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 41 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: (i) imperfect intellectual property protection and (ii) tax havens. The gravity equation is estimated using nonlinear methods. The model's fundamentals account for 56% of the variation in royalty payments. Counterfactual analysis sheds light on the role of intellectual property rights and tax havens on international technology licensing.

Keywords: Technology Diffusion; Royalty Payments; Intellectual Property Rights

JEL Classification: F12, O33, O41, O47

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1 Introduction

Throughout the last few decades, intangibles have become increasingly important in international trade. Trade in intellectual property (IP), as measured by international technology licensing, has increased by a factor of 3 between 1995 and 2012; in contrast, trade in merchandise has done so by a factor of 1.3. Trade in intangibles is an important source of technology diffusion, innovation, and economic growth. However, the lack of comprehensive data on intangibles has challenged the empirical and theoretical work, which has been mainly focused on studying of trade in goods.

In this paper, I investigate the determinants of international technology licensing. Technology licenses are agreements by which a patent's owner sells the rights to use IP, and the know-how to exercise those rights to another party. There are several advantages to exploring technology licensing data. First, despite accounting for a small fraction of total trade, technology licensing is used heavily in critical sectors of the economy, such as computers and electronics, pharmaceuticals, and transportation. These are also the most innovation-intensive industries (see Robbins, 2009). Second, technology licensing captures a more direct way by which firms transfer know-how 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). Third, technology licensing involves a market transaction and it is easier to measure than other channels of technology diffusion that are not internalized.

While recent theoretical papers point at technology licensing as a source of innovation and growth (Benhabib, Perla, and Tonetti, 2017; Monge-Naranjo, 2019), the empirical work on their main determinants is still limited, being focused on just one country or a small set of countries (See Yang and Maskus, 2001; Branstetter, Fisman, and Foley, 2006). In this paper, I provide an exhaustive longitudinal analysis of international technology licensing, using new data for bilateral royalty payments for 41 countries from 1996 to 2012. The data are recorded in the balance of payments of a country as a trade in services and include both intra-firm and arm's length transactions.[1]

I begin by describing the main patterns of technology licensing across countries and over time, as well as its connections to innovation, IP rights, and tax havens. First, the data show

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

that exports of technology are concentrated in a few countries. Innovative countries such as the United States, Japan, and Germany are net exporters of technology. Second, countries that are closer geographically tend to share more technology and engage in more bilateral royalty payments. Third, tax havens have increased their dominance as either net exporters (the Netherlands) or net importers (Ireland, Singapore, and Switzerland) of technology, especially after the 2000s. Indeed, multinationals in high income taxes countries have an tendency to use technology licensing to shift profits around the world in order to avoid paying corporate taxes. Finally, large countries which have improved their IP enforcement over time have become an important destination of technology of developed countries.

I then address the following questions: What factors can explain the patterns of international technology licensing documented in the data? And, what is the role of IP rights and tax havens? To address these questions, I set up an Armington trade model of innovation and international technology licensing. Innovators choose their research effort to create new ideas; the efficiency of innovation depends on the quality of IP rights in that country. A fraction of ideas is adopted by a firm to produce a new intermediate good. The fraction of adopted ideas depends on exogenous forces that capture the quality of IP rights of the destination and the role of tax havens through differences in taxation between the countries. Adopters pay royalties to innovators for the right to use their technology; royalty payments are modeled as a share of the adopter's profits each period.

The model yields a dynamic structural gravity equation of royalty payments as a function of economic fundamentals.[2] In particular, bilateral royalty payments depend on: (i) the exporter's R&D intensity, productivity, and IP rights protection; (ii) the importer's size, productivity, and IP rights protection; (iii) time-varying differences in taxation across countries; and (iv) a bilateral parameter that reflects geography and cultural reasons for technology transfer.

I estimate the structural gravity equation in two ways. First, 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). The fixed effects have a one-to-one correspondence with the model's economic fundamentals. Second, I regress

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

royalty payments directly on economic fundamentals using PPML methods.[3]

The results from the regression analysis show that: (i) countries that do more innovation and have a better quality of IP rights enforcement tend to export, on average, more technology; (iii) larger countries, and those with better IP rights enforcement tends to import, on average, more technology; (iii) country pairs that are close to each other geographically or share a common language share more technology; and (iv) countries with high corporate income taxes relative to those of their trading partners tend to receive fewer royalty payments, which is consistent with firms in high tax countries shifting their IP's ownership to tax havens. Model fundamentals have a strong predictive power of bilateral royalty payments-the correlation between the data and the predicted value of the regression is around 56%.

To better understand the impact of tax havens and IP rights on international technology licensing, I conduct two counterfactual exercises. Specifically, I ask the following questions: (i) how much larger would international technology licensing have been if China's IP rights enforcement had been as strong as those in the United States? (ii) how did differences in corporate income taxation impact technology licensing between the United States and tax havens? The model is calibrated using data on innovation, royalty payments, geography, and trade flows, as well as data on corporate income taxes and an index capturing the quality of IP rights. I assume full depreciation of technologies, so that the model can be solved as a sequence of static models, as in Anderson, Larch, and Yotov (2015).[4] Two wedges are introduced to fully match data on bilateral royalties and R&D intensity in every period between 1996 and 2012. The counterfactual exercises consist on varying the quality of IP reforms and tax rates, respectively, while keeping the wedges constant.

I find that, if China's IP rights had been identical to that of the United States, royalty payments from China to the world would have been, on average, 36% higher. Restricting the analysis to royalty payments from China to the main technology leaders—i.e, the United States, Germany, Japan, and South Korea—, I find that royalty payments from China would have been 27.8%, 14%, 67.5%, and 74.2% higher, respectively. Higher royalty payments from China to the world are the result of two forces. First, better IP rights imply more technology transfer to China, as innovators invest more in R&D when their efforts get compensated.

[3]See Head and Mayer (2014) for a survey of techniques to estimate and interpret gravity equations.

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

This would be beneficial for China since technology transfer is an important source of economic growth, generating positive spillovers in the local economy and increasing innovation incentives in China. Second, better IP rights in China leads to less imitation and higher royalty payments. This would be the downside to improving IP rights, since Chinese adopters are now paying more for technology they were previously given for free.

Finally, by removing differences in corporate income taxes across countries, I find that royalty payments from the United States to Ireland would have been, on average, 8% lower. A feature of profit-shifting practices is that multinationals in the United States may be transferring the property of their IP to affiliates in Ireland in order to benefit from lower taxes. This practice would result in the US firm, which is where innovation took place originally, paying royalties to the Irish affiliate. The counterfactual exercise shows that, by removing tax differences, the United States would be paying fewer royalties.

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 modeled trade as the vehicle of diffusion in the context of general equilibrium models of international trade (see Santacreu, 2015; Aghion and Jaravel, 2015; Buera and Oberfield, 2019; Perla, Tonetti, and Waugh, 2015). 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 IP rights 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 (2017) 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, by 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 lies at the intersection of technology diffusion through market and non-market channels. In the model I set up, technology is both non-rival and partially excludable. It is non-rival in that ideas can diffuse freely through non-market channels to increase the stock of knowledge abroad. It is partially excludable in that the innovator receives royalty payments for those ideas that have been adopted to produce an intermediate good by a foreign firm. Excludable technologies are transferred internationally through market channels. 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. Interestingly, Monge-Naranjo (2019) finds that openness allows developing countries to completely close the gap with the technology frontier only when market transactions dominate the externalities. His findings reinforce the importance of analyzing technology licensing as a vehicle of international technology transfer. Arque-Castells and Spulber (2019) 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 IP rights 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., 2017; Bruner, Rassier, and Ruhl, 2018). 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 and documents salient features of the data on international technology licensing.[5] The data, which is reported on the OECD Balanced Trade in Services dataset (EBOPS) as bilateral royalty and license fees, is available for over 100 countries and the period 1995-2012. It is recorded in the balance of payments of a country as a trade in services and includes: (i) charges for the use of proprietary 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, 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 suggests that almost 80% of these payments were composed by the outcome of research and development and software,

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

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. I restrict the analysis to a sample of 41 countries, for which there are also available data on innovation, corporate income taxation, and measures of quality of IP rights protection for the period of analysis. There is a total of 25,308 observations, corresponding to 1,408 trading partners and 18 years.[6] There are 1,282 zeros in the data (i.e., 5% of the observations).

