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Do Preferential Trade Agreements Stimulate Non-Resident Patenting? Evidence from BRICS

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Do Preferential Trade Agreements Stimulate Non-Resident Patenting? Evidence from BRICS

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Abstract

Utilizing a novel cross-country dataset on patent filings, this study employs an augmented version of gravity model to explore the impact of preferential trade agreements (PTAs) on non-resident patent filings in emerging market economies of BRICS. PTAs, however, vary in terms of content and design, we therefore analyse their differential impact on patent filings while focussing on deep and shallow PTAs. The PPML estimates suggest that PTAs have a positive and statistically significant impact on non-resident patent filings in BRICS. In particular, country-pairs with PTAs increase their patent flows by 43% relative to control group (dyads with no PTAs). Further, compared to shallow PTA, deep PTAs appear to induce foreign patenting upsurge in BRICS. Shallow PTAs exhibit positive effects in the medium-term but negative effects in the long- term on patent flows, whereas deep PTAs unveil positive anticipatory effects.

Key words: Gravity model, Multilateral resistance, Preferential trade agreements, Patent filings, PPML

JEL Classification: F00, O3

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1. Introduction

In today's globalized economy, the importance of owning patents have grown significantly. For firms, investors and entities patenting beyond their national borders has become a popular strategy to seek protection on their intellectual property (IP) and eventually appropriate rents in the destination markets. Since patents are territorial. They protect an innovation only in the jurisdictions in which they have been filed. Therefore, firms need to file patents in multiple jurisdictions to protect their inventions globally. However, not all firms engage in cross border patenting activities as the decision when, where and what to patent abroad is complex and usually involves costs and risks. Besides the cost of filling patents in various destination markets, there are translation and maintenance costs associated with patenting abroad. Often firms have to bear substantial costs that arise out of imitation risk and theft of IP in the destination markets. Small businesses and entrepreneurs, in particular, are vulnerable to these hazards, as they typically face time constraints, limited financial resources, and less knowledge of foreign IP systems.

Despite these obstacles, evidence suggests that the exploitation of technology through international patenting has become popular during last couple of decades. For example, Archibugi and Iammarino (2002) find that during the early 1990s, there was a significant increase in the proportion of patents filed by non-residents in both the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO), indicating a greater internationalization of patenting activities. They also find that the proportion of patent applications from national inventors abroad increased in all OECD countries, suggesting a diffusion of inventive capabilities across borders. Similarly, the number of patent applications by US assignees at the World Intellectual Property Organization (WIPO) more than doubled from 23,845 in 1997 to 50,134 in 2006 (WIPO, 2009). While examining the small business patent activity, Mogee (2003) find that between the period 1988 through 1998 the number of patents filed by small businesses in the US increased by more than a factor of three.

The national patent offices of Brazil, Russia, India, China and South Africa (BRICS) witnessed a similar surge in patent applications, specifically in non-resident patent filings. More than 1.65 million patent applications were filed in BRICS in 2018 as against about 0.39 million in 2008 reflecting a more than fourfold rise in the number of filings between 2008 and 2018. During the same period the patent filings at the USPTO, EPO and JPO (Japanese Patent Office) put together grew from 0.99 million applications to just over 1 million applications.

The rise in IP filings is largely due to an excessive growth of foreign filings in BRICS as opposed to domestic filing. The surge is puzzling because the legal and intellectual property regime in BRICS has been questioned in recent times (Prud'homme and Zhang, 2019). In other words, unlike the 1980s patenting boom in advanced countries where IP rights are rigorous, the recent filing surge in BRICS occurred in presence of relatively weak IP system existing in these countries.

The prevailing literature supports the notion that flow of patents from one country to another can be primarily attributed to the hypotheses related to market covering, competition and threat of imitation (Cai et. al., 2020; Hu, 2010; Sun, 2003). In contrast, this study takes a different perspective by examining the impact of trade agreements on the level of non-resident patenting in the BRICS nations. We argue that the trade agreements specifically agreements that tackle behind the border regulations and membership in multilateral trade treaties like GATT/WTO, have substantially reduced the trade and patenting frictions, eventually leading to higher bilateral patent flows. In addition to the formation of large multilateral treaties focussing on IPRs and trade liberalisation across member nations, there has been the proliferation of regional and bilateral trade agreements many of which include explicit regulation regarding IPRs, particularly patents (Coleman, 2022). A close inspection of the data on trade and patenting activities suggests a significant link between acceleration of trade flows and an increase in cross-country patent applications. In particular, this cohesive movement between trade flows and patent numbers becomes more evident post the introduction of the WTO/TRIPS in the global trade.

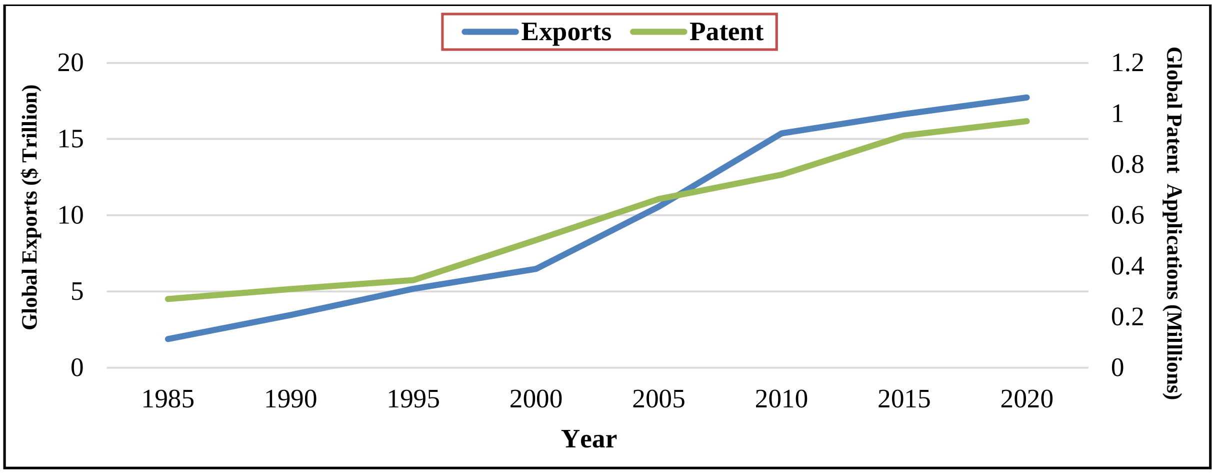

Figure 1: Exports vs. Patenting. *"Domestic" patents have been removed to be comparable to exports which does not include "domestic" trade. The two measures are plotted on different scales to be visually comparable. Trade flows follow the left axis and patent flows follow the right axis. Trade flows compiled from UN Comtrade Database are measured in total USD value; patent flows taken from WIPO are measured as aggregate patent applications.*

Thus far, less empirical research has been devoted to evaluate the impact of multilateral treaties and trade agreements on patent filings. We attempt to develop a comprehensive approach that integrates both trade agreements, and joint membership to multilateral treaties while also controlling for factors such as market size, imitation, and competition in our analysis of patent filings. In this direction we investigate the flow of patents across various industries from a set of origin country, which include advanced nations, primarily from OECDs to destination markets comprising the BRICS group. By examining the interplay between trade and patenting while controlling for potential endogeneity in trade agreements, our analysis yields three major findings. 1) PTAs and joint member to multilateral treaties have significant impact on non-resident patenting in BRICS. 2) Further, deep PTAs matter more than shallow PTAs in enhancing patent flows. 3) PTAs have both anticipatory and lagged short-and-long term effects on non-resident patenting in our dataset.

The rest of this paper is structured as follows. In Section 2, we provide a brief overview of the relevant literature. Section 3 outlines the construction of the dataset. In Section 4, we introduce a model of patent flows that serves as the basis for our subsequent empirical analysis. In section 5, we delve into discussions on empirical strategies, followed by the interpretation of the empirical findings. Finally, in Section 6, we offer some concluding remarks.

1. Literature

Patenting is closely tied to the quantity of innovative ideas generated within a country, which is, in turn influenced by the available stock of knowledge capital. An increase in the pool of knowledge capital leads to the creation of new ideas and technologies that can be harnessed for commercial gains. As a result, firms in the source country are compelled to venture into the destination markets in order to leverage these innovations. To ensure the continued exploitation of their technological assets, these firms often engage in an extensive process of patenting within the destination markets. Therefore, the theoretical notion of knowledge or capability exploitation appears to be a useful starting point to understand the increase in cross-country patent flows. A further theoretical justification for the upsurge in cross-country patenting comes is rooted in resource-based theory. According to this theory, possession of valuable intellectual resources bestows foreign firms a competitive edge over their rivals. To protect their intellectual resources and sustain the competitive advantage, these firms excessively indulge in strategic patenting practices. This entails the construction of comprehensive patent portfolios to ensure that their technological development activities are not stifled by patent infringement suits from rival firms (Hall & Ziedonis 2001; Ziedonis 2004).

