Dynamic Gains from Trade Agreements with Intellectual Property Provisions[*]

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Abstract

I develop a quantitative multi-country growth model to study the dynamic effects of trade agreements with intellectual property (IP) provisions. The model incorporates imperfect IP protection and uses Nash bargaining to determine tariff levels and IP protection within the agreement. I find that the trade agreement leads to long-term welfare, innovation, and growth increases. However, the distribution of gains varies among countries during the transition. Developing countries initially experience short-run losses due to higher licensing prices. A "myopic" government could design an agreement that mitigates these losses, but this would result in lower growth and welfare.

Keywords: Technology Licensing; Trade Agreements; Intellectual Property Rights

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1 Introduction

The enforcement and protection of intellectual property rights (IPR) has become an important component of current trade policy. Prior to the formation of the World Trade Organization (WTO) in 1995, regional trade agreements (RTAs) were mostly about removing trade barriers between member countries and required only minimum standards of IP enforcement. However, recent decades have seen substantial improvements in IPR with most agreements since 1995 containing such provisions.[1] RTAs with IP provisions require that countries signing the agreement reach IP standards similar to those in developed countries. In return, they offer increased access to international markets. These are known as deep trade agreements. For instance, on January 6, 2003, Chile and the United States signed a trade agreement with high-level IPR protection and enhanced IPR enforcement mechanisms, such as border measures to prevent entry of products infringing IP laws.[2] More recently, in August 2007 the United States, under Section 301 of the US Trade Act, initiated an investigation into China's supposed misappropriation of IPR. The finding of several discriminatory IP-related practices prompted the US administration to impose additional tariffs, ranging from 7.5% to 25%, on approximately $370 billion of U.S. imports from China.[3]

This paper provides a normative and positive analysis of trade agreements with IP provisions through the lens of a quantitative dynamic trade model with imperfect IP protection. From a normative perspective, the model introduces a Nash bargaining framework where governments choose optimal tariffs and the level of IP protection within a trade and growth model with imperfect IPR. From a positive perspective, the paper studies, quantitatively, the short- and long-run implications on innovation, growth, and welfare of improving IPR within the trade agreement. The quantitative trade and growth model captures the interactions between innovation, technology adoption, and IP reforms in the context of international trade.

The model is built upon an Armington trade framework with endogenous productivity growth driven by both innovation and technology licensing. Innovators invest resources to develop new technologies, while adopters invest resources to use these technologies in inter-

[1] See `https://www.stlouisfed.org/on-the-economy/2021/june/intellectual-property-rights-become-key-part-trade-deals`.

[2] In 2007, Costa Rica put to a national referendum a trade agreement that included substantial reductions in tariffs as well as guidelines about IPR (see Van Patten and Méndez, 2022).

[3] `https://crsreports.congress.gov/product/pdf/IF/IF11346`.

mediate goods production, whether domestically or through foreign licensing agreements. Adoption is a slow and costly process, by which adopters can use a newly developed technology with a certain productivity to produce an intermediate good. They earn profits, while paying royalties to innovators. These royalty payments are determined as a share of the total profits generated by adopters in each period, and they reflect the bargaining power of the innovators. The level of IP protection of adopters determines such bargaining power. Weak IP protection diminishes the innovators' ability to negotiate favorable terms, resulting in underinvestment in R&D and subsequently reducing long-term growth prospects. High-enforcement countries can impose tariffs on low-enforcement countries. Tariffs lead to reduced market access for exports, decreasing innovation and adoption in low-enforcement countries, and a lower number of imported varieties in high-enforcement countries. To mitigate the inefficiencies, governments can sign a trade agreement and optimally choose the level of tariffs and IP enforcement. The agreement consists of a Nash bargaining protocol that maximizes their joint surplus. The model exhibits a balanced growth path (BGP), in which all countries experience uniform growth rates but differ in relative levels. Variations in growth rates across countries emerge during the transition period.

The model is calibrated to 2000 data on international trade flows, income, innovation, and royalty payments for three countries: the United States, China, and an aggregate rest of the world. Countries are heterogeneous in their innovation and adoption efficiency, the quality of IP protection, and their geography and trade policy. A novelty of the calibration strategy in this paper is that it estimates the probability of adoption using data on international technology licensing. The model yields a structural gravity equation of bilateral royalty payments that can be estimated with gravity methods to compute the probability of adoption across country-pairs on the BGP. Royalty payments are a more direct form of technology diffusion than other measures used in the literature such as international patenting, trade, or patent citations (see Eaton and Kortum, 1996, 1999; Santacreu, 2015; Buera and Oberfield, 2019; Cai, Li, and Santacreu, 2021).

I conduct a counterfactual exercise in which China and the United States negotiate a trade agreement consisting of choosing the levels of tariffs and IP protection as part of a Nash bargaining problem. Although China and the United States do not currently have a trade agreement with IP provisions, the United States has mechanisms in place to restrict imports from developing countries with poor IP protection (section 337 of the US Tariff Act, Section 301 and special 301 or Generalized system of preferences). Moreover, on January 15, 2020, the United States and China signed the first phase of a trade deal in which the United States committed to lower tariffs from Chinese goods in exchange for China, among other things, improving its IP protection. The agreement in this paper is designed similarly to Bagwell, Staiger, and Yurukoglu (2020, 2021), who solve for optimal tariffs resulting from various bilateral trade agreements. The main difference is that I consider a trade agreement between one country pair on both tariffs and non-tariff instruments. The payoff function is the pair's Nash bargaining product of dynamic welfare gains, computed as consumption-equivalent units, and the strategies are the tariffs and quality of IP protection, both domestic and foreign, being negotiated between the pair. The trade agreement is conditional on both countries having positive welfare gains. The optimal agreement implies: (i) Reforms of Chinese IP laws so domestic and foreign firms receive higher royalty payments; and (ii) lower US tariffs on imported Chinese products.[4]

I solve for the perfect foresight solution of the model after the agreement is signed, which is an unanticipated, permanent, one-time shock. The trade agreement increases innovation and growth in the long run everywhere. Innovators, both in China and in the United States, receive more royalties, which increases their returns to R&D. Adoption increases in the United States, as there are more technologies ready to be used in production. Adopters in China are impacted by two opposing forces: The return to adoption decreases, as they now have to pay more royalties; however, they have access to a larger market through lower tariffs, which increases adoption incentives. The net effect is a decline in adoption. Hence, resources reallocate away from adoption and toward innovation in China. Welfare increases in all countries as higher innovation around the world drives the BGP growth rate up. However, there are heterogeneous cross-country effects on how gains accrue along the transition. Despite benefiting from lower tariffs, China suffers short-term losses, as adopters must now pay for technology that was previously copied; short-term gains occur in the United States, as innovators receive more royalties and the return on innovation increases.

I perform several counterfactual exercises to disentangle the main channels at play. First, IP protection is reformed without trade liberalization. In this case, all countries experience positive gains. However, China experiences a larger initial drop in consumption, as the

[4] Several trade agreements with IP provisions require strengthening and harmonizing IP laws among countries by requiring uniform minimum standards of IP protection and enforcement in domestic laws—an example includes the Trans-Pacific Partnership Agreement.

standard forces of a trade liberalization are not present. Overall, China gains but less than when the United States lowers tariffs on imported products. In a second counterfactual exercise, the United States lowers tariffs on Chinese exports but China maintains imperfect IP protection. In this case, China experiences short-term gains. Moreover, there are dynamic losses everywhere through lower R&D investment and lower long-term growth. On the one hand, US innovators are not compensated from their R&D efforts, decreasing innovation and long-term growth. On the other hand, US firms face higher competition from imitated Chinese products through lower tariffs. This effect reinforces the decrease in innovation and long-term growth, leading to long-term welfare losses.

An important component of the trade agreement is that China has to reform its domestic IP laws. This feature is motivated by current trade agreements that require significant changes in the domestic legislation of participating countries.[5] Improving domestic IPR implies that domestic innovators receive more royalties, thus invest more in R&D. At the same time, China benefits from lower tariffs from the United States, but China has to pay higher prices for using foreign technology. The question, then, is whether China would be better off by reforming its domestic IP laws without signing a trade agreement, or whether there are additional benefits from doing such reforms as part of an agreement. I find that improving domestic IPR unilaterally generates positive welfare gains both in the short- and in the long-run in China. However, the gains are lower if IP laws are not reformed as part of a trade agreement. That is, the positive effects of domestic IP reforms and having access to a larger export market dominate the negative effects of paying higher prices for licensed technology. Therefore, signing the trade agreement not only encourages China to improve its IPR, but it also offers access to larger export markets through lower tariffs, thereby compensating for the higher adoption prices as royalties.

Finally, the main trade agreement has been designed by a welfare-maximizing government. That is, tariffs and levels of IP protection are selected so as to maximize welfare as calculated in consumption-equivalent units at the consumer's discount factor. China suffers short-term losses in this case, but both countries gain overall. These losses in China might not be attractive to a politically motivated government with short-term goals.[6] I then consider the design of a trade agreement made by a government with short-term objectives

[5] See `https://unctad.org/system/files/official-document/iteipc20064_en.pdf`.
[6] See Grossman and Helpman (1995) and Grossman (2016).

(i.e., the government is more impatient and has a lower discount factor). Here, the trade agreement generates positive gains, both in the short-run and in the long-run, everywhere, but the overall gains are lower than in the welfare-maximizing trade agreement. The reason is that when an agreement is designed by a myopic government, China agrees to improve foreign IP less than before, resulting in a lower increase of the BGP growth rate.

One of the model's implications of trade agreements with strict IP provision is that royalty payments from China to the United States increase following the agreement. The increase occurs for two reasons: (i) China starts paying royalties for technology it was previously getting for free, and (ii) China starts receiving more foreign technology, hence paying royalties for it. In contrast, trade agreements that do not require IP improvements have no effect on royalty payments. I provide empirical validation for this channel by studying the dynamics of international technology transfer in the data following membership into RTAs with IP provisions. I find that country-pairs that sign RTAs with strict IP provisions experience more royalty payments following the year of enforcement. These results are stronger when the agreement is signed between developed and developing countries. An econometric analysis that includes country-time fixed effects and country-pair fixed effects shows that only RTAs with IP provisions matter for royalty payments between developed and developing countries, increasing these payments by 25% following an agreement. The model can thus capture the dynamics of technology licensing observed in the data, following the enforcement of a trade agreement with strict IP provisions. This result provides empirical support for the main channel of technology transfer in the model.

The paper is related to several strands of literature. First, recent papers have studied the welfare effects of trade negotiations on tariffs (see Bagwell, Staiger, and Yurukoglu, 2021, 2020; Ossa, 2011, 2014). However, the existing literature on trade negotiations involving non-tariff issues, such as IP, remains relatively scarce.[7] This paper contributes to the literature by exploring both theoretically and quantitatively the short- and long-term dynamic gains of reforming IPR as part of a trade agreement that includes non-tariff issues.

Second, the paper is related to recent studies analyzing dynamic gains of trade liberalization through innovation (Somale, 2021), knowledge spillovers (Buera and Oberfield, 2019), and both innovation and knowledge spillovers (Cai, Li, and Santacreu, 2021). The contribu-

[7] Maggi and Ossa (2021) document the change in the nature of trade agreements, studying deep integration from the perspective of the political economy of trade policy. Grossman, McCalman, and Staiger (2021) study governments' incentives to engage in deep integration.

tion with respect to those studies is to introduce imperfect IPR and study the design of deep trade agreements that include both changes in tariffs and in the quality of IP protection. Moreover, while most of this work studying dynamic gains through innovation has focused on the balanced growth path (BGP)—see Cai, Li, and Santacreu (2021); Somale (2021); Sampson (2019); Lind and Ramondo (2022)—very few papers compute welfare gains along the transition (Akcigit, Ates, and Impullitti, 2018; Perla, Tonetti, and Waugh, 2015; Buera and Oberfield, 2019). This paper provide an evaluation of deep trade agreement that include transitional dynamics.

Third, the paper is related to a large literature studying the effects of IPR improvements on growth and welfare in developing countries (Helpman, 1993; Lai, 1998; Lai and Qiu, 2003; Kwan and Lai, 2003; Yang and Maskus, 2001; Branstetter et al., 2007, 2011; Tanaka and Iwaisako, 2014; Diwan and Rodrik, 1991). In their work, Grossman and Lai (2004) explore a North-South model wherein the North exhibits higher innovation efficiency, and they consider globally efficient patent protection regimes. Their findings suggest that stronger patent protection in the South leads to gains for the North at the expense of the South. In contrast, this paper highlights that the South can experience welfare gains from IP improvements, as domestic innovators can benefit from increased royalty payments. However, for this to occur, the South must have reached a sufficiently high level of innovation. Furthermore, if the North reduces tariffs on products exported by the South, it creates incentives for the South to enhance its IPR. My paper considers optimal patenting regims in an open economy, in the context of deep trade agreements.

Finally, the connections between IPR and trade in the context of deep trade agreements have not been explored quantitatively. Mandelman and Waddle (2019) investigate the interaction between tariffs and IPR enforcement within a quantitative general equilibrium framework. Their research delivers insightful findings: (i) tariffs can effectively deter weak IP protection, and (ii) weakening IPR enforcement can serve as a deterrent to raising tariffs. In their approach, tariffs are contingent on IPR enforcement, and they evaluate the impact of exogenous shocks on key economic variables. In contrast, this paper treats tariffs and IPR as distinct instruments, chosen optimally to maximize global welfare. The paper is also related to Holmes, McGrattan, and Prescott (2015), who study the welfare effects of improving IPR in China, through the lenses of forced technology transfer. In particular, they evaluate the effect of removing quid-pro-quo practices in China on global welfare and innovation. Quid-pro-quo practices resemble a situation in which firms first license a technology and then imitate it. Different from their work, this paper analyzes the role of the interaction between trade and IPR in a unified framework.

The remaining of the paper is organized as follows. Section 2 presents the model. Section 3 describes the calibration and counterfactual analysis. Section 4 presents external validation, and Section 5 concludes.

2 Model

The global economy consists of a trade and growth model with endogenous innovation and international technology licensing. The model allows imperfect enforcement of IPR. High-enforcement countries can impose tariffs on low-enfrocement countries. Governments can enter a trade agreement to choose optimally the level of tariffs and the quality of IP protection to address the inefficiencies caused by imperfect IPR. The world consists of M countries indexed by i and n. Time is discrete and indexed by t.

2.1 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

$$P_{nt}C_{nt} + P_{nt}B_{nt} + \frac{\eta}{2}\left(B_{nt} - \bar{B}_n\right)^2 = W_{nt}L_{nt} + \Pi_{nt}^{\text{all}} + R_t P_{nt} B_{n,t-1} + \text{IBT}_{nt} + Tr_{nt}, \tag{2}$$

where β is the discount factor, W_{nt} is the wage, L_{nt} is population, Π_{nt}^{all} are the profits of all the firms in the economy, and B_{nt} is a one-period risk-free bond that is traded internationally at the world interest rate R_t. To ensure stationarity and the existence of a unique steady-state solution for bond holdings, I assume there are quadratic costs to adjusting the international portfolio, with $\bar{B}_n$ the steady-state value of bond holdings. These costs are rebated lump sum to consumers as Tr_{nr} (see Ghironi and Melitz, 2007; Heathcote and Perri, 2002). Finally, the consumers get a lump-sum transfer from the government based on the amount of tariff revenues, IBT_{nt}, to be defined later. Consumers lend to innovators and adopters to finance their activities and, in return, get the profits from all firms in the economy.

2.2 Final Production

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

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

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 constant-returns-to-scale 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 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:

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

subject to equation (4).

