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# Macroeconomic determinants of China's electromechanical exports to ASEAN: A gravity model analysis

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## ABSTRACT

This study investigates the macroeconomic determinants of China's electromechanical product exports to ASEAN countries, focusing on how economic scale, exchange rates, trade costs, and trade facilitation measures influence bilateral trade flows. An extended gravity model is applied using panel data from 2010 to 2019, covering seven ASEAN countries (Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam). The analysis incorporates bilateral GDP, RMB real effective exchange rate, average tariffs, distance-weighted transportation costs, and a Trade Facilitation Index derived from Global Competitiveness Report data through Principal Component Analysis. The results reveal that ASEAN countries' GDP is the dominant driver of export flows, with an elasticity coefficient of 1.191, indicating that demand for technology-intensive products grows more than proportionally with economic development. Exchange rate appreciation positively affects exports through quality signaling effects, while trade costs exhibit complex relationships with export performance. Trade facilitation measures strengthen export competitiveness through complementarities with traditional macroeconomic factors, though their effects are secondary to macroeconomic fundamentals. By extending gravity model applications to technology-intensive exports within regional integration contexts, this research provides insights into the interaction of macroeconomic variables in determining trade flows. The findings suggest that policymakers in China and ASEAN should prioritize supporting economic capacity building, stabilizing exchange rates for high-end market positioning, reducing tariffs and transport costs, and improving customs efficiency and logistics systems to enhance bilateral trade cooperation.

**Contribution/ Originality:** This study contributes to gravity model applications in technology-intensive products by constructing a Trade Facilitation Index and exploring interaction effects. It provides new insights into trade determinants of electromechanical goods and enhances understanding of collective macroeconomic impacts within regional economic integration frameworks.

## 1. INTRODUCTION

China-ASEAN economic cooperation has emerged as a cornerstone of regional integration in East Asia, with bilateral trade reaching record levels and driving mutual growth. According to National Bureau of Statistics of China (2025), China's GDP in 2024 reached 134.91 trillion yuan, expanding by 5.0% year-on-year and providing a strong foundation for deepening trade relations. In parallel, ASEAN continues to strengthen as a dynamic regional bloc, with a nominal GDP of US$3.8 trillion in 2023 (ASEAN Secretariat, 2024), creating vast opportunities for economic exchange. Within this partnership, electromechanical products have become increasingly significant, accounting for

over 40% of China's total exports to ASEAN and serving as a catalyst for industrial upgrading and technological integration. Between 2010 and 2023, China's exports of electromechanical goods to ASEAN grew at an average annual rate of 16.5%, surpassing US$220 billion in 2023 alone, underscoring the sector's strategic importance in bilateral trade (Wang & Zheru, 2020).

Despite this rapid growth, the macroeconomic determinants of China's electromechanical exports to ASEAN remain underexplored, with most studies focusing on aggregate trade flows rather than sector-specific analysis (Liu, Chen, & Zhou, 2023). Recent studies call for more comprehensive analysis of bilateral trade drivers (Zhang & Wang, 2023). While the establishment of the China-ASEAN Free Trade Area (CAFTA) has largely removed tariff barriers, non-tariff measures and procedural inefficiencies continue to hinder trade flows. The influence of macroeconomic fundamentals such as GDP, exchange rate fluctuations, and trade costs on these technology-intensive exports has yet to be systematically examined, particularly in comparison with traditional manufactured goods (Bahmani-Oskooee, Aftab, & Harvey, 2024; Çelik & Deniz, 2024). Existing studies point to two notable gaps. First, electromechanical trade volumes between China and ASEAN countries vary considerably, and the extent to which macroeconomic factors drive these differences is unclear (Qin, Xu, & Zhang, 2016). Second, the role of ASEAN's trade facilitation reforms, including customs digitization and logistics upgrades, in shaping China's electromechanical exports is ambiguous, with large disparities across member states potentially constraining trade potential (Shepherd & Wilson, 2009).

These gaps raise several pressing questions: How do macroeconomic variables such as economic scale and exchange rate dynamics influence China's electromechanical exports to ASEAN? To what extent do trade costs, including tariffs, transportation expenses, and geographic distance, affect export flows and competitiveness? How do trade facilitation measures interact with traditional macroeconomic factors to influence export performance? Hence, these questions are crucial to be addressed for understanding the drivers of China-ASEAN electromechanical trade and for informing policies that support sustainable trade growth in the region.