The effective utilization of intellectual assets and the realization of associated gains are heavily contingent on the host country's market size. Bosworth (1984) mentions recipient country's market size and trade inflows as key factors shaping the decision of source country firms to demand IP rights of the former. According to Yang and Kuo (2008), rise in the exports and outward foreign direct investment of a country is linked to a greater likelihood of filing a higher a higher number patents in the partner country. In their analysis on bilateral patenting among OECD countries, Eaton and Kortum (1996) discover that market size is the key determinant of firms patenting endeavours. However, in the destination markets foreign firms have to face the imitation hazard which constraints their ability to appropriate the innovation rents. In the presence of imitation threat, profits of foreign firms are either completely or in part, wiped out and the extent of this impact is contingent on the imitative abilities of the local firms and the effectiveness of IPRs in the destination market. The higher imitative capability of the local firms in the destination market compels foreign firms to undertake protection of their innovations. Moreover, robust IPR systems act as a deterrent to imitation, assisting innovative firms in to recoup their investment in innovation. Therefore, alongside market size, the decision to patent is influenced by both the existence of imitation risks and the nature of IPR regime in the destination country.

Another strand of trade-literature builds on the theoretical underpinnings of the gravity model. This strand broadly studies the impact of multilateral trade and IP treaties and free trade agreements (FTAs), on the international trade flows. It also provides evidence for the impact of technology-related content of FTAs on trade flows and internationalization of technology (Maskus & Ridley, 2016; Campi & Duenas, 2019; Martinez-Zarzoso & Chelala, 2021). The provisions covered in FTAs ensure implementation of policy commitments by the member states that can create incentives for firms to exchange technology-intensive goods with their trading partners (Buthe & Milner, 2008; Santacreu, 2022). Capitalizing on the recent advances in the empirical structural gravity literature, Larch et al., (2019) find conclusive evidence that both GATT/WTO has been effective in promoting trade between member states. However, as opposed to the conventional view, Rose (2004) reported striking findings which suggest that countries acceding or belonging to the GATT/WTO did not have significantly different trade patterns than non-members. In line with Rose's (2004) seminal work, Silviano et al., (2020) find that unlike regional trade agreements (RTAs) and currency unions, the GATT/WTO accession has not generated positive trade effects. Accounting econometrically for the endogeneity in FTAs, Baier and Bergstrand (2007) find that the effect of FTAs on trade flows is quintupled. By the same token, Baier et al., (2019) applied a novel two stage methodology to study the empirical determinants of the *ex post* effects of past FTAs and estimate *ex ante* predictions for the effects of future FTAs on trade. Their results indicate asymmetries in FTA effects, e.g., FTA effects are weaker for more distant dyads and for dyads with otherwise high levels of *ex ante* trade frictions. Furthermore, Anderson and Yotov (2016) show FTAs have varying effects across industries and these industry-level differences in turn have important consequences for quantifying the welfare impact of FTAs.

Over the years, the scope of FTAs has grown from mere trade liberalization to a vast range of policy areas that include the IPRs, the labour market, the environment, as well as investment and technology transfers (Dur et al., 2014; Hofman et al., 2017). The existing empirical literature has shown that content of trade agreements fosters internationalization of technology through bilateral exchange of goods with diverse technological intensities (LaBelle and Santacreu, 2021; Erixon et al., 2022). However, the impact of the content of trade agreements on international patent filings remains, to the best of our knowledge, understudied. This paper attempts to bridge this gap by examining the role PTAs in explaining the flow of non-resident patents in the BRICS group. Moreover, we exploit the variation across PTAs in terms of their substance and design to see whether the differences in the scope and depth of these agreements matter for cross-border patent flows. Incorporating design differences will assist us to better understand why narrow or shallow agreements are unlikely to have same consequences as broad and deep agreements for some sectors of the economy.

Our study is closely related to Coleman (2021) who investigates the impact of trade liberalizing treaties as well as on treaties strengthening intellectual property rights on patent flows. We also draw from the Santacreu et. al., (2022) and Jinji (2019). In the former study, the emphasis is on the impact of RTAs on bilateral patenting activities; while the latter study examines the link between ratification of FTAs and patent citations across countries. Our contribution to this evolving body of literature lies in our emphasis on deep and shallow PTAs. We shed light on their anticipatory and phase-in effects on the outcome variable, both at the industry and country levels. Given that trade agreements often undergo multiple rounds of negotiations before taking effect, there is a possibility that the impact of these agreements may be felt before they are officially enacted. Therefore, to fully assess the impact of PTAs, it is essential to consider both anticipatory and delayed effects of these agreements.

2. Dataset on Patent Filings and PTAs

Our patent filing dataset is distinctive and sets itself apart from other commonly used patent databases in several aspects. Notably, the patent data provided by the USPTO exclusively archives applications filed within the US. This database lacks information on patent filings made at other patent offices around the world. In contrast, the publicly available OECD database offers a more comprehensive scope as it includes patent applications filed not only in the US but also with the EPO and under the Patent Cooperation Treaty (PCT) system. The limitation of the OECD database is that, apart from OECD member countries and a handful of emerging economies, it does not offer data on patents filed with the patent offices of other nations. The WIPO database is the primary publicly accessible database offering comprehensive coverage, encompassing patents filed in patent offices worldwide and categorizing them into three distinct categories: total filings, resident filings, and non-resident filings. However, a notable challenge with WIPO and other publicly available databases is the way patent data is categorized under various technology domains or fields (comprising 35 technology areas). Since there isn't a direct one-to-one correspondence between these technology fields and specific manufacturing industries, assigning patents to their respective industries becomes increasingly complex. Moreover, many of these technology fields have multiple facets, further complicating the process of linking them to their relevant industries.

To map tech-fields with industries, we generate weights using four-digit alpha-numeric International Patent Classification (IPC) codes. Following the IPC system each of the 35 tech-domains is assigned a certain number of IPC codes. These codes link invention patents and utility models with their technology areas[1]. Based on the count of IPC codes in each tech-filed we track their distribution across industries using IPCV8-NACE2 concordance scheme[2].

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[1] IPC has defined 35 technology areas and each technology area may have many facets. These technology areas can be linked to various manufacturing industries according to IPC-NACE concordance scheme.

[2] The concordance IPCV8-NACE2 relates industries to relevant technology classes. NACE2 is the statistical classification of economic activities in the European Community and it serves a similar purpose as the NAICS (North American Industry Classification System) and SIC (Standard Industrial Classification). The concordance table between IPCV8 and NACE2 maps IPC main groups/ IPC sub classes to the first 2-4 digits of the

This scheme relates industries to relevant technology classes. Depending upon the total IPC code counts belonging to each tech-field and their distribution across various industries, we were able to generate the weights that an individual industry carries in each tech-field. Weights actually describe the fraction of an industry patent codes falling in each tech-field[3]. The weights vary between 0 and 1, where extreme value 0 means absence of a link between a tech-field and an industry and value 1 suggests a complete overlap between the two. However, a value between 0 and 1 would mean that each tech-field can be connected to many industries. This procedure results into fractional patent counts ensuring none of the tech-field is missed out or underrepresented in the final analysis of patenting at industry level. Moreover, fractional count allows us to take care of double counting which otherwise plagues the datasets on patent counts. To arrive at yearly bilateral patenting dataset by country and industry, we multiply the patent numbers filed in each tech-class with the weights and then sum across industries. Finally, through text matching two-digit NACE2 is compared with the two-digit ISIC3 and then mapped to the later[4]. This is done to align our filing data with the widely accepted two-digit ISIC3 industry classification system.

Data on design and content of PTAs is sourced from the Design of Trade Agreements (DESTA) by Dur et al., (2014). The DESTA project is focused on systematically gathering data about various types of PTAs, which can encompass customs unions, free trade agreements, or partial free trade agreements (often referred to as economic integration agreements). The DESTA project involves manual coding of design features for over 710 agreements. These design features include detailed information on a wide range of aspects, such as market access commitments, flexibility mechanisms, enforcement tools, and non-trade issues. The data spans the time period from 1948 to 2019.

