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# Deep trade agreements and cross-border innovation collaboration: Evidence from ASEAN

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## ABSTRACT

This study investigates whether deeper regional trade agreements (RTAs) increase the likelihood of co-patenting activities between ASEAN nations and innovative partners, addressing a potential gap in the literature. Unlike prior studies, we construct indices capturing co-invention and co-application of patents based on the fractional patent counting approach. A gravity-like model of cross-country technological collaboration is developed, incorporating fixed effects to account for unobserved heterogeneities at the country-pair level and time-varying characteristics that may influence cross-border links. The baseline results suggest that, although the static positive effects of trade integration on joint innovation activities are not immediately evident, agreements with a broader scope tend to promote such activities, particularly in the case of co-invention of patents. Sensitivity analyses indicate that RTAs containing provisions related to innovation are more likely to foster intra-bloc collaboration among signatories. Additionally, dynamic analysis reveals anticipation and phasing-in effects of trade policy changes, as evidenced by estimates of leads and lags in trade agreement indices. Overall, the findings demonstrate that deep trade integration has both short-term and long-term positive effects on collaborative innovation activities.

**Contribution/ Originality:** This study is the first to analyze the impact of deep trade agreements on international patenting activities, measured in terms of both co-invention and co-application of patents concerning the ASEAN region. Furthermore, we conduct a long-term analysis to observe the pre- and post-implementation effects of these agreements, whereas most previous studies focus solely on contemporaneous effects.

## 1. INTRODUCTION

The organization of trade has significantly evolved, and trade negotiations concerning regional trade agreements (RTAs) have become increasingly prevalent in a context of reduced costs. Their content and coverage have expanded considerably over time. Historically, most agreements aimed to facilitate trade liberalization. However, the scope has broadened to include additional areas, partly due to globalization and the increasing complexity of modern business processes. The discussion now encompasses non-trade categories such as intellectual property rights, investment, innovation policy, research, and technology. Santacreu (2025) notes that trade liberalization without strengthening IPRs can disincentivize innovation and diminish welfare in the long term. Advances in information and communication technologies (ICTs) have improved communication and knowledge exchange among organizations and individuals. A likely outcome is the formation of international inventor teams collaborating across countries to develop new technologies. Modern trade negotiations can influence firms' decisions to internationalize their technology operations for two primary reasons (Martínez-Zarzoso & Arregui Coka, 2025). Firstly, trade agreements enhance economic contact between trading partners, including access to foreign innovation, the establishment of technological alliances, and the relocation of R&D facilities, among others. Secondly, technology-related clauses in agreements mandate a specific level of commitment for member states to adhere to and actively facilitate knowledge exchange. Consequently, modern trade agreements with advantageous features are expected to enhance the propensity to co-patent among signatories. Concurrently, collaboration in the development of new technologies or the creation of innovative products has also surfaced, albeit to a lesser extent. Importantly, Freeman (1991) states that the globalization and proliferation of ICTs have influenced the establishment of innovation networks. Since then, networks of innovators have garnered significant interest as a means of analyzing the distribution of innovative labor. Diverse types of these networks are examined using the progressively accessible data on numerous forms of collaboration and patent filings (Morescalchi, Pammolli, Penner, Petersen, & Riccaboni, 2015). The co-patenting relationships are viewed as a network that mediates knowledge spillovers, hence enhancing productivity and fostering economic growth (Cortinovis & van Oort, 2019).

Despite the evident ubiquity of deep trade agreements, little work to date analyzes whether they trigger cross-country innovation collaboration, especially between asymmetric nations. Most existing studies typically rely on patent citations to capture knowledge flows (Jinji, Zhang, & Haruna, 2019), bilateral patent applications (Howard, Maskus, & Ridley, 2025), or other metrics like domestic ownership of foreign inventions (Martínez-Zarzoso & Arregui Coka, 2025). None of these consider the impact of deep trade integration on direct co-patenting activities between at least two parties from different countries, which represents a potential gap in the literature. In particular, we contribute by devising co-invention and co-application indexes to trace these collaborative activities. Moreover, most prior studies emphasize mainly the static analysis of the contemporaneous effects of RTAs and overlook the adjustment dynamics in the long run. Only the work of Martínez-Zarzoso and Arregui Coka (2025) takes into account maturation effects of agreements but disregards anticipatory effects prior to implementation. We perform a dynamic estimation that includes both pre-RTA and post-RTA periods, providing a more comprehensive overview of the adjustment process. Additionally, many past studies arbitrarily select IP-related or technology-related provisions to assess their influence on variables of interest; however, we propose that several other provisions can indirectly promote intra-bloc innovation collaboration. To address this, we apply factor analysis to construct an alternative index embodying a set of provisions that both directly and indirectly influence cross-country innovation.

The following sections comprise the remaining paper: Section 2 reviews prior contributions. Section 3 lays a theoretical foundation for this study. Section 4 explains an empirical strategy for the analysis. Section 5 provides estimation results and discussion. Section 6 introduces robustness analysis. Section 7 summarizes the main findings and insights.

## 2. LITERATURE REVIEW

This study mainly encompasses three strands of the literature regarding trade and innovation. The first group of studies documents the evolving trend of technological and innovation activities due to the fragmentation of production processes, which brings about the transfer of knowledge, ideas, know-how, and the like within international production networks. According to Dachs and Pyka (2010), the internationalization of innovation activities has gained momentum recently, as witnessed by, for instance, a higher number of cross-border technological partnerships, a rising share of collective scientific publications undertaken by authors from distinct countries, and so on. With a focus on inventor networks, Crescenzi, Nathan, and Rodríguez-Pose (2016) posit that innovation has become a more collaborative activity in recent years, given that various inventors form cross-country cooperations to a higher extent in the inventive process. Additionally, De Rassenfosse and Seliger (2020) assess the sources of knowledge dissemination between developed and developing economies, distinguishing between international R&D collaboration, technology sourcing, and technology transfer. The analytical results exhibit that East Asia (especially

China) and South Asia have become developing regions that attract a majority of innovative activities from advanced regions, as evidenced by the pattern of cross-border R&D activities and patent ownership transfer.

Secondly, there is a group of studies that rely on the gravity model framework to examine co-patenting activities and their potential determinants. These studies usually consider common factors widely used in the gravity model for bilateral trade flows, starting from the spatial distance between two partners, which is a hurdle for cross-border knowledge transfer as measured by patent citations (Peri, 2005). This physical distance is also proven to be a non-negligible cost of collective innovation activities, especially in terms of communication and travel costs, since several studies find its negative impact on the joint creation of patents (Basche, 2022; Dachs & Pyka, 2010; Picci, 2010). Conversely, time-invariant bilateral covariates such as common language, sharing a border, and similar cultural traits are found to facilitate cross-border joint inventions (Montobbio & Sterzi, 2013; Picci, 2010). Likewise, time-varying country characteristics, including market size, technological capacity, and IPR enforcement level, positively contribute to a higher extent of such international activities (Dachs & Pyka, 2010). It is noteworthy that most of these studies, except the work of Peri (2005), overlook the role of trade integration in cross-border technological collaborations between units of interest. This present study also employs a gravity model to analyze joint patenting activities with the incorporation of three-dimensional fixed effects. Another crucial issue is that a majority of previous studies typically trace innovation ties through patent citations due to data availability (Jaffe, Trajtenberg, & Henderson, 1993; Jinji et al., 2019; Peri, 2005). However, this metric has drawbacks since it captures codified knowledge transfer through a paper trail, regardless of whether two parties physically contact each other. Additionally, these studies do not distinguish between patents cited by examiners and those by subsequent innovators, as the former does not reflect actual knowledge flows. The co-invention or co-application index, in contrast, better captures the interactive innovation process, especially via joint invention activities and tacit knowledge exchange, which are encouraged by personal interaction.

Thirdly, there has been an increasing number of RTAs over time, and a majority of recent ones include provisions or clauses beyond trade policy. That said, they contain provisions relevant to a wide range of policy areas, e.g., IPR, information society, innovation policies, research, and technology. The evolving trend of trade treaty content prompts researchers to evaluate the impact of these "deep" trade agreements on diverse economic variables. A nascent group of studies stresses the effect of deep trade agreements on transnational innovation linkages. Essentially, Jinji et al. (2019) first accounts for various provisions embodied in the RTAs and computes indices to capture their coverage. They examine RTAs' effects on cross-country technology spillovers, proxied by patent citations, estimating a structural gravity model. The results indicate that RTAs positively affect international technology spillovers regardless of disparate country groups. Additionally, the depth of trade agreements exerts a positive effect on such spillovers, although when the inclusion of WTO-X indexes and dummy variables for RTAs is considered, the coefficients of these depth indexes become insignificant. However, the coefficients are significant in the cases of North-South and South-South bilateral pairs, implying that deeper coverage of agreements entails an additional effect on spillovers for these pairs. Subsequently, Jinji et al. (2019) further extend their work in various dimensions mainly relevant to data samples, econometric specification, and the breadth side of RTAs. Once again, they find the positive effects of RTAs on patent citations that capture international technology spillovers. Besides, the deeper the RTAs are, the greater in magnitude the spillovers are. Likewise, the breadth of RTAs has a positive correlation with patent citations. More recently, Martínez-Zarzoso and Arregui Coka (2025) evaluate the impact of numerous free trade agreements (FTAs) and their coverage related to technology collaboration on the domestic ownership of foreign inventions (DOFI) based on the gravity equation. Two main conclusions can be drawn, starting with the finding that trade agreements trigger a substantial increase in cross-border patenting activities measured by the DOFI, but this impact is heterogeneous and conditional on the policy scope and spatial distance between participating parties. Secondly, with lower communication costs, more geographically and institutionally proximate parties tend to exchange more knowledge as well as technology. Overall, these aforementioned studies utilize patent citations or other proxies to represent international technology cooperation. Put differently, none of them computes indexes to capture co-patenting practices in terms of co-invention and co-ownership of patents, which reflect a higher extent of interaction between partners compared to paper trails. Also, most of them focus solely on static or contemporaneous effects of trade agreements and disregard dynamic ones, even though there is evidence of anticipation and phase-in effects of trade agreements according to Egger, Larch, and Yotov (2022).

