GOETHE UNIVERSITÄT FRANKFURT AM MAIN

FOUNDATIONS OF LAW AND FINANCE

LawFin Working Paper No. 23

Cross-Border Institutions and the Globalization of Innovation

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July 20, 2021

Abstract

We identify strong cross-border institutions as a driver for the globalization of innovation. Using 67 million patents from over 100 patent offices, we introduce novel measures of innovation diffusion and collaboration. Exploiting staggered bilateral investment treaties as shocks to cross-border property rights and contract enforcement, we show that signatory countries increase technology adoption and sourcing from each other. They also increase R&D collaborations. These interactions result in technological convergence. The effects are particularly strong for process innovation, and for countries that are technological laggards or have weak domestic institutions. Increased inter-firm rather than intra-firm foreign investment is the key channel.

Keywords: Innovation, technology diffusion, globalization, cross-border institutions, bilateral investment treaties

JEL classification: F21, F61, G18, G38, K33, O31, O33

*We thank Jan Bena, Hans Christensen, Pengfei Han, Christian Helmers, Johan Hombert, Jiekun Huang, Cree Jones, Brandon Julio, Erik Loualiche, Elena Loutskina, Song Ma, Filippo Mezzanotti, Ramana Nanda, Debarshi Nandy, Thomas Rauter, Delphine Samuels, David Schoenherr, Henri Servaes, Jan Starmans, Steven Xiao, and conference and seminar participants at the 3rd Junior Entrepreneurial Finance and Innovation Workshop, the 2021 China International Conference in Finance, the European Finance Association 2020 Annual Meetings, the Midwest Finance Association Annual Conference 2020, the Northern Finance Association 2020 Annual Meetings, the Pacific Northwest Finance Conference, the SFS Cavalcade 2021, the Thirteenth Annual Northwestern/USPTO Conference on Innovation Economics, George Mason University, UBC, UT Dallas, and UVA Darden for their helpful comments and suggestions. We thank Jan Bena for sharing data and Keerthi Bisaramanempalli Reddiwandla for excellent research assistance. The paper has benefited significantly from a fellow visit of Bo Bian at the Center for Advanced Studies Foundations of Law and Finance funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) - project FOR 2774.

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1 Introduction

Solutions to many important issues today requires technological coordination at the global level (Cantner and Rake, 2014; Rubio, 2017). For example, the recent Pfizer-BioNTech COVID-19 vaccine was invented through a collaboration between a US firm and a German startup, the latter founded by two Turkish immigrants. Another important global issue is inequality across countries, which can be mitigated through technology diffusion that increases developing countries' productivity. Despite its importance, there is a lack of academic work measuring the globalization of innovation and quantifying its various stages from diffusion to collaboration. We also have limited understanding of what constrains the globalization of innovation, and what policies can relax these constraints.

This paper fills this gap by first introducing novel measures of the globalization of innovation for a large set of country-pairs. Our measures capture the three stages of innovation interactions (Archibugi and Michie, 1995): adoption, sourcing, and collaboration. We then study how these technological interactions respond to cross-border institutions—the set of rules governing economic transactions between countries—using Bilateral Investment Treaties (BITs) as shocks.

We focus on cross-border institutions because theory predicts that innovation activities can be particularly sensitive to them. Due to high uncertainty and intangibility, innovation contracts are often complex and hard to enforce (Acemoglu et al., 2007), especially across countries. Global innovation activities also require the exchange of capital between countries, which benefits from property rights protection. Strong cross-border institutions can therefore facilitate the globalization of innovation by reducing contracting frictions, and by increasing the mobility of innovation capital across countries.

To test the above hypothesis, we leverage 67 million patents from 105 patent offices worldwide to develop patent-level globalization measures, which we then aggregate to the country-pair-year level. We use patent priority to measure the *adoption* of existing foreign

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knowledge, the initial stage of innovation globalization.[1] We then use patent citation and transfer to measure the *sourcing* of foreign knowledge in producing new innovation. Last, we measure international *collaboration* in innovation production using co-applications and co-inventions. These measures capture increasing technological interactions between countries.

We investigate how these country-pair-level technological interactions respond to the signing of BITs, an important shock to cross-border institutions. BITs provide legal protection for foreign investments between signatory countries, irrespective of their domestic institutions. Since 1959, more than 2,500 pairs of countries have signed BITs. The bilateral and staggered nature of these treaties gives us rich variation for identification, and allows a difference-in-differences design with an extensive set of fixed effects.

We find that BITs have large positive effects on the globalization of innovation. After signing a BIT, the two signatory countries adopt and source more innovations from each other, increase their collaborations in patenting, and start to converge in the directions of their innovation. These effects are economically large, amounting to 20%–40% increases relative to the pre-treatment averages, and are stronger for interactions associated with greater frictions (i.e., collaboration > sourcing > adaption). These results highlight the important role of cross-border institutions in shaping the geographic boundaries of innovation. Our findings suggest that BITs can be a useful policy tool to promote the globalization of innovation.

To understand which countries and technologies benefit the most from strong cross-border institutions, we examine the cross-sectional heterogeneities of our results. We find that BITs have a larger effect on the globalization of innovation when the host (knowledge-importing) country is less technologically advanced than the source (knowledge-exporting) country, consistent with the scope of learning being higher for such country pairs. We also find stronger results when the host country has weaker domestic institutions than the source country. In

[1] A priority right is triggered by the first filing of a patent application. It allows the claimant to file subsequent patent applications in other countries for the same invention, effective as of the first application's filing date. The sequence of applications with the same priority right captures the adoption of the same invention across different countries.

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these cases, the improvement in cross-border institutions is larger. Lastly, we show that our results are stronger for process innovation than for product innovation. Compared with product innovation, process innovation captures more disembodied knowledge, knowledge that cannot be easily reverse-engineered from final products. The diffusion of such knowledge therefore relies more on in-person interactions and the physical exchange of capital (Akcigit et al., 2018; Hovhannisyan and Keller, 2019), both of which are facilitated by BITs.

Next, we examine the channels underlying our results. We hypothesize that BITs reduce frictions associated with foreign investments, which in turn lead to innovation diffusion and collaboration. Consistent with this, we find that BITs significantly increases inter-firm investments such as joint ventures, strategic alliances, and mergers and acquisitions between signatory countries, particularly those involving technology transfer or in R&D-intensive sectors. However, BITs have minimal impact on intra-firm investments such as greenfield investments, consistent with these investments facing lower frictions than investments outside of firm boundaries. These results highlight the heterogeneity among different types of foreign investments, which may play differential roles in promoting the globalization of innovation.

Our identification strategy relies on the assumption that the timing of a BIT for a given country pair is exogenous to the countries' technological interactions. Consistent with this assumption, the law literature documents that the signing of BITs is often driven by political or diplomatic motivations, and often reflects the bureaucrats' poor understanding of these treaties (Chilton, 2015; Bonnitcha et al., 2017). Nevertheless, we use multiple approaches to address the remaining identification concerns.

First, to address potential endogeneity concerns, we exploit the granularity of our sample and include an extensive set of fixed effects. We include country-year fixed effects for both the host and source countries. This ensures that our results are not driven by unobserved country-specific shocks, such as changing economic, political, or technological conditions. We also include country-pair fixed effects to absorb time-invariant heterogeneity across country pairs, such as two countries' distances in geography, culture, or institutions. These fixed

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effects greatly limit the set of confounders that can plausibly explain our findings.

Second, we use a dynamic difference-in-differences model to verify the parallel trends assumption. We find that treated and control country pairs exhibit similar trends in various innovation outcomes before the signing of BITs, and that the increases in outcomes only show up after the signing of BITs.

Third, we show that our estimated effects increase with treatment intensity. As mentioned earlier, BITs have larger impacts on globalized innovation when the host country has weaker domestic institutions than the source country; for these country-pairs, the improvement in cross-border institutions, and hence the treatment intensity, are larger. We also exploit variation in treatment intensity within a BIT over time. Specifically, we use a natural experiment from an arbitration ruling that strengthened the legal protection offered by BITs signed before 2000. In January 2000, for the first time, the ruling of *Maffezini v. Spain* allowed investors to invoke the most favored nation (MFN) provision to gain access to better legal remedies in other BITs already signed by a host country (Jones, 2018a). We find that the treatment effect of BITs signed before 2000 increases significantly after this ruling. These results suggest that our main findings are driven by variation in cross-border institutions, rather than other confounding shocks that may correlate with BITs.

Lastly, we demonstrate that our estimated treatment effects exhibit high stability when we gradually add a large number of country-pair-year-level controls (e.g., trade, the degree of economic integration, or other treaties) or add region-pair-year fixed effects. This suggests that bias from omitted variables is probably limited. A formal Oster (2019) test shows that our results are robust to correcting for potential omitted variable bias.

We conduct a number of robustness tests. One concern is that our results may be driven by a relabeling of existing innovations as patents. For example, by better protecting intellectual property (IP) rights by foreign investors, BITs may shift innovation output from secrecy to patenting; BITs may also motivate less developed countries to change their patenting standards, thus generating the observed changes in globalized patents. In these cases,

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stronger cross-border institutions motivate "patenting", but not necessarily the underlying innovation. Inconsistent with the IP rights explanation, we find that our results remain strong in technology classes that rely little on secrecy to protect innovation, i.e, technology classes with little room to substitute patenting for secrecy. Our results are also similar when restricting to patents from top patent offices, whose patenting standards are unlikely to be affected by BITs. Overall, these results suggest that our findings are not driven by increasing patenting rates, but by actual increases in innovation.

Another concern is that our findings might be driven by certain data peculiarities or data coverage issues. To address this concern, we conduct 1,000 placebo tests that randomly assign BITs to placebo partner countries. Our true estimates are significantly larger than the placebo estimates. Lastly, we show that our results are robust to including small countries or focusing on large countries, as well as dropping European countries or tax haven countries.

The contribution of our paper is to document cross-border institutions as a friction constraining the globalization of innovation. Our results also highlight the value of BITs in driving a country's technological advancement. However, our paper does not imply that BITs are always good, since there are costs of BITs, whose analysis is beyond the scope of this paper.

This paper adds to the literature on technology transfer and diffusion. Prior work has documented the role of FDI (Aitken and Harrison, 1999; Javorcik, 2004; Keller and Yeaple, 2009), intellectual property rights (Branstetter et al., 2006; Cockburn et al., 2016), financial development (Comin and Nanda, 2019), and geography (Comin et al., 2012; Hovhannisyan and Keller, 2019) in the diffusion of technologies (see Keller (2004) for a survey). Our paper differs from these studies in three ways. First, while most studies focus on the transfer of existing knowledge, our paper predominantly examines the creation of new knowledge and the collaborations therein. Second, the literature frequently relies on aggregate country-level R&D and total factor productivity to measure technology diffusion. We leverage granular patent data to measure technology adoption, sourcing, and collaboration at the country-pair

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level. Third, we document important heterogeneities in technology diffusion across product and process innovation.

We also contribute to a growing literature on globalization and knowledge production. Several studies have highlighted the importance of immigration and ethnic diversity for innovation (Kerr, 2008; Kerr and Lincoln, 2010; Bernstein et al., 2018). Others examine international collaboration in knowledge production (Griffith et al., 2006; Branstetter et al., 2015; Iaria et al., 2018; Kerr and Kerr, 2018). Our paper contributes to this literature by showing that strong cross-border institutions are an important driver for the globalization of innovation. BITs can therefore be an effective policy tool to help less developed countries catch up to the global technological frontier.

Lastly, our paper adds to the literature on *international* law and finance. Prior papers have investigated the impact of international law on country-level financial integration (Kalemli-Ozcan et al., 2010), business cycle synchronization (Kalemli-Ozcan et al., 2013), stock market liquidity (Christensen et al., 2016), firms' investment and financing decisions (Meier, 2019), and resource reallocation (Bian, 2019). Broz and Bowen (2020) highlight the need for a new research agenda on *global* institutions. We contribute to this literature by identifying and quantifying the impact of cross-border institutions on the globalization of innovation. Related to our paper, Bhagwat et al. (2020) document that cross-border mergers and acquisitions roughly double when two countries sign a BIT. Our paper focuses on innovation diffusion and documents the heterogeneous responses of different types of foreign investments to BITs.

2 Measuring the Globalization of Innovation

We use patent data to construct micro-based measures of the globalization of innovation. Our data is from PATSTAT Global, a worldwide patent database that provides detailed bibliographical information on over 100 million patent applications in more than 100 patent offices. The largest patent offices (based on the number of patent applications in 2016)

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in PATSTAT Global are Japan Patent Office (JPO) (20.9%), State Intellectual Property Office of China (17.8%), U.S. Patent and Trademark Office (USPTO) (15.9%), German Patent and Trademark Office (7.3%), Korean Intellectual Property Office (4.2%), European Patent Office (EPO) (3.8%), UK Intellectual Property Office (3.8%), and World Intellectual Property Organization (WIPO) (3.7%). Figure 1a shows an upward trend in the number of patent applications across patent offices in the past four decades. The total annual number of patent applications across all offices increases from one million in 1980 to four million in 2016. The comprehensive and global nature of this database is crucial to consistently measuring the globalization of innovation across a large number of countries.

Following the taxonomy in Archibugi and Michie (1995), we measure three dimensions of cross-border technological interactions, in order of increasing depth: (1) the *adoption* of existing foreign knowledge, (2) the *sourcing* of foreign technology in producing new knowledge, and (3) direct *collaboration* in producing new knowledge. We first identify patents that capture these interactions, which we define as globalized patents. We then aggregate these patent-level measures to a country-pair-year-level data set. For some of our subsequent analyses, we also extend these measures to the country-pair-technology class level.

To measure the adoption of existing foreign knowledge, we use patent priority records to extract information on the adoption of the same invention in different countries over time. A priority right is triggered by the first filing of a patent application. It allows the claimant to file a subsequent patent application in another country for the same invention, effective as of the filing date of the first application. Given that patenting in a particular country signals the adoption or commercialization of an invention in that country, the sequence of applications therefore captures the timing of adoption of the same invention across different countries (Eaton and Kortum, 1999). For example, Figure A.1 shows that a medical device for drug delivery was originally patented by Bayer in Germany in 2002, then patented in many other countries between 2003 and 2017.[2] We aggregate this measure to the country-

[2]A country can show up multiple times in a patent priority sequence due to changes to the same underlying invention. Our measure only counts the first time a country shows up in a patent priority sequence.

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pair-year level by counting the number of patents in country H that have priority rights traced back to country S, thus capturing country H's adoption of technologies from country S. (We use country S to refer to the source country and country H to refer the host country.)

We then measure the sourcing of foreign technology in producing new knowledge. We first measure technology sourcing through patent citations. Specifically, we count the number of patents in country H that cite country S's patents. Figure A.2a provides an example. It shows that a USPTO patent owned by the Chinese company Huawei cites 13 patents, whose assignees are from six foreign countries. Next, we measure a country's direct sourcing of innovation—the transfer of technology from foreign inventors to companies in a host country (Griffith et al., 2006). We count the number of patents whose inventors are in country S but whose applicants or assignees are in country H. This measure reflects the extent to which country H sources innovation from country S through technology transfers. Figure A.2b provides an example, where a patent invented by a team of UK inventors is assigned to Microsoft in the US.

Our third group of measures focuses on cross-border collaboration in innovation (Kerr and Kerr, 2018). We count the number of patents whose inventors come from both country S and country H (co-inventions), as well as the number of patents whose applicants are in both country S and country H (co-applications). Figures A.3a and A.3b provide examples.

Lastly, we measure the technological proximity between two countries. We compute the cosine similarity between country S's and country H's shares of patents in different technology classes. Since learning takes place gradually, we focus on country H's patent flow and country S's patent flow as well as patent stock (3-year or 10-year). This measure reflects the extent to which country H's innovations are converging toward country S's.

Our innovation globalization measures have several appealing features. First, they are micro-based. Unlike prior literature that relies mainly on country-level aggregates such as R&D and TFP to measure technology spillovers, our measures are constructed from patent-level data. Second, our measures can be flexibly extended to different levels of granularity.

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Because each patent has an exact date (application or issuance), an exact geographic location (inventor's or assignee's), and can be assigned to different levels of technology classes, our measures allow different levels of aggregation along the dimensions of time, geography, and technology space. This offers researchers insights into the granular network of technology diffusion and its dynamics at the high-frequency level. Lastly, though not conducted in this paper, our globalized patents can be matched to firms, which allows the study of the role of firms in the globalization of innovation.

3 Descriptive Statistics

3.1 The Importance of Globalized Innovation

How important are globalized innovations? Panel A of Table 1 provides summary statistics of our patent-level sample, which covers all patents in PATSTAT Global from 1980 to 2016 with no missing country information—a total of 67 million patents. In our sample, 34% of patents have priority in a foreign country, 18% cite foreign patents, 4% are sourced from foreign inventors, 2% are co-invented by inventors from different countries, and 1% involve applicants from different countries. Together, these globalized patents (i.e., patents captured by at least one of the five measures) constitute 41% of all patents worldwide.[3] Figure 1b shows a dramatic increase in globalized patents in the past four decades. Such a pattern holds across different patent offices. In Figure 2, we further confirm an overall upward trend in the share of globalized patents across different innovation globalization measures.[4]

To understand the value of globalized patents, we compare the forward citations received by globalized patents with those received by local patents in Figure 2. Figures 2b to 2f focus on patents captured by each of the globalization measures described above, while Figure 2a examines patents captured by any of these measures. Across all figures, we see that globalized

[3]Our globalization measures are not mutually exclusive.

[4]The slight decline towards the sample end is explained by the time lag in patent publications, which tends to be longer for globalized patents, and a recent trend of deglobalization (James, 2018). The sharp decline in co-applications in 2013 is due to an increase in application fees for international applications at USPTO in 2013. All our results are robust to ending our sample period in 2012.

