b) R&D spending: Model vs Wedges

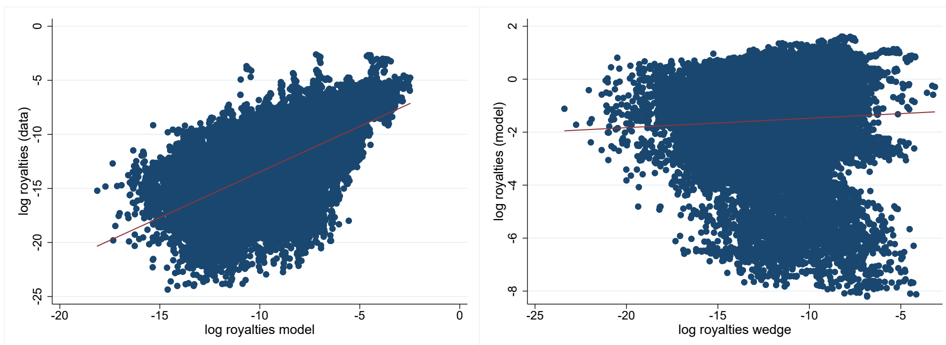



**Notes:** The figure shows the correlation between R&D intensity in the data and two variables: (i) R&D in the model, representing R&D intensity without factoring in the wedge (left panel), and (ii) the wedges estimated from the model (right panel).

Next, I obtain a value for the wedge $me_{in,t}$ that exactly matches royalty payments from the data. I find that the model (i.e., royalty payments without including the wedge) explains around 60% of the variation of royalty payments (consistent with the 63% in Table 1). Figure 8a shows a strong correlation between royalty payments in the data and in the model. Moreover, the royalty wedge and the royalty payments explained by the model (without wedges) are uncorrelated (see Figure 8b).

Figure 8: Royalties in the model and in the data

(a) Model (without wedge) vs Data (b) Model (without wedge) vs Wedge




**Notes:** The figure shows the correlation between royalty payments in the model—, representing royalty payments without factoring in the wedge—and two variables: (i) royalty payments in the data (left panel), and (ii) the wedges estimated from the model (right panel).

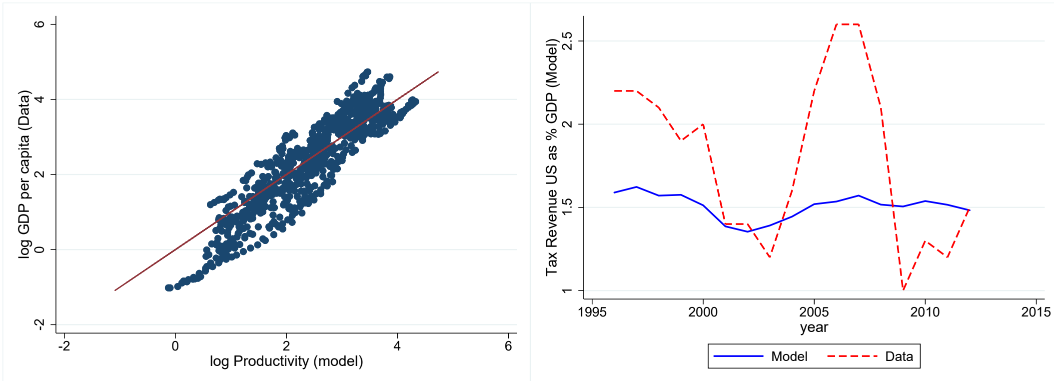
**Corporate Tax Revenues** The model can also capture the cyclicality of corporate tax revenues in the data for the United States. Corporate tax revenues in the model are computed as:

$$IBT_{nt} = \tau_{nt}(\pi_{nt}^{mn} + \sum_{i \neq n} \pi_{ni,t}^{aff})$$

Figure 9 shows that corporate tax revenues in the model track well those in the data. The correlation is about 0.70. However, tax revenues are 6 times smoother in the model than in the data.

Figure 9: Validation: GDP per capita and corporate tax revenues

(a) Productivity (corr.=0.93) (b) Corporate tax revenues (corr.=0.70)




## 5.2 Policy Analysis: Understanding the role of tax differences

I conduct two exercises to evaluate the role of tax differences on international technology licensing and innovation. Throughout the exercises, I vary some of the parameters of the model while keeping the rest, as well as the wedges fixed to their baseline values.

### 5.2.1 Tax on foreign profits

This exercise aims to analyze the role of tax havens by addressing the question: How much would R&D intensity and royalty payments have been if foreign profits were taxed at the domestic rate, eliminating the incentive for profit shifting? The experiment is motivated by a recent reform of international taxation proposed by the OECD, which applies a minimum 15 percent tax rate to multinationals by 2023.[20] Essentially, this reform eliminates incentives for multinational corporations to shift profits from high-tax countries to low-tax ones.

The exercise I implement in this section differs slightly from that in the global minimum tax reform, but I maintain the principle of removing profit-shifting incentives. Specifically, I set corporate taxes on foreign profits at the same level as corporate taxes on domestic profits while keeping all other parameters and wedges the same. In this way, profit shifting

[20]For more information on this policy, see: `https://www.oecd.org/tax/beps/oecd-releases-pillar-two-model-rules-for-domestic-implementation-of-15-percent-global-minimum-tax.htm`.

is eliminated. From equation (12), instead of transferring ownership of the technology, the innovator keeps it and receives royalties. The purpose of this policy is to prevent companies in high-tax countries from selling their technology abroad and instead license it outright. Then, I analyze the effect of this policy change on R&D investment, royalty payments, and corporate tax revenue received by the government.

