Intellectual Property Protection and Growth: Evidence from Post-TRIPS Development of Manufacturing Industries

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Intellectual property protection has long been recognized as a fundamental determinant of innovation and economic growth, and weak rights in developing countries are one of the significant barriers to the takeoff of their economy. Taking countries' reactions to the Agreement on Trade-Related Aspects of Intellectual Property Rights as an experiment, I examine this linkage by exploiting within-country variation in the growth of industries' value-added in a context with overall increasing intellectual property protection. Specifically, I ask whether industrial sectors that are more in need of R&D developed faster in developing countries that had raised their intellectual property strength to a relatively higher level in accordance with the Agreement. I find this to be true in a sample of up to 22 industries in 38 countries during 2000-2005. I show this result is unlikely driven by the reverse causality or other confounders, and my findings are robust to alternative measures of industrial R&D intensity.

Dating at least as far back to the 1980s, researchers and policymakers have adhered to the tenet that economic growth is endogenously sustained by technological change (Romer, 1986). Intellectual property rights (IPR), as a significant institution that could determine the incentive to innovate, therefore, has received unprecedented attention.

The relationship between IP protection, innovation, and economic growth involves some tradeoffs. Whereas IP protection increases the returns to creativity, the monopoly power offered to inventors blocks competitors from entering the market and encourages rent-seeking, both impede subsequent innovations (Boldrin and Levine, 2009). Even the usefulness of disclosure in IP applications is not guaranteed especially when many protected ideas cannot work, not to say building functioning devices or software programs from them (Boldrin and Levine, 2013). Strong IPR could particularly be harmful to the social welfare in developing countries because strong protection inhibits these countries from learning new technology through imitation (Helpman, 1993; Officer, 2002). Whether strong IPR spurs innovation and economic growth deserves empirical checks.

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However, as Arora et al. (2008) concluded: "studies analyzing the impact of IPs on innovation and growth have yielded mixed and, at times, difficult-to-interpret results." Some even mistakenly interpreted the correlation between strong IPR and high economic growth observed in literature (for example in Rapp and Rozek, 1990; Rushing and Thompson, 1996; Falvey, Foster and Greenaway, 2006) causally without accounting for omitted variables and the reverse causality (as we will see in the next section). Despite the inconclusiveness of empirical evidence on IP protection's effect, evidence does show that the global IP landscape has shifted to strong protection over the past decades (Boldrin and Levine, 2013). Whether this wave of legal reforms has boosted economic growth, especially in developing countries, since a central argument is that weak rights in developing countries are one of the most significant barriers to the takeoff of their economy, remains unclear and is the primary motivation of our research.

Suppose the innovation channel applies and IP protection benefits economic growth; in that case, one would see that the effect of increasing national IPR will vary by industry, depending on industry's dependence on innovative activities. I focus on R&D, so this would imply that an industry such as the pharmaceutical industry, which relies heavily on R&D, should develop relatively faster in response to stronger IPR than the apparel industry, which requires little R&D. Drawing on the variation in IP strength across countries, I investigate whether industries that are more dependent on R&D grow disproportionately faster in countries that have stronger IPR. Consider, for instance, the rapidly developing South American countries of Chile, Argentina, and Brazil, each of which has a different level of IP strength. Consistent with my hypothesis, chemicals (including pharmaceuticals) grew at a 13% higher annual real rate during 2000-2005 than apparel in Chile, where IPR was protected the strongest by our measures. In Argentina, where IPR was moderately protected, chemicals grew at an 8% higher rate than apparel. In Brazil, where IPR was protected the weakest, chemicals grew at only a 2% higher rate than apparel. I more systematically establish this finding across a wide range of industries and countries in the main parts of the paper.

Delving deeper into the components of IPR, IPR can be decomposed into copyrights, patent rights, trademarks, and trade secrets. While different forms of IPR in each country may vary in strength, I restrict attention to patent rights assuming only this specific form of IPR is related to the incentive to innovate of the manufacturing industries I am concerned about in this research. This assumption should be relaxed, and there is no harm in accounting for other aspects of IPR in future work.

A challenge of constructing causal claims in IP research is dealing with reverse causality. In particular, it is highly possible that, in countries where R&D-intensive industries are growing faster, these industries would lobby for stronger IPR. My solution is to specify 2000, when the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) was fully implemented, as the beginning of our reference period and restrict the analysis to developing countries. I argue that the increase in IPR due to TRIPS was exogenous to developing countries' willingness and highlight the randomness of developing countries' re-setting of their IP systems around 2000, based on which are we able to use countries' IP strength in 2000 as an experiment to understand how countries' *ex ante* setting of IPR influenced the *ex post* pattern of countries' industry growth.

I exploit within-country variation in the growth of value-added for up to 22 industries in 38 countries over the period 2000-2005 and find that R&D intensive industries had higher *ex post* growth rates in countries with relatively stronger IPR in 2000. For instance, an industry at the 75th percentile level of R&D intensity (equivalent to the electrical machinery industry) grew 0.68 percent faster with respect to an industry at the 25th percentile level (equivalent to the tobacco industry) when it was located in a country at the 75th percentile of IP strength (equivalent to Chile) rather than in one at the 25th percentile (equivalent to Mexico). The differential of 0.68 percent is not a small number compared to the average real growth rate of all industries in developing countries at the time, which was only 2.96 percent per year. I find the effect is significant only in developing countries.

To rule out the potential contribution of the creation of WTO, I provide the case study of China in the 1990s, during which time China became a signatory country to TRIPS but was not a member of WTO. Reform of the IP system in China seems to affect the relative growth rates of its industries in the way predicted. My findings are also robust to extensive checks of specifications and measurements, including controlling for initial growth rates, excluding countries with severe fluctuations in IP strength during 2000-2005, and varying measures of R&D intensity. Thus, my study provides new evidence of IP protection's supportive influence on economic growth, at least for developing countries in a context with overall increasing IP protection.

The remainder of the paper is organized as follows. Section I reviews some conventional methodologies for addressing the same research question as mine. Section II introduces TRIPS and justifies my selection of research objects. Section III then presents the empirical method. Section IV describes data, while Section V delivers randomization checks. Section VI presents the main results and rules out some confounders, and Section VII provides robustness checks. Conclusions are presented in Section VIII.

I. Literature Review in Research Methodology

Testing the innovation channel through which IP protection may affect economic growth is a persistent topic in empirical works. I classify conventional methodologies according to two types: the case study and the cross-country comparison. Each of these approaches, on its own, has its weakness.

In terms of case study, Arora et al. (2008) studied the introduction of product patents for pharmaceuticals in India and found that an increase in R&D investment coincided with the patent reform in the early 21st century. Besides, there are studies of IP reforms in several other countries, for example, the strengthening of Italian patent law to include pharmaceuticals in 1978 (Korenko, 2005); the Japanese patent reforms of 1988 (Sakakibara and Branstetter, 2001); and the 1982 formation of the Court of Appeals for the Federal Circuit in the US (Hall and Ziedonis, 2001). These studies drew mixed conclusions about the effect of IP protection on R&D investment and innovative activities. More importantly, case studies that study the impact of one specific IP reform policy at a time are commonly contracted with weak generalizability. To overcome this limitation, Lerner (2009) studied 177 significant shifts in patent policy across 60 countries over 150 years, but his results did not support the beneficial effect of strengthening patent protection on innovation. One caveat is that the author selected patent policy merely based on the shifts in laws on paper but overlooked information from the enforcement side. His selection approach also encountered subjectivity, which further qualified the credibility of his conclusions.

Alternatively, some research focuses on cross-country comparisons, of which a widely-used approach is regressing variables that IP protection is supposed to impact, like national R&D investment, on some quantitative measures of IP strength. This approach typically rests on the cross-country variation in IP strength. Variations within countries over time are sometimes applicable if panel data is available. A study by Park and Ginarte (1997) on a cross-section of countries for the period 1960-1990 found that IP protection is correlated to R&D activities, suggesting that strong IPR might affect economic growth by stimulating the accumulation of factor inputs. However, conclusions from other studies following Park and Ginarte's footsteps are mixed. Even restricting objects to developing countries, some studies found that strong IPR has no impact (Allred and Park, 2007) or even negative impact (Sweet and Eterovic Maggio, 2015) on domestic R&D and innovation, while others suggested that the effect is positive (Kanwar and Evenson, 2003; Chen and Puttitanun, 2005).

