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ECONOMIC COMPLEXITY AND BILATERAL TRADE FLOWS IN SELECTED COMESA AND EAST ASIA COUNTRIES

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Abstract. A particular country's productive knowledge and sophistication become a crucial determinant for the exported products in the increasingly integrated global trade. However, studies that emphasize the connection between economic complexity and trade flows are still sparse. This research aims to examine the role of economic complexity on bilateral trade flows of 27 countries in COMESA and East Asia using the gravity model from 1995 till 2019. Based on countries' geographical regions and income levels, the empirical estimation of the study applied the Poisson pseudo maximum likelihood (PPML) estimator. The main results are robust to various model specifications and consistent with the expectations of the gravity model indicators. The study found strong empirical evidence that the expansion of economic sophistication and diversification enlarges trade flows of different exported goods. Explicitly, economic complexity increases the exports of machinery and transport equipment alongside manufactured products, while its effects on agricultural exports are negligible. Thus, this study proposes that the countries should engage in more sophisticated Research and Development (R&D), attract multinational companies, establish industrial policies, and improve their productivity by utilizing the existing production network. They should move to a more diversified production and trade structure to enhance their bilateral trade flows.

Keywords: economic complexity, bilateral trade flows, export diversification, gravity model, PPML, regional trade agreement.

JEL Classification: F1, F4.

Introduction

The significance of sophisticated and diversified exports for economic development evolved into the focal point of emphasis for the increasingly interconnected global trade. The demand for more sophisticated products is expanding due to the current intense global competition

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(Neagu, 2019). Even though many emerging economies are increasingly dependent on agriculture and natural resources as the primary contributor to their export baskets, only a few are enhancing to more diversified exports (United Nations Conference on Trade and Development [UNTCAD], 2019). Due to the extensive quantities of productive knowledge needed to produce certain traded goods, some economies are more complex and prosperous (Center for International Development [CID], 2013). Contrarily, nations that export a greater variety of simple and poorly diversified items tend to have a smaller network of productive knowledge, which raises the level of income inequality in those economies (Hartmann et al., 2017).

The economic complexity index (ECI) developed by Hausmann and Klinger (2006) serves as the most appropriate indicator of positioning countries' productive knowledge and evolution. The economic complexity metric quantifies the amount of productive knowledge embedded in a country and its capabilities to generate and export more complex products. These capabilities are non-tradeable inputs required to produce commodities, such as institutional quality, infrastructure, property rights, and human and physical capital (Hausmann & Klinger, 2006; Hidalgo et al., 2007; Hidalgo & Hausmann, 2009). According to the ECI indicator, a nation's production structure is influenced by its degree of knowledge accumulation and availability of skilled labour. An economy can be described as complex when it can assemble relevant knowledge across broad networks of people to produce and export higher amounts of products with revealed comparative advantage (RCA), and a small number of other countries can export these goods. The economy is then diversified and less ubiquitous (Koch, 2021). However, less developed economies manufacture ubiquitous items that demand narrow knowledge networks and have a limited productive knowledge base (Neagu, 2019). Furthermore, Hidalgo and Hausmann (2009) emphasized that economic complexity measures can illustrate cross-country income differences based on the diversity of the capabilities present in each country that can predict their respective living standards.

Economic diversification raises the number of economic activities a country involves in, which lowers the risks of economic crisis, market fluctuations, and technological changes (Ferraz et al., 2021). However, very few developing countries have reached a level of diversification comparable to developed countries (UNTCAD, 2019). The advanced economies are the leading exporters of high-value-added products because these nations have the necessary productive knowledge to diversify their exports (Erkan & Yildirimci, 2015). Complex products such as machinery, electronics, and chemicals which represent large shares of the world trade in goods (US$2 trillion), require a higher accumulation of capabilities. Contrarily, simpler products such as agricultural goods, textiles, and other basic manufacturing activities need less productive knowledge, although these goods have contributed less than 10 percent of the global trade value (UNTCAD, 2019; Center for International Development, 2013).