There are several effects of the reform on R&D investment. To see them, we can express the value of an innovation as follows:

$$
\begin{aligned}
V_{nt} = (1-\tau_{nt}) \Big( & A_{nnt} rp_{nn,t} + \textstyle\sum_{i \neq n} A_{in,t} \left[ (1-\lambda_{in,t}) rp_{in,t} + \lambda_{in,t} \psi rp_{int,} - C(\lambda_{in,t}) TR_{in,t} \right] \Big) \\
& + (1-\tau_{it}) \left( A_{in,t} \psi_{it} \left[ (1-\lambda_{in,t})(\Pi_{it} - rp_{in,t}) + \lambda_{in,t}(rp_{ii,t} - \psi rp_{in,t}) \right] \right)
\end{aligned}
\tag{23}
$$

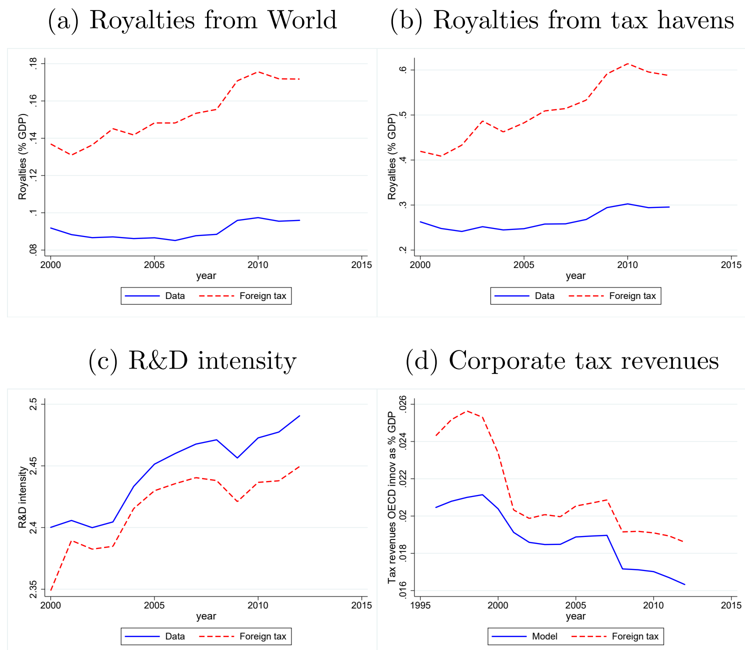
First, when foreign profits are taxed at the domestic rate, innovators receive more royalties from foreign firms since $\lambda_{in,t} = 0$ (see equation 12). Prior to the reform, those royalties were retained abroad through the transfer of technology ownership, while domestic innovators received a transfer price at a discount $\psi$ ($\lambda_{in,t}\psi rp_{int,}$ in equation 23). Second, when corporate taxes are the same, innovators do not have to pay for the transfer of technology ($C(\lambda_{in,t})TR_{in,t}$). Both of these effects boost the value of a domestic innovator. However, the reform has a negative effect on R&D investment since the additional royalties innovators receive are taxed at a higher rate, thus lowering the value of innovation through a higher $\tau_{it}$. When firms can use foreign profits to finance domestic R&D—i.e., when foreign profits are included in innovation value—the negative effect dominates. Foreign profits benefited from lower tariffs before increasing global profits for innovators. The inability to transfer technology and benefit from such lower tariffs on foreign profits decreases an innovator's value, which leads to a decrease in R&D investment.

Figure 10 shows these results for OECD innovative countries that are more prone to engaging in profit-shifting practices (i.e., Germany, Japan, United States, Canada, and France). I examine the period after 2001; Guvenen et al. (2022) document that profit shifting was not a significant factor in the United States until the late 1990s when both income on U.S. foreign direct investment and profit shifting accelerated. The solid line captures the evolution of key variables in the baseline model. The dashed line captures the evolution of those variables if there were a tax on foreign profits that removes profit-shifting incentives.

We observe that additional taxes on foreign profits increase royalty payments toward OECD innovative countries that engaged in more profit-shifting. By removing profit-shifting incentives, innovators retain the technology ownership and receive royalties instead. Figure 10 shows the results for royalty payments from the world and from tax havens to countries that do more profit shifting (panels a and b, respectively). Absent differences in corporate tax rates, innovative countries would have received more royalty payments, especially from tax havens (on average, 91.5 percent higher than in the baseline). Royalty payments from non-tax havens would have been 35 percent higher, as profit-shifting to these countries is less prevalent. Despite more royalty payments, innovators invest less in R&D as the additional royalties are now taxed at a higher rate.

The reform has effects on other groups of countries as well. In the case of tax havens, R&D intensity would have been lower, especially in the most recent years. Tax havens lose the externality effect on R&D investment of owning more technologies domestically. As technologies are instead owned by the innovator, they cannot free-ride on other's innovative efforts, which hampers their own innovation. The negative effect on R&D intensity, however, is much smaller than in OECD innovative countries that are more prone to profit-shifting (i.e., 0.12 percent lower). Other countries would have remained virtually unchanged, with a slight increase in R&D intensity at the end of the sample. One could interpret the results in R&D intensity as suggestive that R&D in high-tax countries was artificially high because innovators in those countries were engaging in profit-shifting practices that increased their value of an innovation (as they could use foreign profits to finance domestic R&D). By removing that distortion, R&D reallocates according to comparative advantage forces in innovation (i.e., from innovative countries engaging in profit shifting to other innovative

Figure 10: Policy Reform: Tax on foreign profits (Baseline vs Counterfactual in countries that do more profit shifting)

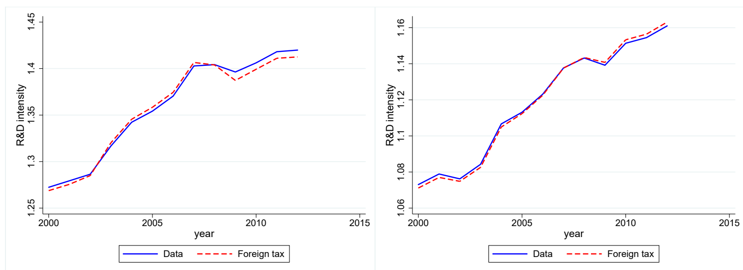



**Notes:** The figure shows the evolution of key economic variables in the data and in the counterfactual in which foreign profits are taxed at the domestic corporate rate, for the period 2001-2012 for countries more prone to profit-shifting (United States, Germany, France, Canada, and Japan).

countries where profit-shifting practices are less prevalent). Finally, tax revenues would have been 12% higher in innovative countries engaging in profit shifting, as the government receives revenue generated with technology that was previously kept abroad.