The mixed conclusions in literature are mainly due to the limitations of the cross-country methodology. Firstly, it is inappropriate to interpret the observed correlation between IP strength and economic growth in a causal sense. Causation here indeed runs from both directions, with innovation being both the consequence and the trigger of IP reform. Without a designed identification strategy, even panel data is less helpful in overcoming this issue because any within-country variation in the setting of IPR over time is likely endogenous to countries' dynamic of industry composition. Secondly, explanatory variables in existing research are sometimes chosen arbitrarily, leading to issues of multicollinearity and omitted variable. The above two problems may cause IPR to appear significant in cross-country comparisons when it is merely a proxy for some other variable possibly measured with error. The conventional cross-country methodology also confronts the problem of limited degrees of freedom since typically there are data from fewer than 100 countries on which the theories have to be tested.

To circumvent some of these problems, in this paper, I attempt to use a within-country, between-industry methodology, developed by Rajan and Zingales (1998) in a study on the causal relationship between financial development and economic growth, to exploit the details of the R&D channel through which increasing IPR might affect economic growth. My focus is on whether the *ex ante* development of IP systems facilitates the *ex post* growth of industrial sectors dependent on R&D.

This study relates closely to three previous studies that attempted to establish the IP protection-growth causation. Park (2005) used both country- and industry-level samples to develop a test of the influence of increasing IPR on growth. Whereas his regression analysis on country-level samples was the same as the conventional cross-country methodology, he pushed the methodology one step further by repeating regressions on industry-level samples. However, with 21 countries and 18 industries in total, but only about 10-14 observations per industry, his study was impossible to provide industry-by-industry results. Fortunately, with more observations available for each industry in a different dataset, I can compare growth rates between industries within each country in my study.

In a study on the impact of IP protection on FDI, Smarzynska (2002) looked at the interaction effects by constructing an interaction term of IP index and IP sensitivity of the industry.[1] There are two essential differences from my study. First, her study focused on exploiting whether firms in IP-sensitive industries receive more FDI based on a unique firm-level dataset from Eastern Europe and the former Soviet Union, while my comparisons are broader, thus providing more informative policy implications for market economy countries. Second, IP sensitivity in her study was a dummy (i.e., =1 if the firm belongs to an IP-sensitive industry by common sense), which failed to reveal the variations in industries' dependence on IPR. In comparison, I quantify industries' needs for R&D based on US firm-level data.

Finally, Woo, Jang and Kim (2015) examined how IP protection affects different industries' value-added, which coincides with my purpose. Whereas they ran separate regressions for each of the three industries (chemical, electronics, machinery) using data from 12 countries, I set an interaction term against regression by arm to cover more industries. One should also note that they used panel data for analysis, so both countries' R&D patterns and IP strength changed over time. With causality possibly running from both directions, the positive interaction effect observed in their research does not guarantee that IP protection benefits economic growth. My approach, instead, is regressing the compounded annual growth rates of industry value-added over several years on countries' predetermined levels of IP protection.

[1] IP sensitivity of the industry is not the same as industry's demand for R&D that I need to measure in my study, but Smarzynska's method of measuring IP sensitivity, especially its limitations deserve careful review.

II. Empirical Strategy

My objective is to investigate whether stronger IPR promotes economic growth. With the inspiration of Rajan and Zingales (1998), I draw the identification of this impact on within-country differences between industries. More specifically, I investigate whether industries that are more dependent on R&D have relatively higher growth rates in countries that have stronger IPR. The model I want to estimate is then

$$\begin{aligned} Growth_{j,k} = {} & Constant \\ & + \alpha \cdot (R\&D\ intensity\ of\ industry\ j \times IP\ strength\ of\ country\ k\ in\ 2000) \\ & + \beta \cdot (Industry\ j's\ growth\ rate\ in\ country\ k\ between\ 1999\ and\ 2000) \\ & + \gamma_k \cdot Indicator\ of\ country\ k + \delta_j \cdot Indicator\ of\ industry\ j \\ & + \varepsilon_{j,k} \end{aligned}$$

where the dependent variable is the average annual real growth rate of value-added in industry j in country k over the period 2000-2005. IP strength represents the strength of country k's patent rights in 2000; R&D intensity characterizes the importance of R&D to industry j in appropriating the returns from innovations. Country and industry fixed effects are included to correct for country and industry characteristics. I cannot come up with any significant explanatory variables that vary across both industries and countries within such a short period as I specified; but still, to remove any concerns, I include industry's initial growth rate, that is, the real growth rate of value-added over 1999-2000, as a control for time-invariant industry-country specific characteristics in robustness tests.

My primary interest is the coefficient estimate for the interaction between IP strength and R&D intensity. If IP protection incentivizes R&D investment, it will stimulate the prospective invention of new products and processes, thus promoting the growth of industries where innovation matters much. One would then see industrial sectors that are more in need of R&D to develop disproportionately faster in countries with more-developed IP systems, or $\alpha > 0$. In contrast, limiting the usage of existing inventions can inefficiently block competitors from entering the market and encourage rent-seeking, reducing follow-on inventions. A negative α would then align with the alternative hypothesis that strong IPR needs not necessarily be a potent source of economic growth.

One should note that my focus is on whether the pre-determined level of IP protection affects growth. This identification strategy does depend on the assumption that the IP system cannot develop instantaneously over the reference period. Otherwise, either strong protection at the beginning or initially weak protection combined with the follow-up reform of IPR could lead to the same pattern of *ex post* growth. This assumption seems plausible since the development of a whole system cannot be out of thin air (World Intellectual Property Organization, 2004). I will re-examine the credibility of this assumption while justifying my choice of

2000 as the beginning year of analysis in the following section. Further, in a robustness check, I exclude countries with severe fluctuations in IP strength over the period I build tests on.

Meanwhile, the endogeneity of countries' setting of IPR could be a potential threat to my identification strategy. In particular, it is highly possible that, in countries where R&D-intensive industries are growing faster, these industries would lobby for stronger IPR. I notice that in the spirit of Rajan and Zingales (1998), specifying IP strength as at the beginning of any arbitrarily chosen period, even though which approach would guarantee countries' *ex ante* setting of IPR to chronically precede any industry-specific shocks during the period, is insufficient to address the concern since IP regimes are always determined upon the anticipation of future industrial development. My strategy instead is to specify 2000, since when the TRIPS Agreement was fully implemented (to developing countries), as the beginning year of the reference period. Moreover, I restrict attention to different subgroups of developing countries whose setting of IPR in 2000 was most likely to be exogenous to their industry composition at the time. The selection of research objects distinguishes my study from the previous literature.

III. The TRIPS Agreement

A. Background

The TRIPS Agreement is so far the most comprehensive multilateral agreement on intellectual property that has changed the global IP landscape, setting the minimum level of protection for intangible goods and services. Negotiated during the 1986-1994 Uruguay Round, TRIPS introduced nearly all aspects of intellectual property rules, from basic principles to dispute settlement mechanisms, into the global trading system for the first time. It directly resulted in the establishment of the World Trade Organization (WTO).

Unlike previous research on TRIPS that focused on its history and detailed articles, I am concerned about two different questions: who are the demandeurs for an agreement on trade-related aspects of IPR, and why does the Agreement's implementation provide us a potential natural experiment to understand how IP protection affects economic growth?

The US was the first driver behind the inclusion of IPR in the Uruguay Round. Prior to the Uruguay Round, the US government had begun to believe that what they perceived as insufficient or inefficient protection of US IP abroad was unfairly weakening US industry's competitiveness and harming US trade interests (Otten, 2015). Evidence is a series of Acts amended or newly implemented over the 1970s that legitimized the investigation and sanction of potential IP infringement. Some notable legal files are the Manufacturing Clause of the US Copyright Act, which prohibited the importation into or public distribution in the US of certain copyrighted works unless they had been manufactured in the US or Canada

(World Trade Organization, 2020); the Section 337 of the US Tariff Act that prohibited the importation or sale of products unfairly produced abroad by a process covered by the US patent (US International Trade Commission, n.d.); and the Section 301 of the US Trade and Tariff Act that granted trade sanctions on foreign countries that engaged in unjustifiable and unreasonable acts (Schwarzenberg, 2022).