Based on the seven key provisions that can be included in a PTA, Dur et al., (2014) uses two different measures to operationalize depth of a PTA. The first measure, *"depth_index,"* is an

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hierarchical NACE code. For further details see Patent Statistics: Concordance IPC V8-NACE REV.2 available at *forums.epo.org/concordance-table-between-ipc-and-nace2-9756*

[3] Each technology area has a certain number of IPC codes, for instance the tech-field electrical machinery apparatus energy has a total of 33 IPC codes and these codes have been distributed across various industries such as electrical equipment (27 codes), computer, electronics and optical products (5 codes) and, machinery and equipment (1 code). The weights thus calculated are 27/33 = 0.81, 5/33=0.15 and 1/33=0.03 implying 81% of total patents filed in the tech-field electrical machinery apparatus energy in a year are mapped to electrical equipment industry [ISIC 27], 15% to computer, electronics and optical products [ISIC 26] and about 3% to machinery and equipment N.E.C. industry [ISIC 28].

[4] We compare NACE2 and ISIC3 using text matching and observed that both classifications overlap at two-digit level. NACE is derived from ISIC, in the sense that it is more detailed than ISIC, and both ISIC and NACE have exactly the same items at the highest levels, where as NACE is more detailed at lower levels.

additive index that takes on a value ranging from 0 to 7. This value depends on the count of provisions included in the PTA. A higher score indicates a greater number of provisions and potentially a deeper agreement.[5] The second measure, *"depth_latent,"* is more extensive in its assessment. It encompasses a total of 49 items that are theoretically associated with the depth of an agreement. It utilizes *"latent trait analysis"* to select only those items considered critical in assessing the extent of countries' commitments within the agreement.[6] This results in a more comprehensive and nuanced understanding of the PTA's depth.

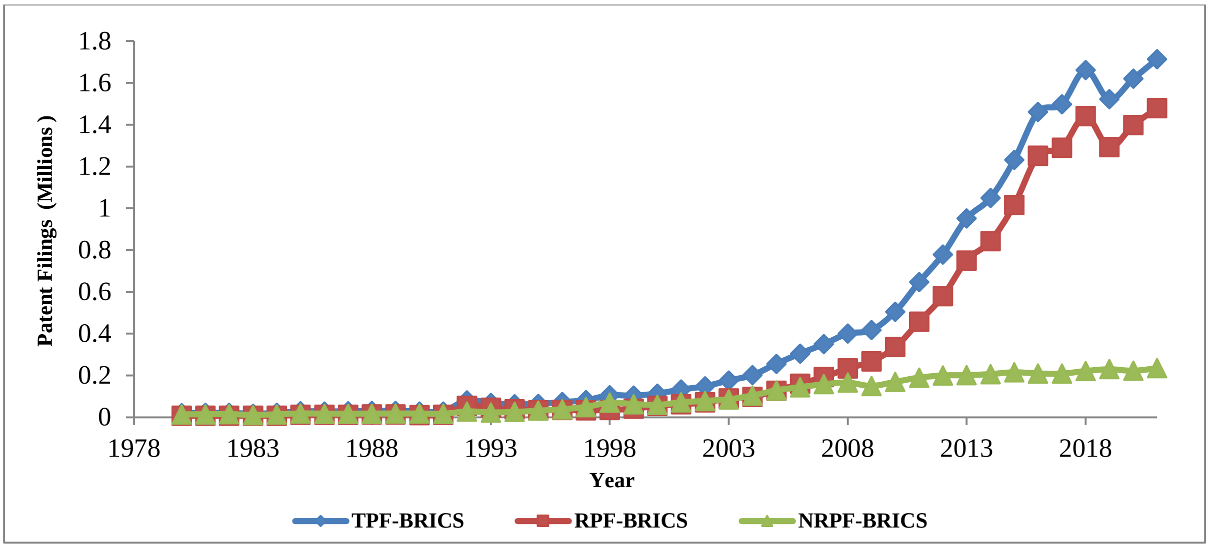
3. BRICS as Destination of Patent Applications

We use our dataset to document salient features of international patenting flows across industries and countries. Among other facts, we document the rise of BRICS as a destination of patents applications over the past decades.

Figure 2 tracks the evolution of the total, resident and non-resident patent applications filed in BRICS over the past four decades spanning from 1980 to 2021. Notably, there has been a recent surge in total patent applications received by the BRICS group as a whole, and this increase appears to be primarily driven by a rise in domestically filed patent applications. In 1995, out of the total patent applications filed within the BRICS, around 48% were resident patent applications, while nearly 52% constituted the non-resident patent applications. However, by 2021, there was a significant shift, with patent filings claiming domestic ownership soaring to as high as 86%, reducing the non-resident share to just 14%. This change can be largely attributed to the remarkable increase in the number of domestic applications filed in China, which significantly contributes to the overall resident filings within the BRICS group.

[5] Depth_index is an additive measure that combines seven key provisions that can be included in PTAs. These include a provision on creation of a full-FTA which essentially indicate that all tariffs (with few exceptions) should be eliminated among the trading partners. The other six provisions capture cooperation that goes beyond tariff reductions, in areas such as services trade, investments, standards, public procurement, competition and IPRs.

[6] Depth_latent relies on latent trait analysis which a type of factor analysis for binary data (Bartholomew et al., 2011). The analysis allows to deal with highly correlated data and accounts for the fact that not all items are equally important in establishing the extent of countries' commitments. The measure uses a total of 49 variables pertaining to such aspects as services liberalisation, trade-related investment measures, IPRs and standards. The information on these variables is provided in the main codebook available under the "Content Coding" section of the DESTA.



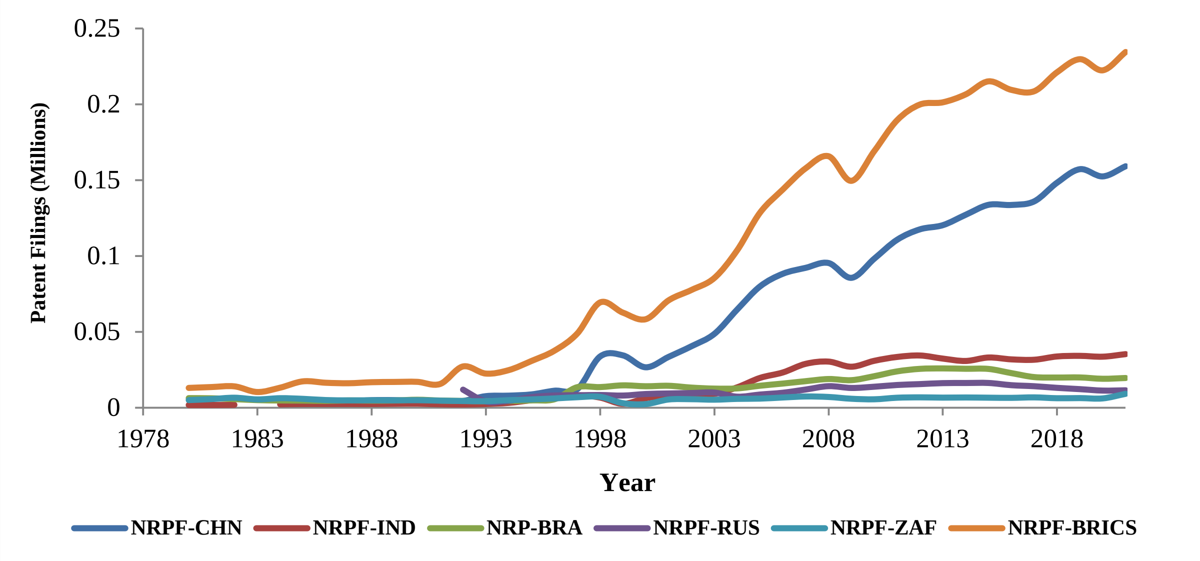
Source: WIPO

Figure 2: Growth of Total Patent Filings (TFP), Resident Patent Filings (RPF) and Non-Resident Patent Filings (NRPF) in BRICS.

The non-resident patenting trends plotted in figure 3, indicate that among the BRICS group, China is the main destination of non-resident patent applications followed by India, Brazil, Russia and South Africa. During the second half of 1990s decade, China overtook all other major economies except US as a major destination of non-resident patent applications. In 2021 as many as 0.16 million foreign patent applications were received by Chinese Patent Office (CNIPA) as opposed to 0.33 million, 0.11 million and 0.07 million by three major global IP offices viz., the United States Patent and Trademark Office (USPTO), the European Patent Office (EPO) and the Japanese Patent Office (JPO) respectively. While US is still a top destination in terms of patents applications received, its growth path is almost mirrored by China since the mid-1990s.