Figure 11: R&D intensity: Data vs. tax on foreign profits (2001-2012)

(a) Tax havens (b) Others




**Notes:** The figure shows R&D intensity in the data and when foreign profits are taxed at the domestic corporate rate, for the period 2001-2012 and for two groups of counties: tax havens, and countries that are neither tax havens nor OECD innovative countries engaging in profit shifting.

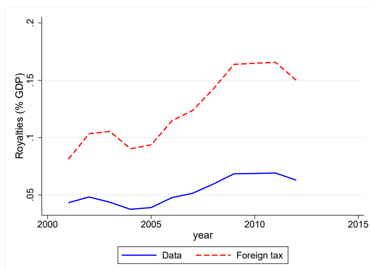
In Figure 12, I focus on the United States. Specifically, the figure shows royalty payments between the United States (exporter of technology) and four OECD tax havens (Ireland, Switzerland, Netherlands, and Singapore). If profit-shifting had not occurred from 2000-2001, the United States would have received higher royalty payments from these countries because the intellectual property would have remained in the US.

Finally, Table 3 shows the results for changes in welfare (computed as changes in consumption), R&D intensity, tax revenues, royalties received, and royalties paid, between the baseline and the case when there is no profit shifting.[21] In OECD innovative countries, differences in consumption would have been more pronounced. Despite experiencing a greater decline in R&D intensity, these countries would have benefited from higher welfare, as measured by consumption. This is because the static model measures welfare by consumption in each period, without considering the negative impact of lower R&D on future output. The increase in consumption is attributed to higher royalty payments and increased tax rebates

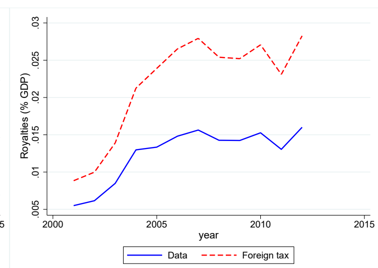
[21] Appendix G shows the same results for all the individual countries in the sample.

Figure 12: Royalty payments to the United States from several tax havens: Data vs. tax on foreign profits (2001-2012)

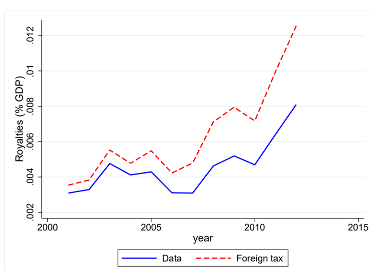
(a) Ireland



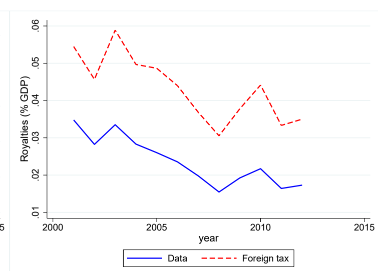

(b) Switzerland




(c) Netherlands




(d) Singapore




**Notes:** The figure shows Royalty payments to the United States from four tax havens (Ireland, Switzerland, Netherlands, and Singapore) in the data and when foreign profits are taxed at the domestic corporate rate for the period 2001-2012.

to consumers. However, the additional royalty payments are subject to higher tax rates, which is why R&D intensity decreases more in these countries.

Table 3: Tax on foreign profits: Country-group analysis

| Group | Welfare | R&D | Revenues | Royalties received | Royalties paid |
|---|---|---|---|---|---|
| OECD innov | 0.026 | -0.50 | 3.29 | 20.91 | 7.51 |
| OECD noninnov | -0.020 | -0.14 | -1.62 | 13.56 | 17.93 |
| TH | 0.0039 | -0.21 | -2.03 | 9.65 | 23.66 |
| ROW | 0.015 | -0.17 | -3.80 | 11.03 | 13.21 |

**Notes:** The table reports the results from the counterfactual on key variables of interest. It displays the average difference between the baseline and the counterfactual (no profit shifting) values, over the period of analysis.

### 5.2.2 GILTI

The next exercise is reminiscent of the US 2017 TCJA, which included a tax on IP held abroad by multinational corporations with US headquarters. The tax, also known as GILTI, reduced the gap with foreign rates. To implement that reform in my setup, I tax foreign profits from US affiliates abroad at the US corporate tax rate. All other tax rates remain the same. Thus, while the United States has eliminated incentives for profit shifting, other high-tax countries remain unchanged. The results are shown in Figures 13.

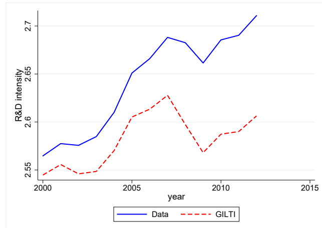
Similarly to the previous reform, R&D intensity in the United States would have been lower than in the baseline, despite higher royalty payments. The reason is that the additional profits are taxed at a higher rate. As before, royalty payments to the United States would have been higher, especially from tax havens. Corporate tax revenues as a percentage of GDP would have been 7% higher.

The results presented in the quantitative exercises show that levying taxes on foreign profits would have a detrimental effect on innovation, even though innovators receive more royalties, which is in line with Dyrda et al. (2022)'s findings.

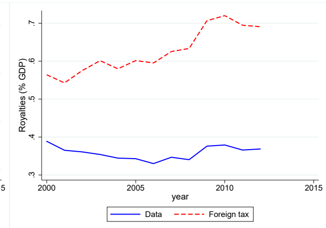
While these policy reforms always have a positive effect on royalty payments toward innovative high-tax countries, the results on R&D investment are contingent upon certain

Figure 13: R&D intensity in the United States: Data vs. GILTI (2001-2012)

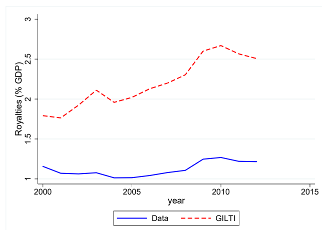
(a) R&D intensity



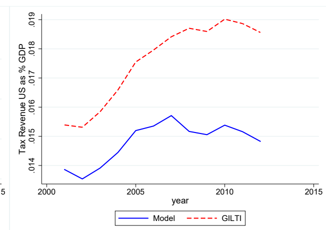

(b) Royalties from World




(c) Royalties from tax havens




(d) Tax Revenues




**Notes:** The figure shows the evolution of key economic variables in the data and in the GILTI counterfactual in which foreign profits are taxed at the US corporate rate for the period 2001-2012 and for the United States

assumptions regarding how multinationals can employ their foreign profits. If firms are unable to employ foreign profits to finance local innovation, R&D could rise under the reform, as innovators receive more royalties from overseas. In reality, multinationals can channel these foreign profits into local investments but not within the company. Lastly, if multinational corporations utilize foreign profits to distribute dividends among shareholders, R&D investment may not be impacted significantly.

