Rethinking Agri-Food Trade in ASEAN: Issues and Prospects

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ABSTRACT

Global shocks and disruptions in the food supply chain are a wake-up call for Southeast Asia nations to ensure food supplies are made secure at the regional level. The intraregional trade share of agri-food remains less than one-fourth of its global trade. This then begs the question of the prospects for promoting intraregional agri-food trade. One of the reasons cited for the poor performance in intraregional agri-food trade is "behind-the-border" factors, among others. The paper, therefore, employs a stochastic frontier approach to an augmented gravity trade model, which models the aggregate effect of "behind-the-border" factors. Intraregional agri-food export potential is estimated for the 1990 to 2020 period across 24 broad product groups. On average, the trade efficiency levels are found to be rather low and far less than one at 0.22, after considering the determinants of trade potential - economic size, convergence in income levels, geographical distance, total investments, investment capacity, factor endowments, tariffs, and exchange rate. The efficiency scores are also found to be low for the highly tradable processed food products segment. The findings indicate that "behind the border" regulations constrain the region from exploiting its potential exports.

Keywords: Agri-food, Intra-regional trade, Stochastic frontier gravity model, Trade efficiency

JEL Classification: F13, F63, O24

1. Introduction

Agri-food trade plays an important role in regional and global food security. Through agri-food trade, food availability is assured for importing nations, while generating export revenues for exporting nations. Trade policies also matter as trade liberalization can increase

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access to food. Agri-food products are part of the regional value chains (RVCs) and global value chains (GVCs) (Fan et al., 2021), as they are often processed and re-exported by intermediary countries (Oizumi, 2020). The intensity of the food chain networks, in turn, increases the vulnerability of the region to external shocks, such as the disruptive consequences of the COVID-19 pandemic, the Russia-Ukraine war and the volatility in the prices of global commodities. The trade-food security nexus is obviously not something new.

Likewise, promoting food security through regional trade is also not a new agenda for a regional group like the Association of Southeast Asian Nations (ASEAN) that has a sizeable agriculture-dependent population, and where the agri-food sector plays a vital role for export earnings (ASEAN-Japan Centre, 2020). Efforts to balance food security and regional trade concerns were already identified as a challenge since the 2007/2008 global food crisis[2] (see Chandran and Lontoh, 2010). Tightening food supplies and soaring prices since the pandemic have further put food security high on the agenda of ASEAN. Expanding the intra-ASEAN market is therefore a critical issue for the regional policy agenda on agri-food trade, particularly when extra-regional[3] trade continues to dominate intraregional trade until the present day (Fan et al., 2021; Teng et al., 2021).

Several reasons have been cited in the literature for the limited flows of agri-food within the region. Diao and Li (2020) reason that the low level of intra-ASEAN agri-food trade is due to a mismatch between demand and supply. Others believe that intraregional trade is hindered by restrictive regulations for agri-food trade that increase trade costs and limit market access (Mizik, 2021; Teng et al., 2021; Oizumi, 2020; Suvannaphakdy and Pham, 2020; Devadason and Govindaraju, 2019). Diao and Li (2020) however add that trade opportunities can still be

[2] In the aftermath of the food crisis, the ASEAN Integrated Food Security (AIFS) Framework and Strategic Plan of Action on Food Security in the ASEAN region (SPA-FS) were both adopted at the ASEAN Summit in 2009. Then followed the 2015 Vision and Strategic Plan to ASEAN Cooperation in Food, Agriculture and Forestry (2016-2025).

[3] ASEAN countries that rank in the top three exporters in the world include: vegetable oil (Indonesia, Malaysia), coconuts (Philippines, Indonesia), sugar (Thailand), pineapple (Thailand, Philippines), coffee (Vietnam), pulse grains (Myanmar) and cassava (Indonesia).

created (see also Teng et al., 2021) since the region comprises net exporters and net importers[4], and partnerships where high trade complementary and high forward linkages in agri-food trade (ADB, 2022) are both combined with disproportionately low levels of bilateral trade.

Against the backdrop of the global shocks, disruptions to the food supply chain, significant gaps in the regional food supply and restrictive regulations for agri-food trade, it is now even more critical than before for ASEAN to ensure food supplies are made secure through regional trade. Teng et al. (2021) note that during the pandemic, some ASEAN Member States (AMS) had already responded by shortening the supply chains through intra-ASEAN trade. That said, participation of AMS in regional value chains for agri-food is only at 8% relative to their engagement in global value-chains at 39% (ADB, 2022). At the opposite end of the spectrum, countries like the Philippines, Malaysia and Indonesia had adopted self-sufficiency strategies to address shortfalls on food supply, while other AMS resorted to directly curbing exports.

Though it remains far from clear to what extent the global shocks and corresponding responses by the AMS have impacted intraregional trade in agri-food, it is important to bring analytical weight to the question of the untapped trade potentials at the regional level, that is how the recent changing dynamics of intraregional trade relationships are affecting the efficiency of agri-food trade. The key objectives of the study, therefore, are first, to identify the intra-ASEAN potential trade and technical efficiency for agri-food and second, to verify the importance of "behind-the-border[5]" measures in constraining intra-regional trade from reaching its potential level. Knowing the potential for agri-food trade is important for the AMS to realize the benefits of regionalization and subsequently the significance for minimizing existing restrictive measures for agri-food trade.

The paper is structured as follows. The next section provides a detailed picture of intra-ASEAN agri-food trading relationships and illustrates

[4] The net exporters of agri-food in ASEAN are Malaysia, Indonesia, Thailand, and the Philippines (to a lesser extent).

