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Cross-border Patenting and the Margins of International Trade[*][†]

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Abstract

This paper investigates the impact of cross-border patenting on the margins of international trade using disaggregated data on international patenting and trade flows. We develop a theoretical framework of trade and firms' patenting decisions that motivates our empirical analysis. The main results reveal that cross-border patenting has a larger effect on the extensive margin of trade compared to the intensive margin. This finding suggests that firms tend to seek patent protection in international markets prior to entering those markets with new products, rather than with their existing products.

JEL classification: F63, O14, O33, O34.
Keywords: Cross-border Patents, Gravity Model, Margins of Trade, Trade Agreements.

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1 Introduction

In an increasingly globalized economy, understanding the interplay between international trade, technology transfer, and intellectual property rights (IPRs) is crucial. As firms expand into foreign markets, they face decisions about whether and when to file patents to protect their technologies and maintain their competitive edge. While a growing literature has explored the relationship between trade and patenting, less attention has been paid to how this relationship may differ along the extensive (increasing variety of goods) and intensive (increasing volume of existing goods) margins of trade.

Some exceptions in the literature include Chen (2013), who focuses exclusively on patents granted by the US as a proxy for innovation, and Elliott, Jabbour, and Vanino (2020) for French firms. Additionally, the work of Gong et al. (2023) on Chinese inventors' patenting and subsequent increase in exports provides valuable insights on the motives for patenting. However, there is a lack of studies using global datasets that comprise the whole universe of innovators.

A recent study by Brunel and Zylkin (2022) makes important contributions in this direction by using a rich industry-level dataset to examine how bilateral trade flows respond to cross-border patent filings. They find that patents have a positive overall effect on the patent-filing country's exports to the patent-granting country, with the effect being stronger in industries with a higher demand elasticity and in downstream industries. In a related paper, Palangkaraya, Jensen, and Webster (2017) use a PPML gravity model to investigate how successful patent applications impact trade between countries. However, their analysis does not distinguish between the roles of extensive and intensive margin trade growth in driving patenting decisions.

Building on these findings, we study the impact of patents on international trade, making four key contributions to the literature. First, we decompose trade into extensive and intensive margins, explicitly comparing how patents affect each margin differently. Second, we develop a theoretical model that incorporates patent decision-making and yields a structural gravity equation. Third, we employ state-of-the-art structural gravity methods with high-dimensional fixed effects, using a comprehensive dataset that combines

product-level trade data with bilateral patent filings. This approach allows us to analyze the relationship between patents and trade on a global scale, overcoming limitations of previous studies that focused on specific countries or regions. Fourth, we address potential endogeneity using an instrumental variables approach, revealing that OLS estimates may underestimate the true impact of patents on trade.

Our hypothesis is that patents influence the decision to export a new variety (extensive margin) and the decision to expand market share in an existing product (intensive margin) through distinct mechanisms. To rationalize these hypotheses, we develop a theoretical model that extends the framework of LaBelle et al. (2023). Our model considers a world with multiple countries and industries, where final goods producers use a combination of domestic and imported intermediate products. Innovators create new ideas through R&D and strategically choose which to patent before engaging in international trade. This strategic decision-making process is key to understanding the link between patenting and trade patterns.

The model yields a structural gravity equation that expresses bilateral trade flows as a function of key country characteristics, including technology stocks, market sizes, and bilateral factors such as trade costs and patent stocks. This theoretical framework, building on the work of Anderson and Yotov (2010) and Yotov et al. (2016), explicitly incorporates the role of patenting in the extensive margin of trade while suggesting that patenting affects the intensive margin primarily through general equilibrium effects. This prediction guides our empirical strategy to examine the differential impacts of patenting on the extensive and intensive margins of trade.

Guided by our theoretical model, we employ a variety of econometric techniques to test these hypotheses empirically. Our analysis uses a comprehensive product-level trade dataset that allows us to track bilateral trade over time (UN-COMTRADE), linked to bilateral patent filings (INPACT-S, LaBelle et al. (2023)). We use the data to analyze the relationship between patents and trade globally, overcoming limitations of previous studies that focused on specific countries or regions.

To disentangle the distinct effects of patenting activity on the extensive and inten-

sive margins of trade, we employ state-of-the-art structural gravity models with high-dimensional fixed effects, following the approaches of Baier and Bergstrand (2007) and Yotov (2012). This methodology allows us to control for a wide range of unobserved factors and to isolate the specific impact of patenting on both the variety of goods traded and the volume of existing trade.

Our findings reveal that patent stocks have a positive and statistically significant effect on overall trade value, primarily driven by the extensive margin of trade. Specifically, we find that a 10% increase in patent applications is associated with a 0.09% increase in the extensive margin of trade, while the same increase in granted patents show a smaller but still significant effect of 0.03%. These results suggest that applying for patents, which captures innovative activity, may be more important for expanding trade relationships than the actual granting of patents.

To address potential endogeneity concerns suggested by our theoretical model, we employ state-of-the-art gravity regressions with instrumental variables (IV). Our IV estimates suggest that the OLS results may underestimate the true impact of patents on trade. When accounting for endogeneity, the effect of a 10% increase in patent applications on the extensive margin increases to 2.1%, while for a similar increase in granted patents it rises to 1.9%. This substantial increase in magnitude highlights the importance of addressing endogeneity issues in analyzing the patent-trade relationship.

The main results show that the causal impact of innovation on trade is heterogeneous across country groups and sectors, as predicted by our model. Our country-group analysis reveals that without accounting for endogeneity, the effect on the extensive margin is primarily driven by North-North flows. However, when using instrumental variables, we find stronger effects for South-South and North-South flows. This suggests that patents play a crucial role in facilitating trade relationships involving developing countries, particularly when endogeneity is addressed. These findings have important implications for understanding the role of intellectual property rights in promoting economic development and global trade integration.

Finally, we conduct a battery of robustness analyses. These include using alternative

measures of patenting activity, exploring heterogeneity in the relationship between patenting and trade, and employing various econometric techniques such as Poisson Pseudo Maximum Likelihood (PPML) estimation. In particular, we investigate potential heterogeneity in the effects across different industry groups and examine how the impact of patenting on trade varies with the strength of intellectual property protection in different groups of countries. These robustness checks consistently support our main findings, providing strong evidence for the differential impact of patenting on the extensive and intensive margins of trade.

Our study contributes to the literature by providing a comprehensive analysis of the relationship between cross-border patenting and international trade margins globally. We contribute to a recent literature studying the motivation of innovators to seek patent protection (LaBelle et al., 2023; Gong et al., 2023). In our framework, trade is the main channel for cross-border patenting. By distinguishing between the extensive and intensive margins, we offer new insights into the mechanisms through which innovation affects trade patterns, complementing the work by Brunel and Zylkin (2022). Finally, the paper contributes to recent work studying the effect of trade policy on cross-border patenting (LaBelle et al., 2023; Coleman, 2022).

Our paper also contributes to the theoretical literature on the relation between trade and patenting. The theoretical literature on the relationship between patents and international trade is extensive; however, there is no consensus on whether patents and trade act as complements or substitutes. Some models, such as those by Lai and Qiu (2003) and Grossman and Lai (2004), suggest that stronger patent rights in developing countries might actually decrease trade. This could occur by stimulating innovation-intensive production in the South, potentially reducing the North–South comparative advantage. Yang and Maskus (2009) present a model where Northern firms can serve Southern markets through exports, foreign direct investment (FDI), or licensing. They demonstrate that strengthening patent rights in the South can have ambiguous effects on trade in both directions. The impact depends on the optimal mode of foreign sales chosen by Northern firms and their strategic incentives for transferring know-how to the South. Additionally,

Bond and Saggi (2014) show that patent regimes incorporating the threat of compulsory licensing might induce innovating foreign firms to serve a market directly rather than voluntarily license their patented products. The lack of consensus in these theoretical models might be better understood by considering the extensive margin of trade. Theoretical models focusing on the extensive margin could provide insights into how patent regimes affect market entry decisions. For instance, stronger patent protection might encourage firms to enter new markets with their innovative products. While some models predict that stronger patents might reduce comparative advantage in certain sectors, others could show how the same policy might encourage a wider range of firms to engage in cross-border trade, particularly in knowledge-intensive industries.

The rest of the paper is organized as follows: Section 2 develops a theory of cross-border patenting and international trade, distinguishing between the extensive and intensive margins. Section 3 presents the empirical specification, describes the data, and reports the main results. Section 4 concludes.

2 A Theory of Cross-border Patenting and the Margins of International Trade

We develop a theory of patenting and trade in intermediate goods. The model is set up to discipline the empirical analysis and provide a theoretical foundation for the gravity equations we estimate, rather than for quantitative analysis. We present the main equations that give us the key ideas and notation behind the gravity equations for the extensive and intensive margins of trade, and refer the readers for other details of the model to Santacreu (2023).