Next, I consider the case where the firm chooses $\lambda_{in,t}$ to maximize global profits as in equation (10), but innovators can use only domestic profits when doing R&D, so that

$$V_{nt} = (1 - \tau_{nt})\pi_{nt}^{mn} + \mu \sum_{i \neq n} (1 - \tau_{it})\pi_{int}^{aff}$$

with $\mu \in (0, 1)$. The parameter $\mu$ captures the share of foreign profits that innovators can use to finance domestic investment into R&D. If $\mu = 1$, innovators can use all foreign profits to finance domestic innovation. If $\mu = 0$, innovators can only use domestic profits to finance internal innovation. In practice, in order to use foreign profits for domestic purposes, a firm must repatriate them and pay any residual U.S. taxes, which would imply that $\mu = 0$. However, innovators can use part of their profits abroad through inter-firm loans to finance their R&D, so $\mu \leq 1$.

Finally, I compare R&D nvestment in high-tax innovative countries under the baseline and when foreign profits are taxed at the domestic rate, both when innovators can use all foreign profits (earlier case) and when they can use only 75% of foreign profits.[22] I find that eliminating profit-shifting motives when innovators could use foreign profits would imply higher innovation intensity as innovators get access to new royalties that they were not able to use before. Hence, despite those royalties being taxed at a higher rate, R&D intensity goes up. The same holds under GILTI for the United States.

# 6 Concluding Remarks

This paper has identified, through the lens of a multi-country general equilibrium model of innovation and international adoption, the main economic fundamentals of international technology licensing, with special focus on the impact of differences in corporate taxation across countries. The paper has used royalty payments as a novel and more direct measure of technology transfer that is available for a large sample of countries over time. An empirical analysis shows that the model's fundamentals have a good predictive power of international technology licensing. A counterfactual analysis sheds light on the role of corporate tax differences on R&D and international technology licensing. As such, there are interesting policy implications to be inferred from the results.

The analysis has identified several important channels that would be relevant to the model explicitly in a quantitative framework analyzing international technology licensing. Specifically, there is potential for future research to extend the model to include patenting

[22] To do this exercise, I recalibrate the model by setting $\mu = 0.75$ in equation 13.

decisions of innovators in the presence of imperfect IP rights enforcement. Additionally, a more formal analysis of optimal tax policy to mitigate profit-shifting incentives could be explored. I leave these extensions for future research.

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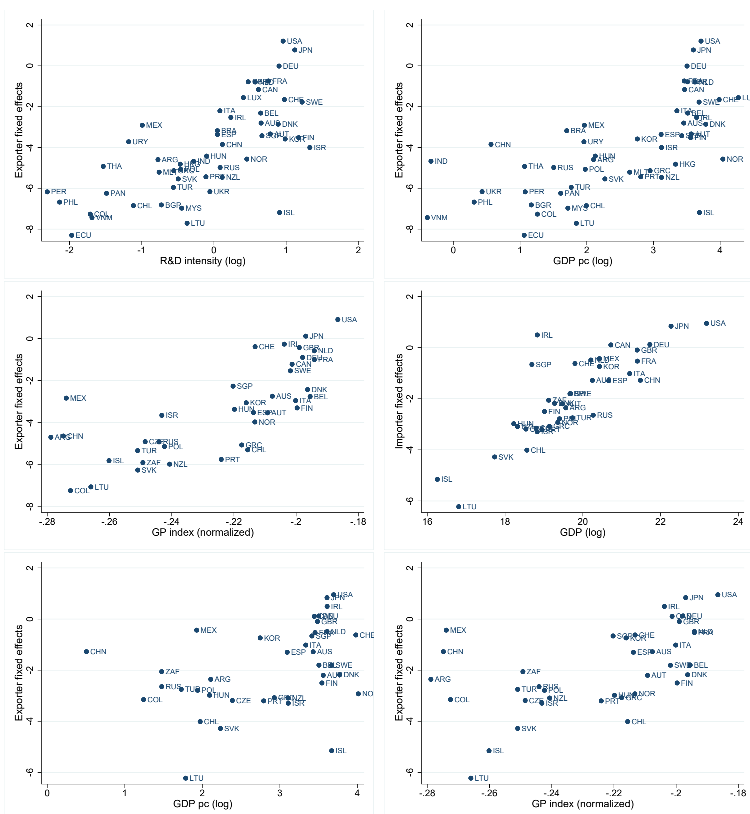
# APPENDIX

## A Additional Figures

Figure A.1 reproduces the graphs in Figure E.1, averaging across time for each country. The results are consistent with the model. For instance, the United States and Japan are the main technology exporters (i.e, have the largest average exporter fixed effects), and they also have the largest R&D spending and productivity. The United States, Japan, and Ireland are the main technology importers (i.e, have the largest average importer fixed effects). The United States and Japan have the lowest remoteness index and the largest GDP. Ireland is an outlier in that, despite not being among the most profitable countries based on its remoteness index and GDP, it is one of the main recipients of foreign technology. The next section explores this point further.