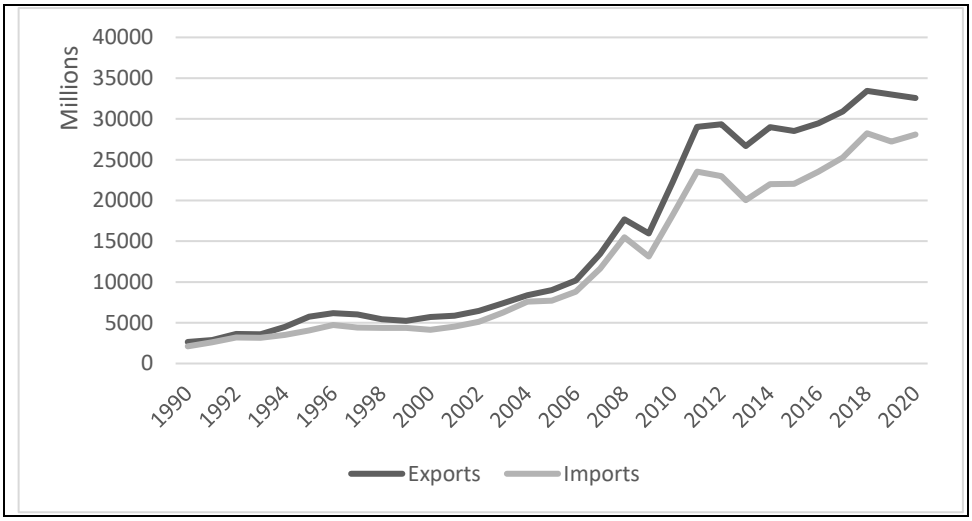
[5] "Behind the border" constraints refer to the quality of infrastructure and regulatory environment (a variety of non-tariff barriers (NTBs), or even protective non-tariff measures (NTMs) that operate inside countries rather than at the border) that nonetheless can restrict trade and alter comparative advantages.

significant developments in the regional agri-food market. Section 3 estimates the trade potential of agri-food trade in ASEAN. The final section, Section 4, concludes with some policy recommendations on the direction of agri-food trade in ASEAN.

2. Agri-Food Trade Relationships - Defining Issues

Intra-ASEAN trade in agri-food[6] increased from USD4.8 billion in 1990 to USD60.2 billion in 2020. On average, intra-ASEAN agri-food exports and imports grew by 9.5% and 9.9% for the period 1990 to 2020 and the trade balances for agri-food recorded consistent surpluses for the entire period (see Figure 1). However, since 2012, the growth in intraregional agri-food trade began to moderate significantly, at below 2.5% per annum (see also Mizik et al., 2020; Teng et al., 2021).

Figure 1: Intra-ASEAN Agri-Food Trade, 1990-2020 (USD million)



Note: Agri-food refers to HS01-HS24 (see Appendix Table 1).
Source: Compiled from UN Comtrade (2022).

[6] There are various definitions and classifications of agri-food in the literature. This paper defines agri-food based on the harmonized system (HS) for 24 product categories at the HS2-digit level, comprising HS01 – HS24 (see Appendix Table 1).

The major contributors to agri-food exports within the region are also countries with relatively higher comparative advantages (see Mizik, 2021) - Thailand, followed by Indonesia, Malaysia, Singapore, and Viet Nam (see Table 1). Since 2010, the major importers of agri-food within the region are Malaysia, Singapore, the Philippines, Viet Nam, and Indonesia. Within the newer AMS, Viet Nam has emerged as a significant regional trading partner for agri-food since the 2000s. In contrast, Singapore is no longer the largest importer of agri-food in the region. Its regional import share declined drastically from 48.9% to 18.5% between 1990 to 1999 and 2010 to 2020 respectively. Overall, the concentration of import shares appears to be more balanced relative to that of exports.

Table 2 presents the product market concentration for agri-food trade within the region. The major product traded within the region is animal or vegetable fats and oils (HS15), and even then, the extra-regional market share is much higher than the regional market share for this product group. Generally, intraregional trade seems to be concentrated as the top three products accounted for 37.3% and 36.6%, on average, from the export and import perspectives based on the 2010 to 2020 period. Some notable changes are also observed in terms of the contribution of the different product groups to intraregional trade. For example, the importance of HS3 (fish and crustaceans, molluscs, and other aquatic invertebrates) has reduced over time, while the opposite holds for HS21 (miscellaneous edible preparations). Worth noting here also is that the share of processed food (HS4, HS9 and HS16-HS22) in intra-regional exports (imports) had increased substantially from 29.9% (26.8%) in 1990 to 46.9% (43.9%) in 2020.

Despite the increase in intraregional agri-food trade, ASEAN has not increased its presence on the regional front for both the import and export of agri-food. Intraregional exports and imports of agri-food only constituted 22.4% (16.4%) and 26.8% (23.9%) of ASEAN's corresponding global agri-food trade in 2020 (1990). ASEAN is still heavily dependent on extra-regional agri-food trade as the AMS differ widely in their production capacities of rice, wheat, soybean, maize, vegetable oil and livestock.