According to Woetzel et al. (2014), the majority of ASEAN nations produce low-complex products, which prevents them from progressing to a stage of higher income levels. Additionally, exports of raw materials constitute a significant part of East African economies. The production of similar goods with close RCA restricts the potential for interregional trade expansion in these countries (African Union Commission [AUC] & OECD, 2019). Despite the fact that East African nations have greater RCA in raw materials and vegetables, they have low or no comparative advantage in highly sophisticated products. The linkage between ECI and export performance for COMESA (Common Market for Eastern and Southern Africa) and East Asia (ASEAN plus China P.R, Hong Kong, South Korea, and Japan) in 2019 is depicted in Figure 1. Countries with higher ECI tend to demonstrate higher export value, while less complex economies have lower export performance, as illustrated in the figure. This indicates that whenever the country is diversified, such as Japan, South Korea, and Singapore, it tends to export products with higher export values, whereas the least diversified economies, such as Sudan, Libya, and D.R. Congo, export ubiquitous products that generate low export values.

A considerable number of COMESA and East Asia countries are delineated by low complexity rankings due to their engagement in the production of simpler goods. This is reflected by the credence of the agriculture sector, which employs more than 60% in the East Africa region (International Labour Organization [ILO], 2019). However, the sector is vulnerable to shocks brought by environmental conditions, such as droughts and price volatility in international markets (OECD, 2019). Therefore, it is pivotal that these countries make a productive transformation to move from the production of primary products towards highly intensive manufacturing activities for long-term employment and trade opportunities. Notably, the establishment of a firm economic complexity with accumulated productive capabilities can be achieved through a structural transformation that shifts developing countries from less productive activities to a more diverse set of manufacturing activities (Bhorat et al., 2019; Hausmann & Hidalgo, 2011).

The study of complexity methods has been vitalized by the revival of industrial policy and the development of endogenous growth theory, which considers the advancement of knowledge as the driver of future economic growth (Hidalgo, 2021). Besides, the gravity model has long been used to measure trade flows associated with economic size and trade costs. Jun et al. (2020) underlined that market size, transportation costs, common language, and cultural ties do not determine trade flows entirely. They emphasized that knowledge diffusion

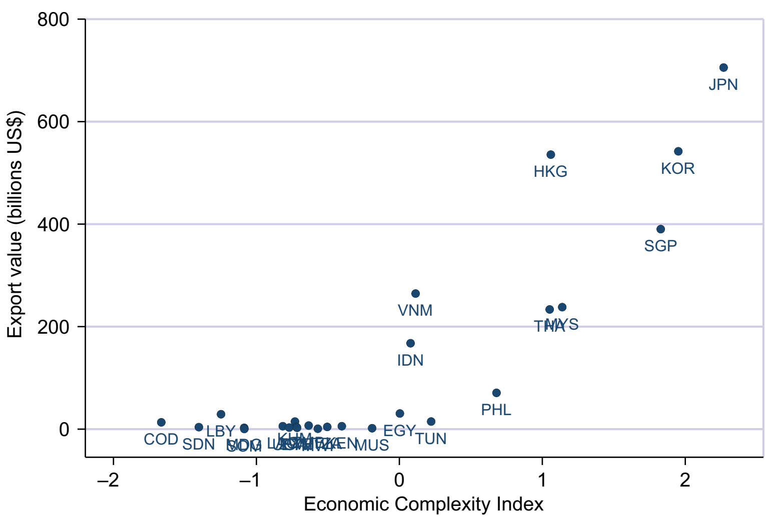

Figure 1. The relationship between ECI and Export Performance in 2019
(source: UN COMTRADE, 2021; Observatory of Economic Complexity [OEC], 2020)

and information friction direct the variety of products a country can export. Remarkably, economic complexity is likely to affect trade volume due to the growing intra-industry trade. It is striking to quantify the importance of economic sophistication and knowledge accumulation on trade performance. Numerous studies have analyzed the effects of ECI on income inequality, foreign direct investment, and output volatility (Güneri & Yalta, 2021; Hartmann et al., 2017; Khan et al., 2020; Lee & Wang, 2021). To the best of our knowledge, there is an absence of empirical literature that focuses on the consequences of productive knowledge and diversification for bilateral trade flows, despite the increasing interest in research on economic complexity.