Figure A.1: Gravity fixed effects and the model's economic fundamentals



# B Groups of countries used in Section 2

Table B.1: Country groups

| Tax Havens | OECD innovative | OECD non innovative |
|---|---|---|
| Antigua and Barbuda | Australia | Chile |
| Belgium | Austria | Colombia |
| Bahrain | Belgium | Costa Rica |
| Bahamas | Canada | Czechia |
| Belize | Switzerland | Estonia |
| Bermuda | Germany | Greece |
| Barbados | Denmark | Hungary |
| Switzerland | Spain | Iceland |
| Cyprus | Finland | Italy |
| Grenada | France | Lithuania |
| Hong Kong | United Kingdom | Latvia |
| Ireland | Ireland | Mexico |
| Lebanon | Israel | Poland |
| Luxembourg | Japan | Portugal |
| Macao | Republic of Korea | Slovakia |
| Malta | Luxembourg | Slovenia |
| Mauritius | Netherlands | Turkey |
| Netherlands | Norway | |
| Panama | New Zealand | |
| Singapore | Sweden | |
| Seychelles | United States of America | |
| Vanuatu | | |
| Samoa | | |

**Notes:** The table reports the list of countries used in Section 2. Countries are classified as innovative OECD if their average GDP per capita over the sample period is above the cross-country OECD average during that period. Tax havens are classified as in Tørsløv, Wier, and Zucman (2023).

# C Data

**Royalties data** Total trade in services and IP services: OECD, Trade in Services Balanced Panel EBOPS 2012.

**Trade Gravity Data** Collected from CEPII Gravity and contain bilateral dummy variables (such as common language, colonial relationship, etc) and other bilateral country-specific variables (such as GDP, area, weighted distance, etc).

http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=8

**Trade Data** Reported by CEPII's BACI dataset by year in the HS6-92 level of industry aggregation. Data are reported as thousands of USD.

http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=37

**Research and Development Spending Data** Collected from the World Bank's World Development Indicators dataset. They are reported as an annual percentage of GDP for each country. Data downloaded for each year and country in the sample.

https://databank.worldbank.org/source/world-development-indicators/preview/on

**Patent applications** WIPO patent database for total patents applied, by applicants' origin, for each country by year.

https://www3.wipo.int/ipstats/index.htm?tab=patent

**Ginarte-Park index** Collected from:

http://fs2.american.edu/wgp/www/res_policy08.pdf

**Value added by industry** Data reported by UNIDO INDSTAT 2 2020 by year and by industry aggregated at ISIC rev.3 for Manufacturing industries. Data are reported in current prices of USD in exact units value.

https://stat.unido.org/

**Patent data by industry** USPTO's PTMT database. Data are reported at the three-digit NAICS level.

https://www.uspto.gov/web/offices/ac/ido/oeip/taf/naics/naics_stc_wgall/naics_stc_wg.htm

**Royalty payments by affiliation** US Trade, Services, by Affiliation (current prices, millions, US$) from the BEA for 2007-2012.

https://apps.bea.gov/iTable/bp_download_modern.cfm?pid=4

**GDP Deflator** World Bank for 1996-2012

https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS

Table C.1: Country list

| Country Name | ISO-code | Country Name | ISO-code |
|---|---|---|---|
| Argentina | ARG | Luxembourg | LUX |
| Australia | AUS | Malaysia | MYS |
| Austria | AUT | Malta | MLT |
| Belgium | BEL | Mexico | MEX |
| Brazil | BRA | N. Zealand | NZL |
| Bulgaria | BGR | Netherlands | NLD |
| Canada | CAN | Norway | NOR |
| Chile | CHL | Panama | PAN |
| China | CHN | Peru | PER |
| Colombia | COL | Philippines | PHL |
| Denmark | DNK | Poland | POL |
| Ecuador | ECU | Portugal | PRT |
| Finland | FIN | Russia | RUS |
| France | FRA | Singapore | SGP |
| Germany | DEU | Slovak Republic | SVK |
| Greece | GRC | Spain | ESP |
| Hong Kong | HKG | Sweden | SWE |
| Hungary | HUN | Switzerland | CHE |
| India | IND | Thailand | THA |
| Ireland | IRL | Turkey | TUR |
| Israel | ISR | United Kingdom | GBR |
| Italy | ITA | United States | USA |
| Japan | JPN | Ukraine | UKR |
| South Korea | KOR | Uruguay | URY |
| Lithuania | LTU | Vietnam | VNM |

# D Equations to solve the model

Guess wages and $T$:

Resource constraint

$$P_{nt}Y_{nt} = P_{nt}C_{nt} + P_{nt}H^{r}_{nt}$$

Prices

$$P_{nt} = \left(\sum_{i=1}^{M} \Omega_{it}^{\sigma-1} T_{it} \left(\bar{m} W_{nt} d_{in}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

Trade share

$$\frac{X_{ni,t}}{\sum_{n=1}^{M} X_{ni,t}} = \frac{\Omega_{nt}^{\sigma-1} T_{nt} \left(W_{nt} d_{in}\right)^{1-\sigma}}{\sum_{k=1}^{M} \Omega_{kt}^{\sigma-1} T_{kt} \left(W_{kt} d_{ik}\right)^{1-\sigma}}$$

Labor market clearing condition

$$W_{nt}L_{nt} = \sum_{i=1}^{M} \pi_{in,t} P_{it} Y_{it} \bar{m}^{-1}$$

Profits intermediate good producers

$$\Pi_{nt} = \frac{1}{\sigma} W_{nt} L_{n}$$

Profits multinational headquarters

$$\pi_{nt}^{mn} = \left(A_{nnt} - \sum_{i \neq n} A_{in,t}\lambda_{in,t}\right) rp_{nn,t} - \sum_{i \neq n} A_{in,t}\lambda_{in,t} \left(\frac{\Pi_{nt}}{T_{nt}} - rp_{ni,t}\right)$$
$$+ \sum_{i \neq n} A_{in,t} \left[(1-\lambda_{in,t}) rp_{in,t} + \ \lambda_{in,t} TR_{in,t} - C(\lambda_{in,t}) TR_{in,t}\right]$$

Profits affiliates

$$\pi_{int}^{aff} = A_{in,t}\phi_{it}\left[(1-\lambda_{in,t})(\Pi_{it}/T_{it} - rp_{in,t}) + \lambda_{in,t}(rp_{ii,t} - TR_{in,t}) + \lambda_{in,t} rp_{ni,t}\right]$$

Global profits

$$\Pi_{nt}^{\text{global}} = (1-\tau_{nt})\pi_{nt}^{mn} + \sum_{i \neq n}(1-\tau_{it})\pi_{in,t}^{aff}$$