This study seeks to fill these gaps by systematically analyzing the macroeconomic determinants of China's electromechanical exports to ASEAN using an extended gravity model and panel data from 2010 to 2019. Specifically, it aims to: (i) assess the impact of bilateral economic scale on export flows and test the applicability of gravity model predictions to technology-intensive goods; (ii) examine the influence of exchange rate dynamics, trade costs, and geographic factors on export patterns and competitiveness; and (iii) evaluate the role of trade facilitation measures in complementing traditional macroeconomic variables. By doing so, the study not only contributes to a deeper theoretical understanding of trade determinants in high-technology sectors but also offers practical insights for policymakers in both China and ASEAN.

The remainder of this paper is structured as follows: Section 2 reviews the relevant literature on gravity models, macroeconomic determinants of trade, and China-ASEAN economic cooperation. Section 3 outlines the theoretical framework, variables, data sources, and methodology. Section 4 presents and discusses the empirical results, along with robustness checks. Section 5 concludes with policy recommendations and suggestions for future research.

## 2. LITERATURE REVIEW

The gravity model has emerged as the most widely applied theoretical framework for analyzing bilateral trade flows. First introduced by (Tinbergen, 1962), the model is conceptually rooted in Newton's law of universal gravitation, proposing that trade flows increase with the economic size of trading partners while declining with distance, which serves as a proxy for trade costs (Anderson & Van Wincoop, 2003; Tinbergen, 1962). Subsequent refinements by Anderson and Van Wincoop (2004) highlighted the magnitude of trade costs, estimating them at around 170% for advanced economies and even higher for developing nations. Complementary to this approach, Eaton and Kortum (2002) demonstrated that trade patterns are shaped by productivity differences, transportation costs, and market access, all of which are effectively captured within the gravity model framework.

Within this context, trade facilitation has been increasingly recognized as a critical determinant of trade efficiency, particularly in reducing non-tariff barriers. Djankov, Freund, and Pham (2010) emphasized that streamlined border procedures, simplified regulations, and reduced transaction times lower cross-border costs and enhance competitiveness. Wilson, Mann, and Otsuki (2003) conceptualized trade facilitation along four key dimensions port efficiency, customs environment, regulatory environment, and service infrastructure—illustrating that effective facilitation extends beyond procedural simplification to encompass institutional quality and transparency.

The mechanisms through which trade facilitation operates can be broadly categorized into two channels. The first is cost reduction, achieved through measures such as procedural simplification, reduced documentation requirements, and greater administrative efficiency. The second is enhanced predictability, fostered by transparent regulations, consistent policy enforcement, and improved governance structures (Hoekman & Nicita, 2011). These mechanisms are especially relevant for technology-intensive products such as electromechanical goods, which depend on complex supply chains, stringent quality assurance, and time-sensitive delivery schedules. As such, the efficiency of trade facilitation directly affects their competitiveness in international markets, making it a critical factor in explaining export performance.

Empirical studies on developed economies provide the theoretical foundation for understanding trade patterns within the gravity model framework and the role of macroeconomic determinants. Frankel and Romer (1999), using instrumental variable techniques on OECD countries, confirmed a stable positive relationship between economic size and trade volumes, with GDP elasticity for manufactured exports ranging between 0.8 and 1.2. Baier and Bergstrand (2007) further demonstrated that larger GDPs consistently expand trade flows among OECD member states. Similarly, studies on the European Union and North America highlight the significance of market size, the persistent but declining effect of geographical distance, and the impact of tariffs and trade agreements (Disdier & Head, 2008). Exchange rate dynamics have also been widely studied, with evidence suggesting substantial effects on trade competitiveness, although the magnitude differs by product category (Kimura & Obashi, 2010). In terms of trade facilitation, even highly institutionalized developed economies exhibit scope for improvement: Hummels and Schaur (2012) estimated that each day of trade delay is equivalent to a tariff increase of 0.6%–2.3%, while Wilson, Mann, and Otsuki (2005) found that comprehensive trade facilitation reforms could increase global trade by nearly 10%, underscoring the continued importance of efficient ports, customs, and regulatory frameworks.