There are M countries indexed by i and j and K industries indexed by k. Time is discrete and indexed by $t \in (0, \infty)$. In our model, final goods producers in each country use a combination of domestically produced and imported intermediate products, which determines the extensive margin. The number of available intermediates evolves through innovation and adoption. Innovators choose to patent their inventions before engaging in

international trade.

2.1 Production

Each country j produces a non-traded final good Y_{jt} using a Constant Elasticity of Substitutions (CES) aggregate of intermediate products from each country i and industries k at time t:

$$Y_{jt} = \left(\sum_{k=1}^{K} \alpha_{jk,t}^{1/\eta} \left(\sum_{i=1}^{M} \sum_{p=1}^{A_{ji}^{k}} Q_{jik,t}(p)^{(\eta-1)/\eta} \right)^{\eta/(\eta-1)} \right)^{\eta/(\eta-1)}, \tag{1}$$

where Y_{jt} is the total output in country j at time t, $\alpha_{jk,t}$ is the share of sector k in country j's output, η is the elasticity of substitution between sectors, A_{ji}^{k} is the number of varieties in sector k being sold from country i to country n. $Q_{jik,t}(p)$ is the quantity of variety p in sector k being sold from country i to country j at time t.

In each industry k, intermediates are produced by monopolistic competitive firms using labor with a constant return to scale technology.

2.2 Innovation, Adoption, and Patenting

Innovators in country i invest resources into R&D to create new ideas. Denote the stock of new ideas that have been invented by country i in industry k at time t as $N_{ik,t}$. A share ε_{jik} of these ideas can be used in country j. This share can be interpreted as capturing diffusion, that is, country j can only access a fraction of the ideas developed by country i.[1] Innovators choose the share of ideas to patent before exporting them to country j. A firm can only export an idea that has diffused. Traded ideas that are not patented are imitated and the innovators receive no return for them (LaBelle et al., 2023).

The number of varieties that are exported, $A_{jik,t}$, depends on the number of patents filed by firms from country i in country j and industry k at time t, denoted by $\text{Patents}_{jik,t}$:

[1] Note that there is diffusion across countries within the same industry, but we abstract away from inter-industry diffusion, different from Cai, Li, and Santacreu (2022).

$$A_{jik,t} = \varepsilon_{jik,t} \left(\frac{\text{Patents}_{jik,t}}{N_{ik,t}} \right)^{\gamma} N_{ik,t}, \tag{2}$$

where ε_{jik} captures factors that affect trade between specific country pairs, such as geographical proximity, shared language, colonial ties, or trade agreements (some of these factors are time-invariant), and $\gamma > 0$ are parameters governing the effect of patents on adoption. Note that if there is no patenting, i.e., $\text{Patents}_{jik,t} = 0$ then $A_{jik,t} = 0$; instead, if all technologies are patented, i.e., $\text{Patents}_{jik,t} = N_{ik,t}$ then $A_{jik,t} = \varepsilon_{jik,t} N_{ik,t}$. In general, $\text{Patents}_{jik,t} = \lambda_{jik,t} N_{ik,t}$, with $\lambda_{jik,t} < 1$. We can interpret this through the lens of a model in which patenting is costly, so that it guarantees an interior solution for the share of patented ideas (LaBelle et al., 2023).

We assume $\varepsilon_{jik,t} = \eta_{jk,t} \rho_{ik,t} \xi_{ijk}$ where $\eta_{jk,t}$ represents the attractiveness of country j to do business there or the ability of country j to absorb technologies from sector k at time t. This term captures factors specific to the destination country that may influence its capacity to integrate new technologies or products in a particular sector; $\rho_{ik,t}$ represents the factors specific to country i in sector k that affect the diffusion of ideas from country i to other countries; ξ_{ijk} accounts for origin-destination-sector time-invariant characteristics impacting diffusion.

2.3 The Extensive and Intensive Margins of Trade

The demand function for a variety p exported from country i to country j in sector k is:

$$Q_{jik,t}(p) = \alpha_{jk,t} \left(\frac{P_{jik,t}(p)}{P_{jk,t}} \right)^{-\eta} Y_{jt}, \tag{3}$$

where $P_{jk,t}$ is the price index for industry k in country j, and P_{jt} is the overall price index in country j.

Under monopolistic competition, the price of an intermediate good exported from country i to country j in sector k is a constant markup over the marginal cost, given by

the wage w_{it}, taking into account the iceberg transport cost d_{jik}:

$$P_{jik,t}(p) = \frac{\eta}{\eta - 1} w_{it} d_{jik}. \tag{4}$$

Aggregating the value of trade across all varieties exported from country i to country j in sector k at time t:

$$X_{jik,t} = \sum_{p=1}^{A_{jik,t}} P_{jik,t}(p) Q_{jik,t}(p) \tag{5}$$

$$= A_{jik,t} \frac{\eta}{\eta - 1} \alpha_{jk,t} w_{it} d_{jik} \left(\frac{\frac{\eta}{\eta-1} w_{it} d_{jik}}{P_{jk,t}} \right)^{-\eta} Y_{jt}. \tag{6}$$

Substituting the expression for $A_{jik,t}$ from equation 2 and taking into account that $\varepsilon_{jik,t} = \eta_{jkt} \rho_{ikt} \xi_{ijk}$:

$$X_{jik,t} = \eta_{jkt} \rho_{ikt} \xi_{ijk} \left(\frac{\text{Patents}_{jik,t}}{N_{ik,t}} \right)^{\gamma} N_{ik,t} \left(\frac{\eta}{\eta - 1} \right)^{1-\eta} \alpha_{jk,t} (w_{it})^{1-\eta} d_{jik}^{1-\eta} P_{jk,t}^{\eta} Y_{jt}. \tag{7}$$

Structural gravity equation Rearranging the terms we have a structural gravity equation for trade flows:

$$X_{jik,t} = \left(\frac{\eta}{\eta - 1} \right)^{1-\eta} \underbrace{(\text{Patents}_{jik,t})^{\gamma}}_{\text{Patents}} \underbrace{\xi_{ijk} d_{jik}^{1-\eta}}_{\text{Country-pair-sector}} \underbrace{\alpha_{jk,t} \eta_{jkt} P_{jk,t}^{\eta} Y_{jt}}_{\text{destination-sector-year}} \underbrace{\rho_{ikt} N_{ik,t}^{1-\gamma} (w_{it})^{1-\eta}}_{\text{Origin-sector-year}}. \tag{8}$$

The gravity equation for trade flows shows that the value of trade depends on: the exporting country's characteristics, $N_{ik,t}$, $\rho_{ik,t}$ and $w_{i,t}$; the importing country's characteristics, Y_{jt}, $P_{jk,t}$, and $\alpha_{jk,t}$; and bilateral factors, $\text{Patents}_{ijk,t}$, ξ_{ijk}, and d_{jik}. This structural gravity equation incorporates the role of patenting in the extensive margin of trade. The intensive margin equation suggests that patenting affects the average value of exports per variety through GE effects.

3 From Theory to Empirics: Do Patents Impact the Margins of Trade?

Our theoretical model provides a framework for empirically estimating the determinants of trade and its margins using gravity equations. The model emphasizes the role of patenting in impacting both the extensive and intensive margins of trade. To test these theoretical predictions, we decompose the total value of exports from country i to country j in industry k at time t into its intensive and extensive margins:

$$X_{ijk,t} = IM_{ijk,t} \times EM_{ijk,t} \tag{9}$$

where $IM_{ijk,t}$ denotes the intensive margin (average value of exports per variety) and $EM_{ijk,t}$ represents the extensive margin (number of varieties exported).

Building on our theoretical framework, we estimate the following two equations to quantify the effects of patenting on the intensive and extensive margins of trade:

$$\log(IM_{ijk,t}) = \alpha_0^{im} + \alpha_1^{im} \log(\text{Patents}_{ijk,t}) + \nu_{ijk}^{im} + \gamma_{ik,t}^{im} + \delta_{jk,t}^{im} + u_{ijk,t}^{im} \tag{10}$$

$$\log(EM_{ijk,t}) = \alpha_0^{em} + \alpha_1^{em} \log(\text{Patents}_{ijk,t}) + \nu_{ijk}^{em} + \gamma_{ik,t}^{em} + \delta_{jk,t}^{em} + u_{ijk,t}^{em} \tag{11}$$

Here, $IM_{ijk,t}$ represents the average trade volume per product for the same country-pair, industry, and time period t, while $EM_{ijk,t}$ is defined as the number of unique products traded from country i to country j in industry k at time t. $\text{Patents}_{ijk,t}$ measures the number of patents filed by firms from country i in country j and industry k at time t. We include various fixed effects (FE) to control for unobserved heterogeneity at the country-pair-sector, and time-varying factors at the origin-industry and destination-industry levels. The first set of FE is intended to control for endogeneity that is due to time invariant factors. Nevertheless, to address potential endogeneity concerns due to omitted time-variant factors that could be correlated with our target variable, we employ instrumental variables (IV) techniques. Our instruments include changes in patent laws and regulations that are exogenous to trade flows, such as the Patent Cooperation Treaty

(PCT). These instruments are correlated with patenting decisions but do not directly affect trade margins, allowing us to identify the causal effect of patenting on trade.

