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RESEARCH ARTICLE

Predicting Indonesia's Manufacturing Exports in the RCEP Region: A Machine Learning Approach to the Gravity Model of Trade

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Abstract
This study evaluates the structural determinants of Indonesia's manufacturing exports to Regional Comprehensive Economic Partnership (RCEP) member countries from 2007 to 2024. By utilizing a machine learning approach through the Random Forest algorithm within the Knowledge Discovery in Databases framework, this research transcends the rigid linearity assumptions of traditional econometric models. The computational model demonstrates superior predictive precision, with the model's accuracy reaching a score of 0.983. A specialized variable importance analysis reveals that economic similarity is the primary catalyst for export flows, thereby strongly confirming the Linder hypothesis regarding intra-industry trade. Furthermore, fundamental gravity model variables, namely economic distance, population size, and gross domestic product, remain highly significant in dictating bilateral trade volumes. Interestingly, the empirical results indicate that the implementation of the RCEP pact and the global pandemic shock possess negligible immediate impacts on the export volume. This anomaly suggests a substantial time lag effect, as domestic industrial supply chains require a considerably long adaptation period to optimally capitalize on tariff eliminations. Consequently, this paper recommends strategic policy interventions for fiscal and customs authorities. The government must synergize logistical infrastructure improvements with targeted industrial incentives, particularly the super tax deduction for research and development and the Import Facility for Export Purposes. These synchronized efforts are essential to reduce economic distance friction, enhance structural competitiveness, and transform Indonesia's participation in the RCEP agreement into tangible manufacturing trade creation.

Keywords
Economic Distance; Gravity Model; Indonesia; Machine Learning; Manufacturing Exports Random Forest.

1 | INTRODUCTION

International trade serves as a primary pillar in driving global economic growth, acting as a crucial catalyst for technology transfer and efficient cross-border resource allocation (Khan *et al*., 2025; Matondang *et al*., 2024; Todaro & Smith, 2020). Within the context of modern macroeconomics, no single nation can achieve optimal prosperity in isolation, rendering market interconnectedness an absolute prerequisite. The dynamics of global trade architecture continue to evolve, wherein the inherently multilateral trade patterns have gradually shifted toward more exclusive regional systems (Perskaya *et al*., 2024). This shift reflects the strategic responses of nations to form regional alliances aimed at securing supply chains. The most significant manifestation of this regionalism trend in the Asia-Pacific is the establishment of the Regional Comprehensive Economic Partnership (RCEP) agreement. RCEP has not only successfully created a massive single market but also marked a fundamental shift in the epicenter of global trade gravity toward the Asian region.

Economic projections based on quantitative modeling indicate that the implementation of RCEP possesses a substantial potential to increase global income by hundreds of billions of dollars annually, as well as to propel an exponential rise in global trade value over the coming decade (Petri & Plummer, 2020; Zreik, 2024). Statistically, this super-regional trade agreement unites the ten ASEAN member states alongside their five strategic trading partners, with an accumulative contribution representing approximately thirty percent of the world's total Gross Domestic Product (GDP) (Faiz *et al*., 2025). The profound optimism surrounding the strength of the RCEP pact is fundamentally grounded in the region's track record of successful economic development, widely known as the East Asian Miracle phenomenon (Seyoum, 2024; World Bank, 2021). This historical success was driven by the formulation of aggressive industrialization policies strongly oriented toward supply chain integration (Kimura *et al*., 2022). Therefore, the presence of RCEP is anticipated to serve as a robust foundation for Indonesia to execute extensive diversification measures toward high value-added commodities.

Table 1. RCEP Member States Based on Effective Date

Country	Region	Effective Date
Australia	Australia	January 1, 2022
New Zealand	Oceania	January 1, 2022
China PR	East Asia	January 1, 2022
Japan	East Asia	January 1, 2022
Cambodia	Southeast Asia	January 1, 2022
Lao PDR	Southeast Asia	January 1, 2022
Brunei Darussalam	Southeast Asia	January 1, 2022
Singapore	Southeast Asia	January 1, 2022
Thailand	Southeast Asia	January 1, 2022
Viet Nam	Southeast Asia	January 1, 2022
Korea Republic	East Asia	February 1, 2022
Myanmar	Southeast Asia	March 4, 2022
Malaysia	Southeast Asia	March 18, 2022
Indonesia	Southeast Asia	January 2, 2023
Philippines	Southeast Asia	June 2, 2023

Source: Processed by the author from Australian Goverment (2024)

Based on the detailed effective dates presented in Table 1, the heterogeneity in development levels among member states has generated a highly ununiform dynamic in the technical implementation of the agreement. The majority of primary trading partners adopted a proactive stance by enforcing the pact in early 2022, whereas Indonesia only officially ratified and fully implemented it in early January 2023. This crucial delay spanning a full year necessitates a radical acceleration in policymaking to ensure that national industrial supply chains do not lose their footing in this golden momentum due to the time lag. For the Indonesian economy, the urgency to maneuver rapidly is critical, considering that the countries within the RCEP bloc cumulatively serve as the destination for more than half of the nation's total exports (Quang, 2025). This high regional market dependency ratio underscores that any macroeconomic demand discrepancies within the bloc will directly impact Indonesia.

