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The Impacts of Intellectual Property–Related Preferential Trade Agreements on Bilateral Patent Applications

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Abstract

Intellectual property rights have become a central emphasis in the negotiation of "deep" preferential trade agreements containing provisions on regulatory environments besides trade policy. These provisions typically require member countries to implement heightened standards on various aspects of intellectual property rights, such as coverage and enforcement, that go beyond the baseline requirements of international intellectual property rights agreements such as the World Tarde Organization's Trade-Related Aspects of Intellectual Property Rights agreement. This study implements a structural gravity framework to investigate empirically the impacts of these agreements on bilateral international patenting, to quantify the effects of countries' membership in intellectual property–related preferential trade agreements on within-agreement patent applications at national patent offices, as well as extra–preferential trade agreement patenting at member country destinations originating from non-member countries. The study further explores the heterogeneity of these effects as originating from the attributes of the agreements, such as whether the major partner in the agreement is the United States or the European Union/European Free Trade Association, and the presence of key "Trade-Related Aspects of Intellectual Property Rights–Plus" provisions in the agreement texts. The findings suggest that intellectual property rights standards in preferential trade agreements tend to generate positive impacts on international patenting, and that the specific features of the agreements give rise to significant disparities in these impacts. Most intriguing is that those agreements involving multiple Trade-Related Aspects of Intellectual Property Rights–Plus norms significantly increase patenting within members compared to patenting from outside those areas, while other types of intellectual property rights encourage more patenting from non-members.

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1. Introduction

In recent decades, preferential trade agreements (PTAs) have evolved considerably from exercises in discriminatory tariff cutting to deeper and broader commitments to set minimum standards in a variety of regulatory areas, such as financial services, consumer data collection, competition policy, and investment regulations. Intellectual property rights (IPRs) play a central role in this regulatory convergence. Increasing numbers of PTAs embody extensive chapters covering detailed requirements regarding eligibility, scope of coverage, and enforcement of patents, designs, trademarks, copyrights, geographical indications (GIs), and other forms of protection.

Such agreements, which may be called IP-Related PTAs, or IPAs, typically build on minimum standards required in the TRIPS Agreement at the World Trade Organization. The TRIPS Agreement itself achieved a marked degree of convergence in rules covering IPRs across WTO members, raising standards in emerging and developing countries toward those in the developed economies that remain the largest producers of knowledge goods. However, the primary *demandeur* countries in this context, the United States and the European Union, increasingly have demanded even stronger protection, in the form of so-called TRIPS-Plus requirements, in the PTAs they negotiate. For example, the United States has PTAs with Jordan, Peru, Australia, the Republic of Korea, and other countries that contain, compared to TRIPS, substantively tighter standards of patent protection for pharmaceuticals, new regulations for copyrights in digital goods, and expanded penalties for infringing IPRs. Such requirements pertain as well in the US-Mexico-Canada Agreement, which supplanted NAFTA. The 11-country Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) added further rules, including expanded protection of trade secrets. In 2014, Canada and the EU ratified their bilateral Comprehensive Economic and Trade Agreement, containing an extensive chapter on intellectual property with elevated standards.

A recent literature has emerged attempting to estimate the effects of such agreements on international trade in merchandise. It is evident that trade in goods could be sensitive to IP reforms in PTAs, for prior literature had established that TRIPS and expanded patent rights generally expanded trade, particularly in higher technology sectors (Ivus, 2010; Delgado, et al, 2013; Maskus and Yang, 2018). Regarding IPAs, Campi and Duenas (2019) estimated a gravity model and found evidence of a positive effect on bilateral trade five years after partner countries signed such agreements. Perhaps surprisingly, this result held equally for both high-intellectual-property goods and low-intellectual property goods, raising questions about whether the effects of the trade aspects of these PTAs were sufficiently well controlled. Maskus and Ridley (2021) studied this question in an identification context, defining treatment trade agreements as those with elevated IP standards of various forms versus those without such rules. They found significantly positive impacts on the trade of members with third parties (those outside the IPAs), controlling for prior TRIPS membership, in biopharmaceuticals, medical devices, and other sectors that are highly reliant on intellectual property protection.

Unstudied to date is whether and how IPAs influence international knowledge flows, as measured by bilateral patent applications among member countries and between non-member and member countries. This is a remarkable omission in light of the evident intent of intellectual-property chapters to reduce application costs and strengthen protection for patent holders. Our aim is to address this shortcoming by estimating the effects of IPA membership on bilateral applications, both at the country level and using various high-tech sectoral clusters. We make use of the World Bank's extensive database covering regulatory provisions in comprehensive PTAs (Mattoo et al., 2020), employing various definitions of what constitutes TRIPS-Plus agreements.

Prior literature has emphasized the interrelationships between patent filings or grants and detailed trade flows. For example, countries that engage in unilateral patent reforms tend to find rapid increases in foreign patenting in their economies, relative to domestic patenting (Lerner, 2002). The essential reason is that foreign firms seek to sell products, whether exported or produced through local affiliates, in markets where their goods may be patented and those patents enforced. This correlation between patenting and trade has attracted significant attention in recent years, given the widespread availability of micro data on patents and trade. Brunel and Zylkin (2022), in an extensive panel-data study between 1974 and 2006, find that international patent grants have a positive impact on bilateral exports to the patent-destination country, though these effects varied across sectors. De Rassenfosse, et al. (2020) studied transactions data among French exporting firms between 2002 and 2011, concording patent categories with traded products. They found that owning patents generated a patent premium in exports to countries where patents were sought, which emerged primarily from greater export volumes rather than higher prices.

Again, neither strand of literature addresses the basic question of how IP-related PTAs influence bilateral patent application flows, which is our concern in this study. Rather than a difference-in-differences approach, we opt for estimating a structural gravity model, as explained below, in which bilateral patent applications are related to joint membership in an IPA versus cases where the patent-destination country is in an IPA and the patent-source country is not. A particularly attractive feature of our structural gravity approach, in which we account for unilateral origin- and destination-specific time-varying factors through the use of high-dimensional fixed effects, is that we are able to implicitly control for a wide assortment of confounding factors, such as countries' adoption of and compliance with the TRIPS Agreement. Our approach seeks to distinguish between the impacts on patent flows of mutual IPA membership (within-agreement effects) and those on patent flows from outside IPAs and on patenting from IPA partners to non-member nations (extra-agreement effects).

2. Background

In recent decades, PTAs have evolved greatly in subject matter and intent. Earlier agreements sought primarily to reduce tariffs and other formal barriers to trade, thereby increasing market access between member countries. Beginning in the 1990s they expanded in ambition and depth. The earliest major agreements with enhanced coverage were the North American Free Trade Agreement (NAFTA) and several bilateral accords between the European Free Trade Association (EFTA) and individual countries, such as Estonia, Latvia, and Mexico. This round of trade agreements included rules covering certain regulatory regimes, including IPRs. Not long after, the EU announced its "new trade policy," increasingly emphasizing regulatory systems, including enhanced standards for patents, copyrights, GIs, and other IPRs in its PTAs with countries in Eastern Europe, the Middle East, Latin America, Canada, and Japan.

NAFTA was among the first multi-country PTAs to set minimum standards for nearly every aspect of IPRs as they existed then. Regarding patents, the agreement established certain TRIPS-Plus rules, including confidentiality for pharmaceutical clinical trials data and extensions in patent length to compensate for administrative delays in granting protection. These provisions, and others, were the foundation on which other TRIPS-Plus patent standards were erected in subsequent PTAs. NAFTA also mandated a minimum copyright length, expanded the types of literary and artistic works (including software) that must be protected, and recognized various neighboring rights. It further required automatic recognition of internationally well-known trademarks, another TRIPS-Plus standard. Finally, the agreement set out minimum protection of geographical names through systems quite similar to those covering trademarks and collective marks. Trade agreements negotiated by the EU and EFTA in this era had similar requirements, though they emphasized somewhat different areas of concern, most prominently in establishing specific systems for recognizing and protecting GIs.

NAFTA was preceded by the formation of the European Economic Area (EEA) in 1994, linking three members of EFTA to the EU's single-market program. Over time, an essential component of policy making in the EEA has been the adoption of stronger and more harmonized intellectual property standards throughout the region.