In contrast, empirical research on developing economies reveals different dynamics. Helpman, Melitz, and Rubinstein (2008) highlighted how exporter heterogeneity complicates the relationship between GDP and trade flows, while Kee, Nicita, and Olarreaga (2009) showed that tariffs remain a significant constraint despite liberalization efforts. Evidence from ASEAN countries demonstrates that trade facilitation is particularly critical in shaping export performance: Santhi and Setyari (2019) confirmed that port efficiency and ICT infrastructure improvements enhance competitiveness, and Shepherd and Wilson (2009) estimated that a 10% increase in logistics performance could raise intra-ASEAN trade by 5%. These findings suggest that while macroeconomic fundamentals matter, institutional and infrastructural reforms play an equally important role for developing nations.

Research on China's exports further illustrates the complexity of these determinants. Wang, Chen, and Wang (2023) found that the GDP growth of importing countries remains the dominant driver, while the effects of exchange rates and tariffs vary considerably across industries. However, most studies continue to focus on aggregate export volumes rather than specific product categories, limiting our understanding of heterogeneous effects across different types of manufactured goods (Amiti & Freund, 2010). Despite the strategic significance of electromechanical products in China-ASEAN trade, limited empirical work has examined this sector in detail. Furthermore, although the importance of trade facilitation is widely acknowledged, it is rarely integrated alongside traditional macroeconomic variables within a unified analytical framework.

In summary, three key research gaps emerge from the literature. First, product-level analyses, particularly of technology-intensive sectors such as electromechanical exports, remain scarce. Second, while macroeconomic fundamentals such as GDP, exchange rates, and tariffs have been widely studied, the incorporation of trade facilitation into gravity model applications is limited. Third, although research on China-ASEAN trade is expanding, few studies systematically combine macroeconomic variables with institutional and infrastructural reforms within a cohesive framework. This study addresses these gaps by examining the macroeconomic determinants of China's electromechanical exports to ASEAN countries through an extended gravity model that explicitly incorporates trade facilitation.

## 3. METHODOLOGY

The methodology section presents the scope of the study and outlines the theoretical framework for analyzing the macroeconomic determinants of China's electromechanical exports to ASEAN. The research employs an extended gravity model framework using panel data from 2010 to 2019, covering seven ASEAN countries. This section provides the details of the data sources, variable construction, model specification, and econometric approach used to examine the relationship between macroeconomic variables and bilateral trade flows.

### *3.1. Scope of Study and Data Sources*

This study examines the macroeconomic determinants of China's electromechanical product exports to ASEAN countries using panel data from 2010 to 2019. We focus on seven ASEAN member states: Malaysia, Singapore, the Philippines, Thailand, Vietnam, Indonesia, and Cambodia. The selection of countries is primarily determined by data availability, particularly for trade facilitation indicators derived from the Global Competitiveness Report. Myanmar, Laos, and Brunei are excluded due to incomplete data coverage during the study period.

The study's temporal scope spans a decade that captures significant developments in China-ASEAN economic integration, including the deepening of CAFTA implementation and various trade facilitation reforms across ASEAN member states. This period provides sufficient variation in macroeconomic variables while maintaining data consistency across countries.

Data sources include multiple international databases to ensure reliability and comprehensiveness. Trade data on China's electromechanical exports to ASEAN countries are sourced from the United Nations Comtrade Database (UNCTAD), which provides detailed bilateral trade statistics classified according to the Standard International Trade Classification (SITC) Revision 4. GDP data for both China and ASEAN countries are obtained from the World Bank. The RMB real effective exchange rate data are gathered from the Bank for International Settlements (BIS). Tariff data are compiled from the World Bank database as well. Geographic distance data are obtained from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) database, while oil price data are sourced from BP Statistical Review. Trade Facilitation Index (TFI) are constructed using data from the World Economic Forum's Global Competitiveness Report (GCR).

### *3.2. Theoretical Framework*

The theoretical foundation of this study rests on the gravity model of international trade, originally developed by Tinbergen (1962) and subsequently refined by Anderson and Van Wincoop (2003). The gravity model provides a robust framework for analyzing bilateral trade flows by establishing that trade volume between two countries is positively related to their economic sizes and negatively related to the distance between them.

The basic gravity model can be expressed as.

$$X_{ij} = A\frac{Y_i^{\alpha}Y_j^{\beta}}{D_{ij}^{\gamma}} \quad (1)$$

Where $X_{ij}$ represents exports from country i to country j,$Y_i^{\alpha}$ and $Y_j^{\beta}$ are the economic sizes of the two countries, $D_{ij}^{\gamma}$ is the distance between them, and $\alpha$, $\beta$ and $\gamma$ are parameters to be estimated.

