Intellectual Property Rights, Technology Transfer and International Trade

Ana Maria Santacreu*

This version: July 12, 2021

Abstract

I study the short- and long-term effects of regional trade agreements (RTA) with strict intellectual property (IP) provisions. An empirical analysis using gravity methods suggests that regions signing these agreements share more technology in the form of technology licensing following the year of enforcement. I set up a multi-country model with endogenous productivity through innovation and adoption to quantify the effect of such agreements on innovation, growth and welfare. Adopters pay royalties to innovators for the use of their technology; the model allows for various degrees of IP rights enforcement ranging from pure imitation to perfect enforcement of IP rights. An improvement of IP protection in exchange for market access increases welfare, growth and innovation in the world. Developed countries benefit from a higher return to innovation and a lower home trade share, accruing welfare gains both in the short and long term. Developing countries are impacted through three channels: (i) internal IP reforms increase the return to domestic innovators,(ii) lower trade costs increase profits from exports, and (ii) higher royalty payments reduce the return to adopters. A counterfactual exercise shows that while the first two forces dominate in the long run, there are short-term losses from a lower return to adoption.

Keywords: Technology Licensing; Regional Trade Agreements; Intellectual Property Rights

JEL Classification: F12, O33, O41, O47

*Santacreu, Federal Reserve Bank of St. Louis, email: am.santacreu@gmail.com. I thank Jesse LaBelle and Fernando Leibovici for very insightful comments, and Jesse LaBelle for excellent research assistance. I also thank participants at Universitat Autonoma de Barcelona, Goettingen University, the Virtual Trade and Macroeconomics Workshop, the Federal Reserve Bank of Saint Louis, and the University of Tokyo. The views in this paper are those of the author and do not necessarily reflect the views of the Federal Reserve Bank of St. Louis or the Federal Reserve System.

1 Introduction

The enforcement and protection of intellectual property rights (IPR) has become an important component of current trade policy. Regional Trade Agreements (RTAs) prior to the formation of the World Trade Organization (WTO) in 1995 were mostly concerned with removing trade barriers between the member countries, and required only minimum standards of IP enforcement. However, the scope of RTAs has changed over the recent decades, gradually including more substantial intellectual property (IP) provisions as part of their negotiations a majority of the time.[1] RTAs with IP provisions require that the countries signing the agreement reach IP standards similar to those in developed countries. Indeed, many of these agreements—which take the form of patent protection, enforcement of payments for the use of foreign IP, equal treatment of domestic and foreign firms—are proposed by developed countries in order to avoid imitation and leakages of IP and trade secrets by developing economies. In exchange, they offer increased access to international markets.

Technology provisions in RTAs are established on the basis of improving incentives of innovation in developed countries and technology transfer and market access in developing countries. One concern is that an increase in patent protection could have negative effects for developing countries as they have to pay for foreign technology that they were previously imitating for free. Moreover, this may give monopoly power to innovators and increase prices in developing countries (Taylor, 1993, 1994).

There is a large theoretical 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). While the theoretical literature has not reached a consensus as to whether improvement of IP protection in developing economies is beneficial or detrimental for these countries, several empirical studies have shown a positive impact on technology transfer to developing countries: either by increasing imports of more sophisticated goods or by increasing R&D and exported goods in developing countries (Branstetter and Saggi, 2011; Maskus and Ridley, 2021; Campi and Dueñas, 2019; Martínez-Zarzoso and Chelala, 2021). However, empirical studies do not account for the effects that these provisions have on

[1] According to data for 437 RTAs listed in the WTO between 1948-2019 from the Design of Trade Agreements (DESTA) database, prior to 1948, only 20% of those included specific IP provisions, whereas after 2015, 95% of the agreements did.

innovation and welfare in developing countries, and cannot disentangle the different channels at play. Moreover, the theoretical literature has not studied the interconnections between trade liberalization and intellectual property rights. These limitations call for a quantitative framework to study the trade-off faced by countries that need to improve their IP in exchange for market access.

This paper fills the gap in the literature along several dimensions. First, it studies the connections between trade and IPR improvement that are missing in theoretical models. Second, it does so through the lens of a model of trade and growth with international technology licensing that can shed light on the main channels. Third, the model is tractable for quantification, and it can be solved along the transition to analyse the short- and long-term effects of RTAs with strict IP provisions on innovation, growth and welfare.

I start the analysis by documenting the dynamics of international technology licensing following the enforcement of RTAs with IP provisions. Following Santacreu (2020), I use royalty payments data from the OECD for 41 countries and period 1995 to 2012. The empirical literature has mainly focused on the effect of RTAs and improvement of IP protection on indirect channels of technology transfer such as international trade (see Keller, 2002; Campi and Dueñas, 2019; Lin and Lincoln, 2017; Dhingra, Freeman, and Mavroeidi, 2018; Martínez-Zarzoso and Chelala, 2021; Maskus and Ridley, 2021) and foreign direct investment (Branstetter, 2006; Branstetter et al., 2007; Branstetter and Saggi, 2011). However, several recent papers find that improvements of IPR may also have a positive effect on technology licensing (Branstetter, Fisman, and Foley, 2006). Using technology licensing as a measure of diffusion in the context of RTAs with IP provisions has several advantages: (i) it is a more direct measure of diffusion as it leaves a paper trail: the owner of a patent transfers the right and the know-how to use a technology to a foreign producer in exchange for a fee, and this transaction is recorded in the balance of payments of the countries; (ii) licensing is more likely to be affected by improvements of IP protection, as the owner of an innovation gets rewarded for their efforts through royalty payments, and (iii) there are data available for many countries and over time. As the measure of RTAs with IP provisions, I use the data compiled by Martínez-Zarzoso and Chelala (2020), who classify RTAs into those with IP provisions and those without for trade agreements that enter into force between 1995 and 2012. 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 the agreement. The results imply that following the agreement: (i) developing countries are receiving more foreign technology, and (ii) they are now paying for the technology they receive. While (i) may have positive effects though higher innovation and growth, (ii) may have a negative effect as firms in a developing country need to pay for technology they may have previously received at no cost. To evaluate the net effect of (i) and (ii) on innovation, growth and welfare, we need a quantitative framework.

I develop a multi-country endogenous growth model in which productivity evolves through endogenous innovation and endogenous technology adoption. There is Armington-type trade in intermediate goods and monopolistic competition. Innovators invest resources to create new technologies; adopters invest resources to use a technology, either domestic or foreign, in the production of an intermediate good. Adoption is a slow and costly process: with a certain probability, which depends on the adoption intensity, they are successful and can start producing a good. In that case, adopters get profits from monopolistic competitive firms and pay royalties to innovators. Royalties are paid as a share of total profits, and this share is captured by a parameter that reflects the quality of IP protection, ranging from pure imitation (no royalty payments) to perfect enforcement (royalty payments are paid as negotiated). The model has a balanced-growth path (BGP) in which all countries' productivity grows at a constant a common rate, but countries differ in their relative productivity. I assume that countries in which adoption occurs through pure imitation cannot export the goods produced with the stolen technology. Countries are heterogeneous in their innovation and adoption efficiency and in their trade costs. In the model, an improvement in IPR enforcement in developing countries has the following effects: (i) innovation increases everywhere as innovators start receiving more royalties; (ii) the return to adoption in developing countries decreases as adopters need to pay royalties to use technology that was previously being imitated; (iii) there is an effect on the BGP growth and relative productivity through the impact on the return to innovation and adoption. A trade liberalization that reduces export trade costs in developing countries benefits developed countries through access to more foreign technologies and a lower home-trade share, whereas developing countries benefit from an improvement in their terms of trade. The interaction effects between the IPR improvement and a trade liberalization as well as the distinction between short-term and long-term effects of these policies are a quantitative question.

In a quantitative exercise, I analyse the short-run and long-run effects of IPR improvements in exchange for access to export markets. The model is calibrated to data on international trade flows, innovation and royalty payments for three countries: the United States, China and an aggregate rest of the world. I then solve for the perfect foresight solution of the model following an unanticipated, permanent, one-time shock that consists of an improvement of IP protection in China accompanied by a liberalization of its exports. In the initial BGP adoption in China happens through imitation (i.e., China does not pay royalties), and China cannot export goods that are produced with stolen technology. In period 1 there is an unanticipated and permanent policy change in which China improves its IPR and starts paying royalties in exchange for access to export markets of its goods that are produced with licensed technology. This policy has three main effects. First, it has a positive effect on innovation around the world as innovators start getting royalties from China, which increases the return to R&D. Second, the improvement in IPR has a negative effect on China's adoption as adopters need to pay royalties for technology they were previously getting for free. However, the trade liberalization has a positive effect on adoption as adopters get profits from exporting the licensed technology. The net effect on China's adoption is negative. Third, the trade liberalization has a positive effect on the United States through a reduction in its home trade share and a positive effect on China though an improvement in its terms of trade. Moreover, trade introduces a market size effect on innovation and adoption as profits increase through increased market access. After the policy the economy reaches a higher BGP growth rate, which increases from 1.61% to 1.85%.