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patents have significantly higher impact than local patents, receiving two to three times the number of citations compared to local patents. Panel A of Table 1 confirms this finding. Panel A of Table 2 further compares the private value of globalized versus local patents, using the patent-level stock market response measure from Kogan et al. (2017). For this analysis, we focus on patents issued to US public firms by USPTO. We find that globalized patents have significantly higher private value than local patents, with an average additional USD 6.3 million per patent.[5]

We then examine the social value of globalized innovation by studying its potential positive spillover effect on domestic innovation and the local economy. Panel B of Table 2 presents the relationship between a country's number of local patents and the lagged number of globalized patents at the country-year-technology class level. The granularity of our data allows us to control for a rich set of fixed effects, including country-year fixed effects, country-class fixed effects, and class-year fixed effects. We find a significantly positive relationship between globalized and future domestic innovations across all globalization measures, with an elasticity of 0.08 to 0.16. Panel C of Table 2 examines the relationship between a country's GDP and its lagged number of globalized patents at the country-year level, controlling for country fixed effects and year fixed effects. We find a significantly positive correlation for almost all measures. Although these results are not causal, they suggest that the value of globalized innovation probably goes beyond the globalized patents themselves—it potentially benefits a country's domestic innovation and overall economy through positive spillovers.

3.2 Regression Sample

The sample for most of our regression analyses is a country-pair-year panel. Except for the collaboration measures, all measures are directional, from the source country (country S) to the host country (country H), implying that each country pair appears twice, with one country as the source country and the other as the host country, and vice versa. Our raw sample contains 205 countries and 41,820 (205 $\times$ 204) country pairs. We restrict our

[5]This number is large as the stock market response measure focuses on US public firms.

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baseline sample to countries with at least 50 patents over our sample period. This yields a sample of 826,950 country-pair years covering 150 countries from 1980 to 2016. Panel B of Table 1 provides country-pair-year level summary statistics. In a given year, an average country pair has 13.5 patent applications that have priority in the partner country (of which 8.2 are granted), 32.1 patent applications that cite the partner country's patents, 3.8 patent applications sourced from inventors in the partner country, 4.7 co-invented patents, and 1.5 co-applied patents. The relatively low values are due to averaging across all possible country-pair years, many of which have no innovation interactions.

4 Bilateral Investment Treaties

To generate variation in cross-border institutions, we exploit the signing of bilateral investment treaties (BITs) at the country-pair level. BITs are one of the most ubiquitous policy tools used by countries to protect foreign investment. More than 2,900 BITs have been signed since 1959, with 2,321 BITs in force as of 2018 (UNCTAD, 2018).

BITs are commonly employed to overcome the fundamental problem that when a national of one country invests in another country, legal frictions inhibit contract enforcement across borders. Given the lack of a supranational judicial system, investors have to rely solely on the host country's judicial system. Host countries may change laws after an investment is made, enforce laws poorly, or even expropriate foreign investors. Anticipating this, firms rationally either withhold investment or only invest if the terms are quite favorable. This leads to a time-inconsistency problem, as host countries cannot commit to not expropriate. International law contains no generally accepted rules for dealing with investment disputes, and lacks a binding mechanism to resolve disputes between investors and host countries. Hence, cross-border institutions surrounding investments are generally weak in the absence of BITs.

BITs protect foreign investment from adverse actions by the host government through the following mechanisms: First, BITs guarantee that investments made by individuals and

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firms from the other country will be treated fairly and equitably. Second, the agreements limit expropriation of investors and provide for compensation when expropriation does occur. Third, BITs give investors the right to transfer their property out of the foreign state freely. Fourth, the agreements place restrictions on trade-distorting performance requirements, such as local content requirements or export quotas. Fifth, BITs often allow investors to choose their own management team, without regard to residency or nationality requirements. Lastly, and most importantly, if the terms of a BIT have been violated, investors can force the foreign state to participate in binding international arbitration, often without having to go through local courts first.[6] Taken together, these provisions give foreign investors assurances that investments made in a partner country will be provided with enforceable protection.

The types of investments protected by BITs are very broad, covering practically all assets owned or controlled by a foreign investor. Most treaties refer to "every kind of asset," followed by an open-ended list including tangible property, debt and equity (including portfolio investments), contractual rights, intellectual property rights, and concession contracts. BITs also cover a broad range of foreign investors, including both individuals (natural persons) and juridical entities (legal persons). Most treaties cover investments made both before and after a treaty enters into force. Overall, the signing of a BIT between two countries can be viewed as a positive shock to cross-border property rights protection and contract enforcement.

Law and political economy scholars have documented that the motivation for BITs is often political or bureaucratic. Chilton (2015) shows that the United States has used BITs as a foreign policy tool to improve relationships with countries that provide political benefits. Consistent with this, he finds that investment considerations do not explain the pattern of U.S. BIT formations, while political considerations do. Reviewing existing studies on investment treaties, Bonnitcha et al. (2017) conclude that developed countries have largely promoted BITs for bureaucratic and political reasons, not as a response to lobbying by investors or corporations. Bonnitcha et al. (2017) further document that, due to a lack of

[6]These international arbitrations are overseen by an independent international tribunal, such as the International Center for Settlement of Investment Disputes (ICSID).

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expertise, many developing countries have rushed into BITs with little consideration of their implications. The negotiation of BITs in these countries has rarely involved legal experts, and has often been delegated to mid-level bureaucrats, many of whom had misunderstandings about the treaties.[7] This explains why many developing countries with no commercial ties have signed a BIT. Overall, many BITs seem to have been signed for reasons unrelated to technological interactions between signatory countries. Nevertheless, we take the potential endogeneity of BITs seriously and design our empirical tests to address these concerns to the best extent possible.

We obtain BIT data from the Investment Policy Hub of the United Nations Conference on Trade and Development (UNCTAD). This database provides detailed information on 2,913 BITs, including the signing countries, signing date, and enforcement date. Following the prior literature (Chilton, 2015; Bhagwat et al., 2020), we use the signing year as the year of treatment, as these treaties can be retroactively applied to investments made before the enforcement date. In our main sample, 12% of country-pair years have a BIT in effect.

There is substantial variation in the timing of BITs, as well as in the type of countries signing them. Figure 3a shows the distribution of these treaties by signing year from 1960 to 2018. A large number of treaties were signed between 1990 and 2010. However, within a host country, the timing of these treaties is much more even (Figure 3b). There is great dispersion in the level of economic development and the geography of countries signing BITs, as shown in Figures A.4 and A.5. These heterogeneities allow us to estimate results applicable to a broad set of countries, and to investigate what type of countries benefit the most from BITs.

Figure 4a illustrates, for the year 2016, the cross-sectional relationship between the number of innovation partner countries and the number of BIT partner countries a country has.

[7]For example, South African officials incorrectly assumed that the treaties contained only broad statements of policy principles, and failed to realize that the provisions gave foreign investors protections over and above those in the local legal system. In the Czech Republic, a former negotiator recalls that the staff involved "really didn't know that the treaties had any bite in practice...They were neither aware of the costs or the fact that it could lead to arbitration." A Mexican representative says that "many here in Latin American thought it was harmless to sign these treaties, no one had an idea what they mean...They just signed them off within a few days or hours...There was no legal review, control, or scrutiny of the content...No one cared until the dispute came" (Poulsen, 2014, 2015).

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The fitted line shows a strong positive correlation between the two variables. Figure 4b examines this relationship in the time-series for China, Russia, Korea, and Germany. We again observe a strong positive correlation between a country's number of innovation partner countries and its number of BIT partner countries. Although many other factors can drive these correlations, these figures suggest that the presence of strong cross-border institutions may play an important role in the globalization of a country's innovation activities.

5 Empirical Strategy

Our primary empirical strategy exploits the staggered signing of BITs as shocks to legal institutions governing the enforcement of contracts and property rights between different country pairs. We use a difference-in-differences research design with granular fixed effects. The bilateral and staggered nature of BITs offers us rich variation. First, we can compare countries that have signed BITs with those that never have. Second, for countries that have signed BITs, they do so at different points in time, and with different partner countries. This allows us to use a rich set of fixed effects to absorb potential confounding factors. We estimate the following two specifications at the country-pair-year level:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\kappa_t} + \beta BIT_{ij,t} + \varepsilon_{ij,t} \tag{1}$$

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t} \tag{2}$$

In both equations, the dependent variable $Y_{ij,t}$ is a measure of the globalization of innovation as described in Section 2. It varies at the level of country i, country j, and year t, where country i is the source (knowledge-exporting) country and country j is the host (knowledge-importing) country. To facilitate interpretation, we construct $Y_{ij,t}$ by scaling the number of globalized patents between countries i and j with the total number of such patents generated by country j with all its partner countries. We then multiply this number by 100 for ease of reporting the coefficients. $Y_{ij,t}$ can therefore be interpreted as the percentage share of knowledge imported from country i by country j. As such, the mean of dependent variables

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in our main sample is always 0.671%.[8] We apply the same scaling method to the mechanism variables examined in Section 8. By bounding our outcome variables between zero and one, this scaling method mitigates the influence of outlying values in raw patent counts; it also facilitates the comparison of results across different outcomes and country-pairs, which can have drastically different raw means.[9]

In both equations, $\boldsymbol{\gamma_{ij}}$ is a set of fixed effects that absorbs time-invariant country-pair-specific factors, such as two countries' distance in geography, culture, or institutions. $BIT_{ij,t}$ is the variable of interest—a dummy variable indicating whether a BIT is in place between countries i and j in year t. In equation (1), we additionally control for year fixed effects κ_t that absorb global macroeconomic shocks. In equation (2), we use a tighter set of fixed effects, $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, to absorb country-specific shocks at the country-year level for both the host and the source countries. This specification rules out any time-varying country-specific factors in explaining our results, such as a country's changing institutions, technological advancement, or economic shocks. It also absorbs a country's general time-varying tendency to participate in the global economy. Standard errors are robust and clustered at the country-pair level. To address potential correlation structure in dyadic data, we also show robustness to double-clustering standard errors by the host and the source countries (Table A.1) and standard errors estimated through permutation (Figure A.6).

6 Main Results

6.1 Baseline Results

To examine the effect of cross-border institutions on the globalization of innovation, we start by analyzing the effect of BITs on cross-border technology adoption. As described in Section 2, our adoption measure captures the number of inventions originating in country S that are subsequently patented, and thus adopted, in country H. Table 3 presents the

[8]Our main sample contains 150 countries, meaning each country has 149 potential partners. The mean of our dependent variable, partner country share, is then calculated as $1/149 \times 100\% = 0.671\%$.

[9]We do not apply log transformation because previous literature (Silva and Tenreyro, 2006) shows that it is problematic for dyadic regressions.

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results. Columns (1) to (3) use the specification in equation (1), and columns (4) to (6) use the specification in equation (2). The dependent variable is based on patent applications in columns (1) and (4), and on granted patents in columns (2) and (5). Instead of equal weighting all granted patents as in columns (2) and (5), the granted patents are weighted by their forward citations in columns (3) and (6). Across all dependent variables, we find a strong effect of BITs on the adoption of foreign innovation, regardless of the set of fixed effects used. The estimated effect is economically large and statistically significant at the 1% level. For instance, in column (4), the signing of a BIT between two countries increases the share of patents adopted from the partner country by 0.13%, which is a 19.8% increase relative to a mean of 0.671%.

We then move from the adoption of existing knowledge to the creation of new knowledge. In Table 4, we study how BITs affect technology sourcing from abroad. Panel A studies sourcing through patent citations. In columns (1) and (4), the dependent variable is based on the number of times a country's patents cite a partner country's patents. The dependent variable in columns (2) and (5) (columns (3) and (6)) is based on the number of patent applications (granted patents) that cite a partner country's patents. Throughout all columns, we find a statistically significant and large effect of BITs on international cross-citations. In column (5), for example, the introduction of a BIT between two countries increases their cross-citation shares by 0.259%, which is a 38.6% increase relative to a mean of 0.671%.

Panel B of Table 4 studies a more direct type of sourcing—the transfer of technology from foreign inventors to companies in a host country. The columns are defined analogously to Table 3. Across all specifications, we observe a strong effect of BITs on the cross-border transfer of technology. In column (4), for instance, the signing of a BIT between two countries increases patent transfers by 0.169%, which is a 25.2% increase relative to a mean of 0.671%.

Next, we investigate the effect of cross-border institutions on countries' collaborations in producing innovation. We start with international co-inventions (Panel A of Table 5), which measures collaboration between inventors from two countries. The columns are defined

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analogously to Table 3. Across all specifications, the signing of a BIT between two countries significantly increases their co-inventions. In column (4), the introduction of a BIT increases cross-border co-inventions by 0.268%, which is a 39.9% increase relative to the mean. Panel B examines co-applications, which measures the joint ownership of new knowledge between two countries. We find a similarly strong effect of BITs on the extent of co-applications between signatory countries. For instance, in column (4), the signing of a BIT between two countries increases their patent co-applications by 0.218%, which is a 32.5% increase relative to the mean.

Finally, we examine whether these increased interactions lead to the convergence of countries in the technology space. As discussed in Section 2, we measure technological proximity as the cosine similarity between two countries' patenting weights across technology classes. Because this variable has a value between 0 and 1, it is not scaled as partner country share. Table 6 presents the results. We follow the International Patent Classification (IPC) and define technology class at the patent class level (3-digit IPC) in columns (1) to (3), and at the patent subclass level (4-digit IPC) in columns (4) through (6). Columns (1) and (4) use yearly flows of new patent applications for both countries. Columns (2) and (5) (columns (3) and (6)) focus on the proximity between the host country's patent flow and the source country's 3-year (or 10-year) patent stock. Regardless of the measure used, we find a strong effect of BITs on signatory countries' technological convergence—an increase of 3% to 10% relative to the mean.

Taken together, the above results suggest that stronger cross-border institutions induced by BITs facilitate innovation diffusion and collaboration between countries, leading to the convergence in the directions of their technological changes.

6.2 Extensive Margin

An important question is whether our results are driven by the deepening of existing technological interactions (the intensive margin), or by the initiation of new interactions (the extensive margin). We investigate this in Table A.2, where the dependent variables are indicators of whether the prior outcome variables are positive or zero within a country-pair year. For brevity, we focus on outcome variables based on patent application counts. We find a large and statistically significant effect of BITs on the incidence of any innovation interactions between two countries for all measures except co-application. This suggests that the extensive margin plays an important role in driving our main results, and that BITs prompt countries with no prior innovation ties to initiate such interactions.

6.3 Identification Tests

Our baseline identification relies on a difference-in-differences design with granular fixed effects that absorb country-pair and country-year level confounders. Nevertheless, there could be remaining identification concerns. This section discuss these concerns and how we address them.

A. Dynamics. A key assumption of our difference-in-differences design is parallel trends in unobservables between our treated and control country pairs in the absence of treatment. We provide strong evidence supporting this assumption in Figure 5, where we estimate a dynamic difference-in-differences model. As shown in Figure 5a, there is no pre-trend in the adoption measure between treated and control country pairs. The increase in adoption only starts after the treatment (i.e., the signing of BITs). Similar patterns can be observed in Figures 5b and 5c, which focus on technology sourcing and collaboration. These results support the validity of our research design.

Further, the dynamics of these reactions are consistent with the different natures of our globalization measures. In particular, adoption reacts immediately and the effect is stable thereafter, consistent with it being the early stage of technological interaction. In contrast, sourcing and collaboration take longer to react, and the effects slowly rise over time, consistent with these being more advanced forms of technological interaction. The increasing magnitude of the effects from adoption to sourcing and collaboration is consistent with BITs being more effective in promoting interactions with greater frictions.

B. Cross-BIT Variation in Treatment Intensity: Domestic Institutions. To ad-

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dress any remaining concerns about time-varying country-pair-level unobservables, we exploit variation in treatment intensity—the effect of BITs on cross-border institutions—both across BITs and within a BIT over time. If we find that the treatment effects increase with treatment intensity, this provides assurance that our results are not driven by confounding shocks, but by shocks to institutions induced by BITs.

We first exploit variation in treatment intensity across BITs. The prior literature documents that BITs matter the most when the host country has weaker institutions than the source country (Bonnitcha et al., 2017). In these cases, the risk of expropriating foreign investors is particularly pronounced. Such country pairs would therefore benefit more from BITs. If our main findings are indeed driven by BITs improving cross-border institutions rather than other confounding shocks, we should expect our results to be stronger when the host country has weaker institutions than the source country, as such country pairs would receive higher treatment intensity than an average country pair.

To test this heterogeneity, we construct a variable capturing the distance in the rule of law between the source country and the host country, using data on the rule of law from the Worldwide Governance Indicators project (Kaufmann et al., 2009). We then interact this measure with the BIT indicator in Equation (2). For brevity, we focus on the version of outcome variables based on patent applications. Table 7 presents the results. Consistent with our conjecture, we find a positive and highly significant coefficient on the interaction term for most dependent variables. This suggests that countries with a weaker rule of law relative to the BIT partner country experience a stronger increase in R&D interactions with the partner country.

C. Within-BIT Variation in Treatment Intensity: *Maffezini v. Spain.* One may argue that variation in treatment intensity *across* BITs may correlate with unobserved country-pair-level trends that affect countries' technological interactions. Further, BITs may be endogenously timed based on the expected benefits from innovation globalization or the influence of lobbying. To address this, we exploit a natural experiment that shocks the

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treatment intensity of existing BITs *within* a treaty across time. Our natural experiment is an arbitration ruling, *Maffezini v. Spain*, issued in January 2000 (Jones, 2018a). This arbitration decision was the first to allow an investor to invoke the most favored nation (MFN) provision in a BIT to access better legal remedies in other active BITs signed by the same host country. Prior to *Maffezini v. Spain*, it was generally understood that the MFN provision in the context of investment treaties was limited in scope to similar commercial policies like taxes, subsidies, and regulatory issues, and did not extend to legal remedies like access to arbitration. *Maffezini v. Spain* gave investors entitled to MFN provision legal precedent for invoking any legal remedy in any active treaty signed by the host country, rather than relying exclusively on the legal remedies in the treaty with the investor's home country.[10] Thus, investors gained access to better legal protections after the ruling. Given that most BITs contain an MFN provision (98.2%), the ruling significantly increased the impact of BITs on cross-border legal protection, even within a BIT across time. This natural experiment addresses the concern about the endogenous timing of BITs, since it exploits an unexpected arbitration decision that is exogenous to the timing of BITs signed before the decision.