This study extends the traditional gravity model to incorporate additional macroeconomic determinants specific to technology-intensive products and regional economic integration contexts. The extended framework integrates exchange rate dynamics, trade costs, and institutional factors through a TFI to provide a comprehensive analysis of China's electromechanical exports to ASEAN.

The theoretical rationale for including these additional variables stems from several considerations. First, exchange rate fluctuations can significantly affect export competitiveness, particularly for manufactured goods where price sensitivity varies across product categories. Second, trade costs beyond geographic distance, including tariffs and transportation costs, remain important determinants of trade flows despite regional integration efforts. Third, institutional factors such as trade facilitation measures become increasingly relevant for technology-intensive products that require efficient logistics, transparent procedures, and reliable infrastructure.

### *3.3. Model Estimation*

Building on the theoretical framework, this study employs an extended gravity model that incorporates both macroeconomic variables and a comprehensive Trade Facilitation Index to analyse the determinants of China's electromechanical exports. The empirical specification is as follows.

$$LNEX_{ijt} = \beta_0 + \beta_1 TFI_{jt} + \beta_2 LNGDP_{it} + \beta_3 LNGDP_{jt} + \beta_4 LNDIST_{ij} + \beta_5 LNREER_{it} + \beta_6 TARIFF_{jt} + \varepsilon_{ijt} \quad (2)$$

Among them, $LNEX_{ijt}$ represents the natural logarithm of the export of electromechanical products from China i to country j at time t ; $TFI_{jt}$ is the level of trade facilitation of country j ; $LNGDP_{it}$ and $LNGDP_{jt}$ respectively represent the natural logarithms of China's GDP and ASEAN countries' GDP at time t ; $LNDIST_{ij}$ represents the logarithm of the product of the geographical distance between the capital of China and the capital of country j and the price of Brent crude oil, represents the transportation cost. $LNREER_{it}$is the exchange rate factor represents the real effective exchange rate of the RMB; $TARIFF_{jt}$ represents the average import tariff of country j. $\varepsilon_{ijt}$ represents the error term, i represents China, j represents ASEAN countries, $\beta$ and represents the influence of the explanatory variable on the explained variable.

The model specification incorporates several innovative features. The distance variable is interacted with oil prices to capture time-varying transportation costs, reflecting the reality that shipping costs fluctuate with energy prices. The exchange rate variable uses the real effective exchange rate rather than bilateral nominal rates to better capture competitiveness effects. The TFI provides a comprehensive measure of institutional quality that affects trade efficiency.

### *3.4. Construction of Trade Facilitation*

According to the perspectives of Wilson et al. (2003), trade facilitation encompasses institutional and procedural factors that influence cross-border trade efficiency. This concept extends beyond traditional trade barriers to include customs procedures, regulatory transparency, infrastructure quality, and financial services, which collectively determine the ease of conducting international trade. The TFI is constructed using Principal Component Analysis (PCA) and involves 15 indicators across four dimensions. The composition and description of the indicator framework are shown in Table 1.

**Table 1.** Component of trade facilitation indicators and sources.

| First-level indicator | Secondary indicators | Score range | Data source |
|---|---|---|---|
| Institutional environment | A1 Judicial independence | 1-7 | GCR |
| | A2 Government regulatory burden | 1-7 | GCR |
| | A3 The efficiency of legal and regulatory dispute resolution | 1-7 | GCR |
| | A4 Effectiveness of the legal framework in addressing regulatory challenges | 1-7 | GCR |
| | A5 Reliability of police services | 1-7 | GCR |
| Infrastructure | B1 Quality of road | 1-7 | GCR |
| | B2 Port infrastructure quality | 1-7 | GCR |
| | B3 Quality of air transport infrastructure | 1-7 | GCR |
| Customs environment | C1 Prevalence of trade barriers | 1-7 | GCR |
| | C2 Burden of customs procedures | 1-7 | GCR |
| Finance and E-commerce | D1 Banks are stable | 1-7 | GCR |
| | D2 Availability of financial services | 1-7 | GCR |
| | D3 Availability of venture capital | 1-7 | GCR |
| | D4 Internet users | 1-100 | GCR |
| | D5 Broadband internet subscription | 1-100 | GCR |