GATT's missing IPR where US competitiveness lay, when combined with the losing international competitiveness of the US in other areas due to the enormous increase in the international value of the US dollar, eventually pushed the US to put forward a proposal to negotiate rules on trade in counterfeit goods towards the end of the Tokyo Round of multilateral trade negotiations, which immediately preceded the Uruguay Round. Although few countries supported the proposed code by the end of the Tokyo Round in 1979, and it was not included in the results of the Round, the code eventually became what is now a part of the TRIPS Agreement, suggesting that the US had taken the initiative throughout the following Uruguay Round.

A few more developed countries started to join as demandeurs for a common base of IP protection in 1982 when pursuant to a work program agreed on by trade ministers, a revised version of the US proposal was submitted. This time with the support from the so-called "Quad" (Canada, the EC, Japan, and the US), the draft was referred to a group of experts mainly from developed countries in 1984. The expert group submitted its report a year later, agreeing that there was a growing problem with counterfeit goods commerce and a justification for stronger international intervention. The further consideration of the appropriate framework for such action was left to the GATT Council to make a decision in 1986.

As regards future GATT negotiations, in April 1986, the US Administration outlined its objective to include not just the completion of an anti-counterfeiting code but also the conclusion of a more comprehensive IP agreement based on the pre-existing World Intellectual Property Organization (WIPO) standards. Pressures from the US helped enlarge the size of the demandeurs, but were still restricted to developed countries. During the ministerial meeting of Organisation for Economic Co-operation and Development (OECD) countries two months later, other OECD countries expressed support for the statement from the US when their ministers agreed that the new round should handle IPR as long as it touched "trade-related aspects". This claim from developed countries later directly became the mandate for negotiations under the title "Trade-Related Aspects of Intellectual Property Rights, including Trade in Counterfeit Goods" since trade ministers met at Punta del Este, Uruguay, in September 1986, even though many developing countries were hostile to both a GATT anti-counterfeiting code and more ambitious ideas at that time. A negotiating group was formed to pursue this mandate.

From 1986 to April 1989, the group mainly discussed whether there was a mandate to negotiate regulations on IPR in general or just those that had to do with trade. A number of developing countries argued that WIPO is a more appropriate body than GATT to host IP negotiations, claiming that IP treaties were basically about the protection of rights, but the GATT was primarily about trade in products. On the other hand, developed countries considered a TRIPS Agreement part of the package on market access for products. Given the disadvantaged position of developing countries in negotiations, the result of the mid-term review during 1988-1989 was predictable. In April 1989, a decision was made to give the TRIPS negotiating group a full mandate to develop new or higher standards of IP protection, including measures of enforcement, which till now is still the basis for the structure of the TRIPS Agreement. As Piragibe Dos Santos Tarragô (2015), the negotiator who represented Brazil during the Uruguay Round, said, "the demandeurs succeeded in having their approach to the negotiations prevail in the terms of the new mandate."

The conflict between developing and developed countries had become so irreconcilable since the decisive turn after the mid-term review. Whereas developed countries aimed to raise the international standards of IP protection with a high degree of ambition, developing countries, led by the now called emerging countries, including Argentina, Brazil, China, and India, aimed to preserve the current standards as much as possible. It was not until this stage that some developing countries became the major players of negotiations. Between the spring of 1989 and the spring of 1990, a group of 14 developing countries (these countries are Argentina, Brazil, Chile, China, Colombia, Cuba, Egypt, India, Nigeria, Pakistan, Peru, Tanzania, Uruguay, and Zimbabwe) joined the US, the EC, Switzerland, and Japan to draft detailed proposals.

However, developing countries' defense failed to revert their disadvantaged position. Although the objections raised by the group of 14 developing countries were incorporated in a "composite text" drafted in June 1990, their objections, as the Chair of the Negotiating Group Ambassador Lars E.R. Anell said, "were duly noted and to be addressed at a later stage." Actually, they were, according to Tarragô (2015), "to be taken up only after the demandeurs had settled their differences and reached agreement. It was usually commented within the group of 14 developing countries that the Chair was clearly bent on giving primacy to the big players' positions, for they represented the only possibility of giving substance to the mandate agreed in the mid-term review, as the group of 14's positions were considered too limited or did not cover all the issues." Nevertheless, the "composite text" eventually became the basis for detailed negotiations conducted on every aspect. Progress was made over the following three years until the Final Act was released in 1993. As the Annex 1C of the Marrakesh Agreement Establishing the World Trade Organization (WTO Agreement), the TRIPS Agreement was signed on April 15, 1994, and finally, it came into effect on January 1, 1995.[2]

[2]For more details about negotiations during the Uruguay Round, please refer to Taubman, Wager and Watal (2020).

B. Selection of Objects

For two reasons my analysis is better to be built on countries in the defensive positions during the Uruguay Round, mainly developing and least developed countries in the WTO. Firstly, the increase in IPR due to TRIPS was most significant in these countries. Taking patent protection as an example, while based on a survey conducted by WIPO in 1988, only three of the 42 developing countries studied had a duration of patent protection of over 20 years at the time (World Intellectual Property Organization, 1988), all countries were subject to the 20-year protection policy with no exception after TRIPS came into effect. Secondly, the forced improvement of IPR was largely exogenous to these countries' willingness. Their new setting of IPR converged to the minimum level set by TRIPS, but with sufficient variations attributed to external factors.[3] In comparison, IP regimes in developed countries were not much affected by TRIPS due to their consistently strong protection; consequently, their setting of IPR was highly possible to be determined by country-specific characteristics of industrial growth.

In the WTO, least developed country members are those recognized as least developed countries by the United Nations. These countries had initially until January 1, 2006 to apply the TRIPS Agreement's provisions, and then extended to July 1, 2013, with the possibility of further extension to July 1, 2034, or to the date they are no longer "least-developed". Developing countries, on the other hand, were offered a unified transition period of only 5 years since TRIPS came into effect.[4] There is no explicit definition of developing countries in the WTO, so I identify developing countries as those whose transition periods expired on December 31, 1999, and were reviewed by the TRIPS Council in 2000 and 2001.[5] Besides, most new members of WTO joined after 1995 have agreed to apply the TRIPS Agreement as soon as they joined. These countries are better not to be included because they might have come up with the optimal IPR adaptive to both TRIPS rules and their industry composition during the long-term planning of joining WTO. Given all these facts, developing country members of WTO since 1995 that are not least-developed countries seem to be most free of endogeneity issues.[6] This is because they were unlikely to raise their IPR to the new optimal

[3]Hamdan (2009) checked and found no apparent trend in countries' compliance with TRIPS and countries' wealth, innovation capacities, and geographic regions. In Section 6, I also find that differences in 2000 IP strength across countries exist even in countries with similar initial mixes of industry. Thus, the variation in developing countries' new setting of IPR is sufficient, and it does not seem to be just industry composition, even in a context of global IPR convergence.

[4]Some developing countries were allowed to delay patent protection for pharmaceutical products (and agricultural chemicals) until January 1, 2005 under Article 65.4. However, for pharmaceuticals and agricultural chemicals, countries eligible to use this provision had to allow inventors to file patent applications from January 1, 1995 under the "mailbox" provision of Article 70.8 and provide the patent application some exclusive marketing rights under Article 70.9 (see `https://www.wto.org/english/tratop_e/trips_e/factsheet_pharm04_e.htm`). Pharmaceuticals, like other manufacturing industries in developing countries, should have been fully affected by TRIPS by 2000. Thus, I did not exclude pharmaceuticals from my analysis.

[5]See `https://www.wto.org/english/tratop_e/trips_e/tripfq_e.htm` for more details.

[6]Developing countries in the rest of this article refer to developing country members of WTO since 1995 that are not least-developed countries.

level that adapted to their industrial development status in such a short period from 1995 towards the end of the transition period.

One might argue that developing countries were not eventually "forced" to increase their IPR. Instead, they had accepted to sign the TRIPS Agreement because at least part of their proposals had been incorporated in the final draft. If that is the case, then there might be endogenous attrition of TRIPS requirements to developing countries' willingness. My response to this concern is that even if the endogeneity issue remains, the beneficial effect of IP protection would still be identified if estimates of the interaction term are positive. The reason is that GATT documents of the Uruguay Round point that developing countries were likely to accept raising their IP strength in exchange for negotiations aiming at enhancing market access, mainly for agricultural, textile, and other light industries where developing countries had comparative advantages. In other words, endogeneity predicts that developing countries dominated by less R&D-intensive industries initially should comply with TRIPS more by setting relatively stronger IPR, which is contrary to the reverse causality that bothers.