To exploit this shock to legal protections offered by BITs, we restrict our sample to country pairs that signed BITs before 2000, the year of the *Maffezini v. Spain* ruling, and country pairs that never signed BITs. We interact *BIT* with a dummy, *Post-ruling*, indicating the years of and after 2000. This allows us to test whether BITs signed before *Maffezini v. Spain* have a stronger treatment effect in the years after *Maffezini v. Spain* than in the years before it. Table 8 presents the results. Consistent with our conjecture,

[10] In 1997 the Argentine investor Maffezini led an arbitration claim at the ICSID against Spain under the Argentina-Spain BIT. According to the BIT, Maffezini was required to fully litigate his claim in the Spanish courts before a claim could be brought before an arbitration tribunal (local remedy first). Maffezini cited two facts. First, Spain had signed a BIT with Chile that did not include the local remedy first condition. Second, the Argentina-Spain BIT included MFN protection. Maffezini then argued that the MFN protection in the Argentina-Spain BIT allowed him to invoke the better legal remedy in the Chile-Spain BIT to avoid litigating first in the Spanish courts. Spain argued that access to different procedural remedies did not constitute treatment by a host economy under MFN and so MFN could not be used to circumvent the domestic court requirement. In 2000, an ICSID panel of three arbitrators unanimously agreed with Maffezini, allowing the claim to move forward. For more details see Jones (2018a).

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we find that pre-2000 BITs have a significantly stronger impact on our innovation outcomes after 2000 than before 2000, except for the adoption measure.[11] In conclusion, these results suggest that it is the legal protections offered by BITs that drive our main results, rather than confounding factors that correlate with the timing of BITs.

D. Assessing Omitted Variable Problems: Additional Controls. Last, to assess the extent to which our results are driven by remaining omitted variables, we gradually add a large number of country-pair-year-level controls and examine the stability of our coefficients. If the coefficients are highly stable across specifications with different controls, this suggests that bias from omitted variables is likely limited. We then formalize this assessment using the Oster (2019) test. Under the assumption that selection on the observed controls is proportional to the selection on the unobserved controls, the test offers bounds on our coefficients that are adjusted for potential omitted variable bias.

Specifically, we add to our specification a country-pair-year-level measure of economic integration,[12] indicators for currency regimes (Ilzetzki et al., 2019), and a set of indicators for capital account openness (Chinn and Ito, 2006). We additionally control for the presence of bilateral labor agreements, bilateral tax treaties, tax information exchange agreements, and the amount of trade between the two countries.[13] Panel A of Table A.3 presents the main results including the above controls. The estimates and R^2 are very similar to those reported in Tables 3 to 5.

One might also be concerned that the signing of BITs coincides with countries joining international treaties regarding intellectual property. Panel B of Table A.3 additionally controls for countries' membership in the Patent Cooperation Treaty (PCT), the Patent Law Treaty (PLT), the World Intellectual Property Organization (WIPO), and the Agreement

[11] A likely explanation is that the adoption of existing knowledge places less stringent requirements on cross-border institutions than new knowledge creation through sourcing and collaboration.

[12] This is a categorical variable takes values of 1 through 6, representing different degrees of integration between two countries. For details, see NSF-Kellogg Institute Data Base on Economic Integration Agreements.

[13] Data on bilateral labor agreements are from Chilton and Posner (2018). Data on bilateral tax treaties and tax information exchange agreements are from the Exchange of Information Database. Data on trade are from UN Comtrade.

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on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Again, the estimates remain highly similar. To formally evaluate the robustness to omitted variable bias, we also conduct the Oster (2019) test. Table A.4 presents the results. Across all dependent variables and for different test parameters, we can almost always reject the null that the bias-adjusted coefficient equals zero. This means that potential omitted variable problems are rather limited in most scenarios, and that the relation between BITs and globalized innovation is robust to such concerns.

Another concern is that the timing of BITs may correlate with improved geopolitical relationships or economic ties between different regions of countries. To address this, we add region-pair-year fixed effects to absorb such region-pair specific shocks. We follow the definitions of UNCTAD and define five regions: Africa, Americas, Asia, Europe, and Oceania. The results remain very similar, as shown in Panel C of Table A.3. Overall, the stability of our coefficients across specifications with different controls suggests that potential bias from omitted variables is probably limited.

E. Further Discussion. Despite the above battery of tests addressing various identification concerns, we caveat that we cannot claim full causality of our results due to the possibility of remaining confounders. However, in order for these confounders to explain our results, they have to simultaneously 1) be specific to country-pairs that sign BITs and not be explained by country-level shocks or fixed country-pair characteristics, 2) correlate with innovation outcomes after the signing of BITs but not before them, 3) correlate more strongly with innovation outcomes when BITs provide stronger legal protections—both across BITs and within a BIT after *Maffezini v. Spain*, 4) and not be explained by various proxies of economic integration, participation in other international treaties, or region-pair-specific shocks. As such, our multi-pronged identification significantly shrinks the set of possible alternative explanations.

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6.4 Robustness

A. Changes in Intellectual Property Protection. One potential concern with interpreting our results is that, by allowing foreign investors to better enforce intellectual property rights (IPR), BITs motivate patenting but not necessarily innovation. We think this is unlikely to happen in our sample. First, although IPRs fall under the range of assets BITs protect, studies show that BITs play practically a limited role in *directly* protecting investors against IPR infringement or outright theft(Liberti, 2010; Boie, 2010).[14]

We then address two specific channels through which IP rights might drive our results. First, firms may shift from secrecy to patenting if BITs improve IP rights, leading to a "relabeling" of innovation activities. To address this concern, we use data from an innovation survey in Germany (Crass et al., 2019) to construct a technology-class-level (3-digit IPC) measure of reliance on secrecy.[15] If this concern is valid, one should see a weaker treatment effect for technology classes less reliant on secrecy, since the room to substitute secrecy with patenting is smaller. Table A.5 shows that the treatment effect remains similar for technology classes with a below median reliance on secrecy, suggesting that our results are not driven by a shift from secrecy to patenting. Second, firms could shift from counterfeiting to patenting. This shift should be stronger for product innovation than for process innovation, since the latter is harder to copy or to reverse engineer. Our subsequent analysis in Section 7.2 shows that our results are in fact stronger for process innovation than for product innovation, suggesting that a shift from IP stealing to patenting is unlikely to drive our results. Overall, these results suggest that our main findings are unlikely to be driven by changing patenting incentives or patenting rates, but instead reflect actual increases in underlying innovation production and diffusion.

[14]This is due to a few reasons. First, most IPR infringements result from actions of private individuals that are not attributable to states. Second, most BITs imply that the international wrongful act consists of an action rather than an omission. Finally, BITs do not set autonomous substantial standards for IPR protection. A claim based on the violation of the treatment of IPRs as investments may thus be difficult to substantiate. See Liberti (2010) for more details.

[15]The survey asks firms to report their reliance on secrecy to protect innovations and is available at the industry level, which we map to 3-digit IPC technology classes.

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B. Changes in Patenting Standards: Restricting to Top Patent Offices. Another related concern is that BITs may correlate with some patent offices tightening their patenting standards, especially in less developed countries. For example, a developing country's patent office may tighten its examinations of prior art and enforcement of patent citations, especially when such patents build on knowledge from BIT partner countries. Such patenting standard changes could affect our globalization measures, even when underlying innovation activities do not change. To address this possibility, we reconstruct our globalization measures, restricting to patents from a single patent office, or from the top patent offices whose patenting standards have always been the highest and are therefore unlikely to be changed by BITs. Table A.6 presents these results. Panel A repeats our main analysis using only patents applied through EPO, while Panel B restricts to patents applied through the top four patent offices: EPO, USPTO, JPO, and WIPO. In both panels, our results remain similar. These results also address the concern that certain patent offices, especially newer or smaller ones, have incomplete data coverage during our sample period.

C. Alternative Samples. One may be concerned that dropping countries with little patenting activity may bias our estimation. We rerun all analyses using the full sample, which includes all 205 countries. Results are reported in Panel A of Table A.7, and are similar to those for the main sample. To address the concern that our results are driven by tax havens or small countries with limited economic activity, we restrict our analyses to a subsample of large countries with above-median GDP, or exclude tax haven countries from our samples. Panels B and C of Table A.7 show that the results remain similar. Panel C of Table A.7 further shows that our results are robust to excluding all European countries, which are highly integrated with each other and may be less affected by the signing of BITs.

D. Placebo Tests. Another potential concern is that our results may be spurious due to data issues. For example, some patent offices may have better coverage of patent data over time. Another possibility is that the error terms in our dyadic data may have correlation structures unaccounted for by clustering at the country-pair level or double-clustering at the

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source and host country level. Erikson et al. (2014) recommend randomization tests to infer the correct p-values in dyadic regressions. We therefore follow Erikson et al. (2014) and conduct a placebo test that randomly assigns BITs to partner countries while keeping each country's number of BITs and their timing fixed. We run 1,000 such placebo regressions for each of our outcome variables, and plot the distributions of the estimated coefficients in Figure A.6. We find that the coefficients in our main results are substantially above the empirical distributions of the placebo coefficients. This suggests that our main results are not driven by peculiarities or unaccounted correlation structure of the underlying data.

7 Cross-Sectional Heterogeneity

Next, we examine which countries or technologies benefit the most from strong cross-border institutions.

7.1 Distance in Technological Development

We first examine whether countries' levels of technological development affect the treatment effects from signing BITs. On the one hand, countries that are less technologically advanced than their BIT partner countries have more to gain through learning and spillovers. On the other hand, larger technology gaps may make it harder for countries to collaborate in innovation.

To test this, we interact the BIT indicator with the distance in ex-ante technological development between the two countries in a pair. Specifically, we measure the lagged difference in the number of patents between the host and the source countries. Panel A of Table 9 presents the results. We find that the coefficient on the interaction term is positive and statistically significant for all outcome variables, including the collaboration outcomes. This indicates that countries that are technological laggards benefit particularly from signing a BIT with a technological leader. Improvements in cross-border institutions induced by BITs can therefore play an important role in helping developing countries catch up to the technological frontier.

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7.2 Process vs. Product Innovation

Next, we investigate whether the effects of BITs depend on the nature of the innovation. In particular, we distinguish between process and product innovation. Process innovation concerns a method or process of producing a product, while product innovation refers to product designs and features. Consider, for example, Apple's iPhone. If another company wants to imitate the iPhone's designs or features (product innovation), it can reverse-engineer them by disassembling an iPhone and studying its parts. In contrast, the technologies used in the production of an iPhone (process innovation) are harder to copy, as it involves tacit, disembodied knowledge that cannot be easily reverse-engineered from the product. The diffusion of process innovation therefore relies more on in-person interactions and the exchange of production factors, as opposed to simple trading of products. Because BITs encourage the direct exchange of financial and human capital (we provide evidence on this in Section 8), they can be especially effective in diffusing process innovation.

To test this, we leverage technology-class-level data and classify technology classes by the fraction of process versus product innovation in each class, based on the data from Bena and Simintzi (2019). Table A.8 lists the top 10 technology classes with the most process innovations and product innovations. We first present our technology class-level results graphically in Figure 6. The x axis represents the share of process innovation in each technology class (IPC three-digit level). The y axis represents the estimated treatment effect of BITs for that technology class. The graphs show a strong positive correlation between the share of process innovation and the estimated treatment effect of BITs across technological classes. This holds true for all our globalization measures.

Panel B of Table 9 provides the regression results. The analysis is at the country-pair-technology-class level. The granularity of this analysis allows us to add even tighter fixed effects, including country pair × technology class fixed effects, country pair × year fixed effects, and country × year × technology class fixed effects. By adding country pair × year fixed effects, we absorb any remaining unobserved shocks to a country pair (the BIT

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indicator is thus absorbed). Consistent with Figure 6, the coefficient on the interaction between BIT and process innovation share is positive and significant for most specifications. This suggests that BITs are particularly effective in diffusing process innovation, which contains more disembodied knowledge than product innovation.

8 Channels

We continue by exploring the channels underlying our results. We hypothesize that BITs promote the globalization of innovation by reducing frictions associated with foreign investments. These investments either directly contribute to innovation production or diffusion, or facilitate them through the exchange of capital. These investments also correlate with the creation and expansion of multinational corporations (MNCs), which have been shown to play an important role in international technology diffusion (Teece, 1977; Gupta and Govindarajan, 2000; Branstetter et al., 2006; Foley and Kerr, 2013).

Prior literature has found mixed evidence on the effect of BITs on foreign direct investments (FDI).[16] This can be explained by two reasons. First, there are significant measurement issues with aggregate FDI data (Damgaard et al., 2019; Bertaut et al., 2019; Coppola et al., 2020). Damgaard et al. (2019) estimate that 40% of FDI volume is driven by phantom investments routed through offshore centers and tax havens. Further, countries may adopt different reporting standards for FDI, making cross-country-pair comparison difficult. Second, FDI takes a variety of forms and not all of them may react to BITs in similar ways. Motivated by these considerations, we unpack FDI by examining a spectrum of foreign investments using micro data. We order these investments by the amount of contracting frictions they face and explore their heterogeneous responses to BITs.

Specifically, we examine (1) joint ventures (JVs) and strategic alliances (SAs), (2) mergers and acquisitions (M&As), and (3) greenfield investments. The former two are inter-firm investments, while the latter is intra-firm. Inter-firm investments involve contracting outside

[16]Neumayer and Spess (2005), Rose-Ackerman and Tobin (2005), and Desbordes and Vicard (2009) find some evidence of BITs increasing FDI, while Gallagher and Birch (2006), Chilton (2016), and Jones (2018b) find no significant effects. See Bonnitcha et al. (2017) for a review.

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of firm boundaries, and hence face higher frictions than intra-firm investments (Grossman and Hart, 1986; Antras, 2014). If BITs promote globalized innovation through alleviating investment frictions, we expect BITs to have a stronger effect on the formations of joint ventures, alliances, and M&As transactions, and a weaker effect on greenfield investments. We test these hypotheses using deal- or project-level investment data.

8.1 Inter-Firm: Joint Ventures and Strategic Alliances

Joint ventures (JVs) and strategic alliances (SAs) are two important vehicles through which companies contract and collaborate on innovative activities. The literature has long documented their importance in knowledge sharing across organizations (Gomes-Casseres et al., 2006; Müller and Schnitzer, 2006; Li et al., 2019). Due to their collaborative nature, cross-border JVs and SAs are particularly sensitive to the legal institutions of the participating countries (Roy and Oliver, 2009). We therefore expect BITs to significantly increase the formation of JVs and SAs between signatory countries, particularly those involving technology transfer and licensing, which may face higher frictions due to their innovative nature.

We obtain joint venture and alliance data from the SDC Platinum Database, which has global coverage of deals from more than 200 countries. The database provides information on the country of the participants as well as the form of collaboration, which allows us to identify technology transfer and licensing. Our sample has about 148,000 international JV and SA deals from 1990 to 2016.[17] We collapse these deals to the country-pair-year level and create measures of the share of deals among partner countries for a given host-country-year.

Panel A of Table 10 presents the results. We find that the signing of a BIT significantly increases the formation of joint ventures and strategic alliances between firms of the signatory countries (columns 1 and 2). It also increases the formation of JVs/SAs that directly involve technology transfer or licensing (column 3). These results suggest that, in response to reduced cross-border contracting frictions, companies set up more collaborative vehicles that facilitate the transfer and joint production of knowledge across countries.

[17]The coverage of alliances and joint ventures in SDC Platinum is sparse before 1990.

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8.2 Inter-Firm: Mergers and Acquisitions

M&As are another major form of foreign investments. The literature has documented the role of M&As in technology diffusion and collaboration (Bena and Li, 2014; Li and Wang, 2020). Relative to inter-firm collaborative vehicles like SAs and JVs, M&As involve control rights and hence longer-term commitments. Prior literature shows that M&As are sensitive to cross-border institutional shocks such as BITs (Bhagwat et al., 2020). We further hypothesize that such sensitivity should be higher in R&D-intensive industries, where intangible and risky investments are harder to monitor and contract on.

We obtain M&A data from the SDC Platinum Database, which has a global coverage of 338,813 cross-border M&A deals between 1980 and 2016. We collapse these deals to the country-pair-year level and create measures of the share of these deals among partner countries for a given host-country-year. Panel B of Table 10 shows the results. We find that the signing of a BIT increases M&A volume between signatory countries by 45% (column 1), consistent with the finding in Bhagwat et al. (2020). However, this effect is not uniform. In particular, it is stronger in high-R&D industries but much weaker or insignificant in low-R&D ones (columns 2 and 3).[18] The pattern also holds when we examine mergers and acquisitions separately (columns 4 to 7). The concentration of our results in R&D-intensive industries suggests that our main findings are not explained by a general increase in foreign investments but rather increased investments in innovative sectors that benefit particularly from property rights protection.[19]

8.3 Intra-Firm: Greenfield Investments

Greenfield investments are another important form of FDI (Bank, 2020). Unlike, JVs/SAs and M&As, these investments are intra-firm and happen within firm boundaries. Hence, relative to inter-firm investments, greenfield investments should face relatively lower fric-

[18] We define high-R&D industries as 2-digit SICs with above-median R&D-to-asset ratio based on Compustat data.

[19] Most JVs and SAs involve some R&D endeavors (Müller and Schnitzer, 2006; Li et al., 2019), even if they may not explicitly use technology transfer and licensing.

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tions, and should thus be less sensitive to cross-border institutions. The FDI literature has documented some evidence of knowledge diffusion through greenfield investment, though the evidence is sparse and may not be applicable to a wide set of countries (Abebe et al., 2018; Ashraf et al., 2016).