Table 1: Share of Intra-ASEAN Trade, by Country, 1990-2020 (%)

Period	BRN	CAM	IDN	LAO	MMR	MYS	PHL	SGP	THA	VNM
	Intra-regional export share (%)									
1990-1999	0.0	0.0	17.6	0.0	0.2	30.7	1.0	24.4	26.1	0.0
2000-2009	0.0	0.2	20.1	0.0	0.0	23.3	3.4	17.9	24.8	10.2
2010-2020	0.0	0.4	21.6	1.7	2.3	19.2	2.1	15.0	26.7	10.9
Period	Intra-regional import share (%)									
1990-1999	2.1	0.0	15.7	0.0	0.2	22.7	4.4	48.9	6.0	0.0
2000-2009	2.0	1.8	12.3	0.0	0.4	25.7	12.0	27.9	9.5	8.4
2010-2020	1.6	2.6	12.4	1.5	4.5	21.9	13.0	18.5	11.1	12.8

Notes: The shares are calculated as period averages. BRN – Brunei Darussalam; CAM – Cambodia; IDN – Indonesia; LAO – Lao PDR; MMR – Myanmar; MYS – Malaysia; PHL – Philippines; SGP – Singapore; THA – Thailand; VNM – Viet Nam.
Source: Calculated from UN Comtrade (2022).

Table 2: Share of Intra-ASEAN Trade, by Product Group, 1990-2020 (%)

HS2-digit	Export Share			Import Share		
	1990-1999	2000-2009	2010-2020	1990-1999	2000-2009	2010-2020
1	4.9	1.8	1.8	6.3	2.3	1.7
2	1.1	0.5	0.9	0.8	0.5	0.4
3	10.5	6.4	5.6	12.3	10.5	6.1
4	3.2	4.6	2.5	2.9	4.7	2.9
5	0.1	0.1	0.1	0.1	0.2	0.1
6	0.3	0.2	0.2	1.0	0.6	0.4
7	3.2	1.8	2.3	3.6	3.0	4.0
8	3.6	2.7	4.1	3.1	3.0	4.8
9	3.6	3.0	3.0	4.0	2.7	3.3
10	10.4	11.4	7.7	17.3	13.4	8.4
11	2.1	1.9	2.1	2.5	2.0	2.5
12	1.6	1.3	0.7	2.8	1.6	1.1
13	0.4	0.2	0.2	0.2	0.2	0.2
14	0.2	0.1	0.1	0.7	0.2	0.2
15	17.4	16.1	16.5	17.0	14.3	18.1
16	1.9	2.1	1.7	1.5	1.8	1.8
17	6.8	7.3	7.2	7.3	6.3	7.9
18	3.7	4.4	3.7	3.2	5.9	3.8
19	3.5	6.2	7.7	3.5	6.1	8.1
20	2.2	1.7	1.4	2.3	1.3	1.3
21	2.9	5.7	9.7	2.6	5.7	10.1
22	4.1	7.4	11.1	1.9	3.2	4.4
23	1.7	2.6	3.2	2.1	3.5	4.1
24	10.4	10.3	6.8	1.2	6.9	4.5

Notes: The shares of each product group in total agri-food trade are calculated as period averages. See Appendix Table 2 for description of product groups.
Source: Calculated from UN Comtrade (2022).

Mizik (2021) attributes the low level of regional trade to the low value-added for agri-food, characterized by inter-industry (IT) transactions (Kusano, 2018). He however adds that the divergence in agri-food trade between the AMS renders the region less competing. The complementary effects of agri-food trade across the AMS are supported by Hoang (2018) and Diao and Li (2020). Hoang (2018) states that ASEAN countries are in fact weakly complementary with each other in agricultural trade, while Diao and Li (2020) observe complementarity in some dominant bilateral partnerships. That is, Malaysia's import demand was found to be most compatible with Thailand's export structure, while Indonesia had the lowest trade complementarity with its regional partners. Oizumi (2020) and Teng et al. (2021) opine that regional integration in agri-food is somewhat limited due to high tariff and NTBs (price controls, quotas, subsidies etc.) (including the diversity in NTMs) in the AMS (see also Mizik, 2021; Devadason, 2020; Suvannaphakdy and Pham, 2020; Diao and Li, 2020; ASEAN-Japan Centre, 2020; Asia Pacific Foundation of Canada, 2021).

The agri-food sector in ASEAN is highly regulated, with 2,181 measures (calculated from UNCTAD TRAINS database, 2022) in the region's priority sectors. Sanitary and phytosanitary (SPS) measures dominate the agri-food NTM portfolio, and the largest number of SPS measures are found in the following countries - Thailand (282), followed by the Philippines (150), Indonesia (144), Malaysia (88), and Vietnam (83). Worth noting here is that during the pandemic, the number of new NTMs had increased from both the export and import sides. For example, Thailand and Viet Nam had increased the barriers to food exports (Teng et al., 2021). Likewise, increases in tariffs and import duties were reported in the Philippines, Indonesia, and Vietnam, while import restrictions and outright import bans were also imposed by the Philippines, Malaysia, Indonesia, and Viet Nam[7]. New health-related excise taxes on salt content, processed food, and sugar-sweetened beverages, which are in various stages of implementation in Thailand, Malaysia, Indonesia, and Viet Nam, are another potential risk for the sector.

The data analysis and the arguments forwarded above on the low level of intraregional trade, high market- and product concentration, selective trade complementarity relationships and high barriers to trade beg the

[7] Some of these measures were subsequently rolled back.

inquiry on the potential for agri-food trade within ASEAN. It is therefore important to compare the level of intraregional trade efficiency for major agri-food products (including processed food). This is taken up in the following section that examines the trade efficiency scores to inform the debate on the prospects for increasing agri-food trade within the region.

3. Agri-Food Trade – Identifying Prospects

Agri-food trade results from the complex interactions among several factors, such as economic size, prosperity and convergence in income, investments and capacity for trade, factor endowments and trade policies (namely tariffs). To explore the influence of some of these trade determinants, an augmented gravity model is employed. The conventional gravity model, however, cannot satisfactorily control for the various resistances to trade as most of them, such as "behind-the-border" constraints are hard to quantify. Hence, they are added into the unobserved disturbance term.