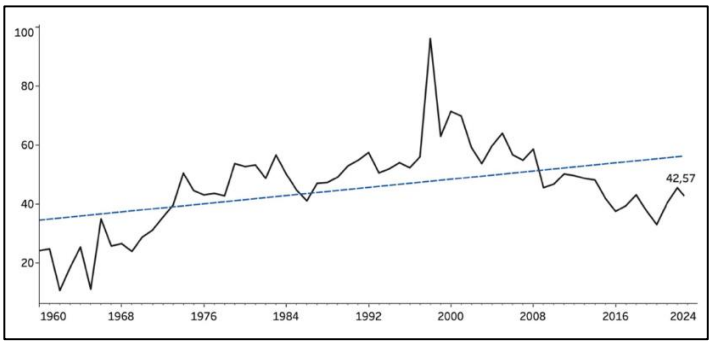

Figure 1. Indonesia's Trade Openness Index
Source: Processed by the author from (World Bank, 2025b)

Referring to the historical trends explicitly visualized in Figure 1, mapping Indonesia's competitive position at the regional level must be evaluated using a fundamental metric, namely the trade openness indicator. This macroeconomic indicator, formulated as the percentage ratio of total export and import activities to the GDP, reflects the depth to which a nation's economic pulse has been incorporated into international market traffic (Putra *et al*., 2025). The curve of Indonesia's trade openness index exhibits a relatively high volatility tendency over the past few decades, indicating an acute structural vulnerability to external market shocks. The involvement of the national industrial sector within the labyrinth of Asia's regional supply chain architecture is empirically classified as highly limited when compared to equivalent competitors such as Vietnam (Prabheesh & Vidya, 2025). Without a solid degree of structural openness, the core efficiency of the tariff reduction schemes within RCEP will be exceedingly difficult to capitalize upon.

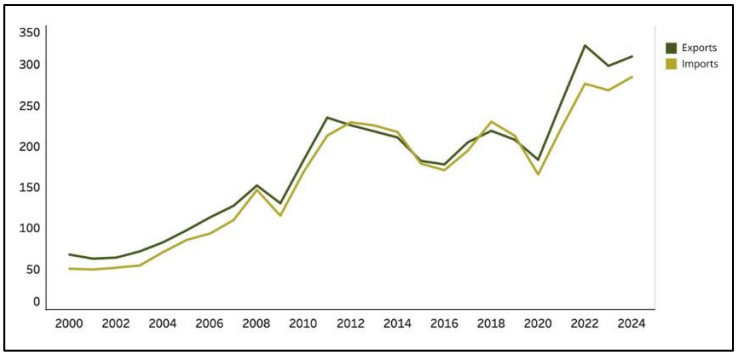

Figure 2. Indonesia's Export and Import Values
Source: Processed by the author from World Bank (2025a)

Deepening the analysis beyond the degree of market openness, a further dissection of the national trade balance performance can be observed from the historical movement illustrations summarized in Figure 2. This longitudinal data configuration provides empirical confirmation that the portfolio of Indonesia's export and import volume flows is demonstrably unable to evade a rather extreme dual fluctuation cycle. National export performance exhibits characteristicsof high vulnerability and tends to reactively follow the volatility currents of global primary commodity price movements, ultimately triggering a recurring pattern of expansion and contraction (boom-and-bust) cycles. The structural fragility of these flagship export commodities harbors a destructive capacity that possesses substantial potential to exert sustained pressure on the trade balance, simultaneously threatening the stability and resilience of the national payment system (Ufi *et al*., 2025). Therefore, evaluative measures to review the relationship between regional trade integration and the retention capacity of export values become a paramount priority.

By tracing the root causes of sectoral competitiveness problems, structural anomalies are clearly identified in the form of a push-pull phenomenon between the dominance of the manufacturing and raw commodity industrial sectors. Absolute reliance on natural resource extraction during global price surges in previous periods has triggered the emergence of the Dutch Disease economic syndrome domestically (Kuncoro, 2018). The massive explosion of financing in the extractive sector gradually drained vital capital flows from the manufacturing industry, thereby causing the growth rate of Indonesia's manufacturing exports (SITC 5-8) to lag comparatively (Mardiah, 2020; Wei *et al*., 2024). Existing statistical facts demonstrate that the national manufacturing sector has experienced deterioration in the form of premature deindustrialization, indicated by the decline in the manufacturing export rate reaching over eight percent in 2023 (BPS, 2025; Pitaloka & Budiningsih, 2025). In reality, strategic commodities from this exact sector fundamentally play an absolute role as the primary engine driving the economy.

The opportunity for strategic revitalization toward the resurgence of the manufacturing sector currently heavily depends on the success of the trade creation scheme facilitated by the RCEP pact. This preferential tariff efficiency mechanism is conceptually designed to boost bilateral export performance, increase value-added aggregation, and deepen the degree of participation in global industrial value chains (Cai *et al*., 2025; R. M. Putri, 2024). However, the process of cross-border market liberalization essentially operates as a double-edged sword, where the expansion of access is inevitably accompanied by an escalation in severe domestic competition threats (Xiong *et al*., 2024a). Ironically, the majority of academic literature attempting to map regional economic opportunities remains constrained to predictive simulation models based on pre-implementation or ex-ante scenarios (Natanael, 2025). An essential research gap persists, as there remains a scarcity of empirical studies focusing on factually evaluating the impact of the agreement during the post-implementation years.

While literature regarding regional economic integration is extensive, a critical research gap persists in two primary dimensions. First, most studies on the economic opportunities of RCEP remain limited to predictive simulation models based on ex-ante scenarios. There is a notable scarcity of empirical research that factually evaluates the impact of the agreement during the post-implementation years. Second, traditional inferential approaches often fail to map complex non-linear interactions among macroeconomic variables, particularly when member territories encounter extreme asymmetric shocks. Without a more flexible framework, trade flow estimations tend to be biased by rigid statistical distribution assumptions.