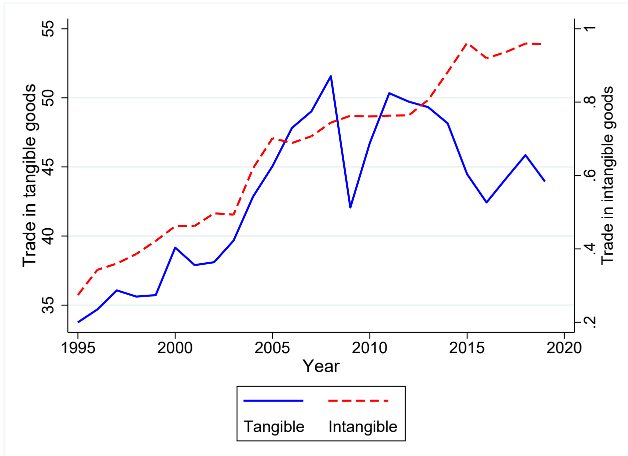
Next, I document several cross-country and dynamic patterns of the data. First, international technology licensing, which is a type of trade in intangibles, behaves differently than merchandise trade. Figure 1 shows that world royalty payments and receipts have increased at a faster pace than trade in merchandise goods, especially during the period after the Great Recession.[7] 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 it is the case for other types of trade in services, technology licensing was less affected by the trade collapse during the Great Recession than trade in goods was. Moreover, while trade in merchandise decelerate after the Great Recession, trade in intangibles kept increasing continuously.

Second, while exports of IP are concentrated in a few countries, several economies have become net exporters of technology during the period of analysis. Throughout the paper, the exporter of technology is the country sending technology, hence receiving royalty payments; the technology importer is the country licensing the technology, hence making royalty payments. In 1996, the net exporters to the world were Switzerland, the United States, the Netherlands, Denmark, and the United Kingdom; in 2012, Sweden, Israel, Japan, France, and Germany joined this group. The Netherlands had the largest surplus (as a % GDP) in 2012 (2.35%), followed by Sweden (0.54%), the United States (0.35%), Israel (0.13%), and Japan (0.12%). Switzerland, instead, went from being a net exporter to being a net importer. Hence, despite the dominance of a few countries as net exporters of technology, several others have positioned themselves closer to the frontier. Figure 2 shows three large countries that became net exporters of IP between 1996 and 2012—France, Germany, and

[6] The list of countries is reported in Appendix B.

[7] 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:
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.

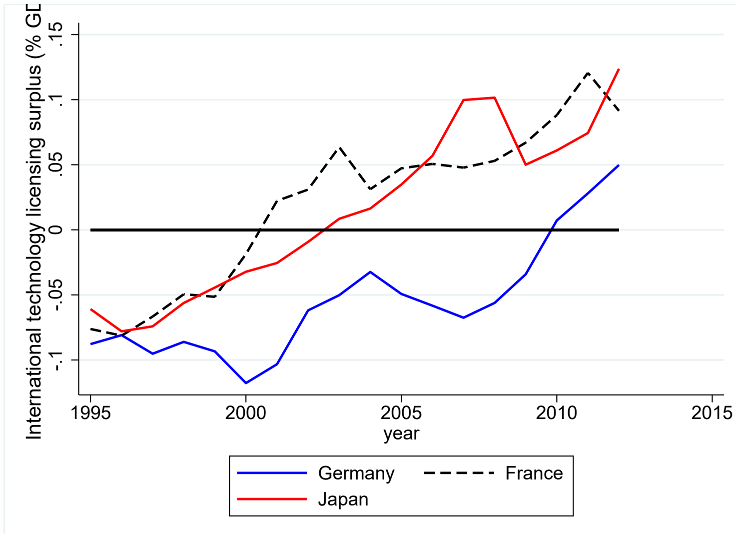


Japan. They are also innovative countries that invest a large fraction of their GDP into R&D and that are patenting at a high pace.

The United States and the Netherlands have maintained their position as net exporters of IP (see Figure 3). However, while US net exports, as a % of GDP, have remained stable over time, the Netherlands has experienced a dramatic increase. It is not surprising that the United States produces and sends more technology abroad, being one of the most innovative countries in the sample. In the case of the Netherlands, however, there may be additional reasons that explain these dynamics. For instance, the Netherlands is considered a tax haven, with special tax regime and a large presence of multinational activity. As Bruner, Rassier, and Ruhl (2018) have argued, multinational corporations in high tax countries are prone to transferring their IP's ownership to low tax countries in order to shift profits abroad and avoid paying taxes. In those cases, they start receiving royalty payments from abroad, showing up in the royalty data as large exporters of technology. This could be the case with the Netherlands and other tax havens. Thus, that countries receive a large amount of royalty payments from abroad could either mean that they are innovating and licensing IP internationally or that they are profitable destinations for multinational corporations to transfer their IP's ownership.

Net technology importers are also concentrated in a few countries (see Figure 4). In 2012, Ireland was, by far, the country with the largest deficit of technology, as a % of

Figure 2: New Net Exporters of Technology:
The figure plots net exports of technology for countries that have switched from net importers to net exporters during the period 1995 to 2012 (i.e., Germany, France and Japan)



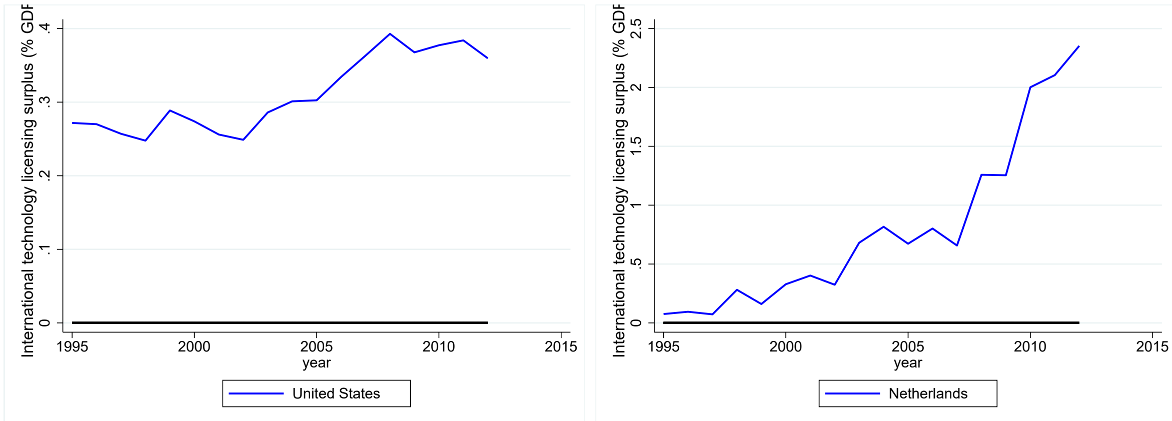
GDP (-11.5%), followed by Singapore (-4%), South Korea (-0.5%), and Canada (-0.45%). Moreover, Ireland has increased its dominance as a net importer, widening its technology deficit. Similar to the Netherlands' case, Ireland and Singapore have special tax regimes and are considered tax-havens. These trends have been more prevalent since the early 2000s and they have been the center of a current debate on profit-shifting through IP movements. Table 1 reports statistics for trade imbalances of IP (as a % of GDP).