International Trade Intermediate products are traded internationally. Trade is Armington, as varieties are differentiated both between varieties and across countries. Trade is costly and subject to two types of trade barriers. One barrier is an ad-valorem tariff, τ_{in}, whereby $1 + \tau_{in}$ is the gross tax rate that country i levies on the value of imports from country n. The second barrier is an iceberg transport cost by which, 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. This means that, in equilibrium, $y_{nt}(j) = \sum_{i=1}^{M} x_{in,t}(j) d_{in}$.

The import share is given by

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

Manipulating equation (7), I can obtain an expression of real wages that follows the formula derived in Arkolakis, Costinot, and Rodríguez-Clare (2012).

$$\frac{W_{nt}}{P_{nt}} = \frac{\sigma-1}{\sigma} \left(\frac{\Omega_n^{\sigma-1} T_{nt}}{\pi_{nn,t}}\right)^{1/(\sigma-1)}.$$

Changes in trade costs drive changes in real wages through the home trade share and through changes in the number of intermediate goods produced in country n at time t, T_{nt}. These goods can be produced either with domestically developed technology (*innovation*) or with foreign technology that has been adopted by the firm (*adoption*). I explain these processes in detail next.

2.3 Innovation and Technology Adoption

The number of technologies available to produce intermediate goods, T_{nt}, evolves endogenously through two endogenous processes: innovation and technology adoption. The innovation and adoption processes are solved in two steps. First, innovators and adopters choose the optimal investment in each activity, taking as given the royalty fee. Second, the optimal fee is negotiated as Nash braining between the innovator and the adopter.

Innovation In each country n a monopolist invests final output, H^r_{nt}, to produce a new prototype or technology. Technologies arrive at a Poisson process given by

$$\lambda_n T_{nt} \left(\frac{H^r_{nt}}{\bar{Y}_t} \right)^{\beta_r}, \tag{8}$$

where $\lambda_n T_{nt}$ represents the efficiency of innovation, with λ_n a country-specific parameter that captures innovation policy in the country and T_{nt} the stock of knowledge available in country n at time t, capturing a spillover effect by which innovators learn from domestic and foreign technology that is being used to produce intermediate goods. Moreover, $\bar{Y}_t$ is world output and β_r is diminishing returns to adding one extra unit of final output into the innovation process.

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

$$Z_{n,t+1} = \lambda_n T_{nt} \left(\frac{H^r_{nt}}{\bar{Y}_t} \right)^{\beta_r} + Z_{n,t}. \tag{9}$$

Equation (9) implies that there is no depreciation of new ideas over time.

New technologies developed through innovation need to be adopted to be used in the production of a new intermediate product. This process is called adoption. Innovators have a monopoly over the technology, which they license to adopters. The value of an innovation is given by V_{nt}, and it will be defined later.

The innovator chooses H^r_{nt} to maximize

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

Technology Adoption When a new prototype is introduced in country n, the innovator in that country licenses the technology to an adopter that invests resources to make it usable for production of intermediate goods. Adoption is costly and takes time. An adopter j that wants to make a prototype from country n usable for production in country i invests $h^a_{in,t}$ units of final output in adoption. With probability $\varepsilon_{in,t}(j)$ the adopter in country i is successful and can use the technology from country n by paying a licensing fee. The probability of adoption is given by

$$\varepsilon_{in,t}(j) = \bar{\varepsilon}_{in} \left(\frac{h^a_{in,t}(j)}{\bar{Y}_t} \right)^{\beta_a}, \tag{11}$$

where $\bar{\varepsilon_{in}}$ represents the ability of country i to adopt a technology from country n, and $\beta_a \in (0,1)$ is a parameter of diminishing returns to adoption investment.

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

$$A_{in,t+1} = \varepsilon_{in,t} \left(Z_{nt} - A_{in,t} \right) + A_{in,t}. \tag{12}$$

Here, $Z_{nt} - A_{in,t}$ is the stock of technologies from country n that have not yet been adopted by country i.

Successful adopters start producing the good and pay a royalty fee to the innovator. I assume that royalties are paid as a fraction of the profits made by the adopter once the technology has been adopted.

2.4 Optimal Investment into Innovation and Adoption

Innovators receive royalties every period from successful adopters around the world. The value for an innovator in country n of a successfully adopted technology by country i is the present discounted value of the share χ_{in} of profits made by intermediate producers in country i that use the technology from country n; that is,

$$V^{\text{innov}}_{in,t}(j) = \chi_{in} \pi^{i}_{nt}(j) + \frac{1}{R_t} \frac{P_{it}}{P_{i,t+1}} V^{\text{innov}}_{in,t+1}(j). \tag{13}$$

where $\pi^{n}_{it}(j)$ are profits made by firm j in country i using technologies that were developed by innovators in country n. These profits include both domestic and export profits.

The value for the innovator in country n of an unadopted technology in country i is given by

$$J^{\text{innov}}_{in,t}(j) = \frac{1}{R_t} \frac{P_{it}}{P_{i,t+1}} \left[\varepsilon_{in,t} V^{\text{innov}}_{in,t+1}(j) + (1 - \varepsilon_{in,t}) J^{\text{innov}}_{in,t+1}(j) \right]$$

With probability $\varepsilon_{in,t}$ the technology is adopted and innovators receive profits forever, which is captured in $V^{\text{innov}}_{in,t+1}(j)$. With probability $(1 - \varepsilon_{in,t})$, adopters are not successful but can keep trying to adopt the technology in the future. Because there is a continuum of adopters trying to adopt a technology and ideas do not depreciate over time, there is always an entrepreneur trying to adopt a previously unadopted technology.

Combining all the above expressions, the value of an innovation is the present discounted value of the share of intermediate producers' profits that operate with the innovator's technology once the technology has been adopted. Summing across all countries that can adopt a technology, the value of an innovation in country n, V_{nt}, is given by

$$V_{nt} = \sum_{i=1}^{M} J_{in,t}^{\text{innov}}.$$

The first-order condition (FOC) for investment in innovation is

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

Successful adopters in a country receive the share of profits that is not paid out as royalties to the innovators. Thus, the value for an adopter in country i from successfully adopting a technology from country n is

$$V_{in,t}(j) = (1 - \chi_{in}) \pi_{it}^{n}(j) + \frac{1}{R_t} \frac{P_{it}}{P_{i,t+1}} V_{in,t+1}(j). \tag{15}$$

The value of an unadopted prototype j that an adopter is trying to adopt is

$$J_{in,t}(j) = -P_{it} h_{in,t}^{a}(j) + \frac{1}{R_t} \frac{P_{it}}{P_{i,t+1}} \{\varepsilon_{in,t} V_{in,t+1}(j) + (1 - \varepsilon_{in,t}) J_{in,t+1}(j)\}. \tag{16}$$

In each period t, there are $Z_{nt} - A_{in,t}$ technologies that were not adopted at time t. That is also the number of adopters trying to adopt technologies between time t and time $t+1$.

Hence, the total amount of output invested to adopt a technology in period t is $H_{in,t}^{a} = \sum_{i=1}^{M} (Z_{nt} - A_{in,t-1}) h_{in,t}^{a}$.

In equilibrium, $h_{in,t}(j) = h_{in,t}\ \forall j$. Hence, $\varepsilon_{in,t}(j) = \varepsilon_{in,t}$, with

$$\varepsilon_{in,t} = \bar{\varepsilon}_{in} \left(\frac{H_{in,t}^{a}}{\bar{Y}_t} \right)^{\beta_a}. \tag{17}$$

The FOC of adoption is

$$P_{it} H_{in,t}^{a} = \beta_a \varepsilon_{in,t} \frac{1}{R_t} \frac{P_{it}}{P_{i,t+1}} (V_{in,t+1} - J_{in,t+1}). \tag{18}$$

The Optimal Royalty Fee Once a technology has been successfully adopted, the innovator and adopter engage in Nash bargaining to determine a one-time royalty fee, χ_{in}, that maximizes their joint surplus.[8] This negotiation takes place after the adoption has occurred. If the innovator and adopter fail to reach an agreement on the fee, the innovator would receive zero profits, while the adopter would receive zero profits net of the adoption costs. This outcome arises because the adopter has already incurred the adoption cost regardless of the negotiation's outcome. Specifically, the innovator and adopter negotiate χ_{in} to maximize the following expression:

$$\left(V_{in,t}^{\text{innov}}(j) - 0\right)^{\rho_{in}} \left(V_{in,t}(j) - P_{i,t-1}h_{in,t-1}^{a}(j) - W_0(j)\right)^{1-\rho_{in}} \tag{19}$$

Here, $V_{in,t}^{\text{innov}}(j)$ is defined as $\chi_{in}W_{in,t}(j)$, $V_{in,t}(j)$ is defined as $(1-\chi_{in})W_{in,t}(j)$, and $W_{in,t}(j)$ is calculated as $\pi_{nt}^{i}(j) + \frac{1}{R_t}\frac{P_{it}}{P_{i,t+1}}W_{in,t+1}(j)$. The parameter ρ_{in} represents the bargaining power of the innovator in country n, while $1-\rho_{in}$ denotes the bargaining power of the adopter in country i. Furthermore, the adopter's outside option $W_0(j)$ is given by $0 - P_{i,t-1}h_{in,t-1}^{a}(j)$.

The optimal royalty fee is determined by the bargaining power of the innovator, ρ_{in}.

A few important points should be noted. First, it is assumed that the fee cannot be renegotiated once agreed upon. Second, the bargaining power of the innovator is assumed to be influenced, among other factors, by the adopter country's IPR quality (Yang and Maskus, 2001; Tanaka and Iwaisako, 2014). Specifically, $\rho_{in} = \bar{\rho}_{in}\eta_i$, where η_i represents the quality of IPR in country i, the technology adopter. A value of $\eta_i = 1$ indicates perfect IPR enforcement, while $\eta_i < 1$ indicates imperfect IPR enforcement. The quality of IPR remains constant unless there are policy changes, such as IPR reforms. To capture improvements in the quality of IPR, I introduce the policy parameter $\xi_{in} \in (1, 1/\eta_i)$. Note that, while η_i depends solely on the characteristics of the adopter, ξ_{in} varies for each country pair, implying that IPR quality reforms in country i can differ depending on the innovator country. Hence, the royalty fee can be expressed as $\chi_{in} = \rho_{in}\xi_{in}$, reflecting how improvements in IPR quality translate into increased bargaining power for the innovator.

2.5 Market-Clearing Conditions

Output is used for consumption, innovation, and adoption; that is,

[8] See Benhabib, Perla, and Tonetti (Forthcoming) and Hopenhayn and Shi (2020) for examples of models of licensing where the royalty fee is negotiated.

$$Y_{nt} = C_{nt} + H^r_{nt} + \sum_{i=1}^{M} H^a_{ni,t}. \tag{20}$$

Labor is used for the production of intermediate goods that are sold in the domestic and foreign markets; that is,

$$W_{nt}L_{nt} = \sum_{i=1}^{M} \Omega_n^{\sigma-1} T_{nt} W_{nt} l_{in,t} = \sum_{i=1}^{M} T_{nt} \frac{p_{in,t}}{\bar{m} d_{in}(1+\tau_{in})} x_{in,t} d_{in}. \tag{21}$$

From here,

$$\bar{m} W_{nt} L_{nt} = \sum_{i=1}^{M} \Omega_n^{\sigma-1} T_{nt} \frac{p_{in,t} x_{in,t}}{1+\tau_{in}} = \sum_{i=1}^{M} \frac{\pi_{in,t}}{1+\tau_{in}} P_{nt} Y_{nt}. \tag{22}$$

The government collects tariff revenue that is rebated back to consumers lump sum:

$$\mathrm{IBT}_{nt} = \sum_{i \neq n}^{M-1} \frac{\tau_{ni}}{1+\tau_{ni}} \pi_{ni,t} P_{nt} Y_{nt}. \tag{23}$$

From the budget constraint of consumers, I derive an expression for the balance of payments. Note that royalties are a trade service, so they will appear as part of net exports. Also note that there is borrowing and lending with the rest of the world, so there are trade imbalances:

$$\sum_{i \neq n}^{M-1} \frac{\Omega_i^{\sigma-1} T_{it} p_{ni,t} x_{ni,t}}{1+\tau_{ni}} = \sum_{i \neq n}^{M-1} \frac{\Omega_n^{\sigma-1} T_{nt} p_{in,t} x_{in,t}}{1+\tau_{in}} + \sum_{i \neq n}^{M-1} RP_{in,t} - \sum_{i \neq n}^{M-1} RP_{ni,t} + R_t B_{n,t-1} - B_{nt}, \tag{24}$$

with $RP_{in,t} = \chi_{in} \frac{A_{in,t}}{T_{it}} \Pi_{it}$.

The world market-clearing condition for bonds is given by

$$\sum_{n=1}^{M} B_{nt} = 0. \tag{25}$$

Finally, there is a government that collects import tariffs and rebates them back to consumers lump sum:

$$\text{IBT}_{nt} = \sum_{i=1}^{M} \frac{\pi_{ni,t}}{1+\tau_{ni,t}} Y_{nt} \tau_{ni,t}. \tag{26}$$

2.6 Tariff and IP protection negotiation

I assume that countries i, a low-enforcement country, and country n, a high-enforcement country, engage in bilateral negotiations regarding tariffs, represented by τ_{ni}, and the quality of IPR enforcement denoted as ξ_{in}. During these negotiations, the pair of countries aim to maximize their Nash product while considering the actions of the other countries as given. This negotiation procedure follows the concept of Nash-in-Nash bargaining, as described in Bagwell, Staiger, and Yurukoglu (2021). However, unlike that approach, which is applied to multilateral negotiations where several pairs of countries choose their tariffs, in my model, there are only two countries negotiating an agreement over both tariffs and the quality of IP, while the rest of the world maintains fixed tariffs and IPR enforcement. I assume that the government chooses the policy instruments once and for all at time zero. Hence, the new IPR protection applies to new technologies that are adopted after time zero.[9] Second, there is perfect enforcement of IPR, and neither country can deviate once they have signed the agreement.

Formally, when country i negotiates with country n, they determine tariffs τ and the quality of IPR ξ that maximize their joint surplus, represented by the following equation:

$$\max_{\tau,\xi} \Delta W_i(\tau,\xi)^{\theta} \Delta W_n(\tau,\xi)^{1-\theta} \tag{27}$$

subject to $\Delta W_i > 0$ for all i. Here, ΔW_i represents the welfare change, measured in consumption-equivalent units (inclusive of the transition), between maintaining the current level of tariffs and quality of IPR enforcement from the beginning of the negotiation or signing the agreement and maintaining it indefinitely. The parameter $\theta \in (0,1)$ denotes the bargaining power of country i.

Specifically, welfare gains, ΔW_i, are computed as :

$$\sum_{t=0}^{\infty} \beta^t u\left(C^{*}_{it}(\tau_0,\xi_0)\left(\frac{\Delta W_i}{100}+1\right)\right) = \sum_{t=0}^{\infty} \beta^t u\left(C_{it}(\tau,\xi)\right). \tag{28}$$

[9]This is similar to Grossman and Lai (2004).

This equation computes the constant amount of consumption, denoted as ΔW_i, that needs to be provided to the consumer in each period to make them indifferent between signing the agreement and remaining in the status quo, represented by the star symbol.