The stochastic frontier analysis (SFA)[8] instead is considered appropriate for estimating unobservable resistances to trade (Baier and Bergstrand, 2009) and is widely used with the gravity equation (Armstrong, 2007). It is commonly employed to identify trade potentials and trade efficiencies (TEs)[9], and is therefore considered relevant for examining the case of the agri-food sector in ASEAN, which is highly regulated[10] (UNCTAD TRAINS database, 2022) Some recent studies employing the SFA for estimating trade potentials/ efficiencies include Jiang et al. (2022), Abdullahi et al. (2021), Dadakas et al. (2020), Nguyen (2020), Atif et al. (2017), and Barma (2017), among others.

[8] The SFA estimates a production frontier indicating the maximum possible (and not the average) output that is produced given a certain level of inputs. A fully efficient unit operates at the frontier, and those inefficient units operate at a point within the frontier signifying a shortfall between the observed and the maximum possible levels of output.

[9] Trade potential is the trade achieved at a frontier; the level of trade that might be achieved in the case of the most open and frictionless, while TE is a measure of actual levels of trade against potential trade and can be estimated statistically using the stochastic frontier gravity model for all trade flows.

[10] For example, regulations in the form of NTMs can increase the cost of doing business through increased compliance costs, thus reducing trade flows and trade efficiency.

3.1 Method and Data

The SFA analysis is applied to the gravity specification of Wang et al. (2010), as follows:

$$X_{ij}^{t} = f\left(GDPT_{ij}^{t},\ SIMGDPPC_{ij}^{t},\ FDIT_{ij}^{t},\ SIMFDI_{ij}^{t},\ RLFAC_{ij}^{t}, TRF_{j}^{t}, ER_{ij}^{t},\ DIST_{ij},\ CB_{ij}\ LL_{ij}\right) \exp\left(v_{ij}^{t}\right) \exp\left(-u_{ij}^{t}\right) \quad (1)$$

where X_{ij}^{t} are the bilateral agri-food export flows between country *i* (reporter) and country *j* (partner) at time *t*. GDP_{ij}^{t} and $SIMGDPPC_{ij}^{t}$ are the total gross domestic products (*GDP*) of countries *i* and *j* and the similarity in the levels of GDP per capita (*GDPPC*) in *i* and *j*, respectively. $FDIT_{ij}^{t}$ and $SIMFDI_{ij}^{t}$ are the total inward foreign direct investment (*FDI*) stock of *i* and *j* and the similarity in inward *FDI* stocks in *i* and *j*, respectively. $RLFAC_{ij}^{t}$ refers to the relative factor endowments (land-labour; LD/L) in *i* and *j*; TRF_{j}^{t} is the importing country's tariff rate; and ER_{ij}^{t} is the bilateral exchange rate between i and j. $DIST_{ij}$ is the geographical distance between the capitals of the two partner countries; CB_{ij} indicates if the two partner countries share a common border; and LL_{ij} represents a landlocked economy for *i* and/or *j*. The error term of the gravity model comprises two components, namely v_{ij}^{t} representing statistical noise due to measurement error and the one-sided inefficiency element represented by u_{ij}^{t} that measures trade performance. v_{ij}^{t} follows a normal distribution while u_{ij}^{t} is assumed to be distributed independently of the random error and the regressors.

The one-sided inefficiency representing the technical inefficiency is a non-negative random variable. It denotes the degree to which actual trade levels deviate from the potential or maximum trade performance. A zero value of u_{ij}^{t} indicates that the inefficiency term reduces to the random noise component where the actual and potential trade levels equal. While a non-zero value of u_{ij}^{t} indicates that there is a deviation of actual and potential trade providing scope for trade integration. This deviation can be due to multilateral resistances (economic distance), which is often unobservable and difficult to quantify. In other words, it can be "behind-the- border" barriers that are specific to the trading countries (Armstrong

2007; Kalirajan 2007). The estimate of the total error variance is represented by $\sigma^2 = \sigma_u^2 + \sigma_v^2$, while the estimate of the ratio of the standard deviation of the inefficiency component to the standard deviation of the idiosyncratic components is represented by $\lambda = \sigma_u/\sigma_v$. If λ is significant, then it signifies the use of the SFA since it assesses the degree of inefficiency relative to random error. In addition, testing the presence of TE requires the one-sided likelihood ratio (LR) test to be performed on the null hypothesis, $H_0: \sigma_u^2 = 0$, against the alternative hypothesis, $H_1: \sigma_u^2 > 0$. If one fails to reject the null hypothesis, then the SFA model reduces to an ordinary least squares (OLS) model.

The point estimates of the TE for each bilateral partner can be computed as $TE_{ij}^t = E[\exp(-u_{ij}^t)\,\varepsilon_{ij}^t]$. The estimated TE ranges between zero to one. TE with a unitary value implies that the actual and potential trade levels coincide and values moving towards zero indicate that there is scope to raise actual trade levels to the maximum levels, for example, a lower efficiency level.

The full gravity stochastic frontier model specification of intra-ASEAN agri-food exports is specified below:

$$\begin{aligned}\ln X_{ij}^t = {} & \beta_0 + \beta_1 \ln GDPT_{ij}^t + \beta_2 SIMGDPPC_{ij}^t + \beta_3 \ln FDIT_{ij}^t + \\ & \beta_4 SIMFDI_{ij}^t + \beta_5 RLFAC_{ij}^t + \beta_6 \ln TRF_j^t + \beta_7 \ln ER_{ij}^t + \\ & \beta_8 \ln DIST_{ij} + \beta_9 CB_{ij} + \beta_{10} LL_{ij} + v_{ij}^t - u_{ij}^t \end{aligned} \quad (2)$$

where $DIST_{ij}$, CB_{ij}, and $LL_{i,j}$, geographical distance, common border and landlocked economy, respectively, are time-invariant explanatory variables. Other definitions of the explanatory variables follow equation (1). *GDPT*, *FDIT*, *TRF*, *ER*, and *DIST* are transformed into logarithmic form.