A welfare analysis shows that all countries gain in consumption-equivalent units from this policy. The United States experiences a welfare gain of 8.32% whereas China gains 3.46%. However, the way gains are accrued along the transition is different across countries. Whereas all countries gain in the long run, China experiences loses for the first 10 periods after the policy is implemented as there is an initial drop in the level of consumption caused by the reduction in adoption intensity. The United States, however, experiences gains both in the short- and in the long-run.

How do trade liberalization and IPR improvement interact to drive the results? I perform two counterfactual exercises to disentangle the main channels of the model. First, IP protection is reformed without a trade liberalization. In this case, all countries experience positive gains, but they are smaller than in the main exercise: the United States gains 6.49% and China gains 2.15%. Although the BGP growth rate is the same as in the case in which there are both a trade liberalization and an IPR improvement, the China experiences a larger initial drop in Consumption (and the United States experiences a lower initial increase in consumption). Therefore, improvements in IP protection are welfare improving whether or not they are accompanied by a trade liberalization. In a second counterfactual exercise there is a trade liberalization by which China can export its products even if it does not improve IPR rights, everybody experiences welfare losses. The BGP decreases from 1.61% to 1.55%. Innovators reduce their R&D intensity as they do not get profits from their technologies but face higher competition from Chinese imports produced with stolen technology. In the short-run, however both countries gain as they experience static gains from trade. However, dynamic gains driven by lower innovation and growth dominate in the long-run.

The results suggest that imperfect IPR enforcement introduces a distortion in the economy, which is amplified by international trade. If there is a trade liberalization without IPR improvement, every country loses. However, with an improvement in IPR every country gains. An improvement in IP protection ensures that incentives are correctly aligned and the policy is welfare improving. Hence the interaction between trade and IPR has important implications for welfare and growth that need to be studied through the lens of quantitative dynamic models of trade and growth. Recent papers have also emphasized the importance of introducing dynamics in models of trade (see Perla, Tonetti, and Waugh, 2015; Buera and Oberfield, 2019; Cai, Li, and Santacreu, 2019; Somale, 2018). Other recent papers studying the interplay between openness and IP are Holmes, McGrattan, and Prescott (2015) who analyse the effect of quid-pro-quo practices in China on FDI and welfare, and Mandelman and Waddle (2019) who, in the context of the trade-war between US and China, evaluate the effect that retaliatory tariffs have to prevent weakening of IP protection.

2 Empirical Analysis

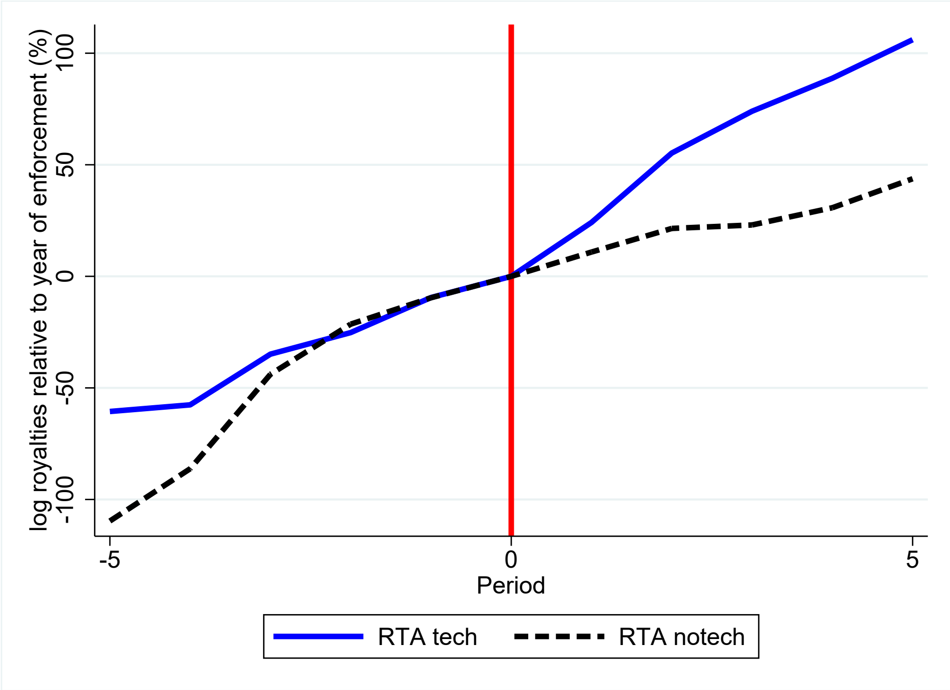
In this section, I study the dynamics of international technology transfer following membership into RTAs with IP provisions. The main question of interest is: Do trade agreements with IP provisions increase technology transfers from developed to developing economies?

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 (2020) and use data on bilateral royalty payments collected from the OECD Balanced Trade in Services dataset for 41 countries and the period 1995-2012. These data are a more direct measure of technology diffusion than what has been typically used in the literature, such as international trade or 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).[2] These numbers could be reflecting both an increase in technology transfer around 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 exterme 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 has 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 have 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) intellectual property.

Before conducting a more serious econometric analysis, Figure 1 shows the evolution of royalty payments from developing countries to developed countries during 1995-2012, before

[2]Data from WDI World Bank.

Figure 1: Dynamics of International Technology Licensing During RTAs with IP Provisions



and after they have signed an RTA agreement.[3] RTAs with strict IP provisions are a way for developed countries to enforce IPR improvements by developing countries. I split the sample of country-pairs into those that only sign RTAs with IP provisions (solid line) and those that only sign RTAs without IP provisions (dashed line).[4] I restrict the attention to country-pairs involving a developed country sending technology (i.e, receiving royalties) to a developing country. Royalty payments are normalized to one 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 agreement with IP provisions enters into force. Instead, RTAs without IP provisions imply a slower rate of technology transfer to developing economies signing the agreements.[5]

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

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

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

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

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:

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

with RTA_{int} a free trade agreement with technology provisions as classified by Martinez-Zarzoso and Chelala (2021), S_{nt} exporter-time, F_{it} importer-time, and fe_{in} country-pair characteristics. I estimate equation 1 using PPML methods, as it has been 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 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 1. 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 the agreement enters into force, and (ii) it also includes country-pairs never signing any agreement during the period of analysis.

Table 1 shows that both RTAs with technology and with 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 we 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 results suggest that signing RTAs with IP provisions increases royalty payments between the

Table 1: 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

Standard errors in parentheses

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

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

countries by 25%.[6] 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.[7] Moreover, as Maskus and Ridley (2021) mention, the concern of potential endogeneity in this type of agreements is limited by how 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 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.

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

[7] In the Appendix I introduce leads of the dependent variable and show that the main empirical findings are preserved.

The results are robust to estimating different specifications of the gravity regression. Following Baier and Bergstrand (2007), we consider: (i) 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 that have 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 though higher innovation and growth, (ii) may have a negative effect as firms in a developing country need to pay for technology they may have previously received at no cost.

To evaluate the net effect of (i) and (ii) on innovation, growth and welfare, we need a quantitative framework. In the next sections I present a model and perform a quantitative analysis to evaluate the impact of RTAs with IP provisions on innovation, growth and welfare and disentangle the effect of the different channels at play.

3 Model

The world consist of M countries indexed by i and n. Time is discrete and indexed by t. Productivity in each country evolves endogenously through innovation and technology transfer.

3.1 Preferences

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

$$\sum_{t=0}^{\infty} \beta^t \log\left(C_{nt}\right) \tag{2}$$

subject to the budget constraint

$$P_{nt}C_{nt} = W_{nt}L_{nt} + \Pi_{nt}^{\text{all}} - B_{nt} + R_{nt}B_{n,t-1} \tag{3}$$

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, B_{nt} represents lending to innovators and adopters and R_{nt} is the interest rate.

3.2 Final Production

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

$$Y_{nt} = \left(\sum_{i=1}^{M} \int_{j=1}^{T_{it}} x_{ni,t}(j)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{4}$$

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

$$x_{ni,t}(j) = \left(\frac{p_{ni,t}(j)}{P_{nt}} \right)^{-\sigma} Y_{n,t} \tag{5}$$

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

$$y_{nt}(j) = \Omega_n l_{nt}(j) \tag{6}$$

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

Intermediate producers take the demand of final producers as given and choose the price and the amount of labor to hire to maximize profits

$$\pi_{nt}(j) = \sum_{i=1}^{M} p_{in,t}(j) x_{in,t}(j) - W_{nt} l_{nt}(j) \tag{7}$$

subject to equation (5).