2.7 Equilibrium

For all i and n, an equilibrium in which all firms behave symmetrically is defined as a vector of policy instruments $\{\tau_{in,t}, \xi_{in,t}\}_{t=0}^{\infty}$ an initial vector $\{A_{in,0}, Z_0\}$, a set of parameters $\{\sigma, \beta_r, \beta_a, \eta, \theta\}$ that are common across countries, a set of parameters $\{\lambda_n, \bar{\varepsilon}_{in}, d_{in}, \eta_i, \bar{\rho}_{in}\}$ that differ across countries, a sequence of aggregate prices and wages $\{P_{it}, W_{it}, R_t, V_{it}\}_{t=0}^{\infty}$, a sequence of intermediate prices $\{p_{in,t}\}_{t=0}^{\infty}$, a sequence of royalty fees, $\{\chi_{in}\}_{t=0}^{\infty}$ a sequence of value functions $\{V_{in,t}, V_{in,t}^{\text{innov}}, J_{in,t}, J_{in,t}^{\text{innov}}, W_{in,t}\}_{t=0}^{\infty}$, and profits $\{\Pi_{it}, R_{in,t}, \text{IBT}_{it}\}_{t=0}^{\infty}$, a sequence of quantities $\{Y_{it}, H_{it}^r, H_{in,t}^a, \pi_{in,t}\}_{t=0}^{\infty}$, and laws of motion $\{A_{in,t+1}, Z_{nt}\}_{t=0}^{\infty}$ such that:

1. $\{A_{in,t+1}, Z_{nt}\}_{t=0}^{\infty}$ satisfy the law of motions in equations (12) and 9).

2. Given prices, allocations solve the consumer's problem maximizing equation (1) subject to (2).

3. Given prices, allocations solve the final producer's problem in equation (4).

4. Given prices, allocations solve the intermediate producer's problems in equation (6) subject to (4).

5. Given prices, allocations solve the innovator's and adopters' problems in equations (14) and (18).

6. The royalty fee is determined as the result of Nash bargaining between the innovator and adopter.

7. Tariff and quality of IPR bargaining equilibrium are defined as a vector of tariffs, τ, and IPR enforcement, ξ_n, such that for each pair i, n these vectors solve equation (27) taking as given all other tariffs and IPR enforcement. I assume that the agreement is perfectly enforced and time consistent. In other words, the equilibrium policies and outcomes remain optimal and consistent over time.

8. Feasibility is satisfied in equation (20).

9. Prices are such that all markets clear (labor market, government tax revenues, consumer's budget constraint, and bond market) in equations (22)-(25).

A list with all the equations of the model is presented in Appendix C.

2.8 Balanced Growth Path

Cross-country adoption guarantees that the model has a unique BGP equilibrium in which all countries grow at a constant rate but differ in relative levels. Growth in the BGP is endogenous. Changes in trade costs, d_{in}, and in the quality of IPR enforcement, χ_{in}, have both growth and level effects. I stationarize all the endogenous variables so that they are constant on the BGP, denote the normalized variables with a hat, and remove all time subscripts in the derivation. Here I characterize the BGP growth rate of the economy (variables on the BGP are characterized with a star).

The stock of knowledge T_n^* grows at the constant rate $g*$, which is common across all countries. Combining equations (9) and (12), I can express the BGP growth and relative productivity of country i as

$$g^* \hat{T}_i^* = \sum_{n=1}^{M} \frac{\varepsilon_{in}^*}{\varepsilon_{in}^* + g^*} \lambda_n \hat{T}_n^* \left(\frac{\hat{H}_n^{r*}}{\hat{Y}_n^*} \right)^{\beta_r}. \tag{29}$$

Following Eaton and Kortum (1999), the Frobenius theorem guarantees that there is a unique growth rate on the BGP in which all countries grow at the same rate g. The expression for the growth rate can be expressed in matrix form as

$$g^* \hat{T}^* = \Delta(g^*) \hat{T}^*.$$

If the matrix $\Delta(g^*)$ is a positive definite, then there exists a unique positive BGP rate of technology $g^* > 0$, given research intensities and diffusion parameters. Associated with that growth rate is a vector T (defined up to a scalar multiple), with every element positive, which reflects each country's relative level of knowledge along that BGP. Changes in trade costs, d_{in}, and IPR, χ_{in}, have an effect on g and T through changes in $\hat{H}_n^{r*}/\hat{Y}_n^*$ and ε_{in}^*.

In Appendix E, I provide details on the derivation of the BGP, and in Appendix D, I summarize the equations of my model's equilibrium conditions after normalizing all endogenous variables.

3 The Mechanism

I study the main channels from signing a trade agreement with IP provisions in a simplified version of the trade and growth model. Consider a two-country world composed of North and South, characterized by varying levels of IP enforcement. North enforces IP rights perfectly ($\eta_N = 1$), while South exhibits imperfect IP enforcement ($\eta_S < 1$). Additionally, North imposes tariffs on imports from South, whereas South does not impose any tariffs.

Upon signing a trade agreement, North and South engage in a bargaining process to determine the level of IP enforcement in South (ξ_{Sn}) and the tariff level imposed by North on imports from South (τ_{NS}). The objective of this Nash bargaining process is to maximize the joint surplus of the two countries, as represented by equation (27).

The model identifies several inefficiencies arising from imperfect IP enforcement and existing tariffs before the trade agreement. The trade agreement aims to address these inefficiencies and enhance economic outcomes for both countries.

Imperfect IP enforcement in the South enables IP infringement, which diminishes incentives for domestic and foreign investment in R&D. The presence of tariffs imposed by the North creates trade barriers, restricting market access for South's products and diminishing the potential gains from trade.

Countries with low IP enforcement do not fully internalize the negative impact of their actions on R&D investment and the global growth rate. Policies that enhance IP protection can help rectify these inefficiencies, albeit at the cost of low IP enforcement countries facing higher adoption costs. Tariffs can be employed as a means to incentivize low-enforcement countries to improve their IP protection, thus addressing the inefficiency. Importantly, changes in tariffs and IP protection also have spillover effects on other countries when the analysis is extended to a multi-country framework.

Increasing ξ_{Sn} reduces IP infringements and encourages innovation in the South, while reducing tariffs enhances market access for South's products. In the model, a trade agreement that improves the quality of patent protection in the South and eliminates tariffs from the North to the South has the following effects:

Firstly, innovation efforts increase in both the North and the South as innovators from both countries receive higher royalty payments. Tariff reductions also stimulate innovation in the South by expanding its market size. Adopters in the South face higher costs for adopting foreign technologies and earn reduced profits, resulting in a decrease in adoption intensity. The increased innovation in both the North and the South contributes to a higher BGP growth rate, yielding dynamic gains for both countries.

However, the distribution of welfare gains during the transition period differs significantly between the North and the South. The North experiences positive gains in the short run, whereas the South faces short-term losses due to higher adoption costs. The specific characteristics of the trade agreement and its impact on welfare, innovation, and growth depend on several factors, which will be further explored in the quantitative analysis. One important factor is the initial level of tariffs, as it plays a crucial role in motivating the South to reform its IP protection. When the initial tariffs imposed by the North are low, the South has less incentive to enhance its IP protection compared to scenarios with higher initial tariffs.

To fully capitalize on the benefits of the trade agreement, it is essential for the South to make domestic improvements in its IP regime. These trade agreements often involve restructuring the court system in the South and granting increased protection to domestic innovators, which is then extended, sometimes at lower levels, to foreign innovators. Therefore, the efficiency of innovation in the South is critical for the country to realize gains from the agreement.

In general, the greater the efficiency of innovation and the higher the initial level of tariffs, the more significant the optimal improvement in IP protection that the South will be willing to undertake. These factors shape the overall outcome of the trade agreement, highlighting the complex interplay between IP enforcement, tariffs, innovation, and economic growth.

4 Quantitative Analysis

The model is calibrated to data on trade flows, geography, income, R&D spending, and international technology licensing for the year 2000 for 41 countries aggregated into three regions: the United States, China, and an aggregate rest of the world. A quantitative exercise evaluates the effects on innovation, growth, and welfare of a trade agreement by which China improves its IPR and benefits from lower tariffs when exporting to the United States. I then evaluate the short-term and long-term effects of the agreement, assuming that it is perfectly enforced.[10] To explore further the interaction between trade liberalization and IP reforms, I evaluate the model under three alternative counterfactual scenarios: (i) China reforms its IP but the United States does not lower its tariffs on Chinese imports; (ii) the United States lowers its tariffs but China does not reform its IP; and (iii) China improves its domestic IP laws but does not sign a trade agreement.

4.1 Calibration

Some of the parameters of the model are calibrated using values from the literature; others are estimated outside the model by running gravity regressions; the remaining parameters are calibrated by solving the BGP of the model, taking as given the value of the other parameters. I begin by describing the parameters that are calibrated from the literature. 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). I set the discount factor β to 0.96, which implies an annual interest rate of 4%. The remaining parameters of the model are calibrated in three steps using data on trade flows, geography, R&D spending, income, and royalty payments for the year 2000. First, I calibrate trade costs and productivity, estimating a gravity equation of bilateral trade flows, following Waugh (2010). Second, I calibrate the adoption parameters estimating a BGP gravity equation of bilateral royalty payments, following the methodology developed in Santacreu (2021). Third, I calibrate the innovation parameters, adapting the algorithm developed by Cai, Li, and Santacreu (2021). I provide details on the calibration strategy next. The calibrated parameters are reported in Table 1.

Trade costs and relative productivity Using data on bilateral trade flows, geography, and GDP per capita from CEPII for 2000, I calibrate transport costs, $d_{in}(1+\tau_{in})$, and productivity, $\Omega_n^{\sigma-1}T_n$, by running the following reduced-form regression, derived from manipulating equation (39):

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

[10] I abstract away from a potential hold-up problem as in Celik, Karabay, and McLaren (2020), since there is no upfront investment needed ahead of the agreement. Indeed, this is an agreement on flows: It involves more royalty payments and lower tariffs.

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_{ni} and include a common border effect, common currency effect, and regional trade agreement between country n and country i. I include an exporter fixed effect, S_n; an importer fixed effect, $\log(S_i)$; and an exporter fixed effect, $\log(S_n) - (\sigma-1)fe_n$, where fe_n is part of the trade costs, which has been shown to better fit the patterns both in country incomes and in observed price levels (see Waugh, 2010). According to the model, $S_i = \Omega_i^{\sigma-1} T_i \left(\frac{\omega_i}{P_i}\right)^{1-\sigma}$. Using the estimated value for S_i, data on GDP per capita, and $\sigma = 5$, I recover $\Omega_i^{\sigma-1} T_i$ and obtain trade costs from the following expression:

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

Finally, I use data on bilateral tariffs from UN-CTAD to calibrate τ_{in} and back out the iceberg transport costs, d_{in}, from the gravity estimation results. The results are reported in the top panel of Table 1.

Probability of Adoption A novelty of the calibration strategy in this paper is that it estimates the probability of adoption using data on bilateral royalty payments and gravity methods. The model yields a structural gravity equation of royalty payments that can be estimated and allows us to infer the probability of adoption across country-pairs. Royalty payments are a more direct form of technology diffusion than other measures used in the literature such as international patenting, trade, or patent citations. See Santacreu (2021) for a detailed description of the advantages and drawbacks of using royalty payments as a measure of trade in intangibles.

In particular, I calibrate the probability of adoption, ε_{in}, by estimating a structural gravity equation of royalty payments from the BGP of the model. Royalty payments from country i to country n are given by

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

Solving for equations (12) and (9) on the BGP, I obtain an expression for royalty payments given by

$$RP_{in,t} = \frac{\varepsilon_{in}}{\varepsilon_{in} + g} \lambda_n T_{nt} \left(\frac{H^r_{nt}}{Y^w_t} \right)^{\beta_r} \Pi_{it}. \tag{30}$$

Note that this expression resembles a gravity equation with exporter-time and importer-time fixed effects and time-invariant bilateral fixed effects. Taking logs of 30,

$$RP_{in,t} = \exp\left(fe_{in} + S_{nt} + F_{it} + \epsilon_{in,t}\right) \tag{31}$$

with $fe_{in} = \log\left(\frac{\varepsilon_{in}}{\varepsilon_{in}+g}\right)$, $S_n = \log\left(\lambda_n \frac{T_n}{T_i}\left(\frac{H^r_n}{Y_n}\right)^{\beta_r}\right)$, and $F_i = \log\left(\frac{\Pi_i}{T_i}\right)$. I then estimate the nonlinear version of equation (31) with PPML methods as in (Santacreu, 2021). In particular, I regress bilateral royalty payments on exporter-time, importer-time, and country-pair fixed effects. I recover ε_{in} from the bilateral fixed effects, assuming a productivity growth rate of 1.85%. Finally, I impose adoption within the country so that $\varepsilon_{ii} = 0.5$, which implies that domestic adoption occurs every two years as it was established to be the case for the United States (Cai, Li, and Santacreu, 2021; Caballero and Jaffe, 1993). The results are reported in Table 1.

The royalty fee structure I calibrate the royalty fee structure by setting a value for $\bar{\chi}_{in}$ and the quality of IPR ξ_{in} as follows. First, I assume that innovators charge a royalty fee of 25% to both domestic and foreign adopters. This assumption follows the 25% rule by which a party selling a product based on another party's IP must pay that party a royalty of 25% of the gross sales profit before taxes.[11] The 25% rule was initially invented by Goldscheider, Jarosz, and Mulhern (2018) and is used in actual licensing and litigation settings. It assumes that the licensor invented the IP but does not take on the risk associated with developing or selling the product. In the context of my model, since adopters incur costs to learn how to use the technology, they may need a lower royalty fee to have incentives to invest in adoption.[12]

Finally, I assume that there is perfect enforcement of IPR in the United States and in the rest of the world but partial enforcement in China. That is, $\xi_{in} = 1$, $\forall n$ and $i = \{\text{US}, \text{ROW}\}$. However, Chinese adopters only pay a fraction of the agreed royalty fee either domestically or abroad, so that $\xi_{in} = 0.01$, $\forall n$ and $i = \{\text{CHN}\}$.

[11] `https://assets.kpmg/content/dam/kpmg/pdf/2015/09/gvi-profitability.pdf`.

[12] Alternatively, this parameter could be the result of a negotiation process in which the innovator and adopter split their surplus, as in Benhabib, Perla, and Tonetti (Forthcoming) and Hopenhayn and Shi (2020).

Parameters calibrated within the model The remaining parameters, which are calibrated by solving the model on the BGP, are β_r, β_a, λ_n, Ω_n, and $\bar{\varepsilon}_{in}$. I calibrate β_r and λ_n to match a productivity BGP growth rate of 1.85% and R&D intensity data for 2000. In particular, I adapt the algorithm developed by Cai, Li, and Santacreu (2021), which uses the expression for the BGP growth rate in equation (29) and the Frobenius theorem. This algorithm delivers productivity T_n also, which then allows me to back out Ω_n from the estimated $\Omega_n^{\sigma-1}T_n$. Finally, I set $\beta_a = \beta_r$, since there are no bilateral data on adoption spending, and recover $\bar{\varepsilon}_{in}$ by setting ε_{in} to its calibrated value when solving the model.