## 3. THEORETICAL BACKGROUND

### *3.1. Gravity Model*

In the context of international economics, this model was first proposed by Tinbergen (1962) to analyze bilateral trade flow patterns among European economies. The fundamental idea is that bilateral trade flows between two countries resemble the gravitational force in the Newtonian sense between two objects. Thus, bilateral trade is a function of both economic size and geographical distance between two economies. In the multiplicative form, the model can be written as follows.

$$T_{ij} = \beta_0 Y_i^{\beta_1} Y_j^{\beta_2} D_{ij}^{\beta_3} \qquad (1)$$

Where

$T_{ij}$ = the trade flows between economies i and j

$Y_i$ and $Y_j$ = economic masses of countries i and j

$D_{ij}$ = the geographical distance between these two countries.

Thereafter, a gravity model has been applied to several empirical applications regarding international trade hitherto. Nonetheless, it is criticized since there is no underlying theory explaining this relationship fairly well. To lay a theoretical foundation, Anderson (1979) and Bergstrand (1985) are the first set of pioneering studies. They suggest that it can be derived from classical trade theories, for example, the Ricardian Model and the Heckscher-Ohlin Model, on the grounds of microeconomics. Alternatively, Helpman and Krugman (1987) introduce an assumption of monopolistic competition to provide rationale for this model. Also, the gravity model has been applied to explain ties other than conventional trade in goods, such as immigration flow, knowledge diffusion in terms of patent citations, and others.

### *3.2. Model of International Knowledge Flows*

We rely on the analytical framework labeled as the model of international knowledge flows proposed by Peri (2005). Firstly, it is assumed that the actual knowledge flows from country j to i at time t regarding the impact on country i's research output. Also, let us suppose that such flows are subject to country j's knowledge stock, denoted as $K_{jt}$, and the research capability of local firms in country i, represented as $A_{it}$, as in Jinji et al. (2019).

$$\tau_{ijt} = (A_{it})^{\mu_1} (\pi_{ijt} K_{jt})^{\mu_2} \qquad (2)$$

Where

$\pi_{ijt} \in [0,1]$ is the extent of accessibility for firms located in country i to the knowledge stock of country j at time t. Therefore, $\pi_{ijt} K_{jt}$ refers to the effective unit of knowledge stock in country j from the viewpoint of enterprises in country i. Both parameters $\mu_1$ and $\mu_2$ are positive and I also denote $\widetilde{\pi_{ijt}} = (\pi_{ijt})^{\mu_2}$.

Premised on Peri (2005), the degree of knowledge stock accessibility is contingent on the economic distance between a country pair i and j, which encompasses not only spatial distance but also other resistance terms. These terms include both time-varying and time-invariant characteristics of the country pair. In the context of this study, the former refers to the depth and breadth aspects as well as innovation-related provisions of RTAs that two parties are signatories to in a given year t, while the latter includes geographical distance between the two parties, common language, religious beliefs, and other factors. In this regard, suppose $X_{ijt}$ to be a vector of time-varying country-pair characteristics, and the aforementioned accessibility degree is a function of these characteristics in the following way.

$$\begin{aligned}\widetilde{\pi_{ijt}} &= \pi(X_{ijt}) \\ &= e^{\rho_{ij}} e^{\beta_1 (DEPTH_{ijt} \text{ or } BREADTH_{ijt} \text{ or } IND_{ijt})} \end{aligned} \quad (3)$$

Where

$\rho_{ij}$ = Time-invariant country-pair characteristics.

$DEPTH_{ijt}$, $BREADTH_{ijt}$, and $IND_{ijt}$ = the indices to measure the depth, breadth and innovation-related provisions of RTAs, respectively

As $\tau_{ijt}$, $A_{it}$, and $K_{jt}$ are all not directly observable; we need to choose proper proxies for them. Particularly, we construct the indices $COIN_{ijt}$ and $COAPP_{ijt}$ based on fractional patenting concept according to Dernis and Khan (2004), which exhibits the co-invention and co-application of patents between bilateral pairs of countries i and j at time t, representing $\tau_{ijt}$. Besides, time-varying country i fixed effects denoted as $\gamma_{it}$ and time-varying country j fixed effects denoted as $\delta_{jt}$ are employed to capture $A_{it}$, and $K_{jt}$, respectively. Following Peri (2005), we presume the following linkage.

$$IC_{ijt} = \theta_{ij} \widetilde{\pi_{ijt}} e^{\epsilon_{ijt}} \quad (4)$$

Where

$IC_{ijt}$ = The innovation collaboration between countries i and j at time t.

$\theta_{ij}$ = Time-invariant individual effect related to joint patenting activities.

$\epsilon_{ijt}$ = Disturbance term.

Substituting Equation 2 to 4, we obtain the following expression.

$$IC_{ijt} = \theta_{ij} (\gamma_{it})^{\mu_1} (\delta_{jt})^{\mu_2} e^{\rho_{ij}} e^{\beta_1 (DEPTH_{ijt} \text{ or } BREADTH_{ijt} \text{ or } IND_{ijt})} e^{\epsilon_{ijt}} \quad (5)$$

## 4. METHODOLOGY

### *4.1. Data Description*

#### *4.1.1. Trade Agreement Index*

Essentially, past studies that assess the impact of trade agreements commonly use binary variables to represent their presence due to the lack of comprehensive data. Alternatively, some works, such as Baier, Bergstrand, and Feng (2014), distinguish between various types of trade arrangements, e.g., free trade agreements (FTAs), customs unions (CUs). However, these methods do not adequately capture the variation in the content of trade agreements over time (Mattoo, Mulabdic, & Ruta, 2022). In other words, this binary measure of trade agreement status fails to account for the intrinsic heterogeneity across agreements (Egger & Masllorens, 2024). This limitation also introduces estimation bias resulting from measurement error of the trade policy covariate.

To address this limitation, several computational methods are employed to assess the depth of trade agreements, supported by a recent database released by the World Bank (Deep Trade Agreements Database). The primary focus is to determine whether provisions in the WTO+ and WTO-X areas are legally enforceable, which indicates the degree of agreement depth. In this context, Horn, Mavroidis, and Sapir (2010) first conceptualize the terminology and classify the characteristics and provisions within each RTA, distinguishing them into two categories: WTO+ and WTO-X areas across 52 policies. They also develop two indices to measure the coverage and legal enforceability of policy areas in RTAs, namely the area-covered (AC) and legally-enforceable (LE) indices. Subsequently, Limão (2016) reorganize all policy areas based on the concepts of depth and breadth of each RTA. The depth refers to the level of bilateral economic cooperation, while breadth pertains to the extent of coverage of each policy area, as detailed in Table 1. According to this table, 29 policy areas are classified under the depth dimension of RTAs, and 23 are categorized under the breadth dimension. Consequently, the trade agreement index is computed and modified following the methodology outlined by Jinji et al. (2019).

$$T_{ijt} = \frac{\sum_{p=1}^{n} Max\_LE_{ijt}^{p}}{2*n} \quad (6)$$

Where

$T_{ijt}$ = RTA Depth ($Depth_{ijt}$) or Breadth ($Breadth_{ijt}$) Index.

p = Policy area.

$Max\_LE_{ijt}^{p} \in [0,1,2]$ = The maximum value of the legally enforceable (LE) index of policy area p in every RTA to which both countries i and j are member states in year t.

n = Total number of provisions in the depth and breadth aspects, which are 29 and 23, respectively.

Since the maximum value of the LE index for each policy area is 2, the denominators of these two indexes are the product of the number of policy areas and 2, indicating that they are normalized between zero and one. Table C in the appendix provides an example of the actual data structure, and the computation method is explained.

**Table 1.** The terminology of depth and breadth of the RTAs.

| **Depth** | | **Breadth** | |
|---|---|---|---|
| **Field** | **Policy area** | **Field** | **Policy area** |
| 1. Import tariffs | FTA in industrial goods | 1. Services | General agreement on trade in services |
| | FTA in agricultural goods | | |
| 2. Non-tariff barriers | Customs administration | 2. Technology | TRIPS |
| | Export taxes | | Intellectual property rights |
| | Sanitary and phytosanitary measures | | Innovation policies |
| | Technical barriers to trade | | Economic policy dialogue |
| | Anti-dumping | | Information society |
| | Countervailing measures | | Research and technology |
| 3. Behind the border policies | State trading enterprises | 3. Investment/ Capital | Trade-related investment measures |
| | State Aid | | Investment |
| | Public Procurement | | Movement of capital |
| | Anti-corruption | | |
| | Competition policy | | |
| 4. Other policies | Consumer protection | 4. Labor | Labor market regulation |
| | Data protection | | Illegal immigration |
| | Agriculture | | Social matters |
| | Approximation of legislation | | Visa and asylum |
| | Civil protection | 5. Non-economic Policies | Environmental laws |
| | Education and training | | Audio visual |
| | Energy | | Cultural cooperation |
| | Financial assistance | | Health |
| | Industrial cooperation | | Human rights |
| | Mining | | Illicit drugs |
| | Nuclear safety | | Money laundering |
| | Public administration | | Political dialogue |
| | Regional cooperation | | Terrorism |
| | SMEs | | |
| | Statistics | | |
| | Taxation | | |

**Source:** Limão (2016).

Also, it is our interest to assess whether ad-hoc provisions more directly related to innovation collaboration exert a greater effect on international patenting activities compared to deeper or broader trade negotiations. A previous study by Jinji et al. (2019) found that the total degree of deep trade integration exhibits a stronger influence on cross-border technology spillovers than provisions directly related to competition and technology. To differentiate, we select 9 out of 52 WTO policy areas associated with innovation and technology, including data protection, economic policy dialogue, industrial cooperation, information society, innovation policies, investment, IPR, research and technology, and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). It should be noted that six of these eight policy areas are categorized as technology fields according to the classification of Limão (2016), which includes economic policy dialogue, information society, innovation policies, IPR, research and technology, and TRIPS. According to Martínez-Zarzoso and Chelala (2021), clauses regarding data protection and innovation policies generally promote innovative collaboration, while IPR, information society, and research & technology specify patterns of such collaboration. They also indicate that a subset of these provisions, including information societies, innovation policies, IPR, and research and technology, determine a particular form of collaboration between member countries without requiring extensive institutional, infrastructural, or policy reforms. Separately, as a covariate in the model, Martínez-Zarzoso and Arregui Coka (2025) find that provisions related to IPRs, innovation policies, and research & technology significantly promote domestic ownership of foreign inventions or indicators of technological cooperation, whereas provisions on data protection and information societies hinder cross-country technological collaboration.

