Dynamic Gains from Trade Agreements with Intellectual Property Provisions

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Abstract

I develop a quantitative theory of bilateral trade agreements with intellectual property (IP) provisions in a multi-country growth model. The model's dynamics are driven by innovation and technology licensing. Imperfect IP enforcement leads to reduced royalty payments and growth. Governments negotiate tariffs and IP enforcement through Nash bargaining. Gains from the trade agreement vary along the transition. Developing countries experience short-term losses, while developed countries gain in both the short and long run. A government with short-term goals may reduce losses but at the cost of lower growth and welfare. Tariffs could discourage developing countries from deviating from the agreement.

Keywords: Technology Licensing; Trade Agreements; Intellectual Property Rights

JEL Classification: F12, O33, O41, O47

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1 Introduction

The enforcement and protection of intellectual property rights (IPR) has become an important component of current trade policy. Recent decades have seen a proliferation of regional trade agreements (RTAs) with IP provisions that expand and strengthen the minimum standards set by the WTO's TRIPS agreement.[1,2] In return, these agreements offer increased access to international markets.[3] Governments have also used trade policy to prevent IP misappropriation, such as the US imposing tariffs on China in response to discriminatory IP practices.[5] Despite the increasing prevalence of such agreements, existing research has not quantitatively explored the dynamic trade-offs for involved parties.

This paper develops a quantitative theory of bilateral trade agreements with IP provisions to analyze the dynamic trade-offs. The model bridges the gap between quantitative dynamic models of trade, innovation, and adoption, which traditionally do not include trade agreements, and theoretical political-economy models of trade agreements, which do not comprehensively analyze the dynamics of trade and welfare quantitatively. It uses royalty payments data to measure technology licensing, shedding light on the impact of IP reforms within trade agreements. The paper emphasizes the importance of analyzing dynamic effects by conducting the analysis along the transition.

The model is an Armington trade framework where productivity growth is driven by innovation and technology licensing. Innovators invest to develop new technologies, while adopters invest to be able to use them in production. If successful, adopters license them from innovators and pay a portion of their profits as royalties. The royalty fee is determined by the innovator's bargaining power, which depends on the adopter's IP enforcement quality. Weak IP protection leads to less-favorable terms for innovators, underinvestment in R&D, and lower long-term growth. High-enforcement countries can use tariffs to restrict market access for low-enforcement countries. To address inefficiencies, governments are endowed with two instruments, mirroring real trade agreements. Specifically, they negotiate tariffs and IP protection levels through bilateral Nash bargaining to maximize joint welfare. The

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

[2] For a reference of different standards between TRIPs and the new RTAs, see: `https://www.wipo.int/ip-development/en/policy_legislative_assistance/advice_trips.html`

[3] 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 violating intellectual property (IP) laws.[4]

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

payoff is the Nash product of dynamic welfare gains, including transition. The agreement is cooperative, requires positive welfare gains for both countries, and is perfectly enforceable. The model has a balanced growth path with uniform growth rates across countries, but relative levels differ. I solve the model to study both the balanced growth path (BGP) and the transition.

In the model, international technology licensing, measured by royalty payments, is the primary channel for technology transfer. The model assumes that imperfect IPR reduce global royalty payments; hence, the model predicts that signing a trade agreement that strengthens IPR will lead to an increase in royalty payments. This modeling approach is justified by empirical evidence that demonstrates the positive impact of IP reforms in recent trade agreements on the evolution of royalty payments.

The model is calibrated for the United States, China, and the rest of the world combined. Countries differ in their innovation and adoption efficiency, size, IP protection quality, geography, and trade policy. A novel aspect of the calibration is using royalty payment data to estimate the adoption probability. The model produces a gravity-type equation for royalty payments, which is estimated using advanced methods from empirical trade research. The results show differences in adoption rates across countries and reveal imperfect IPR in China, through lower royalty payments. In a counterfactual exercise, China and the US negotiate a trade agreement where they choose US tariff levels on Chinese imports and China's protection of domestic and foreign IP through Nash bargaining. The third country aligns the model with global trade data while focusing on bilateral negotiations. I solve for the perfect foresight solution of the model after signing the agreement, which is assumed to be an unexpected, permanent, one-time shock. With equal bargaining power of the negotiating parties, the agreement results in the US removing tariffs on Chinese products and China improving IP enforcement for both domestic and foreign IP. This agreement increases welfare in all countries, but gains vary during the transition: the US has short-term gains, while China has short-term losses. The agreement boosts global innovation and growth in the long run. Innovators in both countries receive more royalties, increasing R&D returns and welfare. China's short-term losses are due to higher adoption costs, as lower tariffs encourage adoption but higher royalties increase costs, leading to less adoption and more innovation. The US has short-term gains from higher royalties and innovation returns. Transitional dynamics show significant distributional effects of trade agreements in the short term.

Trade policy and IP reforms interact in complex ways over time. Counterfactual exercises explore these interactions. China always has an incentive to improve domestic IPR, but improves foreign IP enforcement only if the US reduces tariffs, making tariffs a tool to encourage China's foreign IPR enhancement. I then relax the trade agreement assumptions and analyze results under (i) uncooperative equilibrium, (ii) short-term government goals, (iii) China's deviation with and without US retaliation, and (iv) an anticipated, gradual agreement. The findings show that there are (i) gains from cooperative agreements, (ii) reduced short-term losses at the cost of lower overall gains by shortsighted governments, (iii) tariff threats that may deter China's deviation if they are credible, and (iv) reduced short-term losses in China, larger overall gains, and more gradual adjustment with anticipated, gradual agreements. Finally, the specific characteristics of the trade agreement hinge on several features of the countries involved in the Nash bargaining negotiation.[6]

Literature Review The paper is related to several strands of literature. First, it contributes to political economy models of trade agreements that study welfare effects of trade negotiations on tariffs (see Maggi and Rodriguez-Clare, 2007; Ossa, 2014; Bagwell and Staiger, 2016; Bagwell, Staiger, and Yurukoglu, 2020) and to the relatively scarce literature on non-tariff issues like IP, including theoretical work by Maggi and Ossa (2021), Grossman, McCalman, and Staiger (2021), and Limão (2007) by exploring dynamic trade-offs of reforming IPR in trade agreements with non-tariff issues.

Second, it relates to quantitative dynamic models of trade, innovation, and knowledge spillovers, building on Somale (2021); Buera and Oberfield (2019); Cai, Li, and Santacreu (2021); Sampson (2023); Lind and Ramondo (2023). My paper introduces imperfect IPR and focuses on the role of deep trade agreements that include both tariffs and IP protection. Furthermore, I evaluate the impact of these agreements using transitional dynamics, extending the work of Akcigit, Ates, and Impullitti (2018); Perla, Tonetti, and Waugh (2021); Buera and Oberfield (2019) on computing welfare gains along the transition path.

Third, it contributes to the literature on effects of IPR improvements on growth and welfare in developing countries. In particular, Helpman (1993) analyzes, theoretically, the effect of the policy of tightening IPR on the rate of innovation in the North and on the welfare in both the North and South. This paper builds on that work by studying, quan-

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[6] In the Online Appendix, I investigate which parameters and data moments influence the quantitative results.

titatively, the impact of IP reforms within a trade agreement on welfare, innovation, and licensing. Other papers in this literature include 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). Closely related is Hémous, Lepot, and Schärer (2023), who build upon Grossman and Lai (2004) to study, quantitatively, optimal patent policy in the global economy. While they provide a broader perspective on the global implications of patent policy and the potential gains from international cooperation in this area, I develop a theory of the specifics of bilateral trade agreements and the dynamic aspects of IP reforms.

Fourth, my paper relates to work on interactions between technology licensing and IP reforms (Branstetter, Fisman, and Foley, 2006; Saggi, 1999; Santacreu, 2023), studying these interactions. Finally, the paper is closely related to recent work analyzing the interaction between trade and IPR. In particular, Mandelman and Waddle (2019) investigate the interaction between tariffs and IPR enforcement within a quantitative general equilibrium framework, finding that tariffs can effectively deter weak IP protection and weakening IPR enforcement can deter raising tariffs. However, in their approach, tariffs are contingent on IPR enforcement and they evaluate the impact of exogenous shocks on key economic variables, while 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 IPR effects in China through forced technology transfer via FDI. It differs by focusing on licensing, which allows for broader applicability and direct measurement across countries and over time.

The remainder of the paper is organized as follows: Section 2 motivates patterns of royalty payments that motivate the use of international technology licensing as the main measure of technology transfer in the model. Section 3 presents the model, and Section 4 discusses the mechanism. Section 5 describes the calibration and counterfactual analysis. Section 6 concludes.