The level of *GDP* of both reporter and partner countries is supposed to positively affect their trade. Instead of using the levels of *GDP* of both countries independently, the total GDP of both partners, *GDPT*, is included in the estimations to jointly capture economies of scale or the size effect. The higher the *GDPT*, the larger the trade flows, given that a greater division of labor and specialization becomes feasible under a larger scale of operation. However, the level of *GDP* alone may not be enough to explain trade as the similarities of the two trading partners'

GDPs are of no less importance. From a theoretical perspective, similarity in the level of *GDPPC* (*SIMGDPPC*) or convergence in income levels (or tastes) is likely to increase trade either through expansions in nutritious and processed foods (Doan and Li, 2020) or the increase in scope for product diversity.

The next core argument of the gravity model is the *DIST* variable. *DIST* remains important for considerations of transport costs, transaction costs, and timeliness in delivery and is included in the estimations. Thus, the expectations are for $\beta_8 < 0$.

Theoretically, *FDI* contributes to intra-firm trade through global production networks and the increase in product variety in the host economy. This, in turn, increases the volume of trade, mainly through intra-industry trade (IIT). However, if *FDI* and trade are substitutes, for example, if *FDI* is mainly channelled into the domestic production of the host economy, then it does not necessarily contribute to expansions in exports. As such, the relationship between *FDI* and international trade in agri-food remains inconclusive. According to Fan et al. (2021) and the ASEAN-Japan Centre (2020), the FDI-trade relationship (see also Teng et al., 2021) is relevant for agri-food as the supply chains for the major primary commodities in ASEAN are operated increasingly by large international trading companies.

Similarly, the distribution of *FDI* amongst trade partners is also considered important for international trade. If the size of *FDI* (*SIMFDI*) is similar between trade partners, one may expect similar volumes and varieties of bilateral exports from the partner countries. Following which, the import capabilities of both partner countries are also likely to be similar, leading to expansions in bilateral trade. Conversely, if the *SIMFDI* is uneven between trade partners, the country with a smaller stock offers less export capabilities and, likewise, smaller import capabilities, resulting in lower expansions in bilateral trade. Based on this reasoning, a positive relationship is envisaged between *SIMFDI* and trade.

Differences in factor endowments or factor intensity (agricultural land-labour ratio or LD/L) do matter for international trade. Traditional neoclassical trade theories suggest that comparative advantages based on differences in factor endowments (*RLFAC*) explain basically IT. Alternatively, newer trade theories based on economies of scale and

product differentiation attribute similarities in factor endowments to trade expansions through IIT. Thus, the differences and similarities of factor endowments (apart from *SIMGDPPC*) are closely linked to the structure of trade. If the structure of trade is IT-based, *RLFAC* will most likely facilitate trade expansion vis-à-vis similarities in factor endowments. In this respect, the expected sign for β_5 will be positive (negative) if IT (IIT) dominates.

The applied tariff (*TRF*) rate is an explicit "beyond-the-border" constraint (Kalirajan and Singh 2007; Miankhel et al., 2014) in the importing country (*j*), and it can pose a hindrance to country *i*'s exports to *j* and is, therefore, included in Equation (2). Equation (2) is also augmented with the bilateral exchange rate (*ER*) to explain export flows. As *ER* is defined as the ratio of country *i*'s currency per USD to country *j*'s currency per USD, an increase in *ER* reflects a depreciation of the exchange rate, which is then expected to increase exports.

Dummies are incorporated in Equation (2) to control for the omitted variable effects, common border and landlocked, on export flows. It takes the value of 1 for countries with a common border or no sea nor ocean access (only Lao in the ASEAN sample). Landlocked countries have a certain disadvantage since they cannot easily use ship transport for their goods. The expected signs for β_9 and β_{10} are positive and negative respectively.

Exports (*X*) are compiled from the UN Comtrade database. Data for *GDP*, *GDP* per capita (*GDPPC*), gross fixed capital formation (*GFCF*), nominal exchange rate (*ER*) and average weighted tariffs (*TRF*) for primary products are sourced from the World Development Indicators (WDI) database. The data on *FDI* is obtained from the online database of the United Nations Conference on Trade and Development (UNCTAD), which is UNCTADstat. Data for geographical distance (*DIST*), based on the average distance between the capitals of country pairs, and the information for common border (*CB*) landlocked economy (*LL*) are extracted from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) database. The definition and measurement of the key variables used in the regression analysis are summarized in the Appendix Table 2.

The panel data set constructed for two-way intra-ASEAN[11] agri-food exports span the 1990 to 2020 period (31 years) and comprises 2,160 country-product-pairs. Hence, the total number of observations is 66,960. The descriptive statistics and correlation matrix are presented in the Appendix, Tables 3A and 3B, respectively. The high standard deviations for *SIMGDPPC* and *SIMFDI* (Appendix Table 3A) indicate the high dispersion of those values. This also indicates that the trading partners are quite heterogenous. As the absolute correlation coefficients are all less than 0.7 in Appendix Table 3B, it can be concluded than multicollinearity is not present.