Table 1: Summary statistics: Net exports (% GDP)

Variable	Obs	Mean	Std. Dev.	Min	Max	Median
Net exports (% GDP)	41	-0.46	1.99	-11.45	2.35	-0.18

Finally, in terms of bilateral relations in 2012, the main destinations of technology from the United States were Ireland, followed by Japan, Switzerland, and Canada. The main emerging country where the US exports its IP was, by far, China, followed by Mexico. In the case of technology exports from Japan, the main destinations were the United States, China, and the United Kingdom. Ireland exchanges a lot of IP with the United States, the Netherlands, and the United Kingdom; whereas South Korea does so with China, Japan, and the United States. These results suggest that; (i) there is a distance effect on international technology licensing: Countries that are closer geographically share more IP (Japan and

Figure 3: Net exporters of technology:
The figure plots net exports of technology for the United States and the Netherlands during the period 1995 to 2012

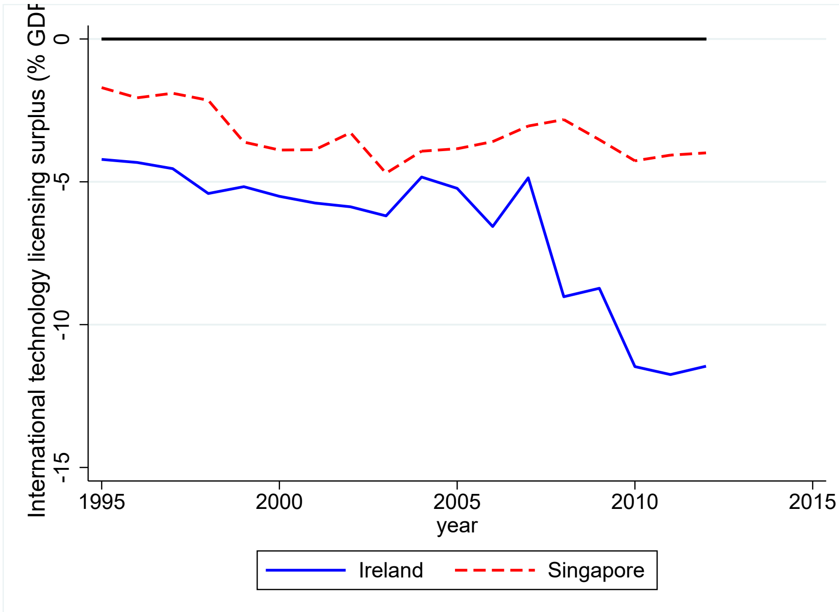


China; the United States, Mexico and Canada; South Korea and China,...); and (ii) there is a large amount of technology licensing that involves tax-havens. I elaborate more on this point next.

The role of tax havens The fact that tax havens are among the largest net suppliers or net receivers of IP is a prevalent feature of the data. A current debate between academics and policymakers discusses the role of international movements of IP to avoid paying corporate income taxes See Zucman (2014). In particular, it has been argued that multinational companies use transfer-pricing through royalty payments to shift profits abroad and avoid paying taxes (see Guvenen et al., 2017; Bruner, Rassier, and Ruhl, 2018). Countries with special tax regimes and a large presence of multinational activity tend to be more prone to engage in these practices, as these payments occur between affiliates of multinational corporations. Being able to disentangle how much of royalty payments involving tax havens happen in intra-firm transactions rather than at arm's length can shed light on the extent to which multinationals operating in tax havens are engaging in these practices.

Bilateral data that decompose royalty payments between affiliated and unaffiliated transactions are not available for many countries and over time. However, the BEA publishes these data for the United States as either the origin or the destination of these payments. That is, with those data we can measure the number of royalties paid by the United States to Ireland or by the Netherlands to the United States, but we cannot measure royalties paid from Ireland to the Netherlands. The data are reported in the International Transactions,

Figure 4: Net importers of IP:
The figure plots net imports of technology for Ireland and Singapore during the period 1995 to 2012



International Services, and International Investment Position tables of the BEA under the title "Charges for the use of intellectual property."[8] They are disaggregated into affiliated and unaffiliated transactions and are available between 2006 and 2012 for the United States—both as a sender and as a recipient of technology—with respect to the other countries in the sample.[9]

Between 2006 and 2012, 40% of all royalty payments received by the United States proceeded from unaffiliated parties. However, these numbers vary substantially across technology-importing countries. In the case of Ireland, less than 2% of royalty payments to the United States proceeded from unaffiliated firms. In Switzerland, this ratio was also low, while in South Korea it was about 80%, and in China, it was about 50%. Hence, the fact that a large share of royalty payments between the United States and tax havens involve affiliated transactions suggests that profit-shifting motives may be explaining international technology

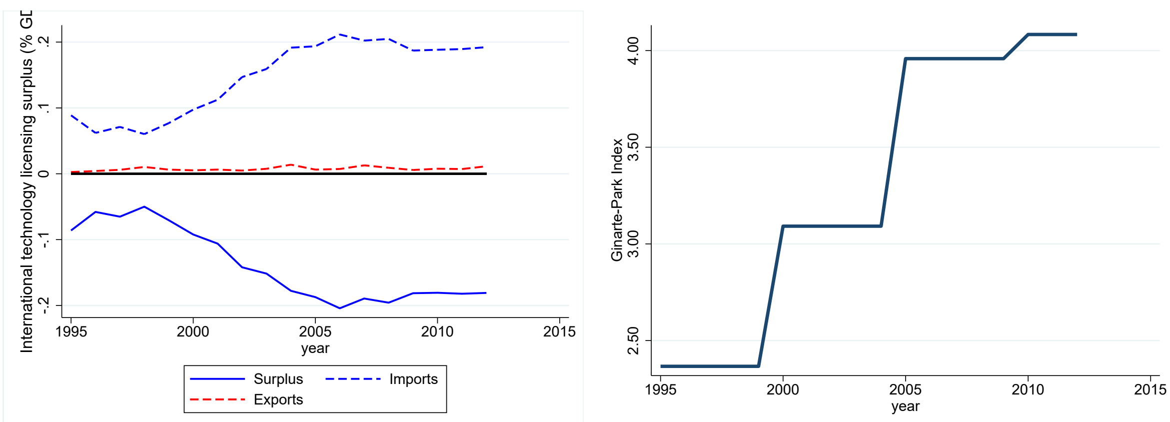
[8] See `https://apps.bea.gov/itable/itable.cfm?reqid=62&step=1`. Table 2.2 in that link contains information on trade in services by type of service and by country or affiliation between 2006 and 2012.

[9] The partner countries are Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Chile, China, Colombia, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malaysia, Malta, Mexico, the Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Romania, Russia, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Kingdom, and Vietnam.

licensing in those cases.

The role of IP protection Finally, restricting attention to developing countries, China has become the main destination of international technology licensing, especially from the United States and Japan. After joining the World Trade Organization (WTO) in 2001, China improved its IP rights substantially, according to the Ginarte-Park index (see Ginarte and Park, 1997)) In general, we observe that developing countries that have improved their IP rights protection, have also experienced a faster increase in international technology. This could reflect that either (i) they are receiving more technology from abroad, or (ii) they are paying higher prices fro technology they were previously receiving fro free.

Figure 5: The rise of China as technology recipient:
The figure plots the evolution of exports, imports and net exports of technology for China between 1995 and 2012 (left panel), and the evolution of the Ginarte-Park index for China between 1995 and 2012 (right panel)



The rest of the paper develops a methodology to investigate the main determinants of international technology licensing, with emphasis on the role of tax havens 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 with endogenous productivity through innovation and adoption. There are M countries indexed by i and n, and time is discrete and indexed by t. Innovators invest resources to introduce new technologies, of which a fraction is licensed to foreign adopters. The model allows for imperfect enforcement of IP rights and differences in taxation to affect this fraction. Adopters then produce a traded intermediate good and pay royalties to innovators for the use of their technology. The model yields a dynamic structural gravity equation of royalty payments as a function of economic fundamentals.