We test the effect of BITs on greenfield investments using project-level data from fDi Markets, a comprehensive database that tracks cross-border greenfield investment across all sectors and countries worldwide. Our sample contains 185,830 greenfield investment projects in 202 countries from 2003, the year when the data starts, to 2016. We collapse the project-level data to the country-pair-year level and similarly create partner share measures for a given host-country-year. Panel C of Table 10 shows the results. In contrast to the findings for JVs, SAs, and M&As, BITs do not have a significant effect on greenfield investment volume, measured by either the number of projects or total capital invested. The magnitude is also economically very small. Further, this null effect holds for both R&D-related and non-R&D related projects. These results suggest that greenfield investments are not sensitive to BITs-induced cross-border institutional shocks, consistent with these intra-firm investments involving less frictions to begin with.

Overall, the results in this section show that BITs increase globalized innovation by mitigating investment frictions associated with foreign investments. However, not all foreign investments respond equally. Investments that expand firm boundaries and/or in innovative sectors are particularly sensitive to BITs, while other investments are less so. These results highlight the heterogeneity among different types of FDI, which play different roles in promoting the globalization of innovation.

9 Further Discussions

9.1 The Role of Multinational Firms

The results in Section 8 already highlight the potentially important role of MNCs behind our main finding. In addition, our globalization measures—the diffusion of patents with

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the same priority, the transfer of patents from foreign inventors to domestic firms, and the international collaboration of inventors and applicants—all could happen within a MNC. Increased M&As and JVs documented in our channel analysis also help MNCs expand their operations to foreign countries. Applying our globalized patent measures to analyze MNCs at the firm-level is therefore an interesting avenue for future research.

Nevertheless, activities happening outside of firm boundaries are equally, if not more, important drivers of our results. For example, strategic alliances and technology licensing are inter-firm contracts, while joint ventures and M&As are inter-firm investments. For our co-application measure, we are able to quantify the fraction of these collaborations happening between independent companies as opposed to within a MNC, by researching the relationship between the applicants. We find that 62% of international co-applications happen between two independent companies, while the remaining 38% are within a MNC (e.g., between two subsidiaries or between a subsidiary and the headquarter).[20]

9.2 Policy Implications

Economists have long agreed on the far-reaching benefits of globalization. Yet in recent years, the world has witnessed a backlash against globalization, including the US-China trade war, "Brexit", and more closely related to our paper, the cancellation of BITs by some countries.[21] Our paper highlights the value of BITs in enabling global knowledge diffusion. To gauge the importance of this value, we conduct a back-of-the-envelope calculation. Combining estimates from Tables 2 and 4 shows that, if a country moved from the 25$^{\text{th}}$ to the 75$^{\text{th}}$ percentile in the number of BITs signed, through the effect on globalized innovation, domestic

[20]We obtain these numbers from a random subsample of 2,000 co-applied patents. We manually research the relationship between the applying companies using their names and addresses, together with corporate ownership data from Bureau van Dijk Orbis, Dun & Bradstreet, Bloomberg, and companies' own websites.

[21]For example, India terminated 57 BITs and put on notice the remaining 25 BITs in 2016. South Africa, Indonesia, Venezuela, Bolivia, and Ecuador have also terminated many of their BITs. (accessed September 21, 2020)

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innovation and GDP would increase by 5% and 1.8%, respectively.[22] This highlights the potential of BITs in driving a country's overall innovation and growth. Moreover, as a policy tool, BITs are more incremental and targeted than other institutional reforms, and are thus easier to implement. That said, we are not able to evaluate the full costs and benefits of BITs or to recommend optimal policies. For example, BITs can impose sizable litigation and liability costs on signing countries should investment disputes occur (Johnson et al., 2018).

Skeptics may argue that the globalization of innovation, while benefiting developing countries, has no or even a negative effect on developed countries such as the US. Intellectual property theft and forced technology transfer are two major concerns for advanced economies. To assess the merits of such arguments, we rerun our analyses of the effect of BITs on globalized innovation, domestic innovation, and GDP by restricting the sample to countries that have GDP per capita in the highest decile in 1980. Despite the substantially smaller sample and therefore lower statistical power, we find that BITs are associated with increases in globalized innovation, domestic innovation, and GDP, even for the most highly developed countries (see Table A.9). As suggested by Branstetter et al. (2018), these countries benefit mostly through tapping foreign human capital and R&D collaborations.

10 Conclusion

Using novel measures of innovation diffusion and collaboration across a large number of countries, this paper documents a dramatic increase in the globalization of innovation in the past four decades. We show that globalized innovations are more impactful than local innovations, and that these innovations are sensitive to cross-border institutions.

We exploit the staggered signings of bilateral investment treaties (BITs) as shocks to

[22] To illustrate the calculation, we use the citation-based measure as an example. We start by taking the coefficient in column (5), Panel A of Table 4. Signing BITs with 41 more countries would increase sourcing through citation by $(0.259/0.571) \times (41/150) = 10.6\%$. We multiply this number by the coefficient in column (2), Panel B of Table 2. The increase in domestic innovation due to the increase in sourcing through citation is thus $0.157 \times 10.6\% = 1.7\%$. We can similarly calculate the increase in GDP based on Panel C of Table 2, as well as the increases due to other forms of globalized innovation.

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cross-border contract enforcement and property rights. We find that countries significantly increase their technological interactions after signing a BIT: they adopt and source more technologies from each other and collaborate more in innovation, resulting in technological convergence. Countries with weak domestic institutions and technology laggards benefit the most from strong cross-border institutions, as does process innovation as opposed to product innovation. Shedding light on the channels, we find that BITs significantly increase the mobility of financial and human capital across countries. Our paper illustrates the instrumental role of strong cross-border institutions in expanding the geographic boundaries of innovation. Improving the institutional environment for foreign investors may be an important policy tool to promote technological spillover at the global level.

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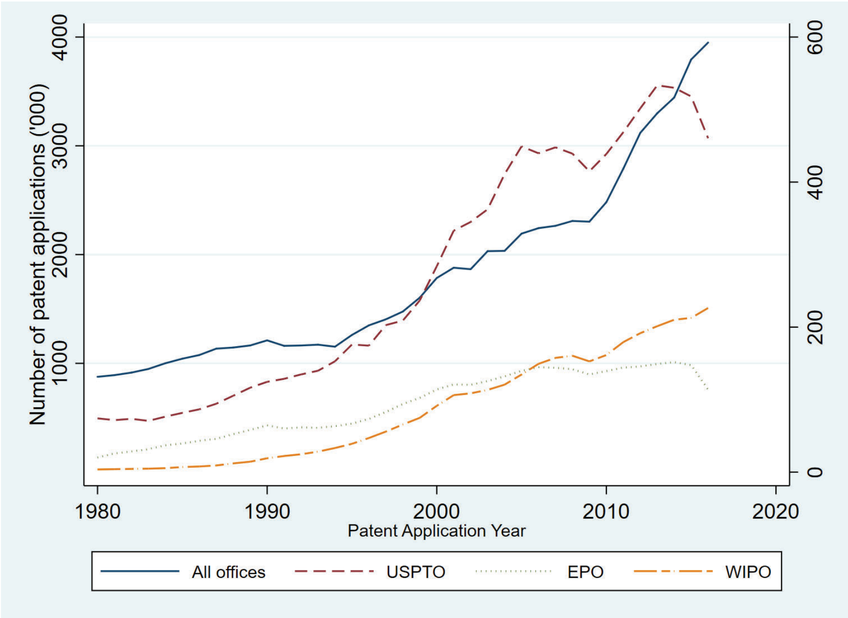
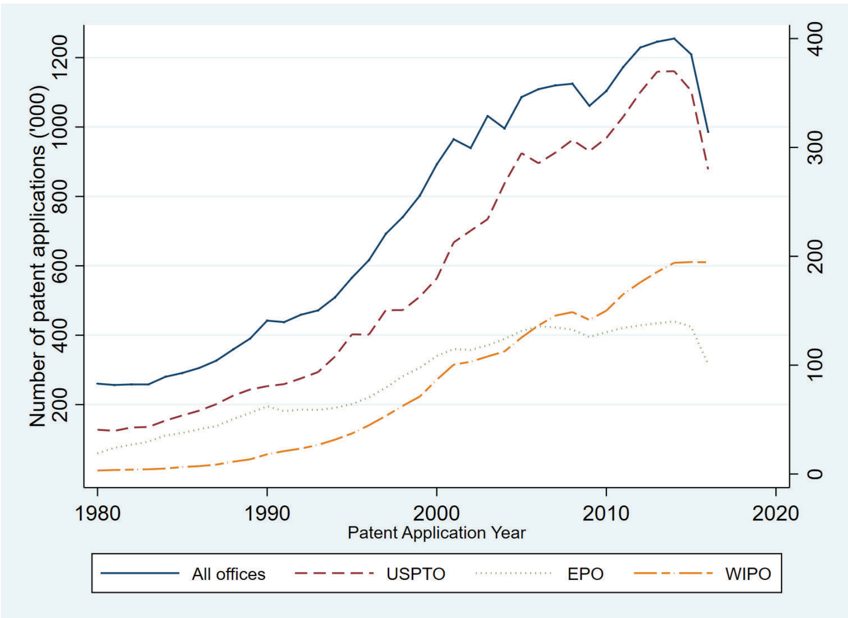
Figure 1: Number of Patent Applications Over Time



(a) all patents



(b) globalized patents

This figure shows the number of patent applications (in thousands) received by different patent offices over time (USPTO: United States Patent and Trademark Office, EPO: European Patent Office, WIPO: World Intellectual Property Organization). Patent counts from all offices use the left y axis, while patent counts from individual patent offices use the right y axis. Figure 1a includes all patents while Figure 1b focuses on globalized patents, which are patents involving foreign adoption, citation of foreign patents, transfer from foreign inventors, collaboration with foreign inventors, or collaboration with foreign applicants, or any of the above interactions.

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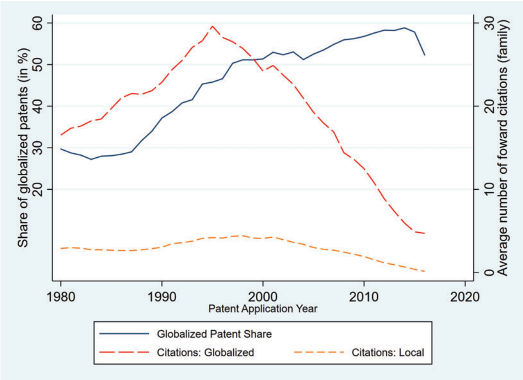
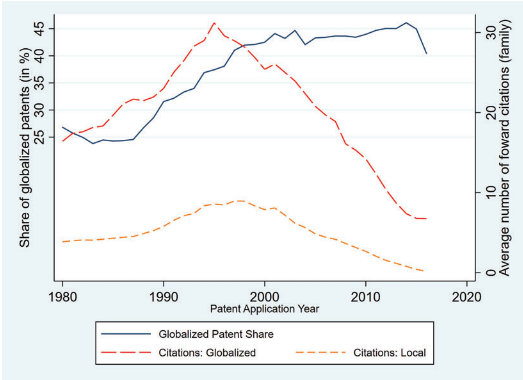
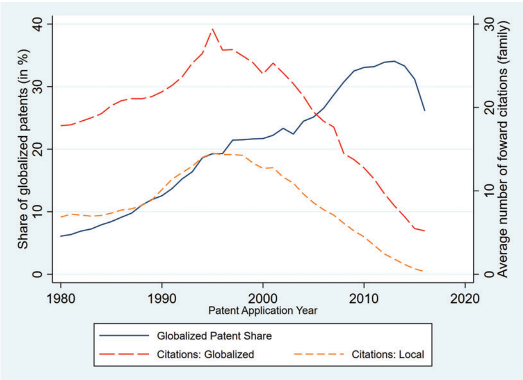
Figure 2: Globalized vs. Local Patents



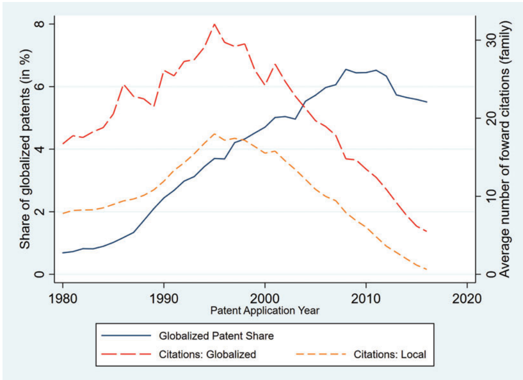
(a) Any type



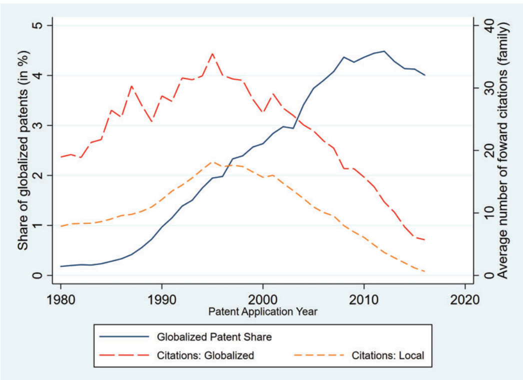
(b) Adoption



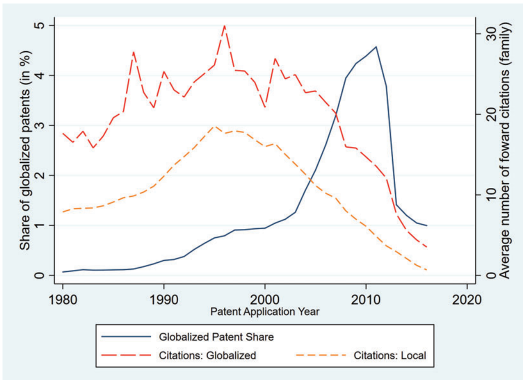
(c) Sourcing: Citation



(d) Sourcing: Transfer



(e) Collaboration: Co-invention



(f) Collaboration: Co-application

These figures show the share of globalized patents over time (solid line, left y-axis) and compare the forward citations received by globalized vs. local patents (dotted lines, right y-axis). Globalized patents are patents involving foreign adoption (Figure 2b), citation of foreign patents (Figure 2c), transfer from foreign inventors (Figure 2d), collaboration with foreign inventors (Figure 2e), or collaboration with foreign applicants (Figure 2f), or any of the above interactions (Figure 2a). In each figure, local patents refer to all other patents that do not have the respective globalization feature.

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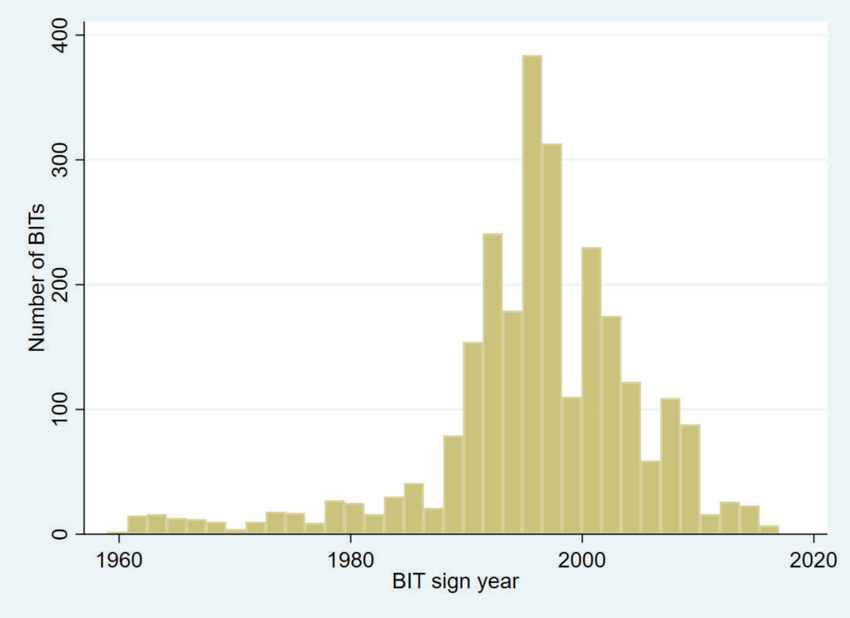
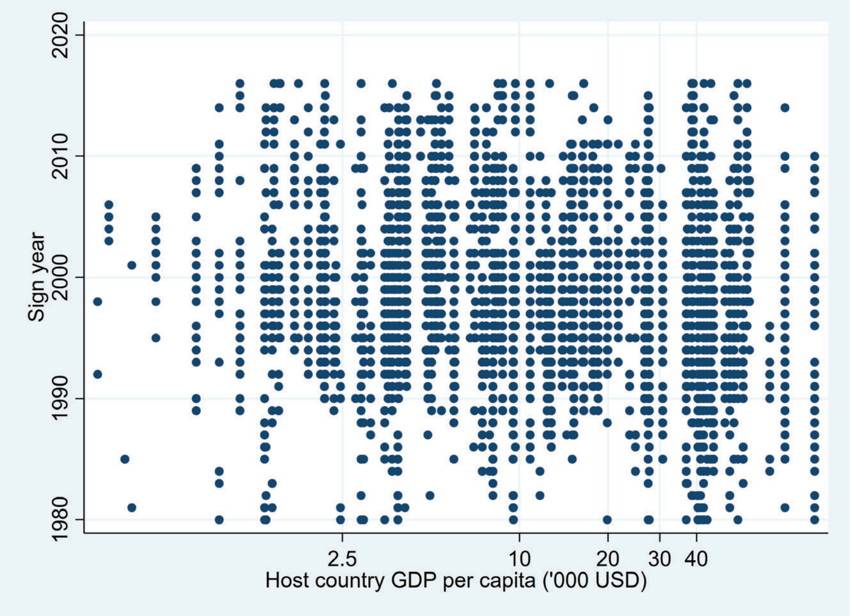
Figure 3: Distribution of BITs across Time



(a) Number of New BITs Signed over Time



(b) Within-country Timing of BITs by GDP per capita

Figure 3a shows the number of newly signed bilateral investment treaties by signing year. Figure 3b plots the distribution of BITs according to the GDP per capita of the host country (x axis) and the sign year (y axis). Each dot represents one treaty.