Transfer price

$$TR_{in,t} = \psi \frac{\Pi_{it}}{T_{it}}$$

Cost of technology ownership transfer

$$C(\lambda_{in,t}) = \lambda_{in,t} + (1-\lambda_{in,t})\log(1-\lambda_{in,t})$$

Probability of transferring technology ownership

$$\lambda_{in,t} = 1 - \exp\left(-\frac{1-\psi}{\psi}\frac{\tau_n - \tau_i}{1-\tau_n}\right)$$

Value innovation

$$V_{nt} = (1-\tau_{nt})\pi_{nt}^{mn} + \mu \sum_{i \neq n}(1-\tau_{it})\pi_{int}^{aff}$$

FOC innovation

$$H_{nt}^{r} = \beta_r \frac{V_{nt}}{P_{nt}}$$

Law of motion of innovation

$$Z_{nt} = \kappa_{nt} T_{nt}\left(\frac{H_{nt}^{r}}{Y_{nt}}\right)^{\beta_r}$$

Royalties

$$rp_{in,t} = \frac{\Pi_{it}}{T_{it}}$$

Law of motion of adoption

$$A_{in,t} = \varepsilon_{in}\phi_{it}Z_{nt}$$

Trade balance equation: Update wages

$$\sum_{i\neq n}^{M} \Omega_{it}^{\sigma-1}T_{it}p_{ni,t}x_{ni,t} = \sum_{i\neq n}^{M} T_{nt}\Omega_{nt}^{\sigma-1}p_{in,t}x_{in,t} + \sum_{i=1}^{M} RP_{in,t} - \sum_{i=1}^{M} RP_{ni,t}$$

Total number of adopted technologies: Update T as the solution to a fixed point problem

$$T_{nt} = \sum_{i=1}^{M} \varepsilon_{ni}Z_{it}$$

Tariff revenue

$$IBT_{nt} = \tau_{nt}\left(\pi_{nt}^{mn} + \sum_{i\neq n} \pi_{ni,t}^{aff}\right)$$

# E Reduced-form gravity equation

I estimate a reduced-form gravity equation of royalty payments as a function of country-time fixed effects and time-invariant bilateral fixed effects using PPML methods as in Silva and Tenreyro (2006), Zylkin (2018), Correia, Guimarães, and Zylkin (2019) or Larch et al. (2019). We can express equation (15) in logs as a function of fixed effects to illustrate its gravity-type structure. The fixed effects have a one-to-one correspondence with the model's economic fundamentals.

$$\log(RP_{in,t}) = \tau_{in,t} + S_{nt} + F_{it} + d_{in} + u_{in,t}, \tag{E.1}$$

where $\tau_{in,t} = -\frac{1-\psi}{\psi}\frac{\tau_{nt}-\tau_{it}}{1-\tau_{nt}}$; $S_{nt} = \log\left(\kappa_{nt}T_{nt}\left(\frac{H^r_{nt}}{Y_{nt}}\right)^{\beta_r}\right)$ and $F_{it} = \log\left(\frac{\Pi_{it}}{T_{it}}\right)$; $d_{in} = \log\left(\bar{\varepsilon}_{in}\right)$; and $u_{in,t}$ is a residual.

To evaluate the importance of the model's fundamentals in capturing the dynamic patterns of international technology licensing, I first estimate royalty payments as a function of country-time fixed effects and time-invariant bilateral fixed effects using PPML methods as in Silva and Tenreyro (2006), Zylkin (2018), Correia, Guimarães, and Zylkin (2019) or Larch et al. (2019). This allows me to recover the fixed effects that have one-to-one correspondence with the variables from equation (15).[23] The regression includes a time-varying bilateral variable that captures differences in taxation across countries. That is,

$$RP_{in,t} = \exp\left[\xi \log\left(\frac{\tau_{nt}}{\tau_{it}}\right) + S_{nt} + F_{it} + d_{in} + u_{in,t}\right] \tag{E.2}$$

where $u_{ni,t}$ is a residual. The results are reported in Table E.1

Table E.1: Three-way fixed effects

| | Royalties |
|---|---|
| $\frac{\tau_{nt}-\tau_{it}}{1-\tau_{nt}}$ | -5.478*** |
| | (0.756) |
| $N$ | 42,672 |
| pseudo $R^2$ | 0.983 |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

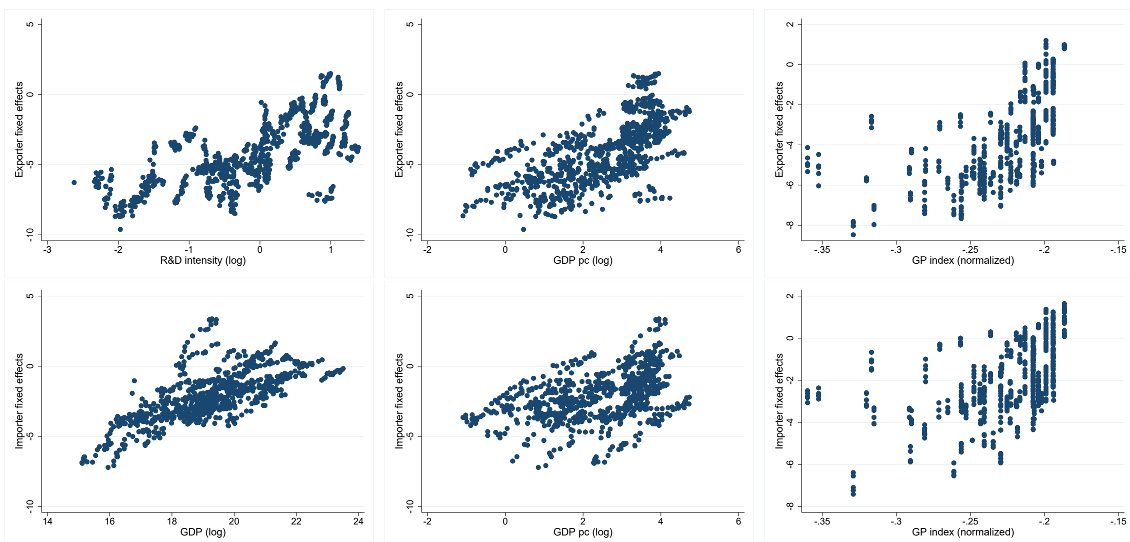
**Notes:** The table reports results from estimating with PPML methods equation (E.2) using data on bilateral royalty payments between 1996 and 2012. The regressors include differences in corporate income taxes between exporter and importer, exporter-time, importer-time, and time-invariant country-pair fixed effects.