3.3 Trade Efficiency Estimates

Table 3 presents the results of the maximum likelihood (ML) estimates of the stochastic frontier gravity model (SFGM) for intra-ASEAN agri-food exports. The reported estimates are based on the time-invariant model of Battese and Coelli (1988, model bc88) and the time-varying inefficiency specifications of Battese and Coelli (1992, model bc92). For purposes of comparison, the stochastic frontier estimates are compared with that of the fixed effects (FE), random effects (RE) and poison-pseudo maximum likelihood (PPML)[12] models.

The signs and the significance of the coefficient estimates for the panel gravity model in Table 3 follow theoretical expectations. Economic size, similar income levels, FDI, investment capabilities, differences in factor endowments, lower geographical distance and lower tariffs and depreciations in the exchange rate, encourage agri-food exports between the AMS. The results of the SFGM estimates are relatively robust compared to the conventional gravity estimates. The following discussion therefore focuses on the former.

[11] ASEAN consists of 10 countries, Malaysia, Singapore, Thailand, Philippines, Indonesia, Brunei, Cambodia, Lao PDR, and Viet Nam.

[12] The PPML is employed as it can deal with zero trade observations and can also addresses the problem of heteroscedasticity and multicollinearity.

Table 3: Panel Gravity Estimates

Variables	Conventional Method			Stochastic Frontier Approach	
	PPML	**FE**	**RE**	**bc88**	**bc92**
ln*GDPT*	0.967***	0.423	0.457**	0.505***	0.618***
	(0.043)	(0.394)	(0.185)	(0.083)	(0.075)
SIMGDPPC	0.032***	0.101***	0.092***	0.088***	0.060***
	(0.002)	(0.011)	(0.006)	(0.003)	(0.004)
ln*FDIT*	0.346***	0.313***	0.217**	0.418***	0.744***
	(0.028)	(0.103)	(0.098)	(0.034)	(0.036)
SIMFDI	0.009***	0.015***	0.022***	0.024***	0.029***
	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)
RLFAC	-0.058***	-1.399***	-0.299***	-0.461***	-0.156***
	(0.011)	(0.112)	(0.042)	(0.029)	(0.031)
ln*TRF*	-2.109***	-3.663***	-4.961***	-4.319***	-5.370***
	(0.461)	(0.581)	(0.589)	(0.245)	(0.243)
ln*ER*	-0.003	-0.028	-0.018	-0.031***	-0.044***
	(0.005)	(0.023)	(0.015)	(0.009)	(0.008)
ln*DIST*	-0.912***		-1.825***	-2.114***	-1.911***
	(0.060)		(0.242)	(0.235)	(0.183)
CB	0.372***		0.524**	0.142	-0.708***
	(0.063)		(0.250)	(0.263)	(0.188)
LL	-0.135		-0.125	0.126	1.064***

	(0.083)		(0.252)	(0.234)	-0.21
Sigma-squared				2.465***	2.146***
				(0.000)	(0.029)
Gamma				1.427***	0.984***
				(0.000)	(0.041)
Mu				9.601***	7.828***
				(0.000)	(0.340)
Eta					-0.008***
					(0.001)
Year dummies	No	Yes	Yes	No	No
R-squared	0.095	0.005	0.160		
Hausman test		χ^2 = 1387.05 (0.000)			
F-statistics		46.87 (0.000)			
Pseudo log-likelihood	-7.254e+11			-6.25E+04	-6.24e+04
Wald chi2			1824.17	10021.41	5506.46
No. of groups		1748	1748	1748	1748
No. of observations	66,960	32,152	32,152	32,152	32,152

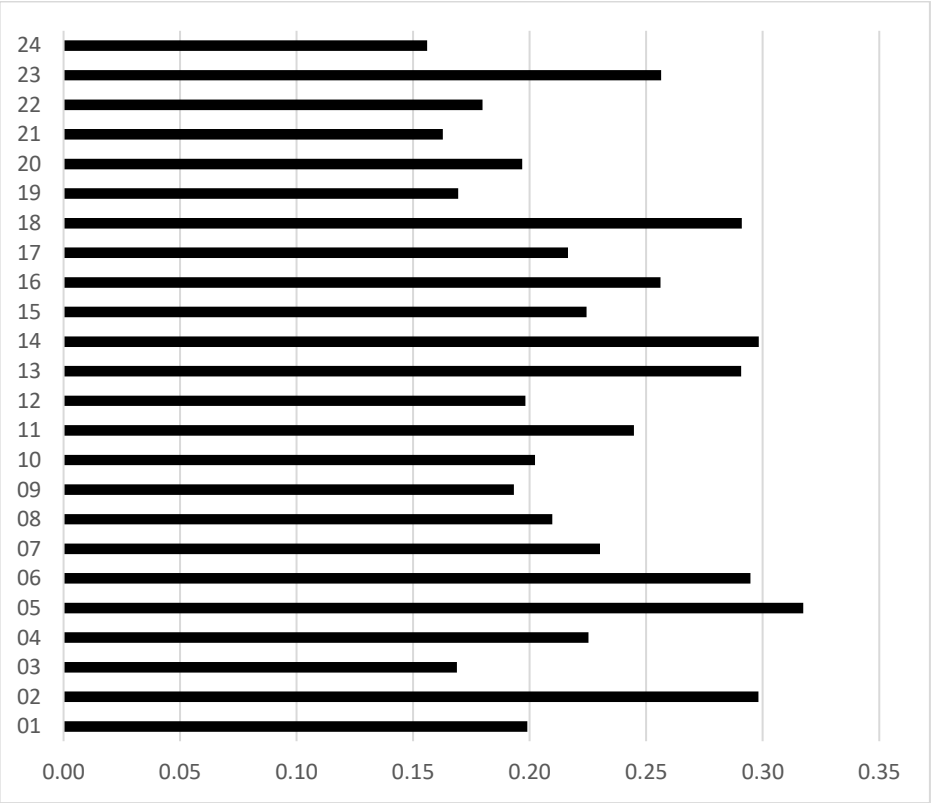
Notes: The dependent variable is ln*X*, except for PPML, where the dependent variable is *X*. The robust standard errors are reported in parentheses for the fixed effects (FE) and random effects (RE) models. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