Over the last two decades, India and Brazil have shown some strides in attracting a higher number of foreign patent applications than filled domestically. In 2021, out of the total of 61,537 applications filled at Indian Patent Office (IPO), approximately 58% had foreign origin. This percentage was 54% in 2000 and reached as high as 84% in 2008. Since then, the applications claiming foreign ownership have shown a consistent decline in terms of their percentage share in total filings, although their absolute number at IPO has risen.

For Brazil, out of the total 24,232 patent applications filed in 2021, only 19% of applicants claimed domestic ownership. In the case of Russia and South Africa, the percentage share of non-resident applications to total filings stood at 37% and 84% in 2021, respectively.



Source: WIPO

Figure 3: Country wise trends in Non-Resident Patent Filings (NRP) in BRICS since 1980s.

4. The Motivating Model

Patents empower a firm to charge mark-ups and seek monopolistic profits over its patented products within a given territory. The rents generated by the patents primarily hinge on many of the same factors that incentivise international trade, such as the size and wealth of the destination market, and trade costs (commonly referred to as the iceberg trade costs). Given these similarities in the factors explaining patent and trade flows, we adopt a model developed in Coleman (2022) which modifies the gravity equations originally described by Anderson and Van Wincoop (2003). Based on the several structural characteristics of the country pairs, a gravity equation that models the patent flow from a country of origin to a country of destination is given as:

$$N_{od,t} = \frac{Y_{ot} E_{dt}}{Y_t^w} \left(\frac{t_{odt}}{P_{ot} P_{dt}} \right)^{1-\sigma} \quad (1)$$

Where:

N_{odt} indicate the number of patent applications filed by origin *o* in destination *d* at time *t*. Y_{ot} and E_{dt} denote actual output and expenditure of origin *o* and destination *d* respectively. $Y_t^w = \sum_{O=1}^{N} Y_{ot} = \sum_{d=1}^{N} E_{dt}$ is the world income. t_{odt} is a vector of bilateral resistance. P_{ot} and

P_{dt} designate the multilateral resistance faced by the origin *o* and destination *d* from their trading partners. These multilateral resistance terms can be expressed as:

The expression in (2) sums bilateral trade resistance across *d* often termed as multilateral resistance faced by origin country across its destination markets. Similarly, the expression (3) sums bilateral trade cost factors across *o*, therefore denotes multilateral resistance faced by country of destination across its trading partners. Therefore equation (1) states that after controlling for size bilateral patents depends on bilateral trade resistance relative to the product of multilateral resistance.

We use the model developed by Coleman (2022) which modifies the gravity equations in Anderson and Van Wincoop (2003) to describe bilateral patent flows:

$$N_{od,t} = \left(\frac{P_{dt}}{\mu c_{ot} \tau_{odt}} \right)^{\theta} \left(\frac{E_{dt}}{\sigma} \right)^{\frac{\theta}{\sigma-1}} \ell_{ot} b_{ot}^{\theta} \left(\frac{\psi_{od,t}}{F_{odt}} \right)^{\frac{\theta}{\sigma-1}} \qquad (4)$$

Where c_o is the cost of factor-input in origin/source country *o*, ℓ_o represents the total number of innovations in source country *o* at time *t*, b_o is the minimum productivity of those innovations with exponent θ as the dispersion parameter[7]. The term $\psi_{od,t}$ is expected gain in the profits of the origin *o* with patent protection in destination market *d.* The vector of filing costs F_{od} signifies formal application fee, some legal and translation costs.

Equation (4) expresses patenting as an increasing function of the destination market size $\left(\frac{E_d \psi_{od}}{P_d^{1-\sigma}} \right)$ as well as of the product of innovative capacity and factor inputs costs $(\ell_o C_o^{-\theta})$ of the origin but it is decreasing in the level of bilateral trade and patenting frictions $(\tau_{od} F_{od})$.

This model provides some insights into why trade treaties could impact patent flows. Treaties dealing with IPRs will affect both the overall value of patent (Ψ) and the cost of the patent

[7] Productivity is distributed according to Pareto distribution with minimum b and dispersion θ. The value or productivity of innovations (Patents) is highly skewed, so their productivity is typically modelled using Pareto or lognormal distribution (Hall and Harhoff, 2012). In other words, the size distribution of profit returns on innovations is highly skewed to the right. The most valuable patents contribute a disproportionate fraction of the total profits from innovation.

application (F) whereas treaties involving trade liberalization (GATT/WTO) will have an effect through a reduction in trade fictions (τ).

5. Empirical Strategy

In this section we discuss the different empirical strategies adopted in this paper and the estimations obtained from various model specifications.

5.1. Random Effect with cross section control on MRT

To assess the potential impact of PTAs on patent flows between country pairs, we transform equation (4) into an estimable form by incorporating fixed effects for both the origin and destination. We begin with a random effect estimation, which assumes that country-specific characteristics are random and uncorrelated with either PTAs or the vector of control variables. The estimation equation is as follows:

$$\ln(N_{od,t}) \;=\; \alpha_0 + \lambda_d + \delta\, PTA_{od,t} + T_{od,t}\gamma + X\beta + \varepsilon_{odt} \qquad (5)$$

The dependent variable $\ln(N_{od,t})$ is the logarithm of patent filings by origin o in destination d at time t. The origin and destination fixed effects are denoted by α_o and λ_d. PTA is the target variable denoting presence (or not) of a preferential trade agreement between dyads, $T = [GATT/WTO]$ is the vector denoting the joint membership of the country pairs in international agreements, and $X = [\ln(MODGP_d), \ln(\exp_o), \ln(knowcap_o), ...]$ is a vector of controls. The vector X further includes link specific dyadic variable like common language, distance, common colony, and columnony_45 discussed elsewhere. ε is the error term. The variables included in vector X are further discussed as follows:

$\ln(MODGP_d)$ is the logarithm of modified Ginarte-Park index taken from Sheikh and Kanwar (2022). It incorporates various aspects of legal enforcement and property rights in the destination country. $\ln(\exp_o)$ is the logarithm of exports denoting value of merchandise exports from a country of origin to a country of destination. The data on the variable is compiled from UN Comtrade database. $\ln(GDP)$ is the combined gross domestic product in USD representing the market size of the individual country-pairs. The data on GDP is taken from Penn World Table (PWT) version 10.0. $\ln(compt)$ is logarithm of the sum of the patent filings of the rest of the source countries in the destination country, except the country in under consideration. The *compt* variable measures the competition faced by a source country from rest of the source countries in the destination. The data on filings is from WIPO database. $\ln(knowcap_o)$ is the knowledge capital measured as the total number of patent filings filed by the origin at USPTO, except for the US. In the case of US, knowledge capital is measured by the total number of US patent filings at EPO. This approach is employed to mitigate the potential bias associated with applications from the home country. $\ln(hc\_d)$ denotes the human capital of the destination country. It is measured by the number of patent applications filed by of each destination country at the USPTO. $\ln(hc\_o)$ is a measure of human capital of the origin country which represents the total expenditure on education. The variable is sourced from PWT Version 10.0. The data spans over a period of 23 years from 1986 to 2009.

The link specific gravity variables such as distance $\ln(dst)$ represent the distance between the capitals of country-pairs; common language (com_lang) is an indicator variable set to 1 if country-pairs share a common language and 0 else; common colony (com_col) is an indicator variable set to 1 if the dyads had a common colonizer in the past and 0 else; (com_45) an indicator variable which is set to 1 if one of the countries in a pair had been a colony of the other after the year 1945 and 0 else. All of the mentioned trade cost indicators are taken from geographical database provided by the Centre d' Etudes Prospective et d' Informations Internationales (CPII).

We report the estimations based on random effect model (Eq. 5) in Table 1. The results inform that PTA, depth_index and depth_latent do not have a significant impact on the non-resident patent flows in BRICS. Across all four specifications PTA is a dichotomous variable denoting presence or absence of an agreement between country pairs. It, however, ignores heterogeneity in those agreements in terms of institutional design and legal enforceability. The estimates on PTA, except in model (1) are negative and statistically insignificant. The second and third specifications in Table 1 include terms on the depth of the trade agreements. The coefficient on the depth_index in column. (2) is negative and statistically insignificant suggesting depth of an agreement does not affect patent filings. Similarly, in column (3), the negative and statistically insignificant estimate on depth_latent infers that depth of a trade agreement does not induce patent filings. GATT/WTO variable, however, is positive and highly significant across all specification indicating joint member to international treaties improves non-resident filings by a factor of about 0.85 as opposed to non-members.