Premised on this narrower definition of index construction, the index computation can then be expressed as below.

$$IND_{ijt} = \frac{\sum_{p=1}^{9} Max\_LE_{ijt}^{p}}{2*9} \quad (7)$$

Where

$IND_{ijt}$ = Innovation-related RTA provision indices.

It should be noted that these modern developments in the construction of trade agreement indices give rise to continuous variables against time-invariant ones in the case of binary variables. Therefore, they are more effective in accurately evaluating the content of RTAs over time. In other words, the standard usage of binary variables does not take into account the intrinsic heterogeneity across trade agreements (Egger & Masllorens, 2024).

The following Table 2 presents the summary source of data for each variable in the estimation model. In total, the sample spans from 1996 to 2020.

**Table 2.** Definitions and sources of variables.

| Variable | Definition | Data source |
|---|---|---|
| **Dependent variable** | | |
| $COIN_{ijt}$ | A number of PCT patent applications co-signed or co-invented by two individuals, i and j, residing in different countries (one must reside in an ASEAN country) in year t, based on the inventor's address criterion. | OECD REGPAT database |
| $COAPP_{ijt}$ | A number of PCT patent applications, collectively owned by two entities from different countries in year t, based on the applicant's address criteria. | |
| **Independent variable** | | |
| $K_{it}$ | The knowledge stock of country i in year t which is represented by the stock of PCT patent applications filed by domestic residents of country i. | WIPO IP Statistics Database which covers the period 1995-2021. |
| $K_{jt}$ | The knowledge stock of country j in year t | |
| $G_{it}$ | Worldwide governance indicators of country i in year t | WGI database, The World Bank |
| $G_{jt}$ | Worldwide governance indicators of country j in year t | |
| $U_{it}$ | The upstreamness measure of country i in year t | TiVA Database, Mancini, Montalbano, Nenci, and Vurchio (2024) |
| $U_{jt}$ | The upstreamness measure of country j in year t | |
| $RTA_{ijt}$ | The binary variable takes a value of one if both countries i and j are signatories of a given RTA in year t. | Deep Trade Agreements Database by the World Bank |
| $DEPTH_{ijt}$ | The RTA depth index | |
| $BREADTH_{ijt}$ | The RTA breadth index | |
| $IND_{ijt}$ | The index to capture the inclusion of innovation-related provisions | |
| $DIST_{ij}$ | The spatial distance between two important cities of countries i and j. | CEPII database |
| $TD_{ijt}$ | The technological distance between countries i and j in year t | - OECD Patent Statistics - WIPO IP Statistics |
| $SICT_{ijt}$ | The degree of similarity in ICT levels between countries i and j in year t. | The World Development Indicator (WDI) by the World Bank. |
| $X_{ij}$ | A vector of dyadic covariates in terms of dummy variables, including common language and colonial traits. | CEPII database |

### *4.2. Empirical Strategy*

We primarily rely on the gravity equation framework in accordance with Head and Mayer (2014) to derive a reduced-form empirical model. To implement this, we recall the model of international knowledge flows introduced by Peri (2005), as elaborated earlier, we can rewrite Equation 5 into an estimated equation as follows. It is a gravity model that analyzes cross-country innovation activities following prior studies like Picci (2010) and Jinji et al. (2019).

$$IC_{ijt} = exp\,[\emptyset_0 + \emptyset_1 K_{it} + \emptyset_2 K_{jt} + \emptyset_3 DIST_{ij} + \emptyset_4 T_{ijt} + \emptyset_5 X_{ijt} + \theta_{ij} + \gamma_{it} + \delta_{jt}] + \varepsilon_{ijt} \quad (8)$$

Where

$IC_{ijt}$ = Innovation collaborations between economies i and j in year t.

$T_{ijt}$ = One out of three aforementioned trade agreement indexes.

After including control variables and substituting a proxy that captures the innovative linkage between one country pair, we can formulate a gravity equation in multiplicative form instead of a logarithmic one and estimate it using the PPML estimator, which has been proven to be robust in the presence of large zeros in the dependent variable, as demonstrated by Silva and Tenreyro (2006). Additionally, we account for the ownership dimension of patent application data, as doing so helps illustrate the innovative collaboration between different types of entities, such as individuals, multinational firms, academic institutions, and research organizations. These entities may differ across various dimensions regarding collaborative relationships and play a significant role in the context of multinational enterprises (MNEs), which typically operate globally and create technological networks across borders. The decision to offshore R&D activities abroad, regardless of the motives, can lead to innovative collaboration with local enterprises. In summary, there are two dependent variables of interest: joint invention and joint patent application. The baseline specification can be expressed as follows.

$$C_{ijt} = exp\,[\emptyset_0 + \emptyset_1 X_{it} + \emptyset_2 Y_{jt} + \emptyset_3 DIST_{ij} + \emptyset_4 T_{ijt} + \emptyset_5 Z_{ijt} + \emptyset_6 A_{ij} + \theta_{ij} + \gamma_{it} + \delta_{jt}] + \varepsilon_{ijt} \quad (9)$$

Where

$$C_{ijt} = \begin{bmatrix} COIN_{ijt} \\ COAPP_{ijt} \end{bmatrix}, X_{it} = \begin{bmatrix} K_{it} \\ G_{it} \\ U_{it} \end{bmatrix}, \quad Y_{jt} = \begin{bmatrix} K_{jt} \\ G_{jt} \\ U_{jt} \end{bmatrix}, \quad Z_{ijt} = \begin{bmatrix} RTA_{ijt} \\ TD_{ijt} \\ SICT_{ijt} \end{bmatrix}, \quad A_{ij} = \begin{bmatrix} CL_{ij} \\ CT_{ij} \end{bmatrix} \quad (10)$$

$COIN_{ijt}$ = The co-invention index of a country pair i and j in year t.

$COAPP_{ijt}$ = The co-application index of a country pair i and j in year t.

$\theta_{ij}$ = Dyadic fixed effects, $\pi_{it}$ = Time-varying country i fixed effects.

$\lambda_{jt}$ = Time-varying country j fixed effects.

To control for potential bias, the dyadic fixed effects are augmented to capture unobserved heterogeneities between two distinct parties that may influence co-patenting behavior. In other words, these fixed effects help account for heterogeneity in joint patenting relationships that may not be captured by observable factors. Baier and Bergstrand (2007), along with Yotov, Piermartini, and Larch (2016), assert that these pairwise fixed effects are beneficial in tracing unobserved connections between the endogenous trade policy covariate and the disturbance term in gravity equations. Furthermore, they address the issue of self-selection into signing RTAs with innovation-related provisions. In other words, these terms account for unobservable, time-invariant heterogeneity among bilateral pairs, which can bias estimation results in cross-sectional studies and thus reduce concerns about endogeneity arising from omitted variable bias. Similarly, Dhingra, Freeman, and Huang (2023) affirm that augmenting pairwise fixed effects is the most effective method to mitigate endogeneity concerns related to trade agreements, as they help account for time-variant factors such as spatial distance and common language used among parties. Additionally, these pairwise terms account for other time-invariant, pair-specific frictions in collaborative patenting efforts (Egger & Nigai, 2015). Next, country-time fixed effects help account for time-varying multilateral resistance terms (MRTs) as well as unobservable heterogeneities of each party over time, as demonstrated by Baier and Bergstrand (2007), which may influence collaborative patent creation and registration in the context of this study.

## 5. RESULTS

The following Table 3 reports descriptive statistics of data sample utilized in this study.

**Table 3.** Descriptive statistics.

| Variables | Notation | Mean | S.D. | Min. | Max. | Observation |
|---|---|---|---|---|---|---|
| Co-invention index | $COIN_{ijt}$ | 0.1353 | 0.6248 | 0 | 13.9447 | 7,500 |
| Co-application index | $COAPP_{ijt}$ | 0.0622 | 0.4932 | 0 | 28.6856 | 6,450 |
| Knowledge stock of country i | $K_{it}$ | 4.1905 | 2.4336 | -3.8367 | 8.5870 | 7,500 |
| Knowledge stock of country j | $K_{jt}$ | 6.9007 | 3.114 | -5.4898 | 12.7750 | 7,500 |
| Worldwide governance indicator of country i | $G_{it}$ | 0.0567 | 0.7297 | -0.9524 | 1.6358 | 6,600 |
| Worldwide governance indicator of country j | $G_{jt}$ | 0.8330 | 0.7810 | -0.9524 | 1.9468 | 7,455 |
| Upstreamness measure of country i | $U_{it}$ | 2.2714 | 0.2335 | 1.7709 | 2.6639 | 7,500 |
| Upstreamness measure of country j | $U_{jt}$ | 2.0751 | 0.1972 | 1.6490 | 2.7630 | 7,500 |
| RTA dummy for co-invention of patents | $RTA1_{ijt}$ | 0.3315 | 0.4708 | 0 | 1 | 7,500 |
| RTA dummy for co-application of patents | $RTA2_{ijt}$ | 0.3177 | 0.4656 | 0 | 1 | 6,450 |
| RTA Depth Index for Co-invention of Patents | $DEPTH1_{ijt}$ | 0.0357 | 0.0037 | 0.0284 | 0.0490 | 7,500 |
| RTA Depth Index for Co-application of Patents | $DEPTH2_{ijt}$ | 0.0358 | 0.0034 | 0.0284 | 0.0476 | 6,450 |
| RTA breadth index for co-invention of patents | $BREADTH1_{ijt}$ | 0.0008 | 0.0001 | 0.0006 | 0.0011 | 7,500 |
| RTA breadth index for Co-application of patents | $BREADTH2_{ijt}$ | 0.0008 | 0.0001 | 0.0006 | 0.001 | 6,450 |
| Spatial distance between both countries | $DIST_{ij}$ | 8.9109 | 0.6821 | 5.7543 | 9.892 | 7,500 |
| Technological distance between both countries | $TD_{ijt}$ | 0.6722 | 0.2216 | 0.1458 | 1 | 7,500 |
| Similarity degree of ICTs level between both countries | $SICT_{ijt}$ | 2.7455 | 1.3697 | -7.2964 | 4.4553 | 7,500 |
| Common Language | $CL_{ij}$ | 0.1008 | 0.3011 | 0 | 1 | 7,500 |
| Colonial Trait | $CT_{ij}$ | 0.0194 | 0.1379 | 0 | 1 | 7,500 |

**Note:** Some variables are transformed into logarithmic term to ensure the consistency of estimation results and corresponding interpretation.