2 Royalty Payments and Deep Trade Agreements

The paper uses international technology licensing, measured by royalty payments, as a key indicator of technology transfer and IP enforcement. It assumes that these payments proportionally represent technology transfer between countries and predicts that trade agreements with IP provisions substantially impact royalty payments. This raises two questions: (i) the accuracy of royalty payments in reflecting technology transfer and (ii) the extent to which comprehensive trade agreements affect international technology licensing. I use data for bilateral royalty payments for 50 countries from 1995 to 2012. The data are recorded in the balance of payments of a country and reported by the OECD in EBOPS 2012: Balanced International Trade in Services (1995-2012) (see Santacreu, 2023, for details).

The data show a significant increase in global royalty payments, from 0.06% of world GDP in the 1980s to 0.50% in 2019, indicating a notable expansion in technology transfer activities. Although there are concerns about potential profit-shifting from high-tax to low-tax countries (Santacreu, 2023), the rapid increase in royalty payments between developed and developing countries suggests that growth is not solely driven by tax-avoidance strategies.

To explore the relationship between IPR and international technology licensing within deep trade agreements, the paper uses a dataset of RTAs with IP provisions from Martínez-Zarzoso and Chelala (2021) and bilateral royalty payment data from the OECD Balanced Trade in Services dataset. The focus is on technology flows from developed to developing countries, as the impact of RTAs with IP provisions is particularly pronounced in this context.

Figure 1 shows the evolution of royalty payments from developing to developed countries during 1995-2012, before and after signing an RTA agreement. The sample is split into country-pairs that sign only RTAs with IP provisions (solid line) and those that sign only RTAs without IP provisions (dashed line). Royalty payments are normalized to 1 on the year the agreement is enforced, and each line represents the average across all country-pairs of normalized royalty payments. The figure shows a sharp increase in royalty payments from developing to developed countries after an RTA with IP provisions enters into force. In contrast, RTAs without IP provisions lead to a slower rate of technology transfer to developing economies that sign such agreements.[7]

The Online Appendix shows that the contrasting effects of RTAs with IP provisions versus those without IP provisions are significantly more pronounced for royalty payments compared with alternative technology transfer channels like cross-border patenting or FDI.

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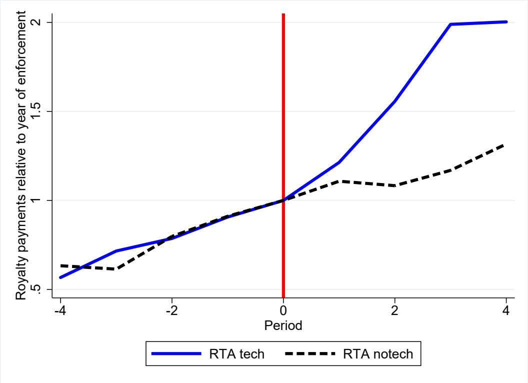
[7] The Online Appendix presents a comprehensive empirical analysis demonstrating the impact of trade agreements with IP provisions on international technology licensing, differentiating between country groups based on their level of development.

Figure 1: 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 only technology provisions (solid line) and with only non-technology provisions (dashed line). 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.

3 Model

The global economy encompasses M countries indexed by i and n, with time being discrete and indexed by t. The model consists of two main components: a trade block that determines the static equilibrium, taking as given productivity and trade frictions, which include tariffs and iceberg trade costs; additionally, there is a growth block that governs productivity dynamics through innovation and international technology licensing. Imperfect IP protection is reflected in the form of low royalty fees paid to innovators. The presence of tariffs and weak IP enforcement introduces inefficiencies into the model, which can be addressed by governments engaging in bilateral Nash bargaining negotiations.

3.1 Preferences

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

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

subject to the budget constraint

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

where β is the discount factor, P_{nt} is the price index, W_{nt} is the wage, L_{nt} is population, Π_{nt}^{all} are the profits of all the firms operating in country n, 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_{nt} (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.

3.2 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:

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

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, to be determined later; and $\sigma > 1$ is the elasticity of substitution across intermediate products.

The demand for intermediate goods is given by

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

where $p_{ni,t}(j)$ is the price that the final producer in country n pays for an intermediate good j from country i at time t, and P_{nt} is given by

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

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, $\pi_{nt}(j)$:

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

subject to equation (4). Here, W_{nt} represent wages of country n at time t.

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, $\tau_{in,t}$, whereby $1 + \tau_{in,t}$ is the gross tax rate that country i levies on the value of imports from country n at time t. 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, $\pi_{ni,t}$, is given by

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

where $X_{ni,t}$ represents spending of country n from intermediate goods produced by country i at time t. The number of intermediate goods, T_{it}, evolves endogenously through *innovation* or *adoption*. I explain these processes in detail next.

3.3 Innovation and Adoption

The number of technologies available to produce intermediate goods, T_{nt}, evolves endogenously through two endogenous processes: innovation and adoption. These 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 bargaining 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. The stock of technology innovated in each period is given by the following law of motion:

$$Z_{n,t+1} = \lambda_n T_{nt} \left(\frac{H^r_{nt}}{\bar{Y}_t} \right)^{\beta_r} + Z_{n,t}, \tag{8}$$

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 in n learn from domestic and foreign technology used to produce intermediate goods in that country. Moreover, $\bar{Y}_t$ is world output, which guarantees the existence of a BGP, and $\beta_r \in (0,1)$ represents diminishing returns to adding one extra unit of final output into the innovation process. Equation (8) implies that there is no depreciation of new ideas over time.

Innovators have a monopoly over their technology. The innovator chooses H^r_{nt} to maximize

$$\Delta Z_{nt} V_{nt} - P_{nt} H^r_{nt}, \tag{9}$$

where V_{nt} is the value of an innovation, which will be defined later.

Technology Adoption New technologies developed through innovation need to be adopted for use in the production of a new intermediate product. This process is called adoption and, if successful, an adopter produces an intermediate good with that technology, earns profits, and pays royalties to the innovator.

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 $h^a_{in,t}(j)$ 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

$$\varepsilon_{in,t}(j) = \bar{\varepsilon}_{in} \left(\frac{h^a_{in,t}(j)}{\bar{Y}_t} \right)^{\beta_a}, \tag{10}$$

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.

Successful adopters start producing the intermediate product and pay a royalty fee to the innovator. I assume that royalties are paid every period as a share, $\chi_{in,t}$, of the profits made by the adopter once the technology has been adopted.

The Value of 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 royalty payments made by intermediate producers in country i that use the technology from country n; that is,

$$V^{\text{innov}}_{in,t}(j) = \chi_{in,t}\Pi_{in,t}(j) + \frac{1}{R_t}\frac{P_{it}}{P_{i,t+1}} V^{\text{innov}}_{in,t+1}(j), \tag{11}$$

where $\Pi_{in,t}(j)$ 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

$$J^{\text{innov}}_{in,t}(j) = \frac{1}{R_t}\frac{P_{it}}{P_{i,t+1}} \left[\varepsilon_{in,t}(j) V^{\text{innov}}_{in,t+1}(j) + (1 - \varepsilon_{in,t}(j)) J^{\text{innov}}_{in,t+1}(j) \right]. \tag{12}$$

With probability $\varepsilon_{in,t}(j)$, the technology is adopted and innovators receive profits forever, which is captured in $V^{\text{innov}}_{in,t+1}(j)$. With probability $(1 - \varepsilon_{in,t}(j))$, adopters are not successful and get the continuation value $J^{\text{innov}}_{in,t+1}(j)$. 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.

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

$$V^{\text{adopt}}_{in,t}(j) = (1-\chi_{in,t})\Pi_{in,t}(j) + \frac{1}{R_t}\frac{P_{it}}{P_{i,t+1}}V_{in,t+1}(j). \tag{13}$$

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

$$J^{\text{adopt}}_{in,t}(j) = -P_{it}h^a_{in,t}(j) + \frac{1}{R_t}\frac{P_{it}}{P_{i,t+1}}\{\varepsilon_{in,t}(j)V^{\text{adopt}}_{in,t+1}(j) + (1-\varepsilon_{in,t}(j))J^{\text{adopt}}_{in,t+1}(j)\}. \tag{14}$$

The total value of an innovation from country n, $V_{nt}(j)$, is the sum of the values across all potential adopting countries:

$$V_{nt}(j) = \sum_{i=1}^{M} J^{\text{innov}}_{in,t}(j).$$

The Royalty Fee Once a technology has been successfully adopted, the innovator and adopter engage in Nash bargaining to determine a one-time royalty fee, $\chi_{in,t} = \chi_{in}\ \forall t$, 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:

$$(\chi_{in}W_{in,t}(j) - 0)^{\rho_{in}}\left((1-\chi_{in})W_{in,t}(j) - P_{i,t-1}h^a_{in,t-1}(j) - O_{in,t}(j)\right)^{1-\rho_{in}}. \tag{15}$$

Here, $W_{in,t}(j)$ is calculated as $\Pi_{in,t}(j) + \frac{1}{R_t}\frac{P_{it}}{P_{i,t+1}}W_{in,t+1}(j)$. 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 $O_{in,t}(j)$ is given by $0 - P_{i,t-1}h^a_{in,t-1}(j)$. The optimal royalty fee is determined by the bargaining power of the innovator, ρ_{in}, which is influenced 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. If $\eta_i = 1$, there is perfect enforcement of IPR.