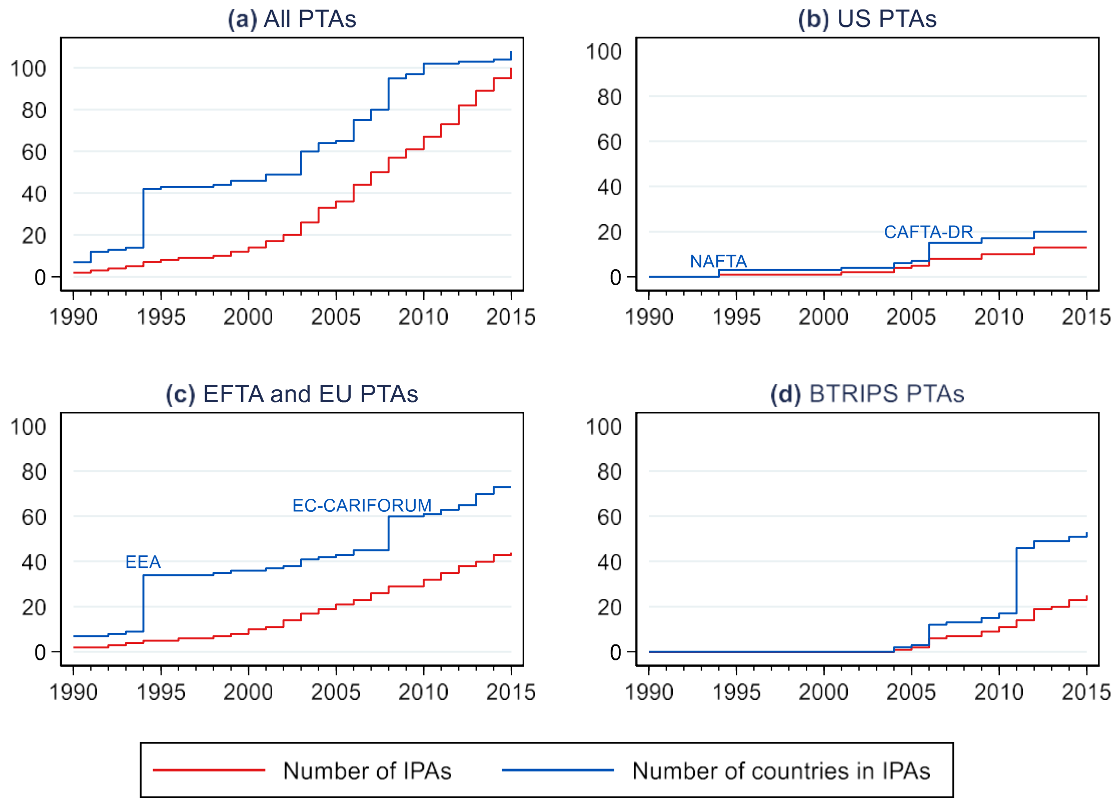
The subject matter coverage of PTAs sharply increased after 2000, with the United States and the EU demanding stronger and more comprehensive IPR provisions. Moreover, other new PTAs, not involving the United States or the EU, were negotiated by Japan, Australia, Korea, Mexico, and Chile, among others. These PTAs also included IPRs chapters, though typically with less rigorous standards in certain areas.

It is important to note that most of these IP-related PTAs are legally enforceable, as designated in the World Bank data. Specifically, the database ranks the legal enforceability (LE) of PTAs on a scale of 0, 1, or 2, with 0 essentially indicating that no enforcement language exists, 1 describing weak enforcement language (e.g., "should" or "may"), and 2 identifying those with clear commitment language (e.g., "shall" or "must"). We use this designation (LE = 2) as one means of selecting the treatment IPAs in the econometric analysis.

Figure 1 illustrates the considerable growth since 1990 in the number of IPAs in the World Bank data that feature strong enforceability.[2] The red lines indicate the number of agreements, and the blue lines show the number of countries in one or more of them.[3] As depicted in panel (a), the number of IPAs rose from fewer than 20 in 2000 to 100 in 2015, while the number of countries involved now exceeds 100. Thus, currently around two-thirds of WTO

[2] Appendix Table A1 gives the full list of IP-related PTAs and the year in which each agreement entered into force.
[3] An important related source of information is the DESTA database described in Dür et al. (2014). It defines IPAs as agreements with an IPRs chapter, regardless of how comprehensive or rigorous.

Figure 1: The Number of Legally Enforceable IP-Related Trade Agreements and Number of Countries with Membership in at least One such Agreement by Year, 1990–2015



contracting parties are members of at least one IPA, as defined here. Panel (b) shows more modest growth in IP-related PTAs involving the United States as a partner. The establishment of the CAFTA-DR agreement in 2005 raised the number of countries, currently around 20, in such agreements. Panel (c) demonstrates the faster growth in EU-related and EFTA-related IPAs, with discrete jumps in country coverage in 1994 with the EEA formation and in 2008 with the establishment of the EU- CARIFORUM agreement. Together, the EU and EFTA are party to more than 40 enforceable IPAs. Because of the high degree of policy requirements and harmonization within them, the EU and EFTA themselves are counted as IP-related trade agreements in our sample. Lastly, panel (d) indicates that there are 25 IPAs, involving around 53 countries, identified as possessing at least three core "TRIPS-Plus" provisions (described in more detail below), in that they are considerably more prescriptive than what is found in TRIPS (Maskus, 2012a), and which we collectively call BTRIPS (for "Beyond TRIPS") to avoid confusing the standard TRIPS-Plus terminology with the World Bank's "WTO-Plus" designation. Though agreements of this type only began to proliferate from around the mid-2000s onward, the number of PTAs possessing these standards continues to increase steadily. Notably (and as seen explicitly in Appendix Table A1), these BTRIPS agreements have increasingly been undertaken by countries besides the United States and EU/EFTA, such as Japan, Korea, and Australia, a fact that points to the increasing centrality of IPRs in these countries' policy emphases.

A second important point is that IPAs, while increasing the scope of protection over time, do not treat all forms of intellectual property equally. They also vary in depth because they incorporate different numbers of specific IPRs provisions and their enforceability. Countries entering PTAs may have different socioeconomic interests in intellectual property protection and related regulatory policies (Maskus, 2012a). For example, the United States attaches considerable importance to assuring copyright protection for its own nationals' rights held in foreign markets and negotiates its international agreements accordingly. The EU and EFTA do so also but prioritize strong systems of registering and enforcing GIs especially. GIs protect the rights to use place names in wines, spirits, and other consumer products, where production locality matters for the quality and character of such goods. Japan and Korea have focused on extending patent rights, while Australia traditionally has preferred weaker copyright rules. Developing countries often seek to sustain access to international technologies and information, perhaps through more limited patent standards or weaker trade secrets protection. Indeed, it may seem surprising that emerging and developing economies increasingly have agreed to strong IPRs chapters in PTAs. Here, we simply note that different countries seek to emphasize specific aspects of IPRs in negotiating and joining IPAs.

Rather than describe fully the many differences in strategies and provisions that can be found in the World Bank database, we summarize them in Table 1. The database identifies 130 detailed IPRs provisions, broken into 16 broad categories. These provisions are simply listed as either 0 (absent in the PTA) or 1 (present). In Panel A we list eight categories that seem relevant for studying potential impacts on both trade and innovation.[4] For example, there are 15 international treaties or conventions covering intellectual property that members of IPAs might

[4] The unlisted categories focus on procedural questions (such as transparency and cooperation mechanisms), do not strengthen existing IPRs (such as incorporation of existing IPRs treaties or recognition of the importance of biodiversity and traditional knowledge), or focus on non-trade issues.

be required to ratify. The United States often demands such rules in negotiating its IPAs, with the average agreement listing 11.5 conventions, compared to 3.3 for the EU/EFTA IPAs and 2 for the others. Clearly, IPAs involving the United States embed considerably more provisions within nearly all categories than do the others. This difference stands out particularly in trademarks, patents, test data protection, copyrights, and enforcement.

In Panel B we consider a subset of categories and, within those, list the number of provisions that are widely considered to be BTRIPS (i.e., TRIPS-Plus).[5] These provisions were selected because they feature prominently in international debates over elevated IPRs norms. By this somewhat ad hoc accounting, there are five BTRIPS provisions in patents, including such items as patents for new uses of known products, patent-term adjustments, and patent linkage. Similarly, there are five standards in test data protection, including confidentiality for trial data in pharmaceuticals and biologics. The largest group is in enforcement, reflecting the fact that TRIPS essentially committed countries to a best-efforts approach, while some recent IPAs require such policies as injunctive relief, destruction of infringing goods, criminal sanctions for willful infringement of intellectual property, and criminalization for misappropriating trade secrets.

This review shows that the United States is easily the top *demandeur* of these BTRIPS conditions, especially in data protection, copyrights, and enforcement. The EU/EFTA IPAs are considerably less prescriptive, though they are comparatively more focused on GIs and enforcement. The rules on GIs, patents, data protection, and copyrights are far less prevalent in the IPAs involving countries other than the United States and EU/EFTA, though there are exceptions as seen in the “max” column. The conclusion we draw is that, among the comparatively few IPAs featuring the United States as a partner, the adoption of BTRIPS standards is far more common than elsewhere.

[5] The list of these BTRIPS standards, broken into “core” standards and “broad” provisions, is given in Appendix Table A2.

Table 1: Summary of IPRs Provisions in Legally Enforceable IP-Related PTAs

Panel A: all IPR provisions as of 2015	**US LE IPAs (13)**			**EU/EFTA LE IPAs (45)**			**Other LE IPAs (42)**		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Accession/Ratification (n = 15)	11.5	2	14	3.3	0	13	2.0	0	13
National Treatment (n = 2)	2.0	2	2	0.9	0	2	0.6	0	2
Trademarks (n = 15)	9.4	4	15	1.6	0	7	1.5	0	11
Geographical Indications (n = 7)	2.6	0	4	2.0	0	7	0.7	0	3
Patents (n = 14)	4.8	1	13	1.0	0	3	0.7	0	10
Data Protection (n = 5)	2.8	0	5	0.9	0	2	0.1	0	5
Copyrights (n = 14)	10.5	4	14	2.0	0	12	1.9	0	12
Enforcement (n = 23)	17.2	4	20	7.6	0	17	4.8	0	17

Panel B: BTRIPS provisions as of 2015	**US LE IPAs (13)**			**EU/EFTA LE IPAs (45)**			**Other LE IPAs (42)**		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Trademarks (n = 4)	2.3	2	4	0.2	0	2	0.4	0	4
Geographical Indications (n = 3)	0.9	0	1	0.8	0	3	0.3	0	2
Patents (n = 5)	1.2	0	4	0.4	0	1	0.2	0	3
Data Protection (n = 5)	2.8	0	5	0.9	0	2	0.1	0	5
Copyrights (n = 6)	5.6	1	6	1.0	0	6	0.8	0	6
Enforcement (n = 10)	7.1	1	9	3.1	0	7	2.0	0	7