The coefficient on taxation differences is negative and statistically significant, which suggests that countries with high corporate income taxes relative to those of their trading partners tend to receive less royalty payments. This is consistent with the discussion that firms in high-tax countries have an incentive to shift their IP's ownership to tax havens

[23] I use the Stata command ppmlhdfe (Correia, Guimarães, and Zylkin, 2019).

and hence pay royalties, instead of receiving them, even after controlling for exporter-time and importer-time fixed effects. The estimated fixed effects can be used to evaluate how well the model's fundamentals in equation (15) can capture the dynamic patterns of royalty payments from the data. In particular, from $S_{nt} = \log\left(\kappa_{nt} T_{nt}\left(\frac{H^r_{nt}}{Y_{nt}}\right)^{\beta_r}\right)$, the exporter-time fixed effects depend on the R&D intensity, $\frac{H^r_{nt}}{Y_{nt}}$ and the GDP per capita, $T_{nt}$.[24] From $F_{it} = \log\left(\phi_{it}\frac{\Pi_{it}}{T_{it}}\right)$, the importer-time fixed effects depend on the quality of IP rights, $\phi_{it}$, and the profits per intermediate producer (or firm), which can be approximated by the GDP per capita of the country.

Figure E.1: Gravity fixed effects and model's economic fundamentals




**Notes:** The figure shows correlations between exporter-time fixed effects and exporter's R&D spending, productivity and quality of IP rights enforcement; and between importer-time fixed effects and importer's GDP per capita and quality of IP rights enforcement. Each dot represents a country-year observation.

Figure E.1 plots correlations between the exporter-time and importer-time fixed effects from the gravity regression and the main model's economic fundamentals. Each dot of the

[24] As is shown in Eaton and Kortum (1999), $T_{nt}$ is a function of the GDP per capita of the country raised to a function of the trade elasticity. In that model:

$$Y_{nt}/L_{nt} = T_{nt}^{1/\theta}$$

.

figure represents a country-year.[25] The top two panels show a clear positive relationship between the exporter-time fixed effects and both the exporter's R&D spending (top-left panel) and its GDP per capita (top-right panel). Highly innovative and highly productive countries are more likely to send technology abroad and hence receive more royalty payments. The middle two panels show that countries with better-quality IPR (left panel) and larger countries (right panel) tend to export more technology and receive more royalties. The bottom two panels are also consistent with the model. Larger countries (left panel) and countries with better IPR enforcement (right panel) are more likely to receive foreign technology.

# F The role of IPR enforcement

Next, I analyze the role of IPR enforcement on royalty payments by addressing the following question: Between 1996 and 2012, how much would China have paid in royalties if its IPR had been the same as the United States' during that period? Specifically, I simulate the model by setting the index of IP rights enforcement in China to have the same value every year as that from the United States while keeping all the remaining parameters and wedges fixed. I then compute the change in royalty payments between the baseline and the counterfactual. I find that, on average, China's royalty payments to OECD innovative countries would have been 52% higher (63% higher to the United States). Most of the action happened before China joined the WTO in 2001. Moreover, the countries that would have benefited the most from better IPR enforcement in China would have been its main trading partners: South Korea, Hong Kong, Vietnam, Philippines, Malaysia, and Thailand would have experienced the largest increases in royalty payments. Among innovative countries, Singapore and the United States would have benefited the most. By improving domestic IPR, China also started doing more R&D investment, which increased by 63%. Its main trading partners also benefit from increases in R&D investment, as they start receiving more royalties (South Korea, Hong Kong, Vietnam, Malaysia, and Philippines). In terms of

[25] Appendix A.1 reproduced the same graphs averaging across years.

welfare, China would have experienced an increase in consumption of 23%, whereas in the United States, consumption would have been 17% higher. South Korea would have been the country with the higher gains, 52%.

Higher royalty payments from China could be interpreted in two ways. First, better IPR increase technology transfer to China. Innovators invest more in R&D when their efforts get compensated and are willing to send more technology abroad if the probability of imitation is lower. Second, better IPR imply that China imitates less and licenses more; thus, it starts paying royalties for technology that it was previously getting for free. An increase in royalty payments that reflects more technology transfer would be advantageous for China since technology diffusion has been shown to be a source of economic growth in developing countries. Instead, an increase in royalty payments that reflect higher prices of adoption would be disadvantageous, as Chinese adopters would be paying more for the same amount of technology. It is difficult to disentangle the two effects in the data. However, since the model is set up so that the quality of IPR impacts the probability of adoption (instead of the royalty fee) the increase in royalty payments from the counterfactual analysis may reflect mainly an increase in technology transfer.

One limitation of this exercise is that an important part of technology misappropriation in China happens through "forced technology transfer" by which foreign firms wanting to do business in China are required to form a joint venture with a local firm and transfer their technology at no cost. These transactions are not reflected in royalty payments, because the Chinese firm receiving the technology does not need to pay a fee. Holmes, McGrattan, and Prescott (2015) develop a quantitative model where they study the effect of these quid-pro-quo practices on innovation and welfare. In their model, innovators can choose the intensity at which intangible capital is deployed in each country. That would be equivalent in my model to choosing how many technologies are licensed abroad, which may depend on the probability of imitation. For instance, one could extend the model to introduce the decision to patent the innovation and license only those technologies. Patenting will depend on the probability of imitation and other fundamental variables of the destination country, as in Eaton and Kortum (1999).