Table 1: Calibrated parameters

Parameter	Value	Source
$\Omega_{\text{US}}\left(T_{\text{US}}\right)^{1/\sigma-1}$	6.25	Gravity trade
$\Omega_{\text{ROW}}\left(T_{\text{ROW}}\right)^{1/\sigma-1}$	2.41	Gravity trade
$\Omega_{\text{China}}\left(T_{\text{China}}\right)^{1/\sigma-1}$	1.00	Gravity trade
$d_{\text{USA,ROW}}(1+\tau_{\text{USA,ROW}})$	2.73	Gravity trade
$d_{\text{USA,China}}(1+\tau_{\text{USA,China}})$	2.95	Gravity trade
$d_{\text{ROW,USA}}(1+\tau_{\text{ROW,USA}})$	6.23	Gravity trade
$d_{\text{ROW,China}}(1+\tau_{\text{ROW,China}})$	6.20	Gravity trade
$d_{\text{China,USA}}(1+\tau_{\text{China,USA}})$	3.18	Gravity trade
$d_{\text{China,ROW}}(1+\tau_{\text{China,ROW}})$	2.90	Gravity trade
L_{US}/L_{China}	0.23	CEPII
L_{ROW}/L_{China}	1.33	CEPII
$\varepsilon_{\text{USA,ROW}}$	0.36	Gravity royalties
$\varepsilon_{\text{USA,China}}$	0.24	Gravity royalties
$\varepsilon_{\text{ROW,USA}}$	0.31	Gravity royalties
$\varepsilon_{\text{ROW,China}}$	0.14	Gravity royalties
$\varepsilon_{\text{China,USA}}$	0.27	Gravity royalties
$\varepsilon_{\text{China,ROW}}$	0.24	Gravity royalties
β_r	0.47	Match $g = 1.85\%$
β_a	0.47	Set $\beta_a = \beta_r$
λ_{US}	0.33	Match R&D intensity in USA
λ_{ROW}	0.28	Match R&D intensity in ROW
λ_{China}	0.19	Match R&D intensity in China
$\bar{\rho}_{in}$	0.25	Royalty fee
η_i	1.00	Perfect enforcement IPR $i = \{\text{US}, \text{ROW}\}$
$\eta_{\text{China},n}$	0.01	Partial enforcement of IPR

4.2 Counterfactual Analysis: Trade Agreement with IP Provisions

I conduct a counterfactual analysis that consists of the United States and China signing a trade agreement with IP provisions. In this agreement, China improves its IPR both domestically and abroad and then benefits from lower tariffs when exporting to the United States. The trade agreement is designed as the solution of a Nash bargaining problem between the two countries, along the lines of Bagwell, Staiger, and Yurukoglu (2020) and Bagwell, Staiger, and Yurukoglu (2021). The payoff function is the pair's Nash bargaining product, and the strategies are the tariffs and quality of IPR enforcement being negotiated by the pair. I then evaluate the effect of this trade agreement on innovation, growth, and welfare. I solve for the perfect foresight solution of the model following the unanticipated, permanent, one-time shock that is the trade agreement.[13]

The Design of the Trade Agreement: Nash Bargaining Equilibrium The trade agreement consists of choosing two policy parameters: US tariffs on imports from China to the United States, $\tau_{\text{USA,China}}$, and the quality of China's IP protection, $\xi_{\text{China},n} = \xi_{\text{China}}$ $\forall n$. The details of the trade agreement are determined as the solution of the following Nash bargaining problem:

$$\max_{\tau,\xi} \Delta W_{\text{USA}}(\tau,\xi)^{\theta} \Delta W_{\text{CHN}}(\tau,\xi)^{1-\theta} \tag{32}$$

subject to $\Delta W_i > 0$ $\forall i$. Here, ΔW_i is the welfare change, in consumption-equivalent units, between staying in the initial BGP or signing the agreement and staying there forever, and $\theta \in (0,1)$ is the bargaining power of the United States. I describe how to compute ΔW_i later.

The result of the Nash bargaining exercise implies elimination of US tariffs on Chinese imports and an increase in the quality of IPR enforcement so that the domestic royalty fee increases to 25% while the foreign royalty fee increases to 11%.

The trade agreement is an unanticipated, permanent, one-time shock. I make two important assumptions that hold throughout the duration of the agreement: (i) There is perfect

[13]The model is solved using a Newton-type algorithm, which uses relaxation techniques. The details of the algorithm can be found in Juillard et al. (1996).

enforcement of the agreement, and (ii) the improvement in IPR applies both to foreign and domestic adopters, although the improvement may have different intensities. That is $\xi_{\text{CHN},n} \neq \xi_{\text{CHN,CHN}}$, $\forall n \neq \text{CHN}$. These assumptions are motivated by current trade agreements that first require significant changes in the domestic legislation of participating countries that then translate into equal treatment of foreign firms.[14]

Then, I solve for the perfect foresight solution of the model, assuming that the economy starts on an initial BGP, which is calibrated to data for the year 2000. In period 1, China and the United States sign the trade agreement as the solution of the problem in equation (32). I then evaluate the impact of such a trade agreement on innovation, growth, and welfare.

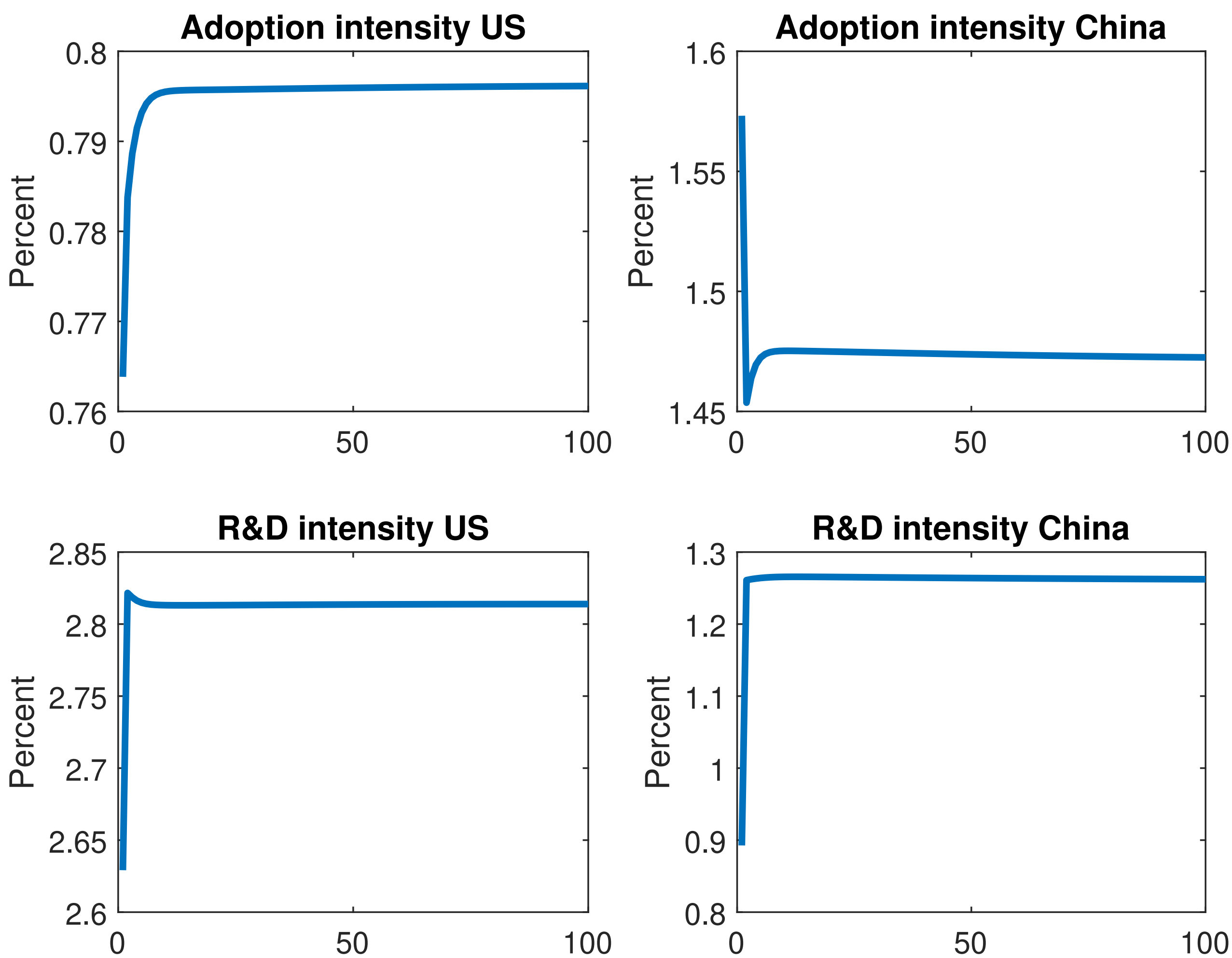
Growth, Innovation, and Adoption The trade agreement has a positive effect on R&D intensity around the world through two channels. First, access to a larger market for Chinese exports increases domestic innovation in China. Second, an increase in IPR enforcement increases the return to innovators, both China and the United States, as innovators start receiving royalties for technologies that are adopted in China. Both countries reach a higher level of R&D intensity in the counterfactual BGP (Figure 1).

Adoption in China is subject to two opposing forces: (i) The return to Chinese adopters decreases, as they now have to pay royalties for technologies they were getting for free, but (ii) adopters profit from exporting intermediate products that are produced with licensed technology. The reallocation effect from adoption to innovation in China implies that, in the counterfactual BGP, R&D intensity is higher and adoption intensity is lower in China. In the United States, however, adoption intensity go up: adopters benefit from more technologies being invented in China.

BGP Growth As a result of more innovation worldwide, the BGP growth rate increases from 1.85% to 1.93%. The left panel of Figure 2 shows the evolution of productivity growth in the United States and in China after they sign the trade agreement. Both countries' productivity grows at the same 1.85% rate on the initial BGP. When the agreement is signed, China's productivity growth increases, overshooting the final BGP, as there is a

[14]For instance, the text of the Central America Free Trade Agreement (CAFTA), a NAFTA-style deal between the United States and five Central American nations (Guatemala, El Salvador, Honduras, Costa Rica, and Nicaragua), states that "each Party shall accord to nationals of the other Parties treatment no less favorable than it accords to its own nationals with regard to the protection and enjoyment of such intellectual property rights and any benefits derived from such rights".

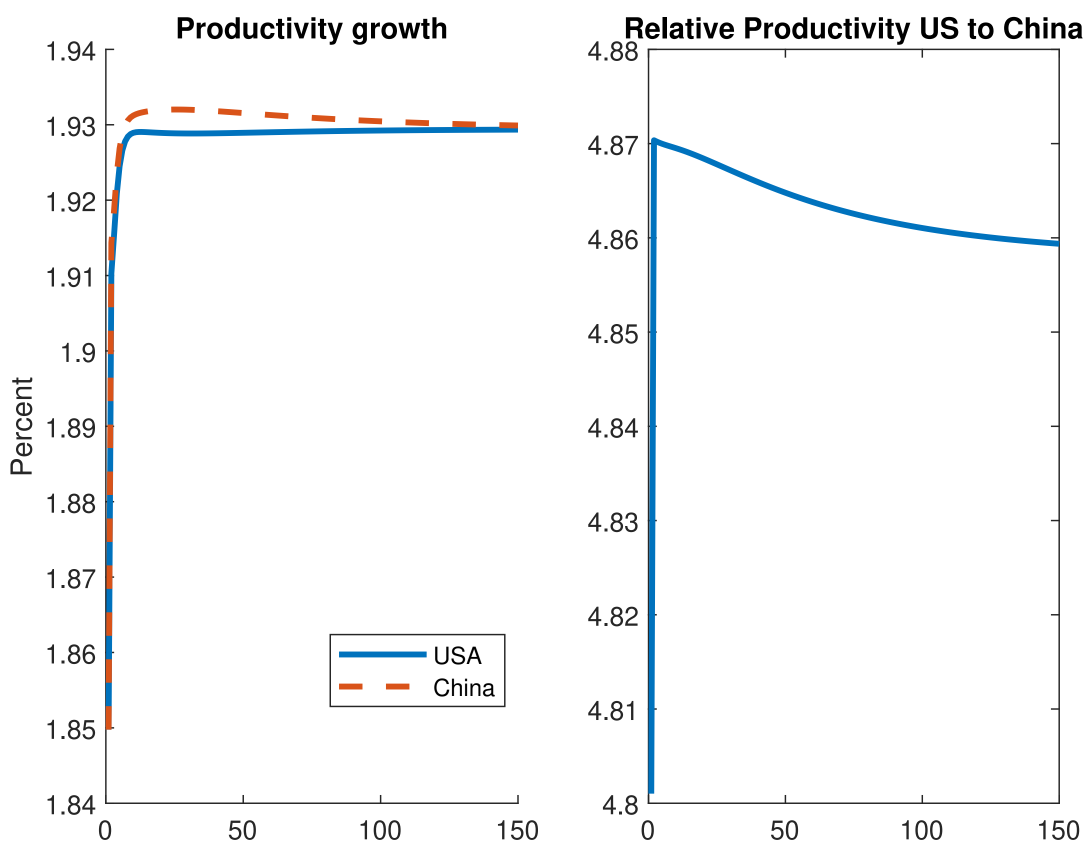
Figure 1: R&D and adoption intensity



Notes: The Figure plots the evolution of adoption and R&D intensity in the United States and China during the 100 years following the signature of a trade agreement with IP provisions designed as Nash bargaining. Period 0 represents the initial BGP.

large increase in innovation that is driven by both improved IPR protection and access to a larger export market. In the United States, the growth rate increases smoothly toward the final BGP. Both countries reach a BGP growth rate of 1.93% on the counterfactual BGP. Changes in growth rates are driven by the endogenous responses of innovation and adoption after changes in IP protection and trade costs. Moreover, the agreement increases inequality through a rise in relative productivity of the United States with respect to China, as the right panel of Figure 2 shows.

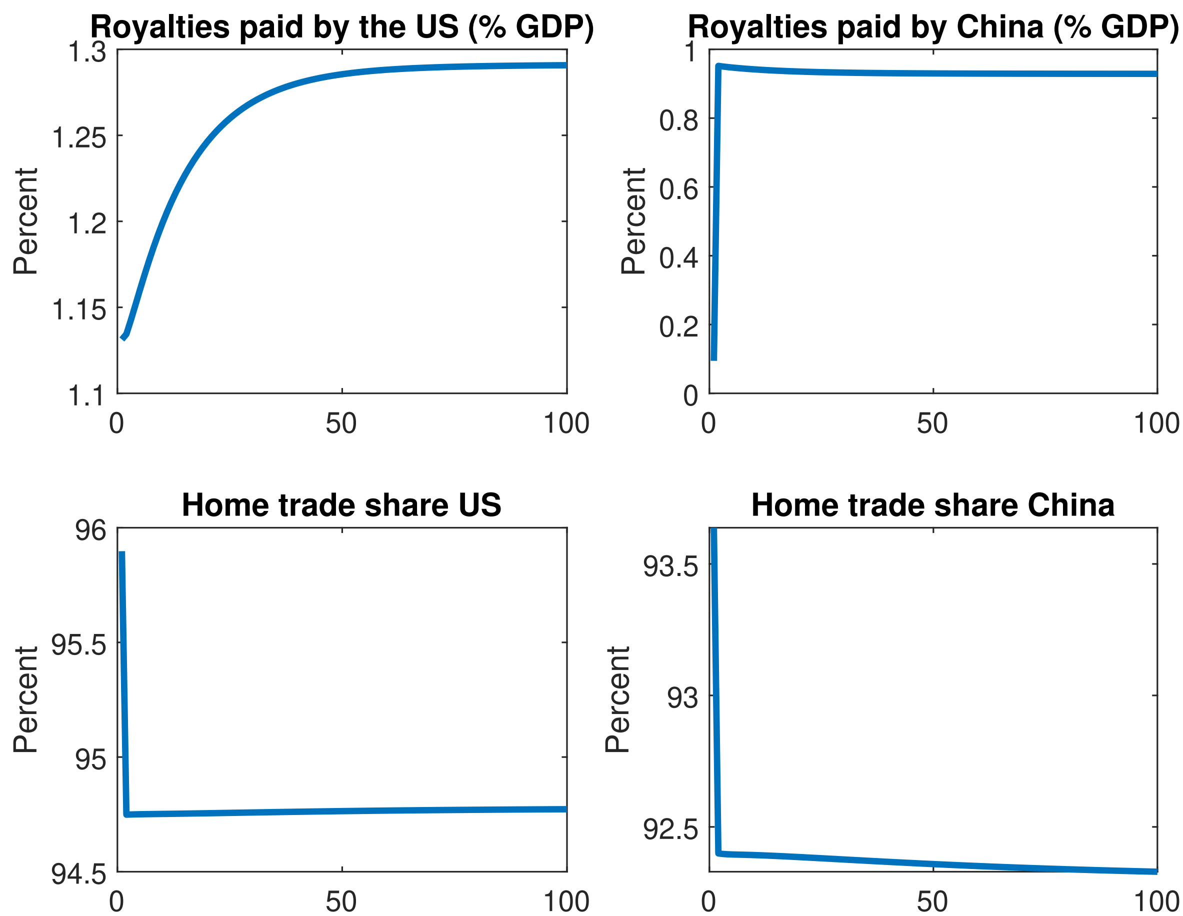
Figure 2: Growth rate of productivity



Notes: The Figure plots the evolution of productivity growth in the United States and China (left panel) and relative productivity of the United States with respect to China (right panel), during the 150 years following the signature of a trade agreement with IP provisions designed as Nash bargaining. Period 0 represents the initial BGP.