3. Patent Data

Our primary research objective is to estimate how the formation of IPAs affects bilateral flows of patent applications, from origin country to destination country across all potential patent-country pairs. In this context, we distinguish among the effects on within-IPA members, the impacts on patenting from member countries to nations outside IPAs, and the effects on flows from origin countries that do not join specific IPAs to countries within them. Our patent data come from the PATSTAT database organized by the European Patent Office (EPO). The database lists the origin nation, from which the patent is originally filed, and the destination nation, which is the patent authority in which registration is desired, as well as the filing date for each application. Because our interest lies in assessing where patents are filed, we include each destination listed in a patent family as a separate application. Similarly, for patents filed through the Patent Cooperation Treaty (PCT) or the EPO, both of which list countries in which protection may be sought during a grace period, we include only those that reached an ultimate national authority. Many applications list only a filing authority, which indicates that the origin is the same country, implying an application that does not cross an international border. Though our focus lies primarily on measuring international patenting effects, we include domestic applications in our empirical setting in order to account for within-country patenting as a reference category in the gravity-model analysis that follows.[6] Our analysis extends over the period 1995 to 2015, during which multiple IPAs were established. We cut off the end date in order to avoid truncation of patents in recent years, which exists due to lags in application filings. Our data covers patent applications originating from 187 origin countries that are ultimately filed in 82 different destination countries. The fact that there are fewer destination countries than origins in our data is a result of the set of patent offices covered in the PATSTAT data set.[7]

Figure 2 depicts changes in average patent shares and volumes in the years before and after the entry into force of three types of IPAs and another simple form of policy protection. Our definition of which trade agreements constitute IPAs is as follows. First, does an agreement include at least three of what we call "core TRIPS-Plus requirements," which are key elements of

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[6] In the trade-gravity context, the inclusion of intranational trade volumes has been shown to be an important consideration for recovering accurate estimates of trade-policy impacts (Yotov, 2022). For instance, Larch et al. (2018) find that the inclusion of intranational trade volumes in the empirical gravity setting leads to substantially different estimates on the impact of countries' accession to the Eurozone relative to specifications based solely on international trade flows.

[7] Details on extracting these data are explained in Appendix B.

IPRs protection that go beyond TRIPS standards? Second, is one of the parties the United States, the European Union, or the European Free Trade Association (EFTA), which demand high standards? Third, a weaker definition includes other PTAs that incorporate some IPRs provisions that the World Bank considers legally enforceable under WTO rules. Finally, for comparison purposes we include patent trends in PTAs that have at least one clause protecting ownership of investment assets, regardless of whether they are IPAs.

To organize the calculations, we consider each patent-destination country and whether it is a member of one or more IPAs. We then compute the number and shares of bilateral patent flows arriving from source countries that are in those IPAs (member to member flows) and those coming from nations that are not members of a particular IPA to the within-IPA members that are not in the High-Income designation.[8] In the calculation of the denominator of these shares, we omit domestic patent applications as part of total patents filed in the destination country. Akin to an event study setting, "time to agreement" indicates the number of years before or after the year in which a particular agreement enters into force.

All four agreement types, as indicated in the first and third rows of the charts, demonstrate that cross-border patenting among member nations ("member to member") rose prior to agreement implementation (year 0) and continued to rise sharply after, both in terms of volumes and shares.[9] This was true also, however, of PTAs with investment protection, suggesting the need to control for that factor. In contrast, patent flows from non-members to members who are not high-income countries, where IPAs typically require the largest policy changes, rose continuously in absolute terms but, except for a small rise immediately after IPA implementation, did not show any patterns in their shares of patenting originating from inside agreements.[10]

[8] As will be explained in the next section, the identification of impacts of IPAs on non-member to member flows, and the reverse flows, requires breaking down countries into high-income and non-high-income categories. For the purposes of Figure 2 we are interested in comparing internal patenting versus patenting from outside IPAs.
[9] The slight reductions in the numbers of patents filed in the last year of some of the charts is likely due to residual truncation of patents associated with lags in processing applications.
[10] Similar results occurred in comparisons of patent flows in the IP-intensive industry clusters (results not shown).

Figure 2. Trends in Cross-Border Patent Shares and Volumes, Pre- and Post-IPA Implementation

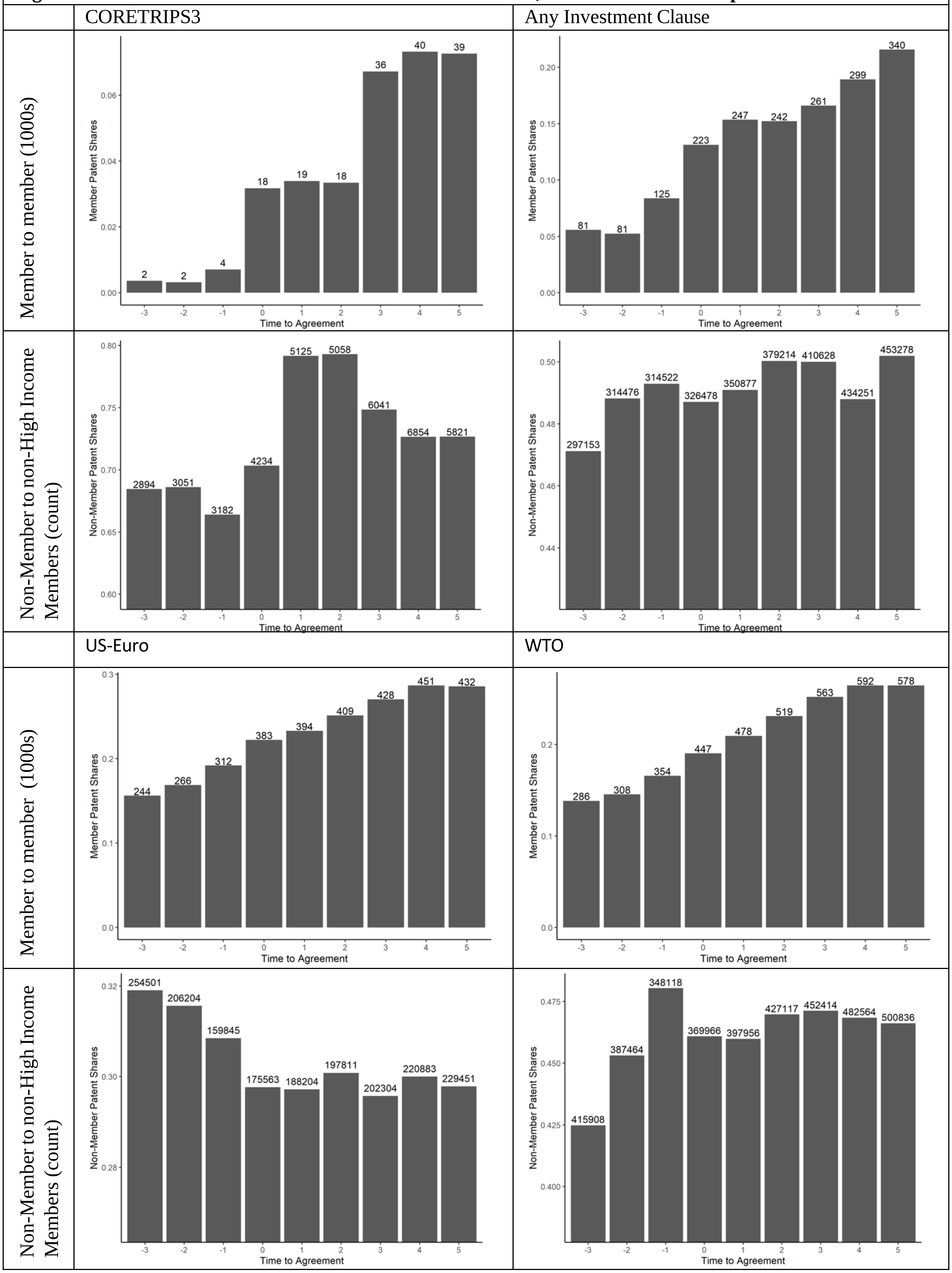

Table 2 presents summary statistics on total patent flows and patent flows for each high-IP cluster, using a concordance between the technology codes in the International Patent Classification (IPC) and sectors in the North American Industrial Classification System (NAICS) to map PATSTAT data to broader industry groupings.[11] The summary statistics are computed over both the full sample (including zero flows) and the sample with only positive flows. Note that because the patent-industry concordance consists of weights less than unity, some patent flows in the positive-only sample appear close to zero. This also explains patent flows that are less than one.

The figures in Table 2 show that the clusters with the smallest mean positive cross-border patent flows are biopharmaceuticals and medical devices. In contrast, the clusters with the largest average flows, as regards both zeros and non-zeros, are information and communication technology and "Other." Despite that, the cluster with the smallest number of positive international applications is the ICT category.

Table 3 lists summary statistics for total patent flows among members and among countries who are not members of IPA agreements, again for all flows including zeros and for positive observations. These figures are organized with a different logic for comparison purposes. The "between members" data demonstrate flows pre- and post-IPA implementation among all country pairs in which both are in the agreement. The "non-members" data depict flows between all country pairs that never sign an IPA with each other, before and after implementation of an agreement between the destination country and any third party or parties. The rationale for this comparison is that it allows us to discern whether this change in the destination's status correlates with changes in extra-agreement patent registrations. That is, does this evident change in destination *j's* IPRs regime influence applications from country *i* within that pair? The data indicate that, following the establishment of IPAs containing three or more core BTRIPS provisions, the average volume of patent applications between countries increases for member-to-member pairs and non-member-to-member pairs. This pattern holds also for PTAs classified in the World Bank's database as featuring any legally enforceable IPR provision. Notably, this relationship is reversed for IPAs in which the United States or EU/EFTA is a partner.

[11] The concordance is in Lybbert and Zolas (2014).