Standing firmly upon the fundamental weaknesses of conventional econometric models, the empirical framework within this paper is sharply designed to introduce methodological novelty by adopting a Supervised Machine Learning Regression ecosystem. Intelligent machine learning algorithms, such as Random Forest and Gradient Boosting, possess superior capacity to encapsulate and isolate predictive information signals without being bound whatsoever by the dogma of classical assumptions (Athey, 2019; Varian, 2014). To preserve the authenticity of the computational instruments, the engineering of input variables will strictly maintain the quantitative data structure in its nominal form, untampered by artificial modifications such as constant multiplication. Strategic adaptation to gravity theory is also applied through the utilization of the natural logarithm mathematical operation specifically targeted at the geographic friction parameter, transforming it into the of economic distance. This cutting-edge computational model is projected to be exceptionally robust in formulating the dynamic integration of GDP movements, inflation rate instability, real foreign exchange rate volatility, and the probability of unforeseen shocks.

Based on the necessity for manufacturing revitalization and methodological renewal, the objective of this research is directed toward two strategic dimensions. First, this study aims to measure and validate the accuracy of supervised machine learning regression algorithms, specifically Random Forest, in predicting the trajectory of Indonesia's manufacturing export volumes to 14 RCEP member jurisdictions from 2007 to 2024. Second, it analyzes the hierarchical order of predictive determination to identify which variables, such as GDP, economic distance, and similarity indices, exert the strongest influence on bilateral trade volumes in the post-pandemic and RCEP era. To safeguard the flow of arguments from interpretative bias, the narrative corridor will subsequently be strictly limited to interpreting only the predictor outputs that are proven technically significant. The harmonization of computational analysis in this paper is ultimately expected to equip regulators with a precise fiscal architecture resilience scheme.

This research contributes to the body of knowledge by introducing methodological novelty through the adoption of a machine learning ecosystem within the Gravity Model of Trade framework. Unlike classical linear models, these intelligent algorithms allow for the isolation of predictive information signals without being constrained by the requirements of classical assumptions, thereby capturing data patterns that change abruptly due to global shocks. Furthermore, the empirical findings provide a foundation for regulators to formulate precise fiscal architecture resilience schemes through the harmonization of industrial incentives, such as super tax deductions and customs facilities, to mitigate the structural friction of economic distance.

2 | BACKGROUND THEORY

Economic integration is a manifestation of international cooperation strategically aimed at eliminating various trade barriers among countries within a specific region (Salvatore, 2019). Conceptually, this integration architecture is constructed to accelerate regional economic efficiency, expand market scale, and consolidate the fundamentals of both economic and political relations (Krugman *et al*., 2018). The depth of integration is classified into several forms, ranging from preferential trade arrangements, free trade areas, customs unions, common markets, economic unions, to political unions (Baier *et al*., 2018). Besides expanding market penetration access, this integration is highly relied upon to attract foreign direct investment and foster economic convergence among nations (Adda *et al*., 2025). Through this unification mechanism, participating countries can maximally exploit their comparative advantages, increase production scale, and spur long-term growth trajectories with a significantly more efficient resource allocation (Salvatore, 2019).

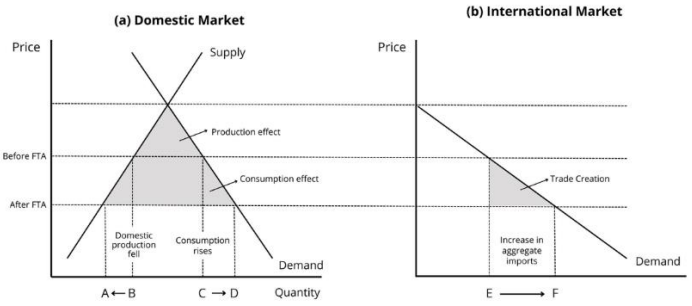

Figure 3. Trade Creation Mechanism
Source: Processed by the author from Nugraha *et al*. (2020)

Building upon this economic efficiency foundation, Jacob Viner made a seminal contribution to international trade literature through the introduction of trade creation and trade diversion concepts. These two fundamental concepts have been firmly established as primary analytical instruments for evaluating the welfare impacts of a free trade agreement. Academic consensus affirms that regionalism literature almost invariably relies on this Vinerian framework to validate the effectiveness of a trade bloc in generating new trade flows (Khalid *et al*., 2022; Xu, 2025). Based on the mechanism hierarchy in Figure 3, trade creation definitively materializes when demand fulfillment activities shift from less efficient domestic producers to significantly more cost-competitive production facilities in bloc member states. The intensity of this trade shift varies depending on the implementation period, where trade creation generally correlates positively with an overall improvement in aggregate national welfare.

Table 2. Viner Effects

Effect	Welfare Impact
Creation	ses national welfare as production shifts to more efficient sources
Diversion	ases national welfare as trade shifts away from the cheapest global sources

Source: Processed by the author from Xu (2025)

Contrary to the efficiency principle of trade creation, the threat of trade diversion potentially arises when low-cost import supplies from non-member countries are displaced by higher-cost products from member countries due to preferential tariff treatments. Such distortion risks massively degrading national welfare due to the loss of customs tariff revenues and detrimental consumer prices (Jadhav & Ghosh, 2024; Sell & Stiefl, 2023). Referring to the effect comparison in Table 2, this diversion risk becomes a structural challenge that developing nations must manage comprehensively to minimize losses from allocative inefficiency (Darma & Hastiadi, 2019; Jagdambe & Kannan, 2020). Within this context of efficiency risk mitigation, a factual evaluation of the massive Regional Comprehensive Economic Partnership (RCEP) agreement becomes highly crucial to ensure that the negative impacts of market distortion do not erode the core essence of the benefits derived from establishing such regional economic integration.