To capture improvements in the quality of IPR, we introduce the policy parameter $\xi_{in,t} \in$

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[8] See Benhabib, Perla, and Tonetti (2021) and Hopenhayn and Shi (2020) for examples of models of licensing where the royalty fee is negotiated.

$(1, 1/\eta_i)$, which varies for each country pair, implying that IPR quality reforms in country i can differ depending on the innovator country. The royalty fee can be expressed as $\chi_{in,t} = \rho_{in}\xi_{in,t}$, reflecting how improvements in IPR quality translate into increased bargaining power for the innovator.

The policy maker's choice of $\xi_{in,t}$ directly impacts the returns to adoption and innovation, as it affects the bargaining power of the innovator and, consequently, the royalty fee. A higher value of $\xi_{in,t}$ increases the innovator's bargaining power and the royalty fee, which can influence the incentives for both adoption and innovation. During the negotiation of the royalty fee at time period t, the value of $\xi_{in,t}$ is assumed to be fixed and constant. This implies that changes in the policy parameter $\xi_{in,t}$ exclusively impact technologies adopted after the implementation of the reform. It is important to note that this royalty fee is privately optimal for the innovator and adopter, but not necessarily socially optimal.

Optimal Innovation and Adoption Note that there is a continuum of adopters, and the equilibrium is symmetric. This symmetry allows for the aggregation of the value functions across adopters, eliminating the need for the j subscript in the expressions for adopters, i.e., $\varepsilon_{in,t}(j) = \varepsilon_{in,t}$ for all j.

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

$$A_{in,t+1} = \varepsilon_{in,t}\left(Z_{nt} - A_{in,t}\right) + A_{in,t}. \tag{16}$$

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

The number of technologies available to produce intermediate goods, T_{nt}, is given by the number of ideas that have been adopted from around the world:

$$T_{nt} = \sum_{i=1}^{M} A_{ni,t}. \tag{17}$$

T_{nt} also denotes the number of intermediate producers in each country n. Among them, $A_{nn,t}$ license domestically-invented technology, while $A_{ni,t}$ license technologies developed in country i and successfully adopted by country n. Note that T_{nt} also introduces an externality in the innovation function in equation (8), as innovators benefit from ideas they have licensed from around the world.

The first-order condition for investment in innovation is

$$P_{nt}H^r_{nt} = \beta_r \Delta Z_{nt} V_{nt}. \tag{18}$$

Moreover, in equilibrium, $h_{in,t}(j) = h_{in,t}\ \forall j$. Hence, the total amount of output invested to adopt a technology in period t is $H^a_{in,t} = \sum_{i=1}^{M}(Z_{nt} - A_{in,t-1})h^a_{in,t}$ and $\varepsilon_{in,t}(j) = \varepsilon_{in,t}$ with

$$\varepsilon_{in,t} = \bar{\varepsilon}_{in}\left(\frac{H^a_{in,t}}{\bar{Y}_t}\right)^{\beta_a}. \tag{19}$$

The FOC of adoption is

$$P_{it}H^a_{in,t} = \beta_a \varepsilon_{in,t}\frac{1}{R_t}\frac{P_{it}}{P_{i,t+1}}(V^{\text{adopt}}_{in,t+1} - J^{\text{adopt}}_{in,t+1}). \tag{20}$$

The first-order conditions for innovation and adoption, along with the value functions and the equilibrium conditions, characterize the symmetric equilibrium. While these conditions are privately optimal for firms, they may not be socially optimal, as firms do not internalize the externalities their decisions impose on other firms and consumers in the market. Diminishing returns through β_r and β_a introduce Inada conditions that guarantee all countries engage in both innovation and adoption. Comparative advantage of innovation versus adoption depends on country-specific parameters, such as λ_i and $\bar{\varepsilon}_{in}$.

3.4 Market-Clearing Conditions

Finally, I close the model by describing the feasibility condition and the market-clearing conditions:

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

$$Y_{nt} = C_{nt} + H^r_{nt} + \sum_{i=1}^{M} H^a_{ni,t}. \tag{21}$$

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

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

From here,

$$\bar{m} W_{nt} L_{nt} = \sum_{i=1}^{M} \Omega_n^{\sigma-1} T_{nt} \frac{p_{in,t} x_{in,t}}{1+\tau_{in,t}} = \sum_{i=1}^{M} \frac{\pi_{in,t}}{1+\tau_{in,t}} P_{nt} Y_{nt}. \tag{23}$$

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

$$\mathrm{IBT}_{nt} = \sum_{i \neq n}^{M-1} \frac{\tau_{ni,t}}{1+\tau_{ni,t}} \pi_{ni,t} P_{nt} Y_{nt}. \tag{24}$$

Bonds market clearing The world market-clearing condition for bonds is given by

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

Balance of Payments The balance of payments equation can be expressed as follows:

$$\sum_{i \neq n}^{M-1} \frac{\Omega_i^{\sigma-1} T_{it} p_{ni,t} x_{ni,t}}{1+\tau_{ni,t}} = \sum_{i \neq n}^{M-1} \frac{\Omega_n^{\sigma-1} T_{nt} p_{in,t} x_{in,t}}{1+\tau_{in,t}} + \sum_{i \neq n}^{M-1} RP_{in,t} - \sum_{i \neq n}^{M-1} RP_{ni,t} + R_t B_{n,t-1} - B_{nt}, \tag{26}$$

with $RP_{in,t} = \chi_{in,t} \frac{A_{in,t}}{T_{it}} \Pi_{it}$ royalty payments. This equation determines the flow of payments to the owners of the main factors of production and is derived by combining the budget constraint in equation (2), the feasibility condition in equation (21), and profit expressions, as I show in the Online Appendix.

3.5 Nash Bargaining: Tariff and IP Protection Negotiation

Imperfect enforcement of IPR creates an inefficiency in the model, leading to underinvestment in innovation and lower long-term growth. To address the inefficiency, governments in high-enforcement countries can sign trade agreements with governments in low-enforcement countries. I assume that country i, a low-enforcement country, and country n, a high-enforcement country, engage in bilateral negotiations regarding tariffs, represented by $\tau_{ni,t}$ and the quality of IPR enforcement, denoted as $\xi_{in,t}$. This negotiation 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.

Formally, when country i negotiates with country n, they determine tariffs, $\tau_{ni,t}$, and the quality of IPR, $\xi_{in,t}$, that maximize their joint surplus, represented by the following equation:

$$\max_{\tau_{ni,t},\xi_{in,t}} \Delta\tilde{W}_i(\tau,\xi)^{\theta}\Delta\tilde{W}_n(\tau,\xi)^{1-\theta} \tag{27}$$

subject to $\Delta\tilde{W}_i > 0$ for all i. Here, $\Delta\tilde{W}_i$ represents the welfare change between signing the trade agreement and remaining in the status quo (i.e., the initial BGP equilibrium) and the parameter $\theta \in (0,1)$ denotes the bargaining power of country i.

Welfare gains, $\Delta\tilde{W}_i$, are computed in consumption-equivalent units (inclusive of the transition); that is, it denotes the constant amount of consumption that needs to be provided to the consumers in each period to make them indifferent between signing the agreement and remaining in the initial BGP, represented by the star symbol:

$$\sum_{t=0}^{\infty}\beta^t u\left(C^*_{it}(\tau_{ni,0},\xi_{in,0})\left(\frac{\Delta\tilde{W}_i}{100}+1\right)\right) = \sum_{t=0}^{\infty}\beta^t u\left(C_{it}(\tau_{ni,t},\xi_{in,t})\right). \tag{28}$$

The agreement operates under several key assumptions. First, it is a cooperative agreement, contingent on positive welfare gains for both negotiating parties, reflecting their welfare-maximizing objectives. Second, governments select policy instruments at time zero, which remain constant thereafter, i.e., $\tau_{ni,t} = \tau_{ni}$ and $\xi_{in,t} = \xi_{in}$, $\forall t$. Consequently, the new IPR protection applies to technologies adopted after time zero, similar to Grossman and Lai (2004). Third, commitment is assumed; and once the agreement is signed, neither country can deviate. [9] These assumptions are subsequently relaxed in the quantitative analysis. Fi-

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[9] The "perfect enforcement" assumption refers to the countries' adherence to the agreed policy actions, rather than the actual realization of IP protection for individual technologies. While the model assumes that countries comply with the agreed policies, it abstracts from monitoring the outcome of individual adoption attempts.