Trade and Royalties The decrease in export costs from China translates into a decrease in the US home trade share (Figure 3), so productivity increases through the standard channel present in static trade models.

Figure 3: Trade and royalty payments



Notes: The Figure plots the evolution of royalty payments made by the United States and China and their home-trade shares during the 100 years following the signature of a trade agreement with IP provisions designed as Nash bargaining. Period 0 represents the initial BGP.

The improvement in IP protection implies that China starts paying more royalties to domestic and foreign innovators for two reasons: (i) They pay higher prices for adopted technology, as they now have to pay royalties for technology they were previously getting for free, and (ii) they start receiving more foreign technology. Royalty payments from China to the United States increase (Figure 3). The United States also pays more royalties to China after signing the agreement, as China becomes more innovative: (i) The return to R&D in China increases through an improvement in IPR and through access to a larger export market, and (ii) there are spillover effects to the innovation process though an increase in foreign technologies being transferred to China. The two forces interact so that so that the technology trade imbalance between the United States and China becomes wider.

4.3 Welfare Analysis

The results presented so far have implications for welfare. I compute welfare gains from IPR improvements accompanied by trade liberalizations in consumption-equivalent units. Denote λ_i, which corresponds to ΔW_i in equation (32), as the additional consumption the consumer needs every period to be indifferent between the baseline and counterfactual. Specifically, welfare gains are computed as

$$\int_{t=0}^{\infty} \beta^t u \left(C_{it}^* \left(\frac{\lambda_i}{100} + 1 \right) \right) dt = \int_{t=0}^{\infty} \beta^t u \left(C_i \right) dt. \tag{33}$$

Evaluating welfare along the transition allows us to address the issue that BGP to BGP gains may be overstated, as firms need to make a costly investment (i.e, R&D or adoption) to benefit from higher long-term growth (see also Ravikumar, Santacreu, and Sposi, 2019; Perla, Tonetti, and Waugh, 2015).

I find that all countries experience welfare gains from signing the agreement (first column of Table 2). The United States has the largest gains in consumption-equivalent units (2.17%), whereas China experiences the lowest gains (1.03%). Despite all countries experiencing positive gains overall, the way these accrue during the transition is heterogeneous across countries. I disentangle the short-term and long-term implications of the trade agreement by analyzing the transitional dynamics of consumption in the United States and in China following the shock.

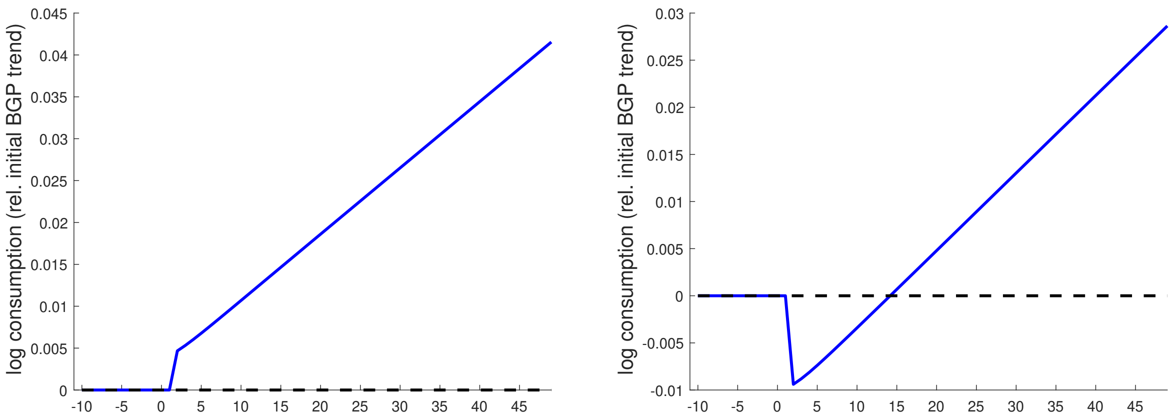
Figure 4 shows the evolution of consumption per capita over time. Specifically, the figure plots the log of consumption relative to its initial BGP path, both in the United States (left panel) and in China (right panel). The solid lines in the two panels represent the log of consumption in the counterfactual—relative to the initial BGP consumption path. The horizontal lines at zero represent the initial BGP. The shock hits in period 1. From period -10 to period 1, the economy is in the initial BGP and consumption per capita grows at the rate of 1.85%. In period 1, China and the United States sign the trade agreement, which implies a jump in the level of consumption and a change in the growth rate. An improvement in IPR leads to a higher BGP growth rate of consumption in both the United States and China, which materializes in positive gains in the long run. However, consumption drops initially in China, implying short-term losses. The log of consumption crosses the horizontal dashed line more than 10 years after the initial shock, and China starts experiencing positive gains. The short-term losses in China from an improvement in its IPR are driven by the following channels: (i) Profits of adopters decrease as they have to pay more royalties, whereas profits of innovators increase as they receive more royalties. Because China has a comparative advantage in adoption versus innovation, overall profits go down, decreasing output; (ii) the increase in profits of innovators increases R&D spending. The decline in output together with the increase in investment in innovation decreases consumption in China in the short run. The trade liberalization helps to dampen the negative effect on consumption, as adopters and innovators benefit from access to a larger market. In the long run, the larger investment in R&D in China increases growth to 1.93% (first column of Table 3), leading to long-term gains. The result is that it takes 10 years for higher BGP growth to replace previously cheaper adoption.

In the United States, there are both short-term and long-term gains. Profits of both adopters and innovators go up, increasing output in the short and long run. The increase in output dominates the increase in R&D investment, driving consumption up. This channel is reinforced by a trade liberalization, as US final producers have access to cheaper intermediate products from China and the home trade share decreases.

Understanding the Mechanism To better understand the main channels at play, I ask the following question: How do reforms in IPR impact the gains from trade liberalization? To address this question, I consider three alternative scenarios. First, I consider the case in which China improves its IP protection but does not benefit from lower tariffs. Second, I consider an alternative scenario in which the United States lowers import tariffs from China, but China does not improve its IPR. Finally, I evaluate whether China has incentives to enter a trade agreement with IP provisions beyond just reforming its domestic IPR unilaterally. Specifically, I conduct a counterfactual exercise in which China improves its domestic IPR but does not sign a trade agreement.

Figure 4: Log of consumption

(a) United States (b) China



Notes: The figure plots the evolution of the log of consumption relative to its initial BGP trend in the United States (left panel) and China (right panel) 10 periods before and 50 periods after signing a trade agreement with IP provisions. The agreement is signed in period 1.

Table 2 reports welfare gains in each scenario. I find that both countries experience positive gains when there is an improvement in IPR, regardless of whether or not tariffs are reduced. However, the United States loses from reducing tariffs if China does not simultaneously improve its IPR. Finally, China gains from improving its domestic IPR, but the gains are larger if these reforms are part of a trade agreement with IP provisions. Hence, becoming part of a trade agreement gives China extra incentives to improve its domestic IP laws.

Table 2: Welfare Gains: Alternative scenarios

	Baseline	Only IPR	Only Trade	Dom. IPR (no agreement)
USA	2.17	3.85	-0.53	0.95
China	1.03	0.29	0.36	1.02

Notes: The table reports welfare gains from alternative policies: (1) Trade agreement with IP reforms and lower tariffs, (2) only IPR reform (both domestic and foreign), (3) only lower tariffs, and (4) improvement of domestic IPR (without trade agreement).

The results presented so far reflect both long-run and short-run effects. In the long run, the three alternative counterfactual exercises have an impact on growth. First, improving

IPR increases innovation, and hence the BGP growth rate regardless of whether or not the United States lowers its tariffs to Chinese imports. However, the BGP growth rate increases more when tariffs are not eliminated: the growth rate increases from 1.85% to 1.98% in this case. Second, a reduction in US tariffs that is not accompanied by an improvement of IPR in China decreases the BGP growth rate from 1.85% to 1.83% (see Table 3). Here, US innovators decrease their R&D investment as they do not receive more royalty payments and firms face more competition from imitated products being imported from China. Finally, improving domestic IPR in China unilaterally increases the BGP growth rate to 1.88%, which represents a lower increase than when domestic reform occurs as a part of a trade agreement.

Table 3: BGP growth: Alternative scenarios

	Baseline	Only IPR	Only Trade	Dom. IPR (no agreement)
Initial BGP	1.85	1.85	1.85	1.85
Final BGP	1.93	1.98	1.83	1.88

Notes: The table reports BGP growth rates from alternative policies: (1) trade agreement with IP reforms and lower tariffs, (2) only IPR reform (both domestic and foreign), (3) only lower tariffs, and (4) improvement of domestic IPR (without trade agreement).

To evaluate the impact of the three alternative counterfactuals on the short run and along the transition, Figure 5 plots the log of consumption relative to the initial BGP consumption path in the three scenarios. The horizontal lines at zero represent the initial BGP, and the shock hits in period 1.

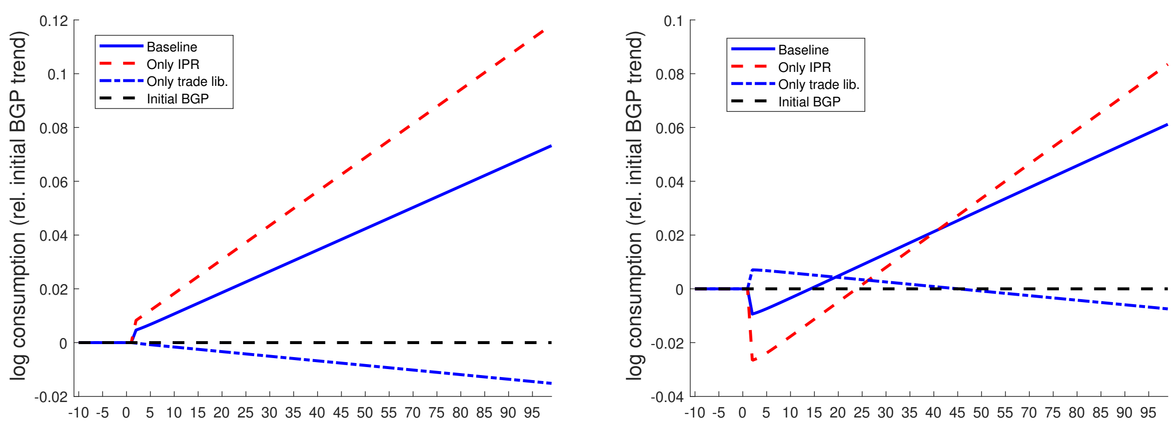
In the case when there is an improvement in IPR without a reduction in tariffs, welfare gains are positive for every country, but they are lower than in the baseline counterfactual for China. Along the transition, China experiences larger short-term losses than in the baseline scenario, which last for almost 20 years. These losses are driven by a larger initial drop in consumption and slower pace toward positive gains. Chinese investment in adoption decreases more than in the baseline counterfactual, as adopters cannot benefit from a larger market where they could sell the intermediate products produced with licensed technology. Profits of adopters decline more, leading to larger decreases in output and hence also in consumption. At the same time, innovators cannot take advantage of a larger market. Because growth rates increase in the long run (column 2 of Table 3), the initial losses convert into gains after several periods, leading to overall positive welfare gains. The United States experiences, as before, short-term and long-term gains. Short-term gains in the United States are larger than in the baseline: there is a larger initial increase in consumption when there is no lowering of tariffs, as the United States does not lose tariff revenue in this case.

Second, when there is trade liberalization without IPR improvement, the United States experiences losses and China experiences gains, although these gains are lower than in the baseline. Lower tariffs increase the return to adoption in China, as intermediate producers can sell their products to a larger market, which translates into higher profits and output. At the same time, Chinese adopters do not pay royalties for the use of foreign technology. As a result, there are positive short-term gains in China. In the United States, lower tariffs lead to a decline in the home trade share, increasing output and consumption. However, the US market faces more competition from Chinese imports produced with imitated technology, which decreases innovation incentives in the United States. These channels translate into negative short-term gains in the United States. Because US innovators are not compensated from their R&D efforts, innovation and world growth decline, generating long-term losses.

Figure 5: Log of consumption relative to initial BGP trend: The Mechanism

(a) USA

(b) China



Notes: The figure plots the evolution of the log of consumption relative to its initial BGP trend in the United States (left panel) and China (right panel) 10 periods before and 50 periods after signing an agreement. The agreement is signed in period 1. The solid line represents the baseline trade agreement with IP provisions. The dashed line represents the case in which China improves IPR, but there is not a reduction in US tariffs. The dash-dotted line represents the case in which there is a reduction in US tariffs but China does not improve its IPR.

The impact of tariff reductions in the United States depends on the initial tariff levels. When the initial tariffs are very low, the United States experiences greater losses from eliminating tariffs if China does not enhance its IPR. This is because high tariffs distort trade, and regardless of China's actions, the US aims to reduce them. However, if China has perfect IPR, removing tariffs would result in more benefits compared to removing them with imperfect IPR. Conversely, when tariffs are initially low, China incurs losses from improving IPR. Therefore, the US requires a margin of tariff flexibility, making it preferable to begin with high tariffs to incentivize China to enhance its IPR.

High tariffs have a distorting effect, so the US desires to lower them, even if China has poor IPR. While the gains from removing tariffs increase with better IPR protection, the US still benefits from reducing tariffs.

If tariffs are initially low, the US faces significant losses if it lowers them without China improving IPR. Additionally, if China enhances IPR and the US removes tariffs starting from low levels, China incurs substantial losses. Therefore, starting with high tariffs allows the US some flexibility to utilize them as an instrument to motivate China to improve its IPR.

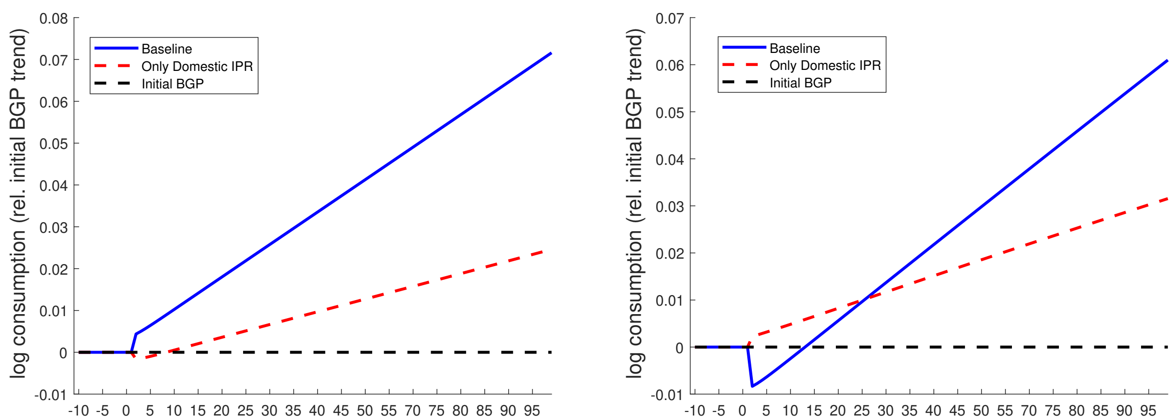
In summary, the US benefits from reducing tariffs, regardless of China's IPR situation. However, having high initial tariffs provides the US with leverage to use them strategically to encourage China to enhance its IPR protection.