RCEP is globally recognized as the world's largest free trade agreement, encompassing at least thirty percent of the total global population and gross domestic product, rendering it a contemporary historical milestone (Hamdan, 2023). This strategic initiative, initially spearheaded by ASEAN in 2012, successfully united ten ASEAN member states alongside their five primary dialogue partners, becoming effectively operational since early 2022 (Cheng *et al*., 2025). Regarding developing economies, trade policy serves as a dual instrument for industrial protection and export promotion. For Indonesia, the transition toward downstreaming policies has redefined its trade stance within the RCEP framework. Studies indicate that for emerging markets, the effectiveness of trade liberalization is highly contingent on domestic structural reforms and the reduction of non-tariff barriers (Damuri & Friawan, 2023). Previous empirical evidence regarding Indonesian trade suggests that while tariff elimination facilitates market access, the primary challenge remains the high logistics costs and regulatory inconsistencies that diminish the competitive advantage of manufacturing exports (Patunru & Rahardja, 2019). Furthermore, the integration into RCEP provides Indonesia with a strategic leverage to mitigate the middle income trap by pivoting from raw material dependency toward high value added manufacturing, provided that fiscal incentives are aligned with regional trade standards (World Bank, 2023b). Fundamentally, this cooperation framework is specifically designed to forge mutually beneficial relations through the implementation of a modern, comprehensive, and high-quality trade system (R. M. Putri, 2024). In its operation, RCEP seeks to strengthen integration through tariff reduction instruments, trade facilitation, and the harmonization of rules of origin. Various empirical studies project that this integration pact will inject positive impacts into regional economic growth and the sustainable expansion of international trade volume over a long-term horizon (Wang & Yan, 2025).

$$T_{ij} = A\frac{Y_i Y_j}{D_{ij}} \quad (1)$$

Where:

i = Country of origin (exporter)
j = Country of destination (importer)
T_{ij} = Trade value between country i and country j
$Y_i\ Y_j$ = Economic size (typically GDP) of country i and country j
D_{ij} = Geographical distance between country i and country j

To precisely evaluate the integration efficiency degree of RCEP, the Gravity Model of Trade is consistently relied upon as the primary empirical instrument due to its computational accuracy level (Kumar *et al*., 2024). This foundational theory adopts Newton's law of gravity analogy, postulating that giant economic entities tend to record massive trade volumes (Leitão, 2024). Equation 1. represents this relationship, where the exchange value is directly proportional to the Gross Domestic Product and inversely proportional to geographical barriers. In the contemporary era, the application of the Gravity Model must account for the shift from global integration toward geo-economic fragmentation. Recent trade dynamics suggest that bilateral flows are no longer dictated solely by physical distance and economic mass but are increasingly influenced by geopolitical alignment and regional security considerations (Xiong *et al*., 2024b). The emergence of mega-regional agreements like the RCEP represents a strategic effort to consolidate supply chains amidst rising protectionism in Western markets. Consequently, the traditional gravity framework now incorporates digital connectivity and institutional quality as modern proxies for economic distance, reflecting the evolution of international trade from simple commodity exchange to complex global value chain integration (Bustaman *et al*., 2022). This orthodox model continuously undergoes theoretical refinement through the expansion of explanatory variables such as borders and pact status (Mehta, 2025). At the cutting-edge analytical level, this model accommodates essential macroeconomic variables like inflation and exchange rate fluctuations (Kartika & Handoyo, 2024). Aligning with this paper's empirical principles, the economic distance variable is transformed into a natural logarithm (ln), while aggregate nominal data is maintained purely without thousand-fold distortion.

3 | METHOD

This study adopts a quantitative research design utilizing a predictive computational approach. The methodology is structured within the Knowledge Discovery in Databases (KDD) framework, which encompasses data selection, preprocessing, transformation, data mining, and evaluation. This systematic process ensures that the transition from raw macroeconomic indicators to predictive insights is executed with high internal validity. The adoption of a machine learning framework is necessitated by the inherent limitations of structural gravity models in capturing the multifaceted nature of modern trade. Traditional econometric approaches, such as Ordinary Least Squares (OLS) or Poisson Pseudo-Maximum Likelihood (PPML), often struggle with high-dimensional data and are sensitive to multicollinearity and heteroscedasticity (Athey & Imbens, 2019). In contrast, the Random Forest algorithm, an ensemble learning method based on the aggregation of multiple randomized decision trees, offers superior predictive power by effectively navigating non-linearities and complex interactions between macroeconomic variables without requiring strict prior functional form specifications (Breiman, 2001). This method is particularly robust in minimizing the generalization error through the bagging mechanism, which reduces model variance and prevents overfitting, ensuring that the findings remain stable even amidst the volatility of international trade data (Hastie *et al*., 2009).

The dataset comprises 255 longitudinal observations covering Indonesia's manufacturing exports (SITC 5-8) to 14 RCEP member countries from 2007 to 2024. The predictive features include GDP, population size, economic distance, and economic similarity indices. To maintain data integrity, all monetary variables were normalized, and missing values were addressed during the preprocessing stage to prevent computational bias.

Table 3. Operational Definition of Variables

Variable	Operational Definition	Unit	Source
Manufacturing Exports	Natural logarithm of Indonesia's total manufacturing export value to RCEP partner countries.	USD (ln)	UN Comtrade
GDP Indonesia	Natural logarithm of Indonesia's GDP.	USD (ln)	World Bank
GDP Partner	Natural logarithm of the partner country's GDP.	USD (ln)	World Bank
Economic Distance	Natural logarithm of geographical distance weighted by economic scale between countries.	Km (ln)	CEPII (calculated)

$$DIST_{ij,t} = \frac{DIST_{geo,ij} \times GDP_{j,t}}{\sum_{j=1}^{N} GD\,P_{j,t}}$$