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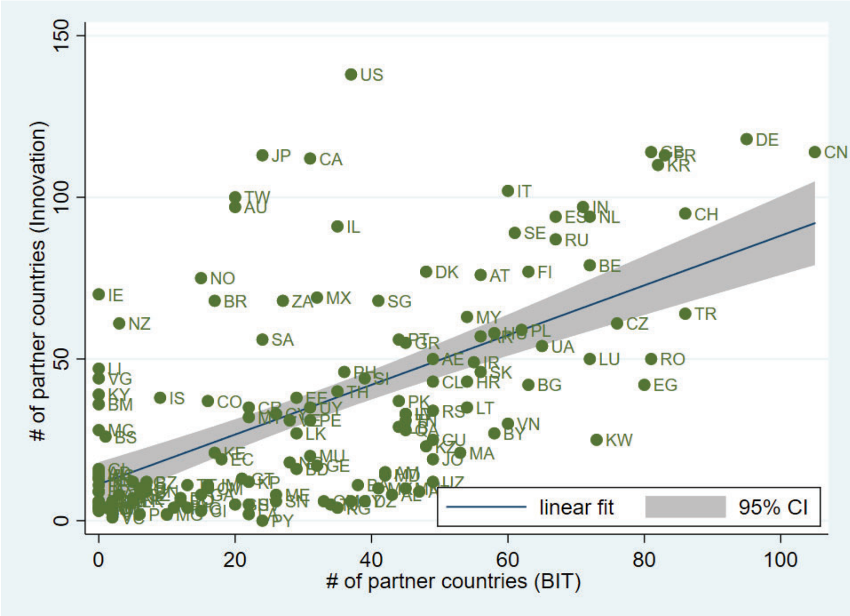
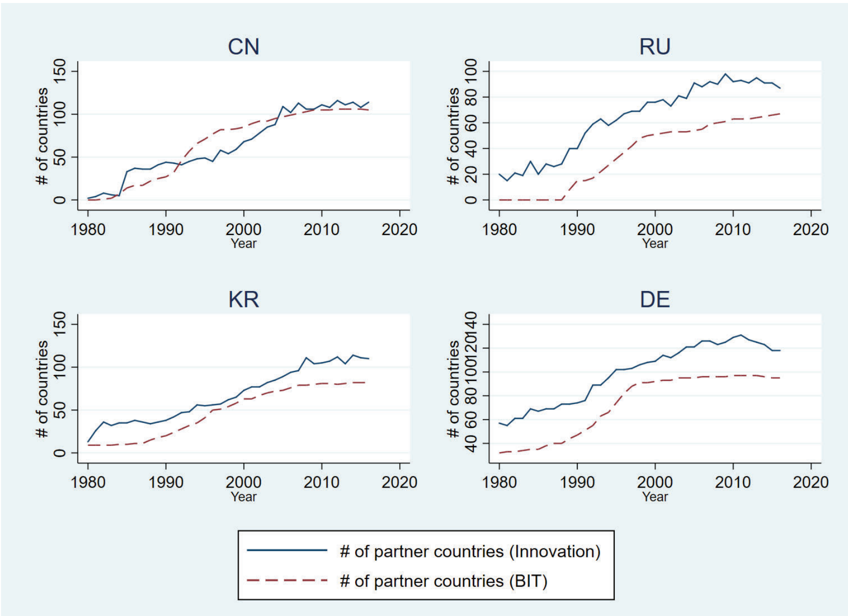
Figure 4: Number of Partner Countries for Innovation vs. for Bilateral Investment Treaties



(a) Cross-section



(b) Time-series

Figure 4a plots for the year 2016 the number of partner countries a country has for its innovation activities against the number of partner countries with which a country has signed bilateral investment treaties. Figure 4b plots for China, Russia, Korea, and Germany, within a country over time, the number of partner countries a country has for its innovation activities against the number of partner countries with which a country has signed bilateral investment treaties.

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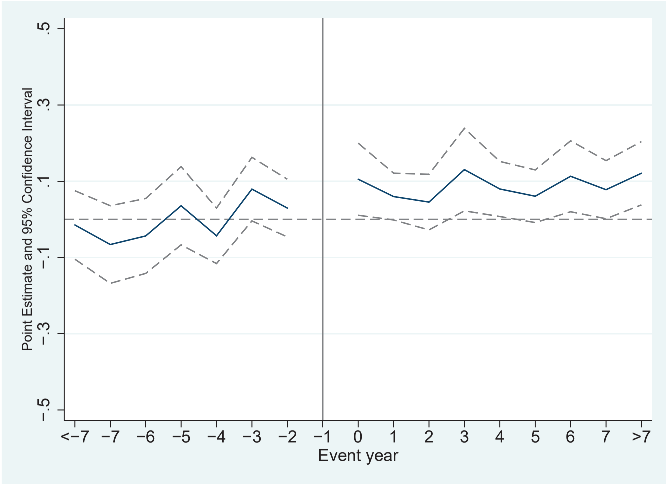
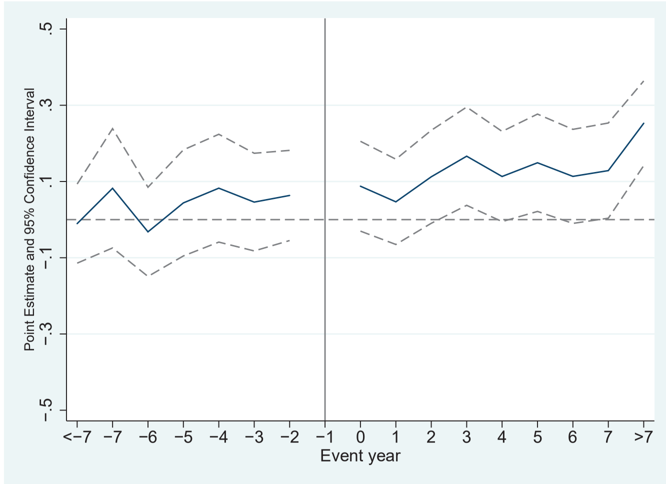
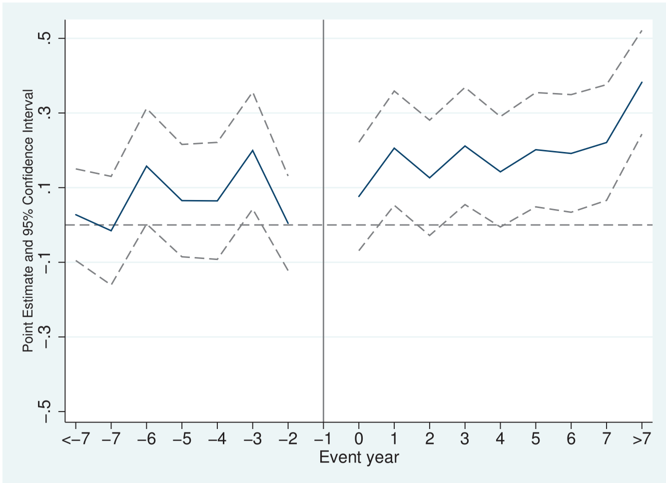
Figure 5: Dynamic Effects



(a) Adoption



(b) Sourcing



(c) Collaboration

Figure 5a shows the dynamic effect of bilateral investment treaties on the adoption of partner countries' technology around the year of signing. Figure 5b shows the dynamic effect of bilateral investment treaties on technology sourcing from partner countries around the year of signing. Figure 5c shows the dynamic effect of bilateral investment treaties on collaboration in patenting with partner countries around the year of signing.

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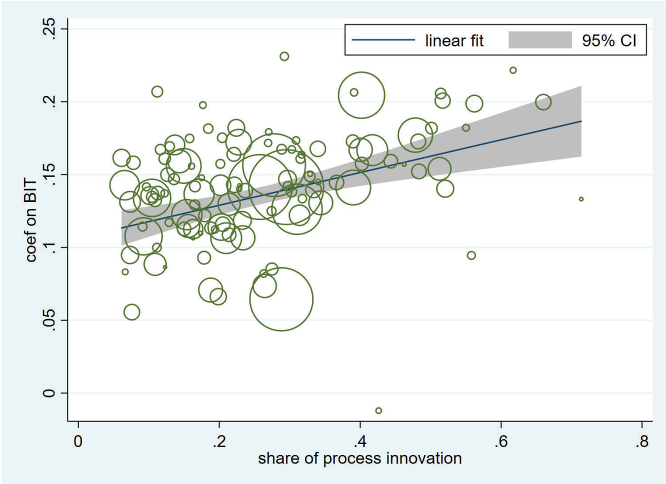
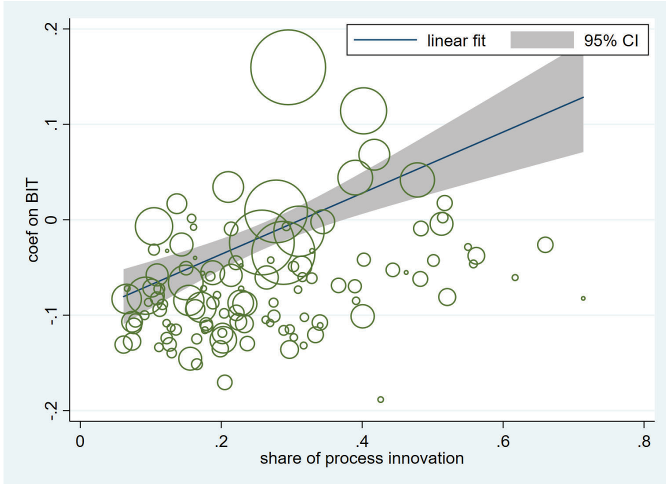
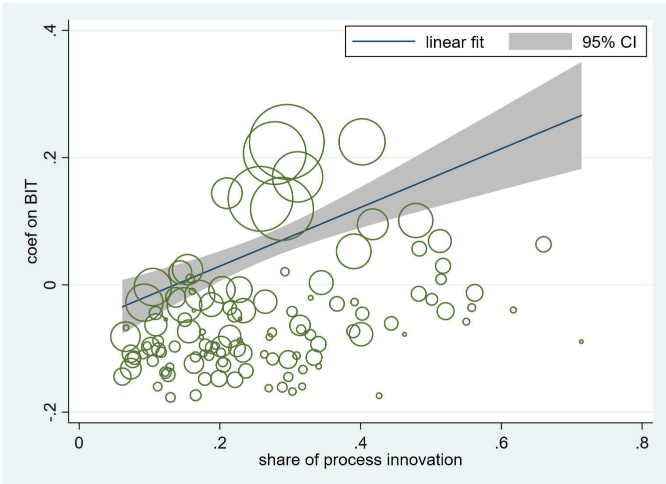
Figure 6: Process vs. Product Innovation



(a) Adoption



(b) Sourcing



(c) Collaboration

This figure illustrates the heterogeneous treatment effects for technology classes with different fractions of process vs. product innovation. The x axis shows the share of process innovation for each technology class (IPC 3-digit class). The y axis shows the magnitude of the treatment effect (i.e., the estimated coefficient on BIT). The fitted line shows the linear relationship between the two variables across technology classes. The size of the bubble indicates the number of patents in each technology class. Figure 6a shows the effects of BITs on the adoption of foreign technology. Figure 6b shows the effects of BITs on technology transfer from foreign inventors. Figure 6c shows the effects of BITs on international co-invention.

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Table 1: Summary Statistics

Panel A: Patent level

Globalization measures	Globalized # (%) of obs	Globalized Citations (family)	Globalized Citations (individual)	Local # (%) of obs	Local Citations (family)	Local Citations (individual)
Adoption	22,406,295 (33.5%)	17.2	3.3	44,533,388 (66.5%)	2.9	2.9
Foreign citation	11,906,129 (17.8%)	15.0	10.1	55,033,554 (82.2%)	6.1	1.6
Transfer	2,336,952 (3.5%)	16.3	6.7	64,602,731 (96.5%)	7.4	2.9
Co-invention	1,446,950 (2.2%)	17.1	5.6	65,492,733 (97.8%)	7.5	3.0
Co-application	816,647 (1.2%)	14.7	7.5	66,123,036 (98.8%)	7.6	3.0
Any of the above	27,251,029 (40.7%)	16.1	5.2			
None of the above				39,688,654 (59.3%)	1.9	1.6
Total	66,939,683	7.7	3.1			

Panel B: Country-pair-year level

Globalization measures	Full Sample # of obs	Full Sample Applied	Full Sample Granted	Restricted Sample # of obs	Restricted Sample Applied	Restricted Sample Granted
Adoption	1,547,340	7.2	4.4	826,950	13.5	8.2
Foreign citation	1,547,340	17.1	11.4	826,950	32.1	21.4
Transfer	1,547,340	2.0	1.1	826,950	3.8	2.1
Co-invention	1,547,340	2.5	1.3	826,950	4.7	2.4
Co-application	1,547,340	0.8	0.4	826,950	1.5	0.7
Number of countries		205			150	
Number of country pairs		41,820			22,350	

Panel A reports the number and the share of globalized vs. local patents for each measure of innovation globalization. Panel A also compares the number of forward citations received by globalized vs. local patent patents or patent families. Panel B presents the mean number of patent applications and granted patents for each globalization measure at the country-pair-year level. The full sample includes all countries and the restricted sample excludes countries with few innovations (below 50 patents). Among the five globalization measures, adoption, foreign citation, and transfer are directional while co-invention and co-application are non-directional.

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Table 2: The Value of Globalized Innovation

Panel A: Private Value of Globalized vs Local Patents

Globalization measures	Globalized			Local			Diff
	Mean	Median	SD	Mean	Median	SD	
Adoption	41.77	13.68	100.91	31.07	11.69	83.50	10.70***
Foreign citation	33.80	12.45	88.29	31.89	10.89	85.35	1.91***
Transfer	39.11	13.96	94.61	32.66	11.84	86.70	6.45***
Co-invention	45.43	13.00	104.11	32.79	12.05	86.71	12.64***
Co-application	60.93	25.99	120.77	33.38	12.05	87.93	27.54***
Any of the above	35.02	12.72	90.57				
None of the above				28.74	10.20	79.58	6.28***

Panel B: Correlation with Future Domestic Innovation

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	ln (# of domestic patents)				
ln (lagged # globalized patents)	0.150***	0.157***	0.114***	0.080***	0.100***
	[0.020]	[0.014]	[0.012]	[0.011]	[0.013]
Globalized patents measured by	adoption	citation	transfer	co-invention	co-application
Country × Year FE	YES	YES	YES	YES	YES
Country × Class FE	YES	YES	YES	YES	YES
Class × Year FE	YES	YES	YES	YES	YES
Obs	606,900	606,900	606,900	606,900	606,900
Adj. R-sq	0.939	0.939	0.938	0.938	0.938

Panel C: Correlation with Future GDP

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	ln (GDP)				
ln (lagged # globalized patents)	0.003	0.057***	0.050***	0.058***	0.028*
	[0.012]	[0.018]	[0.017]	[0.018]	[0.015]
Globalized patents measured by	adoption	citation	transfer	co-invention	co-application
Country FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Obs	4,230	4,230	4,230	4,230	4,230
Adj. R-sq	0.993	0.993	0.993	0.993	0.993

Panel A compares the private economic value of globalized versus local patents using the patent-level stock market response measure from Kogan et al. (2017). The sample is based on patents granted to U.S. public firms by USPTO. Patent values are in millions of dollars (nominal). Panels B and C examine the relationship between a country's lagged number of globalized patents and its number of domestic patents, respectively. Panel B is at the country-year-technology class level, controlling for country-year fixed effects, country-class fixed effects, and class-year fixed effects. Panel C is at the country-year level, controlling for country fixed effects and year fixed effects. All samples are from 1980 to 2016. Robust standard errors clustered at the country level are reported in brackets. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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Table 3: Impact of BITs on the Adoption of Partner Countries' Technology

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries					
	application	grant	citation-w	application	grant	citation-w
BIT	0.185***	0.146***	0.148***	0.133***	0.097***	0.120***
	[0.028]	[0.027]	[0.028]	[0.033]	[0.034]	[0.031]
Year FE	YES	YES	YES	Absorbed	Absorbed	Absorbed
Country × Year FE	NO	NO	NO	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.621	0.604	0.593	0.631	0.609	0.599

The table examines how bilateral investment treaties affect the adoption of partner countries' technology. The unit of observation is a country-pair year. The coefficients in columns (1) to (3) are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\kappa_t} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

The coefficients in columns (4) to (6) are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair and year fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$ and $\boldsymbol{\kappa_t}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. All dependent variables are scaled by the total amount between country j and all partner countries. The dependent variable in columns (1) and (4) (columns (2) and (5)) is based on the number of patent applications (granted patents) in country j whose priority traces back to country i. The dependent variable in columns (3) and (6) is based on the citation-weighted number of granted patents in country j whose priority traces back to country i. The sample period is 1980 to 2016. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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Table 4: Impact of BITs on Technology Sourcing from Partner Countries

Panel A: Citation of Foreign Knowledge

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries					
	citation	application	grant	citation	application	grant
BIT	0.246***	0.295***	0.253***	0.243***	0.259***	0.196***
	[0.040]	[0.033]	[0.030]	[0.032]	[0.032]	[0.032]
Year FE	YES	YES	YES	Absorbed	Absorbed	Absorbed
Country × Year FE	NO	NO	NO	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.637	0.510	0.486	0.663	0.522	0.495

Panel B: Transfer of Foreign Knowledge

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries					
	application	grant	citation-w	application	grant	citation-w
BIT	0.253***	0.229***	0.243***	0.169***	0.126**	0.140***
	[0.045]	[0.045]	[0.048]	[0.047]	[0.049]	[0.050]
Year FE	YES	YES	YES	Absorbed	Absorbed	Absorbed
Country × Year FE	NO	NO	NO	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.356	0.357	0.334	0.373	0.375	0.356