3.1 Preferences

In each country n, a representative consumer chooses C_{nt} to maximize life-time utility

$$\sum_{t=0}^{\infty} \beta^t \log\left(C_{nt}\right) \tag{1}$$

subject to the budget constraint

$$P_{nt}C_{nt} = W_{nt}L_{nt} + \Pi^{\text{all}} \tag{2}$$

where β is the discount factor, W_{nt} is the wage, L_{nt} is population, and Π^{all}_{nt} are the profits of all the firms in the economy.

3.2 Final Production

In each country n, a perfectly competitive final producer demands intermediate inputs to produce a non-traded good according to a CES production function

$$Y_{nt} = \left(\sum_{i=1}^{M} \int_{j=1}^{T_{it}} x_{ni,t}(j)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{3}$$

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

$$x_{ni,t}(j) = \left(\frac{p_{ni,t}(j)}{P_{nt}} \right)^{-\sigma} Y_{n,t} \tag{4}$$

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

$$y_{nt}(j) = \Omega_n l_{nt}(j) \tag{5}$$

where $y_{nt}(j)$ is the amount of intermediate good j produced at time t, Ω_n 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

$$\pi_{nt}(j) = \sum_{i=1}^{M} p_{in,t}(j) x_{in,t}(j) - W_{nt} l_{nt}(j) \tag{6}$$

subject to equation (4).

International trade Intermediate products are traded internationally. Trade is costly and there are 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, $y_{nt}(j) = \sum_{i=1}^{M} x_{in,t}(j) d_{in}$.

The import share is given by

$$\pi_{ni,t} = \frac{X_{ni,t}}{\sum_{n=1}^{M} X_{ni,t}} = \frac{\Omega_i^{\sigma-1} T_{it} \left(W_{it} d_{ni}\right)^{1-\sigma}}{\sum_{m=1}^{M} \Omega_m^{\sigma-1} T_{mt} \left(W_{mt} d_{nm}\right)^{1-\sigma}} \tag{7}$$

In this model, T_{nt} evolves over time through endogenous innovation and exogenous adoption.

3.3 Innovation and Adoption

The number of technologies available for intermediate production, T_{nt}, evolves through innovation and adoption. Here I describe in the detail these two processes.

Innovation In each country n a monopolist invests final output into R&D, H_{nt}^r, to produce a new prototype or technology. Technologies arrive at a Poisson process given by

$$\Lambda_{nt} \left(\frac{H_{nt}^r}{Y_{nt}}\right)^{\beta_r} \tag{8}$$

where Λ_{nt} represents the innovation efficiency, and takes the following functional form: $\Lambda_{nt} = \lambda_n u_{nt}(\chi_{nt})^{\lambda} T_{nt}$, where λ_n is a country-specific parameter reflecting innovation policy, $(\chi_{nt})^{\lambda}$ captures the role of the country's IP rights enforcement, T_{nt} is the stock of knowledge available in country n at time t, and β_r represents diminishing returns to adding one extra unit of final output into the innovation process.

The stock of technologies innovated in each period is given by the following law of motion

$$Z_{n,t+1} = \lambda_n(\chi_{nt})^{\lambda} T_{nt} \left(\frac{H^r_{nt}}{Y_{nt}}\right)^{\beta_r} + Z_{n,t}(1-\delta) \tag{9}$$

With δ the depreciation rate. I assume that there is full depreciation, that is, $\delta = 1$, as in Anderson, Larch, and Yotov (2015).

Innovators have the monopoly over the technology, which they license to foreign adopters to produce an intermediate good. The value of an innovation is given by V_{nt}, to be defined later. The innovator chooses H^r_{nt} to maximize:

$$Z_{nt}V_{nt} - P_{nt}H^r_{nt} \tag{10}$$

Technology Adoption A fraction of technologies developed in country n is adopted by firms in country $i$to produce an intermediate good. I assume that the foreign adopter can adopt only a fraction $\varepsilon_{in,t}$ of the technologies innovated each period, whereas the domestic adopter adopts all of them every period.

The evolution of the number of technologies adopted by country i from country n in each period is given by the following law of motion

$$A_{in,t+1} = \varepsilon_{in,t}Z_{nt} + A_{in,t}(1-\delta) \tag{11}$$

with $\delta = 1$. I assume that the fraction of adopted technologies takes the following expression:

$$\varepsilon_{in,t} = \bar{\varepsilon}_{in} \left(\frac{\tau_{it}}{\tau_{nt}}\right)^{\xi} (\chi_{it})^{\epsilon} \tag{12}$$

where $\bar{\varepsilon}_{in}$ is a time-invariant capturing geography, or cultural variables; the term $\left(\frac{\tau_{it}}{\tau_{nt}}\right)^{\xi}$ captures the role of tax havens through differences in corporate income taxes between the two countries; and the term χ_{it} captures the quality of IP rights enforcement of the destination.

Royalty payments Adopters use the foreign technology to produce an intermediate good, make profits and pay royalties to the innovators. I assume that royalties are paid as a fraction, χ_{in}, of profits made by using the foreign technology in every period. Royalty payments from country i to country n are given by

$$RP_{in,t} = \chi_{in} \frac{A_{in,t}}{T_{it}} \Pi_{it} \tag{13}$$

where $\frac{A_{in,t}}{T_{it}}$ is the share of technologies used by country i that have been developed by country n and Π_{it} are profits from selling the good domestically and abroad.

Optimal investment into innovation Innovators in country n receive royalty payments every period from country i's adopters. Summing across each country i, the value of an innovation V_{nt} is given by

$$V_{nt} = \sum_{i=1}^{M} \bar{\varepsilon}_{in} \left(\frac{\tau_{it}}{\tau_{nt}} \right)^{\xi} \lambda_n \chi_{nt}^{\gamma} T_{nt} \left(\frac{H_{nt}^{r}}{Y_{nt}} \right)^{\beta_r} \bar{\chi}_{in} (\chi_{it})^{\epsilon} \frac{\Pi_{it}}{T_{it}}$$

The first order condition for innovation investment is

$$P_{nt} H_{nt}^{r} = \beta_r Z_{nt} V_{nt} \tag{14}$$

3.4 Market Clearing Conditions

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

$$P_{nt} Y_{nt} = P_{nt} C_{nt} + P_{nt} H_{nt}^{r} \tag{15}$$

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

$$W_{nt} L_{nt} = \sum_{i=1}^{M} T_{nt} W_{nt} l_{in,t} = \sum_{i=1}^{M} A_{in,t} W_{nt} x_{in,t} d_{in} = \sum_{i=1}^{M} T_{nt} \left(\frac{W_{nt} d_{in}}{P_{it}} \right)^{1-\sigma} P_{it} Y_{it} \tag{16}$$

From the budget constraint of the consumers

$$P_{nt}C_{nt} = W_{nt}L_{nt} + \Pi_{nt} + Z_{nt}V_{nt} - P_{nt}H^r_{nt} \tag{17}$$

Combining with equation (15), we have:

$$P_{nt}Y_{nt} = \frac{\sigma}{\sigma-1}W_{nt}L_{nt} + Z_{nt}V_{nt} = \frac{\sigma}{\sigma-1}W_{nt}L_{nt} + \frac{1}{\beta_r}P_{nt}H^r_{nt} \tag{18}$$

4 The Structural Gravity Equation

Combining equation 13, together with the law of motion of innovation and adoption, and the assumption of full depreciation of technologies, the model delivers a dynamic structural gravity equation for bilateral royalty payments as a function of economic fundamentals that takes the following expression:

$$RP_{in,t} = \bar{\varepsilon}_{in}\left(\frac{\tau_{it}}{\tau_{nt}}\right)^{\xi}\lambda_n\chi^{\gamma}_{nt}T_{nt}\left(\frac{H^r_{nt}}{Y_{nt}}\right)^{\beta_r}\chi_{in}(\chi_{it})^{\epsilon}\frac{\Pi_{it}}{T_{it}} \tag{19}$$

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. Term $\chi_{in,t}$ represents the royalty fee, and will be taken as a residual.