We also explore heterogeneity across industries by estimating the model for three different groups of sectors, according to their level of sophistication. The first group includes mostly homogeneous products, the second differentiated products and the third comprises industries related to information and communication technologies and transport equipment.

To ensure the robustness of our findings, we conduct various checks, including using alternative measures of patenting (e.g., granted patents, patent flows), an alternative estimator (PPML), controlling for additional factors (gravity controls), and estimating the model separately for different groups of sectors. By estimating equations (10) and (11), we quantify the impact of patenting on the intensive and extensive margins of trade, as predicted by our theoretical model. This empirical analysis complements the insights from the model and provides evidence on the role of patenting in shaping international trade patterns, while considering complex interactions and potential general equilibrium effects.

3.1 Data Construction

Trade Flows and the Margins of International Trade For trade values, we utilize the United Nations Commodity Trade Statistics Database (UN Comtrade) at the Harmonized System (HS) 6-digit level. To align with industry classifications, we employ concordance tables to convert HS codes to the International Standard Industrial Classification (ISIC) Revision 3. Our analysis of trade margins focuses on two dimensions within each ISIC sector. The extensive margin is calculated by counting the number of distinct products exported within a given sector. The intensive margin, representing the average value per product, is computed as the ratio of total trade value to the extensive margin. This approach allows us to decompose trade patterns into the diversity of products exported (extensive) and the average value per product (intensive) for each industrial sector.

Our concept of extensive margin is based on the number of products using HS-6 digit categories, as employed by Santacreu (2015) and Eaton and Fieler (2019). An alternative measure was proposed by Hummels and Klenow (2005) that weights each category by its importance in world trade. However, Eaton and Fieler (2019) find a high correlation of about 0.93 between these two measures.

Cross-border Patenting Data The patent data are from LaBelle et al. (2023), who build a novel *International Patent and Citations across Sectors* (INPACT-S) database that tracks cross-border and domestic patent flows across industries over four decades.[2] To construct INPACT-S, LaBelle et al. (2023) rely primarily on the PATSTAT Global Autumn 2021. The dataset contains information for patent applications (and patents granted) from a country of origin (i.e., the residence of the inventor or the owner of the technology) to an application authority at the ISIC Rev3 level for the period 1980-2019. In total, there are 91 patent authorities, 213 countries of origin, 40 years, and 31 ISIC Rev. 3 2-digit codes.

The data report flows of patent applications. We use the perpetual inventory method to transform flows into stocks, using a depreciation rate of 15%, choosing as the initial year 1985. In particular, we construct:

$$STOCK_{jik,t} = (1-\delta)STOCK_{jik,t-1} + Pat_{jik,t}$$

where δ is the depreciation rate.

Other control variables employed include common language, common border, common legal origin and the existence of a present or past colonial relationship between the pair of countries are from CEPII, Conte et al. (2022). Gross Domestic Product (GDP) and population come from the World Development Indicators Database from the World Bank. Finally, dummy variables for the World Trade Organization (WTO) and the Patent Cooperation Treaty (PCT) memberships come from the WTO and from the World Intel-

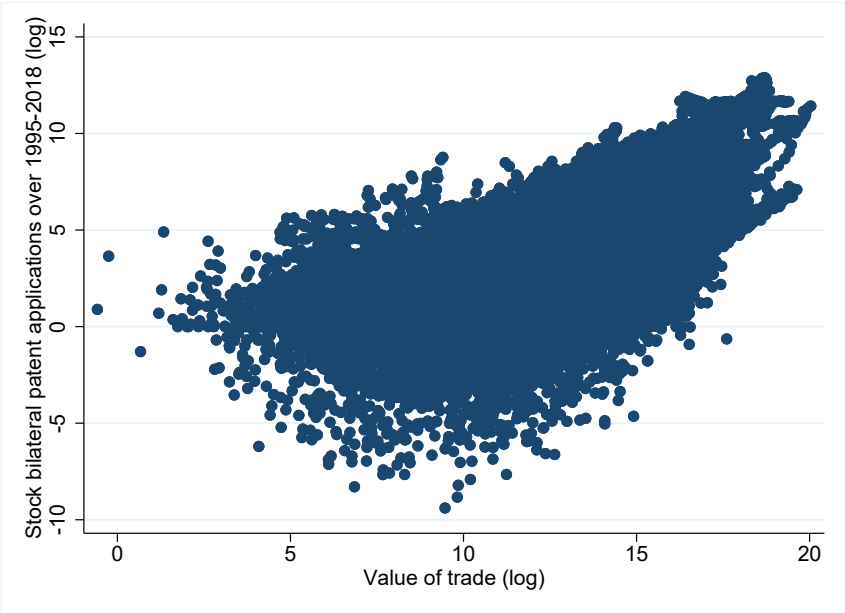
[2]The INPACT-S dataset is available upon request by filling this questionnaire: `https://docs.google.com/forms/d/e/1FAIpQLSfavSMVLbd3VsaIyElT3qgUC4E0KPpM3m4P2OUVpzxit3m27A/viewform?fbzx=2712524605281662872`.

lectual Property Organization (WIPO) websites, respectively. Summary statistics of the variables used in the empirical model are presented in Table A.1.

Motivation figures Before conducting a rigorous econometric analysis of the relationship between patents and the margins of international trade, we present descriptive evidence using aggregate data on patenting and trade flows. This evidence provides insights into the patterns and correlations that motivate our subsequent analytical approach.

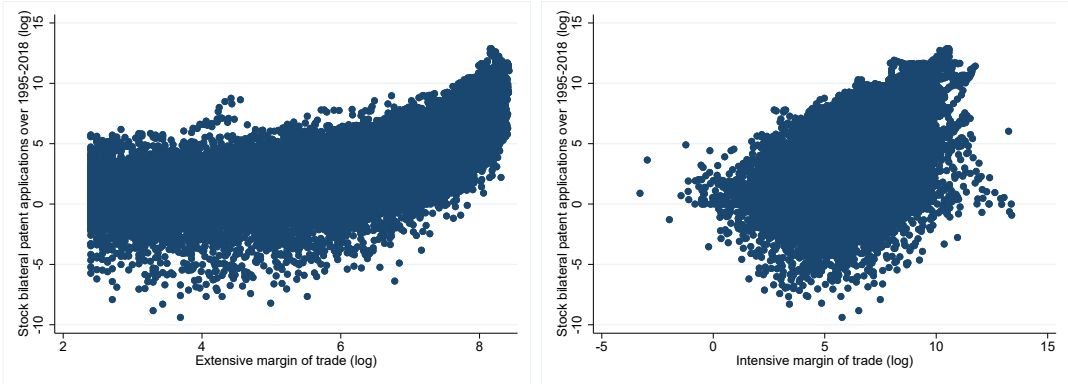
Figure 1 illustrates the correlation between bilateral patent applications and bilateral trade flows over the period 1995-2018. The scatter plot shows a strong positive association between these two variables, with a correlation coefficient of 0.61. This robust relationship suggests that countries with stronger bilateral patenting activity tend to engage in more substantial bilateral trade. Such a pattern may indicate that technological innovation, as proxied by patent applications, plays a significant role in facilitating international trade relationships. This observation aligns with previous evidence as shown by Brunel and Zylkin (2022).

Figure 1: Bilateral Patenting and International Trade



The figure depicts the correlation between bilateral patent applications (INPACT-S) and bilateral trade flows (UN COMTRADE) for the period 1995-2018. Each data point in the scatter plots represents a unique bilateral relationship between two countries, aggregating patent applications and trade flows across all sectors for that country pair over the period 1995-2018.

Figure 2: Bilateral Patenting and the Margins of Trade



The figure illustrates the correlation between bilateral patent applications (INPACT-S) and the extensive margin of trade (UN COMTRADE) for 1995-2018 (left panel), and between bilateral patent applications (INPACT-S) and the intensive margin of trade (UN COMTRADE) for the same period (right panel). Each data point in the scatter plots represents a unique bilateral relationship between two countries, aggregating patent applications and trade flows across all sectors for that country pair over the period 1995-2018.

To further unpack this relationship, Figure 2 examines the correlation between bilateral patent applications and the two key margins of international trade: the extensive and intensive margins. The left panel shows the relationship with the extensive margin, which represents the number of products traded. We observe a strong positive correlation of 0.61, mirroring the overall trade relationship. This suggests that countries with more bilateral patent applications tend to trade a wider variety of products, potentially indicating that innovation leads to product diversification in international markets. The right panel illustrates the relationship with the intensive margin, which captures the average value per product traded. Here, we find a positive but somewhat weaker correlation of 0.48. This implies that while increased patenting activity is associated with higher average trade values per product, the relationship is not as pronounced as with the extensive margin.