nally, governments have two instruments: tariffs imposed by the high-enforcement country and IP reforms carried out by the low-enforcement country. [10]

3.6 Equilibrium

For all i and n, an equilibrium in which all firms behave symmetrically is defined as a vector of policy instruments $\{\tau_{ni,t}, \xi_{in,t}\}_{t=0}^{\infty}$, an initial vector $\{A_{in,0}, Z_{n,0}\}$, a set of parameters $\{\sigma, \beta_r, \beta_a, \theta\}$ 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, $\{\chi_{in,t}\}_{t=0}^{\infty}$ a sequence of value functions $\{V_{in,t}^{\text{adopt}}, V_{in,t}^{\text{innov}}, J_{in,t}^{\text{adopt}}, J_{in,t}^{\text{innov}}, W_{in,t}, O_{in,t}\}_{t=0}^{\infty}$, profits $\{\Pi_{it}, RP_{in,t}, \text{IBT}_{it}\}_{t=0}^{\infty}$, 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. $\{Z_{nt}, A_{in,t+1}\}_{t=0}^{\infty}$ satisfy the law of motion in equations (8) and (16).
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, yielding equation (4).
4. Given prices, allocations solve the intermediate producer's problems in equation (6) subject to (4).
5. Given prices, allocations solve the innovators' and adopters' problems, yielding equations (18) and (20).
6. The royalty fee is determined as the result of Nash bargaining between the innovator and adopter in equation (15).
7. Tariff and quality of IPR bargaining equilibrium are defined as a vector of tariffs, τ, and IPR enforcement, ξ, 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. In other words, the equilibrium policies and outcomes remain optimal over time.

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[10] Achieving the first-best outcome might require additional instruments like R&D or adoption subsidies (see Shim, 2023, who analyzes optimal innovation and adoption policies in the context of technology licensing between Japan and South Korea.).

8. Feasibility is satisfied in equation (21).

9. Prices are such that all markets clear (labor market, government tax revenues, consumer's budget constraint, and bond market) in equations (23)-(26).

A list with all the equations of the model is relegated to an Online Appendix.

3.7 Balanced Growth Path

Cross-country adoption guarantees that the model has a unique BGP equilibrium in which all countries grow at a constant and uniform rate but differ in relative levels. Growth in the BGP is endogenous. Changes in tariffs, τ, and in the quality of IPR enforcement, ξ, have both growth and level effects. Here I characterize the BGP growth rate of the economy (the remaining variables on the BGP are characterized in the Online Appendix). To ensure that the endogenous variables remain constant along the BGP, I transform them by dividing each variable by its respective trend component. This normalization removes the trend component from the variables, resulting in a stationary system of equations that characterizes the BGP equilibrium. I denote the normalized variables with a hat, omit the time subscripts in the derivations, and use a star to indicate the BGP values of the variables.

The stock of knowledge T_i^* grows at the constant rate $g*$. Combining equations (8) and (16), I can express the BGP growth and relative productivity of country i (relative to a reference country M) as

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

where $\hat{T}_n^* = \frac{T_n^*}{T_M^*}$.

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

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

Proposition 1 *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. Associ-*

ated 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 tariffs,* τ*, and IPR,* χ*, have an effect on* g^* *and* T^* *through changes in* $\hat{H}^{r*}$ *and* ε^**, which in turn depends on* $\hat{H}^{a*}$*.*

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

4 The Mechanism

To explore the main channels at play, consider a simplified model with a two-country world consisting of the North and South, which have different levels of IP enforcement. North enforces IP rights perfectly, while South has imperfect IP enforcement. North imposes tariffs on imports from South, but South does not impose tariffs. The two countries engage in a Nash bargaining negotiation to determine the level of IP enforcement in South and the tariff level imposed by North on imports from South. Assume the agreement results in South improving IP protection on both domestic and foreign IP, and North removing tariffs on imports from South.

The model presents several inefficiencies arising from imperfect IP enforcement and existing tariffs before the trade agreement, which the agreement aims to address. Imperfect IP enforcement in South enables IP infringement, reducing incentives for domestic and foreign R&D investment. Tariffs imposed by North create trade barriers, restricting market access for South's products and diminishing potential trade gains. Countries with low IP enforcement do not fully internalize the negative impact of their actions on R&D investment and global growth. IP protection policies can help rectify these inefficiencies, but at the cost of higher adoption costs for low-IP-enforcement countries. Lower tariffs can be used to incentivize low-enforcement countries to improve their IP protection. The main channels through which the trade agreement impacts innovation, growth, and welfare are as follows: (1) Increased IP enforcement in South reduces IP infringements and encourages innovation in both countries by increasing royalty payments to innovators; (2) Tariff reductions stimulate innovation in South by expanding its market size, but the overall effect on South's welfare is ambiguous due to the trade-off between higher profits from lower tariffs and loss in profits from increased licensing fees; (3) Adoption in North increases due to more technologies being produced domestically and internationally, while adopters in South face opposing forces: lower tariffs incentivize adoption through higher profits, but higher royalty fees imply a lower value of adoption; (4) North experiences static effects, benefiting from a lower home trade share but facing a trade-off between losing the ability to manipulate terms of trade and forgoing tariff revenues; (5) Increased innovation in both countries contributes to a higher BGP growth rate, generating dynamic gains from the trade agreement, but the distribution of welfare gains during the transition varies between the two countries.

The details of the trade agreement and its effects depend on several factors, including the bargaining power of the negotiating parties, innovation efficiency, initial tariffs and IP enforcement levels, and the comparative advantage of innovation versus adoption. These factors shape the overall outcome of the trade agreement, highlighting the complex interplay between IP enforcement and tariffs. However, the exact effects of the trade agreement can only be analyzed in a quantitative framework, as I explore next.

5 Quantitative Analysis

I study quantitatively the dynamic implications of a Nash bargaining trade agreement between China and the United States, motivated by the United States' concerns about the alleged misappropriation and forced transfer of American technology by Chinese companies. In the phase one agreement reached at the end of the US-China trade war, China committed to improving its protection of IPR, while the United States agreed to lower tariffs on certain Chinese imports as an incentive for China's compliance. In counterfactual analysis, the agreement is modeled with China choosing the quality of its IP protection and the United States deciding on tariffs for Chinese imports, assuming the agreement is perfectly enforced, unanticipated, permanent, and a one-time shock with perfect foresight.[11] I then explore the dynamic trade-offs by considering various alternative scenarios, including analyzing the interaction between trade policy and IP reforms, examining the impact of each instrument separately, relaxing some of the assumptions underlying the Nash bargaining process, and, in the Online Appendix, exploring the model's characteristics that play a crucial role in

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[11] 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 given it involves more royalty payments and lower tariffs.

determining a specific solution within the Nash bargaining negotiation.

5.1 Calibration

The model is calibrated to match data on trade flows, geography, income, R&D spending, and international technology licensing for a sample of countries that are aggregated into three regions: the United States, China, and an aggregate rest of the world.[12] I set the initial period at 2000, which predates China's entry into the WTO.[13] I provide details on the calibration strategy next and report the calibrated parameters in Table 1.

Common parameters 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 0.98, which implies an annual interest rate of 3%.

Trade costs and relative productivity I calibrate trade costs, $d_{in}(1+\tau_{in})$, and productivity, $\Omega_n^{\sigma-1}T_n$ with gravity methods. From the expression for country i's imports from country n,

$$X_{in,t} = T_{nt}\Omega_n^{\sigma-1}\left(W_{nt}d_{in}(1+\tau_{in})\right)^{1-\sigma}X_{it},$$

we can write the following reduced-form gravity equation:

$$X_{in,t} = \exp\left(\beta_{RTA}RTA_{in,t} + fe_{nt} + \mu_{it} + \kappa_{in}\right)\epsilon_{in,t}, \tag{30}$$

where $RTA_{in,t}$ is a dummy that takes the value of 1 if country i and country n had a regional trade agreement in period t and zero otherwise; $fe_{nt} = \Omega_n^{\sigma-1}T_{nt}\left(W_{nt}\right)^{1-\sigma}$ and $\mu_{it} = X_{it}$ are exporter-time and importer-time fixed effects, respectively; and $\kappa_{in} = \left(d_{in}(1+\tau_{in})\right)^{1-\sigma}$ are bilateral fixed effects, including tariffs. The term $\epsilon_{in,t}$ is the error term in the regression.

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[12] The quantitative analysis has the potential for broader application to a greater number of countries or regions. However, the primary focus of this paper is to examine bilateral trade agreements, with a specific emphasis on understanding their effects on the countries that are directly involved in signing these agreements.