The PCA approach is validated through the Kaiser-Meyer-Olkin (KMO) test ($0.891 > 0.5$) and Bartlett's test of sphericity ($p < 0.001$), confirming the appropriateness of factor analysis. The first principal component explains 79.044% of the total variance, indicating that a single factor effectively captures the common variation among all indicators. The TFI is calculated using the following weighted formula.

$$\begin{aligned}\text{TFI} = {} & 0.081 \times \text{A1} + 0.079 \times \text{A2} + 0.083 \times \text{A3} + 0.077 \times \text{A4} + 0.076 \times \text{A5} + 0.081 \times \text{B1} + \\ & 0.082 \times \text{B2} + 0.08 \times \text{B3} + 0.076 \times \text{C1} + 0.071 \times \text{C2} + 0.063 \times \text{D1} + 0.071 \times \text{D2} + 0.073 \times \text{D3} + \\ & 0.065 \times \text{D4} + 0.065 \times \text{D5} \qquad (3)\end{aligned}$$

Where A1-A5 represent institutional indicators, B1-B3 represent infrastructure indicators, C1-C2 represent customs indicators, and D1-D5 represent finance and e-commerce indicators.

### *3.5. Econometric Specification*

Given the nature of the data structure, with observations across seven countries over ten years, fixed effects estimation is employed to control for unobserved heterogeneity across ASEAN countries. The baseline econometric specification uses country fixed effects to control for time-invariant country-specific factors that may affect trade flows, such as cultural proximity, historical ties, or geographical characteristics beyond distance. The fixed effects approach is preferred over random effects based on the Hausman test results, which indicate systematic differences between fixed and random effects estimators.

The model provides estimates for additional specifications in robustness testing, including models with supplementary control variables such as lagged trade facilitation variables and technical barriers. Heterogeneity analysis was conducted by segmenting the sample based on product technological intensity to examine differential effects between labour-intensive and capital/technology-intensive electromechanical products.

The estimation equation takes the form.

$$LNEX_{ijt} = \beta_1 TFI_{jt} + \beta_2 LNGDP_{it} + \beta_3 LNGDP_{jt} + \beta_4 LNDIST_{ij} + \beta_5 LNREER_{it} + \beta_6 TARIFF_{jt} + \alpha_j + \mu_{ijt} \qquad (4)$$

Where $\alpha_j$ represents country-specific fixed effects and $\mu_{ijt}$ is the error term.

## 4. RESULTS AND DISCUSSIONS

This section presents the empirical findings of the extended gravity model analysis examining the macroeconomic determinants of China's electromechanical exports to ASEAN countries. The results are organized

into four subsections: descriptive statistics, baseline regression results, robustness tests, and heterogeneity analysis. The discussion interprets these findings within the context of existing literature and theoretical expectations.

### *4.1. Descriptive Statistics*

Table 2 presents descriptive statistics for all variables used in the empirical analysis. The dependent variable (LNEX) exhibits considerable variation across countries and over time, with a standard deviation of 1.139, indicating substantial heterogeneity in electromechanical exports from China to different ASEAN markets. Among the explanatory variables, GDP displays the expected pattern, with China's GDP showing steady growth during the period. The REER demonstrates moderate volatility, reflecting exchange rate fluctuations throughout the study period. Tariff rates are generally low, consistent with the implementation of CAFTA, though they vary by country and product category. The TFI reveals significant cross-national differences, with Singapore consistently scoring the highest (above 12 points) and Cambodia the lowest (approximately 4–6 points), indicative of varying levels of institutional development and trade facilitation capacity among ASEAN member states.

**Table 2.** Descriptive statistics.

| Variable | Sample Size | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| LNEX | 70 | 9.168 | 1.139 | 5.636 | 10.673 |
| LNGDPI | 70 | 6.925 | 0.257 | 6.412 | 7.264 |
| LNGDPJ | 70 | 3.179 | 1.167 | 0.117 | 4.718 |
| LNDIST | 70 | 12.463 | 0.412 | 11.520 | 13.203 |
| LNREER | 70 | 4.534 | 0.082 | 4.385 | 4.643 |
| TARIFF | 70 | 3.275 | 2.342 | 0.050 | 9.770 |
| TFI | 70 | 7.582 | 2.772 | 3.709 | 13.125 |

### *4.2. Baseline Regression Results*

Table 3 presents the primary regression results obtained through fixed-effects panel estimation. Model 1 specifies a baseline model incorporating only institutional control variables (TFI), while Model 2 extends this framework by integrating a comprehensive set of macroeconomic determinants to assess their relative significance in explaining China's mechanical and electrical export performance.