Table 2: Summary Statistics of International Patent Flows by High-IP Cluster

	Min.	Mean	Std. dev.	Max	Obs.
Total Patents					
Including Zeros	0.00	55.08	2,521.43	563,592.80	322,014
Positive Flows Only	0.01	349.08	6,339.55	563,592.80	50,810
Analytical Instruments (AI)					
Including Zeros	0.00	6.90	336.34	62,740.98	322,014
Positive Flows Only	< 0.01	65.13	1,031.84	62,740.98	34,094
Biopharmaceuticals (BIO)					
Including Zeros	0.00	0.19	6.67	1,914.34	322,014
Positive Flows Only	< 0.01	1.90	21.12	1,914.34	31,839
Chemicals (CHEM)					
Including Zeros	0.00	2.53	98.98	25,112.73	322,014
Positive Flows Only	< 0.01	22.20	292.66	25,112.73	36,643
Information and Communications Technology (ICT)					
Including Zeros	0.00	15.95	745.95	135,309.85	322,014
Positive Flows Only	< 0.01	161.79	2,370.51	135,309.85	31,754
Medical Devices (MED)					
Including Zeros	0.00	1.43	46.20	11,019.49	322,014
Positive Flows Only	< 0.01	13.85	143.06	11,019.49	33,304
Production Technology (PT)					
Including Zeros	0.00	4.98	257.73	67,061.03	322,014
Positive Flows Only	< 0.01	41.86	746.19	67,061.03	38,311
Other					
Including Zeros	0.00	13.47	592.92	114,855.77	322014
Positive Flows Only	< 0.01	91.97	1,547.02	114,855.77	47,161

Notes: Data reflects bilateral patent applications data for the years 1995–2015. Categories reflect groupings of NAICS industry that we define based on a US Department of Commerce classification of sectors with above-mean patenting intensity (patents per industry employee).

Table 3: Summary Statistics by IPA

	Min.	Mean	Std. dev.	Max	N
		Three or more BTRIPS provisions IPAs			
		Flows Between Members (Prior)			
Including Zeros	0.00	106.09	1,132.10	27,240.70	4,328
Positive Flows Only	0.03	368.81	2,088.31	27,240.70	1,245
		Flows Between Members (Post)			
Including Zeros	0.00	256.74	1,555.41	18,687.55	859
Positive Flows Only	0.02	586.54	2,311.14	18,687.55	376
		Flows Between Non-Members			
Including Zeros	0.00	43.03	2,398.93	563,592.79	274,936
Positive Flows Only	0.01	291.16	6,234.71	563,592.79	40,629
		Flows Between Non-Members after j joins			
Including Zeros	0.00	124.79	3,303.33	195,802.61	41,891
Positive Flows Only	0.01	610.69	7,287.61	195,802.61	8,560
		WTO-X IPR LE IPAs			
		Flows Between Members (Prior)			
Including Zeros	0.00	28.55	431.29	27,240.70	33,063
Positive Flows Only	0.01	104.73	821.24	27,240.70	9,013
		Flows Between Members (Post)			
Including Zeros	0.00	42.35	483.69	18,687.55	25,590
Positive Flows Only	0.02	111.30	779.29	18,687.55	9,736
		Flows Between Non-Members			
Including Zeros	0.00	40.09	2,206.00	233,245.36	115,453
Positive Flows Only	0.02	404.13	6,993.81	233,245.36	11,453
		Flows Between Non-Members after j joins			
Including Zeros	0.00	74.92	3,155.93	563,592.79	147,908
Positive Flows Only	0.01	537.68	8,440.28	563,592.79	20,608
		US/EU/EFTA			
		Flows Between Members (Prior)			
Including Zeros	0.00	32.24	494.01	27,240.70	30,985
Positive Flows Only	0.01	120.68	950.25	27,240.70	8,277
		Flows Between Members (Post)			
Including Zeros	0.00	23.47	212.09	9,134.89	24,203
Positive Flows Only	0.02	63.15	344.28	9,134.89	8,996
		Flows Between Non-Members			
Including Zeros	0.00	70.11	3,351.92	563,592.79	159,680
Positive Flows Only	0.01	540.72	9,295.50	563,592.79	20,703
		Flows Between Non-Members after j joins			
Including Zeros	0.00	46.43	1,510.42	113,832.38	107,146
Positive Flows Only	0.01	387.65	4,349.17	113,832.38	12,834

4. Econometric Approach and Results

To analyze the impacts of countries' IPA membership on international patenting activity, we implement a structural gravity model of bilateral flows of patent applications analogous to the widely used structural gravity of bilateral trade.[12] We specify an estimating equation given by

$$Patents_{ijt} = \exp[\beta_0 Intra_{ijt} + \beta_1 Extra1_{ijt} + \beta_2 Extra2_{ijt} + \beta_3 Extra3_{ijt} + \beta_4 ANYIPR_{ijt} + \beta_5 ANYINV_{ijt} + \gamma_{it} + \delta_{jt} + \eta_{ij} + \varepsilon_{ijt}] \quad (1)$$

where $Patents_{ijt}$ is the count of the total number of patent applications originating from source country i filed at the national patent office of destination country j in year t. $Intra_{ijt}$ is an indicator variable equaling one when both i and j share mutual membership in one of the three types of IPAs as defined above (legally enforceable IPAs, US, EU, and EFTA-associated IPAs, and BTRIPS/TRIPS-Plus agreements), and zero otherwise. Coefficient β_1, therefore, captures the average effect of accession to an IPA on within-agreement patenting between agreement member countries.

Following are three indicator variables identifying the membership status and income group of countries i and j. For the latter purpose we use the World Bank's designation of countries as either high-income (HI) or not high-income (NHI), where the latter group includes all countries in our sample designated low-income (LI), lower-middle-income (LMI) or upper-middle-income (UMI).[13] Specifically, $Extra1_{ijt}$ takes the value of one when both countries are HI nations but only one of them is a member of an IPA, and zero otherwise. Next, $Extra2_{ijt}$ captures cases where the destination is NHI and part of an IPA but the source country is outside the IPA but can be any income level. Finally, $Extra3_{ijt}$ refers to observations in which the origin is a NHI country inside and IPA but the origin is any country outside the IPA. Thus, β_1

[12] The gravity model has been widely employed to analyze many types of bilateral flows, including trade, investment, migration, and knowledge and innovation, among others. Recently, a small but growing literature has adapted the gravity equation to assess various determinants of bilateral patenting. See, for example, Picci (2010), Scherngell and Hu (2011) on bilateral patenting in international and intranational settings, or Montobbio and Sterzi (2013) for related work on a gravity model of international patent collaborations. Most closely related to our analysis is that of Coleman (2022), who conceptualizes a theoretical basis for a gravity equation of international patenting for the purpose of measuring the impacts on patenting of countries' accession to international IP conventions, such as the Patent Cooperation Treaty (PCT) or the WTO TRIPS Agreement.

[13] For purposes of identification in the gravity model, it is necessary to include this income-based breakdown to estimate impacts on both directional flows with non-members. See Beverelli et al. (2018) for discussion of this point in the trade-gravity context. We also estimate our specifications accounting for heterogeneity in countries' R&D intensity (national rates of R&D spending over GDP) to divide countries into high-R&D and non-high-R&D categories. This approach yielded no qualitative differences from the baseline results. Because the R&D data are less complete than data for our other variables, we report the results only for the income-based regressions.

reflects the change in bilateral patenting flows between high-income members of one of the different IPA types and non-member HI countries. Coefficient β_2 reflects changes in bilateral filings originating from non-member countries and registered in NHI members of the various IPA types. Coefficient β_3 has an analogous interpretation.

We also include two controls for other bilateral policy variables that may affect patenting. First, $ANYIPR_{ijt}$ is an indicator variable equal to one if countries i and j are in an agreement that has at least one active provision regarding intellectual property rights that the World Bank does not describe as legally enforceable, and zero otherwise. This variable should control for the possibility that it is the existence of an IPA itself, rather than its legal strength, that could influence cross-border patenting. Second, $ANYINV_{ijt}$ is a dummy variable capturing whether country pairs share a bilateral investment treaty (BIT) or some other form of international investment agreement (IIA). The rules in such agreements often explicitly include IPRs as protectable investments and they may implicitly encourage patenting through their impacts on foreign direct investment (Maskus, 2012b).

The other components of equation (1) include the fixed effects γ_{it}, δ_{jt} and η_{ij}, which, respectively, control for origin-year, destination-year, and bilateral-pair-specific factors. The first two terms account for all time-varying (as well as time-invariant) features of origin and destination countries. These features include, for example, attributes such as countries' innovative and R&D capacity, as well as compliance with relevant non-discriminatory policies and international treaties such as the TRIPS agreement or the PCT. These effects also account for the origin and destination size terms that characterize the structural gravity equation (corresponding in trade-based gravity to the levels of the origin country's output and the destination country's expenditures). Perhaps most importantly, these elements fully account for the outward and inward multilateral resistance terms described in Anderson and van Wincoop (2003). Controlling for these terms is important for obtaining accurate estimates of policy impacts on patent flows. The country-pair effects η_{ij} are also important because they capture the role of all long-run bilateral factors that influence the volume of patenting between pairs of countries. Such factors encompass traditional impediments such as geographical distance or linguistic and cultural similarities, as well as all other time-invariant, pair-specific frictions in bilateral patenting flows (Egger and Nigai, 2015). This term also helps mitigate potential endogeneity in the implementation of bilateral trade and regulatory policy (Trefler, 1993; Baier and Bergstrand, 2007).