Despite its limitations, there are several advantages to assuming full depreciation of technologies: (i) the model can be solved as a sequence of static models; (ii) the growth part of the model has a closed-form solution, and (iii) the model delivers an intuitive dynamic structural gravity equation that can be estimated taking advantage of the time-series dimension of the data. 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 partial depreciation on technologies and that innovators get profits for an infinite period of time, as in Santacreu (2022). In this case, the functional form of the structural gravity equation (19) would only hold exactly on the balanced growth path (BGP), and we would lose the time dimension when doing the estimation.

How do tax havens and IPR impact bilateral royalty payments? The term $\left(\frac{\tau_{it}}{\tau_{nt}}\right)^{\xi}$ represents differences in corporate income taxation, and are introduced to capture the role of tax havens. If there were no differences in corporate taxation, the country developing a technology would keep the IP and license the right to use it to other countries in exchange for royalty payments. However, the presence of tax havens gives incentives to inventors in high income tax countries to transfer their IP's ownership to a low income country that then licenses the IP to the high income country in exchange for royalties. Hence, absent any differences in corporate taxation, the inventor country would be receiving more royalty payments form abroad. Instead, if corporate taxes in the inventor country are very high, that country will be paying royalties to countries with low corporate taxation if IP is moved international for profit-shifting motives.

The term χ_{it} captures the quality of IP rights enforcement of the destination. Lower enforcement of IP rights implies that the country receives less technology transfer and pays less royalties. The term χ_{jt} captures the IP rights enforcement of the innovator. Better IP rights enforcement translates into more R&D and more receipts in royalties, everything else constant. Note that the way I have modeled the role IPR in the model is by assuming they affect the fraction of adopted technologies. An alternative would be to have them affecting the royalty fee. In that case, the interpretation would be different. The assumption that it affects the share of adopted technologies is meant to capture that innovators may be reluctant to license technology to countries that are likely to copy or imitate it (hence, less technologies will be transferred to those countries, and less royalties will be received by the innovators). If, instead, it affects the royalty fee, countries with low IP rights enforcement would receive technology but would not pay what is has been negotiated. That would show up in the share of profits being paid out as royalties: Adopters would be getting the technology but not paying for it. In reality, there is a mix of both: some technology will not be licensed by the innovators for fear of imitation and some will be transferred but adopters will not pay for it. However, it is difficult to empirically disentangle between the two from equation (19).

5 Empirical strategy

I estimate the structural gravity equation in two ways. I first 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. The fixed effects have a one-to-one correspondence with the model's fundamentals. hence, this method allows me to evaluate the role of exporter and importer's characteristics through the lens of the model. In a second step, I regress royalty payments directly on economic fundamentals using PPML methods. This allows me to study how well model's fundamentals can explain bilateral royalty payments.

Estimating a reduced-form gravity equation To illustrate the gravity-type structure of equation (19), we can write the expression in logs as a function of fixed effects.

$$\log(RP_{in,t}) = \tau_{in,t} + S_{nt} + F_{it} + d_{in} + u_{in,t}. \tag{20}$$

where $\tau_{in,t} = \xi \log(\left(\frac{\tau_{nt}}{\tau_{it}}\right)$; $S_{nt} = \log\left(\lambda_n \chi_{nt}^{\gamma} T_{nt} \left(\frac{H_{nt}^r}{Y_{nt}}\right)^{\beta_r}\right)$ and $F_{it} = \log\left(\frac{\Pi_{it}}{T_{it}}\right)$; $d_{in} = \log(\bar{\varepsilon}_{in})$; and $u_{in,t}$ a residual.

To evaluate the importance of 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 (19).[10] The regression includes a time-varying bilateral variable that captures differences in taxation across countries. That is,

$$RP_{in,t} = \exp\left[\xi \log\left(\frac{\tau_{nt}}{\tau_{it}}\right) + S_{nt} + F_{it} + d_{in} + u_{in,t}\right] \tag{21}$$

where $u_{ni,t}$ is a residual. The results are reported in Table 2

The coefficient on taxation differences is negative, 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 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 model's fundamentals in equation (19) can capture the dynamic patterns of royalty payments from the data. In particular, from $S_{nt} = \log\left(\lambda_n \chi_{nt}^{\gamma} T_{nt} \left(\frac{H_{nt}^r}{Y_{nt}}\right)^{\beta_r}\right)$, the exporter-time fixed effects depend on the quality of

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

Table 2: Three-way fixed effects:
The table reports results from estimating with PPML methods equation (21) 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.

	Royalties
$\log\left(\frac{\tau_{nt}}{\tau_{it}}\right)$	-1.297***
	(0.128)
constant	8.874***
	(0.165)
N	28367
pseudo R^2	0.984

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

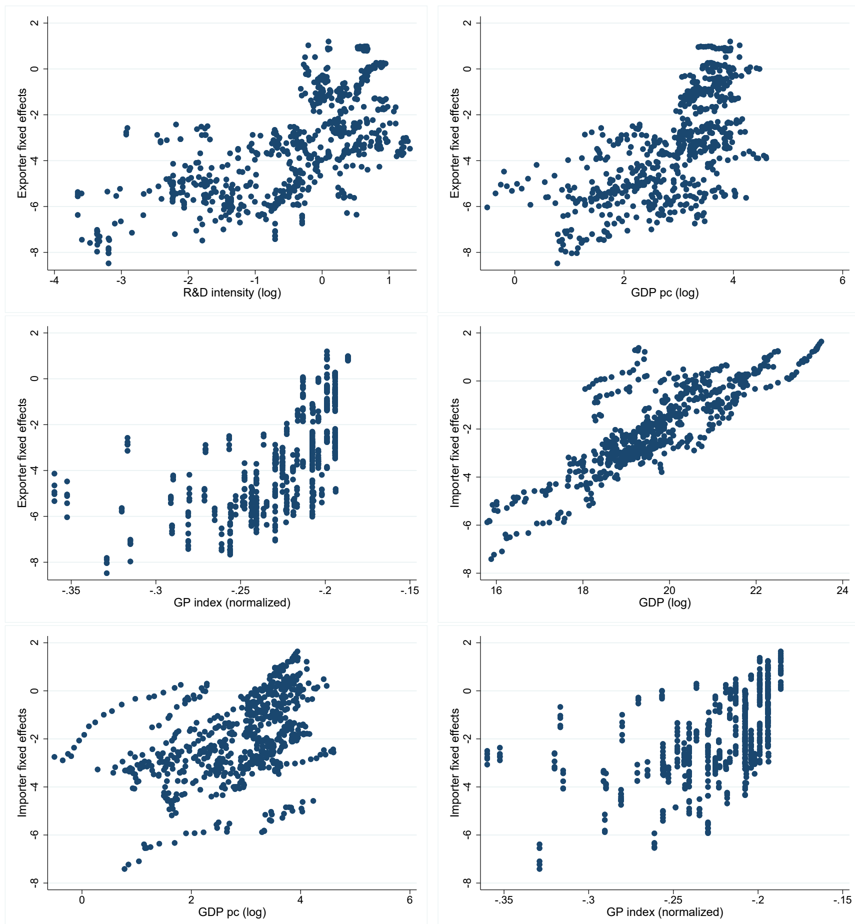
IP rights, χ_{nt}, the R&D intensity $\frac{H^r_{nt}}{Y_{nt}}$ and the GDP per capita, T_{nt}. From $F_{it} = \log\left(\frac{\Pi_{it}}{T_{it}}\right)$, the importer-time fixed effects depend on profits, which are a function of profits, which can be approximated by total GDP and the GDP per capita.

Figure 6 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 figure represents a country-year.[11] 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 of IP rights (left panel) and larger countries (right panel) tend to be 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 IP rights enforcement (right panel) are more likely to receive foreign technology.

More formally, I regress the estimated exporter-time and importer-time fixed effects from equation (21) on the model's economic fundamentals from equation (19). The results are displayed on Tables 3 and 4. Consistent with the model, Table 3 shows that countries that invest more in R&D, are more productive or are better at protecting IP rights, receive on

[11] Appendix 10 reproduced the same graphs averaging across years.