These findings suggest there exists a relationship between innovation and trade. The stronger correlation with the extensive margin might indicate that patenting activity is particularly important for expanding the range of products traded between countries. The positive but weaker relationship with the intensive margin suggests that patents also contribute to increasing the value of existing trade relationships, albeit to a lesser extent.

These descriptive patterns motivate our subsequent analysis, where we employ econometric techniques used in the trade, migration, and FDI literature to more rigorously examine the causal relationships between patenting activity and the various dimensions of international trade, controlling for other relevant factors that may influence these relationships.

3.2 Empirical Results

Guided by our theoretical framework, we employ linear models to analyze three key aspects of trade: the logged export value, the intensive margin (equation 10), and the extensive margin of trade (equation 11). This approach follows the Baier, Bergstrand, and Feng (2014)'s methodology. A property of the margin decomposition is that the product of the extensive and intensive margins equals the total export value from country i to country j. Therefore, we can linearly decompose the logarithm of the trade flow value from i to j in any given year t into the sum of the logarithms of the extensive and intensive margins.

We present results for patent stocks in Tables 1 to 5. We present results for a gravity model using three different dependent variables and two target variables. The dependent variables are: Tradeval, IM and EM. Tradeval refers to the disaggregated bilateral trade flow from i to j (or $X_{ijk,t}$ in equation 9). IM refers to the intensive margin of trade (or $IM_{ij,t}$ in equation 10). EM refers to the extensive margin (or $EM_{ij,t}$ in equation 11). From the linearized version of equation (9), the sum of the logs of the extensive and intensive margins equals the log of the aggregate trade flow. This allows us to infer from the empirical results the relative extensive and intensive margin elasticities of an increase in patent applications. The two alternative target variables are the stock of patent applications and the stock of patents granted.

Table 1 reports the estimated coefficient for patent stocks considering applications in columns (1)-(3) and granted patents in columns (4)-(6). The coefficient for log-stock of patent applications in column (1) is positive and statistically significant, indicating that an increase in patent applications is associated with higher overall trade value. This find-

ing captures the importance of innovation in driving international trade, and is consistent with the findings in Brunel and Zylkin (2022). Looking closer into the mechanics of this relationship, we observe that the positive effect on the trade value is predominantly driven by the EM, as shown in column (3). This aligns with theoretical predictions and suggests that patent applications primarily facilitate entry into new markets or the trading of new products, rather than intensifying existing trade relationships. Quantitatively, the analysis reveals that 75% of the increase in trade value attributable to patent applications is explained by the extensive margin, while only 25% is accounted for by the IM. This difference highlights the crucial role of innovation in expanding the scope of international trade.

Interestingly, when we examine granted patents in columns (4)-(6), we observe a slightly weaker effect on the extensive margin (column 6) compared to patent applications. This finding might indicate that the signaling effect of innovation, as represented by patent applications, could be more influential in international trade than the actual granting of patents (Gong et al., 2023). For granted patents, 42% of the increase in trade value is attributed to the extensive margin. While this is still a substantial portion, it is notably lower than the 75% observed for patent applications.

It is important to note that the coefficients for the IM are not statistically significant at conventional levels, both for patent applications (column 2) and granted patents (column 5). This lack of significance suggests that neither patent applications nor granted patents have a robust effect on the volume of trade within existing trade relationships.

The analysis also provides insights into the effects of other key variables. Interestingly, Regional Trade Agreements (RTAs) show a positive effect on the intensive margin but a negative and significant effect on the extensive margin. This result suggests that while RTAs may deepen existing trade relationships, they might reduced the number of traded products. This finding is also consistent with Foster, Poeschl, and Stehrer (2011), who report a small decrease in the IM. In contrast to RTAs, WTO membership exhibits a positive effect on the extensive margin but a negative effect on the intensive margin. This implies that WTO membership may facilitate trading of new products, but might

not necessarily intensify existing trade flows. This is consistent with Dutt, Mihov, and Van Zandt (2013).

Table 1: Do Cross-Border Patent Stocks Promote Trade? Value, EM, IM

	(1) ln_tradeval b/se	(2) ln_trade_im b/se	(3) ln_trade_em b/se	(4) ln_tradeval b/se	(5) ln_trade_im b/se	(6) ln_trade_em b/se
log_stock	0.012***	0.003	0.009***			
	(0.003)	(0.003)	(0.001)			
log_stockg				0.007**	0.004	0.003***
				(0.003)	(0.003)	(0.001)
rta	0.035***	0.046***	-0.011***	0.038***	0.045***	-0.007*
	(0.012)	(0.011)	(0.004)	(0.013)	(0.012)	(0.004)
wto	0.167***	-0.132**	0.299***	0.153**	-0.134**	0.287***
	(0.059)	(0.053)	(0.022)	(0.061)	(0.055)	(0.022)
N	583537	583537	583537	519365	519365	519365
R^2	0.945	0.913	0.981	0.946	0.915	0.982

This table reports estimates of the effects of cross-border patent application stocks on bilateral trade flows. Three dependent variables are used. Specifically, column (1) presents the effects on the trade value. Column (2) on the intensive margin of trade. In column (3) we estimate the effect on the extensive margin. In columns (4)-(6), we use the same three dependent variables, but the target variable in now the stock of patents granted. The dependent variables are all in natural logs and the estimator is a linear model with high dimensional fixed effects (origin-sector-year, destination-sector-year, pair-sector). Standard errors in parentheses are clustered by country pair in all columns. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

Table 2 presents the results obtained using instrumental variables, addressing potential endogeneity concerns in the previous regressions. The endogeneity problem in this context may arise from reverse causality or omitted variable bias. Reverse causality could occur if increased trade activity leads to more patent applications or grants, rather than patents driving trade. Omitted variable bias might exist if there are unobserved time-variant factors affecting both patent activity and trade patterns simultaneously, such as sector-specific technological advancements or changes in IP regimes. While our inclusion of pair-sector and country-sector-year fixed effects partially accounts for these factors, the industry-level analysis may not be sufficiently granular when technological advancements or regulations apply to specific products.

To address these endogeneity issues, we employ the first and second lags of PCT applications as external instruments. PCT applications are considered a good instrument for several reasons. First, they are likely to be correlated with the endogenous variable (patent stocks) because PCT applications are often a precursor to national patent ap-

plications and grants. Second, lagged PCT applications are less likely to be directly influenced by current trade patterns, satisfying the exclusion restriction. The use of lags further reduces the potential for reverse causality, as past PCT applications are predetermined with respect to current trade flows.

The strength and validity of these instruments are crucial for the reliability of the IV estimates. The tests for weak instruments (K-P test) indicate that the instruments are strong, suggesting a robust correlation between the instruments and the endogenous variables. Additionally, the Hansen test does not reject the validity of the instruments, providing evidence that the instruments are uncorrelated with the error term and correctly excluded from the main equation.

The IV estimation results reveal a more pronounced effect on the EM compared to the OLS estimates in Table 1. For patent applications, the coefficient increases from 0.009 to almost 0.21, while for granted patents, it rises from 0.003 to 0.19. This substantial increase in magnitude suggests that the OLS estimates may have been biased downwards, potentially due to endogeneity issues.

The larger IV coefficients imply that the true impact of patents on trade, particularly on the extensive margin, may be higher in magnitude than initially estimated. The results provide stronger evidence for the role of patents in facilitating trading of new products, reinforcing the notion that innovation and IP protection are crucial drivers of trade expansion.

Table 3 shows some further regressions to prove that the instruments are exogenous and strong. Columns (1)-(3) report the results of a falsification test. This test involves adding two lags and two leads of the PCT dummy variable to the original models from Table A.2. The purpose of this test is to examine whether future PCT applications (leads) have any significant effect on current trade patterns. If the instruments are truly exogenous, we would expect future PCT applications to have no significant impact on current trade. The results from this falsification test are largely supportive of the instrument's exogeneity. For the overall trade value and EM, neither the lags nor the leads of the PCT dummy are statistically significant at conventional levels. This lack of

Table 2: Do Cross-Border Patent stocks Promote Trade? IV Results

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_tradeval	ln_trade_im	ln_trade_em	ln_tradeval	ln_trade_im	ln_trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_stock	-0.031	-0.245	0.208***			
	(0.180)	(0.173)	(0.068)			
log_stockg				0.022	-0.166	0.190***
				(0.159)	(0.148)	(0.063)
rta	0.013	0.032**	-0.019***	0.012	0.025*	-0.014***
	(0.015)	(0.014)	(0.005)	(0.015)	(0.014)	(0.005)
wto	0.116	-0.007	0.127**	0.073	-0.068	0.140***
	(0.141)	(0.135)	(0.051)	(0.127)	(0.119)	(0.047)
N	381694	381694	381694	357955	357955	357955
K-P Stat	58.249	58.249	58.249	49.214	49.216	49.216
Hansen Test (Prob)	0.601	0.939	0.238	0.528	0.563	0.798

This table reports instrumental variables results. The external instruments are the first and second lags of the Patent Cooperation Treaty dummy variable, which takes the value of one when a pair of countries has ratified the treaty, zero otherwise. Standard errors in parentheses are clustered by country pair in all columns. K-P denotes the underidentification test (Kleibergen-Paap rk LM statistic). The Hansen test associated probability indicates that the instruments are valid. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

significance suggests that future PCT applications do not predict current trade patterns, which is consistent with the assumption of instrument exogeneity. For the IM, only the first lead of the PCT dummy shows weak statistical significance. However, this significance is only at a marginal level, and given that it is the only significant result out of multiple tests, it could potentially be due to chance rather than a systematic relationship.