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

The import share is given by

$$\pi_{ni,t} = \frac{X_{ni,t}}{\sum_{n=1}^{M} X_{ni,t}} = \frac{\Omega_i^{\sigma-1} T_{it} \left(W_{it} d_{ni}\right)^{1-\sigma}}{\sum_{m=1}^{M} \Omega_m^{\sigma-1} T_{mt} \left(W_{mt} d_{nm}\right)^{1-\sigma}} \tag{8}$$

Real wages are given by the standard ACR expression

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

In this model, T_{nt} evolves over time through endogenous innovation and endogenous adoption. That is, the number of technologies available to produce intermediate goods is endogenous.

3.3 Knowledge Creation: Innovation and Adoption

The number of technologies available for intermediate production, T_{nt} evolves through two activities that require a costly investment; innovation and adoption. Knowledge expansion involves the creation of new intermediate goods.

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

$$\lambda_n T_{nt} \left(\frac{H_{nt}^r}{\bar{Y}_t} \right)^{\beta_r} \tag{9}$$

where $\lambda_n T_{nt}$ represents the efficiency of innovation, with λ_n a country-specific parameter that captures innovation policy in the country, T_{nt} is the stock of knowledge available in country n at time t, $\bar{Y}_t$ is the world output, and β_r represents diminishing returns to adding one extra unit of final output into the innovation process.

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

$$Z_{n,t+1} = \lambda_n T_{nt} \left(\frac{H_{nt}^r}{\bar{Y}_t} \right)^{\beta_r} + Z_{n,t} \tag{10}$$

Innovators have the monopoly over the technology, which they license to entrepreneurs who invest resources to make the technology usable abroad. This process is called adoption.

The value of an innovation is given by V_{nt}. The innovator chooses H_{nt}^r to maximize:

$$\Delta Z_{nt} V_{nt} - P_{nt} H_{nt}^r \tag{11}$$

Technology Adoption When a new prototype is introduced in country n, the innovator in that country licenses the technology to a foreign 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 usable in country i invests $h_{in,t}^a$ units of final output into adoption. With probability $\varepsilon_{in,t}(j)$ the adopter in country i is successful and can license the usable technology from country n by paying a licensing fee. The probability of adoption is given by

$$\varepsilon_{in,t}(j) = \bar{\varepsilon}_{in} \left(\frac{h_{in,t}^a(j)}{\bar{Y}_t} \right)^{\beta_a} \tag{12}$$

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

$$A_{in,t+1} = \varepsilon_{in,t} \left(Z_{nt} - A_{in,t} \right) + A_{in,t} \tag{13}$$

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

If adopters are successful, they start producing the good with that technology and pay a royalty fee to have the right to use the technology and make profits forever. I assume that royalties are paid as a fraction $\chi_{in,t}$ of the profits made by the adopter once the technology has been adopted. This parameter captures the quality of IPR enforcement. If $\chi_{in} = 0$, adoption happens through pure imitation and innovators are not compensated on their efforts. If instead χ_{in} is as negotiated by the innovator and the adopter, there is perfect enforcement of IPR.[8]

3.4 Optimal investment into innovation and adoption

The value of an adopted technology by country i from country n innovator's perspective is the PDV of a fraction $\chi_{in,t}$ of the profits made by intermediate producers in country i that are using that technology

$$V_{in,t}^{\text{innov}}(j) = \chi_{in,t}\pi_{nt}^{i}(j) + \frac{1}{R_{nt}} V_{in,t+1}^{\text{innov}}(j)$$

The value for the innovator in country n of a non-yet adopted technology by adopters in country i is given by

$$J_{in,t}^{\text{innov}}(j) = \frac{1}{R_{nt}} \left[\varepsilon_{in,t} V_{in,t+1}^{\text{innov}}(j) + (1 - \varepsilon_{in,t}) J_{in,t+1}^{\text{innov}}(j) \right]$$

Hence the value of an innovation V_{nt} is given by

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

Combining all the above expressions, we can show that the value of an innovator is the present discounted value of the established fraction of intermediate producers' profits that operate with the innovator's technology, once the technology has been adopted.

The first order condition for investment into innovation is

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

The value of an adopted technology—from the adopter's perspective—in period t is

[8] I take the royalty fee as given. An alternative would be to model the negotiation process between the innovator and the adopter, which would take the form of Nash bargaining. See Benhabib, Perla, and Tonetti (Forthcoming) and Hopenhayn and Shi (2020) for examples of models of licensing where the royalty fee is negotiated in advance.

$$V_{in,t}(j) = (1-\chi_{in,t})\pi_{it}^{n}(j) + \frac{1}{R_{it}}V_{in,t+1}(j) \tag{14}$$

where $\chi_{in,t}$ is the fraction of profits paid out in royalties, $\pi_{it}^{n}(j)$ 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 of a non-yet adopted prototype j that an adopter is trying to adopt is

$$J_{in,t}(j) = -P_{it}h_{in,t}^{a}(j) + \frac{1}{R_{it}}\{\varepsilon_{in,t}V_{in,t+1}(j) + (1-\varepsilon_{in,t})J_{in,t+1}(j)\} \tag{15}$$

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 $t+1$ Also, there are $\Delta A_{in,t}$ new technologies adopted.

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

$$\varepsilon_{in,t} = \bar{\varepsilon}_{in}\left(\frac{H_{in,t}^{a}}{Y_{it}}\right)^{\beta_a} \tag{16}$$

The first order condition of adoption is

$$P_{it}H_{in,t}^{a} = \varepsilon_{in,t}\frac{1}{R_{it}}(V_{in,t+1} - J_{in,t+1})$$

3.5 Market Clearing Conditions

Output is used for consumption, innovation and adoption

$$P_{nt}Y_{nt} = P_{nt}C_{nt} + P_{nt}H_{nt}^{r} + P_{nt}\sum_{i=1}^{M}H_{ni,t}^{a} \tag{17}$$

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

$$W_{nt}L_{nt} = \sum_{i=1}^{M}T_{nt}W_{nt}l_{in,t} = \sum_{i=1}^{M}A_{in,t}W_{nt}x_{in,t}d_{in} = \sum_{i=1}^{M}T_{nt}\left(\frac{W_{nt}d_{in}}{P_{it}}\right)^{1-\sigma}P_{it}Y_{it} \tag{18}$$

From the budget constraint of the consumers we can derive an expression for net exports. Note that royalties are a trade service, so they will appear as part of net exports. Also note that there is no borrowing or lending with the rest of the world, so that net exports are zero every period.

$$\sum_{i \neq n}^{M} T_{it} p_{ni,t} x_{ni,t} = \sum_{i \neq n}^{M} T_{nt} p_{in,t} x_{in,t} + \sum_{i=1}^{M} RP_{in,t} - \sum_{i=1}^{M} RP_{ni,t} \tag{19}$$

3.6 Balanced Growth Path

I define the balanced growth path as an equilibrium in which all variables grow at a constant rate. In the model, growth along 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 our derivation. Here I characterize the BGP growth rate of the economy.

Cross-country knowledge spillovers guarantee that the stock of knowledge T_n grows at the constant rate g, which is common across all countries.

$$gT_i = \sum_{n=1}^{M} \frac{\varepsilon_{in}}{\varepsilon_{in} + g} \lambda_n T_n \left(\frac{H_n^r}{Y_n} \right)^{\beta_r} \tag{20}$$

Changes in trade costs, d_{in}, and IPR, χ_{in}, have an effect on g and T through changes in H_n^r / Y_n and ε_{in}.

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

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

If the matrix $\Delta(g)$ is 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.

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.

4 Quantitative Analysis

The model is calibrated to three countries (the United Sates, China and an aggregate rest of the world). I use data on trade flows, geography, income, R&D spending, and international technology licensing together with gravity methods to calibrate the main parameters of the model. A quantitative exercise evaluates the effects of IPR improvements accompanied by a trade liberalization on innovation, growth and welfare, distinguishing between the short-term and long-term effects of these policies.

4.1 Calibration

The Armington elasticity σ is calibrated to 5, which implies a trade elasticity of 4, as is common in the trade literature (see Waugh, 2010). I set the discount factor β to 0.96, which implies an annual interest rate of 6%. I assume a royalty rate $\chi_{in} = 0.2$. The remaining parameters of the model are calibrated in three steps. First, I calibrate trade costs and productivity estimating a gravity equation with international trade and geography data (following Waugh (2010). Second, I calibrate the diffusion parameters following the methodology developed in Santacreu (2020). Third, I calibrate the innovation parameters following Cai, Li, and Santacreu (2019). I provide details on the calibration strategy next.