Figure 6: Gravity fixed effects and model's economic fundamentals
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, productivity and quality of IP rights enforcement. Each dot represents a country-year observation.



average more royalty payments. The coefficients are statistically and economically significant. on the exporter-time fixed effects. These variables explain about 78% of the variation of the exporter-time fixed effects.

The results in Table 4 show that larger countries and those with better enforcement of IP rights receive, on average, more technology. The coefficients are statistically and economically significant. Moreover, these two variables together explain around 53% of the variation in the importer-time fixed effects.

Finally, I regress the estimated time-invariant bilateral fixed effects from equation (21) on the log of distance, a dummy variable that takes a value of 1 if the countries share a border, and a dummy variable that takes a value of 1 if the countries share a language.

Table 3: Exporter-time fixed effects and economic fundamentals
This table reports OLS results from regressing exporter-time fixed effects from the gravity regression on the exporter's log of R&D, log of GDP, log of GDP per capita, and an index of quality of IP rights measured with the Ginarte-Park index.

	Exporter FE
log(R&D Spending)	0.538***
	(0.0468)
log(GDP exporter)	0.786***
	(0.0300)
log(GDP pc exporter)	0.575***
	(0.0640)
GP index exporter	0.360
	(0.379)
N	677
R^2	0.78

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The regression includes exporter and importer fixed effects. I find that countries that are geographically closer, share a common language or share a border have larger country-pair fixed effects. All coefficients are statistically and economically significant (see Table 5).

The results suggest that model's fundamentals can explain the country-time characteristics estimated from a reduced-from gravity equation.

Estimating the structural gravity equation I then estimate equation (19) by regressing royalty payments directly on economic fundamentals using PPML methods. This exercise addresses several econometric challenges that could arise in the previous section. There, royalty payments were first regressed on fixed effects and then the estimated fixed effects were regressed on the main economic variables suggested by the model. The standard errors from the second regression could be wrong as the estimated fixed effects are measured with error. Moreover, if some of these variables are correlated with each other, adding them directly to the regression will yield different estimated coefficients. Yet, the previous analysis was informative, as a first step, to evaluate the predictive power of the model's economic fundamentals on the country characteristics identified from the gravity regression.

The results are reported on Table 6. I include symmetric country-pair fixed effects in the regression and differences in corporate income taxes between the countries. All coefficients

Table 4: Gravity importer-time fixed effects and economic characteristics
This table reports OLS results from regressing importer-time fixed effects from the gravity regression on the importer's log of GDP, log of GDP per capita, and the quality of IP rights enforcement.

	Importer FE
log(GDP importer)	0.664***
	(0.0358)
log (GDP pc importer)	0.369***
	(0.0683)
GP importer	1.362**
	(0.462)
N	677
R^2	0.53

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

have the expected signs and are statistically and economically significant. Countries with high corporate income taxes relative to those of the partners, tend to make on average more royalty payments. Countries that do more innovation and have better quality of IP rights enforcement tend to export, on average, more technology. At the same time, larger countries, with better IP rights enforcement tend to import, on average, more technology. Regressing the time-invariant bilateral fixed effects on geography and cultural variables (i.e., distance, contiguity and common language) yields virtually identical results to those reporte don Table 5. Moreover, 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 56%.

6 Quantitative Analysis

To better understand the role of IP rights and tax havens on international technology licensing, I calibrate the model to data on trade flows, R&D intensity, and royalty payments for each year 1996-2012, as well as data on corporate income taxation and an index measuring the quality of IP enforcement (i.e, the Ginarte-Park index). In 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. I then perform two

Table 5: Country-pair FE and geography and cultural variables:
This table reports OLS results from regressing time-invariant country-pair fixed effects from the gravity equation on the log of distance, a dummy for sharing a border, and a dummy for sharing a language.

	Pair FE
log(distance)	-0.659***
	(0.0436)
Contiguity	0.281
	(0.159)
Common language	0.618***
	(0.104)
Exporter FE	Yes
Importer FE	Yes
N	1406
R^2	0.897

Standard errors in parentheses (clustered by country pair)
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

counterfactual exercises. In the first exercise, I ask the following question: how much larger would international technology licensing have been if China's IP rights enforcement had been as strong as those in the United States? To answer this question, I assume China has the same quality of IP rights enforcement as the United States during the period of analysis. In the second exercise, I ask the following question: How did differences in corporate income taxation impact technology licensing between the United States and tax havens? To answer this question, I remove differences in income taxation across countries, so that high tax countries do not have an incentive to shift the ownership of IP to low income countries. I then compare international technology licensing flows across countries in each counterfactual and in the baseline.

6.1 Calibration

I start by describing the calibration of 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 period between 1996 and 2012.

Parameter calibration The Armington elasticity σ is calibrated to 5, which implies a trade elasticity of 4, as is common in the trade literature (see Waugh, 2010). The remaining

Table 6: Bilateral royalty payments and economic fundamentals: This table reports PPML estimation results of the regression of bilateral royalty payments for 41 countries for the period 1996-2012 on economic fundamentals.

	(1)
Differences in taxation (exporter-importer)	-0.133***
	(0.0373)
log(R&D intensity exporter)	0.789***
	(0.142)
log(GDP exporter)	0.705*
	(0.330)
log(GDP pc exporter)	0.0448
	(0.369)
log(GDP importer)	2.866***
	(0.358)
log(GDP pc importer)	-2.166***
	(0.377)
GP index importer	0.553***
	(0.150)
GP index exporter	1.064**
	(0.389)
N	24524
pseudo. R^2	0.95

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

parameters of the model are calibrated using data on trade flows, geography, R&D spending, income and royalty payments, together with gravity methods, in two steps: First, I calibrate trade costs and productivity, estimating a gravity equation of bilateral trade flows, following Waugh (2010). Second, the parameters that govern the innovation and diffusion processes are calibrated following the empirical methodology developed in Section 5.

Using data on bilateral trade flows, geography and GDP per capita from CEPII for 2000, I calibrate iceberg transport costs d_{in} and productivity, $\Omega_n^{\sigma-1}T_n$, by running the following reduced-form regression, derived from manipulating equation (7) and taking logs:

$$\log\left(\frac{X_{in}}{X_{ii}}\right) = -(\sigma-1)\sum_{p=1}^{6} d_{in,p} - (\sigma-1)B_{in} + \log(S_n) - \log(S_i) + u_{in} - (\sigma-1)fe_n,$$

where, 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. The equation includes an exporter fixed effect, fe_n, which has been shown to fit better the patterns in both country incomes and observed price levels (see Waugh, 2010). From $S_n = \Omega_n^{\sigma-1} T_n \left(\frac{\omega_n}{P_n}\right)^{1-\sigma}$, and Using the estimated value for S_n, data on GDP per capita, and $\sigma = 5$, I recover $\Omega_n^{\sigma-1} T_n$. Finally, I obtain trade costs from the following expression:

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

The correlation between the estimated relative productivity from the gravity regression, and relative GDP per capita in the data is about 0.95; the correlation between trade shares in the data and in the model is about 0.80.

The parameters that govern the innovation and diffusion processes are calibrated following the empirical methodology developed in Section 5. First, I recover $\varepsilon_{i,n}$ from the bilateral fixed effects in the reduced-form gravity equation (21). Second, I set to elasticity with respect to differences in corporate income taxes, ξ to -1.3, using the results from Table 2. The remaining parameters are obtained from the regressions in Table 6. The elasticity of innovation β_r is set to 0.7. The elasticity of IPR for the exporter and importer, γ and ϵ, are set to 1 and 0.5, respectively.

The calibrated parameters that are common across countries are reported in Table 7.