Finally, ε_{ijt} is a mean-zero error term, which in our estimation we calculate with two-way clustering within origin and destination countries, respectively, in order to flexibly account for correlation in the error terms along these dimensions. In line with what has become standard practice in gravity estimation, we estimate equation (1) using the Poisson pseudo-maximum likelihood (PPML) estimator following Santos Silva and Tenreyro (2006, 2011). PPML has the dual advantages relative to log-linearized gravity models of allowing for the inclusion of zero flows and yielding unbiased estimates in the presence of heteroskedasticity.

While equation (1) captures the impacts of IPA membership on total bilateral patent applications, the nature of many of the IPRs provisions of IPAs—for example, test data confidentiality provisions relating to pharmaceutical inventions—is often highly sector-specific. In addition, there are conceivably significant differences in the sensitivity of different broad categories of innovation to the changes in IPRs standards implemented under the provisions of IPAs. We therefore extend equation (1) to accommodate sector-level heterogeneity in the effects of IPA membership by incorporating interaction effects with the Intra and Extra IPA policy variables:

$$Patents_{ijst} = exp[\textstyle\sum_s(\beta_0^s Sector_s \times Intra_{ijt} + \sum_{k=1}^{3}[\beta_k^s Sector_s \times Extra_{ijt}^k] + \beta_4^s ANYIPR_{ijt} + \beta_5^s ANYINV_{ijt}) + \gamma_{ist} + \delta_{jst} + \eta_{ijs} + \varepsilon_{ijst}] \quad (2)$$

Here, *Sector*$_s$ represents a comprehensive set of indicator variables equal to one for observations corresponding to patent applications in one of the seven high-IP sectoral clusters defined previously, as well as a "low-IP" sector reflecting comparatively non-patent-intensive activities.[14] Again, these high-IP sectors include analytical instruments (AI), biopharmaceuticals (BIO), chemicals (CHEM), information and communications technology (ICT), medical devices (MED), production technology (PT), and a residual category (Other) reflecting IP-sensitive industries not belonging to any of the above groupings. We also interact these sectoral indicator variables with the three *Extra* dummies capturing forms of patent flows into and out of IPAs. For each sectoral cluster we also control for any active IPA not considered legally enforceable by the World Bank, or any active investment agreement between countries *i* and *j*. Because regression

[14] See Appendix Table B2 for the list of industries comprising the low-IP cluster.

equation (2) reflects patent flows at the sector level, we also extend our specification to incorporate origin-year-sector, destination-year-sector, and country-pair-sector fixed effects (γ_{ist}, δ_{jst}, and η_{ijs}, respectively).

Again, we estimate equations (1) and (2) for different definitions of IPAs. It seems likely that, to have distinctive impacts on international patenting, IPAs should be particularly strong in their expectations and enforceability. Thus, we entertain three designations of potentially impactful IPAs. First are those agreements with IPRs norms that the World Bank considers to be legally enforceable, which we label WTO LE2 in the tables below. Second are those in which the United States or EU/EFTA are partners, labeled EU/US/EFTA, reflecting the strong provisions those partners seek in negotiating them. Third are those containing at least three of the core TRIPS-Plus provisions listed in Appendix Table A2. We label these CORETRIPS3.

4a. Total Bilateral Patents

Table 4 presents the regression results for equation (1), involving total patent flows between source and destination nations. The columns report regressions with different assignments of countries into HI and NHI. In the first column this split is based on annual World Bank designations of each country through the sample. We also are concerned that variation in income status, rather than IPA membership, might be driving some of our results in the first column. To address this concern, we estimate equation (1) using two additional income-group definitions that are consistent across the sample. In the second and third columns it is based, respectively, on the earliest and latest years in the sample in which a country receives a World Bank designation.[15] This breakdown yields highly similar results across columns in each panel.

In the regressions a distinctive pattern emerges. The first two IPA types have insignificant coefficients on bilateral application flows between agreement members. However, joint membership in a CORETRIPS3 agreement significantly expands bilateral patenting, with an estimated impact of around 26.7%.[16] Thus, the broader set of IPAs focused on core TRIPS-Plus requirements strongly encourage more intra-agreement patenting. This suggests that such

[15] In some years World Bank designations are missing for some countries. Most commonly, some countries do not have income classifications recorded in 1995 or 2015.

[16] The coefficient estimates on the policy indicator variables can be interpreted in percentage change terms based on the calculation ($\exp(\beta) - 1) \times 100\%$.

elevated and enforceable standards adopted in IPAs attract technology transfer through within-agreement patent flows.

Next, both the WTO LE2 and US/EU/EFTA IPAs strongly and positively increase applications between HI members and HI non-members (*Extra1)*. Where the member in the pair belongs to a WTO LE2 agreement the coefficients imply an increase in such flows ranging from 12.2% to 13.0%. This estimate is consistently 14.7% where the member is in a US/EU/EFTA IPA. In contrast, this form of external flow is not affected by membership in CORETRIPS3 agreements. However, both the US/EU/EFTA and CORETRIPS3 accords strongly raise patent flows from outside to NHI countries inside (*Extra2)*, with estimates ranging between 25.1% and 43.0% in the first type and between 28.7% and 42.8% in the second type. Perhaps surprisingly, the model estimates negative impacts on patent filings from NHI members to non-members in these two IP types. These findings suggest that NHI countries within IPAs become more attractive locations to patent, while inventors in such nations may focus their applications more on destinations within the agreements.

Finally, the regressions generate the interesting finding that other policies matter for patent flows regarding IPAs. For example, in both Panel A and Panel B there are significantly positive coefficients on the variable capturing whether country pairs share some kind of bilateral investment agreement. Thus, regardless of whether countries share membership in an IPA their bilateral patenting is positively related with investment protection rules, a finding that deserves further study. Furthermore, in both US/EU/EFTA and CORETRIPS3 IPAs the existence of at least one non-enforceable IPR provision also encourages bilateral patenting.

4b. High-IP Clusters

The results from estimating equation (2) for the three IPA definitions are in Tables 5A through 5C, corresponding to the three IPA definitions. Each table presents results from a single regression, with the various cluster-specific effects of the IPA policy variables depicted in the columns. Similar patterns emerge for the IP-sensitive clusters as for total applications. Specifically, the WTO-enforceable agreements (Table 5A) and those with US or European partners (Table 5B) show relatively little effect on within-IPA patent flows. Next, we again find significantly positive coefficients on the indicator for within-agreement bilateral membership in CORETRIPS3 IPAs (Table 5C). This finding holds for BIO, CHEM, ICT, and MED, which are all areas in which TRIPS-Plus provisions in the patent realm are particularly relevant. Notably, it holds as well for the low-IP and Other high-IP groups, suggesting there are broad-based effects of these assertive IPAs on cross-border patent applications among member nations.

Similar variations also arise regarding patent flows into or out of IPAs. For example, there are significantly positive impacts in the first two IPA types on $Extra1$ patent filings between HI members and HI non-members in certain sectors, including BIO, CHEM, MED, and ICT. There is also a positive and significant coefficient in the low-IP group in Table 5A, suggesting that even in these products membership in IPAs may encourage foreign filings outside the agreement. CORETRIPS3 agreements display little influence in this context, except in ICT.

Next, all three IPA types encourage more $Extra2$ patent applications from outside nations to NHI countries inside the agreement. This holds in BIO, CHEM, and MED in both the WTO LE2 and US/EU/EFTA agreements. The effect is seen most acutely in the CORETRIPS3 cases, where the coefficients are significantly positive across the board and highest in the BIO, CHEM, MED, ICT, and Other sectors. The coefficients suggest increases in external-to-internal patent flows ranging between 29.6% in analytical instruments and 72.5% in medical devices. This result is a striking indication that these TRIPS-Plus IPAs markedly raise the attractiveness of emerging and developing countries joining them as locations for patent applications and the associated technology transfer.

In contrast, there is evidence in both Tables 5B and 5C of negative impacts on $Extra3$ patents from NHI members to countries outside these IPAs. While this result requires further investigation, the initial suggestion again is that IPAs may shift the attention of inventive firms in such countries toward patenting in partner counties, including domestically.

Table 4: Impacts of IPAs on Bilateral Patent Filings

Income Used for HI vs NHI:	Varies by Year	Earliest	Latest
Panel A: WTO LE2			
Intra (member to member)	-0.229	-0.244	-0.241
	(0.182)	(0.187)	(0.187)
Extra1 (between HI member and	0.122**	0.116**	0.115**
HI non-member)	(0.051)	(0.052)	(0.051)
Extra2 (NHI destination in IPA from all	0.188*	0.145	0.191
non-member sources)	(0.104)	(0.147)	(0.176)
Extra3 (NHI source in IPA to all non-	0.024	0.180	0.210
member destinations)	(0.176)	(0.294)	(0.348)
Any IPR provision not meeting WTO LE2	0.012	0.004	0.007
	(0.061)	(0.060)	(0.060)
Any bilateral investment agreement	0.513***	0.523***	0.520***
(BIT or other IIA)	(0.167)	(0.171)	(0.171)
Panel B: US/EU/EFTA			
Intra (member to member)	-0.014	-0.014	-0.010
	(0.128)	(0.130)	(0.128)
Extra1 (between HI member and	0.137*	0.137*	0.137*
HI non-member)	(0.070)	(0.074)	(0.070)
Extra2 (NHI destination in IPA from all	0.224***	0.235**	0.358***
non-member sources)	(0.065)	(0.104)	(0.122)
Extra3 (NHI source in IPA to all non-	-0.364**	-0.252	-0.630**
member destinations)	(0.159)	(0.340)	(0.310)
Any IPR provision not meeting WTO LE2	0.187*	0.187*	0.191*
	(0.101)	(0.103)	(0.101)
Any bilateral investment agreement	0.228**	0.228**	0.229**
(BIT or other IIA)	(0.090)	(0.091)	(0.089)
Panel C: CORETRIPS3			
Intra (member to member)	0.235***	0.238***	0.237***
	(0.076)	(0.074)	(0.074)
Extra1 (between HI member and	0.072	0.071	0.072
HI non-member)	(0.098)	(0.098)	(0.098)
Extra2 (NHI destination in IPA from all	0.252**	0.346***	0.332***
non-member sources)	(0.123)	(0.115)	(0.121)
Extra3 (NHI source in IPA to all non-	-0.371*	-0.290	-0.575**
member destinations)	(0.198)	(0.194)	(0.224)
Any IPR provision not meeting WTO LE2	0.319**	0.319**	0.319**
	(0.157)	(0.156)	(0.157)
Any bilateral investment agreement	0.053	0.051	0.053
(BIT or other IIA)	(0.053)	(0.053)	(0.053)
Observations	104,081	104,081	104,081
Origin-year FEs	Y	Y	Y
Dest-year FEs	Y	Y	Y
Pair FEs	Y	Y	Y
Pseudo R2	0.997	0.997	0.997