# G Additional Tables

Table G.1: Tax on Foreign Profits: Country-specific key variable changes

| Country | Welfare | R&D | Revenues | Roy received | Roy paid |
|---|---|---|---|---|---|
| ARG | -0.04 | -0.14 | -1.41 | 22.20 | 4.41 |
| AUS | -0.04 | -0.04 | -1.46 | 13.03 | 6.57 |
| AUT | -0.07 | -0.10 | 4.30 | 9.43 | 9.90 |
| BEL | 0.10 | -0.66 | 24.51 | 29.11 | 1.60 |
| BGR | -0.08 | 0.13 | 0.44 | 3.85 | 41.09 |
| BRA | -0.03 | 0.04 | 0.59 | 18.76 | 9.26 |
| CAN | -0.17 | 0.52 | -0.24 | 31.47 | 2.48 |
| CHE | -0.33 | 0.65 | 4.38 | 2.76 | 26.46 |
| CHL | -0.10 | 0.25 | -6.18 | 0.47 | 56.74 |
| CHN | -0.07 | -0.02 | 2.22 | 11.06 | 8.27 |
| COL | -0.08 | 0.05 | 22.03 | 20.64 | 3.46 |
| DEU | 0.51 | -3.44 | -3.17 | 68.59 | 0.80 |
| DNK | -0.07 | 0.08 | -0.90 | 7.50 | 11.14 |
| ECU | -0.13 | 0.24 | 2.18 | 9.49 | 17.65 |
| ESP | -0.03 | -0.22 | -2.04 | 17.20 | 4.11 |
| FIN | -0.08 | 0.11 | 7.32 | 5.44 | 15.93 |
| FRA | 0.09 | -0.76 | -11.29 | 27.01 | 1.99 |
| GBR | -0.12 | 0.04 | 2.14 | 8.25 | 10.71 |
| GRC | -0.05 | -0.07 | 1.42 | 15.06 | 8.46 |
| HKG | -0.10 | 0.18 | 11.62 | 0.32 | 55.51 |
| HUN | -0.15 | 0.29 | -2.52 | 0.76 | 48.52 |
| IND | 0.00 | -0.26 | -6.60 | 24.48 | 2.50 |
| IRL | -0.93 | 2.14 | -5.88 | 3.68 | 48.07 |
| ISR | 0.04 | -0.11 | 0.77 | 14.44 | 6.19 |
| ITA | 0.05 | -0.92 | -0.86 | 41.79 | 1.29 |
| JPN | 0.47 | -2.23 | -4.94 | 58.33 | -0.03 |
| KOR | -0.10 | 0.07 | 5.95 | 6.49 | 12.84 |
| LTU | 0.31 | -0.71 | -2.62 | 1.01 | 37.31 |
| LUX | 1.42 | -3.41 | -11.12 | 12.65 | 4.89 |
| MEX | -0.09 | 0.18 | -7.41 | 13.45 | 6.11 |
| MLT | 0.05 | -0.85 | -0.53 | 22.65 | 3.18 |
| MYS | -0.02 | -0.15 | -1.03 | 5.30 | 15.40 |
| NLD | 0.00 | -0.23 | 4.92 | 11.59 | 7.45 |
| NOR | -0.08 | 0.05 | -0.88 | 6.83 | 14.80 |
| NZL | -0.01 | -0.13 | 0.55 | 13.39 | 6.36 |
| PAN | 0.31 | -0.81 | -8.11 | 11.11 | 8.39 |
| PER | -0.09 | 0.12 | 4.87 | 9.78 | 10.74 |
| PHL | -0.04 | -0.28 | -3.29 | 15.57 | 5.62 |
| POL | -0.07 | 0.06 | -24.12 | 6.33 | 22.28 |
| PRT | -0.07 | -0.01 | -17.05 | 13.81 | 7.03 |
| RUS | -0.08 | 0.01 | 0.26 | 6.63 | 17.17 |
| SGP | -0.33 | 0.57 | 3.63 | 1.82 | 32.49 |
| SVK | -0.07 | -0.08 | -0.46 | 8.68 | 22.56 |
| SWE | -0.12 | 0.07 | 0.65 | 6.04 | 15.40 |
| THA | -0.05 | 0.04 | 2.99 | 9.13 | 10.90 |
| TUR | -0.04 | -0.15 | -10.05 | 14.41 | 14.06 |
| UKR | -0.06 | 0.06 | -7.54 | 5.07 | 15.75 |
| URY | 0.93 | -2.16 | -1.32 | 6.26 | 11.08 |
| USA | 0.21 | -1.93 | -1.67 | 41.10 | 0.98 |
| VNM | -0.03 | -0.05 | -0.14 | 6.80 | 15.15 |

# H The Case of Ireland

American multinationals license IP to Irish subsidiaries and give them rights to license that technology to other developed countries. Through the double Irish mechanism, the affiliate in Ireland can then book those profits in an affiliate located in a Caribbean country and pay zero corporate taxes. This results in Ireland paying more royalties abroad than it receives, with the United States being the primary recipient of Irish royalty outflows.

However, recent policy changes, such as the dissolution of the "double Irish" in 2019, have led to a shift in the trend of royalty payments from Ireland to tax havens. This change has been documented in a recent report, which outlines that large outbound royalty payments are made from Ireland as license fees for IP developed elsewhere.[26] The report also documents a geographical shift in the destination of outbound royalty payments from Ireland in 2020, away from tax havens. These changes have been motivated by recent policy changes, such as modifications to the OECD Transfer Pricing Guidelines, changes to corporate residency rules in Ireland, and the impact of the 2017 Tax Cuts and Jobs Act in the United States. Analyzing the determinants of bilateral royalty payments and the role of global taxation is thus challenging for the Irish case, due to its role as an intermediary for profit-shifting rather than a final destination like other tax havens. Tax evasion practices can take various forms and may involve multiple jurisdictions, making it difficult to generalize about the behavior of tax havens.

Furthermore, the unique and complex tax regime of Ireland, particularly with the use of tax avoidance techniques like the "double Irish" and the "double Irish with a Dutch sandwich," makes it challenging to capture bilateral royalty payments as a function of differences in tax rates in that country. While bilateral analysis can provide insights into the factors affecting royalty payments between two countries, it may not fully capture the complexity and nuances of tax avoidance practices and their impact on royalty payments.

[26] https://www.gov.ie/en/publication/fbe28-the-changing-nature-of-outbound-royalties-from-ireland-and-their-impact-on-the-taxation-of-the-profits-of-us-multinationals-may-2021/.