Columns (4) and (5) of Table 3 present the results of the first-stage regressions in the IV estimation process. These regressions are crucial for assessing the strength of the instruments. The coefficients for both the first and second lags of the PCT variable are strongly statistically significant. This strong significance indicates a robust relationship between the instruments (lagged PCT applications) and the endogenous variables (patent stocks).

The strength of these first-stage results is important because weak instruments can lead to biased IV estimates and unreliable inferences. The strong significance observed here suggests that the instruments are not weak, which increases confidence in the IV

estimates presented in Table 2.

The combination of these results provides compelling evidence for the validity of the IV approach used in this study. The falsification tests in columns (1)-(3) support the exogeneity assumption by showing that future PCT applications do not significantly predict current trade patterns. The first-stage results in columns (4) and (5) demonstrate that the instruments are strongly correlated with the endogenous variables, satisfying the relevance condition for valid instruments. While not directly tested here, the lack of significance for the PCT leads in the main regressions provides indirect support for the exclusion restriction, suggesting that the instruments affect trade only through their impact on patent stocks.

These findings strengthen the credibility of the IV estimates in Table 2, which showed larger effects of patents on trade compared to the OLS estimates. The validation provided by Table 3 increases confidence that these larger effects represent a more accurate estimation of the true impact of patents on international trade patterns, particularly on the extensive margin of trade. In conclusion, Table 3 offers important evidence supporting the validity of the instrumental variables approach used in this study, enhancing the reliability of the main findings regarding the relationship between patents and the margins of international trade.

Table 4 analyzes the relationship between patent stocks and international trade flows by categorizing countries into "North" (N) and "South" (S) groups based on the World Bank income classification for the year 2000 (LaBelle et al., 2023). This classification allows us to examine how the effects of patent stocks on trade vary across different economic development levels. The analysis considers four bilateral groups: North to North (NN), North to South (NS), South to North (SN), and South to South (SS).

The main findings from the country-group analysis reveal interesting patterns that were not apparent in the results of Table 1. For patent applications, without accounting for endogeneity (columns 1-3), the positive effect on the EM is primarily driven by flows between developed countries (NN). This suggests that, in the absence of instrumental variable correction, the impact of innovation on market entry and product diversification

Table 3: Are the instruments exogenous and strong?

	(1)	(2)	(3)	(4)	(5)
	ln_tradeval	ln_trade_im	ln_trade_em	log_stock	log_stockg
	b/se	b/se	b/se	b/se	b/se
log_stock	0.015**	-0.004	0.020***		
	(0.007)	(0.007)	(0.002)		
rta	-0.018	0.003	-0.021***	0.036***	0.027**
	(0.018)	(0.017)	(0.004)	(0.010)	(0.011)
wto	-0.038	-0.210**	0.173***	0.336***	0.296***
	(0.091)	(0.085)	(0.025)	(0.040)	(0.043)
pct	-0.075	-0.082	0.007		
	(0.080)	(0.078)	(0.025)		
F2.pct	-0.052	-0.103	0.051		
	(0.112)	(0.104)	(0.042)		
F.pct	0.142	0.147*	-0.005		
	(0.092)	(0.089)	(0.040)		
L.pct	0.118	0.077	0.041	0.226***	0.357***
	(0.083)	(0.084)	(0.027)	(0.031)	(0.034)
L2.pct	-0.102	-0.106	0.004	0.435***	0.334***
	(0.078)	(0.076)	(0.021)	(0.026)	(0.031)
N	269324	269324	269324	571844	537450
R^2	0.959	0.936	0.989	0.974	0.973

This table reports first stage results in columns (1)-(3) for three dependent variables: the log of trade value, intensive and extensive margins of trade, respectively. We use the first and second lags of the Patent Cooperation Treaty dummy as external instruments. (4) and (5) checks whether the instruments are strong for the two instrumented variables, namely the stock of patent applications and of granted patents, respectively. The estimator is a linear model with high dimensional fixed effects (origin-sector-year, destination-sector-year, pair-sector). Standard errors in parentheses are clustered by country pair in all columns. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

appears strongest among high-income economies.

However, when we employ instrumental variables to address potential endogeneity issues (columns 4-6), a different picture emerges. The effect on the extensive margin becomes more pronounced for South-South (SS) and North-South (NS) flows. The significant positive effect on the EM for SS flows suggests that innovation plays a crucial role in expanding trade relationships among developing countries. This could indicate that patents are particularly important for product diversification in emerging economies. Additionally, the positive effect on NS trade flows implies that innovations from developed countries are instrumental in facilitating new trade relationships with developing countries. This could reflect the transfer of technology and knowledge from more advanced economies to emerging markets.

These findings have important implications. First, the contrast between the non-IV and IV results shows the importance of addressing endogeneity in analyzing the patent-trade relationship. The IV approach reveals effects that were not apparent in the simpler model, particularly for developing countries. Second, the strong effects for SS and NS flows in the IV model suggest that patents may play a crucial role in fostering trade relationships involving developing countries. This could have significant implications for development economics and trade policy. Third, the positive effect on NS flows might indicate that patents facilitate technology transfer from developed to developing countries, potentially contributing to economic development and catch-up processes. Lastly, the strong effect on SS flows highlights the growing importance of trade and innovation relationships among developing countries, which could be a key driver of future global economic growth.

Table 5 presents a detailed analysis of the relationship between cross-border patent stocks and trade flows, specifically examining the IM and EM across three distinct categories of industrial sectors. The first category, encompassing sectors 15-19 (food and beverages; tobacco products; textiles; wearing apparel; leather and footwear), is represented in columns (1) and (2). These sectors are generally characterized by lower technological intensity and more traditional manufacturing processes. The results show

Table 4: Do Cross-Border Patent stocks Promote Trade? Country-Group Results

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_tradeval	ln_trade_im	ln_trade_em	ln_tradeval	ln_trade_im	ln_trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_stock_N_N	0.005	0.001	0.005***	-0.244	-0.449**	0.172*
	(0.004)	(0.004)	(0.001)	(0.213)	(0.213)	(0.089)
log_stock_N_S	0.004	0.005	-0.001	0.000	-0.534	0.435***
	(0.006)	(0.005)	(0.002)	(0.374)	(0.376)	(0.163)
log_stock_S_N	-0.009	0.002	-0.011***	-0.169	-0.208*	0.064
	(0.006)	(0.005)	(0.002)	(0.122)	(0.122)	(0.052)
log_stock_S_S	0.012	0.014	-0.002	-0.145	-0.468**	0.282***
	(0.012)	(0.011)	(0.005)	(0.230)	(0.237)	(0.106)
rta_N_N	0.039***	0.037***	0.003	0.028	0.049	-0.018
	(0.015)	(0.014)	(0.004)	(0.031)	(0.031)	(0.011)
rta_N_S	-0.008	0.051***	-0.060***	0.033	0.075**	-0.042**
	(0.022)	(0.020)	(0.008)	(0.030)	(0.031)	(0.017)
rta_S_N	0.003	0.042	-0.039***	-0.077	-0.088	0.005
	(0.032)	(0.030)	(0.009)	(0.057)	(0.057)	(0.020)
rta_S_S	0.080	0.139**	-0.059**	0.108	0.082	-0.097
	(0.070)	(0.060)	(0.029)	(0.194)	(0.313)	(0.158)
wto_N_N	0.037	-0.228**	0.265***	-0.108	-0.007	-0.069
	(0.117)	(0.105)	(0.048)	(0.264)	(0.287)	(0.124)
wto_N_S	0.174***	-0.146**	0.320***	-0.027	-0.129	0.120
	(0.066)	(0.062)	(0.022)	(0.178)	(0.180)	(0.074)
wto_S_N	0.255***	-0.100	0.355***	0.121	0.002	0.136*
	(0.070)	(0.062)	(0.028)	(0.176)	(0.187)	(0.078)
wto_S_S	0.125*	-0.135**	0.260***	-0.034	-0.108	0.101*
	(0.071)	(0.066)	(0.024)	(0.150)	(0.150)	(0.060)
N	604570	604570	604570	384323	384323	384323
K-P stat				49.260	49.260	49.260
Hansen test				0.267	0.334	0.069