Trade costs and relative productivity Using data on international trade flows at the product level, geography variables and GDP per capita from CEPII for 2012, I calibrate iceberg transport costs d_{in} and productivity, $\Omega_n^{\sigma-1}T_n$, by running the following reduced-form regression

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

where $S_n = \Omega_n^{\sigma-1} T_n \left(\frac{\omega_n}{P_n}\right)^{1-\sigma}$ Using the estimated value for S_n, and $\sigma = 5$, I recover $\Omega_n^{\sigma-1} T_n$ and obtain trade costs from the following expression

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

Innovation and diffusion parameters Following Santacreu (2020), I derive a structural gravity equation for bilateral royalty payments that can be used to estimate the parameters of innovation and diffusion. Along the BGP, royalty payments take the following expression:

$$RP_{in,t} = \frac{\varepsilon_{in}}{\varepsilon_{in} + g} \lambda_n T_{nt} \left(\frac{H_{nt}^r}{Y_t^w}\right)^{\beta_r} \Pi_{it} \tag{21}$$

which can be written in logs as

$$\log(RP_{in,t}) = fe_{in} + S_{nt} + F_{it}$$

with $fe_{in} = \log\left(\frac{\varepsilon_{in}}{\varepsilon_{in}+g}\right)$, $S_n = \log\left(\lambda_n \frac{T_n}{T_i}\left(\frac{H_n^r}{Y_n}\right)^{\beta_r}\right)$, $F_i = \log\left(\frac{\Pi_i}{T_i}\right)$. I estimate equation 4.1 with PPML methods using bilateral royalty payments as the dependent variable, and exporter-time, importer-time and country-pair fixed effects.

I recover $\varepsilon_{i,n}$ from the bilateral fixed effects, assuming $g = 1.85 * 4$ (which corresponds to a productivity growth rate of 1.85%.

I calibrate β_r and λ_{nt} to match $g_y = 1.85\%$ and R&D intensity to match R&D intensity data using the algorithm developed by Cai, Li, and Santacreu (2019). Finally, I set $\beta_a = \beta_r$ and recover $\bar{\varepsilon}_{in}$ to match ε_{in}.

The calibrated parameters are reported in table 2-4.

Table 2: Common parameters

Parameter	Value
σ	5
β	0.96
β_r	0.52
β_a	0.52

Table 3: Country-specific parameters

	US	ROW	China
$\Omega_n (T_n)^{1/\sigma-1}$	6.25	2.41	1.00
λ_n	0.61	0.43	0.39
L_n/L_{China}	0.23	1.33	1.00

Table 4: Country-pair specific parameters

Origin	Destination	d_{in}	ε_{in}	χ_{in}
USA	ROW	2.73	0.18	0.20
USA	China	2.95	0.24	0.20
ROW	USA	6.23	0.16	0.20
ROW	China	6.20	0.14	0.20
China	USA	3.18	0.18	0.20
China	ROW	2.90	0.12	0.20

Validation The calibration strategy does a good job at matching income per capita, R&D intensity, home trade shares and royalty payments from the data.

Table 5: Validation

Moment	Data	Model
Rel. prod. USA,CHN	6.00	5.90
Rel. prod. ROW,CHN	2.94	2.43
R&D intensity US	0.69	0.64
R&D intensity ROW	0.31	0.27
R&D intensity CHN	0.25	0.20
BGP growth rate	1.85	1.85

4.2 IPR Improvement and Trade Liberalization

I solve for the perfect foresight solution of the model following an unanticipated and permanent one-time shock.[9] In particular, I evaluate the effect of an increase in IP protection in China in exchange for access to export markets on innovation, growth and welfare. In the initial BGP China does not pay any royalties, either domestically or abroad, so that $\chi_{i,\text{CHN}} = 0$. In this case, adopters in China still need to invest resources to be able to use the technology, but if they are successful in adopting it, they get all the profits from intermediate producers. Moreover, in the initial BGP intermediate producers cannot export the goods that are produced with stolen technology, that is, $d_{i,\text{CHN}} = \infty$. In period 1, China signs an RTA with IP provisions that requires an improvement of its IPR in exchange for a reduction in trade costs of its exports. In this case, $\chi_{i,\text{CHN}}$ increases to 0.20 and the iceberg transport costs are those as calibrated in section 4.1.[10]

4.3 Growth, Innovation, and Adoption

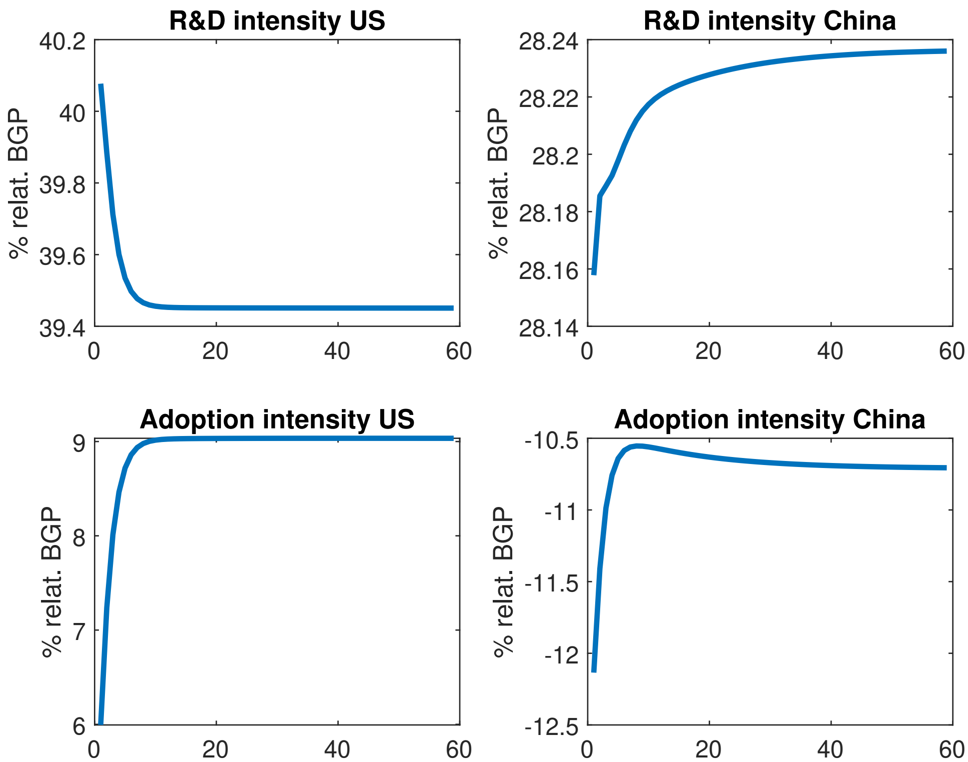
An increase in IPR enforcement increases the return to innovators as they start receiving royalties for the technologies that are adopted by China. The improvement in IPR increases R&D intensity in China. The domestic reforms undertaken to improve IP protection imply that adopters in China begin paying royalties not only to foreign innovators with whom they are signing an RTA agreement, but also to domestic innovators. This translates into an increase in R&D intensity in China. Because innovators in the US also receive more royalties, the return to innovation increases there as well (see figure 2. Both countries reach a higher R&D intensity in the new BGP.

There are two forces that have an opposite effect on adoption in China: (i) the return to adopters decreases as they now have to pay royalties for technologies they were getting for free, but (ii) adopters can now make profits from exporting intermediate products. In the short-run there is an initial reallocation from adoption into R&D in China. In the new BGP R&D intensity is higher and adoption intensity is lower. In the United States, both R&D and adoption intensities go up: innovators get royalties from their R&D investments and adopters benefit from more varieties from China. Because final producers in the United

[9]The model is solved using Newton solution methods.
[10]Note that the model is calibrated at the counterfactual BGP.

States have access to Chinese varieties through a reduction in trade costs, prices go down. Indeed, the terms of trade improve in China and firms get more revenues from their exports.