[13] The assumption that China was on a BGP in 2000 serves as a simplification strategy for analysis and calibration purposes. Another advantage of this assumption is that it allows me to isolate the transitional dynamics resulting from joining the trade agreement from the natural transitional dynamics that stem from the country converging to its BGP. By separating these two sets of transitional dynamics, we can gain a clearer understanding of the specific impacts of policy changes. However, I acknowledge that this assumption may not perfectly reflect the complexities of China's economic reality in 2000.

I estimate equation (30) using panel data for 69 countries and the period 1986-2006. The database reports bilateral trade, including international and intra-national trade, from Centre for Prospective Studies and International Information (CEPII) and United Nations Industrial Development Organization (UN UNIDO) databases. I estimate a matrix of time-invariant bilateral trade costs and a vector of productivity $\Omega_n T_{nt}^{\sigma-1}$, setting $t = 2000$. The details of the calibration strategy are relegated to the Online Appendix.

The royalty fee structure I calibrate the royalty fee structure in the initial BGP as follows. Recall that the royalty fee is given by $\chi_{in} = \bar{\rho}_{in}\eta_i\xi_{in}$. In the initial BGP, I set the value of the policy parameter $\xi_{in} = 1$. Then, I choose the value of $\bar{\rho}_{in}$ according to the 25% patenting rule. The 25% rule, while not a rigorous principle, has emerged as a common heuristic in current licensing negotiations. It implies that a licensee should pay a royalty rate equivalent to 25% of its expected profits from the licensed technology.[14] Through the lens of the model, the 25% figure can be interpreted as the equilibrium outcome of the bargaining process between innovators and adopters when there is perfect enforcement of IPR (i.e, $\rho_{in} = 0.25$ where $\bar{\rho}_{in} = 0.25$ and $\eta_i = 1$). That is the case of the US. If there is imperfect IP enforcement, $\eta_i < 1$ and $\rho_{in} < 0.25$. Below, I describe how I estimate the quality of IP enforcement using data on royalty payments.

Probability of Adoption and the quality of IPR A novelty of the calibration strategy in this paper is to estimate the probability of adoption, ε_{in}, and the quality of IP enforcement, η_i, using data on bilateral royalty payments and gravity methods.

In the model, royalty payments from country i to country n are given by

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

Solving for equations (8) and (16) on the BGP, I obtain an expression for royalty payments given by

$$RP_{in,t} = \bar{\rho}_{in}\eta_i\frac{\varepsilon_{in}}{\varepsilon_{in}+g}\lambda_n T_{nt}\left(\frac{H_{nt}^r}{\bar{Y}_t}\right)^{\beta_r}\frac{\Pi_{it}}{T_{it}}. \tag{31}$$

That equation can be expressed as a gravity-type equation of royalty payments that

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[14] `https://assets.kpmg/content/dam/kpmg/pdf/2015/09/gvi-profitability.pdf`. The 25% rule was initially invented by Goldscheider, Jarosz, and Mulhern (2018).

depend on exporter-time and importer-time fixed effects as well as time-invariant bilateral fixed effects:

$$RP_{in,t} = \exp\left(\sum_{k\in\{\text{T,NT}\}} \text{RTA}_{int}^{k} + S_{nt} + F_{it} + fe_{in}\right) * u_{int}, \tag{32}$$

with RTA_{int}^{k} an RTA with technology (T) and non-technology (NT) provisions (Martínez-Zarzoso and Chelala, 2021), $fe_{in} = \log\left(\bar{\rho}_{in}\frac{\varepsilon_{in}}{\varepsilon_{in}+g}\right)$, $S_{nt} = \log\left(\lambda_n T_{nt}\left(\frac{H_{nt}^{r}}{Y_t}\right)^{\beta_r}\right)$, and $F_{it} = \log\left(\eta_i \frac{\Pi_{it}}{T_{it}}\right)$.

I estimate equation (32) using data on royalty payments for 40 countries—excluding tax havens—during the period 1995-2000, and with 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. The results from the estimation are reported in the Online Appendix.

I recover ε_{in} from the bilateral fixed effects, assuming a BGP productivity growth rate of 1.85% and setting $\bar{\rho}_{in} = 0.25$, following the 25% patenting rule. Finally, I impose adoption within the country so that $\varepsilon_{ii} = 0.5$, which implies that domestic adoption occurs every 2 years, as it was established to be the case for the United States (Cai, Li, and Santacreu, 2021; Caballero and Jaffe, 1993). I then take the cross-country average of the parameters of diffusion for the United States, China, and the rest of the world. For the rest of the world, I take a weighted average using bilateral flows of royalty payments as the weights. On average, it takes countries about 3 years to adopt a foreign technology. The results are reported in Table 1.

Finally, I calibrate the IPR enforcement from the importer-time fixed effects in equation (32). In particular, I estimate the following regression

$$F_{it} = \beta_0 \log(GDP_{it}) + \beta_1 \log(GP_{it}) + \mu_{it}, \tag{33}$$

where GDP_{it} represents gross domestic product (GDP) of country i from CEPII, GP_{it} is an index of patent rights measured with the Ginarte-Park index (Ginarte and Park, 1997), and

μ_{it} is an error term. The idea is that, after controlling for market size (proxied by GDP), the residual variation in the importer-time fixed effects can be attributed to differences in the quality of IPR protection across countries. The coefficient on the patent rights index, β_1, captures the extent to which differences in IPR protection explain the variation in royalty payments, conditional on market size.

As a way to approximate the quality of IP enforcement, η_i, I calculate the time-averaged estimate of $\hat{\beta}_1 \log(GP_{it})$. I then express this measure relative to the United States. I assume perfect enforcement of IPR in the United States and rest of the world, but partial enforcement in China. That is, $\eta_{\text{US,ROW}} = 1$. However, Chinese adopters pay only a fraction of the agreed-upon royalty fee, either domestically or internationally, so that $\eta_i < 1$, $\forall$ $i = \{\text{China}\}$. The findings reveal that $\eta_{\text{China}} = 0.4$, implying a 10% royalty fee paid by China for both domestic and foreign technologies.

Weaker IPR protection leads to lower royalty fees, reducing innovators' returns and resulting in under-investment in innovation.

Parameters calibrated within the model recursively The remaining parameters, namely β_r, β_a, λ_n, Ω_n, and $\bar{\varepsilon}_{in}$, are calibrated using a recursive algorithm developed by Cai, Li, and Santacreu (2021), which involves solving the model on the BGP. The values of β_r and λ_n are determined by targeting a productivity BGP growth rate of 1.85% and exactly matching R&D intensity data in 2000, based on the expression for the BGP growth rate in equation (29) and the Perron-Frobenius theorem. With these parameters in place, we can derive a value for T_n, which, in turn, allows us to infer Ω_n from the estimated $\Omega_n^{\sigma-1} T_n$ in equation (30). I equate β_a to β_r since there is no bilateral data available on adoption spending and obtain the value of $\bar{\varepsilon}_{in}$ by setting ε_{in} to its estimated value in equation (31). Finally, L_{it} is calibrated using population data for 2000.

5.2 Model Validation

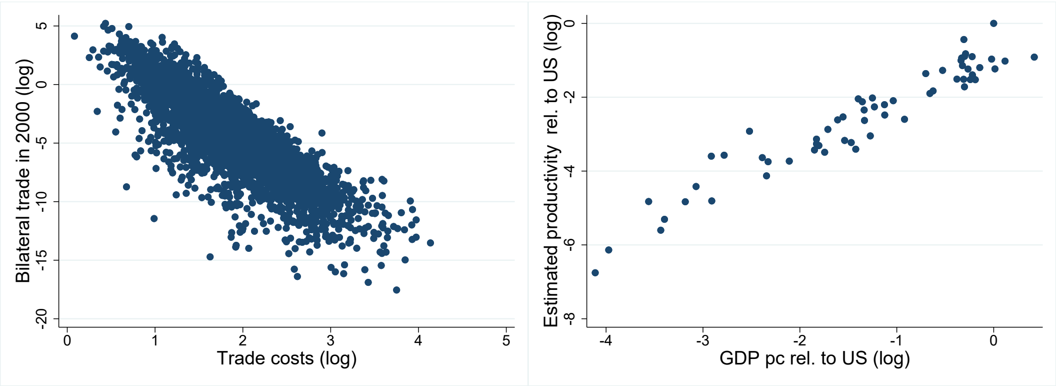
Prior to conducting counterfactual analysis, I provide model validation by examining the estimates derived from the two key gravity equations in the model. The first equation captures trade flows, yielding estimates for trade costs and productivity (equation 30). The second equation relates to royalty flows and provides estimates for the quality of IP enforcement (equation 31).