Finally, Figure 6 plots the evolution of consumption along the transition when China signs a trade agreement with the United States as in the baseline counterfactual and an alternative scenario in which China improves its domestic IPR without signing an agreement. Improving domestic IPR in China has positive long-term effects everywhere since China becomes more innovative and the world BGP growth rate increases from 1.85% to 1.88%. However, this increase is lower than when China improves IPR as part of a trade agreement (1.88% vs 1.93%). Short-term gains from reforming domestic IPR without a trade agreement are positive in China, since domestic innovators receive more royalties but adopters do not need to pay to foreign innovators. This result contrasts with the case in which China improves its IPR as part of a trade agreement. In that case, China suffered short-term losses. Overall, welfare gains in China are positive but slightly lower than with a signed agreement. An improvement of Chinese domestic IPR without a trade agreement generates short-term losses in The United States that last about 7 years. US innovators are not compensated for their

R&D efforts, and innovation goes down. The result is a lower BGP growth rate. These results imply that reforming IPR in China as part of a trade agreement has additional welfare effects for China. However, by signing an agreement, China goes through short-term losses, whereas improving domestic IPR without a signed agreement implies both short-term and long-term gains in China.

Figure 6: Log of consumption relative to initial BGP trend: Domestic IP Reform in China vs Trade Agreement with the United States

(a) USA (b) China



Notes: The figure plots the evolution of the log of consumption relative to its initial BGP trend in the United States (left panel) and China (right panel) 10 periods before and 50 periods after signing a trade agreement with IP provisions in the case of signing a trade agreement with IP provisions (solid line) and in the case in which China improves domestic IPR without being part of a trade agreement (dashed line). The agreement is signed in period 1.

Welfare-maximizing versus Politically-Motivated Government The trade agreement with IP provisions in equation (32) has been designed by a welfare-maximizing government, who chooses tariffs and level of IP protection to maximize welfare as calculated in consumption-equivalent units at the consumer's discount factor. By signing such a trade agreement, I found that both the United States and China gain overall, but China suffers short-term losses (see Figure 4). This agreement may not be attractive to a politically-motivated government that wants to minimize short-term losses in China. Here, I consider the design of a trade agreement made by a government with short-term objectives. Specifically, I assume the government has a lower discount factor than the consumer (i.e., 0.90

vs 0.96). I then compute the level of tariffs and quality of IP enforcement that solve the bargaining problem in equation (32), where welfare gains are computed at the government's discount factor. The new agreement implies a lower decline in US tariffs and a lower increase in Chinese royalty payments for foreign technology. Specifically, the new agreement consists of a reduction of US tariffs on Chinese imports of 80%, full improvement of domestic IPR in China, and an increase of China's foreign royalty fee from 1% to 10%. Compared to the main trade agreement, welfare gains in the United States are now lower, whereas China gains more overall (see Table 4). Both countries have positive gains in the short run (see Figure 7). On the one hand, when an agreement is designed by a politically motivated government, China agrees to improve foreign IP less than before, resulting in a lower increase of the BGP growth rate (1.93% in the welfare-maximizing agreement and 1.90% in the politically-motivated agreement). On the other hand, China pays less royalties abroad, which increases consumption in the short term. Hence, a politically-motivated government can reach a trade agreement where all countries gain both in the the short and in the long run, at the expense of lower BGP growth, hence lower long-term gains.

Table 4: Welfare Gains: Welfare-maximizing vs politically-motivated agreement

	Baseline	Only IPR
USA	2.17	1.11
China	1.03	1.15

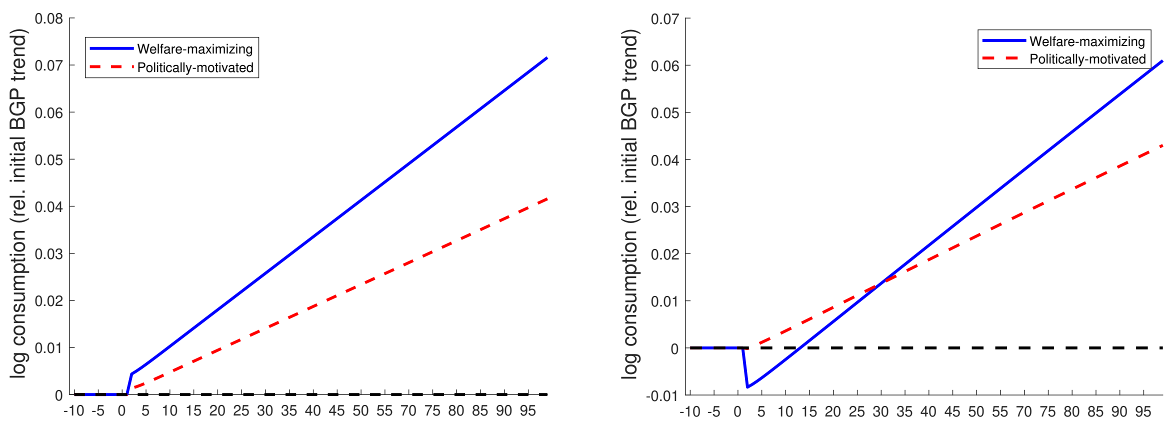
Notes: The table reports welfare gains from trade agreements designed by: (1) welfare-maximizing government ($\beta = 0.96$); and (2) politically-motivated government ($\beta = 0.90$)

5 External Validation: Dynamics of International Licensing Following Deep Trade Agreements

One of the main implications of the model is that deep trade agreements with strict IP provisions increase royalty payments from developing to developed countries that sign such an agreement. However, trade liberalizations that reduce trade costs without requiring IP improvements have a non-negligible or negative effect on royalty payments. In this section, I study empirically the dynamics of international technology transfer following membership into RTAs with IP provisions. The main question of interest is, do trade agreements with

Figure 7: Log of consumption relative to initial BGP trend: Welfare-maximizing ($\beta = 0.96$) vs politically-motivated government ($\beta = 0.90$)

(a) USA (b) China



Notes: The figure plots the evolution of the log of consumption relative to its initial BGP trend in the United States (left panel) and China (right panel) 10 periods before and 50 periods after signing a trade agreement with IP provisions in the case of a welfare-maximizing government (solid line) or a politically-motivated government (dashed line). The agreement is signed in period 1.

IP provisions increase technology transfers from developed to developing economies?

The measure of technology transfer used throughout the analysis is technology licensing across countries (see Maskus, 2004, for a review of different types of technology transfer and the importance of licensing). I follow Santacreu (2021) and use data on bilateral royalty payments collected from the OECD Balanced Trade in Services dataset for 41 countries for 1995-2012. These data represent a more direct measure of technology diffusion than what has been typically used in the literature, such as international trade or foreign direct investment (FDI), because the transactions involved in international licensing leave a paper trail: These are contracts by which a patent owner (the inventor or exporter of the technology) licenses the right to use the patent to a foreign firm (the technology importer) in order to produce a good. In exchange for the license, the technology importer pays a royalty fee to the innovator. Technology licensing has become more important over time. While in the 1980s world royalty payments accounted for 0.06% of world GDP, this share was about 0.50% by 2019 (0.12% in 1995 and 0.40% in 2012).[15] These numbers could be reflecting both an

[15]Data from World Development Indicators (WDI) World Bank.

increase in technology transfer in the world and an increase in payments for technology that previously was obtained for free. Hence, royalty payments are a form of technology transfer that is impacted by the quality of IPR enforcement. In the extreme case of pure imitation, firms do not pay any royalties to the innovator; in the other extreme of perfect enforcement of IPR, foreign firms pay royalties according to a previously stipulated fee. While several studies have found that improvements of IPR have a positive effect on technology licensing across countries (Branstetter, Fisman, and Foley, 2006), the dynamics of international technology licensing in the context of RTAs with IP provisions have not been studied yet. To do that, I follow the methodology developed by Martínez-Zarzoso and Chelala (2021), who compile a database of RTAs with technology transfer and innovation-related provisions from trade agreements that entered into force between 1995 and 2012. They decompose RTAs into those with and without technology provisions. These are RTAs that go beyond the TRIPS agreement that was part of the WTO formation in 1995. They further classify provisions into four subgroups: (1) general intention to transfer technology, (2) technical cooperation, (3) joint R&D effort, and (4) IP.

Before conducting a more rigorous econometric analysis, I show in Figure 8 the evolution of royalty payments from developing countries to developed countries during 1995-2012, before and after they signed an RTA agreement.[16] RTAs with strict IP provisions are a way for developed countries to enforce IPR improvements in developing countries. I split the sample of country-pairs into those that sign only RTAs with IP provisions (solid line) and those that sign only RTAs without IP provisions (dashed line).[17] I restrict the attention to country-pairs involving a developed country sending technology to (i.e, receiving royalties from) a developing country. Royalty payments are normalized to 1 on the year in which the agreement is enforced. Each line in the figure represents the average across all country-pairs or normalized royalty payments.

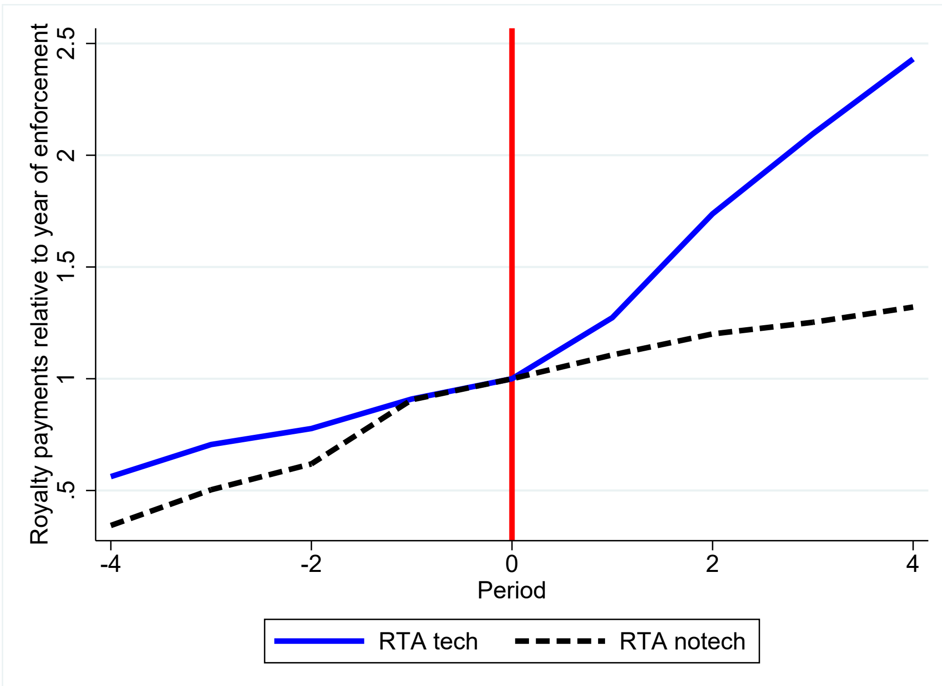
The figure shows a sharp increase in royalty payments from developing to developed countries following the year in which an RTA with IP provisions enters into force. In contrast, RTAs without IP provisions imply a slower rate of technology transfer to developing economies that sign such an agreement.[18]

[16] Developing countries are defined as those with a GDPpc $\leq$ 12,500USD.

[17] There is a total of 101 pairs that have only RTAs that have IP provisions, 130 pairs with only RTAs with no IP provisions, and 7 pairs that have both types of agreements.

[18] In Appendix F I plot the dynamics of royalty payments for a sample of country-pairs.

Figure 8: Dynamics of International Technology Licensing During RTAs with IP Provisions



Notes: The figure shows the evolution of royalty payments from developing to developed countries 5 years before and 5 years after they sign a trade agreement with technology provisions. It considers all trade agreements signed between 1995 and 2012. The vertical line at zero represents the time at which the agreement enters into force.

Next, I conduct an econometric analysis to evaluate the effect of RTAs with IP provisions on technology transfer between countries. I follow Baier and Bergstrand (2007) and estimate a reduced-form gravity regression with exporter-time, importer-time, and country-pair fixed effects to identify the role of IP chapters included in RTAs. In particular, I estimate the following specification:

$$RP_{int} = \exp\left(\sum_{k=1} \text{RTA}_{int} + S_{nt} + F_{it} + fe_{in}\right) * u_{int}, \tag{34}$$

with RTA_{int} a free-trade agreement with technology provisions classified by Martinez-Zarzoso and Chelala (2021), S_{nt} exporter time, F_{it} importer time, and fe_{in} country-pair characteristics. I estimate equation (34) using PPML methods, as recommended by Baier and Bergstrand (2007); Silva and Tenreyro (2006); Yotov et al. (2016); Zylkin (2018). This estimation approach has several advantages. First, as Baier and Bergstrand (2007) show, including time-invariant bilateral dummies allows me to control for potential endogeneity of RTAs (if they are not arbitrarily assigned), as these dummies control for all unobserved heterogeneity related to each country-pair. Second, PPML methods can account for zeros in the dependent variable and can deal with heteroskedasticity of the error term in the gravity equation.

I consider two cases: (i) all 41 countries (1,640 country-pairs) and (ii) only country-pairs that involve a developed and a developing country. The results are reported in Table 5. RTAs include those with technology and non-technology provisions, as well as TRIPS, in order to evaluate whether more-recent RTAs have an effect on technology transfer beyond that of TRIPS. The first two columns focus on the effect on royalty payments, whereas the last two columns focus on the effect on international trade. There are two sources of identification in the regression analysis: (i) It includes observations from before and after an agreement enters into force, and (ii) it also includes country-pairs never signing any agreement during the period of analysis.

Table 5 shows that RTAs with both technology and non-technology provisions have a positive and statistically significant effect on bilateral royalty payments. That is, country-pairs that form RTAs, whether or not they contain strict IP chapters, share more technology. However, when I restrict the attention to country-pairs including a developed and developing country, only RTAs with technology provisions appear to be significant. In this case, the

Table 5: The effect of RTAs with IP provisions on international technology licensing

	Royalties		Trade	
	All	NS	All	NS
RTA tech	0.285***	0.228***	0.0376*	0.103***
	(0.0490)	(0.0533)	(0.0166)	(0.0287)
RTA notech	0.261***	0.0830	0.135***	0.0103
	(0.0646)	(0.0685)	(0.0218)	(0.0418)
TRIPS	0.103	0.128	0.0227	0.00571
	(0.127)	(0.0791)	(0.0398)	(0.0311)
N	28,458	14,544	28,484	14,596
Pseudo R^2	0.71	0.59	0.98	0.98

Notes: Standard errors in parentheses.
Clustered standard errors, clustered by exporter-importer (default).
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Notes: The table captures the effects of RTAs with technology provisions (RTA tech) and without technology provisions (RTA no tech) on bilateral royalty payments (first two columns), and bilateral trade (last two columns) between 1995 and 2012. It controls also for a dummy variable capturing whether the countries are part of TRIPS. The regression is done with PPML methods and it includes exporter time, importer time, and bilateral fixed effects. It considers bilateral flows using the whole sample of countries (columns 1 and 3) and bilateral flows between a developed and a developing country (second and fourth columns).

results suggest that signing RTAs with IP provisions increases royalty payments between the countries by 25%.[19] TRIPS does not have a significant effect when RTAs with IP provisions are considered.