### *5.1. Baseline Results*

This section discusses the effects of deep and broad RTAs, as well as agreements with innovation-related provisions, on cross-country innovation activities, as reflected in both co-inventorship and co-ownership of patents. Estimates of trade agreement variables refer to the contemporaneous or static effects, consistent with most previous studies. The starting point is the scenario of joint invention of patents, as depicted in Table 4.

**Table 4.** Co-invention of patents and RTAs.

| Variable | (1) $COIN_{ijt}$ | (2) $COIN_{ijt}$ | (3) $COIN_{ijt}$ | (4) $COIN_{ijt}$ | (5) $COIN_{ijt}$ | (6) $COIN_{ijt}$ |
|---|---|---|---|---|---|---|
| $K_{it}$ | 0.1873** | | 0.1794** | | 0.1742** | |
| | (0.0756) | | (0.0728) | | (0.0722) | |
| $K_{jt}$ | 0.7277*** | | 0.7356*** | | 0.7392*** | |
| | (0.0496) | | (0.0487) | | (0.0479) | |
| $G_{it}$ | 0.8611*** | | 0.848*** | | 0.8549*** | |
| | (0.1593) | | (0.1598) | | (0.163) | |
| $G_{jt}$ | 0.2662** | | 0.33*** | | 0.3474*** | |
| | (0.109) | | (0.1049) | | (0.1022) | |
| $U_{it}$ | 0.5929 | | 0.6198 | | 0.6167 | |
| | (0.4087) | | (0.3834) | | (0.3757) | |
| $U_{jt}$ | -0.7848* | | -0.9301** | | -0.8811** | |
| | (0.4073) | | (0.3827) | | (0.3743) | |
| $RTA_{ijt}$ | 0.0824 | 0.363 | 0.4068 | 0.0121 | 0.4752* | 0.0168 |
| | (0.3191) | (0.3073) | (0.2736) | (0.3257) | (0.2388) | (0.3639) |
| $DEPTH_{ijt}$ | 0.4754 | 0.1376* | | | | |
| | (0.7239) | (0.8123) | | | | |
| $BREADTH_{ijt}$ | | | 0.1614 | 0.4208* | | |

| Variable | (1) $COIN_{ijt}$ | (2) $COIN_{ijt}$ | (3) $COIN_{ijt}$ | (4) $COIN_{ijt}$ | (5) $COIN_{ijt}$ | (6) $COIN_{ijt}$ |
|---|---|---|---|---|---|---|
| | | | (0.101) | (0.2354) | | |
| $IND_{ijt}$ | | | | | 0.1689** (0.0816) | -0.1051 (0.9335) |
| $DIST_{ij}$ | -0.7468*** (0.0894) | | -0.6604*** (0.102) | | -0.6376*** (0.0996) | |
| $TD_{ijt}$ | -1.8338*** (0.7065) | -0.0962 (0.6711) | -1.8008*** (0.6691) | -0.0443 (0.6884) | -1.758*** (0.6624) | -0.0441 (0.6739) |
| $SICT_{ijt}$ | 0.0023 (0.0424) | -0.0196 (0.0469) | -0.003 (0.044) | -0.0234 (0.0464) | 0.0019 (0.0431) | -0.0239 (0.0473) |
| $CL_{ij}$ | 0.7681*** (0.1627) | | 0.7654*** (0.1565) | | 0.7202*** (0.1568) | |
| $CT_{ij}$ | 0.0948 (0.2454) | | 0.0756 (0.2377) | | 0.113 (0.2273) | |
| Timed fixed effects | No | No | No | No | No | No |
| Dyadic fixed effects | No | Yes | No | Yes | No | Yes |
| Country-year fixed effects | No | Yes | No | Yes | No | Yes |
| N | 6,600 | 2,723 | 6,600 | 2,957 | 6,600 | 2,957 |
| $R^2$/ Pseudo $R^2$ | 0.7426 | 0.5364 | 0.7389 | 0.5363 | 0.7434 | 0.5363 |

**Note:** *, **, and *** denote significance on the levels 10%, 5%, and 1%, respectively. The PPML estimation method is employed across every column.

This type of collaboration reflects a deliberate effort to collectively invent new technologies and innovations, contingent upon the participation of team members from diverse nations. Knowledge exchange certainly takes place, and it is established in the literature that these collective efforts are likely to result in higher-quality innovation outcomes (Branstetter, Li, & Veloso, 2015).

Column (1) reveals that neither the RTA nor the depth index significantly determines international co-inventing activities, whereas other covariates demonstrate anticipated results consistent with prior studies, such as the negative effect of physical distance and the positive effect of a common language. By controlling for time-varying country-specific factors and unobserved bilateral-pair heterogeneities through corresponding fixed effects, the biased correction results in column (2) indicate that RTA, in a general sense, is still not clearly influential in explaining the propensity to co-invent. Nonetheless, there are additional benefits to agreeing to provisions classified within the depth dimension of RTAs. Technological distance and similarity in ICTs negligibly influence cross-border co-invention activities across all specifications. Regarding the breadth aspect, the results in column (3) are relatively similar to those in column (1). Similarly, column (4) shows that a wider range of agreement correlates with a higher extent of cross-country innovative activities. The final scenario involves innovation-related provisions of agreements that are more restrictive than the previous two indices. PPML estimation indicates that both RTA and specific innovation content matter for the tendency to co-invent, as shown in column (5). However, when correcting for bias as in column (6), it appears that RTAs including a higher number of such discussion areas negatively influence cross-border innovation collaboration, with a non-significant degree. Due to this inconsistency, an alternative estimation was performed in the robustness section to validate this negative correlation.

Next, we evaluate whether trade treaties affect co-application activities, considering that the owner of the patent is not necessarily the inventor of a new product. This spatial difference in patent ownership indicates the internationalization of technology (Martínez-Zarzoso & Arregui Coka, 2025). The estimation results are presented in the following Table 5.

**Table 5.** Co-application of patents and RTAs.

| Variable | (1) COAPP$_{ijt}$ | (2) COAPP$_{ijt}$ | (3) COAPP$_{ijt}$ | (4) COAPP$_{ijt}$ | (5) COAPP$_{ijt}$ | (6) COAPP$_{ijt}$ |
|---|---|---|---|---|---|---|
| $K_{it}$ | 0.0694 (0.1446) | | 0.0672 (0.1417) | | 0.0639 (0.1435) | |
| $K_{jt}$ | 0.6671*** (0.0601) | | 0.6697*** (0.0611) | | 0.6744*** (0.0588) | |
| $G_{it}$ | 0.1205*** (0.0236) | | 0.121*** (0.0246) | | 0.1214*** (0.2486) | |
| $G_{jt}$ | 0.1228 (0.1386) | | 0.1373 (0.1371) | | 0.1606 (0.1376) | |
| $U_{it}$ | 0.559 (0.524) | | 0.5564 (0.5245) | | 0.5572 (0.5226) | |
| $U_{jt}$ | -0.7595* (0.4432) | | -0.7644* (0.4456) | | -0.7448 (0.4535) | |
| $RTA_{ijt}$ | 0.4795 (0.3187) | 0.1709* (0.1023) | 0.5693** (0.2806) | 0.1926 (0.9549) | 0.6699** (0.3112) | 0.5904 (1.0434) |
| $DEPTH_{ijt}$ | 0.1357 (0.79) | 0.4756** (0.231) | | | | |
| $BREADTH_{ijt}$ | | | 0.1468 (0.9268) | 1.4111 (2.5048) | | |
| $IND_{ijt}$ | | | | | -0.4425 (0.7881) | -0.8697 (2.05) |
| $DIST_{ij}$ | -0.7608*** (0.106) | | -0.7591*** (0.105) | | -0.7379*** (0.113) | |
| $TD_{ijt}$ | -0.5774 (0.9137) | 2.0182 (1.9606) | -0.5646 (0.8937) | 1.3977 (2.0216) | -0.5393 (0.9056) | 1.6547 (1.9667) |
| $SICT_{ijt}$ | 0.0702 (0.0695) | 0.0695 (0.0911) | 0.0697 (0.0708) | 0.0532 (0.0907) | 0.0692 (0.0714) | 0.0547 (0.0902) |
| $CL_{ij}$ | 0.9497*** (0.1563) | | 0.9376*** (0.162) | | 0.9182*** (0.1643) | |
| $CT_{ij}$ | 0.2322 (0.2787) | | 0.2256 (0.2801) | | 0.2085 (0.2786) | |
| Timed fixed effects | No | No | No | No | No | No |
| Dyadic fixed effects | No | Yes | No | Yes | No | Yes |
| Country-year fixed effects | No | Yes | No | Yes | No | Yes |
| N | 5,676 | 1,234 | 5,676 | 1,234 | 5,676 | 1,234 |
| $R^2$/ Pseudo $R^2$ | 0.4708 | 0.5428 | 0.4705 | 0.5416 | 0.4686 | 0.5419 |

**Note:** *, **, and *** denote significance on the levels 10%, 5%, and 1%, respectively. The PPML estimation method is employed across every column.