The table examines how bilateral investment treaties affect technology sourcing from partner countries through patent citations (Panel A) and patent transfers (Panel B). The unit of observation is a country-pair year. The coefficients in columns (1) through (3) are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\kappa_t} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

The coefficients in columns (4) through (6) are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair and year fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$ and $\boldsymbol{\kappa_t}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. All dependent variables are scaled by the total amount between country j and all partner countries. In Panel A, the dependent variable in columns (1) and (4) is based on the number of times country j's patents cite country i's patents. The dependent variable in columns (2) and (5) (columns (3) and (6)) is based on the number of patent applications (granted patents) in country j that cite country i's patents. In Panel B, the dependent variable in columns (1) and (4) (columns (2) and (5)) is based on the number of patent applications (granted patents) in country j that are transferred from inventors in country i. The dependent variable in columns (3) and (6) is based on the citation-weighted number of granted patents in country j that are transferred from inventors in country i. The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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Table 5: The Impact of BITs on Innovation Collaboration

Panel A: Co-invention

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries					
	application	grant	citation-w	application	grant	citation-w
BIT	0.333***	0.355***	0.392***	0.268***	0.254***	0.300***
	[0.047]	[0.048]	[0.051]	[0.047]	[0.049]	[0.049]
Year FE	YES	YES	YES	Absorbed	Absorbed	Absorbed
Country × Year FE	NO	NO	NO	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.437	0.430	0.404	0.450	0.440	0.419

Panel B: Co-application

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries					
	application	grant	citation-w	application	grant	citation-w
BIT	0.333***	0.259***	0.248***	0.218***	0.148***	0.164***
	[0.044]	[0.040]	[0.041]	[0.047]	[0.046]	[0.045]
Year FE	YES	YES	YES	Absorbed	Absorbed	Absorbed
Country × Year FE	NO	NO	NO	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.248	0.232	0.215	0.280	0.263	0.248

The table shows how bilateral investment treaties affect international collaboration in patenting (co-invention and co-application). The unit of observation is a country-pair year. The coefficients in columns (1) to (3) are obtained by estimating the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\kappa_t} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

The coefficients in columns (4) to (6) are obtained by estimating the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i and j index country, and t indexes year. Country-pair and year fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$ and $\boldsymbol{\kappa_t}$. Country × year fixed effects are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. All dependent variables are scaled by the total amount between country j and all partner countries. In Panel A (Panel B), the dependent variable in columns (1) and (4) (columns (2) and (5)) is based on the number of patent applications (granted patents) involving inventors (applicants) from both country j and country i. The dependent variable in columns (3) and (6) is based on the citation-weighted number of granted patents involving inventors (applicants) from both country j and country i. The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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Table 6: The Impact of BITs on Technology Convergence

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	Proximity: overlap in technology area					
	Class			Subclass		
	flow-flow	3yr stock-flow	10yr stock-flow	flow-flow	3yr stock-flow	10yr stock-flow
BIT	0.009***	0.006***	0.005***	0.012***	0.011***	0.012***
	[0.002]	[0.002]	[0.002]	[0.001]	[0.001]	[0.001]
Country × Year FE	YES	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.809	0.825	0.853	0.794	0.808	0.832

The table shows how bilateral investment treaties affect the overlap in technology classes between countries. The unit of observation is a country-pair year. The coefficients are obtained by estimating the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i and j index country, and t indexes year. Country-pair and year fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$ and $\boldsymbol{\kappa_t}$. Country × year fixed effects are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. Proximity is measured by the cosine similarity between country i and country j's patenting weights across technology classes. Columns (1) to (3) measure proximity at the 3-digit IPC class level. Columns (4) to (6) measure proximity at the 4-digit IPC subclass level. In columns (1) and (4), the cosine similarity is between country i's and country j's 1-year flows of patent applications. In columns (2) and (5) (columns (3) and (6)), the cosine similarity is between country i's 3-year (10-year) patent stock and country j's 1-year patent flow. The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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Table 7: Cross-BIT Variation in Treatment Intensity: Distance in Institutions

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.127***	0.272***	0.177***	0.271***	0.221***
	[0.034]	[0.033]	[0.048]	[0.048]	[0.049]
BIT × Institution_diff	0.113***	0.172***	0.052	0.180***	0.112**
	[0.026]	[0.038]	[0.044]	[0.046]	[0.045]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	699,522	699,522	699,522	699,522	699,522
Adj. R-sq	0.631	0.533	0.387	0.466	0.287

The table shows how bilateral investment treaties differentially affect the globalization of innovation for country-pairs that are more distant in their institutional environments as measured by rule of law. Country-level rule of law data come from the Worldwide Governance Indicators. The unit of observation is a country-pair year. The coefficients are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \kappa BIT_{ij,t} \times Institution\_diff_{ij} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. $Institution\_diff_{ij}$ is country i's rule of law score minus country j's rule of law score. All dependent variables are scaled by the total amount between country j and all partner countries. The dependent variables are based on the number of patent applications in country j with the following globalization characteristics: adoption (priority traces back to country i), citation (cite country i's patents), transfer from country i's inventors, co-invention (co-invent with country i's inventors), and co-application (co-apply with country i's applicants). The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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Table 8: Within-BIT Variation in Treatment Intensity: Shock from *Maffezini v. Spain*

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.186***	0.247***	-0.093	0.167**	0.016
	[0.051]	[0.054]	[0.080]	[0.076]	[0.081]
BIT × Post-ruling	-0.010	0.152***	0.513***	0.268***	0.425***
	[0.051]	[0.048]	[0.082]	[0.075]	[0.092]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	768,046	768,046	768,046	768,046	768,046
Adj. R-sq	0.634	0.529	0.380	0.458	0.284

The table shows the differential impacts of pre-2000 bilateral investment treaties before and after the arbitration decision of *Maffezini v. Spain* in January, 2000. The sample excludes country-pairs that signed BITs in or after 2000. The unit of observation is a country-pair year. The coefficients are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \kappa BIT_{ij,t} \times Post - ruling_t + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. $Post - ruling$ indicates calendar years of or after 2000. All dependent variables are scaled by the total amount between country j and all partner countries. The dependent variables are based on the number of patent applications in country j with the following globalization characteristics: adoption (priority traces back to country i), citation (cite country i's patents), transfer from country i's inventors, co-invention (co-invent with country i's inventors), and co-application (co-apply with country i's applicants). The sample period is 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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Table 9: Cross-sectional Heterogeneity

Panel A: Distance in Technological Development

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.133***	0.252***	0.166***	0.265***	0.213***
	[0.033]	[0.031]	[0.047]	[0.047]	[0.047]
BIT × Tech_diff	0.086**	0.201***	0.210**	0.248***	0.167*
	[0.039]	[0.073]	[0.082]	[0.081]	[0.086]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.631	0.525	0.374	0.450	0.281

Panel B: Process vs. Product Innovation

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijc,t}/\sum_i Y_{ijc,t}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT × Process_Share	0.045**	0.039***	0.067***	0.098***	0.027
	[0.020]	[0.014]	[0.020]	[0.021]	[0.019]
Country × Year × Class FE	YES	YES	YES	YES	YES
Country-pair FE × Class FE	YES	YES	YES	YES	YES
Country-pair FE × Year FE	YES	YES	YES	YES	YES
Obs	81,845,700	81,845,700	81,845,700	81,845,700	81,845,700
Adj. R-sq	0.387	0.345	0.237	0.260	0.212

Panel A shows how bilateral investment treaties differentially affect the globalization of innovation for country-pairs that have different distances in their technological development levels. The unit of observation is a country-pair year. The coefficients are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \kappa BIT_{ij,t} \times Tech\_diff_{ij,t-1} + \varepsilon_{ij,t}$$

Panel B shows how bilateral investment treaties differentially affect the globalization of process versus product innovation. The unit of observation is a country-pair-technology-class-year. The coefficients are estimated from the following specification:

$$Y_{ijc,t} = \boldsymbol{\gamma_{ijc}} + \boldsymbol{\alpha_{ij,t}} + \boldsymbol{\delta_{ic,t}} + \boldsymbol{\vartheta_{jc,t}} + \kappa BIT_{ij,t} \times Process\_Share_c + \varepsilon_{ijc,t}$$

where i and j index country, c indexes technology class (3-digit IPC class), and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. Country-pair × class fixed effects are indicated by $\boldsymbol{\gamma_{ijc}}$. Country-pair × year fixed effects are indicated by $\boldsymbol{\alpha_{ij,t}}$. Country × year × class fixed effects are indicated by $\boldsymbol{\delta_{ic,t}}$ and $\boldsymbol{\vartheta_{jc,t}}$. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. $Tech\_diff_{ij,t-1}$ is the difference between country i and country j's technological development as measured by the lagged number of patent applications. $Process\_Share_c$ denotes the share of process innovation in each technology class (Bena and Simintzi, 2019). In Panel A, all dependent variables are scaled by the total amount between country j and all partner countries. In Panel B, all dependent variables are scaled by the total amount for class c between country j and all partner countries. The dependent variables are based on the number of patent applications in country j with the following globalization characteristics: adoption (priority traces back to country i), citation (cite country i's patents), transfer from country i's inventors, co-invention (co-invent with country i's inventors), and co-application (co-apply with country i's applicants). The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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Table 10: Channels

Panel A: Joint Ventures and Strategic Alliances

	(1)	(2)	(3)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries		
	joint venture	strategic alliance	tech transfer and licensing
BIT	0.211***	0.135***	0.116***
	[0.048]	[0.038]	[0.032]
Country × Year FE	YES	YES	YES
Country-pair FE	YES	YES	YES
Obs	603,450	603,450	603,450
Adj. R-sq	0.191	0.283	0.275

Panel B: Mergers and Acquisitions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries						
	M&A	M&A high-R&D ind.	M&A low-R&D ind.	Mergers high-R&D ind.	Mergers low-R&D ind.	Acq Majority high-R&D ind.	Acq Majority low-R&D ind.
BIT	0.302***	0.288***	0.133***	0.136***	0.031	0.227***	0.098**
	[0.045]	[0.043]	[0.041]	[0.039]	[0.035]	[0.041]	[0.039]
p (diff)		0.001		0.015		0.005	
Country × Year FE	YES	YES	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.218	0.212	0.149	0.202	0.126	0.163	0.119

Panel C: Greenfield Investments

	(1)	(2)	(3)	(4)
Dep. Var.	$Y_{ijt}/\sum_j Y_{ijt}$: share among all partner countries			
	# of projects	total capital invested	# of projects R&D-related	# of projects non-R&D-related
BIT	0.000	0.019	-0.036	-0.004
	[0.072]	[0.114]	[0.066]	[0.073]
Country × Year FE	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES
Obs	312,900	312,900	312,900	312,900
Adj. R-sq	0.218	0.270	0.329	0.420

The table examines how bilateral investment treaties affect various forms of foreign investments between signatory countries sorted by the amount contracting frictions from high to low: joint ventures and strategic alliances (Panel A), mergers and acquisitions (Panel B), and greenfield investment (Panel C). The unit of observation is a country-pair year. The coefficients are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the source country, j indexes the destination country, and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for the source and destination countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. All dependent variables are scaled by the total amount between country j and all partner countries. In Panel A, the dependent variables are the number of joint ventures, strategic alliances, and technology transfer- or licensing-induced joint ventures or strategic alliances between country i and country j. In Panel B, the dependent variables are the number of M&As, M&As in high- vs. low-R&D industries, mergers in high- vs. low-R&D industries, and acquisitions of majority stakes in high- vs. low-R&D industries from country i to country j. A merger or acquisition is in a high-R&D industry if either the acquirer or the target belongs to an 2-digit SIC with above median R&D-to-total assets ratio. $p(diff)$ indicates the p-value of differences in coefficients across equations. In Panel C, the dependent variables are the number of greenfield investment projects or the total dollar amount of greenfield investments from country i to country j. Columns 3 and 4 partition the number of greenfield projects based on whether they are R&D-related. The sample period is 1990-2016 in Panels A, 1980-2016 in Panel B, and 2003-2016 in Panel C. Joint ventures, strategic alliances, and M&As data come from Refinitiv SDC; greenfield investment project data come from fDi Markets. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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Internet Appendix to "Cross-Border Institutions and the Globalization of Innovation"

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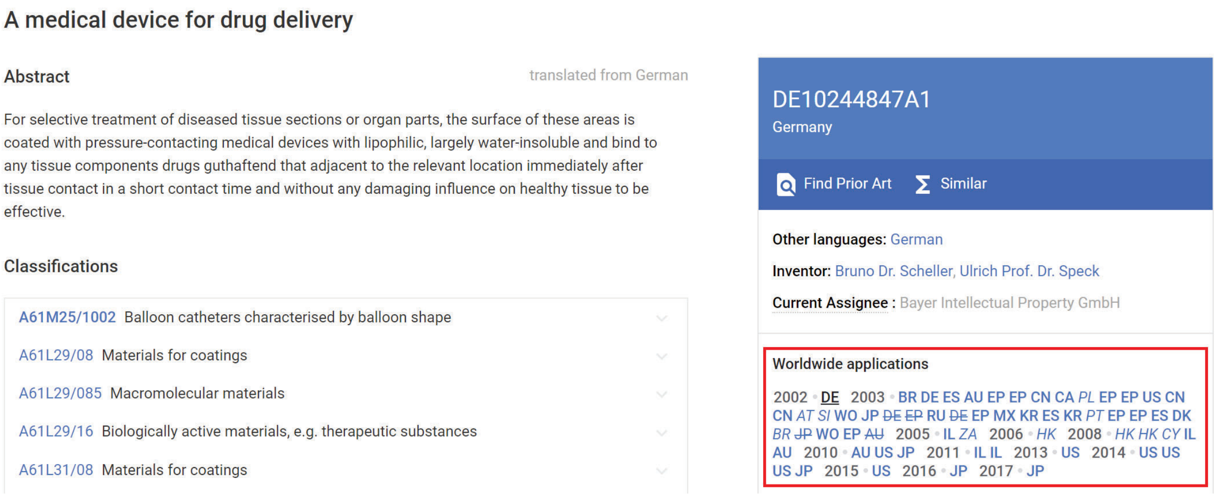
Figure A.1: Example — Adoption Measured from Patent Priority



This figure shows an example of patent priority, based on which we measure technology adoption. A priority right is triggered by the first filing of an application for a patent. The priority right allows the claimant to file a subsequent application in another country for the same invention effective as of the filing date of the first application. The sequence of applications captures the timing of adoption of the same technology across different countries. In this example, the German pharmaceutical company Bayer patented a medical invention initially in 2002 in Germany, and later filed subsequent patents for the same invention in other countries (patent offices).

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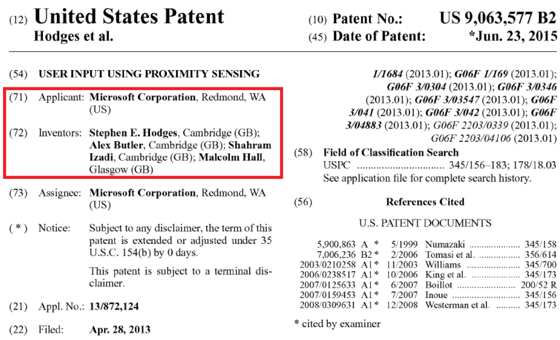
Figure A.2: Example — Sourcing from Foreign Knowledge

Publication number	Priority date	Publication date	Assignee	
US20050047046A1	2003-08-29	2005-03-03	Microsoft Corporation	US
US20050160181A1 *	2004-01-15	2005-07-21	Samsung Electronics Co., Ltd.	Korea
US20060034217A1 *	2004-08-11	2006-02-16	Samsung Electronics Co., Ltd.	Korea
EP1838011A1	2006-03-23	2007-09-26	Interuniversitair Microelektronica Centrum (Imec)	Belgium
US20080095263A1	2006-06-29	2008-04-24	Hao Xu	US
CN101252489A	2007-12-04	2008-08-27	深圳市宙码通讯有限公司	China
EP2063548A1	2007-11-23	2009-05-27	Alcatel Lucent	France
JP2009303029A	2008-06-16	2009-12-24	Ntt Docomo Inc	Japan
US20100098184A1	2008-10-16	2010-04-22	Sun-Heui Ryoo	Korea
US20100120466A1	2008-11-12	2010-05-13	Nokia Corporation	Finland
CN101854706A	2009-03-30	2010-10-06	雷凌科技股份有限公司	China
EP2444875A2	2010-10-25	2012-04-25	Broadcom Corporation	US
US20120149411A1	2010-12-08	2012-06-14	Hitachi, Ltd.	Japan

(a) Citation of Foreign Knowledge



(12) **United States Patent**
Hodges et al.