This table reports estimates of the effects of cross-border patent stocks on trade flows. The estimates are obtained after allowing for the effects of innovation to vary across four bilateral groups (including "North to South", "South to South", "North to North", and "South to North", which are based on the income classification of the World Bank for 2000. In addition, each column of the table introduces a new dependent variable, whose determinants are also allowed to vary across the four bilateral income groups. Specifically, column (1) present the effects on the trade value. Column (2) on the intensive margin of trade. In column (3) we estimate the effect on the extensive margin. Finally, in columns (4)-(6), we use IV for the patent stocks using lags of the PCT. The dependent variables are in natural logs and the estimator is a liner model with high dimensional fixed effects. Standard errors in parentheses are clustered by country pair. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

that for these industries, an increase in the stock of patent applications has a positive and significant effect only on the extensive margin of trade, with no significant impact on the intensive margin. This suggests that in these sectors, innovation primarily leads to the introduction of new product varieties rather than increasing the volume of existing trade relationships.

The second category, covering sectors 20-29 (wood and cork; paper; publishing and printing; coke and refined oil; chemicals; rubber and plastic; non-metallic minerals; basic metals; fabricated metal products; machinery and equipment), is analyzed in columns (3) and (4). These sectors represent a mix of medium-low and medium-high technology industries. Interestingly, the results for this group mirror those of the first category, with positive and significant effects observed only for the extensive margin. Moreover, the magnitude of the effect is even larger than that observed in the first category, indicating that innovation plays a particularly crucial role in expanding the variety of products traded in these sectors.

The third category, encompassing sectors 30-37 (office and computing machinery; electrical machinery; radio, television and communication equipment; medical, precision and optical instruments; motor vehicles; other transport equipment; furniture and other manufacturing n.e.c.; recycling), is represented in columns (5) and (6). These sectors are generally associated with higher technological sophistication and R&D intensity. In contrast to the previous two categories, the results show that an increase in the stock of patents positively affects both the intensive and extensive margins of trade. Notably, the effect on the intensive margin is substantially larger, accounting for approximately 82% of the total impact on trade value, compared to about 18% for the extensive margin. This suggests that in these high-tech sectors, innovation not only leads to the introduction of new product varieties but also significantly increases the volume of trade in existing products.

These findings highlight important heterogeneity across sectors in how innovation impacts trade patterns. In less technologically intensive industries, innovation primarily expands the range of products traded. In contrast, in more sophisticated, high-tech

sectors, innovation has a dual effect, both expanding product variety and intensifying existing trade relationships, with a particularly strong impact on trade volumes. Following Baier and Bergstrand (2007), the table also includes controls for regional trade agreements (RTA) and WTO membership, which show varying effects across sector categories and trade margins.

Table 5: Do Cross-Border Patent stocks Promote Trade? Sectoral Results 1-digit for IM and EM

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_trade_im	ln_trade_em	ln_trade_im	ln_trade_em	ln_trade_im	ln_trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_stock	-0.011	0.010***	0.000	0.014***	0.014***	0.003**
	(0.007)	(0.003)	(0.004)	(0.002)	(0.004)	(0.001)
rta	-0.008	-0.006	0.061***	-0.008	0.035**	-0.020***
	(0.026)	(0.011)	(0.015)	(0.005)	(0.017)	(0.006)
wto	-0.375***	0.193***	-0.184**	0.353***	0.086	0.266***
	(0.111)	(0.060)	(0.072)	(0.031)	(0.102)	(0.038)
N	85404	85404	287159	287159	174525	174525
R^2	0.922	0.975	0.911	0.979	0.940	0.975

This table reports estimates of the effects of cross-border patent stocks on trade flows. Results are presented for the log of the intensive and the extensive margins of trade for three categories of products. Specifically, column (1) present the effects on the intensive margin and column (2) on the extensive margin of trade for sectors 15-19 (ISIC 2-digits). In columns (3) and (4) we estimate the effect on the intensive and extensive margin for sectors 20-29. Finally, in columns (5)-(6), the sectors considered for each margin of trade are 30-37. The dependent variables are in natural logs and the estimator is a linear model with high dimensional fixed effects. Standard errors in parentheses are clustered by country pair. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

A number of robustness exercises are shown in the Appendix. First, estimates for patent flows instead of stocks are shown in tables A.2 to A.6. Table A.2 shows very similar results to those obtained for stocks in Table 1, with the effect of increasing patents (either applications or granted patents) showing a positive and significant effect on the EM of trade. The results also hold when the model is estimated with the dependent variables in levels by Poisson Pseudo Maximum Likelihood (PPML), obtaining almost identical point estimates of the effect on patent flows on the EM of trade as when using the linear model, as shown in A.3. Table A.4 present IV results for patent flows, confirming the previous results for stocks indicating much higher effects when accounting for endogeneity. Table A.5 presents the results for country groups using patent flows and as for patent stocks

the effect on the extensive margin is mostly driven by North-North trade flows. Table A.6 present the sectoral estimates for patent flows, for the IM and EM for 3 groups of sectors as in Table 5. The estimates are less robust than when using stocks in this case. Finally, an estimation for patent stocks with a PPML estimator is presented in A.7 confirming the results obtained for the linear model in Table 1. The coefficient obtained for the patent stock in column (1) is only slightly higher in magnitude than the one obtained by Brunel and Zylkin (2022) for a different period. Similarly, the results are also confirmed for country groups when using a PPML estimator, as shown in A.8. Lastly, tables A.9 and A.10 present traditional gravity estimates with income, population and gravity variables and with income, population and dyadic-sectoral FE, respectively. The main difference with respect to the estimates that account for time-varying multilateral resistance terms is that the effect of patent application on the intensive margin appears now more prominent than the effect on the extensive margin. Concerning the traditional gravity determinants, the GDP coefficients are positive and significant as expected and the trade cost proxies hold the expected signs.

4 Final Remarks

This paper has investigated the impact of cross-border patent applications on the margins of international trade using disaggregated data on global patenting and trade flows. Our analysis reveals several key findings that contribute to our understanding of the relationship between innovation and international trade.

First, we find that cross-border patenting has a larger effect on the extensive margin of trade compared to the intensive margin. This suggests that firms tend to seek patent protection in international markets prior to entering those markets with new products, rather than with their existing products. This finding highlights the importance of IPR in facilitating the expansion of trade relationships and the introduction of new varieties in global markets.

Second, our IV estimates indicate that the impact of patents on trade is substan-

tially larger than suggested by OLS estimates, particularly for the extensive margin. This underscores the importance of addressing endogeneity concerns when analyzing the relationship between innovation and trade.

Third, we find significant heterogeneity in the effects of patenting across different country groups and industrial sectors. Notably, our results suggest that patents play a particularly important role in facilitating trade relationships involving developing countries, especially when endogeneity is accounted for. This finding has important implications for understanding the role of IPR in promoting economic development and global trade integration.

While our study provides important insights, there are several avenues for future research. Investigating the specific mechanisms through which patents affect trade decisions at the firm level could be valuable. Moreover, exploring how the relationship between patents and trade has evolved over time, particularly in response to major changes in global IPR regimes, could yield valuable insights.

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A Appendix: Additional Results

Table A.1: Summary Statistics

	(1)				
	count	mean	sd	min	max
ln_tradeval	583537	9.470	3.191	-6.907	18.695
ln_trade_im	583537	5.691	2.405	-6.907	17.703
ln_trade_em	583537	3.778	1.474	0	6.753
log_stock	583537	1.301	2.528	-11.089	11.181
log_stockg	522332	.673	2.712	-11.667	10.919
log_flow	515958	-.109	2.407	-8.358	9.372
lgdp_o	577981	13.163	1.675	5.071	16.877
lgdp_d	581243	13.120	1.761	6.757	16.877
lpop_o	582171	3.188	1.768	-4.333	7.249
lpop_d	583322	3.537	1.533	-1.318	7.249
ldistw_harmonic	583537	8.364	1.118	4.007	9.886
comlang_off	583537	.152	.358	0	1
contig	583537	.085	.278	0	1
col_dep_ever	582501	.049	.217	0	1
rta	583537	.3762	.484	0	1
wto	583537	.892	.309	0	1