Remarkably, solid country-level IPR protection in ASEAN nations attracts foreign innovators to share ownership of proprietary rights, as they perceive fewer risks of infringement, imitation, and other issues. The higher knowledge stock level of the partner country incentivizes such collaborative initiatives among ASEAN nations. Physical distance still hinders cross-country innovation activities, similar to the findings in and as shown in Table 4. Additionally, a common language exerts an adverse impact on such linkages, with a meaningful degree of influence consistent with the studies by Picci (2010) and Montobbio and Sterzi (2013). Regarding trade integration, it is notable that if two nations participate in a regional trade agreement (RTA), the number of co-applied patents tends to be higher than in non-member country pairs. Based on column (2), becoming a participant increases co-application activities by approximately 18.64%, calculated as (e^{0.1709} - 1) * 100. Similarly, agreements that include legally binding provisions across various policy fields—such as import tariffs, non-tariff barriers, behind-the-border policies, and others—contribute positively to co-patent applications, as indicated by a higher value of the depth index. However, an augmented estimation with fixed effects in column (4) reveals that RTA participation and its breadth dimension are not significantly associated with increased propensity for co-innovation in terms of collective patent ownership. Intuitively, co-ownership of patents does not necessarily reflect a deliberate effort to collaboratively create new inventions, unlike co-inventorship, as illustrated by Belderbos, Cassiman, Faems, Leten, and Van Looy (2014). Therefore, various non-traditional provisions may not fully stimulate shared agreements. Lastly, more restrictive content related to innovation and technology appears to be negligible in influencing cross-country co-application activities; in fact, it may even hinder such collective efforts, consistent with the rationale discussed earlier. A sensitivity analysis will be performed in section 6.4 to test the validity of this outcome.

## 6. ROBUSTNESS ANALYSIS

### *6.1. Estimation with 5-Year Interval Data*

We perform the PPML estimation with 5-year interval data in this section. According to Egger et al. (2022), trade agreements are generally publicized prior to their enforcement date, which tends to incentivize relevant innovators to adjust strategies and investments. These agreements usually contain phasing-in periods and take time to unfold their full effects following implementation. Additionally, there are delayed responses from enterprises to the materialization period of the full trade agreement impact. These features necessitate an appropriate approach to obtain unbiased estimates of the average pattern of the dynamic adjustment process. Motivated by these considerations, some previous studies have applied time-interval panel data estimation to acquire more reliable estimates in the context of trade flows (Baier & Bergstrand, 2007; Cheng & Wall, 2005). We utilize data solely for the years 1996, 2001, 2006, 2011, and 2016 in the estimation model, and the results of the cointegration case are reported in the following Table 6.

**Table 6.** PPML estimation results: co-invention of patents.

| **Variable** | **(1) $COIN_{ijt}$** | **(2) $COIN_{ijt}$** | **(3) $COIN_{ijt}$** | **(4) $COAPP_{ijt}$** | **(5) $COAPP_{ijt}$** | **(6) $COAPP_{ijt}$** |
|---|---|---|---|---|---|---|
| $RTA_{ijt}$ | 0.3673<br>(0.8676) | 1.0471<br>(1.2437) | 0.6436<br>(1.1199) | 0.7171<br>(0.4632) | 0.1389***<br>(0.2621) | 0.3931***<br>(0.1999) |
| $DEPTH_{ijt}$ | 1.6885<br>(2.7949) | | | 0.4905***<br>(0.1718) | | |
| $BREADTH_{ijt}$ | | 2.8828<br>(3.7554) | | | 0.15***<br>(0.557) | |
| $IND_{ijt}$ | | | 1.6545<br>(3.3012) | | | -0.1264***<br>(0.5529) |
| $TD_{ijt}$ | -0.609<br>(1.451) | -0.5647<br>(1.4795) | -0.5822<br>(1.4761) | -0.1531<br>(0.1008) | -0.1628*<br>(0.934) | -0.1028<br>(0.6403) |
| $SICT_{ijt}$ | -0.3732*<br>(0.1974) | -0.3323*<br>(0.1889) | -0.3476<br>(0.1895) | -0.1384**<br>(0.0643) | -0.1445**<br>(0.685) | -0.8557<br>(0.5601) |
| Dyadic fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Country-year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 374 | 374 | 374 | 112 | 112 | 158 |
| Pseudo $R^2$ | 0.5121 | 0.5119 | 0.5119 | 0.4609 | 0.4578 | 0.438 |

**Note:** *, **, and *** denote significance on the levels 10%, 5%, and 1%, respectively.

It is apparent that, although we observe positive economic integration effects of the RTAs, their estimates are not statistically significant across columns (1)-(3). Some research, such as Yotov et al. (2016), suggests that this approach helps address the fact that trade agreement effects may not materialize within a single year. Contrary to the baseline scenario, this may be attributable to the notion that a five-year interval analysis of a trade treaty restricts us to focusing only on a few years over a long horizon. Consequently, such an effect may not reach its full impact in any of these years or show the strongest influence immediately following the implementation period. Additionally, we lose a significant portion of the sample since we perform the estimation with less data. Unlike baseline outcomes, the similarity in ICT development levels between a country pair is proven to be a non-negligible determinant of joint innovation development, whereas the similarity in technological specialization does not exhibit the same influence.

Thereafter, we substitute the co-invention index with the co-application index, and the results are displayed in columns (4)–(6). Participation in RTAs appears to facilitate cross-country ownership of innovation outputs, as evidenced by columns (5) and (6). Furthermore, agreements with deeper or broader legally enforceable provisions demonstrate additional positive effects on such partnerships, whereas those with more restrictive provisions related to innovation hinder this international cooperation, consistent with the baseline results. The issue may stem from high compliance costs and the lengthy time required for ASEAN firms to adapt and align their strategies with higher IPR standards. Some enterprises may decide against forming innovative links with potential international partners due to short-term and medium-term costs. Similarly, (Howard et al., 2025) find that trade agreements with legally binding IPR rules established by the WTO hinder intra-bloc patent flows among signatories. Therefore, the negative impact observed may result from the heterogeneity of agreement types. Additionally, requesting nations, particularly the USA and the European Union, have increasingly demanded stricter IPR enforcement standards stipulated in these agreements Howard et al. (2025). Consequently, developing nations might perceive this as an obstacle to collaboration.

### *6.2. Dynamic Adjustment Process*

As noted earlier, the responsive process of collaborative innovation activity in response to policy changes related to trade agreements is inherently dynamic and necessitates careful econometric analysis to accurately evaluate both short-term and long-term effects. One common approach employed by previous studies is to estimate panel data models using data collected over specific time intervals. However, the effectiveness of this method remains controversial in various aspects. For instance, Egger et al. (2022) offer different motivations for preferring consecutive-year data over interval-based data. They argue that interval data estimation may be negatively impacted by the averaging out of anticipation and phasing-in effects. To address this, we incorporate 5-year and 10-year leads and lags of each trade agreement index into the baseline model to better capture anticipation and maturation effects, respectively.

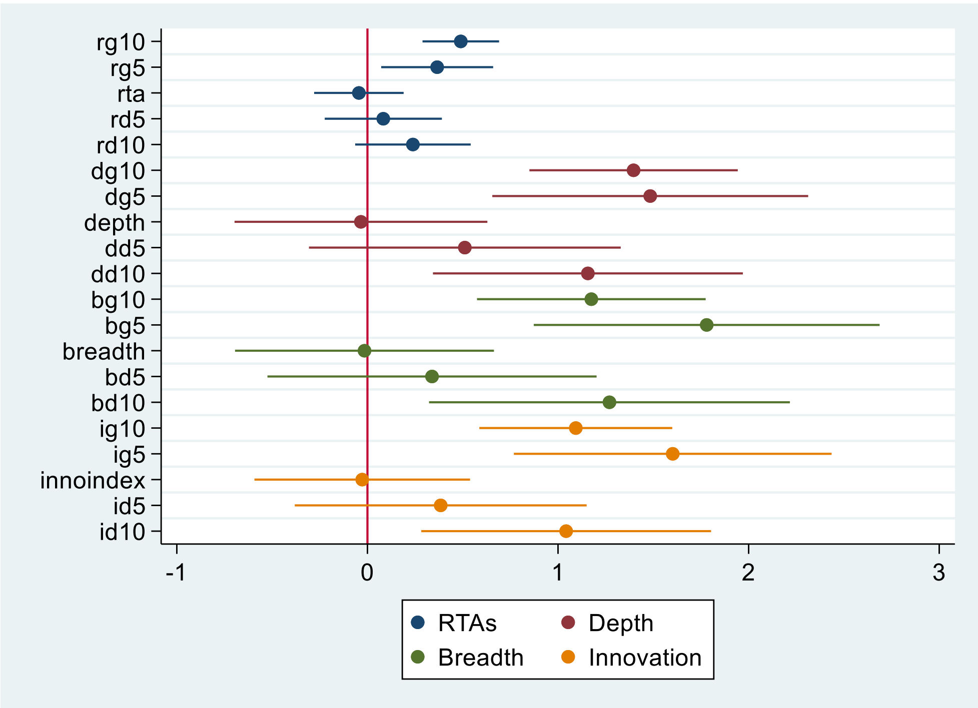


**Figure 1.** Dynamic adjustment path: Co-invention Case.

According to Figure 1, there are two lag terms and two lead terms for every trade agreement index. For instance, the lag of the RTA depth index is denoted by "dg," while the lead is labeled as "dd." In the long run, we can observe phasing-in effects of RTAs, including their depth and breadth aspects, as well as provisions aimed at promoting innovation. On average, it takes approximately five years for RTAs with deeper, broader, or innovation-related provisions to reach their full effects, indicating a non-monotonic relationship between the agreement and collaborative innovation. This finding aligns with previous studies such as Egger et al. (2022) and Martínez-Zarzoso and Arregui Coka (2025). Conversely, anticipation effects captured through the aforementioned lead terms are less prevalent across four specifications, with the most notable effects observed in ten-year lead terms, except for those related to the RTA variable, as indicated by the significance of the estimated coefficients. RTAs with deeper commitments, collectively agreed upon by signatories, tend to induce a higher degree of innovation collaboration, as reflected in the number of co-invented patents even before the agreements are enacted. Once an agreement is announced, some enterprises begin to modify or adjust their strategies in advance to adapt to the evolving environment (Moser & Rose, 2014). Moreover, the cumulative effects are significant across all specifications, as shown in Table A in Appendix 1, indicating the long-term impact of trade integration on co-invention activities.