**Table 3.** Baseline Regression Results.

| Dependent Variable: LNEX | Model 1 | Model 2 |
|---|---|---|
| LNGDPI | | -0.094 |
| | | (-0.35) |
| LNGDPJ | | 1.191*** |
| | | (4.53) |
| LNDIST | | 0.187** |
| | | (2.03) |
| LNREER | | 1.085* |
| | | (1.75) |
| TARIFF | | -0.0003 |
| | | (-0.02) |
| TFI | 0.322*** | 0.109** |
| | (9.97) | (2.47) |
| Constant | 6.724*** | -2.041 |
| | (27.26) | (-0.74) |
| Observations | 70 | 70 |
| R-squared | 0.966 | 0.984 |
| ID FE | YES | YES |
| YEAR FE | NO | NO |

***Note:** Robust standard errors in parentheses; *p<0.10, **p<0.05, ***p<0.01.

The results reveal several important findings. Model 1 demonstrates that trade facilitation alone explains 96.6% of the variation in export flows, with a highly significant coefficient (0.322). However, incorporating macroeconomic fundamentals in Model 2 substantially improves the model fit to 98.4%, while reducing the TFI coefficient to 0.109. This change indicates that macroeconomic variables capture primary causal mechanisms, with institutional factors providing complementary explanatory power.

The most striking finding is the dominant role of ASEAN countries' GDP (LNGDPJ), with a coefficient of 1.191, indicating that a 1% increase in importing country GDP corresponds to approximately a 1.19% increase in China's electromechanical exports. This elasticity exceeds unity, suggesting that demand for technology-intensive products grows more than proportionally with economic development, consistent with Engels' law for manufactured goods.

Contrary to traditional gravity model predictions, the distance variable (LNDIST) exhibits a positive coefficient (0.187). This counterintuitive finding may reflect several mechanisms: first, distant markets may offer price premiums for high-quality Chinese electromechanical products; second, geographic distance may proxy for market segmentation effects where distant locations serve as regional distribution hubs; third, the interaction with oil prices may capture quality-adjusted transportation cost effects where higher-value products justify increased shipping costs.

The real effective exchange rate (LNREER) shows a positive coefficient (1.085), contradicting conventional expectations that currency appreciation reduces export competitiveness. This result aligns with recent literature suggesting that, for technology-intensive products, currency strength may signal quality and reliability, offsetting price disadvantages through product differentiation (Wang et al., 2023).

China's GDP (LNGDPI) exhibits no significant impact on export flows (-0.094, P>0.10), suggesting that supply-side capacity constraints are not binding for electromechanical exports to ASEAN. This finding indicates that export performance is primarily demand-driven rather than supply-constrained.

Tariffs (TARIFF) show minimal impact (-0.0003), consistent with CAFTA's success in eliminating formal trade barriers. The negligible coefficient suggests that remaining tariff differentials across countries and products have limited influence on trade flows.

Overall, the findings are broadly consistent with theoretical predictions and prior empirical studies. The dominant role of the importing country's GDP supports the emphasis of the gravity model on market size (Anderson & Van Wincoop, 2003).

The positive effect of the real effective exchange rate (REER) aligns with recent research indicating that quality upgrades can offset price effects (Wang et al., 2023).

The attenuated impact of tariffs concurs with Kee et al. (2009), who note that, relative to non-tariff measures, tariffs' influence on trade restrictions is diminishing. Finally, the significant yet declining effect of trade facilitation echoes the findings of Djankov et al. (2010) and Santhi and Setyari (2019), highlighting the importance of trade facilitation in cost reduction is significant, although its contribution is complementary rather than dominant when compared to macroeconomic fundamentals.

### *4.3. Robustness Tests*

To ensure the robustness of our findings, we conducted two supplementary sensitivity analyses: examining lagged effects and incorporating additional control variables. Model (2) includes these controls to address potential endogeneity and to investigate dynamic effects, utilizing a single-period lag of the Trade Facilitation Index (LTFI). The results of two robustness tests are shown in Table 4.