(10) **Patent No.:** **US 9,063,577 B2**
(45) **Date of Patent:** ***Jun. 23, 2015**

(54) **USER INPUT USING PROXIMITY SENSING**

(71) Applicant: **Microsoft Corporation**, Redmond, WA (US)

(72) Inventors: **Stephen E. Hodges**, Cambridge (GB); **Alex Butler**, Cambridge (GB); **Shahram Izadi**, Cambridge (GB); **Malcolm Hall**, Glasgow (GB)

(73) Assignee: **Microsoft Corporation**, Redmond, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/872,124**

(22) Filed: **Apr. 28, 2013**

1/1684 (2013.01); ***G06F 1/169*** (2013.01); ***G06F 3/0304*** (2013.01); ***G06F 3/0346*** (2013.01); ***G06F 3/03547*** (2013.01); ***G06F 3/041*** (2013.01); ***G06F 3/042*** (2013.01); ***G06F 3/04883*** (2013.01); *G06F 2203/0339* (2013.01); *G06F 2203/04106* (2013.01)

(58) **Field of Classification Search**
USPC 345/156–183; 178/18.03
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,900,863	A *	5/1999	Numazaki	345/158
7,006,236	B2 *	2/2006	Tomasi et al.	356/614
2003/0210258	A1 *	11/2003	Williams	345/700
2006/0238517	A1 *	10/2006	King et al.	345/173
2007/0125633	A1 *	6/2007	Boillot	200/52 R
2007/0159453	A1 *	7/2007	Inoue	345/156
2008/0309631	A1 *	12/2008	Westerman et al.	345/173

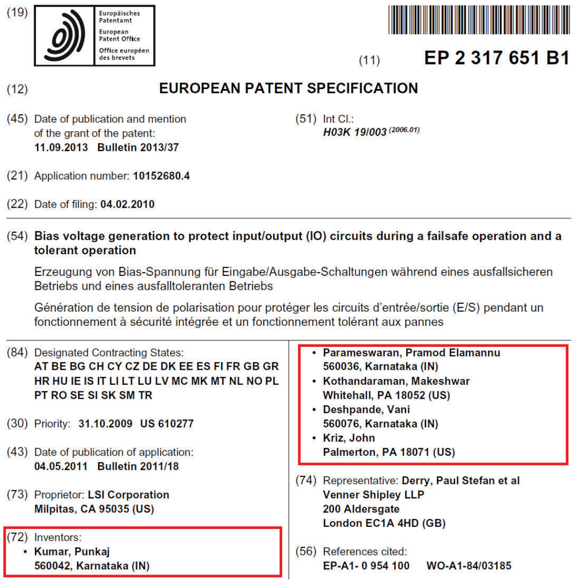
* cited by examiner

(b) Transfer of Foreign Knowledge

The left panel shows an example of citation of foreign knowledge. This patent application, titled "Method and Wi-Fi device for setting communications mode," is from Huawei Device Shenzhen Co Ltd from China. It cites 13 patents from seven countries, of which six are foreign countries. The right panel shows an example of technology transfer. The patent, titled "User input using proximity sensing," is transferred from inventors in the U.K. to the U.S. assignee (or applicant), Microsoft Corporation.

Electronic copy available at: https://ssrn.com/abstract=3503092

Figure A.3: Example — International Collaboration in Patenting



(19) Europäisches Patentamt European Patent Office Office européen des brevets

(11) **EP 2 317 651 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent: **11.09.2013 Bulletin 2013/37**

(51) Int Cl.: ***H03K 19/003*** *(2006.01)*

(21) Application number: **10152680.4**

(22) Date of filing: **04.02.2010**

(54) **Bias voltage generation to protect input/output (IO) circuits during a failsafe operation and a tolerant operation**

Erzeugung von Bias-Spannung für Eingabe/Ausgabe-Schaltungen während eines ausfallsicheren Betriebs und eines ausfalltoleranten Betriebs

Génération de tension de polarisation pour protéger les circuits d'entrée/sortie (E/S) pendant un fonctionnement à sécurité intégrée et un fonctionnement tolérant aux pannes

(84) Designated Contracting States: **AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR**

(30) Priority: **31.10.2009 US 610277**

(43) Date of publication of application: **04.05.2011 Bulletin 2011/18**

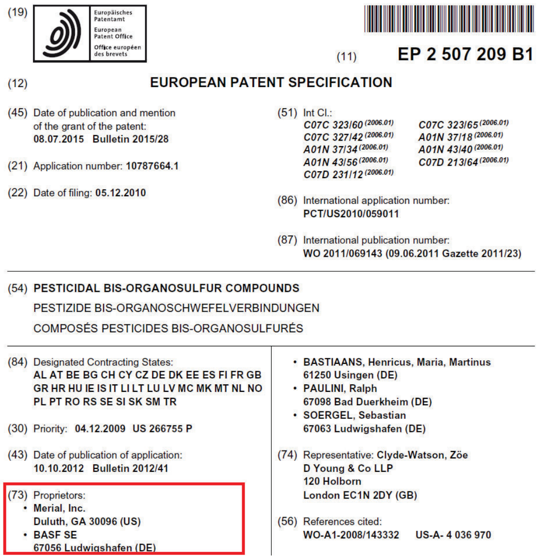
(73) Proprietor: **LSI Corporation Milpitas, CA 95035 (US)**

(72) Inventors:
- **Kumar, Punkaj 560042, Karnataka (IN)**
- **Parameswaran, Pramod Elamannu 560036, Karnataka (IN)**
- **Kothandaraman, Makeshwar Whitehall, PA 18052 (US)**
- **Deshpande, Vani 560076, Karnataka (IN)**
- **Kriz, John Palmerton, PA 18071 (US)**

(74) Representative: **Derry, Paul Stefan et al Venner Shipley LLP 200 Aldersgate London EC1A 4HD (GB)**

(56) References cited: **EP-A1- 0 954 100 WO-A1-84/03185**

(a) Co-invention



(19) Europäisches Patentamt European Patent Office Office européen des brevets

(11) **EP 2 507 209 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent: **08.07.2015 Bulletin 2015/28**

(51) Int Cl.: ***C07C 323/60*** *(2006.01)* ***C07C 323/65*** *(2006.01)* ***C07C 327/42*** *(2006.01)* ***A01N 37/18*** *(2006.01)* ***A01N 37/34*** *(2006.01)* ***A01N 43/40*** *(2006.01)* ***A01N 43/56*** *(2006.01)* ***C07D 213/64*** *(2006.01)* ***C07D 231/12*** *(2006.01)*

(21) Application number: **10787664.1**

(22) Date of filing: **05.12.2010**

(86) International application number: **PCT/US2010/059011**

(87) International publication number: **WO 2011/069143 (09.06.2011 Gazette 2011/23)**

(54) **PESTICIDAL BIS-ORGANOSULFUR COMPOUNDS**

PESTIZIDE BIS-ORGANOSCHWEFELVERBINDUNGEN

COMPOSÉS PESTICIDES BIS-ORGANOSULFURÉS

(84) Designated Contracting States: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(30) Priority: **04.12.2009 US 266755 P**

(43) Date of publication of application: **10.10.2012 Bulletin 2012/41**

(73) Proprietors:
- **Merial, Inc. Duluth, GA 30096 (US)**
- **BASF SE 67056 Ludwigshafen (DE)**

(72) Inventors:
- **BASTIAANS, Henricus, Maria, Martinus 61250 Usingen (DE)**
- **PAULINI, Ralph 67098 Bad Duerkheim (DE)**
- **SOERGEL, Sebastian 67063 Ludwigshafen (DE)**

(74) Representative: **Clyde-Watson, Zöe D Young & Co LLP 120 Holborn London EC1N 2DY (GB)**

(56) References cited: **WO-A1-2008/143332 US-A- 4 036 970**

(b) Co-application

The left panel shows an example of patent co-invention, in which inventors from different countries (in this case, the United States and India) show up simultaneously on the same patent. The right panel shows an example of patent co-application, in which applicants from different countries (in this case, the United States and Germany) show up simultaneously on the same patent.

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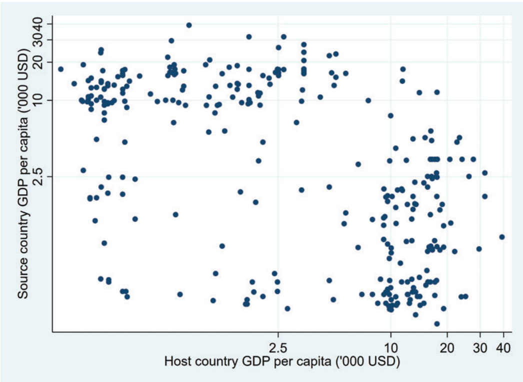
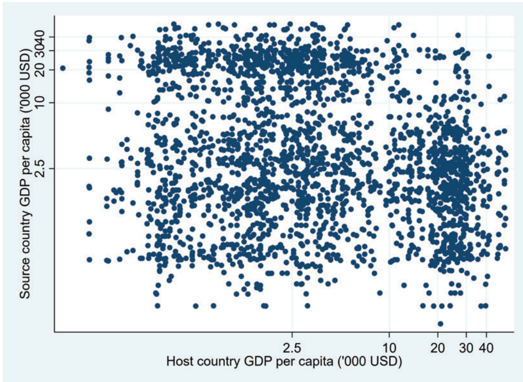
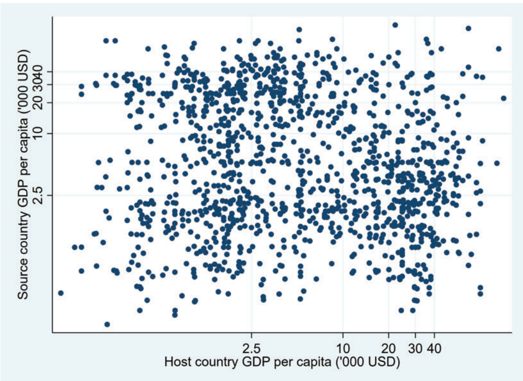
Figure A.4: Distribution of BITs: GDP per Capita



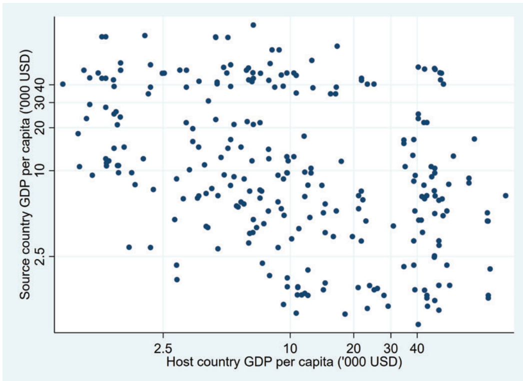
(a) Newly signed BITs: 1980-1989



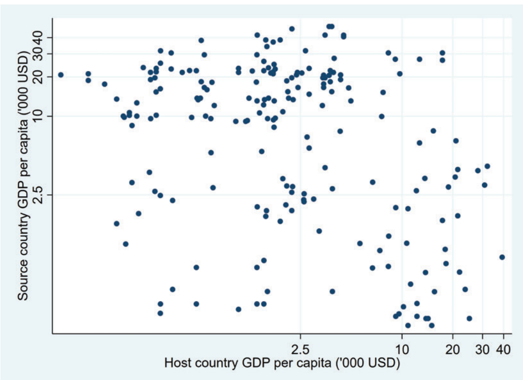
(b) Newly signed BITs: 1990-1999



(c) Newly signed BITs: 2000-2009



(d) Newly signed BITs: 2010-2016



(e) First three BITs

(f) All active BITs by 2016

This figure plots the distribution of BITs according to the GDP per capita of the host country (x axis) and the source country (y axis). Each dot represents one treaty.

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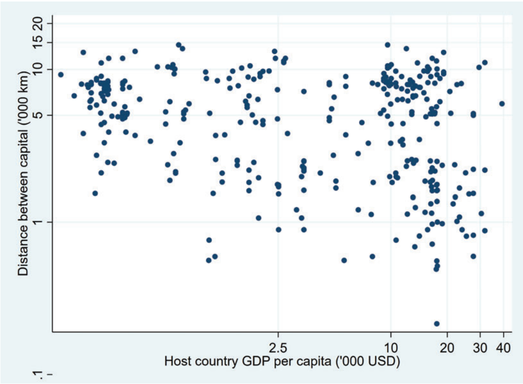
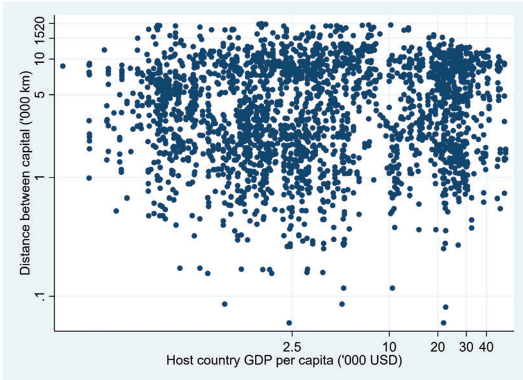
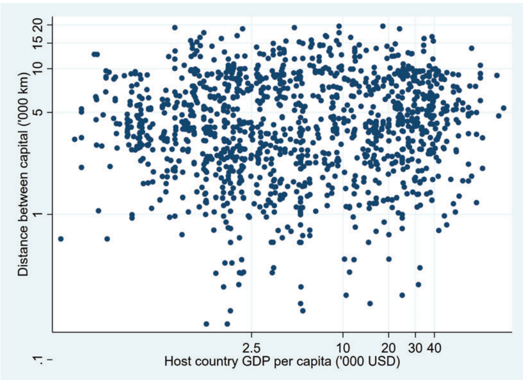
Figure A.5: Distribution of BITs: Distance Between Capitals



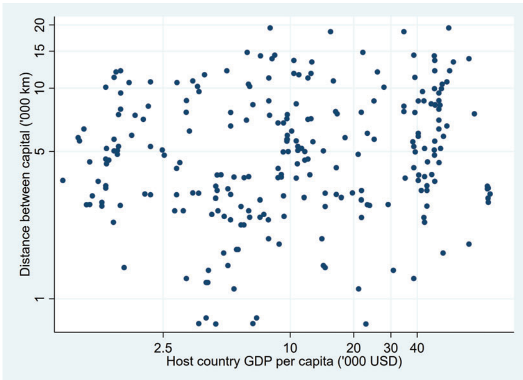
(a) Newly signed BITs: 1980-1989



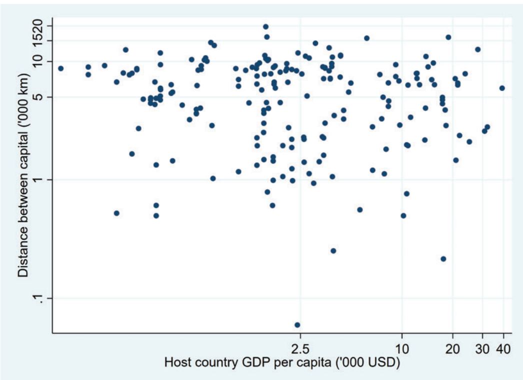
(b) Newly signed BITs: 1990-1999



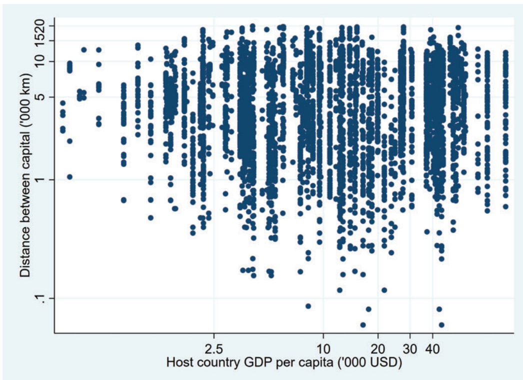
(c) Newly signed BITs: 2000-2009



(d) Newly signed BITs: 2010-2016



(e) First three BITs



(f) All active BITs by 2016

This figure plots the distribution of BITs according to the GDP per capita of the host country (x axis) and the geographical distance between the host and source country's capitals (y axis). Each dot represents one treaty.

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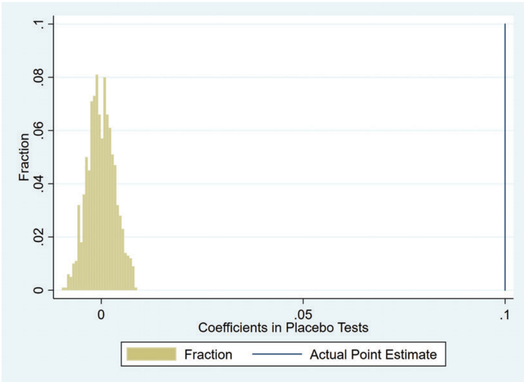
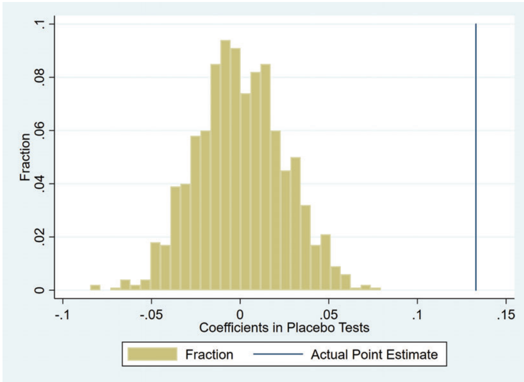
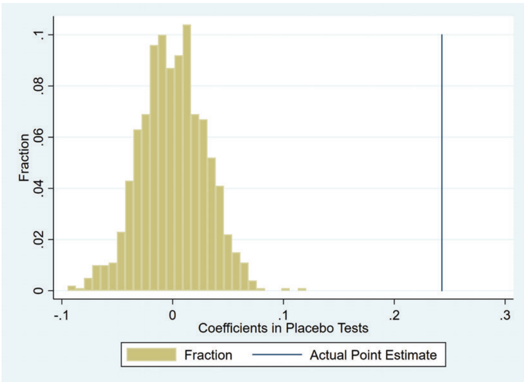
Figure A.6: True Estimate vs. Placebo Estimates



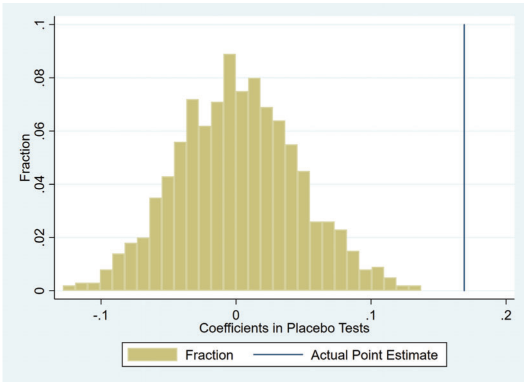
(a) Any type



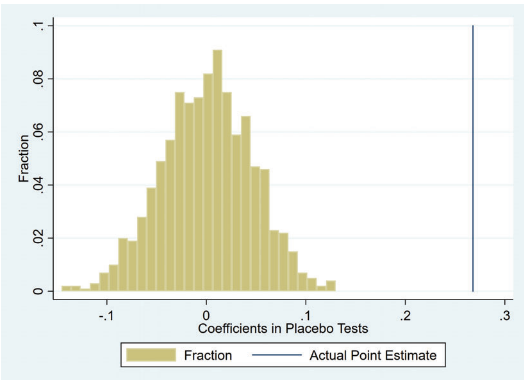
(b) Adoption



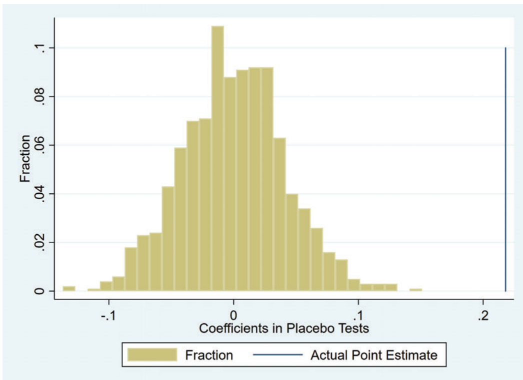
(c) Sourcing: Citation



(d) Sourcing: Transfer



(e) Collaboration: Co-invention



(f) Collaboration: Co-application

This figure plots the histogram of the estimated coefficients on BITs from 1,000 placebo tests. Each placebo test keeps a country's number of BITs and their timing fixed but randomly assigns BITs to partner countries. The sample and regression specifications are the same as those in Table 3.