The time-invariant model (bc88) is considered appropriate given the signs and significance of the parameters σ^2, γ, and μ. Importantly, the parameter gamma (γ) is positive, significant, and close to 1, which means that there is a variation in export efficiency with each (product-country pair) partner. In other words, it is effective to decompose the error term into *u* and *v* for the given data set, and the "behind-the-border" constraints cause deviations of actual exports from potential exports. This concurs with the findings of the Asia Pacific Foundation of Canada and ASEAN Secretariat (2021) and Suvannaphakdy and Pham (2020) that the diversity of NTMs remain a key obstacle for agri-food trade in ASEAN. They report that agri-food exports from Brunei, Cambodia (see also Piseth et al., 2021), Lao, Myanmar, and Singapore have very high potential exposures to SPS measures imposed on imported agri-food products by other AMS, thereby increasing trade costs and reducing exports.

The TE scores, derived by applying the coefficients of the estimations from the time-invariant model of the ML estimator, are presented in Figure 2. Based on bc88, intra-ASEAN exports of agri-food are on average 77.2% below the maximum potential exports. The variation in TE across the country-product pairs is also small at 0.31. Figure 2 shows that the efficiency scores for all agri-food product groups are far less than one; the TE scores for all product groups are below 0.3 except for HS5. Even for HS15, the most highly traded agri-food segment within the region, the TE score is only 0.22.

To sum up, the low trade efficiency scores imply that actual intraregional agri-food exports are below the potential level than determined by the frontier. Specifically, the findings on the constraining effects of "behind-the-border" measures concur with other country specific studies for the AMS, such as Nguyen (2020) for Vietnam's agricultural exports with reference to rice and coffee exports, and Devadason et al. (2018) for Malaysia. A trade policy environment can be counterproductive and damage the prospects for increasing regional trade.

Figure 2: Average Trade Efficiency, by Agri-Food Product Groups



Note: Derived from bc88. TE scores are averaged across country-pairs.

4. Conclusion and Policy Implications

Given that promoting food security through regional trade has become a matter of great significance for ASEAN, this paper examines the prospects for expanding intraregional agri-food exports by estimating the TE for the different segments of this sector spanning the period 1990 to 2020 for the various bilateral trade relationships. The implications of the findings from the study are two-fold.

First, the findings indicate low levels of efficiency for intra-ASEAN trade in agri-food. Higher bilateral trade flows among the dominant/ major exporters within the region do not correspond to higher trade efficiency. This finding on trade efficiency adds to previous evidence where higher

bilateral agri-food trade flows within ASEAN do not necessarily translate into higher comparative advantages (Mizik et al., 2020) or even higher trade complementarity (Doan and Li, 2020). Contrary to expectations, the potentials for agri-food are not solely dictated by large volumes of trade (as identified in this study), comparative advantage and compatible trade structures.

The low efficiency scores, even for processed food that is considered to have high value-addition relative to the other segments of agri-food, signal untapped trade potentials within the ASEAN region. This is rather discouraging since the processed food sector has been identified as a priority sector for expanding regional trade close to a decade ago. The ASEAN-Japan Centre (2020) notes that that there is much room to develop the food processing industry, as countries like Viet Nam, Malaysia, and Thailand use large amounts of foreign inputs to produce food products instead of using local (or even regional) agricultural inputs. Participation of AMS in RVCs (7.5%) is small relative to GVCs (39%) for agri-food. Worth noting here is that some critical intermediate inputs cannot be procured regionally, and likewise, the regional market may not be large enough to consume the export supply of dominant exporters for some final goods.

Second, the finding suggests that "behind-the-border" regulations constrain the region from exploiting its potential exports. Securing market access for agri-food in the region therefore is also still very much work in progress (see also Suvannaphakdy and Pham, 2020). Since NTMs that serve a non-trade policy objective cannot be removed (unlike that of NTBs), NTM reforms are required at the domestic and regional levels to reduce trade inefficiencies. This could involve better design and implementation of NTMs at the domestic level to reduce procedural costs, followed by the streamlining of NTMs (Asia Pacific Foundation of Canada and ASEAN Secretariat, 2021; Devadason, 2016; 2019) at the regional level to bring down compliance costs for traders accessing the regional market.

At the same time, ASEAN should also prevent supply crises arising from new export restrictions. It is time for the AMS to review its trade priorities for agri-food and avoid putting national economic interests above regional solidarity. There is a compelling need to address trade restrictions or protectionism by mobilizing regional mechanisms. Greater coordination

is needed to reduce trade policy discrepancies and national-minded trade policies. Likewise, short-term crises policy responses should be carried out in a coordinated manner to scale up the existing low efficiency of intraregional agri-food trade.