Notes: Country incomes are based on World Bank income group classifications. Column 1 groups countries by their annual classification. Column 2 groups countries by their earliest observed income classification within our sample and Column 3 groups them by their latest observed income classification. Two-way clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Finally, it is notable that the regressions involving WTO LE2 and US/EU/EFTA IPAs feature significantly positive coefficients for the variable indicating that country pairs have a bilateral investment agreement of some kind, for virtually all industry clusters. Clearly, investment protection matters, even within the context of these agreements. However, that significance disappears in Table 5C for CORETRIPS3 IPAs. This outcome suggests that the strongly protective IPRs rules in such agreements somehow substitute for bilateral investment protection, an intriguing finding deserving further study.

Overall, the finding that various IPA types have qualitatively different impacts on intra-agreement patenting versus applications from and to locations outside the agreement is novel. It deserves further scrutiny to demonstrate its robustness and to shed light on the sources of this difference. Pending such investment, we simply speculate here on what may drive the results. Considering the list of agreements in our three IPA definitions, which are listed in detail in Appendix Table A1, we find that the 23 CORETRIPS3 agreements are a subset of the union of the 52 US/EU/EFTA agreements and the 41 other WTO-enforceable agreements. However, the CORETRIPS3 IPAs encompass most of the US IPAs, relatively few of the EU/EFTA accords, and only three others, including agreements between Japan-Malaysia, Japan-Korea, and Korea-Australia.

In this context, there are, as suggested earlier, qualitative differences between the US-brokered and EU/EFTA-brokered IPAs. At least since 2004 the United States has routinely incorporated multiple TRIPS-Plus provisions in its trade agreements. The primary exception is the US-CAFTA-Dominican Republic pact. That is a multilateral accord with a significant number of small developing countries having relatively little innovative capacity and receiving few patent applications from abroad. Many of the other US-partnered agreements are with developed countries or emerging nations with significant production and trade capacity. For its part, the EU/EFTA agreements that are not in the CORETRIPS3 category largely encompass relatively shallow bilateral accords with developing economies, particularly in Eastern and Central Europe. Finally, the other WTO-enforceable agreements tend to involve relatively large trading partners, often in the Asia-Pacific region, while the three in CORETRIPS3 include highly innovative emerging and developed countries.

In this light, it is reasonable to characterize the EU/EFTA accords, as well as the other WTO-enforceable pacts that do not qualify as CORETRIPS3 agreements, as relatively shallow deals that often involve large economic areas with emerging and developed countries. Our results suggest that such arrangements are likely to encourage more patenting activity from outside economies relative to within-agreement members, because they signal a commitment to stronger IPR protection without a deep commitment to the elevated TRIPS-Plus norms. Put differently, those agreements signal a commitment to transparent and enforceable rights that may be amenable to innovation and technology transfer from non-member nations. The CORETRIPS3 agreements, however, largely led by the United States, go beyond that signal to an indication of even stronger protection, favoring applications from innovative member nations, such as the United States, Korea, and Japan. They also stimulate more patenting from outside the region in NHI members, who must adopt these stronger provisions. Further, this elevated protection is particularly important for the highly patent-sensitive firms in our high-IP clusters, explaining the strong growth of patent flows in them both within the agreements and from non- members. Overall, our findings suggest that IPAs have distinctive but intuitively plausible impacts on cross-border patent applications, which may embody significantly more technology transfer, particularly to emerging and developing members.

Table 5A. Impacts of IPAs on Bilateral Patent Filings by Industry Cluster: WTO LE2 IPAs

VARIABLES	(1) Low-IP	(2) AI	(3) BIO	(4) CHEM	(5) ICT	(6) MED	(7) PT	(8) Other
Intra (member to member)	-0.142	-0.475***	-0.141	-0.003	-0.095	-0.001	-0.316	-0.260
	(0.182)	(0.168)	(0.140)	(0.148)	(0.162)	(0.200)	(0.208)	(0.188)
Extra1(between HI member and	0.159**	0.005	0.100*	0.133**	0.223***	0.163***	0.044	0.047
HI non-member)	(0.081)	(0.061)	(0.052)	(0.059)	(0.068)	(0.058)	(0.061)	(0.050)
Extra2(NHI destination in IPA from	0.097	-0.198	0.210**	0.191*	0.229	0.298**	-0.069	0.035
all non-members)	(0.123)	(0.212)	(0.096)	(0.113)	(0.174)	(0.133)	(0.195)	(0.137)
Extra3(NHI source in IPA to	-0.117	0.532	0.006	-0.122	0.549*	0.013	0.112	0.108
all non-members)	(0.322)	(0.371)	(0.317)	(0.272)	(0.295)	(0.357)	(0.463)	(0.311)
Any IPR provision not meeting	0.024	-0.078	-0.060	-0.013	0.084	0.041	0.014	0.068
WTO LE 2	(0.092)	(0.146)	(0.063)	(0.077)	(0.088)	(0.081)	(0.115)	(0.089)
Any bilateral investment agreement	0.412***	0.681***	0.339***	0.206	0.521***	0.416**	0.505***	0.491***
	(0.160)	(0.182)	(0.125)	(0.134)	(0.152)	(0.180)	(0.193)	(0.170)
Observations	664,665	664,665	664,665	664,665	664,665	664,665	664,665	664,665
Origin-sector-year FEs	Y	Y	Y	Y	Y	Y	Y	Y
Dest-sector-year FEs	Y	Y	Y	Y	Y	Y	Y	Y
Pair-sector FEs	Y	Y	Y	Y	Y	Y	Y	Y
Pseudo R2	0.994	0.994	0.994	0.994	0.994	0.994	0.994	0.994

Notes: see Table 4.

Table 5B. Impacts of IPAs on Bilateral Patenting by Industry Cluster: US/EU/EFTA IPAs

VARIABLES	(1) Low-IP	(2) AI	(3) BIO	(4) CHEM	(5) ICT	(6) MED	(7) PT	(8) Other
Intra (member to member)	-0.087	-0.178	0.014	0.068	0.138	0.090	-0.055	-0.115
	(0.155)	(0.132)	(0.136)	(0.160)	(0.143)	(0.161)	(0.187)	(0.149)
Extra1(between HI member and	0.074	0.060	0.144**	0.139	0.339***	0.160**	0.046	0.046
HI non-member)	(0.084)	(0.070)	(0.072)	(0.099)	(0.103)	(0.074)	(0.064)	(0.063)
Extra2(NHI destination in IPA from	0.118	-0.011	0.321***	0.211	0.363	0.340***	-0.042	0.087
all non-members)	(0.116)	(0.200)	(0.108)	(0.132)	(0.306)	(0.124)	(0.169)	(0.115)
Extra3(NHI source in IPA to	-0.261	0.200	-0.275	-0.583**	0.260	-0.423*	-0.312	-0.303
all non-members)	(0.334)	(0.413)	(0.238)	(0.291)	(0.494)	(0.244)	(0.516)	(0.362)
Any IPR provision not meeting	0.147**	0.119	0.033	0.044	0.193	0.127	0.229*	0.193*
WTO LE2	(0.071)	(0.190)	(0.060)	(0.059)	(0.135)	(0.086)	(0.123)	(0.101)
Any bilateral investment agreement	0.237**	0.285***	0.180**	0.109	0.216***	0.289***	0.209*	0.274***
	(0.102)	(0.098)	(0.090)	(0.105)	(0.078)	(0.092)	(0.126)	(0.102)
Observations	664,665	664,665	664,665	664,665	664,665	664,665	664,665	664,665
Origin-sector-year FEs	Y	Y	Y	Y	Y	Y	Y	Y
Dest-sector-year FEs	Y	Y	Y	Y	Y	Y	Y	Y
Pair-sector FEs	Y	Y	Y	Y	Y	Y	Y	Y
Pseudo R2	0.994	0.994	0.994	0.994	0.994	0.994	0.994	0.994

Notes: see Table 4.