Figure 2: R&D and adoption intensity

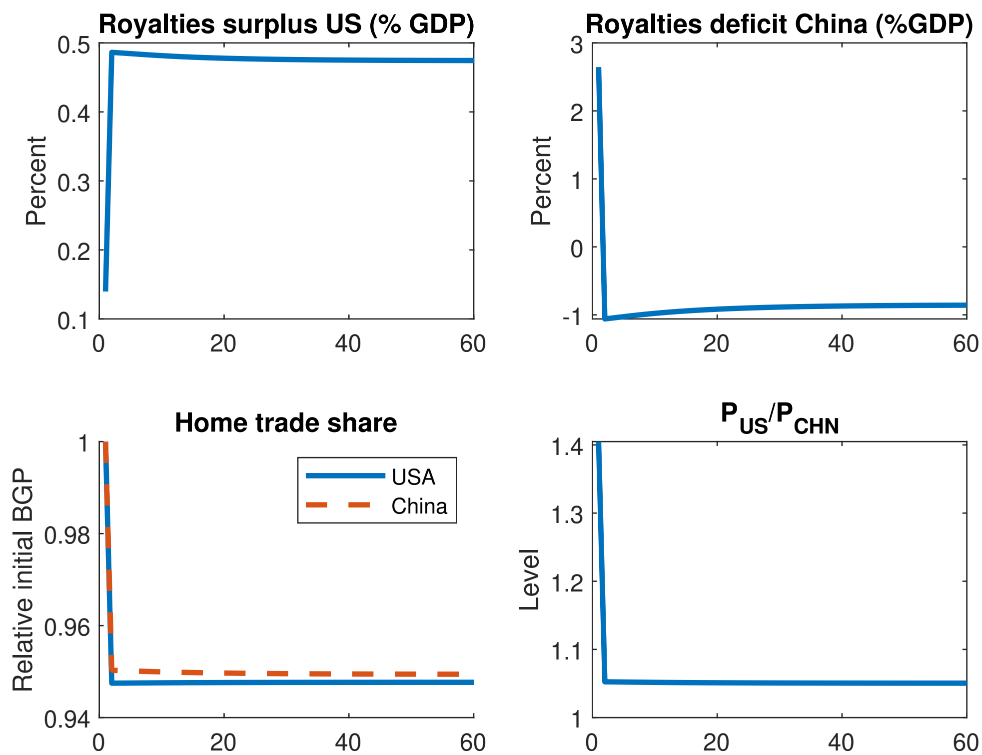


4.4 Trade, Royalties and Productivity

The improvement in IP protection implies that China starts paying royalties to domestic and foreign innovators for technology they were previously getting for free. In addition, they start receiving more foreign technology. Hence royalty payments to the US increase (figure 3), widening the surplus in the US and the deficit in China.

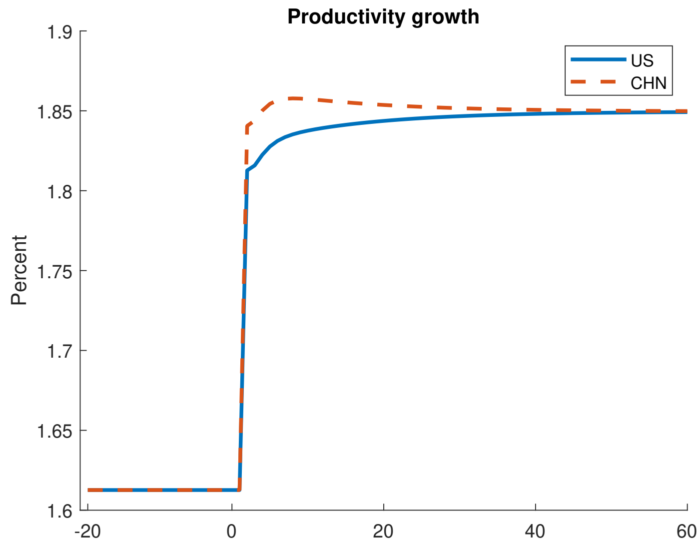
Finally, the decrease in export costs from China translates into a decrease in US home trade share. Figure 3 also shows an improvement in China's terms of trade.

Figure 3: Trade and royalty payments



The BGP growth rate of productivity increases from 1.61% to 1.85%. Figure 4 shows the evolution of the productivity growth in the United States and in China. Both countries' productivity grows at 1.61% in the initial BGP. The improvement in IPR followed by market access increases the growth rate to 1.85%, with China experiencing a faster pace of its growth rate. Indeed there is an overshooting of the growth rate in China. Changes in growth rates are driven by the endogenous responses of innovation, adoption and international trade after changes in IP protection and trade costs.

Figure 4: Growth rate of productivity



4.5 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 as the additional consumption the consumer needs every period to be indifferent between baseline and counterfactual. That is,

$$\int_{t=0}^{\infty} \beta^t u \left(C_{it}^* \left(\frac{\lambda_i}{100} + 1 \right) \right) dt = \int_{t=0}^{\infty} \beta^t u \left(C_i \right) dt \tag{22}$$

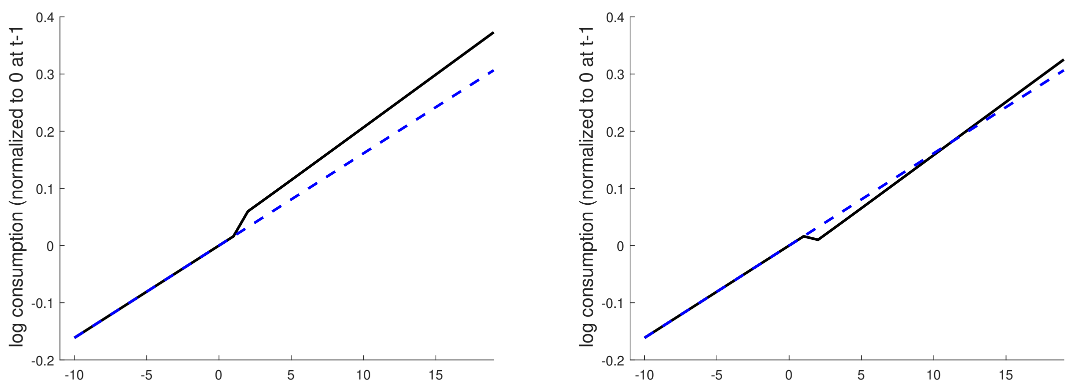
The results are reported in Table 6. All countries experience welfare gains from RTAs with IP provisions. The US experiences a gain of 8.32% whereas China gains 3.46%. Dynamic gains from trade in this set-up can be decomposed into short-term and long-term gains. Long-term gains are characterized by the change in the BGP growth rate of consumption, whereas short-term gains are driven by changes in the consumption level.

Table 6: Welfare gains

	Welfare
USA	8.32
ROW	6.02
China	3.46

Figure 5 shows the evolution of consumption over time. The dashed line represents the log of consumption along the initial BGP. The solid line is the log of consumption in the counterfactual: the shock hits in period 11. The figure shows that an improvement in IPR leads to a higher BGP growth rate in consumption (the slope of the solid line increases after period 11). However, consumption drops initially in China, implying short-term losses. The log of consumption crosses the dashed line more than 10 years after the initial shock, and China experiences positive gains then. In the case of the US, consumption always lies above the initial trend after the shock hits. While both countries gain from an IPR improvement and trade liberalization, China experiences short-term losses.

Figure 5: Log of consumption



There are three main channels behind these results: (i) the improvement in IPR increases technology transfer towards China, as foreign innovators get compensated from their R&D efforts; however, Chinese adopters need to pay royalties for technology that they were previously receiving for free; (ii) domestic R&D increases as the IPR reform applies also to domestic innovators; and (iii) access to export markets implies a decrease in the home trade share in the US, and an improvement in the terms of trade in China.

4.6 Understanding the Mechanism

To better understand the main channels at play, I analyse two alternative specifications of the model. First, I consider the case in which China improves its IP protection but does not get market access. That is, $\chi_{i,\text{CHN}} = 0.2$ and $d_{i,\text{CHN}} = \infty$. Second, I consider the case in which China gets access to export markets without improving its IP protection. That is, $d_{i,\text{CHN}} < \infty$ and $\chi_{i,\text{CHN}} = 0$. Table 7 reports the BGP growth rates in such cases. The world growth rate increases in every scenario except in the case in which there is a trade liberalization without an IPR improvement.

Table 7: BGP growth: Alternative scenarios

	Baseline	Only IPR	Only Trade
Initial BGP	1.61	1.61	1.61
Final BGP	1.85	1.85	1.55

Changes in world growth rates are reflected on welfare gains from improving IP protection, which are reported in Table 8. All countries experience positive gains, except in the case in which there is only a trade liberalization where all countries lose. Gains are the highest in the baseline case. When China reforms its IPR without getting access to export markets, welfare gains are lower everywhere. Although the increase in BGP growth rate is the same as in the baseline scenario, the initial drop in consumption is higher and it takes longer to convert the short-term loses into gains (see Figure 6).