Another concern is that developed countries might want to intervene in what was happening in the developing world intentionally through TRIPS; thus, any pattern of developing countries' post-TRIPS IPR and their industrial growth might just be developed countries' willingness. But it is unlikely because TRIPS at most prescribed a minimum level of IP protection that applied to all countries, while the setting of IPR was eventually up to developing countries themselves. And I have shown there was a lack of endogenous attribution of developing countries' new choices of IP strength in accordance with TRIPS rules to their industry composition.

I choose developing country members of WTO since 1995 as the primary sample to build analysis on. Correspondingly, the year 2000 is set to be the beginning of the reference period. I claim that developing countries' IP strength should be relatively stable in a short time since 2000. On the one hand, since developing countries' strength of IP protection had already been significantly higher than their initial level in the pre-TRIPS era, they did not have an incentive to increase IPR further. Their IP system was not possible to move backward either since TRIPS' enforceability at the multilateral level through the effective dispute settlement mechanism of the WTO, presented a credible threat for developing countries to comply with the obligations (Watal, 2002). Thus even though IP strength of developing countries was impossible to be fixed, should it fluctuate within a narrow range. This discussion helps shed light on the credibility of the stable IPR assumption I proposed in the previous section.

I also test the hypothesis on two subgroups of developing countries. The first subgroup is the "Group of 14" developing countries that contributed to draft the "composite text". These countries used to oppose increasing their IPR so much that they had to stand out to defend against developed countries' proposals. It is reasonable to believe that their new setting of IPR tended to be the most exogenous to economic growth. However, from another angle, one could argue that the same group of countries participated most meaningfully in the negotiations. To avoid any bias due to their potential influence on the outcome of the Uruguay Round, I alternatively take developing countries excluding the "Group of 14" countries as a second subgroup to build analysis on.

IV. Data

A. Data on Industries

Data on value-added for each industry in each country are obtained from the INDSTAT 2 database compiled by the United Nations Industrial Development Organization (UNIDO, 2021). The data are arranged at the 2-digit level of the International Standard Industrial Classification of All Economic Activities (ISIC) Revision 3 pertaining to the manufacturing, which comprises 23 manufacturing sectors for up to 115 countries between 2000-2005. INDSTAT data are collected from various sources, and not all source data are classified by the ISIC code. The problem is that the value-added of some ISIC sectors in some countries are not mutually exclusive. For example, the value-added of textiles (ISIC 17) in Albania in 2000 includes data on wearing apparel and fur (ISIC 18). I checked the data for inconsistencies in the classification of sectors and did not observe any noticeable trend. So, to avoid measurement errors, I dropped all non-exclusive sectors in all countries of all years, like sectors of ISIC 17 and ISIC 18 in Albania 2000.

I want to see if R&D-intensive industries are likely to be better off in countries with well-developed IP systems. The most appropriate measure of an industry being better off is the real growth for that industry, i.e., the annual compounded growth rate in real value-added for the period 2000-2005. Real value-added is obtained by deflating industry value-added in current US dollars by the US GDP deflator, and compounded growth rate is derived from the change in log of real value-added between 2000 and 2005.

B. Strength of IP Protection

A major challenge is to quantify the strength of IPR in each country so that I can compare across countries. According to the Intellectual Property Handbook published by WIPO, intellectual property rights are legal rights which result from heterogenous intangible activities in the industrial, scientific, literary, and artistic fields. Intellectual property is traditionally divided into two branches, "copyright" and "industrial property", where industrial properties mainly include patents, trademarks, and trade secrets (World Intellectual Property Organization, 2004). The type of IPR considered in this research is patent rights because patents are protected primarily to promote new inventions in manufacturing industries, which is most related to the innovation channel through which economic growth is affected.

Following the conventions from previous studies, I use the 2000 update of the Ginarte-Park index (Park and Wagh, 2002) as the measurement of IP strength for each country in 2000. The GP index, first compiled by Park and Ginarte (1997), is constructed using a legislation-based approach (Hamdan, 2009). It assigns each country a score between zero and one for each of the five categories of the patent laws: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5) duration of protection. The final index is the unweighted sum of these individual scores and ranges from zero to five. The 2000 update of the index covers 63 countries. In a robustness check, I also compare the 2000 GP index for each country to its 2005 counterpart from Park (2008) to identify and exclude countries with severe fluctuations in IP strength from 2000 to 2005.

C. R&D Intensity

For each industry, I measure R&D intensity by the ratio of R&D expenditures to sales using data from Standard & Poor's *Compustat* (Standard & Poor's, 1995-2005). I started by summing firm's R&D expenditures over the period 2000-2005 and then divided by the sum of sales over the same period to get US firm's R&D intensity. This smooths temporal fluctuations. Next, I used the industry median to summarize ratios across firms. I did this to reduce the effects of outliers. US industries are classified by the North American Industry Classification System (NAICS). To obtain the R&D intensity of industry in 2-digit ISIC codes by which UN data are classified, I created concordances between NAICS codes and ISIC codes. Typically, the 3-digit NAICS codes correspond to 2-digit ISIC codes. I confine the analysis to manufacturing industries for which we have value-added data from UNIDO.

In Table 1, I tabulate by 2-digit ISIC code the ratio of US firms' R&D expenditures to sales. The recycling industry (ISIC 37) was excluded because we were not able to get a reasonable estimate of its R&D intensity given the limited number of US firms in this field. In line with common wisdom, the chemical industry (ISIC 24), which includes pharmaceuticals, depends most on R&D with an R&D intensity of 0.54481. Some other industries with R&D intensity over 0.1 are the manufacture of computing machinery (ISIC 30), communication equipment (ISIC 32), and precision instruments (ISIC 33). In comparison, the apparel industry (ISIC 18) emerges to depend on R&D the least with an R&D intensity of 0.00061, which is followed by 0.00410 and 0.00487 for the manufacture of petroleum products (ISIC 23) and basic metals (ISIC 27) respectively.

Much of my analysis rests on the dependence of US industries on R&D being a good proxy for reflecting the R&D intensity of industries across all other countries. This is reasonable because I have restricted attention to manufacturing industries, which reduces the dependence on country-specific factors like natural resources; for instance, we know the agricultural sector in Israel is rela-

TABLE 1—R&D INTENSITY ACROSS INDUSTRIES IN THE UNITED STATES DURING 2000-2005

ISIC2	Industries	R&D Intensity
15	Food and beverages	0.00666
16	Tobacco products	0.00777
17	Textiles	0.01744
18	Apparel	0.00061
19	Leather	0.01014
20	Wood products	0.00384
21	Paper products	0.00824
22	Printing and publishing	0.01488
23	Coke,refined petroleum products,nuclear fuel	0.00410
24	Chemicals (incl. pharmaceuticals)	0.54481
25	Rubber and plastics	0.01025
26	Non-metallic mineral products	0.00757
27	Basic metals	0.00487
28	Fabricated metal products	0.00900
29	Machinery and equipment	0.03796
30	Office, accounting and computing machinery	0.13373
31	Electrical machinery and apparatus	0.04330
32	Radio,television and communication equipment	0.14403
33	Medical, precision and optical instruments	0.12271
34	Motor vehicles, trailers, semi-trailers	0.02878
35	Other transport equipment	0.02670
36	Furniture and other manufactures	0.02040

Note: This table reports the median level of R&D intensity for industries classified by the two-digit ISIC code. R&D intensity is the ratio of R&D expenditures to sales of companies covered by *Compustat* between 2000-2005. All manufacturing industries are covered except for the recycling industry (ISIC 37), which field includes only a limited number of firms in the dataset.

tively R&D-intensive because Israel suffers from drought and so scientific planting technology is exceptionally desired. As for manufacturing industries, much of the demand for R&D is likely to arise due to worldwide technological shocks that redistribute R&D resources across industries within a country.

Even though R&D resources a country can provide are subject to its human capital accumulation and economic development, as long as these country-specific elements are common to all industries in the country, they will be absorbed by the country fixed effects in my specification. Therefore, I only need the relative R&D intensity across industries to be the same in all countries.