Population	Natural logarithm of the partner country's total population, representing absolute market size.	People (ln)	World Bank
Economic Similarity	Index measuring the convergence of industrial structures or income levels between Indonesia and partners. $$ES_{ij,t} = 1 - (\frac{GDP_{it}}{GDP_{it} + GDP_{jt}})^2 - (\frac{GDP_{jt}}{GDP_{it} + GDP_{jt}})^2$$	Index	IMF (calculated)
Real Exchange Rate	Effective real exchange rate index of the Indonesian Rupiah against partner currencies. $$RER_{ij,t} = ER_{ij,t} \times \frac{CPI_{j,t}}{CPI_{i,t}}$$	Index	IMF (calculated)
Inflation	Annual percentage change in the Consumer Price Index (CPI) in Indonesia.	Percent	World Bank
RCEP Policy	Binary variable representing the implementation period of the RCEP agreement (1 if active, 0 otherwise).	Dummy	FTA Center
Covid-19	Binary variable representing the impact of the global pandemic during the 2020 to 2022 period.	Dummy	WHO

Source: Processed by the author (2026)

The data mining stage is executed using the Random Forest regressor. To ensure the reliability and validity of the computational output, the algorithm implementation follows a rigorous double-validation protocol. First, the data partitioning into an 80% training set and a 20% testing set serves as an initial safeguard to evaluate the model on unseen observations, thereby mimicking real-world forecasting conditions (Wager & Athey, 2018). Second, the model's hyperparameter configuration, including the deployment of 500 individual decision trees, is designed to reach an optimal convergence point where the forest's collective error rate is minimized.

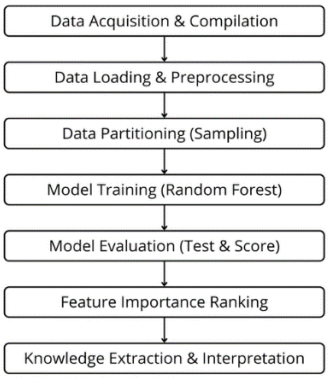

Figure 4. Methodology Flowchart based on the CRISP-DM Framework
Source: Processed by the author (2026)

The integrity of this process is quantified through a multi-metric evaluation suite comprising the Coefficient of Determination (R2), Root Mean Square Error (RMSE), and Mean Absolute Error (MAE). By utilizing the RReliefF algorithm for feature importance extraction, the study further validates the model by ensuring that the predictor rankings are statistically consistent and not merely artifacts of local data noise, thus providing a high-fidelity representation of Indonesia's manufacturing export determinants (Strobl *et al*., 2007). All computational procedures were conducted using Orange software to ensure the stability and reproducibility of the research results.

4 | RESULTS AND DISCUSSION

4.1 Results

The empirical evaluation of the predictive model is anchored on standardized regression metrics to ensure the validity and reliability of the findings. The Random Forest ensemble algorithm was selected due to its superior capability in handling complex non-linear relationships and its proficiency in simultaneously minimizing bias and variance through

the bagging mechanism (Breiman, 2001). Model performance was quantified using the Coefficient of Determination (R2) and Root Mean Square Error (RMSE), which are fundamental parameters in assessing the precision and proximity between actual observed values and model estimations (Hastie *et al*., 2009).

4.1.1 Model Performance and Predictive Accuracy

The computational architecture demonstrates an exceptional level of predictive precision. The summary of the predictive performance metrics of the Random Forest model on the test dataset is presented in Table 4.

Table 4. Predictive Performance Metrics of the Random Forest Model

Evaluation Metric	Value	Interpretation
Coefficient of Determination (R^2)	0.983	The model explains 98.3% of the target data variance
Root Mean Square Error (RMSE)	0.262	Exceptionally low average prediction deviation
Mean Absolute Error (MAE)	0.161	Minimal average absolute estimation error
Mean Squared Error (MSE)	0.069	Well-contained variance of prediction errors

Source: Processed output from Orange Data Mining (2026)

The R2 value of 0.983 confirms that 98.3 percent of the variations in the natural logarithm of Indonesia's manufacturing export values can be explained by the integrated constellation of independent variables. The fact that the RMSE and other error metrics approach zero further validates the robustness of the machine learning-based gravity model, proving its capacity to estimate complex bilateral trade flows with high fidelity without the need for arbitrary numerical scaling (Athey & Imbens, 2019).

4.1.2 Variable Significance and Feature Importance

Following the validation of the model's predictive capacity, the significance rankings of each independent variable were extracted using the RReliefF algorithm. The hierarchical significance of the variables is delineated in the Table 5.

Table 5. Hierarchical Significance of Independent Variables (Feature Importance)

Rank	Independent Variable	Significance Score (RReliefF)	Interpretive Status
1	Economic Similarity	0.284	Significant
2	Economic Distance	0.202	Significant
3	Population	0.163	Significant
4	GDP Indonesia	0.125	Significant
5	GDP Partner	0.121	Significant
6	Real Exchange Rate	0.084	Non-Significant
7	Inflation Partner	0.078	Non-Significant
8	Dummy Covid-19	0.070	Non-Significant
9	Dummy RCEP Status	0.051	Non-Significant

Source: Processed output from Orange Data Mining (2026)

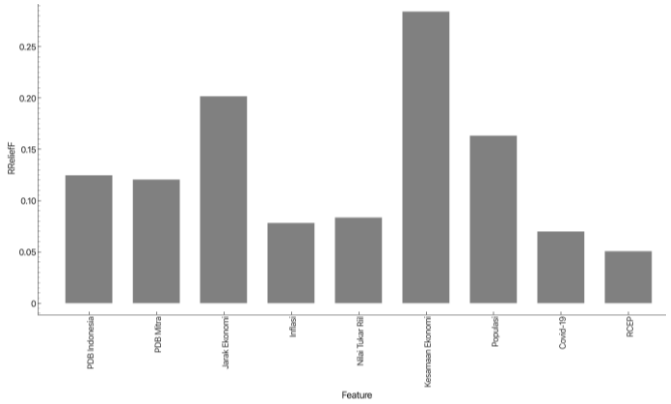

Figure 5. Feature Importance Rankings of Manufacturing Export Determinants
Source: Processed output from Orange Data Mining (2026)