Table 8: Welfare Gains: Alternative scenarios

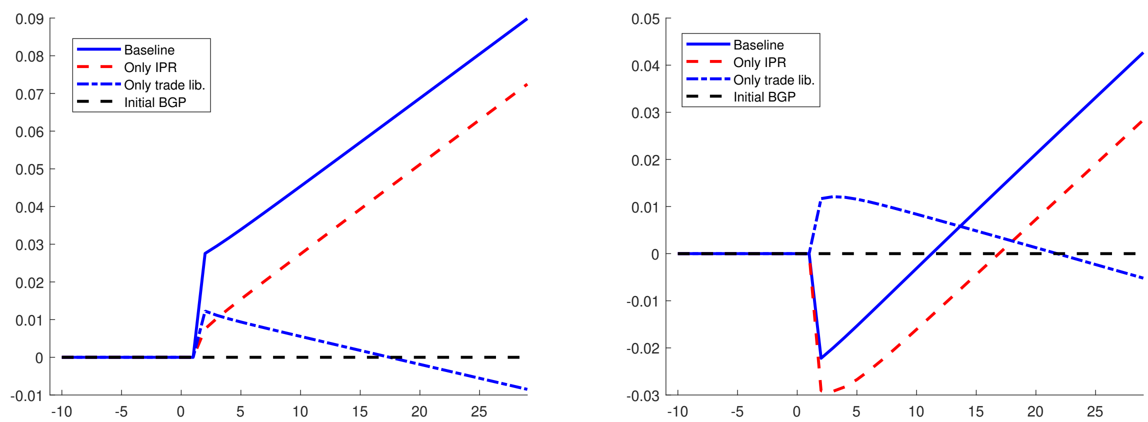
	Baseline	Only IPR	Only Trade	Low R&D
USA	8.32	6.49	-0.56	7.30
ROW	6.02	6.01	-1.69	4.77
China	3.46	2.15	-0.29	2.27

To disentangle the short-run and long-term welfare effects across the different scenarios, I plot the log of consumption relative to the initial BGP consumption path (see figure 6). The horizontal line at zero represents the initial BGP. The shock hits in period 11.

In the baseline exercise, both China and the US experience welfare gains. However, China has short-term loses that last around 10 years. In the case when there is an improvement of IPR without a trade liberalization, short-term loses in China are larger than in the baseline (larger initial drop in consumption and slower pace towards gains). Moreover, gains in the US are lower, despite reaching an almost identical BGP as in the baseline case, as there is an initial increase in consumption. An improvement of IPR that is not met by a trade liberalization decreases investment into adoption even more in China, as adopters cannot benefit from a larger market where to sell the intermediate products that are produced with

Figure 6: Log of consumption relative to initial BGP trend

(a) USA (b) China



licensed technology. Final producers in the US do not have access to more varieties, and its home trade share does not decrease. Hence the initial increase in consumption is lower.

When there is a trade liberalization without IPR improvement both the US and China lose. However, both countries gain in the short run, with China experiencing larger short-term gains. A trade liberalization improves the terms of trade (TOT) in China, generating more revenue to intermediate producers, innovators and adopters. Moreover, the amount of varieties that final producers in the US have access to increases, and hence their productivity raises through lower prices. However, that comes at the cost of increased competition from China, which is selling goods produced with imitated technology, preventing US innovators from getting returns from their R&D efforts. Innovation decreases and that slows down world growth.

The results suggest that imperfect IPR enforcement introduces a distortion in the economy, which is amplified by international trade. If there is a trade liberalization without IPR improvement, every country loses. However, with an improvement in IPR every country gains. An improvement in IP protection ensures that incentives are correctly aligned and the policy is welfare improving. Hence the interaction between trade and IPR has important implications for welfare and growth that need to be studied through the lens of quantitative dynamic models of trade and growth.

5 Final Remarks

The paper develops a quantitative framework to analyze the interconnections between international trade and intellectual property rights. It introduces dynamics into a standard model of trade through endogenous innovation and adoption, which are the main sources of productivity. Adopters pay royalties to the innovators for the right to use their technology. The analysis allows to disentangle between the short and long-run effects of these policies. A quantitative exercise shows that imperfect IPR acts as a distortion in the economy, which is amplified by trade. Countries that improve their IPR gain, especially if they can export the goods produced with licensed technology. However, in the case of a trade liberalization that is not accompanied by IPR improvement every country loses.

The main results have implications for optimal policy, as the interactions between trade and IPR suggest that both policies can be used simultaneously to reach a first best solution. I leave these questions for future research.

References

Baier, Scott L and Jeffrey H Bergstrand. 2007. "Do free trade agreements actually increase members' international trade?" *Journal of international Economics* 71 (1):72–95.

Benhabib, Jess, Jesse Perla, and Christopher Tonetti. Forthcoming. "Reconciling models of diffusion and innovation: A theory of the productivity distribution and technology frontier." Tech. rep.

Branstetter, Lee. 2006. "Is foreign direct investment a channel of knowledge spillovers? Evidence from Japan's FDI in the United States." *Journal of International economics* 68 (2):325–344.

Branstetter, Lee, Ray Fisman, C Fritz Foley, and Kamal Saggi. 2011. "Does intellectual property rights reform spur industrial development?" *Journal of International Economics* 83 (1):27–36.

Branstetter, Lee, Raymond Fisman, C Fritz Foley, and Kamal Saggi. 2007. "Intellectual property rights, imitation, and foreign direct investment: Theory and evidence." Tech. rep., National Bureau of Economic Research.

Branstetter, Lee and Kamal Saggi. 2011. “Intellectual property rights, foreign direct investment and industrial development.” *The Economic Journal* 121 (555):1161–1191.

Branstetter, Lee G., Raymond Fisman, and C. Fritz Foley. 2006. “Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from U. S. Firm-Level Panel Data.” *The Quarterly Journal of Economics* 121 (1):321–349. URL http://www.jstor.org/stable/25098792.

Buera, Francisco J and Ezra Oberfield. 2019. “The Global Diffusion of Ideas.” *Econometrica* .

Cai, Jie, Nan Li, and Ana Maria Santacreu. 2019. “Knowledge diffusion, trade and innovation across countries and sectors.” *Federal Reserve Bank St. Louis Working Paper* (2017-29).

Campi, Mercedes and Marco Dueñas. 2019. “Intellectual property rights, trade agreements, and international trade.” *Research Policy* 48 (3):531–545.

Dhingra, Swati, Rebecca Freeman, and Eleonora Mavroeidi. 2018. “Beyond tariff reductions: what extra boost from trade agreement provisions?” .

Diwan, Ishac and Dani Rodrik. 1991. “Patents, appropriate technology, and North-South trade.” *Journal of International Economics* 30 (1-2):27–47.

Eaton, Jonathan and Samuel Kortum. 1999. “International Technology Diffusion: Theory and Measurement.” *International Economic Review* 40 (3):537–570.

Helpman, Elhanan. 1993. “Innovation, Imitation, and Intellectual Property Rights.” *Econometrica* 61:1247–80.

Holmes, Thomas J, Ellen R McGrattan, and Edward C Prescott. 2015. “Quid pro quo: Technology capital transfers for market access in China.” *The Review of Economic Studies* 82 (3):1154–1193.

Hopenhayn, Hugo and Liyan Shi. 2020. “Knowledge creation and diffusion with limited appropriation.” Tech. rep., working paper.

Keller, Wolfgang. 2002. “Geographic localization of international technology diffusion.” *The American Economic Review* 92 (1):120–142.

Kwan, Yum K and Edwin L-C Lai. 2003. "Intellectual property rights protection and endogenous economic growth." *Journal of Economic Dynamics and Control* 27 (5):853–873.

Lai, Edwin L-C. 1998. "International intellectual property rights protection and the rate of product innovation." *Journal of Development economics* 55 (1):133–153.

Lai, Edwin L-C and Larry D Qiu. 2003. "The North's intellectual property rights standard for the South?" *Journal of International Economics* 59 (1):183–209.

Lin, Jenny X and William F Lincoln. 2017. "Pirate's treasure." *Journal of International Economics* 109:235–245.

Mandelman, Federico and Andrea Waddle. 2019. "Intellectual Property, Tariffs, and International Trade Dynamics." *Journal of Monetary Economics* .

Martínez-Zarzoso, Inmaculada and Santiago Chelala. 2020. "Trade agreements and international technology transfer." .

———. 2021. "Trade agreements and international technology transfer." Tech. rep.

Maskus, Keith E and William Ridley. 2021. "Trade Impacts of Intellectual-Property-Related PTAs." .

Maskus, Keith Eugene. 2004. *Encouraging international technology transfer*, vol. 7. International Centre for Trade and Sustainable Development Geneva.