Table 1: Calibrated parameters

Parameter	Value	Source
$\Omega_{\text{US}}\,(T_{\text{US}})^{1/\sigma-1}$	18.6	Gravity trade
$\Omega_{\text{ROW}}\,(T_{\text{ROW}})^{1/\sigma-1}$	5.98	Gravity trade
$\Omega_{\text{China}}\,(T_{\text{China}})^{1/\sigma-1}$	1.00	Gravity trade
$d_{\text{USA,ROW}}(1+\tau_{\text{USA,ROW}})$	1.95	Gravity trade
$d_{\text{USA,China}}(1+\tau_{\text{USA,China}})$	1.80	Gravity trade
$d_{\text{ROW,USA}}(1+\tau_{\text{ROW,USA}})$	2.48	Gravity trade
$d_{\text{ROW,China}}(1+\tau_{\text{ROW,China}})$	2.15	Gravity trade
$d_{\text{China,USA}}(1+\tau_{\text{China,USA}})$	3.23	Gravity trade
$d_{\text{China,ROW}}(1+\tau_{\text{China,ROW}})$	2.53	Gravity trade
L_{US}/L_{China}	0.23	CEPII
L_{ROW}/L_{China}	1.82	CEPII
$\varepsilon_{\text{USA,ROW}}$	0.28	Gravity royalties
$\varepsilon_{\text{USA,China}}$	0.33	Gravity royalties
$\varepsilon_{\text{ROW,USA}}$	0.34	Gravity royalties
$\varepsilon_{\text{ROW,China}}$	0.15	Gravity royalties
$\varepsilon_{\text{China,USA}}$	0.28	Gravity royalties
$\varepsilon_{\text{China,ROW}}$	0.33	Gravity royalties
β_r	0.52	Match $g = 1.85\%$
β_a	0.52	Set $\beta_a = \beta_r$
λ_{US}	0.40	Match R&D intensity in USA
λ_{ROW}	0.50	Match R&D intensity in ROW
λ_{China}	0.18	Match R&D intensity in China
$\bar{\rho}_{in}$	0.25	Royalty fee
η_{US}	1.00	IP enforcement in USA
η_{China}	0.40	IP enforcement in China
η_{ROW}	1.00	IP enforcement in ROW

Trade costs and productivity Figure 2 shows, in the left panel, the relation between trade flows in the data and trade costs obtained from estimating the gravity equation (30) with PPML methods and pair fixed effects. The right panel shows the relation between relative productivity estimated from the exporter-time fixed effect and GDP per capita in the data (relative to the US). The estimated trade costs exhibit a negative relationship with observed trade flows. Additionally, there is a strong positive correlation between the estimated productivity and the actual GDP per capita levels in the data. Hence, the model can produce estimates of trade costs and productivity that are consistent with the data on trade flows and GDP per capita.

Figure 2: Estimated trade costs and productivity using gravity methods

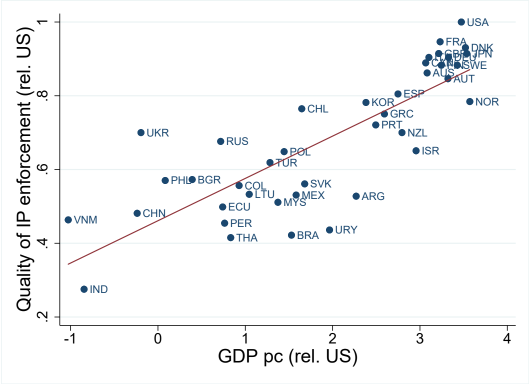


(a) Trade costs $d_{in}(1 + \tau_{in,t})$ (b) Productivity (relative to US)

Notes: The left panel shows trade flows in the data and trade costs from estimating the gravity equation (30) with PPML methods and pair-fixed effects. The right panel shows relative productivity estimated from the exporter-time fixed effect and GDP per capita in the data (relative to the US).

Quality of IP enforcement Figure 3 presents a comparison between the quality of IP enforcement, as calculated from equation (33), and per capita GDP data. The figure shows a general trend where countries with higher GDP per capita tend to better protect IPR. This finding is consistent with richer countries having more effective IP protection.

Figure 3: Quality of IP enforcement and GDP pc, relative to the United States



Notes: The figure shows the quality of IP enforcement (relative to the US) and the GDP pc (relative to the US), averaged over the period prior to 2000.

5.3 The Design of the Trade Agreement

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, $\xi_{\text{China},n}$ with $n \in \{\text{China}, \text{USA}\}$. The improvement in IPR applies to adopters of both domestic and foreign IP, albeit with varying degrees of intensity. In other words, $\xi_{\text{China,US}}$ may not necessarily equal $\xi_{\text{China,China}}$. The details of the trade agreement are determined as the solution of the Nash bargaining problem in 27.

$$\max_{\tau,\xi} \Delta\tilde{W}_{\text{USA}}(\tau,\xi)^{\theta} \Delta\tilde{W}_{\text{China}}(\tau,\xi)^{1-\theta}, \tag{34}$$

subject to $\Delta\tilde{W}_i > 0 \; \forall i \in \{\text{USA}, \text{China}\}$. Here, $\Delta\tilde{W}_i$ is the welfare change, in consumption-equivalent units, between staying in the initial BGP or signing the agreement and staying there forever, as in equation (28), and $\theta \in (0,1)$ is the bargaining power of the United States. Welfare gains are computed inclusive of the transition.[15]

The agreement is assumed to be perfectly enforced, unanticipated by economic agents (including innovators, adopters, producers, and consumers), and permanent. In other words, the countries choose the values of these policy instruments today and commit to maintaining these values indefinitely. The model is solved with perfect foresight, assuming the economy is initially at the BGP. In period 1, China and the United States sign the trade agreement as the solution of the problem in equation (34).[16]

The Nash bargaining outcome, reached with both parties having equal bargaining power ($\theta = 0.5$), results in the elimination of US tariffs on Chinese imports and an improvement in the quality of Chinese IP enforcement. This improvement leads to an increase in the domestic royalty fee (i.e., the fee paid by Chinese adopters to Chinese innovators) from 10% to 25%, while the royalty fee paid to foreign innovators rises from 10% to 18%. By design, all countries benefit from this agreement, as shown in the first row of Table 2. The United States experiences the largest gains in consumption-equivalent units (0.85%), while China experiences the smallest gains (0.26%). This trade agreement yields both growth and level effects, as the BGP growth rate rises from 1.85% to 1.87%.

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[15] Evaluating welfare along the transition allows us to address the issue that BGP to BGP gains may be overstated given 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, 2021).

[16] 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).

Table 2: Welfare Gains from Trade Agreement

	$\Delta\tilde{W}$**(USA)**	$\Delta\tilde{W}$**(China)**	g	$\tau_{\text{USA,China}}$	$\xi_{\text{China,USA}}$	$\xi_{\text{China,China}}$
Baseline	0.85%	0.26%	1.87%	0%	18%	25%

Notes: The table reports welfare gains, inclusive of the transition, computed from equation (28) for the US and China. The first two columns display the welfare gains in the US and China, respectively. The third column provides the BGP growth rate. The last three columns contain the values of the policy instruments selected within the agreement: namely, tariffs, the royalty fee paid to foreign innovators, and the royalty fee paid to domestic innovators.

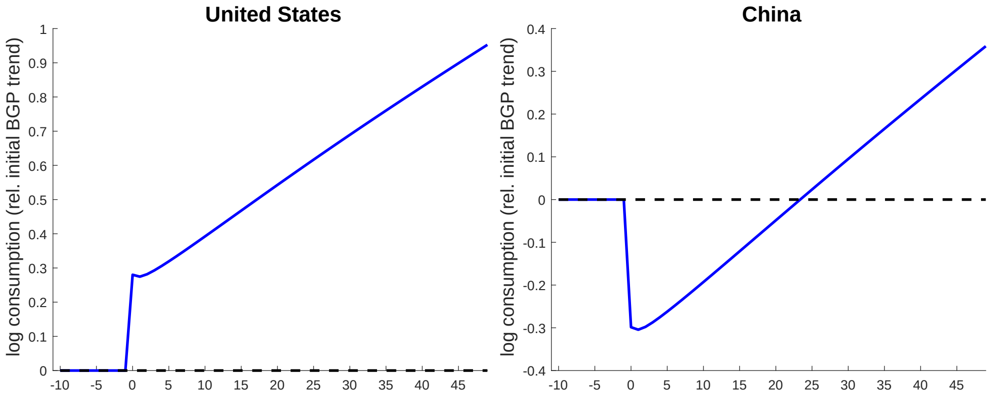
5.3.1 Dynamic effects of the trade agreement along the transition

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. I then analyze the different components of welfare—income, R&D investment, and adoption investment—to understand what drives heterogeneous effects along the transition.

Welfare Figure 4 shows the evolution of consumption 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 0, 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 BGP 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 25 years after the initial shock, and China starts experiencing positive gains. The short-term losses in China are driven by the increase in royalty payments adopters need to make to foreign innovators when they improve IP protection. The trade liberalization helps to dampen the negative effect on consumption, as adopters and innovators in China benefit from access to a larger market. In the long run, the larger investment in R&D in China and the United States increases growth to 1.87% (Table 2), leading to long-term gains. The result is that it takes about 25 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.[17]

Figure 4: Log of consumption



Notes: The figure plots 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.