Table 7: Calibrated parameters

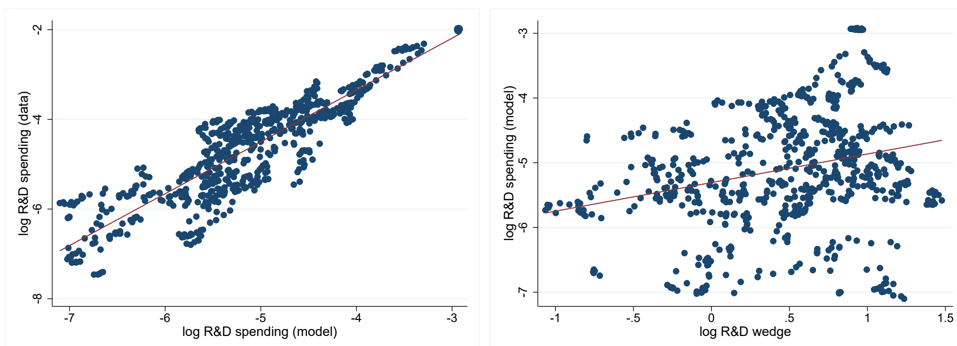
Parameter	Value	Interpretation	Source
σ	5	Armington elasticity	Waugh (2010)
ξ	-1.3	Tax differences	Table 2
β_r	0.7	Elasticity of innovation	Table 6
γ	1	IP rights exporter	Table 6
ϵ	0.5	IP rights importer	Table 6

Wedges calibration I introduce two wedges in the model so that R&D intensity and royalty payments are fully matched in the data every period. Specifically, I introduce the wedge me_{nt} in equation (8), 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 in equation (13), 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; the wedge 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



Next, I obtain a value for the wedge $me_{in,t}$ that exactly matches royalty payments from the data. I find that the wedge explains around 60% of the variation of royalty payments, whereas the model explains 56% (see 6). The remaining 40% is explained by the wedge. 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).

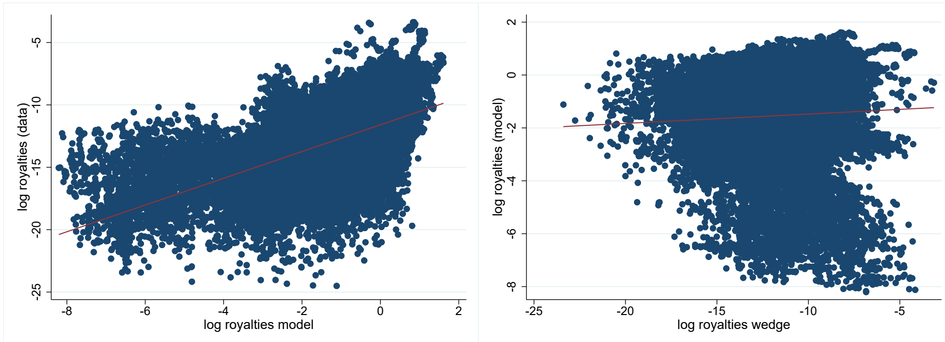
These results suggest that the model does a good job at capturing R&D intensity and royalty payments, and what is left is accounted for by the wedges.

6.2 Counterfactual Analysis

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

Figure 8: Royalties in the model and in the data

(a) Royalties: Model vs Data (b) Royalties: Model vs Wedges

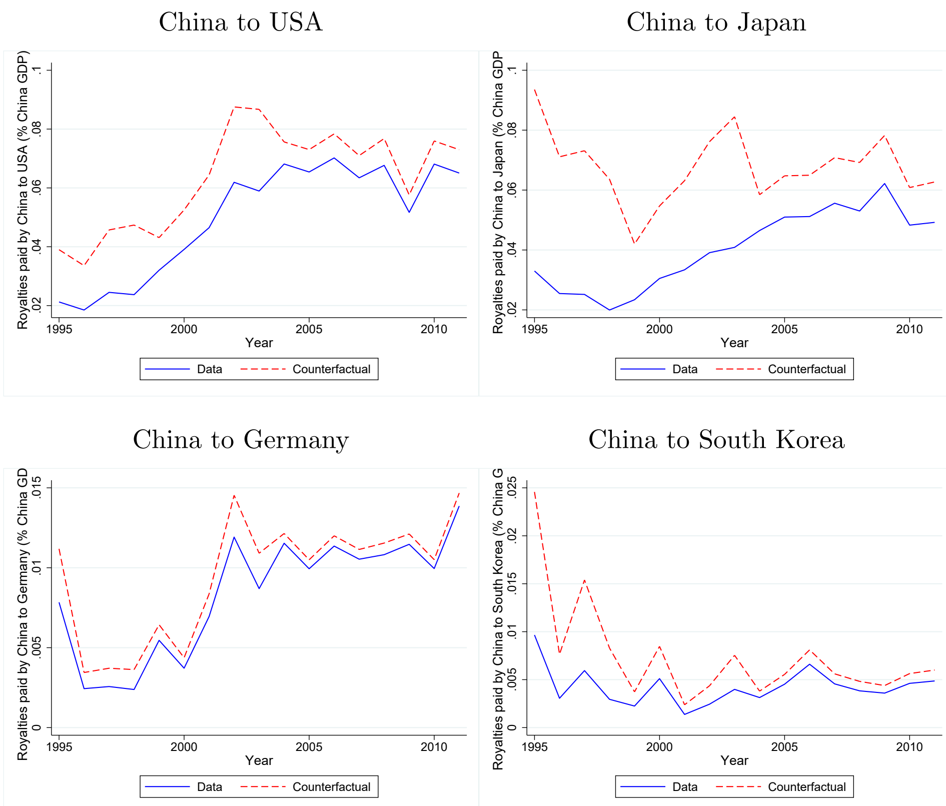


The role of IP rights enforcement In the first counterfactual exercise, I analyze the role of IP rights enforcement on royalty payments by addressing the following question: Between 1996 and 2012, how much would China have paid in royalties if its IP rights had been the same as the United States' during that period? To implement the counterfactual, I simulate the model 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 the world would have been 36% higher.

Figure 9 compares royalty payments (as a percentage of Chinese GDP) from China to its main technology suppliers—i.e, the United States, Germany, Japan and South Korea—between 1996 and 2012, both in the data (solid line) and in the counterfactual (dashed line). Restricting the analysis to royalty payments from China to each technology leaders, I find that royalty payments from China would have been 27.8%, 14%, 67.5%, and 74.2% higher, respectively. Differences between the baseline and the counterfactual scenario are larger at the beginning of the sample, as China's IP rights have been improving over time. The main differences are with Japan and South Korea, countries that are geographically closer to China; the lowest differences would be with respect to Germany, followed by the United States.

The results show that if Chinese IP rights had been stronger, royalty payments to the world would have been larger. Higher royalty payments from China could be interpreted in two ways. First, better IP rights increase technology transfer to China. Innovators invest

Figure 9: Royalties paid by technology importer to technology exporter (Data and Counterfactual)



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 IP rights imply that China imitates less and licenses more; thus, it starts paying royalties for technology that was previously getting for free. An increase in royalty payments that reflects more technology transfer would be advantageous for China, as 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 between the two effects in the data. However, since the model is set-up so that the quality of IP rights 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.

The role of tax havens In this counterfactual exercise, I analyze the role of tax havens by addressing the following question: How much would royalty payments have been if all countries had the same corporate income tax rate? This policy experiment is motivated by a recent reform in the international tax system that was proposed by the OECD, in which multinationals will be subject to a minimum 15% tax rate from 2023.[12]

The counterfactual is implemented by setting corporate taxes to be identical for the source and destination countries every period, while keeping all other parameters and wedges fixed. I then compare royalty payments between the baseline and counterfactual scenarios. I focus on royalty payments between the United States and Ireland, since a large amount of profit shifting has taken place among these countries. I look at the period after 2001: Guvenen et al. (2017) 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 results show that, absent differences in corporate income taxes, royalty payments from the United States to Ireland between 2001 and 2012 would have been, on average , 8% lower than in the baseline scenario. This result is consistent with the discussion on multinational corporations shifting profits abroad using intellectual property. Profit shifting would imply a multinational in the United States transferring the property of their IP to an affiliate in Ireland in order to benefit from lower taxes. This practice would result in the U.S. firm, which is where innovation took place originally, paying royalties to the Irish affiliate. The counterfactual exercise shows that, by removing tax differences, the US multinational would be instead receiving royalties. Specifically, royalty payments from the United States to Ireland during that period would have about 1 billion USD lower than in the baseline scenario. This number can be taken as a lower bound since there are many loopholes in the tax system, other than differences in taxation, that may have triggered profit-shifting practices among multinational corporations. These loopholes are difficult to quantify through the lens of a model. Nevertheless, the introduction of corporate income taxes in the paper allows us to study, at least partially, the role of tax havens on international technology licensing.