It is important to make a few remarks about endogeneity of RTAs and reverse causality. One issue with the previous analysis is that RTAs may not be randomly assigned and instead are more frequently signed among countries that have strong trading relationships. The approach followed in the previous regressions used the methodology proposed by Baier and Bergstrand (2007), who overcome potential endogeneity by introducing bilateral time-invariant dummy variables. These pair fixed effects capture all unobserved heterogeneity associated with each country-pair relationship.[20] Moreover, as Maskus and Ridley (2021) mention, the concern of potential endogeneity in this type of agreement is limited by how

[19] $[exp(\beta) - 1] * 100$.

[20] In the appendix, I introduce leads of the dependent variable and show that the main empirical findings are preserved.

these agreements take place. Typically, strict IP provisions are required by one negotiating party, especially when these agreements are signed between a developed and a developing country, which happens quite frequently in the sample I use. Because developing countries have lower IPR enforcement than do developed economies, their agreement to improve IPR to get access to international markets is unlikely to be driven by any endogeneity of the trade policy.

The results are robust to estimating different specifications of the gravity regression. Following Baier and Bergstrand (2007), I consider (i) using 5-year intervals, (ii) including lags of RTAs to allow for technology transfer to have a delayed response to RTAs, (iii) including leads of the RTAs to test for potential endogeneity or the trade policy variable, and (iv) considering only those RTAs with IP provisions that refer to patents and IP improvement. The results are reported in Appendix A.

The empirical analysis suggests that countries entering into trade agreements with strict IP provisions experience an increase in royalty payments. IP provisions have a particularly positive impact on payments between developed and developing countries. The increase in royalty payments implies that (i) developing countries are receiving more foreign technology and (ii) developing countries are now paying for the technology they receive. While (i) may have positive effects on developing countries through higher innovation and growth, (ii) may have negative effects as firms in a developing country need to pay for technology they may have previously received at no cost.

6 Final Remarks

The paper develops a quantitative framework to analyze the interconnections between international trade and IPR. It introduces dynamics into a model of trade with endogenous innovation and international technology licensing as the main sources of productivity. The quantitative analysis along the transition allows me to disentangle between the short- and long-run effects of these policies. Imperfect IPR acts as a distortion in the economy, which is amplified by trade. Countries that improve their IPR gains, especially if they face lower tariffs when exporting goods produced with licensed technology. However, a trade liberalization that is not accompanied by IPR improvement creates long-term losses through lower incentives to innovate and higher competition.

The main results have implications for optimal trade and IP policy, as the interactions between the two suggest that trade and IP policies can be used simultaneously to reach a first-best solution. Moreover, the analysis abstracts from imperfect enforcement of trade agreements and lack of commitment. I leave these questions for future research.

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APPENDIX

A Empirical Analysis: Robustness

5-Year Intervals

	Royalties		Trade	
	All	NS	All	NS
RTA tech	0.207**	0.199*	0.0585	0.125**
	(0.0766)	(0.0936)	(0.0314)	(0.0464)
RTA notech	0.216	0.0810	0.0685	0.0666
	(0.121)	(0.151)	(0.0402)	(0.0829)
TRIPS	-0.221	0	0.581***	0
	(0.661)	(.)	(0.154)	(.)
N	6,404	3,292	6,480	3,318
Pseudo R^2	0.70	0.58	0.98	0.98

Notes: Standard errors in parentheses.

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

Leads and Lags of the Trade Policy Variable

	All		NS	
RTA tech	0.284**	0.433***	0.202	0.370*
	(0.0899)	(0.109)	(0.109)	(0.188)
RTA notech	0.178	0.494***	0.243	0.454*
	(0.171)	(0.143)	(0.192)	(0.208)
TRIPS	-0.244	-0.341	0	0
	(0.670)	(0.620)	(.)	(.)
RTA tech (t-1)	-0.0168	0.712***	0.0890	0.629***
	(0.0713)	(0.216)	(0.103)	(0.182)
RTA notech (t-1)	0.282	0.166	-0.0627	0.0583
	(0.187)	(0.112)	(0.135)	(0.128)
RTA tech (t+1)		-0.413***		-0.376*
		(0.0884)		(0.159)
RTA notech (t+1)		0.00284		0
		(0.289)		(.)
N	4,797	3,124	2,466	1,610
Pseudo R^2	0.71	0.69	0.58	0.53

Notes: (SE) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

As stated previously, technology-related RTAs could take several forms: technology cooperation, R&D cooperation or patents and IP protections. The conjecture in the empirical analysis is that it is provisions related to patents and IP protection that matter for technology transfer through licensing. Table 6 shows the results when only patents and IP provisions are considered as part of an RTA with technology provisions. The results are consistent with those reported in Table 5. Patent- and IP-related provisions have a positive and statistically significant effect on royalty payments, both when the whole sample of countries is considered, as well as when I restrict attention to country-pairs consisting of a developed and a developing country. These results suggest that agreements requiring an improvement in IPR have a positive effect on technology transfer across member countries. As columns 3 and 4 show, these results also hold for international trade flows, as documented by Martínez-Zarzoso and

Chelala (2021).

Table 6: The effect of different subcategories of RTAs with IP provisions on international technology licensing

	Royalties		Trade	
	All	NS	All	NS
Patents and IP	0.305***	0.292***	0.0394*	0.0917**
	(0.0541)	(0.0506)	(0.0183)	(0.0328)
RTA notech	0.280***	0.128	0.136***	0.000153
	(0.0674)	(0.0669)	(0.0221)	(0.0427)
TRIPS	0.104	0.131	0.0228	0.00612
	(0.128)	(0.0794)	(0.0398)	(0.0309)
N	28,458	14,544	28,484	14,596
pseudo R^2	0.71	0.59	0.98	0.98

Notes: Standard errors in parentheses.

Clustered standard errors, clustered by exporter-importer (default) .

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

B Derivations

Final Good Price Start from equation (3):

$$Y_{nt} = \left(\sum_{i=1}^{M} \Omega_i^{\sigma-1} T_{it} x_{ni,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}. \tag{35}$$

From the demand of intermediate goods,

$$Y_{nt} = \left(\sum_{i=1}^{M} \Omega_i^{\sigma-1} T_{it} \left(\left(\frac{\bar{m} W_{it} d_{ni}(1+\tau_{ni})}{P_{nt}} \right)^{-\sigma} Y_{nt} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{36}$$

where $\bar{m} = \frac{\sigma}{\sigma-1}$.

From here,

$$P_{nt} = \left(\sum_{i=1}^{M} \Omega_i^{\sigma-1} T_{it} \left(\bar{m} W_{it} d_{ni} (1+\tau_{ni}) \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \tag{37}$$

Trade share

$$\pi_{in,t} = \frac{X_{in,t}}{\sum_{i=1}^{M} X_{in,t}} = \frac{\Omega_n^{\sigma-1} T_{nt} \left(\frac{\bar{m} W_{nt} d_{in}(1+\tau_{in})}{P_{it}} \right)^{1-\sigma} P_{it} Y_{it}}{\sum_{k=1}^{M} \Omega_k^{\sigma-1} T_{kt} \left(\frac{\bar{m} W_{it} d_{ik}(1+\tau_{ik})}{P_{it}} \right)^{1-\sigma} P_{it} Y_{it}}, \tag{38}$$

where $X_{in,t}$ is country i's expenditure on goods from country n.

From here,

$$\pi_{in,t} = \frac{\Omega_i^{\sigma-1} T_{it} \left(W_{nt} d_{in} (1+\tau_{in}) \right)^{1-\sigma}}{\sum_{k=1}^{M} T_{kt} \left(W_{it} d_{ik} (1+\tau_{ik}) \right)^{1-\sigma}}. \tag{39}$$

The home trade share is then

$$\pi_{nn,t} = \frac{\Omega_n^{\sigma-1} T_{nt} \left(W_{nt} \right)^{1-\sigma}}{P_{nt}^{1-\sigma}}. \tag{40}$$

ACR formula Relative wages take the ACR formula

$$\frac{W_{nt}}{P_{nt}} = \frac{1}{\bar{m}} \left(\frac{T_{nt}}{\pi_{nn,t}} \right)^{\frac{1}{\sigma-1}}. \tag{41}$$

From this formula, the growth rate of real wages in the steady state is $\frac{1}{\sigma-1} g_T$.

Profits of intermediate producers In each country i there are $T_{it} = \sum_{n=1}^{M} A_{in,t}$ intermediate producers (as many as adopted technologies). Each intermediate producer makes $\frac{\Pi_{it}}{T_{it}}$ in profits. Profits made with each adopted technology are composed of profits from the domestic and export market:

$$\Pi_{it} = \sum_{m=1}^{M} \frac{\pi_{mi,t}}{1+\tau_{mi}} P_{mt} Y_{mt} - W_{it} L_{it}, \tag{42}$$

where $\sum_{m=1}^{M} \frac{p_{mi} x_{mi}}{1+\tau_{mi}} - W_{it} L_{it} = \sum_{m=1}^{M} \bar{m} W_i d_{mi} (1+\tau_{mi}) l_{mi} / (d_{mi}(1+\tau_{mi}) - W_{it} L_{it} = (\bar{m} - 1) W_{it} L_{it}$.

Then,

$$\Pi_{it} = (\bar{m} - 1)W_{it}L_{it}$$

What are the profits of all the firms in the economy?

- Innovators:

$$\sum_{i=1}^{M} RP_{in,t} - P_{nt}H^r_{nt}.$$

- Adopters and intermediate producers:

$$-P_{nt}\sum_{i=1}^{M} H^a_{in,t} + \Pi_{nt} - \sum_{i=1}^{M} RP_{ni,t},$$

  where royalties are given by

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

Note that in the BGP (solving equations 9 and 12)

$$\frac{A_{in}}{T_i}\chi_{in}\Pi_i = \frac{\varepsilon_{in}}{\varepsilon_{in}+g}\chi_{in}\lambda_n\left(\frac{H^r_n}{Y_n}\right)^{\beta_r}\frac{T_n}{T_i}\Pi_i.$$

In equilibrium, $\Pi_i = (\bar{m} - 1)W_iL_i$.

C Equations of the Model

Endogenous variables

$$\{Y_{nt}, P_{nt}, W_{nt}, C_{nt}, \Pi_{nt}, R_t, Z_{nt}, H^r_{nt}, T_{nt}, H^a_{in,t}, A_{in,t}, x_{in,t},$$

$$p_{in,t}, \pi_{in,t}, V_{nt}, J^{\text{innov}}_{in,t}, V^{\text{innov}}_{in,t}, J_{in,t}, V_{in,t}, \varepsilon_{in,t}, RP_{in,t}\}$$

Equations:

Resource constraint

$$Y_{nt} = C_{nt} + H^r_{nt} + H^a_{nt}$$

Prices

$$P_{nt} = \left(\sum_{i=1}^{M} \Omega_i^{\sigma-1} T_{it} p_{ni,t}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

Price intermediate goods

$$p_{in,t} = \bar{m} W_{nt} d_{in} (1 + \tau_{in})$$

Demand intermediate goods

$$p_{in,t} x_{in,t} = \left(\frac{W_{nt} d_{in}(1 + \tau_{in})}{P_{it}}\right)^{1-\sigma} P_{it} Y_{it}$$

Trade share

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

Value innovation

$$V_{nt} = \sum_{i=1}^{M} J_{in,t}^{\text{innov}}$$

Profits firms

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

Value adopted technology

$$V_{in,t} = (1 - \chi_{in}) \frac{\Pi_{it}}{T_{it}} + \frac{1}{R_{it}} V_{in,t+1}$$

Value un-adopted technology

$$J_{in,t} = -\frac{H_{in,t}^{a} P_{it}}{Z_{nt} - A_{in,t}} + \frac{1}{R_t} \frac{P_{it}}{P_{i,t+1}} [\varepsilon_{in,t} V_{in,t+1} + (1 - \varepsilon_{in,t}) J_{in,t+1}]$$

Value adopted innovator

$$V_{in,t}^{\text{innov}} = \chi_{in} \frac{\Pi_{it}}{T_{it}} + \frac{1}{R_t} \frac{P_{it}}{P_{i,t+1}} V_{in,t+1}^{\text{innov}}$$

Value un-adopted innovator

$$J^{\text{innov}}_{in,t} = \frac{1}{R_t}\frac{P_{it}}{P_{i,t+1}}[\varepsilon_{in,t}V^{\text{innov}}_{in,t+1} + (1-\varepsilon_{in,t})J^{\text{innov}}_{in,t+1}]$$

FOC innovation

$$H^r_{nt} = \beta_r \Delta Z_{nt}\frac{V_{nt}}{P_{nt}}$$

FOC adoption

$$P_{it}H^a_{in,t} = \beta_a \frac{1}{R_{it}}\frac{P_{it}}{P_{i,t+1}}(Z_{nt} - A_{in,t})\varepsilon_{in,t}(V_{in,t+1} - J_{in,t+1})$$

Probability of adoption

$$\varepsilon_{in,t} = \bar{\varepsilon}_{in}\left(\frac{H^a_{in,t}}{Y_{it}}\right)^{\beta_a}$$

Royalties

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

Labor market-clearing condition

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

Trade-balance equation

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

Law of motion of innovation

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

Law of motion of adoption

$$\Delta A_{in,t} = \varepsilon_{in,t}(Z_{nt} - A_{in,t})$$

Interest rate

$$R_t = \frac{1}{\beta}\frac{C_{n,t+1}}{C_{nt}}$$

Total number of adopted technologies

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

D Stationary Variables

Because this is an endogenous growth model and the endogenous variables grow along the BGP, I need to find the rate of growth of each variable and stationarize them appropriately. I also do some transformation of the variables. Here is a list of the equations written with stationarized variables that do not growth along the BGP.

From the equation of the home trade share, the growth of the real wage is $T^{\frac{1}{\sigma-1}}$. Also, as is common in these models of diffusion, all countries grow at a common rate. All adopted technologies and newly created technologies grow at the rate of Z.

Resource constraint:

$$\hat{Y}_{nt} = \hat{C}_{nt} + \hat{H}^r_{nt} + \hat{H}^a_{nt}$$

In this expression, $\hat{X}_{it} = \frac{X_{it}}{Z_{Mt}^{\sigma-1}}$. In this economy, the real wage grows at $Z_{Mt}^{\frac{1}{\sigma-1}}$. Real variables grow at $g_z/(\sigma-1)$. Also note that in the Eaton and Kortum (2002) model, I get something similar, where $\theta = \sigma - 1$.

Prices:

$$\hat{P}_{nt}^{1-\sigma} = \sum_{i=1}^{M} \Omega_i^{\sigma-1}\hat{T}_{it}\left(\bar{m}\hat{\omega}_{it}d_{ni}(1+\tau_{ni})\right)^{1-\sigma},$$

where $\hat{\omega}_{nt} = \frac{W_{it}}{W_{Mt}}$ and $\hat{A}_{ni,t} = \frac{A_{ni,t}}{T_{Mt}}$.

Demand intermediate goods:

$$\hat{x}_{in,t} = \left(\bar{m}\hat{\omega}_{nt}d_{in}(1+\tau_{in})\right)^{1-\sigma}\hat{P}_{it}^{\sigma}\hat{Y}_{it} = \pi_{in,t}\hat{Y}_{it}\hat{P}_{it},$$

where $\hat{x}_{in,t} = \frac{\frac{p_{in,t}x_{in,t}}{W_{Mt}}}{Z_{Mt}^{\frac{1}{1-\sigma}}}$.

Trade share:

$$\pi_{in,t} = \frac{\Omega_n^{\sigma-1}\hat{T}_{nt}\left(\hat{\omega}_{nt}d_{in}(1+\tau_{in})\right)^{1-\sigma}}{\hat{P}_{it}^{1-\sigma}}$$

Value innovation:

$$\hat{v}_{nt} = \sum_{i=1}^{M} \hat{j}^{\text{innov}}_{in,t}\frac{\hat{T}_{nt}}{\hat{T}_{it}}$$

where $v_{nt} = T_{nt}V_{nt}/W_{Mt}$ and $j^{\text{innov}}_{in,t} = J_{in,t}T_{it}/W_{Mt}$.