One might argue that the stage of the technology life cycle that US industries are in is likely to be different from that of foreign industries. Given that I want to build tests on developing countries, one might think that the US industry in the 1990s is a better proxy for the position of developing countries in a technology life cycle. For this reason, I also explore the robustness of my results to measuring the R&D intensity of US industries over 1995-1999 rather than from 2000 onwards. In another robustness check, I apply the ratio of the number of patents awarded to an industry to the total sales of the industry as an alternative measurement of the R&D intensity for that industry.

D. Data Combination

I would like data on as many countries as possible. The binding constraint is the availability of measures of IP strength. I started with the 63 countries that the 2000 GP index covers. I dropped countries for which we did not have either 2000 or 2005 data from UNIDO's database. Also, The United States is excluded from the analysis because it is our benchmark. This leaves us with the 38 countries in Table A1 in the Appendix. With 38 countries and almost 20 industries per country, I ended up with a much larger sample than what was used in previous studies at the country-level. Table 2 summarizes the data used in this study.

TABLE 2—SUMMARY STATISTICS

Variable	Mean	Median	Standard deviation	Minimum	Maximum	Number of observations
Industry's real growth	0.045	0.048	0.133	-1.013	0.749	12026
Industry's real growth (WTO members)	0.041	0.046	0.128	-1.013	0.560	880
Industry's real growth (developing countries)	0.030	0.034	0.124	-0.675	0.541	390
Industry's real growth (excl. "Group of 14")	0.017	0.030	0.131	-0.675	0.541	268
Industry's real growth ("Group of 14")	0.056	0.049	0.101	-0.268	0.467	122
Industry's real growth (developed countries)	0.047	0.049	0.128	-1.013	0.553	461
Industry's initial growth	0.276	-0.047	4.863	-1.820	144.420	1171
2000 IP Strength	3.169	3.240	1.011	0.000	5.000	63
2000 IP Strength (WTO members)	3.240	3.285	1.029	0.000	5.000	54
2000 IP Strength (developing countries)	2.823	2.880	0.726	1.500	4.190	26
2000 IP Strength (excl. "Group of 14")	2.811	2.860	0.826	1.500	4.190	17
2000 IP Strength ("Group of 14")	2.846	3.050	0.530	1.990	3.410	9
2000 IP Strength (developed countries)	4.031	4.050	0.452	2.710	5.000	23
R&D intensity (R&D exp./sales 2000-2005)	0.055	0.015	0.115	0.001	0.545	23
R&D intensity (R&D exp./sales 1995-1999)	0.035	0.023	0.034	0.000	0.098	20
R&D intensity (# patents/sales 2000-2005)	0.177	0.054	0.245	0.000	0.864	23

Note: Industry real growth is the annual compounded growth rate in real value-added for the period 2000-2005 for each ISIC industry in each country. The initial growth is the real growth rate in value-added from 1999 to 2000. Annual value-added data is from INDSTATA 2 dataset. IP strength is an index compiled by Park and Wagh (2002) ranking the strength of patent rights protection in each country in 2000. R&D intensity is constructed using *Compustat* firms between 2000-2005 and 1995-1999. NBER Patent Database is used for computing the ratio of patents granted to sales of firms covered by *Compustat* between 2000-2005 as an alternative measure of R&D intensity.

V. Balance Tests

Figure 1 depicts R&D intensity (weighted by industry shares of national value-added) and IP strength by country in 1995 and 2000 respectively. Through this plot, I want to show how countries' IPR changed with the implementation of TRIPS. Non-member countries and countries joined WTO after 1995 were excluded since their IP system was not subject to this policy shock.

At the beginning of TRIPS came into effect in 1995, countries that were dominated by R&D-intensive industries tended to have stronger IPR. This finding

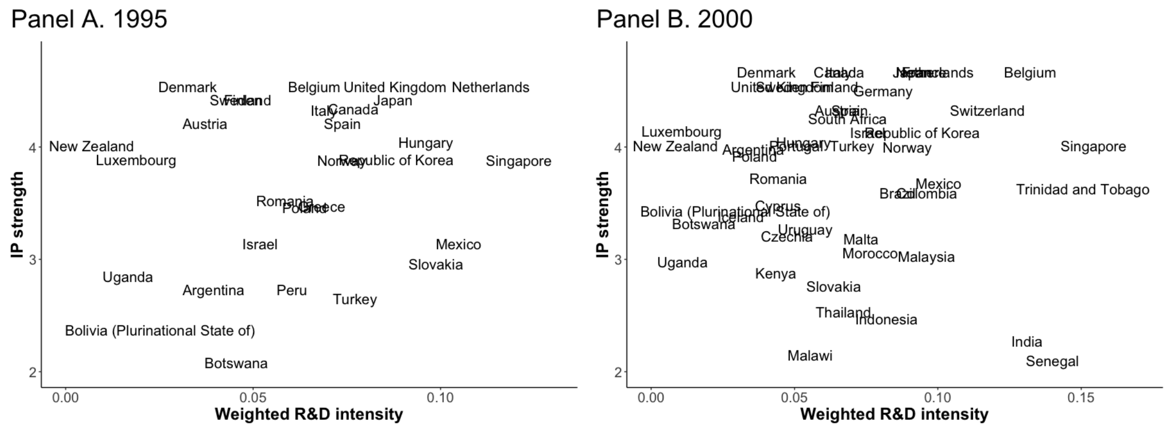

FIGURE 1. R&D INTENSITY AND IP STRENGTH

Note: This figure plots the weighted average R&D intensity of a country against its IP strength. The weights are the industries' shares of national value-added. Industry R&D intensity is constructed using *Compustat*, and national IP strength is obtained from Park (2008).

justifies my concern that specifying IP strength as at the beginning of an arbitrary period needs not guarantee that countries' setting of IPR is uncorrelated to the *ex post* industrial growth. Indeed, the reverse causality predicts that countries rely more on R&D-intensive industries at a point are likely to experience higher growth rates in these industries, and as a result, they should increase IPR. Since countries' mix of industries is always historically determined, the same confounder persists for any arbitrarily chosen year besides 1995.

The year 2000 is exceptional under the policy shock of TRIPS. Clearly, IP strength in developing countries on average increased during the period 1995-2000. This implies that TRIPS effectively forced developing countries to promote IP protection during the transition period. More importantly, the IP strength that developing countries ended up with varied across countries. For instance, while IP strength in Israel and Mexico were similar in 1995, they increased to considerably different levels in 2000, 4.13 versus 3.68. In the meantime, the variation in IP strength across countries (notably developing countries) in 2000 seems uncorrelated to countries' mix of industries. For example, while R&D-intensive industries were of equal importance to Trinidad and Tobago and India, the GP index of the former country was almost double that of the latter. On the other hand, Trinidad and Tobago and Cyprus had a comparable strength of IP protection in 2000, even though R&D-intensive industries had much smaller shares of national value-added in Cyprus.

I claim that TRIPS broke the linkage between IP strength and the initial mix of industries that is closely related to the future growth of industries in developing countries. To justify this claim, Table 3 explores the differences in initial growth rates of industry value-added between developing countries with weak and strong IPR. Industries are classified into three categories based on their R&D intensity terciles. They are R&D-light, R&D-neutral, and R&D-intensive industries. Developing countries are assigned into one of the two groups with either strong or weak IPR depending on whether their IP strength was above average. The first two columns show variable means for developing countries with weak and strong IPR in 2000. The third column reports the p-value for t-tests of the hypothesis that the means are equal.

TABLE 3—DIFFERENCE IN MEAN INITIAL GROWTH RATES OF DIFFERENT INDUSTRY GROUPS BETWEEN WEAK AND STRONG PROTECTION COUNTRIES

	Mean		p-value
	Weak IPR	Strong IPR	
R&D-light industries	0.015	0.043	0.702
R&D-neutral industries	0.025	-0.020	0.288
R&D-intensive industries	0.185	0.102	0.515

Note: This table reports the difference in mean initial growth rate (1999-2000) of industry value-added between developing countries with weak and strong IP protection for three groups of industries classified based on R&D intensity terciles. Columns (1) and (2) present variable means for weak and strong protection countries respectively, where weak and strong protection is defined relative to the sample mean of IP strength in 2000. Column (3) presents the p-value for t-tests of the hypothesis that the means are equal.