Next, I delve into the effect that the trade agreement has on key economic variables: namely, innovation, adoption, growth, and royalty payments.

Growth, Innovation, and Adoption The trade agreement has a positive effect on R&D intensity in both countries through two channels. First, an increase in IPR enforcement increases the return to innovators, both in China and the United States, as innovators start receiving royalties for technologies that are adopted in China. This manifests through an increase in the value of an innovation, V_{nt}, in both countries. As a result, R&D spending, H^r_{nt}, increases in both countries:

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[17] In the Online Appendix, I study the contribution of each component of consumption after the agreement is signed.

$$H^r_{nt} = \left(\beta_r \bar{Y}_t^{\beta_r} \lambda_n T_{nt} \frac{V_{nt}}{P_{nt}}\right)^{1-\beta_r} . \tag{35}$$

Second, access to a larger market for Chinese exports increases domestic innovation in China through an increase in $\Pi_{\text{CHN,USA},t}$. This in turn impacts $V_{\text{CHN}t}$ positively. Both countries reach a higher level of R&D intensity in the counterfactual BGP.

Adoption in China is subject to two opposing forces: (i) the return to Chinese adopters decreases, as they now have to pay higher royalties, but (ii) adopters profit from exporting intermediate products that are produced with licensed technology.

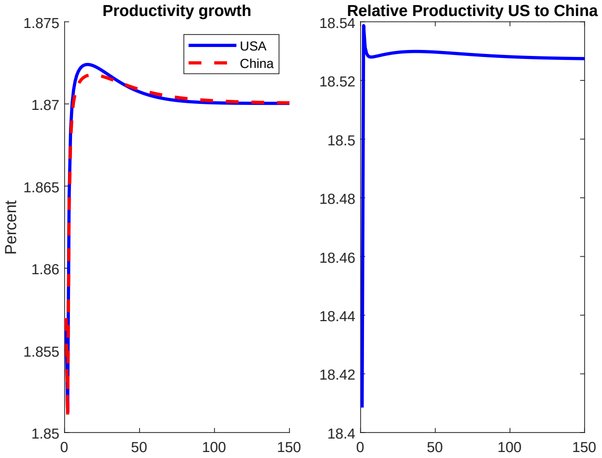
Through the FOC of adoption:

$$H^a_{\text{CHN,USA},t} = \left(\beta_a \bar{\epsilon}_{\text{CHN,USA}} \frac{V^{\text{adopt}}_{\text{CHN,USA},t} - J^{\text{adopt}}_{\text{CHN,USA},t}}{P_{\text{CHN}t}}\right)^{\frac{1}{1-\beta_a}} \tag{36}$$

When $\xi_{\text{CHN,USA}}$ increases, then $V^{\text{adopt}}_{\text{CHN,USA},t} - J^{\text{adopt}}_{\text{CHN,USA},t}$ decreases. The elasticity of adoption with respect to changes in the value of adopted technologies is given by $1-\beta_a$. Reduced adoption rates have a negative impact on innovation through two channels: (i) a lower probability of adoption, $\varepsilon_{\text{CHN,USA},t}$, results in a lower value of innovation, represented by $J^{\text{innov}}_{\text{CHN,USA},t}$, thus adversely affecting innovation; and (ii) the adoption of fewer foreign technologies also leads to a decrease in $T_{\text{CHN}t}$, which in turn diminishes innovation through the externality effect on innovation efficiency. Therefore, the processes of innovation and adoption are linked, and the nature of this connection depends on the royalty fee, $\chi_{\text{CHN,USA},t}$.

The net effect is a decline in adoption intensity, since there is a reallocation from adoption to innovation in China. This reallocation effect depends on the comparative advantage of innovation versus adoption. As a result of more innovation worldwide, the BGP growth rate increases from 1.85% to 1.87%. The left panel of Figure 5 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, in both the United States and China, the growth rate overshoots and then it converges smoothly toward the final BGP. Both countries reach a BGP growth rate of 1.87% on the counterfactual. Changes in growth rates are driven by the endogenous responses of innovation and adoption after changes in IP protection and tariffs. 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 5 shows.

Figure 5: 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 Royalty payments from China to the United States increase after signing the trade agreement, which is consistent with the evidence presented in Section 2, offering external validation for the model. The United States also pays more royalties to China after signing the agreement, as China becomes more innovative. On net, the technology trade imbalance between the United States and China widens. The decrease in US tariffs on Chinese imports translates into a decrease in the US home trade share, resulting in productivity increases through the standard channel present in static trade models.

5.4 Interactions Between IP Reforms and Trade Policy

To better understand the interactions between IP reforms and trade policy, I consider three alternative scenarios to the Nash bargaining problem defined in equation (34), which I refer to as the baseline agreement. First, I consider a scenario in which the United States lowers import tariffs from China, but China does not improve its IPR. Second, I consider the case in which China improves its IP protection but does not benefit from lower tariffs. Third, I evaluate the case in which China reforms its domestic IPR unilaterally—i.e., China improves its domestic IPR but does not sign a trade agreement. In each of these cases, I assume the baseline agreement's outcome as given and then analyze the impact of modifying each instrument individually. Table 3 (middle panel) reports welfare gains and BGP growth rates in each scenario.

Table 3: Welfare Gains: Alternative scenarios

Counterfactual	$\Delta\tilde{W}$(USA) (%)	$\Delta\tilde{W}$(China) (%)	BGP Growth (%)	$\tau_{\text{USA,China}}$ (%)	$\xi_{\text{China,USA}}$ (%)	$\xi_{\text{China,China}}$(%)
Baseline	0.853	0.262	1.87	0	18	25
Only tariffs	-0.097	0.167	1.85	0	0	0
Only IPR	0.944	0.085	1.86	5	18	25
Unilateral IP reform	0.117	0.307	1.85	5	0	25
Nash equilibrium	0.174	-0.528	1.85	20	0	25
Shortsighted government	0.270	0.354	1.86	1	12	25
China deviates	0.096	0.316	1.85	5	0	25
China deviates (retal)	0.228	-0.080	1.85	20	0	25
Anticipated	0.651	0.258	1.86	5	16	25
Gradual	0.657	0.277	1.86	5	16	25

Notes: The table reports welfare gains, inclusive of the transition, the BGP growth rate, and the terms of the agreement for alternative scenarios: (1) Baseline, (2) only lower tariffs, (3) only IPR reform, (4) unilateral improvement of domestic IPR, (5) Nash equilibrium, (6) a shortsighted government, (7) China deviates without retaliation, (8) China deviates with retaliation, (9) anticipated policy, and (10) anticipated and gradual adjustment. In the cases (5), (6), (9), and (10), I recompute the Nash bargaining solution from equation (34). The first two columns display the welfare gains in the US and China, respectively. The third column provides the BGP growth rate. The last three columns contain the values of the policy instruments selected within the agreement, namely tariffs, the royalty fee paid to foreign innovators, and the royalty fee paid to domestic innovators. The values in the royalty fee columns represent the new royalty fees after the policy changes in each scenario.

First, when the US eliminates tariffs on Chinese imports without China reforming its IP enforcement for both domestic and foreign IP, China experiences larger gains than in the baseline scenario, while the US experiences losses. Reduced tariffs on Chinese imports create a higher incentive for innovating and adopting technology, leading to increased profits and output due to access to a larger market, all while avoiding royalties for foreign technology use. Conversely, increased competition from Chinese imports diminishes innovation incentives in the US. This, coupled with lost tax revenues and unfavorable terms of trade, leads to short-term losses in the US. Moreover, the absence of compensation for US innovators from their R&D efforts contributes to a long-term decline in innovation and global growth. Hence, tariff declines are crucial to incentivize improvements in IP enforcement of foreign firms and generate long-term growth.

Second, improvements in IPR that are not accompanied by a reduction in tariffs leave the BGP growth rate virtually unchanged. China experiences almost zero welfare gains (0.085% vs 0.262%). The main reason is that China experiences larger short-term losses than in the baseline scenario, as China has to pay more royalties to foreign firms, but does not benefit from access to larger export markets. Because the BGP growth rate barely moves, it takes longer for these losses to be compensated by a higher growth rate, yielding very low gains in China. The United States experiences larger short-term and long-term gains. Innovators receive more royalty payments, but the government does not give up tariff revenues or controlling its terms of trade in exchange for more royalty payments.

Finally, I examine whether China has incentives to reform its domestic IP enforcement unilaterally without participating in a trade agreement. In this case, welfare gains for China are larger than in the baseline scenario, albeit at the expense of the United States, which sees lower gains. By abstaining from the agreement, China forgoes the potential for lower tariffs but avoids incurring a higher cost for adopting foreign technologies. Throughout the transitional phase, the positive effect of lower US tariffs is outweighed by the negative impact of incurring higher adoption costs, and China experiences short-term gains.