Finally, in order to capture the anticipatory and lagged effects of PTAs' on patent flows and distinguish between deep and shallow PTA, we replace depth index with eight dummies (four each for deep and shallow PTAs') in specification (4) of the model (5). For all country pairs with a value of depth index greater than the median across all dyads, the agreement is deep, otherwise shallow. The database further includes the direct contemporaneous, leading (anticipation) and delayed (phasing-in or sluggish adjustment) responses of country pairs' patent flows to the inception of average PTA, for both deep and shallow agreements respectively[8]. The possibility of anticipatory effect arises from the perception that firms may temporarily delay patent filings in the expectation that an impending trade agreement may bring in additional benefits in terms of reduced application fee and relatively higher level of protection than before. The underlying economic motivation for the inclusion of lagged terms of PTA stems from the fact that, on average, each trade agreement is "phased-in" typically over a period of 10 years (Baier and Bergstrand, 2007). Therefore, the total effect cannot be entirely realized instantaneously in the concurrent year only but may spread over a period of time since the inception of the trade agreement. The estimates on the eight dummies, representing lead and lagged effects of deep versus shallow PTAs', are reported in column. (4) of Table 1. None of the dummies, except shallow_medium term has a statistically significant coefficient suggesting shallow PTAs do have a significant impact on filings between 5 -10 years after the shallow agreement is enforced.

5.2. Fixed Effect with cross section control on MRT

Random-effects model suffers from a limitation that if the country- or time-specific effects are correlated with any of the regressors, random-effects estimates are biased and inconsistent while the fixed-effects estimates remain unbiased and consistent. To demonstrate the robustness of results based on random-effects panel regression, we estimate the model using fixed-effects regression. Equation (5) is rewritten as follows:

$$\ln(N_{od,t}) = \alpha_0 + \lambda_d + \phi_t + \delta\, PTA_{od} + T_{od,t}\gamma + X\beta + \varepsilon_{odt} \qquad (6)$$

Where α_0 and λ_d represent time-invariant unobservable country-specific fixed effects. This model works well if multilateral resistances are time-invariant but does not account for time-

[8] For example., conditional on the agreement is deep, *deep anticipatory* is an indicator that takes the value of 1 five- years prior to the inception of PTA; in the 5 years post the signature of a PTA, the indicator is labelled as *deep short-term*; between 5 -15 years after PTA, it is labelled as *deep medium-term*; and for 15 and more years' post to the signing of a PTA the indicator is termed as *deep long-term*. Same hold true for shallow agreements.

variant multilateral resistance factors under panel data under which proper treatment of multilateral resistance factors is to use *origin-time* and *destination-time* fixed effects. ϕ_t represent unobserved factors that change over time but affect all countries in the same fashion. The matrices T and X contain same exogenous variables as in (5), and ε_{odt} is a well-behaved random term.

The estimates based on (6) are reported in Table 1. We obtained same results as in random effects specifications, except that coefficient on the variable *shallow_medium* term now turns statistically insignificant. The control variables have expected sign; in particular, the logarithm of human capital (hc_d) of the destination as a proxy for imitative ability reduces foreign patenting in BRICS. The human capital (hc_o) of the origin country has expected positive sign but is insignificant. Similarly, the stock of knowledge assets $(know\_cap_o)$ (international patents) of the origin country enhances non-resident patenting in destination markets.

5.3. Fixed Effect Model with Control for MRT

The empirical specifications discussed in (5.1) and (5.2) do not control for MRT, therefore the parameters of interest obtained from them can be considered as nuisance parameters from an econometric point of view. Further, controlling for MRTs with origin and destination fixed effects may work well in the case of cross-section data. In the case of panel data, it is recommended to use origin-time (α_{0t}) and destination-time (λ_{dt}) FEs to control for time-varying multilateral resistance factors (Olivero and Yotov, 2012). Therefore, Eq. (6) can be rewritten as:

$$\ln(N_{od,t}) = \alpha_{0t} + \lambda_{dt} + \delta\, PTA_{od,t} + T_{od,t}\gamma + X\beta + \varepsilon_{odt} \qquad (7)$$

The findings from FE estimator Equation (7), reported in Table 3 show estimates based on four models. All incorporate origin-time and destination-time fixed effects to allow for the effects of institutional and geographic distance on patent flows while avoiding any omitted variable bias that results from time-varying country specific unobservable characteristics, controlling therefore for the time-variant multilateral resistance terms (Anderson & Van Wincoop, 2003).

The estimates on PTA, except in model (1) are negative and statistically insignificant. The second and third specifications in Table 3 include terms on the depth of the trade agreements. The coefficient on the *depth_index* in model (2) is positive and statistically significant at 5%

level suggesting that design of trade agreements matter in determining non-resident patent filing in BRICS countries. The estimate on *depth_latent* in column. (3) is positive and significant, offering therefore further support to the argument that depth of a trade agreement significantly determines foreign filings in BRICS. The *GATT/WTO* variable is omitted across all specifications because of possible collinearity with the *PTA and depth* Variables.

The estimates on anticipatory and phased-in effects of deep and shallow PTAs' are reported in column (4) of Table 3. Out of eight dummies only two unveil positive and statistically significant effect on patent flows. Shallow trade agreements do not exhibit any anticipatory effects on the patent filings nevertheless they appear to have a negative impact on patent filings in the medium-term, specifically between 5 and 10 years after the PTA is signed. On the contrary, deep PTAs' demonstrate strong positive anticipatory effects on patent filings, along with short-term effects that manifest 5 years after a deep PTA becomes operational. The deep anticipatory effect confirms that dyads register a substantial 104% rise in non-resident patent filings 5-years prior to signing of a deep PTA. Furthermore, 5-years after the PTA is enacted, patent filings tend to surge by 178% within the treatment group in comparison to control group. This finding suggests IP situation in the destination markets may improve after deep PTAs' are enacted. This enabling IP scenario following the promulgation of the deep trade agreements may, in turn, stimulate patenting as it becomes relatively easy for the firms to appropriate rents and earn a higher return on their innovations.

An important point to consider here is that there are no feedback effects from patent flows to PTA when the latter is a shallow trade agreement. In our panel, if the PTAs are strictly exogenous they should not lead to changes in the patent flows before their inception. Alternatively, strict exogeneity would mean absence of anticipatory effect of PTAs on patent filings. Regarding shallow PTAs, we observe a positive impact on patent flows, although this effect is statistically insignificant, in the 5-years preceding their implementation, as shown in column. 4 of Table 3. This observation implies the absence of any substantial anticipatory influence on patent flows in the five-year period leading up to the actual entry into force of the agreement. However, in case of deep PTAs, the assumption of strict exogeneity is challenged, indicating the existence of a feedback mechanism where patent flows affect the ratification of a deep PTA[9].

[9] It is imperative to mention that this does not necessarily imply the strict exogeneity in overall PTA indicator does not hold, it is just that deeper agreements may not be strictly exogenous. Our results further suggest that

5.4. Estimating a Gravity Equation with Zero Patent Flows and Heteroskedastic Residuals

An important feature common to both patent and trade flows is the preponderance of zero values. This particularly holds for smaller countries as there might be no patent applications between two countries in a given year. The simplest estimation strategy for analysing patent flows is to log-linearize the equations and use OLS. However, the presence of zeros in the patent data eliminates this possibility. A potential solution to address the issue of zero values in the patent data is data censoring. This involves only considering larger countries that do not have zeros in their bilateral patent flows. However, this approach not only disregards the meaningful presence of zeros in the patent data but also results in a significant loss of information by restricting the sample to larger countries with positive patent flows only. Alternatively, another technique to handle zero values in the data is to add 1 to all observations, effectively eliminating zeros. However, this approach understandably introduces a significant bias in the estimates.

Another challenging aspect of the data is the fact that there is greater variability in the patent flows among large country pairs compared to variation observed among smaller countries. This uneven variance in patent flows among countries gives rise to heteroscedasticity. If un-addressed, heteroscedasticity has the potential to introduce significant bias in the estimates. As suggested by Silva and Tenreyo (2003), Poisson pseudo-maximum likelihood (PPML) estimator effectively resolves the dual challenges of excessive zero values and presence of heteroscedasticity prevalent in the patent data. Therefore, the specification reads,

$$N_{od,t} = \exp\left[\alpha_{ot} + \lambda_{dt} + \phi_{od} + \delta\, PTA_{od,t} + T_{od,t}\gamma + X\beta\right] * \varepsilon_{odt} \qquad (8)$$

To control for unobserved multilateral resistances such as legal costs, translation fees and formal application costs, etc. we employ origin-year and destination-year fixed effects. This unfortunately absorbs the impact of time-variant variables like GDP, IPR index, competition, imitative ability and human capital. Therefore, we are unable to estimate the impact of the time-variant covariates on the patent flows. Nevertheless, this method allows us to preserve our policy-related variables such as PTAs and joint member to treaties and enables us to estimate their impact on patent flows. While the inclusion of 2-way fixed effects imposes

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shallow anticipatory agreements are uncorrelated with concurrent patent flows confirming the strict exogeneity of these agreements. A better way is test strict exogeneity assumption is to take one year lead of PTA and regress it on the outcome variable and check if the coefficient is insignificant.

limitations on what can be incorporated in each regression, it enhances the robustness of our estimates regarding the effects of trade policies. We report the findings from PPML in Table 3.