Table A.2: Do Cross-Border Patent Flows Promote Trade? Value, EM, IM

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_tradeval	ln_trade_im	ln_trade_em	ln_tradeval	ln_trade_im	ln_trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_flow	0.003**	0.000	0.003***			
	(0.001)	(0.001)	(0.000)			
log_flowg				0.002	-0.001	0.002***
				(0.002)	(0.001)	(0.000)
rta	0.030**	0.039***	-0.009**	0.007	0.020	-0.013***
	(0.013)	(0.012)	(0.004)	(0.015)	(0.014)	(0.004)
wto	0.105	-0.155***	0.260***	0.088	-0.161**	0.249***
	(0.065)	(0.059)	(0.023)	(0.070)	(0.065)	(0.024)
N	507612	507612	507612	344550	344550	344550
R^2	0.948	0.917	0.982	0.955	0.928	0.985

This table reports estimates of the effects of cross-border patent flows on trade flows. Three dependent variables are used. Specifically, column (1) presents the effects on the trade value. Column (2) on the intensive margin of trade. In column (3) we estimate the effect on the extensive margin. In columns (4)-(6), we use the same three dependent variables, but the target variable in now the stock of patents granted. The dependent variables are all in natural logs and the estimator is a linear model with high dimensional fixed effects (origin-sector-year, destination-sector-year, pair-sector). Standard errors in parentheses are clustered by country pair in all columns. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

Table A.3: Do Cross-Border Patent Flows Promote Trade? PPML

	(1)	(2)	(3)	(4)	(5)	(6)
	trade_value	trade_im	trade_em	trade_value	trade_im	trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_flow	0.008***	-0.003	0.003***			
	(0.002)	(0.007)	(0.000)			
log_flowg				0.006***	0.004	0.002***
				(0.002)	(0.008)	(0.000)
rta	-0.008	0.117	-0.006*	0.018	0.176*	-0.008**
	(0.020)	(0.083)	(0.003)	(0.018)	(0.105)	(0.004)
wto	0.022	-0.721***	0.178***	-0.001	-0.726***	0.156***
	(0.096)	(0.251)	(0.023)	(0.103)	(0.236)	(0.024)
N	507612	507612	507612	344550	344550	344550
R^2						

This table reports estimates of the effects of cross-border patent application flows on bilateral trade flows. The estimates are obtained from a PPML specification. Three dependent variables are used. Specifically, column (1) presents the effects on the trade value. Column (2) on the intensive margin of trade. In column (3) we estimate the effect on the extensive margin. In columns (4)-(6), we use the same three dependent variables, but the target variable in now the flow of patents granted. The dependent variables are all in levels and the model includes high dimensional fixed effects (origin-sector-year, destination-sector-year, pair-sector). Standard errors in parentheses are clustered by country pair in all columns. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

Table A.4: Do Cross-Border Patent Flows Promote Trade? IV Results

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_tradeval	ln_trade_im	ln_trade_em	ln_tradeval	ln_trade_im	ln_trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_flow	-0.019	-0.202	0.184**			
	(0.187)	(0.180)	(0.076)			
log_flowg				-0.104	-0.309	0.199**
				(0.207)	(0.208)	(0.092)
rta	0.011	0.030*	-0.019***	-0.004	0.021	-0.024***
	(0.017)	(0.017)	(0.006)	(0.020)	(0.020)	(0.007)
wto	0.059	-0.082	0.142***	0.050	-0.070	0.123**
	(0.122)	(0.118)	(0.045)	(0.131)	(0.130)	(0.052)
N	351334	351334	351334	262698	262698	262698
K-P stat	23.185	23.185	23.185	15.808	15.808	15.808
Hansen test (Prob)	0.624	0.945	0.183	0.735	0.991	0.454

This table reports instrumental variables results. The external instruments are the first and second lags of the Patent Cooperation Treaty dummy variable, which takes the value of one when a pair of countries have ratified the treaty, zero otherwise. Standard errors in parentheses are clustered by country pair in all columns. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

Table A.5: Do Cross-Border Patent Flows Promote Trade? Country-Group Results

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_tradeval	ln_trade_im	ln_trade_em	ln_tradeval	ln_trade_im	ln_trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_flow_N_N	0.002	0.001	0.001***	-0.307	-0.092	-0.237
	(0.002)	(0.001)	(0.000)	(0.245)	(0.237)	(0.146)
log_flow_N_S	0.005	0.005*	-0.000	0.050	0.434	-0.393***
	(0.003)	(0.003)	(0.001)	(0.362)	(0.352)	(0.136)
log_flow_S_N	-0.014***	-0.005	-0.009***	-0.292**	-0.286**	0.006
	(0.004)	(0.003)	(0.001)	(0.114)	(0.116)	(0.048)
log_flow_S_S	0.002	0.002	0.000	-0.303*	-0.292	0.018
	(0.008)	(0.007)	(0.003)	(0.181)	(0.187)	(0.072)
rta_N_N	0.040***	0.037***	0.003	0.046	0.025	0.023
	(0.015)	(0.014)	(0.004)	(0.038)	(0.036)	(0.021)
rta_N_S	-0.009	0.051***	-0.061***	0.044	0.050	-0.005
	(0.022)	(0.020)	(0.008)	(0.052)	(0.052)	(0.024)
rta_S_N	-0.001	0.041	-0.042***	-0.132**	-0.102*	-0.026
	(0.032)	(0.030)	(0.009)	(0.058)	(0.057)	(0.022)
rta_S_S	0.080	0.136**	-0.056*	-0.054	-0.021	-0.028
	(0.070)	(0.061)	(0.029)	(0.188)	(0.194)	(0.087)
wto_N_N	0.040	-0.226**	0.267***	-0.179	-0.435*	0.242**
	(0.117)	(0.105)	(0.048)	(0.227)	(0.228)	(0.113)
wto_N_S	0.168**	-0.148**	0.316***	-0.093	-0.442***	0.359***
	(0.066)	(0.061)	(0.022)	(0.146)	(0.141)	(0.054)
wto_S_N	0.250***	-0.100	0.351***	0.087	-0.361*	0.454***
	(0.070)	(0.062)	(0.028)	(0.196)	(0.187)	(0.073)
wto_S_S	0.126*	-0.135**	0.260***	-0.266	-0.661***	0.413***
	(0.071)	(0.066)	(0.024)	(0.198)	(0.194)	(0.079)
_cons	9.289***	5.799***	3.490***			
	(0.079)	(0.071)	(0.032)			
N	604570	604570	604570	384323	384323	384323
K-P stat				25.703	25.703	25.703
Hansen test (Prob)				0.823	0.641	0.088

This table reports estimates of the effects of cross-border patent flows on trade flows. The estimates are obtained after allowing for the effects of innovation to vary across four bilateral groups (including "North to South", "South to South", "North to North", and "South to North", which are based on the income classification of the World Bank for 2000. In addition, each column of the table introduces a new dependent variable, whose determinants are also allowed to vary across the four bilateral income groups. Specifically, column (1) present the effects on the trade value. Column (2) on the intensive margin of trade. In column (3) we estimate the effect on the extensive margin. Finally, in columns (4)-(6), we use IV for the patent stocks using lags of the PCT. The dependent variables are in natural log and the estimator is a linear model with high dimensional fixed effects. Standard errors in parentheses are clustered by country pair. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

Table A.6: Do Cross-Border Patent Flows Promote Trade? Sectoral Results

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_trade_im	ln_trade_em	ln_trade_im	ln_trade_em	ln_trade_im	ln_trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_flow	-0.008***	0.001	0.001	0.005***	0.003*	0.001
	(0.003)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
rta	-0.030	0.000	0.063***	-0.009	0.028	-0.016***
	(0.028)	(0.011)	(0.016)	(0.005)	(0.019)	(0.006)
wto	-0.347***	0.171***	-0.233***	0.314***	0.093	0.208***
	(0.129)	(0.059)	(0.083)	(0.032)	(0.108)	(0.040)
_cons	5.669***	3.990***	5.793***	3.809***	6.186***	3.551***
	(0.117)	(0.054)	(0.074)	(0.028)	(0.098)	(0.036)
N	74474	74474	250775	250775	150906	150906
R^2	0.926	0.976	0.917	0.981	0.943	0.977

This table reports estimates of the effects of cross-border patent flows on trade flows. Results are presented for the log of the intensive and the extensive margins of trade for three categories of products. Specifically, column (1) present the effects on the intensive margin and column (2) on the extensive margin of trade for sectors 15-19 (ISIC 2-digits). In columns (4) and (5) we estimate the effect on the intensive and extensive margin for sectors 20-29. Finally, in columns (5)-(6), the sectors considered for each margin of trade are 30-37. The dependent variables are in natural log and the estimator is a liner model with high dimensional fixed effects. Standard errors in parentheses are clustered by country pair. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