Table 5C. Impacts of IPAs on Bilateral Patenting by Industry Cluster: CORETRIPS3 IPAs

VARIABLES	(1) Low-IP	(2) AI	(3) BIO	(4) CHEM	(5) ICT	(6) MED	(7) PT	(8) Other
Intra (member to member)	0.187***	0.254	0.315***	0.269***	0.438***	0.388***	0.095	0.262***
	(0.060)	(0.157)	(0.077)	(0.082)	(0.162)	(0.114)	(0.099)	(0.074)
Extra1(between HI member and	0.092	0.020	0.152	0.116	0.204**	0.120	-0.021	0.021
HI non-member)	(0.116)	(0.086)	(0.095)	(0.081)	(0.087)	(0.127)	(0.119)	(0.096)
Extra2(NHI destination in IPA from	0.266**	0.259**	0.382***	0.322**	0.489***	0.545***	0.301*	0.420***
all non-members)	(0.122)	(0.124)	(0.125)	(0.145)	(0.121)	(0.148)	(0.175)	(0.140)
Extra3 (NHI source in IPA to	-0.305	-0.266	-0.402*	-0.427	-0.445	-0.852***	-0.399	-0.548*
all non-members)	(0.297)	(0.290)	(0.222)	(0.403)	(0.344)	(0.229)	(0.444)	(0.286)
Any IPR provision not meeting	0.275**	0.309	0.128	0.097	0.361**	0.192	0.313*	0.330**
WTO LE2	(0.136)	(0.198)	(0.096)	(0.098)	(0.170)	(0.148)	(0.162)	(0.161)
Any bilateral investment agreement	0.065	0.034	-0.042	-0.024	-0.003	0.052	0.098	0.032
	(0.058)	(0.119)	(0.052)	(0.063)	(0.118)	(0.062)	(0.072)	(0.055)
Observations	664,665	664,665	664,665	664,665	664,665	664,665	664,665	664,665
Origin-sector-year FEs	Y	Y	Y	Y	Y	Y	Y	Y
Dest-sector-year FEs	Y	Y	Y	Y	Y	Y	Y	Y
Pair-sector FEs	Y	Y	Y	Y	Y	Y	Y	Y
Pseudo R2	0.994	0.994	0.994	0.994	0.994	0.994	0.994	0.994

Notes: see Table 4.

5. Concluding Remarks

The contents of PTAs continue to expand in both scope and depth, increasing the number of trade agreements that devote significant coverage to a wide assortment of regulatory environments extending beyond traditional trade policy and market access considerations. Intellectual property rights in particular have become an area of growing focus in this context, as the ever-increasing importance of the global knowledge economy has sharpened the incentives for policy makers and PTA negotiators to implement more rigorous and consistent systems of IPRs protections across countries. While a nascent literature exists exploring the effects of these developments on IPA member countries' trade in goods, it is striking that little work to date has investigated whether such PTAs impact the dissemination of intellectual property between and beyond agreement member countries.

To explore this question, we empirically assess the role played by the proliferation of PTAs possessing substantive and legally binding language on IPRs, as defined by the World Bank's database on the content of deep trade agreements and which we denote as IPAs, in shaping international flows of innovation as measured by cross-border patenting. To this end, we quantify the impacts of countries' accession to IPAs in a structural gravity setting analogous to the widely used structural gravity model of trade. We employ detailed information on bilateral international patent applications at national patent offices, a data set which covers hundreds of countries over our sample period of 1995–2015. We further consider heterogeneity in the impacts of IPA accession as originating from the attributes of the agreements, delineating between "treatment" definitions that alternatively define IPAs as those possessing legally enforceable provisions on IPRs (WTO LE2 agreements), IPRs-related PTAs negotiated by the United States or EU/EFTA, and finally, IPAs possessing three or more TRIPS-Plus IPRs provisions (CORETRIPS3 agreements).

Our baseline analysis yields evidence that IPAs encourage heightened levels of total bilateral patent flows to member countries, as well as consistent increases in patent applications when broken down across a number of IPRs-intensive, high-technology industry clusters. However, the exact interpretation of this finding hinges on the nature of the IPA under consideration. For WTO LE2 agreements and US/EU/EFTA-negotiated agreements, these impacts manifest as increased patenting volumes to IPA-member countries originating from non-IPA-member countries, with no apparent rise in within-agreement patent flows. In striking contrast, our findings on the impact of membership in IPAs possessing three or more core TRIPS-Plus provisions show that patent flows between members of such agreements are significantly higher, as are inward patent flows from outside the agreements to NHI (emerging and developing) members. While we attribute this disparity in our results to the nature of the agreements comprising the different categories of IPAs, the notable differences in these impacts are a finding that merits further investigation.

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Appendix A.

Table A1. IPAs in Primary Treatment Groups

	Entered into force		Entered into force		Entered into force
US Agreements		**EU/EFTA Agreements (cont.)**		**Other WTO-X IPR LE Agreements (cont.)**	
US-Jordan	2001	EFTA-Colombia	2011	China-Costa Rica	2011
US-Chile	2004	EFTA-Peru	2011	Panama-Peru	2012
US-Singapore	2004	EU-Korea, Rep.	2011	Japan-Peru	2012
US-Australia	2005	EFTA-Ukraine	2012	Mexico-Central America	2012
US-Bahrain	2006	EFTA-Montenegro	2012	New Zealand-Chinese Taipei	2013
US-Morocco	2006	EFTA-Hong Kong SAR, China	2012	Korea, Rep.-Türkiye	2013
US-CAFTA-Dominican Republic	2006	EU-Central America	2013	Costa Rica-Peru	2013
US-Peru	2009	EU-Colombia and Peru	2013	Malaysia-Australia	2013
US-Oman	2009	EU Enlargement (28)	2013	Korea, Rep.-Australia	2014
US-Panama	2012	EU-Republic of Moldova	2014	Iceland-China	2014
US-Korea, Rep.	2012	EU-Georgia	2014	Switzerland-China	2014
US-Colombia	2012	EFTA-Central America	2014	Eurasian Economic Union (EAEU)	2015
		EFTA-Bosnia and Herzegovina	2015	EAEU-Accession of Kyrgyz Republic	2015
EU/EFTA Agreements				EAEU-Accession of Armenia	2015
EU-Türkiye	1996	**Other WTO-X IPR LE Agreements**		Canada-Korea, Rep.	2015
EU-Tunisia	1998	Colombia-Mexico	1995		
EFTA-Morocco	1999	Chile-Mexico	1999	**BTRIPS Agreements**	
EU-Israel	2000	Ukraine-North Macedonia	2001	US-Chile	2004
EU-Morocco	2000	China-Macao SAR, China	2003	US-Australia	2005
EU-North Macedonia	2001	Australia-Singapore	2003	Japan-Malaysia	2006
EFTA-North Macedonia	2002	Gulf Cooperation Council	2003	US-Bahrain	2006
EU-Jordan	2002	Mexico-Uruguay	2004	US-Morocco	2006
EFTA-Jordan	2002	Panama-Chinese Taipei	2004	EFTA-Korea, Rep.	2006
EFTA-Singapore	2003	Chile-Korea, Rep.	2004	Japan-Thailand	2007
EU-Lebanon	2003	Korea, Rep.-Singapore	2006	US-Peru	2009
EU-Chile	2003	Russian Federation-Serbia	2006	US-Oman	2009
EU Enlargement (25)	2004	Japan-Malaysia	2006	EFTA-Albania	2010
EU-Egypt, Arab Rep.	2004	China-Pakistan	2007	EFTA-Serbia	2010
EU-Algeria	2005	CEFTA	2007	EFTA-Peru	2011
EFTA-Tunisia	2005	Japan-Thailand	2007	EFTA-Colombia	2011
EFTA-Korea, Rep.	2006	Japan-Philippines	2008	EU-Korea, Rep.	2011
EU-Albania	2006	Pakistan-Malaysia	2008	US-Panama	2012
EU Enlargement (27)	2007	China-New Zealand	2008	US-Colombia	2012
EFTA-Lebanon	2007	Nicaragua-Chinese Taipei	2008	EFTA-Montenegro	2012
EFTA-Egypt, Arab Rep.	2007	Japan-Switzerland	2009	EFTA-Ukraine	2012
EU-Montenegro	2008	Japan-Vietnam	2009	US-Korea, Rep.	2012
EU-CARIFORUM	2008	New Zealand-Malaysia	2010	EU-Colombia and Peru	2013
EU-Bosnia Herzegovina	2008	ASEAN-Australia-New Zealand	2010	Korea, Rep.-Australia	2014
EFTA-Serbia	2010	ASEAN-Korea, Rep.	2010	EFTA-Central America	2014
EFTA-Albania	2010	Türkiye-Chile	2011	EU-Georgia	2014
EU-Serbia	2010	Peru-Korea, Rep.	2011		

Table A2. List of TRIPS-Plus ("BTRIPS") Provisions in the World Bank Database

Core BTRIPS (18):	
59	Stipulates the scope of protection for a GI
66	Requires patent be made available for new uses of a known product
67	Requires patent be made available for new methods of a known product
68	Requires patent be made available for new processes of a known product
75	Requires patent term adjustment be given for unreasonable delays by granting authority
77	Includes rules governing patent linkage
80	Provides minimum term of protection for undisclosed test or other data for a new agricultural chemical
81	Provides minimum term of protection for undisclosed test or other data for a new pharmaceutical product
83	Provides minimum term of protection for undisclosed test or other data for a pharmaceutical product containing a chemical entity not previously approved by either party
84	Provides minimum term of protection for undisclosed test or other data for a new pharmaceutical product that is or contains a biologic
101	Requires protection against persons seeking to circumvent technological protection measures
102	Requires protection against persons altering rights management information
103	Requires protection against persons who distribute, import, make available product with altered rights management info
112	Stipulates that judicial authorities shall have authority to order injunctive relief
124	Requires parties to provide for criminal procedures & penalties for willful TM counterfeiting on a commercial scale
125	Requires parties to provide for criminal procedures & penalties for willful copyright or related rights piracy on a commercial scale
126	Requires parties to provide for criminal procedures & penalties for unauthorized disclosure/misappropriation of a trade secret
127	Requires parties to make it a criminal offense to unlawfully decode an encrypted program-carrying satellite signal
Other BTRIPS (14):	
25	Requires national exhaustion
39	Provide TMs to include collective and certification marks
40	Requires that TM owner be given exclusive right to prevent 3rd party from using identical or similar signs resulting in likelihood of confusion
43	Prohibits enacting a requirement that a TM must be recognized or registered as a well-known mark elsewhere to be considered "well-known"
57	Requires refusal to register and/or invalidation of a TM that corresponds to a protected GI
82	Provides minimum term of protection for new clinical info for a new indication/formulation/administration method of a previously approved pharmaceutical
95	Requires provision to performers of unfixed performance the right to authorize or prohibit its broadcast
96	Requires provision to performers of unfixed performance the right to authorize or prohibit its fixation
97	Requires provision to performers and producers the exclusive right to authorize or prohibit its broadcast or other public communication by wire or wireless means
116	Requires steps to be taken for provisional measures related to alleged infringement
120	Requires that border authorities shall have ex officio authority to detain suspected counterfeit or pirated goods
121	Stipulates that border authorities shall have authority to order destruction of infringing goods
128	Requires parties to enforce protection of GIs through administrative/legal proceedings, including at customs
130	Requires ISP liability & safe harbor system similar to DMCA