The estimates on PTA reported in column. 1 and 4 are highly significant offering strong support for PTA-induced non-resident patent surge in BRICS. The treatment group (dyads with a PTA) increase their filings by about 43% ($e^{0.36}$=1.43, or 43%) as opposed to the comparison group (country pairs without such agreement). The discrepancy between the OLS and PPML estimates can be possibly attributed to heteroscedasticity bias present in former. Shallow agreements exhibit a positive medium-term impact but negative long-term effect on patent filings. The possible reason for this result is that shallow agreements might not cover the critical areas of PTAs, such as provisions related to IPRs and their de jure enforcement, which appear to be important factors influencing firms' decision to patent in the destination market.

Unlike the shallow PTA, the estimates for deep PTAs indicate the presence of an anticipation effect showing an increase in patent flows up to five years before a deep PTA is enacted. We attribute the anticipation effect to the likelihood that negotiations surrounding deep PTAs may signal the inclusion of property rights provisions within the PTAs being considered. As a result, firms may choose to file more patents in order to secure advantages against their rivals in the destination markets. The short-term impact of deep trade agreements turns out to be negative but statistically insignificant. However, we cannot discern the medium-term and long-term effects of deep PTAs due to the presence of collinearity with other indicators of trade agreements.

5.5. Estimation on Industries

Much of the existing literature on trade agreements primarily assesses their impact at the country level (Baier and Bergstrand, 2007; Baldwin, 2008; Freund and Ornelas, 2010; Egger et al. 2011). However, delving into the effects of trade agreements solely on a national scale may obscure significant variations at the industry level. There is a possibility that not all sectors derive equivalent benefits from these agreements; some sectors may gain significantly while others may experience fewer advantages. For example, trade agreements that include provisions concerning technology transfer and IPRs may hold greater significance for high-tech and IP-intensive industries (such as pharmaceuticals, chemicals, electronics, and machinery and equipment) than those that rely less on intellectual property. Therefore, the differential impact of PTAs in industry context needs some attention to the distinct effects of PTAs within the context of specific industries.

In this section, we provide additional empirical evidence on the impact of PTAs' on patent filings within specific sectors. We group industries into high-IP and low-IP sectors using Comtrade database. Within our dataset, seven industries belong to the high-IP category while thirteen are classified as low-IP sectors. The break-up of industries into high-1P and low-IP groups is based on the methodology outlined in Delgado et., al. (2013)[10].

We zoom in to distinguish between anticipatory, short-term, medium-term and long-term effects of deep versus shallow PTAs' at a disaggregated sectoral level. The estimates on high IP industries are presented in Table 4. Column 1 and 2 report estimates based on pooled sample of high IP sectors while the remaining column (3 to 7) provide estimates on the impact of PTAs on patent filings in specific high-IP sectors such as chemical & chemical products, pharmaceuticals; and machinery & equipment.

The pooled estimates reveal strong evidence that PTAs' and their depth drive patenting in IP intensive industries. Shallow PTAs' appear to have positive and statistically significant anticipatory effect, but in the long-term, they tend to reduce filings in high IP industries as a whole. At the individual industry level, PTAs' seem to matter relatively more for the machinery & equipment sector and, to some extent, for the chemical & chemical products sector in the high IP group. However, patent filings in the pharmaceuticals sector do not appear to be significantly affected by PTAs'. This may be due to the possibility that deep PTAs' may not incorporate provisions related to patents, which are more relevant for the pharmaceutical sector. Coefficient estimates for other high-IP industries such as computer, electronics & optics; electrical machinery; and rubber & plastic could not be identified, possibly because of the limited number of observations in each of these sectors.

In low-IP sectors, the pooled estimates reported Table 6, specifically in columns' 7 and 8 reveal a significant rise in patent activity following inception of PTAs'. However, the level of depth within a trade agreement does not appear to exert a substantial impact on the patent applications in these low-IP industries. Notably, patent filings in construction and LET

[10] To identify the list of industries with high IP-intensity, Delgado et al. (2013) uses the 2012 report by the Economics and Statistics Administration (ESA) and the USPTO. This report provides a list of broad industries (4-digit NAICS code) with above average IP intensity In the US (based on patents, trademarks or copyrights). For further understanding see *ESA-USPTO Report, US Department of Commerce, 2012*.

(referring to Leather, Electrical, and Textiles) sectors demonstrate a robust increase when deep trade agreement between trading partners take effect. Nevertheless, the depth of the agreement does not seem to stimulate patent filings in some of the low–IP sectors such as basic metals and other consumer goods. For certain other low-IP industries, we were unable to determine the coefficient estimates due to a limited number of data points available in these sectors.

6. Conclusion

Trade agreements have been extensively examined for their role in stimulating international trade in goods and services. However, their potential impact on promoting bilateral patent flows has yet not been empirically established. This study extends the empirical evidence on the determinants of cross-border patenting indicating that trade agreements have the potential to influence the patent flows among member states.

By leveraging recent advances in the empirical structural gravity literature, this study endeavours to address the question of whether and to what extent PTAs facilitate patent flows between the member countries. The research question was built on the premise that PTAs, particularly those containing provisions related to intellectual property (IP) & technology can exert economic and informational effects on firms' decision to internationalize their technological endeavours. In their pursuit of internationalizing their technology assets, firms often seek to file patent applications abroad, not only to secure the exclusive rights but also to utilize these patents as a means to capture the value of their inventions and establish a reputable presence in the market place.

Consequently, on one hand, PTAs foster increased economic interactions among member nations, ultimately raising the likelihood of firms gaining access to foreign innovation, relocating their R&D facilities and forging technology ties with their trade counterparts. These interactions are inclined to stimulate innovation activities and potential for some of these innovations to lead to patent applications cannot be discounted.

On the other hand, the provision within PTAs related to technology & IP symbolize a commitment among trading partners to uphold the rights associated with IP & technology. This policy commitment provides firms an enabling environment to file patents and seek returns on their innovative initiatives.

A notable departure from the existing literature lies in the paper's quantitative assessment of the effect of PTAs on patent flows at the level of industry in addition to their impact at aggregate level. Further, the study estimates both the anticipatory and delayed responses of bilateral patent flows to the inception of the trade agreements, while also distinguishing between deep and shallow agreements. Using the PPML estimator to estimate an augmented gravity model, this study offers new insights on the nexus between patent filings and trade agreements.

The principle findings of the study reveal that PTAs lead to significant rise in patent flows, both prior to and following the enactment of these agreements. The PPML estimates suggest that PTAs have a positive and statistically significant impact on non-resident patent filings in BRICS. In particular, country-pairs with PTAs experience a 43% surge in patent flows relative to control group. Furthermore, deep PTAs matter more in foreign patenting upsurge in BRICS compared to shallow PTAs. While shallow PTAs show positive impacts in the medium-term but negative effects in the long-term on patent flows, deep PTAs manifest positive anticipatory and short-term effects.

In general, our estimates regarding PTAs are robust, as they simultaneously account for multilateral resistance terms with origin-time and destination-time fixed effects as well as for heteroskedastic residuals and zero patent flows using PPML. It is important to note; these results are derived from a panel of 22 countries. Future work could enhance the reliability of our findings by expanding the sample size to include more countries in the panel.

Moreover, it is worth considering that the impact of PTAs on target variable might differ depending on the specific type of IP form being studied. For instance, the effects of PTAs could vary across different categories of IP, such as utility model applications, industrial designs, trademarks and copyrights. It will be intriguing to empirically examine the impact of trade agreements on these various forms of IP.

Additionally, the paper does not differentiate between agreements that incorporate IPR and technology related provisions and those that do not contain such content. A subsequent investigation could segregate the PTAs based on their content and assess their impact of on various forms of IP.