Shifting the focus from co-inventorship to co-ownership of patents, the following Figure 2 illustrates the dynamic effect of RTA. The results are relatively similar to those in Figure 1, as phase-in effects reach their full extent five years after the ratification of agreements, and this finding is consistent across all indices except for the RTA variable. Conversely, estimates of lead terms are mixed and show both positive and negative directions across different durations, as demonstrated in Table B in Appendix 1. RTAs containing provisions categorized within the breadth dimension exhibit the strongest anticipatory effects five years prior to the inception date, indicating that innovators plan in advance to meet the evolving commitments required on an international stage.

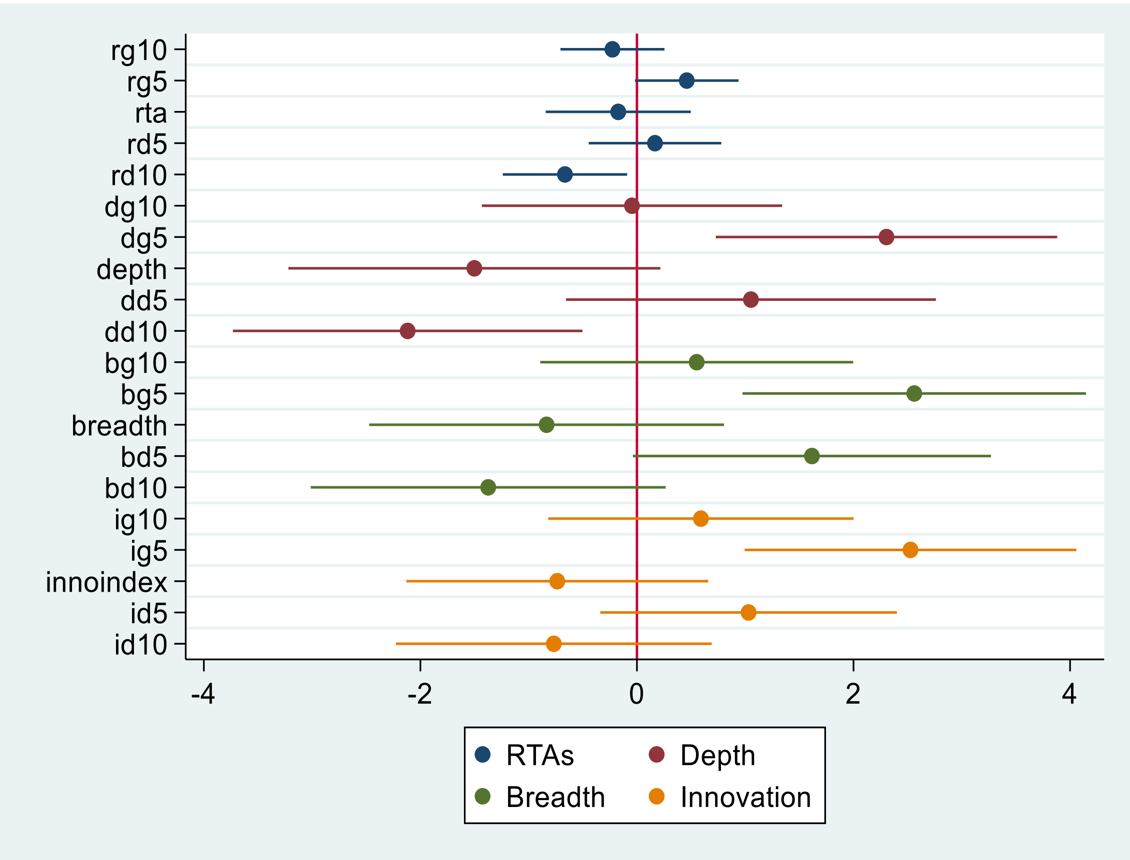


**Figure 2.** Dynamic adjustment path: Co-application case.

## *6.3. Factor Analysis*

According to Jinji et al. (2019), there are numerous correlated provisions within RTAs. Furthermore, a given provision can influence the probability of cross-border innovation collaboration both directly and indirectly. Therefore, it is essential to identify which provisions are significant and to construct an alternative index based on a set of uncorrelated (unobserved) variables that are most likely to impact cross-country innovation activities. To address this effectively, we employ the factor analysis method, which facilitates the extraction of a smaller set of unobservable variables, known as factors, that can largely explain the variations observed in the data. In this study, the legally enforceable (LE) values of provisions in RTAs serve as the observed variables. Additionally, we perform a post-estimation process to validate sampling adequacy using the Kaiser-Meyer-Olkin (KMO) measure, as recommended by Kaiser (1974). Specifically, the KMO value should be greater than 0.49, since Kaiser (1974) states that values between 0.00 and 0.49 are unacceptable. The results of the factor analysis on 40 provisions appearing in RTAs are presented below; however, 12 provisions are omitted due to collinearity issues when maximum likelihood estimation is used for the factor analysis.

**Table 7.** The factor loadings for 40 provisions: Co-invention case.

| Provision | Factor 1 | Factor 2 | Factor 3 | Uniqueness |
|---|---|---|---|---|
| FTA Industrial | 0.232 | 0.5976 | 0.1018 | 0.5787 |
| Customs | 0.3278 | 0.9112 | -0.0288 | 0.0614 |
| Export Taxes | 0.2465 | 0.8997 | -0.0505 | 0.1272 |
| SPS | 0.3202 | 0.9323 | 0.1584 | 0.0032 |
| TBT | 0.3225 | 0.931 | 0.158 | 0.0042 |
| STE | 0.678 | 0.1938 | 0.4141 | 0.3313 |
| AD | 0.2789 | 0.8575 | 0.1628 | 0.1605 |
| CVM | 0.2592 | 0.8523 | 0.1657 | 0.179 |
| State aid | 0.0712 | 0.8763 | 0.1926 | 0.1899 |
| Public procurement | 0.7471 | 0.1555 | 0.0652 | 0.4134 |
| TRIMs | 0.6717 | 0.2834 | 0.3599 | 0.339 |
| GATS | 0.3468 | 0.9159 | 0.1564 | 0.0164 |
| TRIPs | 0.8777 | 0.2355 | 0.3487 | 0.0526 |
| Anti-corruption | 0.2867 | 0.0763 | -0.0088 | 0.9119 |
| Competition policy | 0.8527 | 0.2104 | 0.0655 | 0.2243 |
| Environmental laws | 0.697 | 0.1233 | -0.0166 | 0.4987 |
| IPR | 0.8352 | 0.2312 | 0.365 | 0.1158 |
| Investment | 0.8917 | 0.2433 | 0.0043 | 0.1456 |
| Labor market regulation | 0.5927 | 0.0802 | -0.0152 | 0.642 |
| Movement of capital | 0.9364 | 0.2434 | 0.0653 | 0.0596 |
| Consumer protection | 0.4618 | 0.1045 | -0.0152 | 0.7756 |
| Data protection | 0.3562 | 0.0894 | -0.0138 | 0.8649 |
| Agriculture | 0.2561 | 0.1291 | 0.8268 | 0.2341 |
| Approximation of legislation | -0.3185 | 0.889 | -0.0862 | 0.1007 |
| Innovation policies | 0.3447 | 0.1021 | -0.0119 | 0.8706 |
| Cultural cooperation | 0.0134 | 0.0647 | 0.9861 | 0.0232 |
| Economic policy dialogue | 0.1812 | 0.0516 | 0.1877 | 0.9293 |
| Education and training | 0.4008 | 0.1308 | -0.0078 | 0.8222 |
| Energy | 0.4848 | 0.1645 | 0.5836 | 0.3973 |
| Financial assistance | 0.2392 | 0.0499 | -0.011 | 0.9402 |
| Health | 0.1098 | 0.074 | 0.0118 | 0.9823 |
| Industrial cooperation | 0.0282 | 0.0831 | -0.0089 | 0.9922 |
| Information society | 0.5763 | 0.1511 | -0.0169 | 0.6447 |
| Mining | -0.0041 | 0.059 | 0.9951 | 0.0062 |
| Political dialogue | 0.1049 | 0.0681 | 0.0176 | 0.984 |
| Public administration | 0.5917 | 0.1426 | -0.0245 | 0.629 |
| Regional cooperation | 0.2356 | -0.0158 | 0.1312 | 0.927 |
| Research and Technology | 0.1692 | 0.0991 | 0.8634 | 0.2162 |
| SME | 0.2915 | 0.1486 | 0.7765 | 0.29 |
| Social matters | 0.4657 | 0.114 | -0.0219 | 0.7696 |
| Statistics | -0.183 | 0.8757 | -0.0888 | 0.1918 |
| Visa and asylum | 0.8366 | 0.2385 | 0.0401 | 0.2417 |

Initially, there are 23 provisions with high factor loading values in the category of factor 1, such as intellectual property rights (IPR), investment, and innovation policies; thus, this factor appears to represent a favorable environment for innovative activities and collaboration among member states. Secondly, 12 provisions express high loading values for factor 2, encompassing a wide range of policy areas, especially those related to trade facilitation or barrier removal, such as customs, sanitary and phytosanitary (SPS), technical barriers to trade (TBT), etc. Therefore, factor 2 should be associated with fundamental social and economic conditions advantageous for further trade liberalization among signatories. Finally, only seven provisions have high loading values for factor 3, which is associated with specific industrial collaboration in several sectors along with miscellaneous issues.