These comparisons indicate no statistically significant difference in initial growth rates of industries of all R&D intensities between developing countries with weak and strong IPR. But numerically, countries with strong IPR tended to have faster *ex ante* growth in R&D-light industries and slower *ex ante* growth in R&D-neutral and R&D-intensive industries. These slight baseline imbalances do not pose any challenge to my empirical strategy since they would predict R&D-intensive industries to experience lower growth rates in countries with stronger IPR in the absence of IP protection's effect on industrial growth, which is the opposite of my hypothesis. Tests conducted in this section help shed light on the credibility of my identification strategy.

VI. Results

A. *Main Estimates*

Table 4 presents least squares estimates of the baseline model on all countries in the combined dataset and those that joined WTO in 1995 respectively.[7] By estimating these two specifications, I aim to provide an update to the study from Hu and Png (2013), in which they exploited within-country variation in the growth of value-added over five-year periods from 1981-2000 and found stronger patent rights were associated with faster industrial growth measured by value-added. My estimation on updated data gives comparable results to theirs, where the coefficient on the interaction term was also positive. This confirms that my empirical strategy and usage of data are reasonable. However, neither Hu and Png's results

[7]Standard errors are clustered at the country-industry level and robust to heteroskedasticity throughout the paper. I have checked and obtained similar results with standard errors clustered by country.

nor my findings so far tell the direction of the causality. With non-WTO members, least developed countries, and developed countries that were largely not subject to TRIPS from 1995 to 2000 in the sample, I cannot ensure countries' setting of IPR in 2000 were exogenous to their industry composition. The significant interaction effect observed might result from reverse causality than any beneficial effect of IP protection. To obtain more precise estimate of the effect, I need to focus on developing country members of WTO, only for whom the exogeneity assumption is likely to hold.

TABLE 4—MAIN ESTIMATES FOR THE ENTIRE SAMPLE

	Model estimated on	
	All countries	WTO members since 1995
	(1)	(2)
IP strength × R&D intensity	0.096^{***}	0.112^{***}
	(0.037)	(0.040)
Country fixed effects	YES	YES
Industry fixed effects	YES	YES
Observations	736	658
R^2	0.325	0.325

Note: The dependent variable is the annual compounded growth rate in real value-added for the period 2000-2005 for each ISIC industry in each country. R&D intensity is the ratio of R&D expenditures to sales for US firms in the same industry between 2000-2005. The interaction variable is the product of R&D intensity and IP strength. The first and second columns are estimated on all sample countries and countries joined WTO in 1995 respectively. Both regressions include country and industry fixed effects (coefficient estimates not reported). Heteroskedasticity robust standard errors clustered at the country-industry level are reported in parentheses. (*p<0.1; **p<0.05; ***p<0.01)

Table 5 reports the estimates of the basic specification for various subgroups. I started with confining analysis to all countries whose transition periods expired on December 31, 1999. As shown in the first column of Table 5, the coefficient of the interaction between country IP strength and industry R&D intensity is positive and statistically significant at the 5% level. The impact of IP protection appears to be stronger in developing countries as a subgroup than in all countries as an integral.

To get the economic significance of the results, consider the following. Electrical Machinery is the industry at the 75th percentile of R&D intensity. Tobacco is the industry at the 25th percentile. Chile is the country at the 75th percentile of IP strength, while Mexico is the country at the 25th percentile. According to the coefficient estimate, one would then expect Electrical Machinery to grow approximately 0.68 percent faster than Tobacco in Chile than in Mexico in real terms. Comparatively, the average real annual growth rate of all industries in developing countries was 2.96 percent at the time. A 0.68% differential is therefore not trivial. For each specification, I compute a similar number which is reported as the differential in real growth rate in the table. The countries at the 75th and 25th percentile are specific to the subgroup I apply analysis on.

TABLE 5—MAIN ESTIMATES FOR DIFFERENT SUBGROUPS

	Model estimated on			
	Developing countries (1)	Developing countries excl. "Group of 14" (2)	"Group of 14" countries (3)	Developed countries (4)
IP strength × R&D intensity	0.183** (0.089)	0.215* (0.115)	0.218* (0.129)	0.002 (0.115)
Country fixed effects	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES
Observations	264	159	105	378
R^2	0.374	0.392	0.590	0.353
Differential in real growth rate	0.68	0.91	0.22	0.01

Note: The dependent variable is the annual compounded growth rate in real value-added for the period 2000-2005 for each ISIC industry in each country. R&D intensity is the ratio of R&D expenditures to sales for US firms in the same industry between 2000-2005. The interaction variable is the product of R&D intensity and IP strength. The sample is all developing countries in the first column, developing countries excluding the "Group of 14" countries in the second column, the "Group of 14" countries in the third column, and all developed countries in the fourth column. The differential in real growth rate measures (in percentage terms) how much faster an industry at the 75th percentile level of Rintensity grows with respect to an industry at the 25th percentile level when it is located in a country at the 75th percentile of IP strength rather than in one at the 25th percentile. All regressions include both country and industry fixed effects (coefficient estimates not reported). Heteroskedasticity robust standard errors clustered at the country-industry level are reported in parentheses. (*$p<0.1$; **$p<0.05$; ***$p<0.01$)

Columns (2) and (3) of Table 5 report the estimated effects for two other subgroups. I included developing countries that contributed to the 1990 composite text of the Uruguay Round in the second column and developing countries excluding the previous sample in the third column. The coefficients are uniformly positive and statistically significant at the 10% level. Specifically, I suggest focusing on the fact that even when the sample size in each specification reduces much, the differential in real growth persists and is remarkable.

In column (5) of Table 5, I provide the estimate of the same model but for developed countries. Interestingly, the magnitude of the coefficient is much smaller than that for estimations on all subgroups of developing countries and is not significant at all levels, which contradicts results from previous studies where the impact of IP protection on economic growth was typically stronger in more economically advanced countries. One possible explanation for this result is that developed countries were not subject to the minimum level of protection set by TRIPS due to their consistent strong protection of IPR. Hence, IP strength in developed countries tended to be more endogenous. Factors that determined the optimal IPR in developed countries could be complicated, and it turns out that these factors' aggregate effect on industrial growth was ambiguous. This result justifies the necessity of confining analysis to developing countries.

On the other hand, least developed countries were not subject to TRIPS over 1995-2000 either since their transition periods had not expired in 2000. Following the same logic above, the interaction effect for least developed countries is highly possible to be insignificant as well. Unfortunately, I cannot check the validity of this inference due to the unavailability of the value-added data of most least developed countries during the period I am concerned about.

Before moving to other tests, let us take a look at the actual effects of IP protection on the real growth of selected industries. In Table 6, I summarize the mean growth rates of the three least R&D-intensive and the three most R&D-intensive industries by country group. Developing countries below the sample mean IP strength appeared to have higher growth rates in the three least R&D-intensive industries, and lower growth rates in the three most R&D-intensive industries. The pattern reverses for countries above the mean. This result shows that my findings are not likely driven by either a single industry or a single country, and that the observed differentials in growth rates are systematic.

TABLE 6—EFFECT OF IP PROTECTION ON ACTUAL GROWTH RATES IN DIFFERENT INDUSTRIES

	Countries below the mean in IP strength	Countries above the mean in IP strength
	Least R&D-intensive industries	
Apparel	0.032	0.019
Wood	0.031	0.038
Coke et.al	0.138	0.135
	Most R&D-intensive industries	
Chemicals	-0.01	0.169
Computers	-0.105	0.034
Medical inst.	-0.119	0.036

Note: This table reports the mean actual growth rates of different industries in different groups of developing countries for the period 2000-2005.

B. *Is the Creation of WTO a Necessary Condition?*

Thus far, I have attributed different patterns of industries' growth across countries entirely to the variation in countries' IP strength. An alternative explanation is that R&D-intensive industries grew faster in countries with stronger IP only when countries had access to the global market produced by WTO. This conjecture is reasonable because my estimates come in a context with the establishment of WTO overlapping the implementation of TRIPS. So is the creation of WTO a necessary condition for increasing IPR to benefit innovation and economic growth?