Table 1: Random Effect Estimations vs. Fixed Effect Estimations with no control of MLR

	Random Effect Model				Fixed Effect Model			
Variables	*ln(filings) (1)*	*ln(filings) (2)*	*ln(filings) (3)*	*ln(filings) (4)*	*ln(filings) (5)*	*ln(filings) (6)*	*ln(filings) (7)*	*ln(filings) (8)*
PTA_od	0.0129 (0.133)	0.204 (0.165)	0.337 (0.237)	-0.0686 (0.229)	-0.0164 (0.163)	0.0898 (0.235)	0.850* (0.479))	0.00430 (0.504)
depth_index		-0.189 (0.158)				-0.0880 (0.179)		
depth_latent			-0.206 (0.160)				-0.471 (0.288)	
WTO/GATT	0.858*** (0.243)	0.859*** (0.243)	0.852*** (0.243)	0.875*** (0.243)	0.787*** (0.241)	0.787*** (0.241)	0.774*** (0.242)	0.806*** (0.235)
Shallow _anticipatory				-0.340 (0.222)				-0.423 (0.374)
Shallow_short-term				0.217 (0.223)				0.226 (0.277)
Shallow_ medium-term				0.686*** (0.221)				0.831 (0.502)
Shallow_ long-term				0.265 (0.303)				0.452 (0.638)
Deep_ anticipatory				-0.394* (0.238)				-0.382 (0.288)
Deep_ short-term				-0.0817 (0.254)				-0.183 (0.585)
Deep_ medium-term				-0.229 (0.236)				-0.345 (0.520)
ln(MODGP_d)	0.169 (0.732)	0.171 (0.731)	0.115 (0.742)	0.0967 (0.746)	-0.376 (0.746)	-0.365 (0.744)	-0.441 (0.754)	-0.436 (0.756)
ln(GDP_od)	0.531 (0.410)	0.523 (0.410)	0.494 (0.411)	0.403 (0.434)	0.717* 0.416)	0.718* (0.416)	0.654 (0.418)	0.590 (0.447)
ln(exp_o)	0.0240 (0.0251)	0.0238 (0.0251)	0.0257 (0.0250)	0.0303 (0.0258)	0.0313 (0.0319)	0.0309 (0.0321)	0.0365 (0.0329)	0.0398 (0.0333)
ln(compt_d)	-0.176*** (0.0441)	-0.177*** (0.0440)	-0.177*** (0.0441)	-0.184*** (0.0450)	0.00643 (0.0861)	0.00449 (0.0867)	0.00424 (0.0865)	-0.0194 (0.0931)
ln(knowcap_o)	0.652*** (0.0335)	0.653*** (0.0336)	0.651*** (0.0335)	0.649*** (0.0343)	0.445*** (0.121)	0.444*** (0.121)	0.432*** (0.122)	0.420*** (0.137)
ln(hc_d)	-5.333** (2.557)	-5.557** (2.602)	-5.334** (2.562)	-5.967** (2.907)	-3.130 (2.447)	-3.230 (2.478)	-2.976 (2.463)	-3.732 (2.918)
ln(hc_o)	-0.379 (3.050)	-0.456 (3.058)	-0.207 (3.031)	-0.341 (3.033)	0.795 (3.048)	0.708 (3.073)	0.884 (2.991)	0.611 (3.363)
ln(dst)	-0.584*** (0.108)	-0.588*** (0.107)	-0.589*** (0.107)	-0.571*** (0.110)				
Com_lang	0.540*** (0.166)	0.538*** (0.165)	0.532*** (0.166)	0.474*** (0.181)				
Column_45	-0.363 (0.259)	-0.330 (0.255)	-0.339 (0.256)	-0.301 (0.279)				
Origin FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dest FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No		Yes	Yes	Yes	Yes
Obs.	1185	1185	1185	1185	1185	1185	1185	1185

*Note: ***, **, *denote significance at 1%, 5% and 10%percent level. Standard errors are clustered at by country-pair are in parentheses. The impact of deep long-term and common colony is omitted because of collinearity.*

Table 2: FE OLS results after controlling for MRT

Variable	*ln(filing) (1)*	*ln(filing) (2)*	*ln(filing) (3)*	*ln(filing) (4)*
PTA_od	**0.235***	**- 0.121**	**-0.123**	**-0.0600**
	(0.130)	**(0.130)**	**(0.131)**	**(0.682)**
depth_index		**0.757****		
		(0.375)		
depth_latent			**0.361****	
			(0.179)	
GATT/WTO				
shallow_ anticipatory				**0.513**
				(0.318)
shallow_ short-term				
shallow_ medium-term				**-1.320***
				(0.758)
shallow_ long-term				**0.163**
				(0.716)
deep_anticipatory				**1.046*****
				(0.360)
deep_ short-term				**1.785****
				(0.680)
ln(dist)	**-0.658*****	**-0.652*****	**-0.652*****	**-0.597*****
	(0.145)	**(0.147)**	**(0.147)**	**(0.168)**
com_lang	**0.702*****	**0.704*****	**0.704*****	**0.717*****
	(0.161)	**(0.161)**	**(0.161)**	**(0.160)**
column_45	**-0.695****	**-0.697****	**-0.697****	**-0.708****
	(0.328)	**(0.328)**	**(0.328)**	**(0.329)**
origin-Year FE's	**Yes**	**Yes**	**Yes**	**Yes**
destination-Year FE's	**Yes**	**Yes**	**Yes**	**Yes**
Obs.	**1171**	**1171**	**1171**	**1171**

*Note: ***, **, *denote significance at 1%, 5% and 10%percent level. Standard errors are clustered at by country-pair are in parentheses. The impact of deep medium-term, deep long-term and common colony are omitted because of collinearity.*

Table 3: PPMLHDFE Estimates after controlling for MRT

Variable	***filing (1)***	***Filing (2)***	***Filing (3)***	***filing (4)***
PTA_od	0.364***	0.242	0.241	0.368***
	(0.0990)	(0.152)	(0.153)	(0.0471)
depth_index		0.221		
		(0.180)		
depth_latent			0.105	
			(0.0860)	
shallow_ anticipatory				-0.563
				(0.390)
shallow_ medium-term				0.759***
				(0.194)
shallow_ long-term				-0.362***
				(0.107)
deep_anticipatory				0.268*
				(0.107)
deep_ short-term				-0.0392
				(0.0980)
ln(dist)	-0.438***	-0.446**	-0.446***	-0.465***
	(0.0909)	(0.0949)	(0.0949)	(0.0976)
Com_lang	0.451***	0.449***	0.449***	0.445***
	(0.0894)	(0.0897)	(0.0897)	(0.0901)
column_45	-0.780***	-0.778***	-0.778***	-0.772**
	(0.238)	(0.239)	(0.239)	(0.239)
origin-Year FE's	Yes	Yes	Yes	Yes
destination-Year FE's	Yes	Yes	Yes	Yes
Obs.	2339	2339	2339	2339

*Notes: ***, **, *denote significance at 1%, 5% and 10% percent level respectively. Standard errors in parenthesis are clustered at country pairs. GATT/WTO; Common colony; Shallow short-term; Deep medium-term and Deep long-term in column (4) are dropped because of collinearity.*

Table 4: Estimations on High-IP and Low –IP Industries

	HIGH IP						LOW IP									
	Pooled		CHM		MAC		Pooled		BMT		CON		LET		OTM	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
PTA	0.307*** (0.108)	0.707*** (0.238)	0.345 (0.218)	0.675* (0.353)	0.864*** (0.214)	0.333 (0.357)	0.536*** (0.144)	0.342*** (0.128)	0.774** (0.355)	0.485*** (0.158)	-0.373 (0.292)	2.382*** (0.414)	0.255 (0.462)	2.941*** (0.553)	0.552*** (0.179)	0.309 (0.219)
Depth(index)	0.532** (0.219)		0.344 (0.298)		-0.225 (0.321)		-0.0440 (0.234)		-0.117 (0.369)		3.412*** (0.404)		2.069*** (0.558)		-0.126 (0.298)	
GATT/WTO	-2.309*** (0.131)	-2.309*** (0.131)	-2.751*** (0.253)	-2.751*** (0.253)	-3.055*** (0.105)	-3.055*** (0.105)	-0.500* (0.285)	-0.500* (0.285)	0 (.)	0 (.)	0 (.)	0 (.)	0 (.)	0 (.)	-0.506*** (0.00466)	-0.506*** (0.00466)
Shallow ant.		1.254*** (0.237)		2.200** (1.094)		0.655 (0.852)		-0.0154 (0.449)		0 (.)		0 (.)		0 (.)		-0.409 (0.435)
Shallow short-term		-0.575 (0.826)		-0.428 (0.897)		0.972 (0.919)		-0.534 (0.751)		-0.631 (0.827)		0 (.)		0 (.)		-0.876 (0.792)
Shallow medium-term		-0.227 (0.401)		-0.587 (0.670)		0.696 (0.542)		0.794** (0.357)		1.114 (0.768)		-1.241* (0.659)		0 (.)		1.175** (0.480)
Shallow long-term		-0.561** (0.247)		-0.322 0.375)		0.299 (0.377)		-0.0225 (0.162)		-0.498 (0.338)		-3.190*** (0.415)		-2.017*** (0.580)		0.00970 (0.252)
Deep anticipatory		-0.277 (0.362)		-0.460 (0.323)		0.189 (0.376)		0.381* (0.211)		0.686*** (0.0308)		0.274 (0.456)		0 (.)		0.874*** (0.300)
Deep short		0.139 (0.213)		-0.116 (0.366)		0.400 (0.339)		0.162 (0.282)		0.176 (0.229)		0 (.)		0.606 (0.743)		0.0410 (0.383)
Deep medium term		0 (.)		0 (.)		0 (.)		0 (.)		0 (.)		0 (.)		0 (.)		0 (.)
Deep long term		0 (.)		0 (.)		0 (.)		0 (.)		0 (.)		0 (.)		0 (.)		0 (.)
Origin-time FE's	Yes	yes	Yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	Yes	yes	yes
Destination-time FE's	Yes	yes	Yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	Yes	yes	yes
Obs.	3012	3012	176	176	172	172	5511	5511	136	130	114	112	81	74	176	176