**Table 8.** Kaiser-Meyer-Olkin (KMO) values: Co-invention case.

| Provision | KMO Value |
|---|---|
| FTA Industrial | 0.8237 |
| Customs | 0.6357 |
| SPS | 0.7711 |
| TBT | 0.748 |
| STE | 0.7329 |
| State Aid | 0.7804 |
| Public Procurement | 0.8292 |
| TRIMs | 0.7179 |
| GATS | 0.686 |
| Competition Policy | 0.7554 |
| IPR | 0.7997 |
| Investment | 0.7898 |
| Approximation of Legislation | 0.6827 |
| Energy | 0.752 |
| Public Administration | 0.6247 |
| SME | 0.6415 |
| Social Matters | 0.6007 |
| Statistics | 0.9263 |
| **Overall** | **0.5188** |

**Note:** The table reports only the KMO values higher than 0.6 for selected provisions.

Table 8 indicates that the overall Kaiser-Meyer-Olkin (KMO) value is 0.5188, indicating a moderate level of sampling adequacy for factor analysis. Out of 40 provisions in the trade agreements, 18 have KMO values greater than 0.6. This suggests that these provisions are sufficiently correlated and suitable for factor analysis, as recommended by Kaiser (1974). The findings imply that the sampling is adequate for the complete estimation model. Consequently, constructing trade agreement indexes based on the selected provisions is feasible and can be pursued in subsequent analyses.

Proceeding further, we rely on Table 7 to develop indices that encapsulate the forward-looking provisions aimed at simplifying or harmonizing diverse IPR regulations across countries and fostering innovation cooperation among inventors from disparate jurisdictions. Particularly, we concentrate on factor 1, which covers the widest range of policy domains and encompasses stipulations related to innovation collaboration. Following the same technique used for preceding indexes, this Innovation Collaboration (IC) index can be computed as shown in the following formula. In total, 23 provisions are classified into this group.

$$IC_{ijt} = \frac{\sum_{p=1}^{23} Max\_LE_{ijt}^{p}}{2*23} \qquad (11)$$

We then estimate the gravity equation of co-invention of patents using this new index. The choice of estimator is the PPML, according to Silva and Tenreyro (2006), as in the baseline model.

**Table 9.** Estimation results using IC index.

| Variable | Pooled OLS | PPML |
|---|---|---|
| $K_{it}$ | 0.037*** (0.0042) | |
| $K_{jt}$ | 0.0708*** (0.0051) | |
| $G_{it}$ | 0.1569*** (0.0139) | |
| $G_{jt}$ | 0.0124 (0.0083) | |
| $U_{it}$ | 0.0028 (0.026) | |
| $U_{jt}$ | -0.3285*** (0.0384) | |
| $RTA_{ijt}$ | 0.0967 (0.2086) | 0.0267 (0.0173) |
| $IC_{ijt}$ | 0.4697 (0.4928) | 0.7785*** (0.1829) |
| $DIST_{ij}$ | -0.0768*** (0.0152) | |
| $TD_{ijt}$ | -0.1245 (0.4135) | -0.2700*** (0.0368) |
| $SICT_{ijt}$ | -0.0161 (0.0365) | -0.0668*** (0.0097) |
| $CL_{ij}$ | 0.3618*** (0.0646) | |
| $CT_{ij}$ | 0.1986*** (0.0592) | |
| Country-time fixed effects | No | Yes |
| Dyadic fixed effects | No | Yes |
| $R^2$/Pseudo $R^2$ | 0.2211 | 0.5363 |
| N | 6,600 | 2,957 |

**Note:** *** denotes significance at the 1% level.

According to Table 9, column (1) presents the panel OLS estimation results, which are similar to the baseline results; for example, all estimates of gravity fundamentals are as expected and statistically significant. However, estimates of the RTA and IC index are not significant, possibly because unobserved factors influencing co-patenting activities are not controlled for. To address this issue, column (2) extends the analysis by including a set of fixed effects. Importantly, although we do not observe a significant positive effect of becoming a member of RTAs on the likelihood of joint inventions, the partial scope of agreements particularly those related to favorable environments for cross-country collaboration, as reflected in the IC index does promote a higher degree of innovative links. This finding suggests that a broader scope of obligations within RTAs, including provisions related to innovation and behind-the-border policies, is beneficial and conducive to cross-border innovation activities, as opposed to more restrictive provisions captured by the IND index in the baseline model. In other words, some provisions indirectly reinforce collaborative inventions, which cannot be adequately evaluated by arbitrarily selecting suspected provisions, as done in the previous section. Similarly, the most relevant prior research was conducted by Jinji et al. (2019), who found that the fundamental social and economic aspects of RTAs are more influential for technology spillovers across borders than WTO-X provisions focused solely on technology and related areas.

### *6.4. Two-Part Model*

Since there are many zeros for dependent variables in either co-invention or co-application indices, we undertake an estimation of a two-part model to validate the robustness of the baseline model's results. This two-part model can be decomposed into two components: the first being a probit model where the aforementioned index is the dependent variable. If there is no innovation linkage between a given country pair, the probability of collaboration is then zero, and so is the index's value. The second part models the magnitude of the outcome, which depends on whether it is non-zero or if collaboration occurs. According to Belotti, Deb, Manning, and Norton (2015), this part is specified using a generalized linear model (GLM). Essentially, the disturbance terms in these two equations do not need to be independent to obtain consistent estimates. The following Table 10 reports average marginal effects (AMEs) of each covariate, which capture how a change in each specified covariate influences co-patenting outcomes, while accounting for both the probability of collaboration and its intensity. We can express the AMEs mathematically as below, considering only the dependent variable (Y) that records a value higher than zero.

$$E(Y) = P(Y > 0) * E(Y|Y > 0) \quad (12)$$

Where

E(Y) = Unconditional expected value is the product of both parts.

**Table 10.** Combined marginal effects of two-part model.

| Variable | (1) $COIN_{ijt}$ | (2) $COIN_{ijt}$ | (3) $COIN_{ijt}$ | (4) $COAPP_{ijt}$ | (5) $COAPP_{ijt}$ | (6) $COAPP_{ijt}$ |
|---|---|---|---|---|---|---|
| $RTA_{ijt}$ | 0.1267*** (0.0229) | 0.0969*** (0.0175) | 0.0621*** (0.0166) | 0.0013 (0.0143) | 0.0088 (0.0138) | 0.0232** (0.0115) |
| $DEPTH_{ijt}$ | 0.5905*** (0.0746) | | | 0.2238*** (0.047) | | |
| $BREADTH_{ijt}$ | | 0.7045*** (0.0719) | | | 0.2749*** (0.0382) | |
| $IND_{ijt}$ | | | 0.5031*** (0.0588) | | | 0.1929*** (0.0329) |
| $DIST_{ij}$ | -0.0051 (0.0071) | -0.0488*** (0.0069) | -0.0477*** (0.0071) | -0.0013 (0.005) | -0.0209*** (0.0054) | -0.0205*** (0.0054) |
| $TD_{ijt}$ | -0.4522*** (0.0285) | -0.4361*** (0.0289) | -0.4447*** (0.0292) | -0.2236 (0.0251) | -0.2103*** (0.0258) | -0.2148*** (0.0252) |
| $SICT_{ijt}$ | 0.0019 (0.0041) | 0.004 (0.004) | 0.0039 (0.0041) | -0.004 (0.0028) | -0.0038 (0.0028) | -0.0038 (0.0028) |
| $CL_{ij}$ | 0.1578*** (0.016) | 0.1461*** (0.0149) | 0.1484*** (0.0152) | 0.0683*** (0.0121) | 0.0642*** (0.0116) | 0.0647*** (0.0116) |
| $CT_{ij}$ | 0.2131*** (0.0182) | 0.2131*** (0.0178) | 0.215*** (0.018) | 0.0492*** (0.0119) | 0.05*** (0.0115) | 0.0511*** (0.0116) |
| N | 7,500 | 7,500 | 7,500 | 6,450 | 6,450 | 6,450 |
| Pseudo $R^2$ | 0.1778 | 0.1886 | 0.1869 | 0.1959 | 0.209 | 0.204 |

**Note:** **, and *** denote significance on the levels 5%, and 1%, respectively.

Table 10 reports the marginal effects of this two-part estimation. Overall, trade integration has a significantly positive impact on co-patenting activities, especially in terms of joint patent inventions, as captured by RTA estimates. Zooming into the content of RTAs, the results slightly differ from the baseline ones since they suggest that agreements with a more expansive scope or more provisions classified into the depth or breadth aspect increase the output of the innovation collaboration process, as reflected in both co-invented and co-applied patents with certainty. A higher standard of IPR protection or a conducive environment for the inventive process actually plays a beneficial role in the further extent of cross-country cooperation and the development of novel inventions. This finding contradicts the baseline case, as the previous results indicate that $IND_{ijt}$ negatively affects co-inventorship or co-ownership of patents, but only to a trivial degree.

To justify this, most prior studies conclude that agreements with IPR-related clauses support cross-country technological collaboration or international patenting (Howard et al., 2025; Martínez-Zarzoso & Arregui Coka, 2025). The estimates of $IND_{ijt}$ in this section are statistically significant in both columns (3) and (6), indicating that RTAs containing provisions that promote innovation are more likely to foster collaborative innovation among member states.

## 7. CONCLUSION

This study evaluates the impact of deep RTAs on cross-country innovation collaboration. We construct and estimate a structural gravity equation of international patenting activities based on the model of international knowledge flows by Peri (2005). A model with high-dimensional fixed effects (HDFE), as described by Correia, Guimarães, and Zylkin (2020), is designed to address time-varying specific factors of each country and unobserved heterogeneities between country pairs. The baseline results indicate that trade integration reflected in RTA membership does not significantly promote cross-border innovation ties, while RTAs with deeper or broader commitments measured via legally binding provisions are conducive to such cooperation among signatories. Conversely, RTAs with a narrower scope restricted to innovation and technology appear to be minor obstacles to international collaboration. However, the two-part model estimation suggests that RTAs incorporating more provisions relevant to these policy fields deliver a strong positive impact on collaborative innovation among signatories. Additionally, previous studies show that trade agreements containing provisions on the regulatory environment regarding IPR, which go beyond the minimum standards stipulated in the TRIPS agreement, tend to encourage international patenting activities (Howard et al., 2025) and technological collaboration (Martínez-Zarzoso & Arregui Coka, 2025). Therefore, it can be inferred that more stringent IPR regulations and related conditions are more likely to foster innovation collaboration among participating members. It is important to note that there are trivial differences between the scenarios of co-invention and co-application of patents between one ASEAN nation and a potential partner. Beyond immediate effects, a dynamic analysis reveals both pre- and post-implementation effects of RTAs, in addition to the contemporaneous effects identified in prior studies. Anticipation effects refer to circumstances where innovators adjust their strategies and actions prior to the trade agreement's inception, while maturation effects indicate that it takes several years for the positive impacts of agreements to reach their peak. Estimation with consecutive-year data shows that the positive effect of RTAs has increased over time and peaked approximately five years after ratification. Finally, factor analysis enables the extraction of a set of provisions and the construction of an alternative index that better captures the content influencing innovation cooperation. The model's results provide evidence that RTAs with more of any 23 provisions enhance joint inventive efforts. Essentially, each provision can directly or indirectly foster the propensity to collaborate in innovation activities. The findings suggest that policymakers in these six ASEAN nations can promote innovation development by strategically negotiating trade agreements that include not only general provisions favorable to business operations but also those that strengthen IPR protection and support partnerships, especially with technologically advanced nations. Internal efforts by ASEAN countries to improve IPR enforcement also facilitate further collaboration and significantly contribute to innovation progress.