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Appendix Table 1: Description of Agri-Food Products

Product Description	HS 2-digit
Live animals	01
Meat and edible meat offal	02
Fish and crustaceans, molluscs, and other aquatic invertebrates	03
Dairy produce, birds' eggs, natural honey, edible products of animal origin not elsewhere specified or included	04
Products of animal origin, not elsewhere specified or included	05
Live trees and other plants, bulbs, roots and the like, cut flowers and ornamental foliage	06
Edible vegetables and certain roots and tubers	07
Edible fruit and nuts, peel of citrus or melons	08
Coffee, tea, mat, and spices	09
Cereals	10
Products of the milling industry, malt, starches, inulin, wheat gluten	11
Oil seeds and oleaginous fruits, miscellaneous grains, seeds, and fruit, industrial or medicinal plants, straw, and fodder	12
Lac, gums, resins, and other vegetable saps and extracts	13
Vegetable plaiting materials, vegetable products not elsewhere specified or included	14
Animal or vegetable fats and oils and their cleavage products, prepared edible fats, animal, or vegetable waxes	15
Preparations of meat, of fish or of crustaceans, molluscs, or other aquatic invertebrates	16
Sugar and sugar confectionery	17
Cocoa and cocoa preparations	18
Preparations of cereals, flour, starch or milk, pastrycooks' products	19
Preparations of vegetables, fruit, nuts, or other parts of plants	20
Miscellaneous edible preparations	21
Beverages, spirits, and vinegar	22
Residues and waste from food industries, prepared animal fodder	23
Tobacco and manufactured tobacco substitutes	24

Appendix Table 2: Definition and Measurement of Variables

Variable	Definition	Measurement	Source
X	Gross exports	Bilateral exports, expressed in current USD	UN Comtrade
GDP	Total real GDP	$GDP = GDP_i + GDP_j$ Values are expressed in constant (2015 = 100) USD	WDI database
SIMGDPPC	Similarity in the GDP per capita (GDPPC) level between trade partners	$SIMGDP_{ij} = 1 - \frac{GDPPC_i^2}{(GDPPC_i + GDPPC_j)^2} - \frac{GDPPC_j^2}{(GDPPC_i + GDPPC_j)^2}$ Values of GDPPC are expressed in constant (2015 = 100) USD Range of values = $0 \leq SIMGDP_{ij} \leq 0.5$ $SIMGDP_{ij} = 0$ (divergence in size) $SIMGDP_{ij} = 0.5$ (convergence in size)	WDI database
FDIT	Total inward FDI stock	$FDIT_{ij} = FDI_i + FDI_j$ Refers to inward FDI stock, that is the accumulated value held at the end of the reference period. The values are expressed in current USD	UNCTADstat database
SIMFDI	Similarity in the inward FDI stock between trade partners	$SIMFDI_{ij} = 1 - \frac{FDS_i^2}{(FDS_i + FDS_j)^2} - \frac{FDS_j^2}{(FDS_i + FDS_j)^2}$ Range of values = $0 \leq SIMFDI_{ij} \leq 0.5$ $SIMFDI_{ij} = 0$ (divergence in size) $SIMFDI_{ij} = 0.5$ (convergence in size)	UNCTADstat database
RLFAC	Similarity in land-labour ratios in terms of relative factor endowments	$RLFAC_{ij} = \lvert \ln\left(\frac{LD_{jt}}{L_{jt}}\right) - \ln\left(\frac{LD_{it}}{L_{it}}\right) \rvert$ where *LD* represents agricultural land (sq. km) while *L* stands for	WDI database

		total labour force. *LD* refers to the share of land area that is arable, under permanent crops, and under permanent pastures. Total labour force aged 15 and older who meet the International Labour Organization (ILO)'s definition. The zero value of $RLFAC_{ij}$ means countries share the same proportion of factor endowments	
TRF	Tariffs	Average weighted tariffs for primary products applied in country *j*, expressed as $\ln(1+t_j)$	WDI database
ER	Exchange rate	Bilateral exchange rate is defined as the exporting country's currency per USD to importing country's currency per USD. It is therefore expressed so that an increase in the variable represents a depreciation in the exporting currency per USD, and a positive effect on exports	WDI database
DIST	Geographical distance	The average distance between the capitals of countries *i* and *j*. Values are measured in kilometres	CEPII database
LL	Landlocked economy	Dummy for landlocked economy, where 1 = landlocked economy; 0 if otherwise	CEPII database
CB	Common border	Dummy for adjacent countries, where 1 = common border between *i* and *j*; 0 if otherwise	CEPII database

Appendix Table 3A: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ln*X*	32,152	13.401	3.245	0	21.640
ln*GDPT*	66,960	26.122	1.082	22.700	28.043
SIMGDPPC	66,960	26.605	17.613	1.887	50.000
ln*FDIT*	66,960	24.697	1.758	17.637	28.438
SIMFDI	66,960	23.238	16.428	0.082	50.000
RLFAC	66,960	2.064	2.589	0.003	8.164
ln*TRF*	66,960	0.070	0.065	0	0.359
ln*ER*	66,960	0.038	5.242	-9.735	9.735
ln*DIST*	66,960	7.257	0.471	6.226	7.982

Appendix Table 3B: Correlation Matrix

	ln*X*	**ln*GDPT***	***SIMGDP***	**ln*FDST***	***SIMFDI***	***RLFAC***	**ln*TRF***	**ln*ER***	**ln*DIST***
ln*X*	1								
ln*GDPT*	0.269	1							
SIMGDPPC	0.323	0.374	1						
ln*FDIT*	0.257	0.566	0.232	1					
SIMFDI	0.227	0.442	0.672	-0.111	1				
RLFAC	0.109	-0.100	0.164	0.520	-0.376	1			
ln*TRF*	-0.148	-0.390	-0.098	-0.522	-0.005	-0.161	1		
ln*ER*	0.039	0.133	0.023	-0.014	0.108	-0.048	-0.309	1	
ln*DIST*	-0.156	0.272	0.245	-0.016	0.194	-0.108	-0.072	0.065	1

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