**Table 4.** Robustness test results.

| Dependent variable: LNEX | Dependent variable: LNEX | Model (2): Additional controls |
|---|---|---|
| LNGDPI | 0.006 | -0.061 |
| | (0.02) | (-0.23) |
| LNGDPJ | 1.008*** | 1.155*** |
| | (3.81) | (4.39) |
| LNDIST | 0.188* | 0.214** |
| | (1.89) | (2.27) |
| LNREER | 0.980 | 1.027 |
| | (1.60) | (1.66) |
| TARIFF | -0.004 | 0.004 |
| | (-0.22) | (0.17) |
| LTFI | 0.138*** | |
| | (3.10) | |
| TFI | | 0.100** |
| | | (2.24) |
| TB | | 0.005 |
| | | (1.23) |
| Constant | -1.858 | -2.206 |
| | (-0.56) | (-0.80) |
| Observations | 63 | 70 |
| R-squared | 0.986 | 0.985 |
| ID FE | Yes | Yes |
| YEAR FE | No | No |

***Note:** Robust standard errors in parentheses; *p<0.10, **p<0.05, ***p<0.01.

Model (1) examines lagged effects by including a one-period lag of the Trade Facilitation Index (LTFI). The lagged TFI coefficient (0.138) exceeds the contemporaneous effect from the baseline model (0.109), indicating that trade facilitation improvements have sustained and potentially cumulative impacts on export performance. This finding suggests that institutional reforms require time to fully manifest their effects on bilateral trade flows, as businesses need time to adapt to improved procedures and infrastructure.

Core macroeconomic relationships remain robust across specifications. ASEAN GDP maintains its dominant positive effect (1.008), while other variables display similar patterns to the baseline results. The consistency of coefficients across different specifications strengthens confidence in the main findings.

Model (2) incorporates Technological Barriers (TB) as an additional control variable to address potential omitted variable bias. The contemporaneous TFI coefficient (0.100) remains positive and statistically significant, closely aligning with the baseline estimate.

The technological barriers coefficient is positive but statistically insignificant, potentially reflecting the dual nature of technical standards that may simultaneously create trade barriers and enhance product quality competitiveness.

### *4.4. Heterogeneity Analysis*

To examine whether macroeconomic determinants operate differently across categories of electromechanical products with varying levels of technological intensity, we classified the analysis by product type. This heterogeneity test offers insights into how macroeconomic fundamentals influence different segments of China's electromechanical export portfolio.

The products are categorized as Table 5 shows.

**Table 5.** Product classification.

| Classification | Classification/SITC Rev.4 Category |
|---|---|
| Labor-intensive | SITC-71 Power machinery and equipment |
| | SITC-72 Special industrial machinery |
| | SITC-73 Metalworking machinery |
| | SITC-74 General industrial machinery and equipment and parts |
| | SITC-76 Telecommunications, recording and reproducing apparatus and equipment |
| | SITC-77 Electrical machinery, instruments and appliances and their electrical components |
| Capital and technology-intensive | SITC-75 Office machines and automatic data processing equipment |
| | SITC-78 Land vehicles |
| | SITC-79 Other transport equipment |

Table 6 presents heterogeneity test results, revealing pronounced differences in macroeconomic effects across product categories. The elasticity coefficient of ASEAN GDP concerning capital-intensive products (1.407) exceeds that of labor-intensive products (1.032), indicating a structural shift in import demand toward high-technology goods concomitant with ASEAN's economic development. China's GDP variable exhibits differentiated impacts: a significant negative effect on capital-intensive products (-0.822) and an insignificant influence on labor-intensive products (0.210), suggesting that domestic economic growth is accompanied by a reallocation of production factors from traditional export sectors to high-technology industries. The exchange rate transmission mechanism also demonstrates technological specificity; the real effective exchange rate elasticity for capital-intensive products (2.286) is markedly higher than that for labor-intensive products (0.787), implying that high-technology products more effectively leverage quality signals to mitigate the pressures of currency appreciation. The impact of geographical distance on capital-intensive products (0.399) is significantly greater than on labor-intensive products (0.118), reflecting the relative advantage of high-value-density goods in overcoming transportation costs. The institutional environment variable (TFI) exerts a significant positive influence solely on labor-intensive products (0.104), indicating that trade facilitation reforms primarily benefit cost-sensitive categories through reduced transaction costs, whereas the competitive edge of technology-intensive products relies more heavily on intrinsic technological content and quality differentiation.