[12] 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`.

7 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. 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 that IP rights enforcement and tax havens have for 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 model explicitly in a quantitative framework analyzing international technology diffusion. First, the model could be extended to include patenting decisions of innovators when there is imperfect enforcement of IP rights (i.e., when there is a positive probability of imitation or misappropriation of a foreign technology). Second, it could be extended to model the decision of a firm in a high corporate income tax country to transfer technology to an affiliate in a low corporate income tax country for profit-shifting motives. I leave these extensions, as well as a more formal quantitative analysis of the model, for future research.

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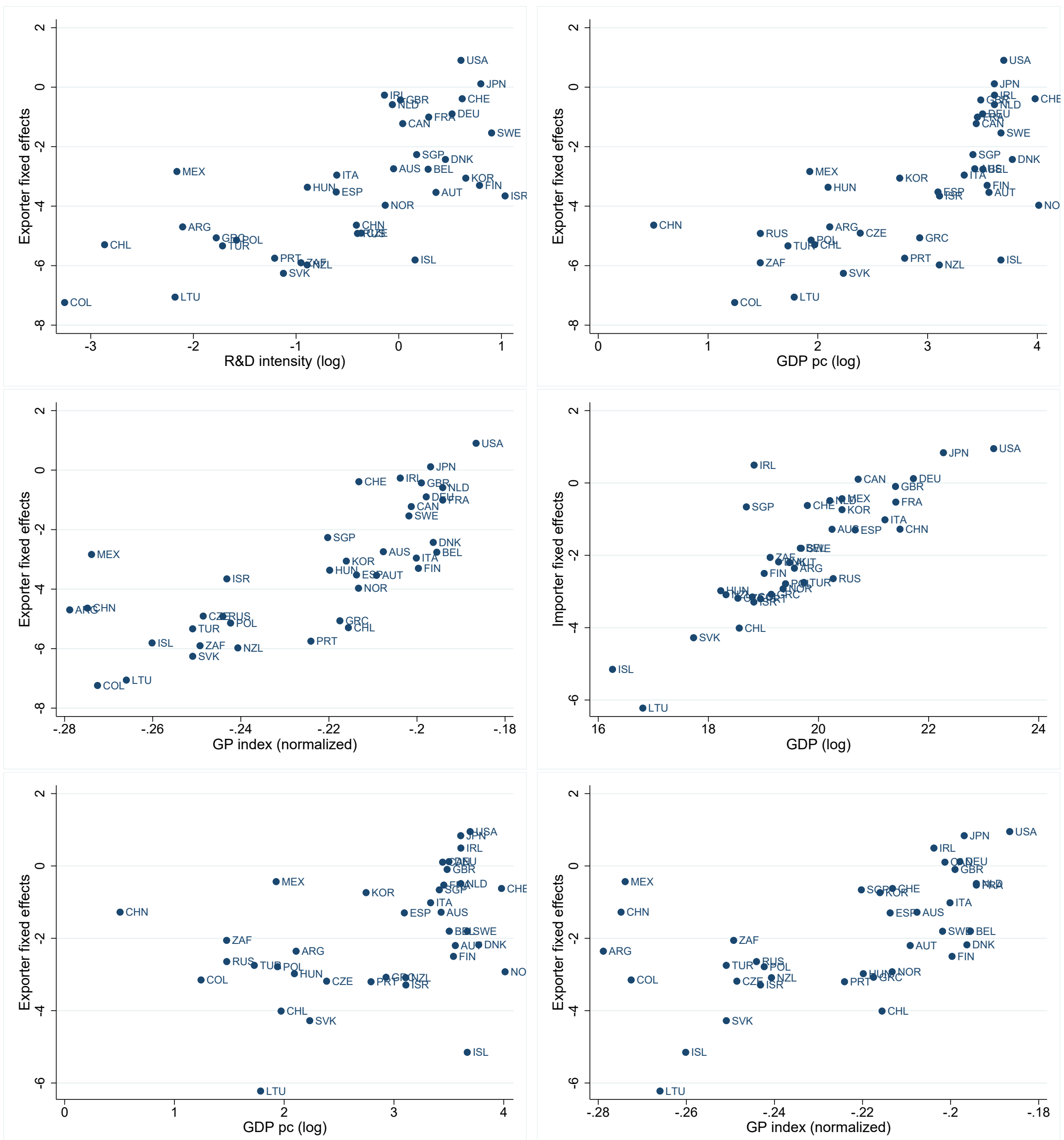
APPENDIX

A Additional Figures

Figure 10 reproduces the graphs in Figure 6, 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 10: Gravity fixed effects and the model's economic fundamentals
The figure shows correlations between exporter fixed effects (Y-axes of top two subplots) and exporter's R&D spending, productivity and quality of IP rights enforcement (X-axes of middle two subplots); and between importer fixed effects (Y-axes of bottom two subplots) and importer's GDP, productivity and quality of IP rights enforcement (X-axes of bottom two subplots). Each dot represents a country.



B 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 contains 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. Raw data: https://www3.wipo.int/ipstats/index.htm?tab=patent

Global Competitiveness Data collected from the World Economic Forum's GCI data. Dataset is a series on indices, on a scale from 1-7.

http://www3.weforum.org/docs/GCR2017-2018/GCI_Dataset_2007-2017.xlsx

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 8: Country list

Country Name	ISO-code	Country Name	ISO-code
Argentina	ARG	Latvia	LVA
Australia	AUS	Lithuania	LTU
Austria	AUT	Mexico	MEX
Belgium	BEL	Netherlands	NLD
Canada	CAN	New Zealand	NZL
Chile	CHL	Norway	NOR
China	CHN	Poland	POL
Colombia	COL	Portugal	PRT
Czec Republic	CZE	Russia	RUS
Denmark	DNK	Singapore	SGP
Estonia	EST	Slovak Republic	SVK
Finland	FIN	Slovenia	SVN
France	FRA	South Africa	ZAF
Germany	DEU	South Korea	KOR
Greece	GRC	Spain	ESP
Hungary	HUN	Sweden	SWE
Iceland	ISL	Switzerland	CHE
Ireland	IRL	Turkey	TUR
Israel	ISR	United Kingdom	GBR
Italy	ITA	United States	USA
Japan	JPN		

C 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

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

Trade share

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

Labor market clearing condition

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

Productivity

$$\Omega_{nt} = T_{nt} S_{nt}^{(} \sigma - 1)$$

Profits firms

$$\Pi_{nt} = \frac{\sigma}{\sigma - 1} W_{nt} L_n$$

Value innovation

$$Z_{nt} V_{nt} = \sum_{i=1}^{M} \frac{A_{in,t}}{T_{it}} \chi_{in,t} \Pi_{it}$$

$$V_{nt} = \sum_{i=1}^{M} \frac{\varepsilon_{in}}{T_{it}} \chi_{in,t} \Pi_{it}$$

FOC innovation

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

Law of motion of innovation

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

Royalties

$$RP_{in,t} = \frac{\varepsilon_{in} Z_{nt}}{T_{it}} \Pi_{it}$$

Law of motion of adoption

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

Trade balance equation: Update wages

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

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

$$T_{nt} = \sum_{i=1}^{M} A_{ni,t}$$