4.1.3 Analysis of Non-Significant Findings

A notable finding from the feature extraction process is the technical insignificance of the bottom four variables, which exhibit a clear score cleavage from the primary determinants. The Real Exchange Rate (0.084) and Inflation (0.078)

show limited predictive power, suggesting that Indonesia's manufacturing exports are more sensitive to structural factors and market size rather than short-term monetary fluctuations. This phenomenon may occur because manufacturing contracts in regional supply chains are often settled using long-term hedging instruments, which dilute the immediate impact of currency volatility (World Bank, 2023). Furthermore, the Dummy Covid-19 (0.070) and RCEP Status (0.051) recorded the lowest significance scores. The insignificance of the pandemic indicates a degree of sectoral resilience, particularly in medical and basic electronic commodities that remained in high demand during global lockdowns. Meanwhile, the minimal impact of RCEP status likely stems from the fact that Indonesia already possessed functional bilateral agreements with most RCEP members prior to its implementation, such as the ASEAN-China and ASEAN-Japan FTAs (Damuri & Friawan, 2022). This administrative overlap minimizes the instant policy shock, suggesting that other unobserved factors, such as non-tariff barriers and domestic regulatory quality may play a more dominant role in dictating trade flows than the mere activation of the regional pact (Patunru & Rahardja, 2019).

4.2 Discussion

4.2.1 Analysis of Model Validity and Computational Robustness

The utilization of computational models based on artificial intelligence algorithms has become an essential requirement in analyzing highly complex international economic data. Traditional analytical approaches are frequently hindered by rigid linearity assumptions, whereas global trade dynamics are replete with anomalies and structural shocks. Empirical evidence indicates that non-linear factors are captured more effectively by Random Forest than by linear panel regression, thereby generating more accurate predictions and insights (Landowska *et al*., 2025). This algorithm possesses a significant technical advantage in mapping the interactions among macroeconomic variables independently without being constrained by artificial normal distribution assumptions.

The robustness of this predictive model stems from its computational architecture, which operates through a structured and iterative randomization mechanism. Specifically, the Random Forest algorithm constructs multiple decision trees from bootstrap data samples and aggregates the results, making it more flexible in capturing non-linear data patterns and abrupt changes (Chen, 2025; Fife & D'Onofrio, 2022; He *et al*., 2018). This flexibility is highly crucial when the model must process macroeconomic variables with extremely wide value ranges, such as a country's GDP to continuously fluctuating currency exchange rates. The ability to replicate and test data internally minimizes the risk of excessive variance.

The precision level of the computational model in this study is ultimately confirmed by highly optimal evaluation metrics during the testing phase. Comparative studies demonstrate that Random Forest provides superior predictive performance with smaller errors (Chahboun & Maaroufi, 2021; Limbong *et al*., 2025). The algorithm's capacity to maintain the integrity of the original data without requiring artificial truncation or scaling ensures that the resulting evaluation values are not statistical illusions. Therefore, all knowledge extraction and variable significance rankings derived from this model possess a highly robust empirical foundation for further interpretation.

4.2.2 Economic Similarity as the Primary Determinant of Manufacturing Exports

The economic similarity variable emerges as the most significant structural determinant driving the flow of national manufacturing exports to regional markets. This significance level provides strong theoretical confirmation of modern trade paradigms. In the Indonesian context, the Linder hypothesis indicates that Indonesia exports not only raw materials but also manufacturing products targeting markets with similar industrial structures, thereby driving intra-industry trade (Wati & Eum, 2025). This paradigm asserts that as a country's income level rises, consumer preferences become more diverse, which in turn triggers demand for differentiated manufactured products from partner countries with equivalent production capacities.

The strong confirmation of the Linder hypothesis indicates that Indonesia manufacturing trade within the RCEP region is driven by intra industry specialization rather than simple factor endowment differences. This aligns with the findings of Bustaman *et al*. (2022), who argue that as emerging economies converge in income levels, the sophistication of traded manufactured goods increases. However, the high significance of economic similarity also suggests a potential risk of crowding out in sectors where Indonesia competes directly with mid tier manufacturing hubs such as Vietnam or Thailand. Without significant product differentiation, Indonesia may struggle to capture higher value added segments of the regional value chain.

Although the intra-industry trade theory provides a strong foundation, field implementation reveals that Indonesia's trade structure still faces complex transitional challenges. Several empirical studies on the Indonesian case found that Indonesia's manufacturing imports are more intensive from countries with higher per capita incomes, which precisely rejects the Linder hypothesis (Dianniar, 2013; Satrio & Jamli, 2013). This disparity indicates that domestic industry dependence on capital goods and imported raw materials from developed countries remains very high. This condition places the position of Indonesia's manufacturing trade balance in vulnerability, especially when faced with open competition in the Asia-Pacific region.

The complexity of regional competition demands an improvement in structural competitiveness to maintain market

share against the aggressiveness of neighboring countries. The main factors distinguishing manufacturing export performance are foreign direct investment (FDI), human resource development, and real exchange rate stability. Thailand and Vietnam tend to be more successful in attracting FDI and developing human capital that supports the enhancement of their manufacturing exports (Adenan *et al*., 2024; Anderson, 2025). Furthermore, Indonesia remains focused on low to medium technology manufacturing products, while Thailand and Vietnam demonstrate higher comparative advantage dynamics and better export product diversification (Hotsawadi & Gea, 2025; Jayadi & Aziz, 2017).

The lag in this manufacturing technology transformation process is directly reflected in the aggregate national export value. UNIDO data show that in 2025, Indonesia's manufacturing export value reached USD102 billion, while Vietnam (USD197.9 billion) and Thailand (USD139.3 billion) (UNIDO, 2025). Vietnam successfully achieved a significantly higher manufacturing export performance primarily due to deep integration into global supply chains through massive FDI from multinational corporations, more competitive labor costs, and active participation in free trade agreements that facilitate low-tariff export market access (Francois *et al*., 2023; World Bank, 2023a).