The results highlight several insights. First, China's drive to improve its domestic IP enforcement is internally motivated and does not necessarily depend on external incentives (i.e., lower tariffs through a trade agreement). However, participation in a trade agreement can act as a stimulus for China to strengthen its protection of foreign IP through lower tariffs. While tariffs predominantly produce short-term impacts, they can be used as a tool for incentivizing IP reforms or discouraging departures from the agreement, especially when it comes to foreign IP.

5.5 Revisiting the Main Assumptions of the Trade Agreement

This section explores alternative scenarios to the baseline Nash bargaining problem (equation 34). It compares the cooperative agreement with the uncooperative Nash equilibrium, considers a shortsighted government prioritizing short-term gains, examines the consequences of China deviating from the agreement and the US responding with higher tariffs, and analyzes the impact of an anticipated agreement with immediate or gradual implementation. The results of these scenarios are presented in Table 3 (bottom panel).

Cooperative vs uncooperative equilibrium I contrast the outcomes of a Nash bargaining agreement, where countries cooperate, with a Nash equilibrium scenario where each country independently selects its optimal response based on the given response of the other country. In the uncooperative solution, the US increases tariffs to 20% and China improves only domestic IP enforcement, with the foreign royalty fee remaining at 10% and the domestic royalty fee increasing to 25%.[18] The welfare implications are significant. In the cooperative baseline scenario, both the US and China experience welfare gains, with US welfare increasing by 0.853% and China's by 0.262%. The Nash equilibrium presents a less optimistic picture, with US welfare increasing by a smaller magnitude (0.174%) and China experiencing losses of -0.528%. The BGP growth rate is also lower at 1.85%. These findings are consistent with China's motivation to improve its enforcement of IPR on domestic technologies, while the United States leans toward imposing higher tariffs to counter foreign competition, particularly from countries with weak IP protection. In fact, the US preference for higher tariffs diminishes as the exporting country's IP enforcement strengthens.

In summary, the cooperative solution yields more favorable outcomes, resulting in higher welfare gains for both countries. Agreeing on tariffs and IP enforcement during negotiations can potentially lead to a mutually beneficial economic path, in contrast to the Nash equilibrium where non-cooperative actions result in suboptimal outcomes.

Welfare-maximizing versus Shortsighted Government In the baseline scenario, the trade agreement is designed by a welfare-maximizing government that chooses tariffs and the level of IP protection to maximize overall welfare, without focusing on the short run. Under this agreement, both the United States and China gain overall, but China suffers short-term losses. This may not be attractive to a government seeking to avoid such short-term losses. I consider the design of a trade agreement made by a shortsighted government with a lower discount factor than the consumer (0.96 vs 0.98). I compute the level of tariffs and quality of IP enforcement that solve the bargaining problem in equation (34), where welfare gains are discounted at the government's discount factor. The new agreement consists of an 80% reduction in US tariffs on Chinese imports, full improvement of domestic IPR in China, and an increase in China's foreign royalty fee from 10% to 12%. Both countries have positive short-run gains. However, compared with the baseline agreement, welfare gains in the United

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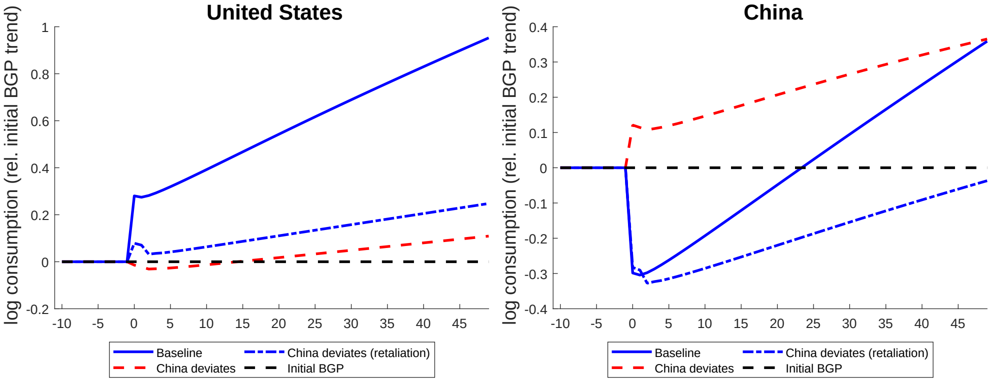
[18] I find that the Nash equilibrium in this game is unique through a numerical analysis.

States are now lower (see Table 3). A shortsighted government can avoid short-term losses at the expense of lower BGP growth and lower long-term gains.

China deviates The baseline trade agreement assumes commitment. Nevertheless, China might find it tempting to deviate from the agreement as a strategy to avoid short-term losses. In this section, I study the case in which China deviates from the agreement two periods after it enters into force—China chooses to maintain royalties paid to domestic innovators at 25% while reducing foreign royalties from the agreed-upon rate of 18% to the initial rate of 10%—considering two different responses from the US: one where the US raises tariffs back to their initial levels (i.e., from 0% to 5%) and another where the US retaliates by increasing tariffs significantly (from 0% to 20%). Under the first response, China experiences gains both in the short run and in the long run, with overall gains exceeding those in the baseline scenario, even if the United States responds by reverting to the initial tariff rate of 5%. During this phase, the US experiences short-term losses for several periods and overall reduced gains. Instead, if the United States chooses to retaliate by increasing tariffs to 20%, China faces overall losses and considerably larger short-term losses than if it had adhered to the original agreement (see Figure 6 and Table 3). Consequently, a credible threat of US tariff retaliation may provide China with an incentive to keep the original agreement, rendering it sustainable.

Figure 6: Log of consumption relative to initial BGP trend: China deviates



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 baseline (solid line), when China deviates 2 periods after the agreement entering in force and the US goes back to the initial tariffs of 5% (red dashed line), and when China deviates 2 periods after the agreement entering in force and the US retaliates imposing high tariffs of 20% (blue dotted line). The agreement is signed in period 1 and enters in force in period 11.

Anticipatory and gradual effects This analysis compares a baseline trade agreement with two alternative scenarios: an anticipated agreement taking effect in 10 years and a gradual adjustment agreement becoming effective in 5 years with slower changes in instruments, reaching final values after 10 years. In the anticipation and gradual adjustment scenarios, agents react in advance, leading to more gradual adjustments in innovation, adoption, and consumption compared with the baseline. These anticipatory effects influence policy decisions and welfare outcomes, with China experiencing higher welfare gains in the gradually anticipated agreement due to reduced short-term losses and a higher balanced growth path (BGP) growth rate.

Finally, the specific terms of a trade agreement resulting from Nash bargaining negotiations are contingent upon various factors. In the Online Appendix, I conduct sensitivity analysis to identify the key characteristics of the negotiating countries that influence the outcomes of the baseline agreement. The results indicate that low innovation efficiency could pose challenges for a trade agreement where China commits to improve its IP protection. Moreover, lower initial US tariffs might not incentivize China to strengthen its IP protection; and, when China's IP protection is initially weak, the US may be less inclined to reduce tariffs, leading to smaller tariff reductions. Finally, China's bargaining power significantly influences the extent of improvements in foreign IPR and the reduction of US tariffs.

6 Final Remarks

This paper develops a quantitative theory to analyze the dynamic trade-offs in bilateral trade agreements with IP provisions, bridging the gap between quantitative trade and growth models and political-economic theories of trade agreements. It emphasizes the importance of transitional dynamics, as these agreements have significant short-term distributional effects, and highlights their impact on technology transfer through royalty payments. The analysis focuses on the role of various parameters and data moments in shaping the outcomes.

Results show that developing countries have an incentive to unilaterally improve domestic IP protection, but need lower tariffs from developed countries to improve foreign IP protection. Despite initial short-term losses, developing countries benefit from higher long-term growth after signing the agreement. Comparing cooperative and uncooperative solutions reveals gains from cooperation, and an anticipated, gradual agreement is beneficial, especially for developing countries with low IP enforcement.

The findings suggest that trade and IP policies can be combined to achieve optimal outcomes, and future research could explore the first-best solution. Additionally, future work could investigate imperfect enforcement and lack of commitment in trade agreements. In the cooperative baseline agreement, credible commitment is essential when countries face short-term losses that may tempt them to deviate. The US can deter China from deviating by signaling its willingness to impose high retaliatory tariffs, and contingency plans with pre-established strategies can further reinforce commitment credibility. The agreement does not address uncertainty in IP investments due to various factors (Handley and Limão, 2017), which could be explored in future research. Lastly, studying trade diversion in a dynamic model of innovation and adoption is another important direction for future study.

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