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**Appendix 1.**

**Table A.** PPML estimation with 5-year & 10-year leads and lags: Joint invention.

| Variable | (1) $COIN_{ijt}$ | Variable | (2) $COIN_{ijt}$ | Variable | (3) $COIN_{ijt}$ | Variable | (4) $COIN_{ijt}$ |
|---|---|---|---|---|---|---|---|
| $RTA_{ij,t-10}$ | 0.4795*** (0.1591) | $DEPTH_{ij,t-10}$ | 1.4642*** (0.3787) | $BREADTH_{ij,t-10}$ | 1.1183** (0.4352) | $IND_{ij,t-10}$ | 1.154*** (0.3503) |
| $RTA_{ij,t-5}$ | 0.3107 (0.2527) | $DEPTH_{ij,t-5}$ | 1.3014** (0.6623) | $BREADTH_{ij,t-5}$ | 1.7883** (0.7038) | $IND_{ij,t-5}$ | 1.4959** (0.6128) |
| $RTA_{ijt}$ | -0.1324 (0.1533) | $DEPTH_{ijt}$ | -0.1598 (0.4627) | $BREADTH_{ijt}$ | -0.1312 (0.4573) | $IND_{ijt}$ | -0.0502 (0.4272) |
| $RTA_{ij,t+5}$ | 0.0288 (0.2626) | $DEPTH_{ij,t+5}$ | 0.5041 (0.6869) | $BREADTH_{ij,t+5}$ | 0.1138 (0.8112) | $IND_{ij,t+5}$ | 0.3086 (0.7348) |
| $RTA_{ij,t+10}$ | 0.292 (0.2019) | $DEPTH_{ij,t+10}$ | 1.5614*** (0.5758) | $BREADTH_{ij,t+10}$ | 1.6195** (0.6378) | $IND_{ij,t+10}$ | 1.3325** (0.5525) |
| $TD_{ijt}$ | -0.1314 (0.7014) | $TD_{ijt}$ | -0.0439 (0.6954) | $TD_{ijt}$ | -0.0404 (0.7105) | $TD_{ijt}$ | -0.0284 (0.7002) |
| $SICT_{ijt}$ | -0.0075 (0.0381) | $SICT_{ijt}$ | -0.0091 (0.0419) | $SICT_{ijt}$ | -0.0052 (0.0388) | $SICT_{ijt}$ | -0.0043 (0.04) |
| Overall effects | 0.9786** (0.4787) | Overall Effects | 4.6713*** (1.2957) | Overall effects | 4.5088*** (1.5359) | Overall Effects | 4.2408*** (1.2435) |
| Dyadic fixed effects | Yes | Dyadic Fixed Effects | Yes | Dyadic Fixed effects | Yes | Dyadic fixed effects | Yes |
| Country-year fixed effects | Yes | Country-year Fixed Effects | Yes | Country-year fixed effects | Yes | Country-year fixed effects | Yes |
| Pseudo $R^2$ | 0.5397 | Pseudo $R^2$ | 0.5398 | Pseudo $R^2$ | 0.5397 | Pseudo $R^2$ | 0.5397 |
| N | 2,947 | N | 2,947 | N | 2,947 | N | 2,947 |

**Note:** *, **, and *** denote significance on the levels 10%, 5%, and 1%, respectively.
PPML estimation is conducted in combination with the biasedness correction method following (Weidner & Zylkin, 2021).

**Table B.** PPML estimation with 5-year & 10-year leads and lags: Joint application.

| Variable | (1) $COAPP_{ijt}$ | Variable | (2) $COAPP_{ijt}$ | Variable | (3) $COAPP_{ijt}$ | Variable | (4) $COAPP_{ijt}$ |
|---|---|---|---|---|---|---|---|
| $RTA_{ij,t-10}$ | -0.2512 (0.2795) | $DEPTH_{ij,t-10}$ | -0.1648 (0.8913) | $BREADTH_{ij,t-10}$ | 0.8644 (1.0064) | $IND_{ij,t-10}$ | 0.9275 (0.9264) |
| $RTA_{ij,t-5}$ | 0.4631 (0.3237) | $DEPTH_{ij,t-5}$ | 2.7708** (1.2449) | $BREADTH_{ij,t-5}$ | 3.1791*** (1.2012) | $IND_{ij,t-5}$ | 3.3264*** (1.10153) |
| $RTA_{ijt}$ | 0.0065 (0.5092) | $DEPTH_{ijt}$ | -1.6758 (1.11) | $BREADTH_{ijt}$ | -0.6876 (1.1154) | $IND_{ijt}$ | -0.7284 (0.9494) |
| $RTA_{ij,t+5}$ | 0.2266 (0.4605) | $DEPTH_{ij,t+5}$ | 1.4823 (1.0335) | $BREADTH_{ij,t+5}$ | 2.165* (1.1315) | $IND_{ij,t+5}$ | 1.4826 (0.952) |
| $RTA_{ij,t+10}$ | -0.8207** (0.3591) | $DEPTH_{ij,t+10}$ | -2.2561* (1.3517) | $BREADTH_{ij,t+10}$ | -1.2519 (1.1989) | $IND_{ij,t+10}$ | -0.4905 (1.1131) |
| $TD_{ijt}$ | 1.0383 (2.0705) | $TD_{ijt}$ | 1.6542 (2.0691) | $TD_{ijt}$ | 1.5323 (2.1234) | $TD_{ijt}$ | 1.7631 (2.0793) |
| $SICT_{ijt}$ | 0.0068 (0.0929) | $SICT_{ijt}$ | 0.0441 (0.1106) | $SICT_{ijt}$ | 0.0361 (0.1066) | $SICT_{ijt}$ | 0.0557 (0.1098) |
| Overall effects | -0.3757 (0.8806) | Overall Effects | 0.1564 (2.9722) | Overall effects | 4.269 (3.0526) | Overall effects | 4.5175* (2.722) |
| Dyadic fixed effects | Yes | Dyadic fixed effects | Yes | Dyadic fixed effects | Yes | Dyadic fixed effects | Yes |
| Country-year fixed effects | Yes | Country-year fixed effects | Yes | Country-year Fixed Effects | Yes | Country-year fixed effects | Yes |
| Pseudo $R^2$ | 0.5449 | Pseudo $R^2$ | 0.5452 | Pseudo $R^2$ | 0.5454 | Pseudo $R^2$ | 0.5453 |
| N | 1,214 | N | 1,214 | N | 1,214 | N | 1,214 |

**Note:** *, **, and *** denote significance on the levels 10%, 5%, and 1%, respectively.
PPML estimation is conducted in combination with the biasedness correction method following (Weidner & Zylkin, 2021).

## Data Construction

### The Construction of Trade Agreement Index

In the baseline model, we use three indexes to assess the impact of trade agreements and their scope on cross-country innovation collaboration. To compute them, we follow the approach of Jinji et al. (2022), which is built on the terminology of depth and breadth of trade agreements as proposed by Limão (2016). Consider the following example: suppose we aim to construct the RTA breadth index in a given year t for a bilateral pair, Thailand-Australia.

**Table C.** Legally Enforceable (LE) Indexes of RTAs between Thailand and Australia: 2000-2016.

| Year | Country i | Partner j | TRIMs | GATS | TRIPs | Environmental Laws | IPR | Investment | Labour Market Regulation | Movement of Capital | Audio Visual | Innovation Policies |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | THA | AUS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2001 | THA | AUS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2002 | THA | AUS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | THA | AUS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2004 | THA | AUS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | THA | AUS | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| 2006 | THA | AUS | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| 2007 | THA | AUS | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| 2008 | THA | AUS | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| 2009 | THA | AUS | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| 2010 | THA | AUS | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 0 | 0 |
| 2011 | THA | AUS | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 0 | 0 |
| 2012 | THA | AUS | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 0 | 0 |
| 2013 | THA | AUS | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 0 | 0 |
| 2014 | THA | AUS | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 0 | 0 |
| 2015 | THA | AUS | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 0 | 0 |
| 2016 | THA | AUS | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 0 | 0 |

**Note:** There are 23 policy areas classified in the breadth aspect, but this table present the LE index of only some areas.
**Source:** The Deep Trade Agreements Database by the World Bank.

Recall the formula as elaborated in the data description section, we can compute the RTA breadth index as follows.

$$Breadth_{ijt} = \frac{\sum_{p=1}^{n} Max\_LE_{ijt}^{p}}{2*n}$$

Where

$T_{ijt}$ = RTA Breadth Index.

p = Provision.

$Max\_LE_{ijt}^{p} \in [0,1,2]$ = the maximum value of the legally enforceable (LE) index of policy area p in every RTA to which both countries i and j are member states in year t.

n = total number of provisions in the breadth aspect, which is 23

Assume that we aim to compute this index for the year 2015, the sum of the numerator terms is equivalent to 14, while the denominator term is equivalent to 2*23 or 46.

Therefore,

$$Breadth_{THA\text{-}AUS,\ 2015} = \frac{14}{46} = 0.3043$$

For the other two indexes, we follow the same steps, except that the total counts of provisions (n) are 29 and 9 for the RTA depth and IND index, respectively.