Table 6. Comparison of Traditional Trade Theories with Empirical Findings

Theoretical Framework	Core Proposition	Relevant Variable	Empirical Score	Conclusion
Linder Hypothesis (Linder, 1961)	Countries with similar economic structures and income levels trade more intensively in manufactured goods.	Economic Similarity	0.284	Strongly Supported. Identified as the primary catalyst for intra-industry trade.
Gravity Model of Trade (Tinbergen, 1962)	Bilateral trade flows are proportional to economic mass and inversely proportional to physical friction.	• Economic Distance • Population • GDP	• 0.202 • 0.163 • 0.125 • 0.121	Highly Supported. Fundamental variables remain the core architects of trade volumes.
Customs Union Theory (Viner, 1950)	Free Trade Agreements (FTAs) instantly catalyze trade creation through tariff elimination.	RCEP Dummy	0.051	Weakly Supported. Suggests a significant time-lag effect before policy shifts overcome structural frictions.

Source: Processed by Author (2026)

4.2.3 Trade Friction: The Relevance of Economic Distance in the Digital Era

Figure 6. Heatmap of Economic Distance between Indonesia and RCEP Partner Countries 2025
Source: Processed from CEPII (2026)

Economic distance proves to remain a highly crucial structural friction even though the world is currently in an era of digital integration and borderless connectivity. For an archipelagic country, distance is not merely a span of kilometers on a map, but an accumulative representation of maritime transit time and port inefficiencies. Indonesia's logistics costs are indeed among the highest in the RCEP region, estimated at approximately 14.29 percent of GDP from 2022 to 2023 (Business Indonesia, 2024). This exceptionally high logistical burden acts as an invisible tax that erodes exporter profit margins and diminishes the price competitiveness of national manufactured products in the regional market. Beyond physical distance, external factors such as logistics performance and non tariff measures exert invisible pressure on export

volumes. While RCEP focuses on tariff elimination, the persistent challenge for Indonesia lies in its high effective distance caused by inefficient port dwelling times and complex customs procedures. Furthermore, the rise of global green protectionism and environmental standards in partner countries acts as a new external determinant that traditional gravity models often overlook. These regulatory shifts necessitate a strategic alignment of Indonesia industrial policy with regional standards to maintain its competitive edge.

Responding to the challenge of this maritime distribution cost burden, strategic measures in infrastructure and bureaucratic reform have begun to be implemented gradually by relevant authorities. Government efforts such as the development of the National Logistics Ecosystem (NLE) and the integration of the National Single Window (NSW) system are expected to reduce costs and improve national logistics efficiency (Syifa & Tohir, 2025). The synchronization of this inter-agency electronic data exchange system is designed to drastically cut the dwelling time of goods at ports. Although domestic improvements continue to be accelerated, institutional barriers at the regional level continue to exert distinct pressure on trade flows. Significant differences in infrastructure and customs efficiency among RCEP countries remain obstacles to optimal regional logistics integration (Zhou, 2025). The disparity in infrastructure quality between developed countries like Singapore or Japan compared to other developing nations within this bloc causes the supply chain to operate less efficiently than expected from a mega-regional scale trade pact.

4.2.4 The Influence of Market Scale: Population and Economic Capacity (GDP)

The economic gravitational pull from destination countries plays a central role in determining the volume and direction of international goods distribution flows. Indonesia's manufacturing exports to RCEP countries are absolutely influenced by the economic size (GDP) and population of trading partners, as explained in the classic gravity model of trade. Partner GDP and population are proven to have a significant positive effect on bilateral export volume, reflecting that trade increases along with the magnitude of economic mass and market absorption capacity (Natanael, 2025; I. G. Putri & Satria, 2025). A massive population size guarantees the absolute availability of consumers ready to absorb basic industrial commodities and consumer goods in large quantities.

This extensive market scale naturally provides economic advantages for domestic industries to mass-produce goods to achieve cost efficiency. Empirical studies using the gravity model on Indonesia's exports to ASEAN and China confirm that partner GDP and partner population variables have strong positive coefficients, explaining why Indonesia's manufacturing exports are more concentrated in large markets like China, even though RCEP as a whole facilitates low-tariff access and diversification potential (Leksono & Maryatmo, 2020; Mardiah, 2020). This market concentration phenomenon indicates that exporters prefer partners with certain and giant-scale demand over exploring small markets with minimal tariff barriers.

The high level of concentration in one dominant economic power unfortunately presents an asymmetric vulnerability risk to the national trade balance. China as a major partner also shows a widening trade deficit with Indonesia, so negotiations to open wider market access are urgently needed to improve the manufacturing trade balance (Abdullah *et al*., 2022; Muzwardi & Mahadiansar, 2024). This persistent deficit signals the need for more aggressive economic diplomacy to ensure that high-value-added Indonesian manufactured products, and not just extractive commodities, can penetrate non-tariff barriers in that capital-intensive market.

4.2.5 Anomaly Analysis: The Insignificance of RCEP Policy and COVID-19

The algorithm's feature extraction results indicate that the implementation of the mega-regional trade pact has not provided an exponential boost in an instant timeframe. This can be traced to the structural fact that before RCEP, Indonesia already had bilateral agreements with almost all RCEP members, such as the ASEAN-China FTA and ASEAN-Japan FTA, so RCEP did not provide major changes or instant shocks to Indonesia's manufacturing export patterns (Li & Li, 2022). The absence of this shock effect confirms the phenomenon of time-lag, where industrial supply chain restructuring cannot respond to tariff elimination in a matter of months. Nevertheless, RCEP serves as a rational solution to the regulatory complexities that have hindered cross-border goods movement thus far. RCEP is designed to consolidate and simplify the five existing ASEAN+1 FTAs through more harmonious common Rules of Origin (ROO) and diagonal cumulation, thereby reducing the inefficiencies of the spaghetti bowl effect in the Asia-Pacific region (Damuri & Friawan, 2022). This administrative simplification allows raw materials from one member country to be processed in another member country without losing tariff privileges when re-exported.