Profits firms:

$$\hat{\Pi}_{nt} = \frac{1}{\sigma-1}\hat{\omega}_{nt}L_n$$

with $\hat{\Pi}_{it} = \frac{\Pi_t}{W_{Mt}}$.

Value adopted:

$$\hat{v}_{in,t} = (1-\chi_{in})\hat{\Pi}_{it} + \frac{1}{r_{it}}\frac{\hat{P}_{it}}{\hat{P}_{i,t+1}}\hat{v}_{in,t+1}\frac{(1+g_{Mt})^{1/\sigma-1}}{1+g_{T,it}}$$

with $\hat{V}_{in,t} = V_{in,t}T_{it}/W_{Mt}$.

Value unadopted:

$$\hat{j}_{in,t} = -\hat{H}^a_{in,t}\frac{\frac{\hat{T}_{it}}{\hat{A}_{in,t}}\varepsilon_{in,t}}{g^a_{in,t}} + \frac{1}{r_t}\frac{\hat{P}_{i,t+1}}{\hat{P}_{it}}\left[\varepsilon_{in,t}\hat{v}_{in,t+1} + (1-\varepsilon_{in,t})\hat{j}_{in,t+1}\right]\frac{(1+g_{M,t})^{1/\sigma-1}}{1+g_{T,it}}$$

where $r_t = R_t\frac{P_{nt}}{P_{n,t+1}}$ and $g_{T,it} = \hat{T}_{i,t+1}/\hat{T}_{it} - 1 + g_{Mt}$.

Value adopted innovator:

$$\hat{v}^{\text{innov}}_{in,t} = \chi_{in}\hat{\Pi}_{it} + \frac{1}{r_t}\frac{\hat{P}_{i,t+1}}{\hat{P}_{it}}\hat{v}^{\text{innov}}_{in,t+1}\frac{(1+g_{Mt})^{1/\sigma-1}}{1+g_{T,it}}$$

Value un-adopted innovator:

$$\hat{j}^{\text{innov}}_{in,t} = \frac{1}{r_t}\frac{\hat{P}_{i,t+1}}{\hat{P}_{it}}\left[\varepsilon_{in,t}\hat{v}^{\text{innov}}_{in,t+1} + (1-\varepsilon_{in,t})\hat{j}^{\text{innov}}_{in,t+1}\right]\frac{(1+g_{Mt})^{1/\sigma-1}}{1+g_{T,it}}$$

FOC innovation:

$$\beta_r \left(\frac{\hat{H}^r_{nt}}{\hat{Y}^w_t} \right)^{\beta_r - 1} \hat{v}_{nt} = \hat{P}_{nt} \hat{Y}^w_t$$

FOC adoption:

$$\hat{P}_{it} \hat{H}^a_{in,t} \frac{\frac{\hat{T}_{it}}{\hat{A}_{in,t}} \varepsilon_{in,t}}{g^a_{in,t}} = \beta_a \frac{1}{r_t} \frac{\hat{P}_{i,t+1}}{\hat{P}_{it}} \varepsilon_{in,t} \left[\hat{v}_{in,t+1} - \hat{j}_{in,t+1} \right] \frac{(1 + g_{Mt})^{1/\sigma - 1}}{1 + g_{T,it}}$$

Probability adoption:

$$\varepsilon_{in,t} = \bar{\varepsilon}_{in} \left(\frac{\hat{H}^a_{in,t}}{\hat{Y}_{it}} \right)^{\beta_a}$$

Royalties:

$$\hat{r}p_{in,t} = \frac{A_{in,t}}{T_{it}} \chi_{in,t} \hat{\Pi}_{it}$$

Labor market-clearing condition:

$$\bar{m} \hat{\omega}_n L_{nt} = \sum_{i=1}^{M} \pi_{in,t} \hat{Y}_{it} \hat{P}_{it}$$

Trade balance equation:

$$\sum_{i \neq n}^{M-1} \Omega_i^{\sigma-1} \hat{T}_{it} \hat{x}_{ni,t} = \sum_{i \neq n}^{M-1} \Omega_n^{\sigma-1} \hat{T}_{nt} \hat{x}_{in,t} + \sum_{i \neq n}^{M-1} \hat{r}p_{in,t} - \sum_{i \neq n}^{M-1} \hat{r}p_{ni,t} + \hat{B}_{it} - r_t \hat{B}_{i,t-1}$$

Law of motion of innovation:

$$g_{Z,nt} \hat{Z}_{nt} = \lambda_n \hat{T}_{nt} \left(\frac{\hat{H}_{nt,r}}{\hat{Y}_{nt}} \right)^{\beta_r}$$

Law of motion of adoption:

$$g^a_{in,t} = \varepsilon_{in,t} \left(\frac{\hat{Z}_{nt}}{\hat{A}_{in,t}} - 1 \right)$$

where $g^a_{in,t} = (\hat{A}_{in,t+1} - \hat{A}_{in,t}) + g$

Bond holdings

$$1+\eta\left(\hat{B}_{nt}-\bar{B}_n\right)=r_t\beta(1+g_{c,n,t+1})$$

with $1+g_{c,t+1}=\hat{C}_{n,t+1}/\hat{C}_{nt}-1+(1+g)^{\sigma-1}$. A small quadratic-adjustment cost in bond holding, η, guarantees the existence of a unique BGP value for $B_n=\bar{B}_n$.

Bond-market equilibrium:

$$\sum_{n=1}^{M}\hat{B}_{nt}=0$$

Total number of adopted technologies

$$\hat{T}_{nt}=\sum_{i=1}^{M}\hat{A}_{ni,t}$$

E BGP

The parameters of the model are $\{\beta,\eta,\beta_a,\beta_r,\sigma,\lambda_n,\bar{\varepsilon}_{in},\xi_{in},\chi_{in},d_{in},\tau_{in},g\}$.

To solve for the BGP, I can use the expressions from the previous section, which are stationary and do not grow along the BGP. I drop the time dimension and the hats.

Note that from the law of motion of adopted varieties,

$$A_{in}=\frac{\varepsilon_{in}}{g+\varepsilon_{in}}Z_n.$$

I will start by guessing a vector for T_n, a value for g, a matrix for $H^a in$, and a vector for wages, and then solve for the equilibrium for wages, prices, trade shares, and income. Wages will be updated using the trade-balance equation, and inside that loop there will be a recursive algorithm to solve for the equilibrium value of $H^a in$. Then I can use the Frobenius theorem to solve for g and T_n/T_M.

To solve for the equilibrium along the BGP, I need the following expressions:

1. Start by guessing w_n, H^a_{in}, g, and T_n

2. $$r=\frac{1+g/(\sigma-1)}{\beta}$$

3.

$$P_n^{1-\sigma} = \sum_{i=1}^{M} \Omega_i^{\sigma-1} T_i \left(\bar{m}\omega_i d_{ni}(1+\tau_{ni})\right)^{1-\sigma}$$

4.

$$\pi_{in} = \frac{T_n \left(\bar{m}\omega_n d_{in}(1+\tau_{in})\right)^{1-\sigma}}{P_i^{1-\sigma}}$$

5.

$$\omega_n L_n = \sum_{i=1}^{M} T_n \left(\frac{\bar{m}\omega_n d_{in}(1+\tau_{in})}{P_i}\right)^{1-\sigma} \frac{Y_i P_i}{1+\tau_{in}}$$

This can be written as

$$\omega_n L_n = \sum_{i=1}^{M} \frac{\pi_{in}}{1+\tau_{in}} Y_i P_i,$$

which can be written in matrix form as $\omega L = BY$ with each entry of B being $b_{in} = \frac{\pi_{in}}{1+\tau_{in}}$.

6. An update rule for wages: Note that because there are royalties, I will not be able to update wages at this stage without first knowing A_{in}, which enters the equation for royalties. To do that I need to guess for H_{in}^a, which I already did, and then use the growth block of the model to update H_{in}^a:

$$\sum_{i\neq n}^{M} \frac{\pi_{ni}}{1+\tau_{ni}} Y_n = \sum_{i\neq n}^{M} \frac{\pi_{in}}{1+\tau_{in}} Y_i + \sum_{i\neq n}^{M} rp_{in} - \sum_{i\neq n}^{M} rp_{ni},$$

where

$$\sum_{n\neq i} \frac{RP_{in}T_i}{W_M} = \sum_{n\neq i} \frac{\Delta A_{in}}{A_{in}} \frac{V_{in}T_i}{W_M} \frac{A_{in}}{T_i}$$

$$\sum_{n\neq i} rp_{in} = \sum_{n\neq i} gV_{in} \frac{A_{in}}{T_i}$$

7.

$$v_{in} = \left(1 - \frac{1}{r}\frac{1+g/(1/\sigma-1)}{1+g}\right)^{-1} \Pi_i$$

8. I combine the law of motion for A_{in} with the definition of ε_{in} to obtain

$$\varepsilon_{in} = \bar{\varepsilon}_{in} \left(\frac{H^a_{in}}{Y^w} \right)^{\beta_a}$$

Note that the law of motion for new varieties tells us that

$$\frac{A_{in}}{Z_n} = \frac{\varepsilon_{in}}{\varepsilon_{in} + g}$$

9. I combine the expression for the FOC of adoption together with the expression for the value of an unadopted technology to obtain an expression for j_{in}:

$$j_{in} = \left(1 - \beta_a \varepsilon_{in} \frac{1}{r} \frac{1 + g/(1/\sigma - 1)}{1+g} - \frac{1}{r} \frac{1 + g/(1/\sigma - 1)}{1+g} (1 - \varepsilon_{in}) \right)^{-1} (1-\beta_a) \varepsilon_{in} \frac{1}{r} \frac{1 + g/(1/\sigma - 1)}{1+g} v_{in}$$

10.

$$V_n = \sum_{i=1}^{M} J_{in} \frac{T_n}{T_i}$$

11.

$$H^r_n = \left(\beta_r V_n \lambda_n Y_n^{-\beta_r} \right)^{1/(1-\beta_r)}$$

12. I use the FOC of adoption to update for adoption, but for that I need an expression for $\frac{A_{in}}{T_i}$. I use the following expressions:

$$A_{in} = \frac{\varepsilon_{in}}{g + \varepsilon_{in}} (1+g) Z_n$$

$$Z_n = \frac{\lambda_n}{g} T_n \left(\frac{H^r_n}{Y_n} \right)^{beta_r}$$

$$T_i = \sum_{i=1}^{M} A_{in}$$

13. I plug into the FOC for adoption and update H^a_{in}.

14. I use the trade balance equation to update wages. If there are M countries, I need $M-1$ updating equations because one of the equations is redundant.

15. Update g and T_n with the Frobenius theorem and equation

$$T_i g = \sum_{n=1}^{M} \frac{\varepsilon_{in}}{\varepsilon_{in}+g} \lambda_n \left(\frac{H_n^r}{Y_n}\right)^{\beta_r} T_n$$

    In matrix form, that expression becomes

$$gT = \Delta(g)T,$$

    where $\Delta(g)$ is a $M * M$ matrix with entry $\Delta_{in} = \frac{\varepsilon_{in}}{\varepsilon_{in}+g}\lambda_n \left(\frac{H_n^r}{Y_n}\right)^{\beta_r}$

    From the Frobenius theorem, as long as matrix Δ is idecomposable, it exists a unique g, which is given by the maximum real eigenvalue of the matrix, and the eigenvector associated with that eigenvalue gives T, which is unique up to a scalar. So I can just compute $\hat{T}_i = T_i/T_M$.

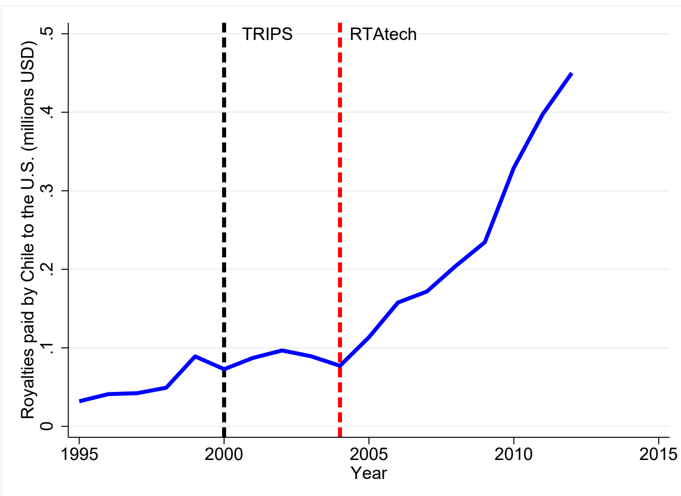
F International Licensing and RTAs with IP Provisions: Examples

Figure 9 shows the dynamics of royalty payments for a sample of country-pairs. There are two types of vertical lines: The one more to the left refers to when TRIPS was ratified by the developing country, and the other one refers to when the first RTA with technology provisions enters into enforcement.[21] Consistent with the previous figure, RTAs with IP chapters seem to increase royalty payments from developing to developed economies, and the effect of these provisions is stronger than the minimum requirements established in TRIPS.

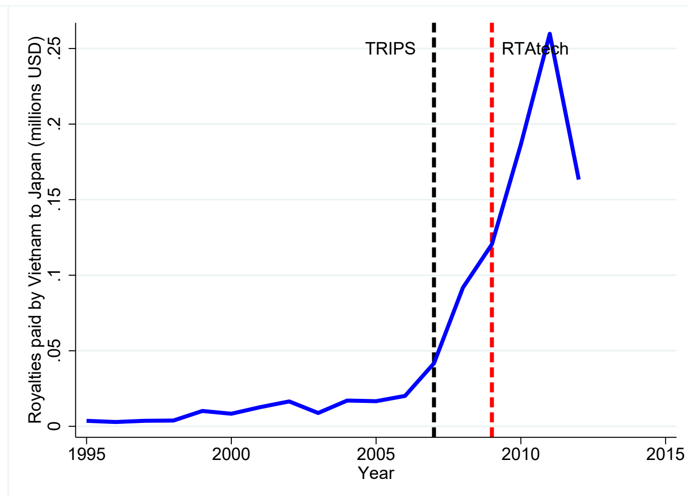
[21] Although TRIPS was established in 1995 as a requirement to be part of the WTO, many developing countries were granted an extension to meet the IP requirements, and in those countries the agreement was ratified after 1995.

Figure 9: Dynamics of International Technology Licensing During RTAs with IP Provisions

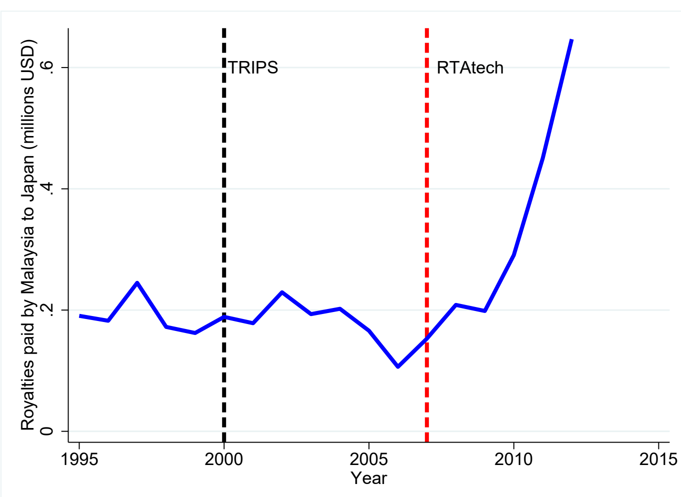
(a) USA to Chile



(b) Japan to Vietnam



(c) Japan to Malaysia



(d) Singapore to China