Appendix B: Details on the Construction of Bilateral Patent Flows from PATSTAT data

Our empirical analysis employs a panel data set of bilateral patent applications from origin countries to destination countries' national patent offices over the years 1995–2015, a data set that we develop based on information in the EPO's PATSTAT database. PATSTAT records individual patent applications at national offices within patent families (the set of applications to various patent offices that reflect the same fundamental invention), which we use to measure each patent application's country of origin, country of destination, filing date, and IPC technology category (or categories). Information on the destination country of patent applications can be readily obtained from the application details, while information on the origin country can generally be inferred based on the country-of-origin of the patent's author(s). In addition, the patent applications in PATSTAT typically record information on the IPC technologies under which each application was classified by the authority that processed the application.

To construct our data set, we also address several issues in the PATSTAT data that relate primarily to missing information for certain of these attributes, as well as ambiguity in the appropriate assignment of applications to unique origin countries or IPC categories. Below, we provide a brief description of each of these deficiencies in the primary data and describe our approach to mitigating these issues.

Multiple applications to a single application authority within a given family

For within-family duplicates of applications to specific national offices (e.g., multiple applications within a family to the USPTO), we take the application with the earliest filing date for that office and that family.

Multiple IPC codes for a given application

When a given application is assigned to multiple 4-digit IPC codes, we weight each IPC code assignment in equal proportion to the number of IPC codes for that application. For example, in instances where we observe

Application	IPC4
11111	A01A
11111	A01B

we assign this application to A01A with weight ½ and A01B with weight ½.

Missing IPC codes

There are 856,482 applications with filing dates between 1995 and 2019 that do not have any associated IPC information. For multi-family applications in this set, we use IPC codes from other applications within the family, but only in instances where the IPC code is unique, or in instances in which multiple IPC codes are assigned to applications within a patent family, the IPC codes are consistent across different patent authorities.

Assigning an origin to a patent family

To ensure that the information on the country of origin of patent applications is consistent across all applications within a family, we implement several procedures. The process of assigning a unique country of origin to a patent family depends on the number of unique patent applications within a given family. Specifically, it depends on whether or not there is a single patent application within the family or if there are multiple applications.

For instances in which there are multiple patent applications within a family, but the country of origin of the applications is not consistent across the different applications, we identify the application within the family that has the earliest filing date and assign the country of origin to the other applications within the family based on this information. For most families the earliest application is uniquely identifiable, however, there exist some patent families that possess multiple applications that share the same earliest filing date. For such families in which multiple applications reflect the same earliest filing date, we remove any of the potential earliest applications that do not have any country information associated with any applicants. This does not resolve all instances in which there are multiple earliest applications, but it does remove applications with no origin information. The next steps focus on the country of origin for applicants.

For a given earliest application (note that this could be a unique earliest application or one of the instances in which there is no unique earliest application), if there are multiple applicants and one of those applicants is associated within a tax haven (low-tax countries which typically undertake low levels of innovation and patenting), we remove such countries from consideration as the origin for the patent family. We then implement a hierarchy of applicants by type that we use to identify the countries of origin for applications for which multiple entities of different types and in different countries are listed in the applicant information, and prioritize the country associated with the highest "ranked" applicant. Applications are ranked as follows:

- Highest priority goes to a Company or Government.
- Second priority is assigned to Hospitals, Universities and Non-Profits
- Lowest priority is given to individuals

Once applications have been filtered in the previous step, we assign the country of origin according to the rank of the applicants by their order in the list of applicants on the patent. This approach inherently assumes that the order of applicants is meaningful for their contribution to the application.

Following this set of steps, there still remain some patent families for which multiple countries could feasibly represent the country of origin. These cases could arise in instances where there are multiple earliest applications, or when there are multiple authors with identical applicant types from non-tax-haven countries. The next step addresses families where there are multiple earliest applications. In this step we prioritize the earliest application (and the origin(s) of the relevant applicant(s)) that is associated with the PCT application, if one exists. If no PCT application exists but a regional patent application exists, we give priority to that application in determining the earliest application within the patent family. The assumption is that large multinational entities might file an application to a specific country with its affiliate within that country; under this assumption, the PCT application is less likely to be influenced by the existence of a local establishment and more likely to be associated with the country of invention.

We next prioritize applicants that are located in the same country in which the patent is filed to fill in remaining gaps in the country-of-origin information. For the remaining applications that still have more than two potential countries of origin, we count the number of applicants associated with each applicant type (governments, corporations, etc.). If there is a maximum in this count, we assign the country of origin to the country associated with that maximum. For example, if there are three individual authors listed on applications within a family and two are from India and the other from China, then the maximum would be associated with India and India would be assigned as the origin of the family. Finally, if there are multiple possible origins still associated with a family even after implementing the preceding steps (though such instances are rare), we pick an origin country for the family at random from the set of possible origins still associated with the country.

For patent families comprising only a single application, we follow the same set of preceding steps except for those related to resolving ambiguities in the country of origin of multi-patent-families. Having followed these steps, for the remaining single-patent families with no country of origin, we assign the origin of the application to be the same as the country destination that received the application.

Table B1: Patent-Intensive NAICS Industries Comprising High-IP Industry Clusters

NAICS industry	Industry description
	Analytical Instruments (AI)
333314	Optical Instrument and Lens Manufacturing
333315	Photographic and Photocopying Equipment Manufacturing
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing
3346	Manufacturing and Reproducing Magnetic and Optical Media
	Biopharmaceuticals (BIO)
3254	Pharmaceutical and Medicine Manufacturing
	Chemicals (CHEM)
3251	Basic Chemical Manufacturing
	Information and Communications Technology (ICT)
333313	Office Machinery Manufacturing
3341	Computer and Peripheral Equipment Manufacturing
3342	Communications Equipment Manufacturing
3343	Audio and Video Equipment Manufacturing
3344	Semiconductor and Other Electronic Component Manufacturing
	Medical Devices (MED)
3391	Medical Equipment and Supplies Manufacturing
	Production Technology (PT)
3332	Industrial Machinery Manufacturing
3334	Ventilation, Heating, Air-Conditioning, and Commercial Refrigeration Equipment Manufacturing
3335	Metalworking Machinery Manufacturing
3339	Other General Purpose Machinery Manufacturing
	Other
3252	Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing
3253	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing
3255	Paint, Coating, and Adhesive Manufacturing
3256	Soap, Cleaning Compound, and Toilet Preparation Manufacturing
3259	Other Chemical Product and Preparation Manufacturing
3331	Agriculture, Construction, and Mining Machinery Manufacturing
3333	Commercial and Service Industry Machinery Manufacturing
3336	Engine, Turbine, and Power Transmission Equipment Manufacturing
3399	Other Miscellaneous Manufacturing

Notes: High-IP clusters are defined by manually assigning the above-mean patent-intensity NAICS industries in US Department of Commerce (2012), as determined by patents per industry employee, to the respective broad industry groupings.

Table B2: Patent-Intensive NAICS Industries Comprising Low-IP Industry Cluster

NAICS industry	Industry description
2111	Oil and Gas Extraction
2122	Metal Ore Mining
2123	Nonmetallic Mineral Mining and Quarrying
3111	Animal Food Manufacturing
3112	Grain and Oilseed Milling
3113	Sugar and Confectionery Product Manufacturing
3116	Animal Slaughtering and Processing
3117	Seafood Product Preparation and Packaging
3119	Other Food Manufacturing
3131	Fiber, Yarn, and Thread Mills
3132	Fabric Mills
3133	Textile and Fabric Finishing and Fabric Coating Mills
3149	Other Textile Product Mills
3151	Apparel Knitting Mills
3152	Cut and Sew Apparel Manufacturing
3159	Apparel Accessories and Other Apparel Manufacturing
3161	Leather and Hide Tanning and Finishing
3169	Other Leather and Allied Product Manufacturing
3211	Sawmills and Wood Preservation
3212	Veneer, Plywood, and Engineered Wood Product Manufacturing
3219	Other Wood Product Manufacturing
3271	Clay Product and Refractory Manufacturing
3272	Glass and Glass Product Manufacturing
3273	Cement and Concrete Product Manufacturing
3274	Lime and Gypsum Product Manufacturing
3279	Other Nonmetallic Mineral Product Manufacturing
3311	Iron and Steel Mills and Ferroalloy Manufacturing
3312	Steel Product Manufacturing from Purchased Steel
3313	Alumina and Aluminum Production and Processing
3314	Nonferrous Metal (except Aluminum) Production and Processing
3321	Forging and Stamping
3323	Architectural and Structural Metals Manufacturing
3324	Boiler, Tank, and Shipping Container Manufacturing
3325	Hardware Manufacturing
3326	Spring and Wire Product Manufacturing
3327	Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing
3329	Other Fabricated Metal Product Manufacturing