Although the revolutionary impact is not immediately observable in aggregate statistics, this integration framework remains essential for medium-term industrial architecture. Empirical studies show that the marginal benefits of RCEP for Indonesia are more incremental than transformative, particularly in the form of procedure simplification, trade bureaucracy reduction, and regional supply chain certainty improvement, although the trade creation effect is more visible in certain sectors like electronics and textiles (Banga *et al*., 2021; Damuri & Friawan, 2022). Nonetheless, RCEP still has the potential to gradually enhance value chain integration and strengthen trade relations among members (Wei *et al*., 2024). On the other hand, the utilization of trade facilities and tariff liberalization in RCEP still needs to be encouraged so that the benefits are more optimal for Indonesia's exports (Novith & Purwana, 2023). A similar analytical anomaly is also

found in the global pandemic shock variable, which surprisingly did not have an absolute destructive effect on the overall performance of the national manufacturing sector. Indonesia's manufacturing exports, including products such as masks, medical equipment, and basic electronics, actually experienced an increase during the Covid-19 pandemic even though national exports in general had contracted due to global disruptions (Astuty *et al*., 2023; Rahayu, 2021). Concrete evidence of this sector's resilience is seen when the Ministry of Industry data noted exports of masks and various COVID-19 preventive medical devices reached a value of around IDR2.9 trillion throughout 2020, with medical mask exports reaching USD73.3 million and cloth masks USD62.2 million (Kemenperin RI, 2020).

4.2.6 Strategic Implications for Indonesia's Fiscal and Manufacturing Sectors

The empirical findings from this computational modeling provide a solid argumentative foundation for formulating public policy instruments in the fiscal sector. Super tax deduction policies are particularly relevant for manufacturing industries targeting markets with a high degree of economic similarity, such as RCEP members, as they can help compensate for additional costs due to distance and logistics through increased productivity and innovation (Nurlaeli & Rahayu, 2024; Ramadhan & Setyawan, 2021). This gross income deduction facility of up to 300 percent for research and development activities must be directed strategically to encourage industries to shift from mere assembly towards the creation of medium and high technologies that align with East Asian market demands.

In addition to direct tax relaxation, the harmonization of customs facilities plays an equally vital role in minimizing the logistical friction scores that appear in the model. The optimization of the Import Facility for Export Purposes (KITE) scheme and the expansion of Bonded Zones are absolute prerequisites for domestic manufacturing industries whose raw materials still heavily rely on global supply chains. The suspension of import duties and tax exemptions for imports through these facilities will directly cut production costs, thereby strengthening the price competitiveness of Indonesian commodities when facing similar products from neighboring countries with lower logistics burdens.

Furthermore, the strategy for strengthening the economic scale of domestic industries must be integrated with maneuvers to attract foreign direct investment through the provision of Tax Holiday and Tax Allowance facilities. The corporate income tax exemption policy for pioneer industries needs to be focused on investments that support the downstreaming of natural resources into intermediate or finished goods. Through this precise and complementary mix of fiscal and customs policies, Indonesia is believed to be capable of replicating the success of global value chain integration, reducing economic distance barriers, and transforming participation in the RCEP pact from a mere regulatory opportunity into the creation of measurable real trade flows within this paper.

5 | CONCLUSIONS AND FUTURE WORK

This study successfully demonstrates that machine learning models, specifically the Random Forest algorithm, provide a robust framework for predicting Indonesia manufacturing exports within the RCEP region. The empirical evidence confirms that structural determinants such as economic similarity and fundamental gravity variables remain the primary drivers of trade flows. While the immediate policy shock of RCEP and the global pandemic appeared negligible in the short term, the long term trajectory of Indonesia trade performance will be dictated by how effectively the country addresses its internal structural bottlenecks. Consequently, the implementation of trade policies must transcend mere tariff elimination to focus on reducing the effective distance by accelerating the digitalization of customs through the National Logistics Ecosystem. Concrete steps include the synchronization of regional data exchange to minimize dwelling times and the alignment of domestic product standards with international benchmarks, which are expected to reduce transaction costs and enhance the price competitiveness of Indonesia manufacturing products in the global market.

A strategic pivot toward high value added manufacturing is essential to mitigate the risk of crowding out by regional competitors. The government should provide targeted fiscal incentives for industries that demonstrate high intra industry trade potential, such as electronics and automotive components, to foster deep industrial integration within the RCEP supply chain. By leveraging regional trade as a catalyst for long term economic transformation, Indonesia can secure a more resilient fiscal position amidst global uncertainty. This approach necessitates a synchronized effort between trade agreements and industrial policy to ensure that domestic producers can meet the increasingly stringent international quality and environmental standards. Ultimately, the success of RCEP for Indonesia depends on a holistic strategy that combines logistical efficiency with the capacity to move up the global value chain through innovation and structural reform.

Despite its high predictive accuracy, this study possesses several limitations that provide avenues for future research. The analysis relies on aggregate manufacturing data, which may not capture the specific dynamics of individual sub sectors, and while the predictive model is highly precise, it does not explicitly account for granular institutional quality or the emerging impact of green trade barriers. Furthermore, as the Random Forest algorithm often functions as a black box, future research should consider integrating Shapley Additive Explanations values to

enhance the interpretability of machine learning outputs. Future studies should also incorporate more disaggregated sectoral data and detailed institutional variables to better capture the nuances of regional policy implementation and provide even more specific, actionable recommendations for Indonesian policymakers in navigating the complex landscape of international trade.

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