To answer this question, I aim to find a non-WTO member country that was subject to TRIPS, and compare its pre- to post-TRIPS patterns of industries' growth. Of course, such an object is not easy to find because 122 of 123 contracting parties accepting the TRIPS Agreement (as part of the WTO Agreement) in 1994 became original WTO members upon the entry into force of the WTO Agreement (January 1, 1995) or within the subsequent two-year period, but China provides an exceptional case.

China was one of the original signatory countries to the TRIPS Agreement, but it was not approved to join WTO by the Ministerial Conference until December 11, 2001. China's reform of its IP system in accordance with TRIPS rules achieved remarkable results almost immediately after TRIPS came into effect. However, this does not mean that the hot wave of IP protection was China's willingness. Instead, China had to accept the TRIPS Agreement, which it once strongly opposed (remember China was one of the 14 developing countries defending against developed countries' proposals during the Uruguay Round), only in exchange for a positive image of complying with international treaties, and a higher possibility of being approved to join WTO. In a word, China's reform of its IP system was the result of an exogenous policy shock, just as in other developing countries.

Progress in China's IP protection is reflected by a jump in its quantitative measure of IP strength from 2.62 in 1990 to 3.48 in 1995 (Chen, 2015). As shown by the complete trend of China's IP protection from 1985-2000 depicted in Panel A of Figure 2, China's IP system reached its peak of development in the mid-1990s, not in 2000, when China's WTO accession negotiations approached their end. This implies that the growth of industry value-added in China had already been affected by TRIPS since 1995; in the meantime, the effect of increasing IPR was not confounded with WTO's influence during 1995-2000.

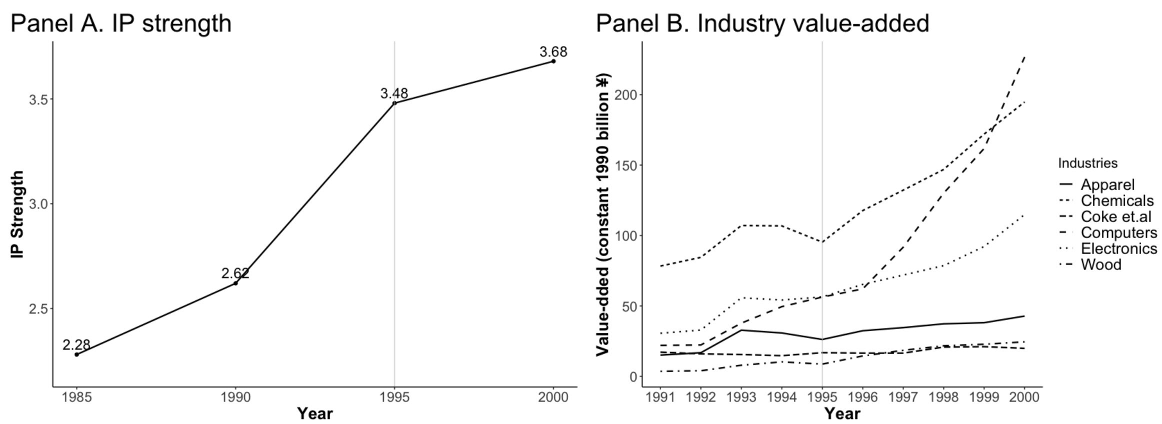

FIGURE 2. IP STRENGTH AND INDUSTRY VALUE-ADDED OF PRE- AND POST-TRIPS CHINA

Note: Panel A plots the IP strength of China at five-year intervals from 1985-2000. IP strength is estimated by Chen (2015) based on the method of Park and Ginarte (1997). Panel B plots the real value-added for the period 1990-2000 for selective ISIC industries in China. The Chinese data is classified by the GB/T 4754 code. All two-digit ISIC industries covered here correspond directly to the two-digit GB/T 4754 industries with the exception of the chemical industry (ISIC 24), which corresponds to three industries classified by the GB/T 4754 code (26-28). Real value-added for each GB/T 4754 industry is estimated by Chen (2011).

Panel B of Figure 2 depicts the trends of selective industries' growth in China before and after TRIPS came into effect. The pattern is still remarkable. While all industries moved in roughly the same direction at similar rates in the pre-TRIPS era, R&D-intensive industries grew much faster when IP system developed in China after TRIPS came into effect. Omitted variables do not likely drive this finding, as I have checked and found no other significant policies that could specifically benefit the development of China's R&D-intensive industries over the same period. The case study of China helps rule out the potential contribution of WTO creation to IP protection's effect.

VII. Robustness Checks

I take various methods to check the robustness of my estimations, including controlling for initial growth rates, excluding countries with severe fluctuations in IP regimes during 2000-2005, and varying measures of R&D intensity.

Table 7 reports estimates of the main specification on different subgroups, with initial growth rates included. By this means, I want to control for country-industry heterogeneity that is not captured by country and industry fixed effects. In all specifications, the coefficients of the initial growth rates are negative, suggesting that slow-growth industries were catching up with fast-growth industries. Besides, the coefficients on the interaction term are similar to those in the previous section.

TABLE 7—CONTROL FOR INITIAL GROWTH RATE

	Model estimated on				
	WTO members since 1995 (1)	Developing countries (2)	Developing countries excl. "Group of 14" (3)	"Group of 14" countries (4)	Developed countries (5)
Initial growth rate	0.0001	-0.035	-0.053	-0.018	0.0002
	(0.001)	(0.029)	(0.036)	(0.052)	(0.001)
IP strength ×	0.109^{***}	0.198^{**}	0.233^{**}	0.285^{*}	0.002
R&D intensity	(0.041)	(0.093)	(0.115)	(0.143)	(0.115)
Country fixed effects	YES	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES	YES
Observations	634	241	157	84	377
R^2	0.321	0.371	0.404	0.606	0.352

Note: The dependent variable is the annual compounded growth rate in real value-added for the period 2000-2005 for each ISIC industry in each country. Initial growth rate is the real growth rate in value-added from 1999 to 2000. R&D intensity is the ratio of R&D expenditures to sales for US firms in the same industry between 2000-2005. The interaction variable is the product of R&D intensity and IP strength. All regressions include both country and industry fixed effects (coefficient estimates not reported). Heteroskedasticity robust standard errors clustered at the country-industry level are reported in parentheses. (*p<0.1; **p<0.05; ***p<0.01)

Next, in Table 8, I check that the results are robust to using countries with stable IP strength, i.e., the strength of IP protection fluctuated within a 10% range over the period 2000-2005. The interaction effect is positive and statistically significant despite the reduction of sample size. The magnitude of the coefficients, however, is larger. One possible explanation for this result is that IP reforms in developing countries continued after 2000. Most likely, some weak protection countries in 2000 experienced IP development over the following years, while some strong protection countries possibly fell back compared to their IP protection in 2000. The beneficial effect of the continuous IPR development in initially weak protection countries, when combined with the harmful impact of the continuous IPR decline in initially strong protection countries, made the differential in industrial growth rates smaller than it should be with no dynamic of IPR.

TABLE 8—STABLE IP STRENGTH

	Model estimated on				
	WTO members since 1995 (1)	Developing countries (2)	Developing countries excl. "Group of 14" (3)	"Group of 14" countries (4)	Developed countries (5)
IP strength × R&D intensity	0.220** (0.102)	1.755*** (0.343)	1.585* (0.749)	1.037* (0.538)	0.379 (0.358)
Country fixed effects	YES	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES	YES
Observations	393	98	36	62	295
R^2	0.335	0.575	0.814	0.639	0.348

Note: The dependent variable is the annual compounded growth rate in real value-added for the period 2000-2005 for each ISIC industry in each country. R&D intensity is the ratio of R&D expenditures to sales for US firms in the same industry between 2000-2005. The interaction variable is the product of R&D intensity and IP strength. Samples are built on countries with IP strength fluctuated within a 10% range over the period 2000-2005. All regressions include both country and industry fixed effects (coefficient estimates not reported). Heteroskedasticity robust standard errors clustered at the country-industry level are reported in parentheses. (*p<0.1; **p<0.05; ***p<0.01)

In part, the adjustment of IP regimes in developing countries after 2000 possibly leads my baseline results to underestimate the effect of IP protection. Nevertheless, I regard this adjustment as an advantage for justifying my selection of the reference period: During 2000-2005, developing countries had just raised their IP strength above the minimum level set by TRIPS while still exploring the new optimal IPR. This was ahead of the new optimal being found, after which the issue of endogenous setting of IPR would emerge again. This robustness test helps shed light on the credibility of both the beneficial effect of IP protection on innovation and my identification strategy.