*Notes: ***, **, *denote significance at 1%, 5% and 10% percent level respectively. Standard errors in parenthesis are clustered at country pairs. Deep medium-term and Deep long-term are dropped because of collinearity.*

References

Anderson, J.E. and Van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. *American Economic Review*, 93(1):170-91.

Anderson, J.E. and Yotov, Y. (2016). Terms of trade and global efficiency effects of free trade agreements, 1990–2002. *Journal of International Economics*, 2016, 99(C): 279-298.

Archibugi, D. and Iammarino, S. (2002). The globalization of technological innovation: definition and evidence, *Review of International Political Economy,* 9(1): 98-112.

Baier, S.L. and Bergstrand, J.H. (2004). Economic determinants of free trade agreements. *Journal of International Economics*, 64(1):29-63.

Baier, S.L. and Bergstrand, J.H. (2007). Do free trade agreements actually increase members' international trade? *Journal of International Economics*, 71(1): 72-75

Baier, S.L., Yotov, V.Y., and Zylkin, T. (2019). On the widely differing effects of free trade agreements: Lessons from twenty years of trade integration, *Journal of International Economics*, 116(1): 206-226

Bartholomew, D. J., Martin, K. and Moustaki, I. (2011). Latent variable models and factor analysis: A unified approach. Chichester: John Wiley and Sons.

Bosworth, D.L. (1984), Foreign patent flows to and from the United Kingdom, *Res. Policy* 13 (2) 115–124.

Buthe, T., and Milner, H.V. (2008). The politics of foreign direct investment into developing countries: Increasing FDI through international trade agreements? *American Journal of Political Science*, 52(4), 741-762.

Cai, H., David, S., Xiaoyun, T. and Guigin, Z (2020). Foreign patents surge and technology spillovers in China (1985-2009): evidence from the patent and trade markets. *Technological Forecasting and Social Change,*15.

Campi, M., and Duenas, M. (2019). Intellectual property rights, trade agreements, and international trade. *Research Policy,* 48(3),531-545

Coleman, E. (2022). The effects of multilateral ip treaties on patenting behaviour. Technical report, Working paper, Vanderbilt University Department of Economics.

Correia, S., Guimares, P., and Zylkin, T. (2020). Fast Poisson estimation with high-dimensional fixed effects. *The Stata Journal*, 20(1):95-115

Delgado, M., Kyle, M. and McGahan, M (2013). Intellectual Property Protection and the Geography of Trade, *The Journal of Industrial Economics*, LXI, 733-762

Dur., A., Baccini, L., and Elsig, M. (2014). The design of international trade agreements: Introducing a new dataset. *The Review of International Organizations*, 9:353-375.

Eaton, J., Kortum, S. (1996). Trade in ideas: patenting and productivity in the OECD. J. Int. Econ. 40, 251–278OECD/EUIPO (2019), *Trends in Trade in Counterfeit and Pirated Goods*, Illicit Trade, OECD Publishing, Paris, https://doi.org/10.1787/g2g9f533-en.

Egger, P., Larch, M., Staub, K.E., and Winklemann, R. (2011). The trade effects of endogenous preferential trade agreements. *American Economic Journal: Economic Policy*, 3(3), 113-143.

Esteve-Perez, S., Gil-Pareja, S., and Llorca-Vivero, R. (2020). Does GATT/WTO promote trade? After all, Rose was right. *Review of World Economics*,156: 337-405.

Freund, C., and Ornelas, E. (2010). Regional trade agreements. *Annual Review of Economics*, 2(1), 139-166.

Hall, B. H. and Harhoff, D. (2012). Recent research on economics of patents. *American Economic Review*, 4(1): 541-565

Hall, B.H. and Ziedonis, R.H. (2001), The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979–1995, *RAND J. Econ*. 32 (1) 101–128.

Hu, A.G. (2010). Propensity to patent, competition and china’s foreign patenting surge, *Research Policy*, 39(7): 985-993.

Jinji, N., Zhang, X., & Haruna, S. (2019). Do deeper regional trade agreements enhance international technology spillovers? *The World Economy*, 42(8):2326–2363.

Kanwar, S. and Sperlich, S. (2023) Direct Foreign Investment and Intellectual Property Reform in the South. The Journal of International Development, doi.org/10.1002/jid.3735

LaBelle, J. and Santacreu, A. M. (2021). Global supply chain disruptions and inflation during the covid-19 pandemic (2022). https://ssrn.com/abstract=4029211

Magee, C.S. (2008). New measures of trade creation and trade diversion. *Journal of International Economics*, 75(2), 349-362

Maskus, K.E., and Ridley, W. (2016). Intellectual property-related preferential trade agreements and the composition of trade. *Robert Schuman Centre for Advanced Studies Research Paper, 2016/35.*

Martinez-Zarzoso, I., and Chelala. S. (2021) Trade agreements and international technology transfer. *Review of World Economics*, 157:631-665

Mogee, M. E., and United States. Small Business Administration. Office of Advocacy. (2003). *Foreign patenting behaviour of small and large firms* [Washington, DC]: US Small Business Administration, Office of Advocacy.

Olivero, M. P. and Yotov, Y.V. (2012). Dynamic gravity: endogenous country size and asset accumulation. *Canadian Journal of Economics/Revue canadienne d'économique,* 45(1):64-92

Park, W.G. (2006). International patenting at the European Patent Office: aggregate, sectoral and family filings. In: Hingley, P., Nicolas, M. (eds) Forecasting Innovations. Springer, Berlin, Heidelberg. https://doi.org/10.1007/3-540-35992-3_7

Picci, L., (2010). The internationalization of inventive activity: a gravity model using patent data. *Res. Policy* 39 (8), 1070–1081

Prud'homme, D., and Zhang, T. (2019). China's intellectual property regime for innovations: Risks to business and national development. Springer Link.

Rose, A. K. (2004). Do we really know that WTO increases trade? *American Economic Review*, 94(1): 98-114

Santacreu, A.M. (2021). Intellectual property rights, technology transfer and international trade. *Technology Transfer and International Trade (July 12, 2021) Available* SSRN: https://ssrn.com/abstract=3885234 or http://dx.doi.org/10.2139/ssrn.3885234

Santacreu, A.M. (2022). Dynamic Gains from Trade Agreements with Intellectual Property Provisions, Federal Reserve Bank of St. Louis or the Federal Reserve System *working paper No 2021-010*

Sheikh, R. A., Kanwar, S., et al., (2022). Does host country intellectual property protection matter for technology-intensive import flows? Technical report.

Silva, J.S. and Tenreyo, S. (2006). The log of gravity. *The Review of Economics and Statistics,* 88(4):641-658.

Sun, Y. (2003). Determinants of foreign patents in china, *World Patent Information*, 25(1): 27-37

WIPO. (2009) *The International Patent System in 2008: Comprehensive facts, figures and analysis of the international patent system.*

Yang, C.H. and Kuo, N.F. (2008). Trade-related influences, foreign intellectual property rights and outbound international patenting, *Research Policy* 37 (3), 446–459

Ziedonis R. H. (2004) Don’t fence me in: fragmented markets for technology and the patent acquisition strategies of firms, *Manag. Sci*. 50 (6) 804–820