Table A.7: Do Cross-Border Patent Stocks Promote Trade? PPML

	(1)	(2)	(3)	(4)	(5)	(6)
	trade_value	trade_im	trade_em	trade_value	trade_im	trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_stock	0.025***	0.002	0.011***			
	(0.005)	(0.009)	(0.001)			
log_stockg				0.022***	0.020***	0.005***
				(0.005)	(0.007)	(0.001)
rta	-0.004	0.010	-0.005	0.009	0.001	-0.002
	(0.019)	(0.035)	(0.003)	(0.018)	(0.034)	(0.003)
wto	0.023	-0.177	0.188***	0.028	-0.160	0.180***
	(0.094)	(0.127)	(0.022)	(0.097)	(0.129)	(0.022)
N	547088	547088	547088	486636	486636	486636

This table reports estimates of the effects of cross-border patent application stocks on bilateral trade flows. The estimates are obtained from a PPML specification. Three dependent variables are used. Specifically, column (1) presents the effects on the trade value. Column (2) on the intensive margin of trade. In column (3) we estimate the effect on the extensive margin. In columns (4)-(6), we use the same three dependent variables, but the target variable in now the flow of patents granted. The dependent variables are all in levels and the model includes high dimensional fixed effects (origin-sector-year, destination-sector-year, pair-sector). Standard errors in parentheses are clustered by country pair in all columns. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

Table A.8: Do Cross-Border Patent Stocks Promote Trade? PPML

	(1) trade_value b/se	(2) trade_im b/se	(3) trade_em b/se	(4) trade_value b/se	(5) trade_im b/se	(6) trade_em b/se
log_stock_N_N	0.014**	-0.027	0.014***			
	(0.006)	(0.024)	(0.001)			
log_stock_N_S	0.032**	0.094*	-0.002			
	(0.016)	(0.056)	(0.002)			
log_stock_S_N	0.022***	0.063**	-0.012***			
	(0.008)	(0.026)	(0.002)			
log_stock_S_S	0.099***	0.053	0.004			
	(0.012)	(0.039)	(0.004)			
rta_S_N	-0.085**	-0.210**	-0.026**	-0.080**	-0.193*	-0.030***
	(0.036)	(0.103)	(0.010)	(0.035)	(0.101)	(0.011)
rta_S_S	-0.125*	-0.375**	-0.041**	-0.087	-0.395**	-0.037*
	(0.071)	(0.165)	(0.020)	(0.074)	(0.168)	(0.020)
rta_N_N	0.022	0.130	0.017***	0.025	0.134	0.019***
	(0.021)	(0.101)	(0.004)	(0.020)	(0.101)	(0.004)
rta_N_S	0.002	-0.043	-0.061***	-0.002	-0.024	-0.062***
	(0.046)	(0.102)	(0.007)	(0.046)	(0.098)	(0.007)
wto_S_N	0.230**	-0.226	0.238***	0.226**	-0.237	0.242***
	(0.106)	(0.236)	(0.026)	(0.108)	(0.240)	(0.026)
wto_S_S	0.204***	-0.467**	0.134***	0.228***	-0.496**	0.138***
	(0.079)	(0.209)	(0.022)	(0.079)	(0.206)	(0.022)
wto_N_N	-0.161	-0.302	0.136***	-0.140	-0.373	0.147***
	(0.178)	(0.309)	(0.043)	(0.178)	(0.308)	(0.043)
wto_N_S	0.023	-0.748***	0.195***	0.044	-0.739***	0.203***
	(0.085)	(0.213)	(0.020)	(0.085)	(0.206)	(0.019)
log_stockg_N_N				0.011**	-0.002	0.004***
				(0.005)	(0.020)	(0.001)
log_stockg_N_S				0.015	0.135***	-0.012***
				(0.016)	(0.051)	(0.002)
log_stockg_S_N				0.029***	0.067***	-0.016***
				(0.008)	(0.025)	(0.002)
log_stockg_S_S				0.090***	0.111**	0.006
				(0.017)	(0.046)	(0.005)
N	604570	604570	604570	604570	604570	604570
R^2						

This table reports estimates of the effects of cross-border patent flows on trade flows. The estimates are obtained from a PPML specification, after allowing for the effects of innovation to vary across four bilateral groups (including "North to South", "South to South", "North to North", and "South to North", which are based on the income classification of the World Bank for 2000. In addition, each column of the table introduces a new dependent variable, whose determinants are also allowed to vary across the four bilateral income groups. Specifically, column (1) present the effects on the trade value. Column (2) on the intensive margin of trade. In column (3) we estimate the effect on the extensive margin. Finally, in columns (4)-(6), we use patent stocks of granted patents. The dependent variables are in natural log and the estimator is a PPML model with high dimensional fixed effects. Standard errors in parentheses are clustered by country pair. * $p < 0.10$, ** $p < .05$, *** $p < .01$. See text for further details.

Table A.9: Do Cross-Border Patent Flows Promote Trade? Traditional Gravity Results with s.e. clustered at the pair-sector level

	(1)	(2)	(3)
	ln_tradeval	ln_trade_im	ln_trade_em
	b/se	b/se	b/se
log_flow	0.174***	0.125***	0.050***
	(0.004)	(0.003)	(0.001)
lgdp_o	0.871***	0.471***	0.400***
	(0.010)	(0.009)	(0.004)
lgdp_d	0.690***	0.540***	0.150***
	(0.009)	(0.007)	(0.003)
lpop_o	0.171***	0.172***	-0.001
	(0.010)	(0.008)	(0.003)
lpop_d	-0.009	-0.008	-0.001
	(0.009)	(0.008)	(0.003)
ldistw_harmonic	-0.997***	-0.648***	-0.349***
	(0.011)	(0.009)	(0.004)
comlang_off	0.089***	0.015	0.075***
	(0.032)	(0.027)	(0.011)
contig	0.521***	0.585***	-0.064***
	(0.039)	(0.033)	(0.015)
col_dep_ever	0.146***	0.009	0.137***
	(0.045)	(0.038)	(0.016)
legal	0.450***	0.262***	0.187***
	(0.024)	(0.020)	(0.009)
rta	0.418***	0.268***	0.150***
	(0.021)	(0.017)	(0.007)
wto	0.622***	0.369***	0.252***
	(0.028)	(0.022)	(0.011)
N	537235	537235	537235
R^2	0.593	0.473	0.779

This table reports estimates of the effects of cross-border patent flows on trade flows. The estimates are obtained from a traditional gravity model specification with time fixed effects. Three dependent variables are used. Specifically, column (1) presents the effects on the trade value. Column (2) on the intensive margin of trade. In column (3) we estimate the effect on the extensive margin. The dependent variables are all in natural logs and the estimator is a linear model. Standard errors in parentheses are clustered by country pair. * $p < 0.10$, ** $p < .05$, ** $p < .01$. See text for further details.

Table A.10: Do Cross-Border Patent Flows Promote Trade? Traditional Gravity Results

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_tradeval	ln_trade_im	ln_trade_em	ln_tradeval	ln_trade_im	ln_trade_em
	b/se	b/se	b/se	b/se	b/se	b/se
log_flow	0.124***	0.103***	0.021***	0.015***	0.009***	0.005***
	(0.004)	(0.003)	(0.001)	(0.002)	(0.001)	(0.000)
lgdp_o	0.443***	0.318***	0.125***	0.521***	0.389***	0.132***
	(0.018)	(0.017)	(0.006)	(0.016)	(0.015)	(0.005)
lgdp_d	0.710***	0.558***	0.151***	0.748***	0.591***	0.156***
	(0.016)	(0.015)	(0.005)	(0.014)	(0.013)	(0.005)
lpop_o	-0.542***	-0.771***	0.229***	-0.461***	-0.695***	0.234***
	(0.089)	(0.074)	(0.031)	(0.080)	(0.066)	(0.030)
lpop_d	-0.758***	-0.605***	-0.153***	-0.601***	-0.498***	-0.103***
	(0.073)	(0.066)	(0.024)	(0.065)	(0.058)	(0.023)
rta	0.059***	0.019	0.040***	0.083***	0.046***	0.037***
	(0.013)	(0.012)	(0.004)	(0.011)	(0.010)	(0.004)
wto	0.107***	0.008	0.099***	0.120***	0.022	0.098***
	(0.017)	(0.016)	(0.006)	(0.015)	(0.014)	(0.005)
N	538009	538009	538009	520979	520979	520979
R^2	0.701	0.560	0.899	0.917	0.871	0.967

This table reports estimates of the effects of cross-border patent flows on trade flows. The estimates are obtained from a traditional gravity model specification. Three dependent variables are used. Specifically, column (1) presents the effects on the trade value. Column (2) on the intensive margin of trade. In column (3) we estimate the effect on the extensive margin. The dependent variables are all in natural logs and the estimator is a linear model with time fixed effects and origin-destination-sector FE. Standard errors in parentheses are clustered by country pair in columns (1)-(3). In columns (4)-(6), we use the same three dependent variables, but the standard errors are clustered at the country-pair-sector level.* $p < 0.10$, ** $p < .05$, ** $p < .01$. See text for further details.