I now check that my result is robust to different measures of R&D intensity. First, motivated by Rajan and Zingales (1998), I check whether the pattern of industry R&D intensity is persistent. Industry R&D intensity measured with US firms can be a reasonable proxy that carries information for other countries (especially developing countries that are at different stages of the technology life cycle as the US) only if the pattern of R&D in the US during 2000-2005 is close from the pattern during 1995-1999. The raw correlation between an industry's R&D intensity during 2000-2005 and its R&D intensity during 1995-1999 is 0.45.[8] The coefficient estimates when R&D intensity is measured with US firms during 1995-1999 are presented in Panel A of Table 9. The results are similar to those from the baseline estimation, but less precisely estimated for all WTO members and the "Group of 14" countries. Besides, the interaction effect for developed countries becomes significantly negative. This is not surprising since endogenous factors that determined developed countries' IP strength could relate to their future industrial growth in many unobservable ways. Discussing these relationships is beyond the scope of this paper.

[8]We do not have estimates for ISIC 16, ISIC 21, ISIC 23 because no recorded firm belongs to these three industries. Estimates for other industries are not reported.

TABLE 9—ALTERNATIVE MEASUREMENTS OF R&D INTENSITY

A: R&D Expenditures to Sales (1995-1999)

	Model estimated on				
	WTO members since 1995	Developing countries	Developing countries excl. "Group of 14"	"Group of 14" countries	Developed countries
	(1)	(2)	(3)	(4)	(5)
IP strength × R&D intensity	0.211	0.477*	0.976***	-0.368	-0.816**
	(0.162)	(0.284)	(0.348)	(0.466)	(0.413)
Country fixed effects	YES	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES	YES
Observations	587	231	138	93	343
R^2	0.346	0.405	0.458	0.589	0.368

B: # Patents Granted to Sales

	Model estimated on				
	WTO members since 1995	Developing countries	Developing countries excl. "Group of 14"	"Group of 14" countries	Developed countries
	(1)	(2)	(3)	(4)	(5)
IP strength × R&D intensity	-0.002	0.032	0.075	-0.081	-0.145***
	(0.022)	(0.041)	(0.053)	(0.062)	(0.054)
Country fixed effects	YES	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES	YES
Observations	658	264	159	105	378
R^2	0.316	0.364	0.385	0.584	0.366

Note: The dependent variables in both panels are the annual compounded growth rate in real value-added for the period 2000-2005 for each ISIC industry in each country. R&D intensity is the ratio of R&D expenditures to sales for US firms in the same industry between 1995-1999 in Panel A, and the ratio of the number of patents granted to a US industry to the total sales of the industry between 2000-2005 in Panel B. Both interaction variables are the product of R&D intensity and IP strength. All regressions include both country and industry fixed effects (coefficient estimates not reported). Heteroskedasticity robust standard errors clustered at the country-industry level are reported in parentheses. (*p<0.1; **p<0.05; ***p<0.01)

In Panel B of Table 9, I perform another robustness check on my measure of R&D intensity. I apply the ratio of the total number of patents awarded to a particular industry to the sales of the industry as an alternative measurement of the R&D intensity for that industry. I use the NBER Patent Database (National Bureau of Economic Research, 2010) and the concordance through the *Compustat* identification numbers to identify the US patents granted. The coefficients of the interaction term are positive for estimations on all developing countries, and developing countries excluding the "Group of 14" countries. However, the interaction variable is negative for the "Group of 14" countries. This result might be driven by the outliers, given the small number of countries in this subgroup.

The interaction effect is insignificant for all specifications estimated on subgroups of developing countries. One explanation of this result is perhaps that the variation in the R&D intensity measured with patent to sales is much smaller than that measured with R&D expenditure to sales (0.0012 versus 0.0132 for variance). Another possible explanation is the lagged effect of IP protection on the pattern of patents. Not as IP protection immediately encourages firms to invest more in R&D, which directly transfers into the growth of R&D-intensive industries' value-added; the increase in patent counts usually lags behind IP protection due to the long processing time of patent approval, and so is the growth of patent-intensive industries. Since these estimates validate the trend that IP protection promotes innovation and economic growth, I considered them to be a reasonable robustness check.

VIII. Conclusion

Although IP protection has long been recognized as a fundamental determinant of economic growth, there has been little conclusive empirical evidence to support this linkage. In this paper, I re-examine whether strong IPR facilitates economic growth by scrutinizing one main rationale for such a relationship: that development in IP system stimulates R&D investment and innovation.

Taking developing countries' reactions to TRIPS as an experiment, I exploit within-country variation in the growth of value-added over the period 2000-2005. My econometric results show that R&D-intensive industries had higher *ex post* growth rates in developing countries that had increased their IPR to a relatively higher level after TRIPS came into effect. The same pattern was observed in post-TRIPS China, suggesting that the creation of WTO is not a necessary condition for IP protection to impact innovation and economic growth. My finding is unlikely driven by the reverse causality since the global reform of IPR in the late 1990s was not developing countries' willingness. Also, the transition period offered to developing countries for them to carry out IPR reforms following TRIPS rules was so short that towards the end of the period, they were not able to find new optimal IPR that adapted to their industrial growth. Besides, I find the impact of having stronger IPR in the post-TRIPS era was ambiguous in developed countries due to the endogeneity of their IP regimes.

These findings suggest that the development of IP system has a substantial supportive influence on economic growth, and this works, at least partly, by stimulating innovation. The policy implication behind this is obvious, that countries should set relatively stronger IPR in pursuit of technological progress, the foundational source of long-term growth. However, IP reform is not easy to take place in developing countries. It always faces various political-economic obstacles, especially when countries' R&D-intensive industries are at the early stage of the learning curve. In this sense, some necessary push from the outside, like TRIPS, could be beneficial to developing countries, even though global regulations of IPR are sometimes first proposed by developed countries for their own benefit, and developing countries themselves may not be aware of the benefit at the beginning.

Of course, My findings are subject to a context with overall increasing IP protection. IP protection might only be beneficial if a country's trading partners uniformly increase their IPR under some global regulations. Whether the reform of a single country's IP system, with global IP landscape being unchanged, would bring the same effect remains further check. Besides, let us be careful that my findings are not necessarily generalizable to least developed countries where copy and imitation industries are prevalent. With the transition period of TRIPS offered to least developed countries approaching the end, it would be good to check the pattern of industry value-added for least developed countries in future work.

The other major issue is my application of R&D intensity measured with US firms as a benchmark for all other countries. Future work should focus on measuring industry R&D in the sample of interest. This, of course, relies on the broader availability of data. Further, my measure of IP strength simply counts the protection of patent rights. While patent rights tend to be the most related to the innovation channel I want to check in this paper, the estimates could be more accurate if quantified strength of other aspects of IP protection are available and incorporated.

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APPENDIX

TABLE A1—COUNTRY SAMPLE

Countries	WTO members since 1995	Developing countries	"Group of 14" countries	Developed countries	Least developed countries
Argentina	✓	✓	✓		
Australia	✓			✓	
Austria	✓			✓	
Belgium	✓			✓	
Botswana	✓	✓			
Brazil	✓	✓	✓		
Bulgaria					
Chile	✓	✓	✓		
Columbia	✓	✓	✓		
Czechia	✓			✓	
Denmark	✓			✓	
Ecuador					
Ethiopia					
France	✓			✓	
Germany	✓			✓	
Hungary	✓			✓	
India	✓	✓	✓		
Indonesia	✓	✓			
Ireland	✓			✓	
Israel	✓	✓			
Italy	✓			✓	
Japan	✓			✓	
Jordan					
Kenya	✓	✓			
Republic of Korea	✓	✓			
Mexico	✓	✓			
Netherlands	✓			✓	
New Zealand	✓			✓	
Norway	✓			✓	
Poland	✓	✓			
Romania	✓			✓	
Senegal	✓				✓
Singapore	✓			✓	
South Africa	✓			✓	
Spain	✓			✓	
Sweden	✓			✓	
Turkey	✓	✓			
United Kingdom	✓			✓	

Note: This table reports the countries which are included.