Perla, Jesse, Christopher Tonetti, and Michael E Waugh. 2015. "Equilibrium Technology Diffusion, Trade, and Growth." Tech. rep., National Bureau of Economic Research.

Santacreu, Ana Maria. 2020. "International technology Diffusion: A Gravity Approach." Tech. rep.

Silva, JMC Santos and Silvana Tenreyro. 2006. "The log of gravity." *The Review of Economics and Statistics* 88 (4):641–658.

Somale, Mariano. 2018. "Comparative Advantage in Innovation and Production." Tech. rep., Mimeo.

Tanaka, Hitoshi and Tatsuro Iwaisako. 2014. "Intellectual property rights and foreign direct investment: A welfare analysis." *European Economic Review* 67:107–124.

Taylor, M Scott. 1993. "TRIPS, trade, and technology transfer." *Canadian Journal of Economics* :625–637.

———. 1994. "TRIPS, trade, and growth." *International Economic Review* :361–381.

Waugh, Michael E. 2010. "International trade and income differences." *American Economic Review* 100 (5):2093–2124.

Yang, Guifang and Keith E Maskus. 2001. "Intellectual property rights, licensing, and innovation in an endogenous product-cycle model." *Journal of International Economics* 53 (1):169–187.

Yotov, Yoto V, Roberta Piermartini, José-Antonio Monteiro, and Mario Larch. 2016. *An advanced guide to trade policy analysis: The structural gravity model*. World Trade Organization Geneva.

Zylkin, Thomas. 2018. "PPML_PANEL_SG: Stata module to estimate structural gravity models via Poisson PML." .

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

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

(SE) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

As stated previously, technology-related RTAs could take several forms, from 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 9 shows the results when only patents and IP provisions are considered as part of the RTA tech agreements. The results are consistent with those reported in Table 1. Patents 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 we restrict attention to country-pairs consisting on a developed and a developing country. These results suggest that agreements requiring improvement of 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 it has been documented by Martínez-Zarzoso and Chelala (2021).

Table 9: The effect of the different sub-categories 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

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 (4)

$$Y_{nt} = \left(\sum_{i=1}^{M} T_{it} x_{ni,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{23}$$

From the demand of intermediate goods

$$Y_{nt} = \left(\sum_{i=1}^{M} T_{it} \left(\left(\frac{\bar{m} W_{it} d_{ni}}{P_{nt}} \right)^{-\sigma} Y_{nt} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{24}$$

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

From here

$$P_{nt} = \left(\sum_{i=1}^{M} T_{it} \left(\bar{m} W_{it} d_{ni} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{25}$$

Trade share

$$\pi_{in,t} = \frac{X_{in,t}}{\sum_{i=1}^{M} X_{in,t}} = \frac{T_{nt} \left(\frac{\bar{m} W_{nt} d_{in}}{P_{it}} \right)^{1-\sigma} P_{it} Y_{it}}{\sum_{k=1}^{M} T_{kt} \left(\frac{\bar{m} W_{it} d_{ik}}{P_{it}} \right)^{1-\sigma} P_{it} Y_{it}} \tag{26}$$

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

From here

$$\pi_{in,t} = \frac{T_{it} \left(W_{nt} d_{in} \right)^{1-\sigma}}{\sum_{k=1}^{M} T_{kt} \left(W_{it} d_{ik} \right)^{1-\sigma}} \tag{27}$$

The home trade share is then

$$\pi_{nn,t} = \frac{T_{nt} \left(W_{nt} \right)^{1-\sigma}}{P_{nt}^{1-\sigma}} \tag{28}$$

ACR formula

$$\frac{W_{nt}}{P_{nt}} = \frac{1}{\bar{m}} \left(\frac{T_{nt}}{\pi_{nn,t}} \right)^{\frac{1}{\sigma-1}} \tag{29}$$

Using the equation for prices we can show that the ACR formula becomes

$$\frac{W_{nt}}{P_{nt}} = \frac{1}{\bar{m}} \left(\frac{T_{nt}}{\pi_{nn,t}} \right)^{\frac{1}{\sigma-1}} \tag{30}$$

From this formula, the growth rate of real wage in steady state is $\frac{1}{\sigma-1} g_T$. Note that in the EK models is $\frac{1}{\theta} g_T$

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 for the domestic and export market.

$$\Pi_{it} = T_{it} \sum_{m=1}^{M} \pi_{mi,t} \tag{31}$$

where $\sum_{m=1}^{M} \pi_{mi,t} = \sum_{m=1}^{M} p_{mi} x_{mi} - W_{it} L_{it} = \sum_{m=1}^{M} \bar{m} W_i d_{mi} l_{mi} / d_{mi} - W_{it} L_{it} = (\bar{m} - 1) W_{it} L_{it}$

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

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

Royalties are paid as a fraction of profits from country i, Π_{it}:

$$RP_{int} = \omega_{in,t} \Pi_{it} \tag{32}$$

where $\omega_{in,t} = \frac{A_{in,t}}{T_{nt}}$ is the fraction of profits paid in royalties, and $T_{nt} = \sum_{n=1}^{M} A_{in,t}$.

Note that in steady-state (solving equation 10 and 13)

$$\omega_{in} \Pi_i = \frac{A_{in}}{T_i} \Pi_i = \frac{\varepsilon_{in}/g}{\varepsilon_{in} + g} \lambda_n \left(\frac{R_n}{Y_n} \right)^{\beta_r} \frac{T_n}{T_i} \Pi_i$$

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

C Equations of the Model

Endogenous variables:

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

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

Equations

Resource constraint

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

Prices

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

Price intermediate goods

$$p_{in,t} = \bar{m} W_{nt} d_{in}$$

Demand intermediate goods

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

Trade share

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

Value innovation

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

Profits firms

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

Value adopted

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

Value un-adopted

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

Value adopted for innovator

$$V_{in,t}^{\text{innov}} = \chi_{in,t} \frac{\Pi_{it}}{T_{it}} + \frac{1}{R_{nt}} V_{in,t+1}^{\text{innov}}$$

Value un-adopted innovator

$$J_{in,t}^{\text{innov}} = \frac{1}{R_{nt}} [\varepsilon_{in,t} V_{in,t+1}^{\text{innov}} + (1 - \varepsilon_{in,t}) J_{in,t+1}^{\text{innov}}]$$

FOC innovation

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

FOC adoption

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

Probability adoption

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

Royalties

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

Labor market clearing condition

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

Trade balance equation

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

In there are trade imbalances: Balance of payments equation

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

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

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

Transforming the interest rate in real terms

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

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, we need to find the rate of growth of each variable and stationarize them appropriately. We also do some transformation of the variables. Here is a list of the equations written with stationarty variables that do not growth along the BGP.

From the equation of the home trade share, we can show that the growth of the real wage is $T^{\frac{1}{\sigma-1}}$. Also, as it 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, $\hat{X}_{it} = \frac{P_{it} X_{it}}{W_{Mt}}$. In this economy, the real wage grows at $Z_m^{\frac{1}{\sigma-1}}$. Real variables grow at $g_z/(\sigma-1)$. Also note that in the EK model, we get something similar where $\theta = \sigma - 1$.

Prices

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

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

Demand intermediate goods

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

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

Trade share

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

Value innovation

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

where $v_{nt} = T_{nt} V_{nt} / W_{Mt}$ and $j_{in,t} = J_{in,t} T_{it} / W_{Mt}$.

Profits firms

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

Value adopted

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

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

Value un-adopted

$$\hat{j}_{in,t} = -\hat{H}_{in,t}^{a} \frac{\frac{\hat{T}_{it}}{\hat{A}_{in,t}} \varepsilon_{in,t}}{g_{in,t}^{a}} + \frac{1}{r_{it}} \left[\varepsilon_{in,t} \hat{v}_{in,t+1} + (1 - \varepsilon_{in,t}) \hat{j}_{in,t+1}\right] \frac{1}{1 + g_{P,it}} \frac{1}{1 + g_{T,it}}$$

where $r_{nt} = R_{nt} \frac{P_{nt}}{P_{n,t+1}}$, $g_{p,it} = \hat{P}_{i,t+1} - \hat{P}_{it} + \frac{1}{1-\sigma} g$ and $g_{T,it} = \hat{T}_{i,t+1}/\hat{T}_{it} - 1 + g$.