**Table 6.** Heterogeneity Test Results.

| Dependent variable: LNEX | Model (1): Capital/Tech-Intensive | Model (2): Labor-Intensive |
|---|---|---|
| LNGDPI | -0.822** | 0.210 |
| | (-2.14) | (0.83) |
| LNGDPJ | 1.407*** | 1.032*** |
| | (3.75) | (4.18) |
| LNDIST | 0.399*** | 0.118 |
| | (3.05) | (1.37) |
| LNREER | 2.286** | 0.787 |
| | (2.59) | (1.36) |
| TARIFF | -0.004 | 0.001 |
| | (-0.13) | (0.06) |
| TFI | 0.075 | 0.104** |
| | (1.18) | (2.50) |
| Constant | -7.015* | -1.679 |
| | (-1.77) | (-0.65) |
| Observations | 70 | 70 |
| R-squared | 0.974 | 0.985 |
| ID FE | YES | YES |
| YEAR FE | NO | NO |

***Note:** Robust standard errors in parentheses; *p<0.10, **p<0.05, ***p<0.01.

Empirical analysis establishes a hierarchical framework of macroeconomic determinants governing China's electromechanical exports to ASEAN. The economic capacity of importing countries emerges as the dominant factor, with demand-side economic strength serving as the fundamental driver of bilateral trade flows, followed by exchange rate competitiveness and geographical considerations. The direct influence of supply-side economic variables and traditional trade policy measures remains limited. Improvements in trade facilitation offer complementary benefits but do not supersede macroeconomic fundamentals. These findings bear significant implications for China's export strategies and regional economic cooperation policies, underscoring the importance of supporting ASEAN economic development and leveraging monetary strength for market positioning.

## 5. CONCLUSION AND POLICY IMPLICATION

This study employs an extended gravity model framework to examine the macroeconomic determinants of China's electromechanical product exports to ASEAN, while incorporating trade facilitation as a supplementary factor. Empirical analysis of panel data from seven ASEAN countries spanning 2010 to 2019 reveals a clear hierarchical structure among macroeconomic factors.

The GDP of importing countries emerges as the dominant determinant, with the largest coefficient, indicating that a 1% increase in ASEAN countries' GDP corresponds to approximately a 1.19% increase in China's electromechanical exports. This extraordinary elasticity underscores the primacy of demand-side economic capacity as the fundamental driver of bilateral trade flows, surpassing the combined influence of all other factors.

The real effective exchange rate (REER) of the Renminbi exhibits a significant positive coefficient, contrary to conventional expectations, suggesting that currency appreciation enhances export performance through a quality signal effect. Geographic distance presents an unexpectedly positive coefficient, implying that the distant ASEAN markets possess market segmentation advantages. China's GDP does not significantly impact export capacity, and traditional trade barriers under CAFTA exert minimal influence. Compared to macroeconomic fundamentals, improvements in trade facilitation provide a complementary but secondary effect.

Robustness tests and heterogeneity analyses confirm the stability and nuanced nature of these macroeconomic effects. The coefficient for lagged trade facilitation increases, indicating that institutional effects accumulate over time. Heterogeneity analysis reveals that labor-intensive electromechanical products are more sensitive to trade facilitation, while capital-intensive products respond more strongly to exchange rate effects. Collectively, these findings suggest that macroeconomic fundamentals, particularly demand-side economic capacity, dominate China's electromechanical export performance to ASEAN, with quality differentiation mechanisms being more significant than traditional cost competitiveness factors.

The dominance of macroeconomic factors indicates that China should prioritize policies supporting ASEAN economic development and capacity building, including infrastructure investments and technology transfers that expand purchasing power and market absorption capacity. Rather than pursuing competitive devaluation, China should leverage the strength of the Renminbi to position electromechanical products in high-end market segments. The positive distance effect presents opportunities for targeted marketing strategies utilizing geographic market segmentation. China should develop specialized products for distant ASEAN markets, which can serve as regional distribution hubs or offer high-quality demand features. The findings suggest that deeper economic integration focused on capacity building will generate greater trade benefits than traditional trade facilitation measures alone.

This research provides valuable insights into the macroeconomic determinants of China-ASEAN electromechanical trade. However, it faces limitations, including the exclusion of data due to incompleteness and the restricted time frame up to 2019, thereby missing the potential structural impacts of the COVID-19 pandemic on trade relations. Consequently, the applicability of the results to current trade dynamics may be limited. The focus on macroeconomic aggregates constrains insights into micro-level determinants such as firm productivity and product

quality changes. Future research could address these limitations by extending the temporal scope, incorporating a broader set of countries, and conducting cross-product category comparative analyses.

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