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Table A.1: Robustness — Double Clustering of Standard Errors

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.133**	0.259**	0.169***	0.268**	0.218***
	[0.061]	[0.117]	[0.064]	[0.105]	[0.074]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.624	0.519	0.37	0.447	0.276

The table reproduces our main analyses by double clustering standard errors by both the host and the source countries. The unit of observation is a country-pair year. The coefficients are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. All dependent variables are scaled by the total amount between country j and all partner countries. The dependent variables are based on the number of patent applications in country j with the following globalization characteristics: adoption (priority traces back to country i), citation (cite country i's patents), transfer from country i's inventors, co-invention (co-invent with country i's inventors), and co-application (co-apply with country i's applicants). The sample is from 1980 to 2016 in all columns. Robust standard errors double clustered at the country i level and country j level are reported in brackets. ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

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Table A.2: Extensive Margin

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	Dummy for positive number of patent applications				
	adoption	citation	transfer	co-invention	co-application
BIT	0.052***	0.057***	0.034***	0.075***	0.000
	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.681	0.646	0.577	0.589	0.54
Dep. Var. Mean	0.084	0.113	0.067	0.083	0.047

The table shows how bilateral investment treaties affect the probability of globalization in innovation (extensive margin). The unit of observation is a country-pair year. The coefficients are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. The dependent variables are dummies indicating whether there is a positive number of patent applications in country j with the following globalization characteristics: adoption (priority traces back to country i), citation (cite country i's patents), transfer from country i's inventors, co-invention (co-invent with country i's inventors), and co-application (co-apply with country i's applicants). The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

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Table A.3: Robustness — Additional Controls

Panel A: Additional Country-pair-year-level Controls

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.110***	0.242***	0.128***	0.235***	0.160***
	[0.032]	[0.033]	[0.047]	[0.048]	[0.048]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.624	0.519	0.370	0.447	0.276

Panel B: Additional Controls for IP-related Agreements

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.109***	0.236***	0.121***	0.234***	0.150***
	[0.032]	[0.033]	[0.046]	[0.048]	[0.048]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.624	0.519	0.37	0.447	0.276

Panel C: Control for Region-pair-specific Shocks

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.122***	0.271***	0.145***	0.242***	0.204***
	[0.036]	[0.035]	[0.049]	[0.050]	[0.050]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Region-pair × Year FE	YES	YES	YES	YES	YES
Obs	751,322	751,322	751,322	751,322	751,322
Adj. R-sq	0.635	0.527	0.376	0.453	0.284

The table reproduces our main analyses including additional control variables. Panels A and B add country-pair-year-level controls. Panel A controls for trade volume, bilateral labor agreements, indicators for different degrees of economic integration, exchange rate arrangement, the degree of capital account openness of each country-pair, bilateral tax treaties, and tax information exchange agreements. Panel B additionally controls for Patent Cooperation Treaties, Patent Law Treaties, membership of the World Intellectual Property Organization, and membership of the Agreement on Trade-Related Aspects of Intellectual Property Rights. Panel C controls region-pair-specific shocks by adding Region-pair × Year fixed effects. We follow the definitions of UNCTAD and define five regions: Africa, Americas, Asia, Europe, and Oceania. The coefficients in Panel A and B are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \boldsymbol{\theta' X_{ij,t}} + \varepsilon_{ij,t}$$

The coefficients in Panel C are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \boldsymbol{\zeta_{r_i r_j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, t indexes year, and r_i and r_j index the regions of country i and country j. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. Region-pair × Year fixed effects are indicated by $\boldsymbol{\zeta_{r_i r_j,t}}$. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

Electronic copy available at: https://ssrn.com/abstract=3503092

Table A.4: Role of Omitted Unobservable Variables — Oster Test

Panel A: $R_{max} = min\{1.25R_c, 1\}$, δ=1

Dep. Var.	adoption	citation	transfer	co-invention	co-application
β_{adj}	0.1	0.225	0.102	0.218	0.127
Identified Set	[0.100,0.108]	[0.225,0.235]	[0.102,0.121]	[0.218,0.233]	[0.127,0.147]
Reject Null	YES	YES	YES	YES	YES
δ s.t. $\beta_{adj} = 0$	13.17	21.97	6.67	15.63	7.25

Panel B: $R_{max} = min\{1.25R_c, 1\}$, δ=2

Dep. Var.	adoption	citation	transfer	co-invention	co-application
β_{adj}	0.092	0.214	0.084	0.203	0.088
Identified Set	[0.092,0.108]	[0.214,0.235]	[0.084,0.121]	[0.203,0.233]	[0.088,0.147]
Reject Null	YES	YES	YES	YES	YES
δ s.t. $\beta_{adj} = 0$	13.17	21.97	6.67	15.63	7.25

Panel C: $R_{max} = min\{2R_c, 1\}$, δ=1

Dep. Var.	adoption	citation	transfer	co-invention	co-application
β_{adj}	0.076	0.192	0.048	0.173	0.029
Identified Set	[0.076,0.108]	[0.192,0.235]	[0.048,0.121]	[0.173,0.233]	[0.029,0.147]
Reject Null	YES	YES	YES	YES	YES
δ s.t. $\beta_{adj} = 0$	3.29	5.49	1.67	3.91	1.24

Panel D: $R_{max} = min\{2R_c, 1\}$, δ=2

Dep. Var.	adoption	citation	transfer	co-invention	co-application
β_{adj}	0.043	0.15	-0.024	0.114	-0.09
Identified Set	[0.043,0.108]	[0.150,0.235]	[-0.024,0.121]	[0.114,0.233]	[-0.090,0.147]
Reject Null	YES	YES	NO	YES	NO
δ s.t. $\beta_{adj} = 0$	3.29	5.49	1.67	3.91	1.24

This table evaluates the robustness to omitted variable bias using the tests developed in Oster (2019) with different test parameter combinations. We first estimate the regression

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where no control variables are included. The regression results are reported in column (4) in Table 3, column (5) of Panel A and Panel B in Table 4, and column (4) of Panel A and Panel B in Table 5, from which we obtain β_u and R_u — the coefficient on BIT and the R-squared for the specification without controls.

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \boldsymbol{\theta' X_{ij,t}} + \varepsilon_{ij,t}$$

where $X_{ij,t}$ includes trade volume, bilateral labor agreements, indicators for different degrees of economic integration, exchange rate arrangement, the degree of capital account openness of each country-pair, bilateral tax treaties, and tax information exchange agreements, and membership statuses for Patent Cooperation Treaties, Patent Law Treaties, membership of the World Intellectual Property Organization, and membership of the Agreement on Trade-Related Aspects of Intellectual Property Rights. The regression results are reported in columns (1) to (5) of Panel B, Table A.3, from which we obtain β_c and R_c — the coefficient on BIT and the R-squared for the specification with controls. For any given test parameter combination δ and R_{max}, Oster (2019) defines the following as an approximation of the bias-adjusted treatment effect, or β_{adj}:

$$\beta_{adj} = \beta_c - \delta[\beta_u - \beta_c]\frac{R_{max} - R_c}{R_c - R_u}$$

The recommended identified set is then the interval between β_{adj} and β_c. In the table, we report the bias-adjusted coefficient and identified set for different combinations of parameters ($R_{max} = min\{1.25R_c, 1\}$ or $R_{max} = min\{2R_c, 1\}$; $\delta = 1, 2$). We also report whether the identified set rejects the null of $\beta = 0$ and the δ value to produce a bias-adjusted coefficient of zero.

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Table A.5: Robustness — Technology Classes with Below-Median Reliance on Secrecy

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.126***	0.179***	0.145***	0.280***	0.156***
	[0.034]	[0.030]	[0.047]	[0.048]	[0.043]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.562	0.467	0.319	0.393	0.243

This table reproduces our main analyses focusing on globalized patents in technology classes that have below-median reliance on secrecy. The coefficients are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. All dependent variables are scaled by the total amount between country j and all partner countries. The dependent variables are based on the number of patent applications in country j with the following globalization characteristics: adoption (priority traces back to country i), citation (cite country i's patents), transfer from country i's inventors, co-invention (co-invent with country i's inventors), and co-application (co-apply with country i's applicants). The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

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Table A.6: Robustness — Restricting to Top Patent Offices

Panel A: Restricting to EPO

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.133***	0.148***	0.127***	0.270***	0.094**
	[0.033]	[0.026]	[0.040]	[0.041]	[0.036]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.624	0.455	0.278	0.339	0.233

Panel B: Restricting to EPO, USPTO, JPO, and WIPO

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.133***	0.259***	0.243***	0.331***	0.260***
	[0.033]	[0.033]	[0.044]	[0.046]	[0.044]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	826,950	826,950	826,950	826,950	826,950
Adj. R-sq	0.624	0.509	0.378	0.470	0.302

The table repeats our main analysis, restricting to patents issued by important patent offices when creating measures of the globalization of innovation. Panel A restricts to patents applied through EPO. Panel B restricts to patents applied through EPO, USPTO, JPO, and WIPO. The unit of observation is a country-pair year. The coefficients are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. All dependent variables are scaled by the total amount between country j and all partner countries. The dependent variables are based on the number of patent applications in country j with the following globalization characteristics: adoption (priority traces back to country i), citation (cite country i's patents), transfer from country i's inventors, co-invention (co-invent with country i's inventors), and co-application (co-apply with country i's applicants). The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

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Table A.7: Robustness — Alternative Samples

Panel A: Full Sample — All Countries

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.151***	0.268***	0.185***	0.282***	0.251***
	[0.029]	[0.030]	[0.043]	[0.044]	[0.042]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	1,547,340	1,547,340	1,547,340	1,547,340	1,547,340
Adj. R-sq	0.626	0.489	0.347	0.408	0.26

Panel B: Restricting to Countries with Above-median GDP

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.134***	0.283***	0.210**	0.437***	0.303***
	[0.049]	[0.059]	[0.094]	[0.093]	[0.090]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	366,300	366,300	366,300	366,300	366,300
Adj. R-sq	0.704	0.558	0.378	0.474	0.312

Panel C: Excluding Tax Haven Countries

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.133***	0.327***	0.162***	0.320***	0.219***
	[0.042]	[0.041]	[0.057]	[0.061]	[0.061]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	485,070	485,070	485,070	485,070	485,070
Adj. R-sq	0.629	0.542	0.392	0.488	0.32

Panel D: Excluding European Countries

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.148***	0.404***	0.200*	0.470***	0.234**
	[0.057]	[0.097]	[0.112]	[0.120]	[0.110]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	419,654	419,654	419,654	419,654	419,654
Adj. R-sq	0.745	0.605	0.445	0.539	0.397

The table shows how bilateral investment treaties affect the globalization of innovation with alternative samples. Panel A uses the full sample that includes all countries (205 countries). Panel B restricts to countries with above-median GDP in our main sample (75 countries). Panel C excludes all tax haven countries (35 countries excluded). Panel D excludes all European countries (43 countries excluded). The unit of observation is a country-pair year. The coefficients are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. All dependent variables are scaled by the total amount between country j and all partner countries. The dependent variables are based on the number of patent applications in country j with the following globalization characteristics: adoption (priority traces back to country i), citation (cite country i's patents), transfer from country i's inventors, co-invention (co-invent with country i's inventors), and co-application (co-apply with country i's applicants). The sample is from 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

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Table A.8: Process vs. Product Innovation Classes

Panel A: Top 10 Process Innovation Classes

IPC class (3 digit)	Classification	Process Share
C13	Sugar Industry	0.750
C01	Inorganic Chemistry	0.688
B09	Disposal of Solid Waste; Reclamation of Contaminated Soil	0.637
C10	Petroleum, Gas or Coke Industries; Technical Gases Containing Carbon Monoxide; Fuels; Lubricants; Peat	0.598
C30	Crystal Growth	0.598
C23	Coating Metallic Material; Coating Material with Metallic Material; Chemical Surface Treatment; Diffusion Treatment of Metallic Material; Coating by Vacuum Evaporation, by Sputtering, by Ion Implantation or by Chemical Vapour Deposition; Inhibiting Corrosion of Metallic Material or Incrustation in General	0.561
C05	Fertilizers; Manufacture thereof	0.560
C22	Metallurgy; Ferrous or Non-Ferrous Alloys; Treatment of Alloys or Non-Ferrous Metals	0.549
C12	Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Enzymology; Mutation or Genetic Engineering	0.545
C02	Treatment of Water, Waste Water, Sewage, or Sludge	0.535

Panel B: Top 10 Product Innovation Classes

IPC class (3 digit)	Classification	Process Share
E05	Locks; Keys; Window or Door Fittings; Safes	0.045
A42	Headwear	0.053
A47	Furniture; Domestic Articles or Appliances; Coffee Mills; Spice Mills; Suction Cleaners in General	0.054
F21	Lighting	0.057
B25	Hand Tools; Portable Power-Driven Tools; Manipulators	0.062
B62	Land Vehicles for Travelling Otherwise Than on Rails	0.067
A45	Hand or Travelling Articles	0.068
B43	Writing or Drawing Implements; Bureau Accessories	0.081
B63	Ships or Other Waterborne Vessels; Related Equipment	0.081
B60	Vehicles in General	0.084

The table shows the top 10 process innovation classes (Panel A) and top 10 product innovation classes (Panel B) by IPC 3 digits. Data on the share of process innovation in each technology class is from Bena and Simintzi (2019).

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Table A.9: Impact of BITs in Highly Developed Countries

Panel A: Effect of BITs on Globalized Innovation

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	$Y_{ijt}/\sum_i Y_{ijt}$: share among all partner countries				
	adoption	citation	transfer	co-invention	co-application
BIT	0.042	0.100***	0.178**	0.191***	0.258***
	[0.040]	[0.038]	[0.074]	[0.068]	[0.077]
Country × Year FE	YES	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES	YES
Obs	93,721	93,721	93,721	93,721	93,721
Adj. R-sq	0.905	0.844	0.69	0.647	0.547

Panel B: Correlation with Future Innovation

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	log (# of domestic patents)				
log (lagged # globalized patents)	0.137***	0.123***	0.076***	0.056***	0.079***
	[0.031]	[0.017]	[0.013]	[0.012]	[0.012]
Globalized patents measured by	adoption	citation	transfer	co-invention	co-application
Country × Year FE	YES	YES	YES	YES	YES
Country × IPC3d FE	YES	YES	YES	YES	YES
Year × IPC3d FE	YES	YES	YES	YES	YES
Obs	60,690	60,690	60,690	60,690	60,690
Adj. R-sq	0.938	0.938	0.937	0.937	0.937

Panel C: Correlation with Future GDP

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	log (GDP)				
log (lagged # globalized patents)	0.013	0.058*	0.042	0.084**	0.026
	[0.009]	[0.028]	[0.039]	[0.038]	[0.017]
Globalized patents measured by	adoption	citation	transfer	co-invention	co-application
Country FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Obs	572	572	572	572	572
Adj. R-sq	0.998	0.998	0.998	0.998	0.998

This table studies how bilateral investment treaties affect the globalization of innovation in developed countries that have GDP per capita in the highest decile in 1980 (Panel A). It also illustrates the value of globalized patents in these countries (Panels B and C). The coefficients in Panel A are estimated from the following specification:

$$Y_{ij,t} = \boldsymbol{\gamma_{ij}} + \boldsymbol{\alpha_{i,t}} + \boldsymbol{\delta_{j,t}} + \beta BIT_{ij,t} + \varepsilon_{ij,t}$$

where i indexes the host country, j indexes the source country, and t indexes year. Country-pair fixed effects are indicated by $\boldsymbol{\gamma_{ij}}$. Country × year fixed effects for source and host countries are indicated by $\boldsymbol{\alpha_{i,t}}$ and $\boldsymbol{\delta_{j,t}}$, respectively. $BIT_{ij,t}$ is an indicator that equals one if country i and country j have an active bilateral investment treaty in year t and zero otherwise. All dependent variables are scaled by the total amount between country j and all partner countries. The dependent variables are based on the number of patent applications in country j with the following globalization characteristics: adoption (priority traces back to country i), citation (cite country i's patents), transfer from country i's inventors, co-invention (co-invent with country i's inventors), and co-application (co-apply with country i's applicants). Panels B examines the relationship between a country's lagged number of globalized patents and its current number of domestic patents. The sample is at the country-year-technology class level, controlling for country-year fixed effects, country-class fixed effects, and class-year fixed effects. Panels C examines the relationship between a country's lagged number of globalized patents and its current GDP. The sample is at the country-year level, controlling for country fixed effects and year fixed effects. The sample period is 1980 to 2016 in all columns. Robust standard errors clustered at the country-pair level are reported in brackets. ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

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