Value adopted innovator

$$\hat{v}_{in,t}^{\text{innov}} = \chi_{in,t} \hat{\Pi}_{it} + \frac{1}{r_{nt}} \hat{v}_{in,t+1}^{\text{innov}} \frac{1}{1+g_{P,it}} \frac{1}{1+g_{T,it}}$$

Value un-adopted innovator

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

FOC innovation

$$\hat{H}_{nt}^{r} = \beta_r g_{Z,nt} \frac{\hat{Z}_{nt}}{\hat{T}_{nt}} \hat{v}_{nt}$$

FOC adoption

$$\hat{H}_{in,t}^{a} \frac{\frac{\hat{T}_{it}}{\hat{A}_{in,t}} \varepsilon_{in,t}}{g_{in,t}^{a}} = \beta_a \frac{1}{r_{it}} \varepsilon_{in,t} \left[\hat{v}_{in,t+1} - \hat{j}_{in,t+1} \right] \frac{1}{1+g_{P,it}} \frac{1}{1+g_{T,it}}$$

Probability adoption

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

Royalties

$$\hat{r}p_{in,t} = \frac{A_{in,t}}{T_{it}} \hat{\chi} in, t \Pi_{it}$$

Labor market clearing condition

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

Trade balance equation

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

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

Interest rate

$$r_{nt} = \frac{1}{\beta}(1 + g_{c,t+1})$$

with $g_{c,t+1} = \hat{C}_{n,t+1}/\hat{C}_{nt} - 1 + \frac{1}{\sigma-1}g$

Total number of adopted technologies

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

E BGP

The parameters of the model are: $\{\beta, \beta_a, \beta_r, \sigma, \lambda_n, \bar{\varepsilon}_{in}, \xi_i, d_{in}, g\}$.

To solve for the BGP, we can use the expressions from the previous section which are stationary and do not growth 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 of T_n, a value for g, a matrix fro $H^a in$, 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 we 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. $$r_n = \frac{1 + g/(\sigma - 1)}{\beta}$$

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

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

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

   This can be written as

   $$\omega_n L_n = \sum_{i=1}^{M} \pi_{in} Y_i$$

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

6. Updating rule for wages (note that because we have royalties, we will not be able to update wages at this stage without first knowing A_{in} which enters the equation for royalties. To do that we will need to guess for H^a_{in} which we already did and then use the growth block of the model to update H^a_{in}.

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

   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.

$$v_{in} = \left(1 - \frac{1}{r_i}\frac{1}{1+g_{pi}}\frac{1}{1+g_{ti}}\right)^{-1}\Pi_i$$

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

$$\varepsilon_{in} = \bar{\varepsilon}_{in}\chi_i\left(\frac{H^a_{in}}{Y_i}\right)^{\beta_a} - g$$

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

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

9. 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}.

$$j_{in} = \left(1 - \beta_a\varepsilon_{in}\frac{1}{r_i}\frac{1}{1+g_{pi}}\frac{1}{1+g_{ti}} - \frac{1}{r_i}\frac{1}{1+g_{pi}}\frac{1}{1+g_{ti}}(1-\varepsilon_{in})\right)^{-1}(1-\beta_a)\varepsilon_{in}\frac{1}{r_i}\frac{1}{1+g_{pi}}\frac{1}{1+g_{ti}}v_{in}$$

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. We need to use the FOC of adoption to update for adoption but for that we need an expression for $\frac{A_{in}}{T_i}$. We 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. Plug into the FOC for adoption and update H^a_{in}.

14. Use trade balance equation to update for wages. If there are M countries, we need $M-1$ updating equations because one is redundant.

15. Update g and T_n with Frobenius theorem and equation

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

In matrix form that expression becomes:

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

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

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 to that eigenvalue gives T, which is unique up to a scalar. So we can just compute $\hat{T}_i = T_i / T_M$.

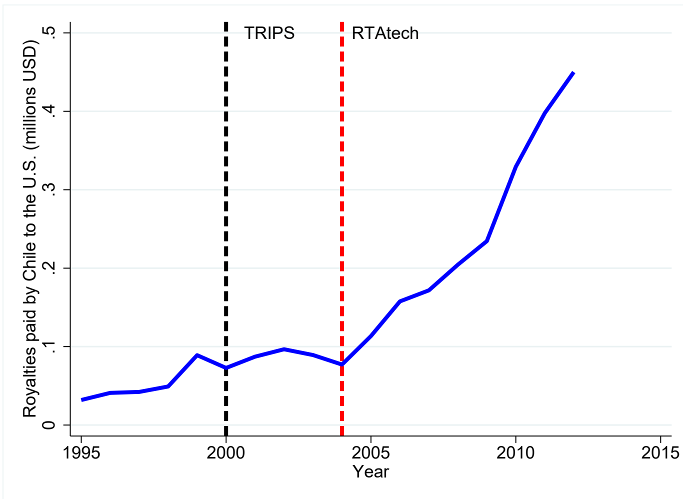
F International Licensing and RTAs with IP Provisions: Examples

Figure 7 shows the dynamics of royalty payments for a sample of country-pairs. There are two vertical lines: one refers to when TRIPS was ratified by the developing country, and the other refers to the time where the first RTA with technology provisions enter into enforcement.[11] Consistent with the previous figure, RTAs with IP chapters seem to increase

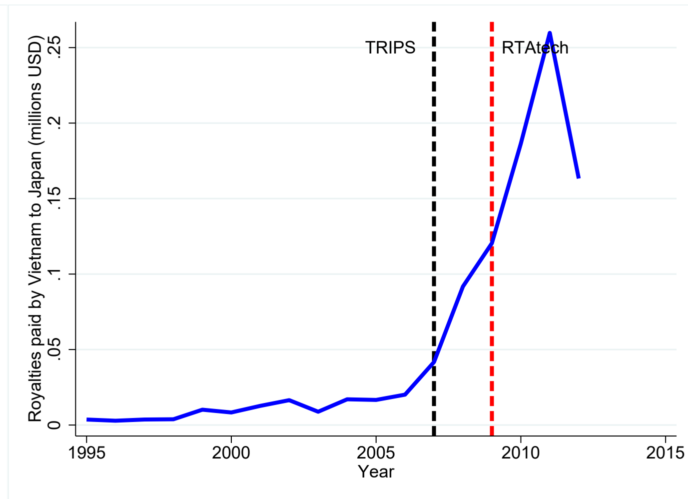
[11] Although TRIPS was established in 1995 as a requirement to be part of the WTO, many developing countries were granted an extension to meet the Ip requirements, and in those countries the agreement was ratified after 1995.

Figure 7: Dynamics of International Technology Licensing During RTAs with IP Provisions

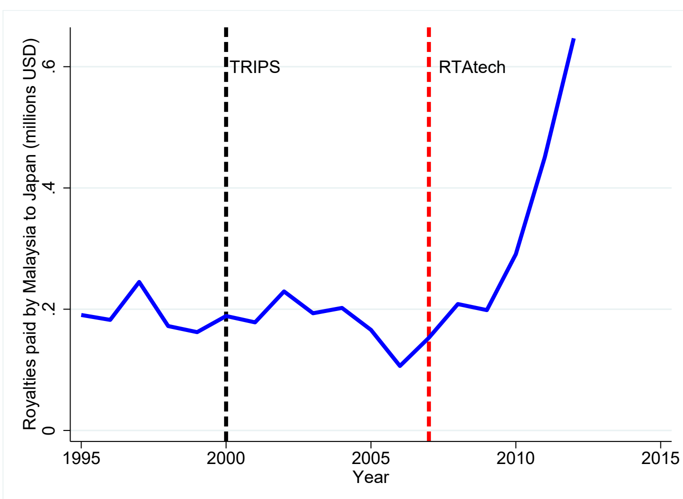
(a) USA to Chile



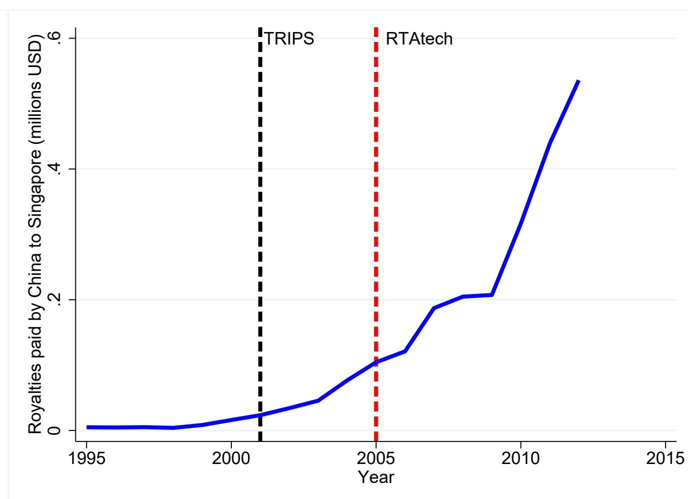
(b) Japan to Vietnam



(c) Japan to Malaysia



(d) Singapore to China



royalty payments from developing to developed economies, and the effect of these provisions is stronger than the minimum requirements established in TRIPS.