A country's trade structure and productive capacity became essential factors for the products that the economy exported. Accordingly, there is a need to elucidate the current complexity status of the economies in our sample to enhance their productive structures and export performance. Hence, this study aims to identify the effect of economic complexity on the bilateral trade flows of the two regions of COMESA and East Asia. The research uses sectoral trade data (SITC–Revision 3) from UN COMTRADE that considers three product communities: machinery and transport equipment, manufactured products, and food and live animals since they contribute a large volume in the global trade. The export of these products is disaggregated because the impact of economic complexity varies among different kinds of goods. For instance, exports of transport equipment, chemicals, and machinery need higher production capabilities than basic manufacturing goods, such as textiles, clothing, and footwear. However, exporting raw materials and agricultural products demand less sophistication due to the smaller network of productive capabilities required in these commodities.

Given this background, this study will contribute to policymakers and the literature as follows. The policymakers in the natural resource-reliant economies of COMESA and East Asia are concerned with the diversification of their exports. Therefore, the study's findings would be beneficial to policymakers in formulating strategies to ramp up economic diversification and enhance productive structures. By identifying the impacts of economic complexity on various export commodities, the policymakers in COMESA and East Asia could enact policies that shift their economic structures from the production of primary products to more sophisticated and high-value-added products. Moreover, it is critical to recognize the relevance of industrial organization and economic policy in accomplishing the structural transformation. The findings of the study enlighten that the productive transformation of the countries' export structures could be achieved through diverse productive activities by adhering to relatively more complex products. The engagement of more sophisticated products enables the economies of COMESA and East Asia to achieve increased export growth and income levels since economic diversification is incorporated with higher per capita income and more trade opportunities.

By investigating the connection between economic complexity and bilateral trade flows, the current study makes several contributions to the expanding literature. Firstly, the study provides the first empirical evidence about the effects of economic complexity on bilateral trade flows using sector-specific trade data. This highlights the importance of economic complexity in stimulating the trade performance of certain commodities. Secondly, unlike the existing literature, we divide the 27 countries covered in our sample in relation to their geographical location and income levels. This presents robust evidence of how bilateral exports react to economic complexity based on geographical and income differences between trading partners. The empirical evidence that classify trading partners based on their geography and income are not only rare but also did not account for the importance of countries' productive structures for the exported goods. For instance, Narayan and Nguyen (2016) used various panels based on regions and income levels to investigate the bilateral trade relations between Vietnam and its top 54 trading partners. However, they did not consider the effect of economic complexity on the bilateral trade flows. Thirdly, the study applies the gravity trade model with multiple specifications using the Poisson pseudo maximum likelihood (PPML) estimator in examining the connection between economic complexity and bilateral trade flows of the countries in COMESA and East Asia. This approach has its advantage in dealing with heteroscedasticity and other common issues in trade data (Piermartini & Yotov, 2016; Silva & Tenreyro, 2006). Fourthly, the study focuses on the two FTAs in COMESA and East Asia, which are among the fastest-growing emerging economies. Although these FTAs consist of countries from various development levels, studying these economies can shed some light on the importance of economic complexity to stimulate their trade performance and economic growth. Even though multilateral trade agreements are essential for facilitating trade flows, little is known about the COMESA countries whose intra-regional trade is much lower than in East Asia.

The rest of the paper will be organized as follows. The second section reviews the related literature on economic complexity and the gravity model of trade. The third section presents the study's methodology, including the specification of the equation and the econometric estimates. The fourth section highlights the results and interpretations from the data. The last section provides conclusion and policy implications based on the findings.

1. Literature review

In significant advancements of the past two decades, a growing body of literature on economic development theory focused on the extent of diversification and the expertise in a country's production and trade structure (Sepehrdoust et al., 2019). For instance, Şeker and Şimdi (2019) discovered that economic complexity had a long-run linkage with the bilateral exports of Turkey and Central Asian and Turkic Republics (CATRs). In the same vein, Erkan and Yildirimci (2015) demonstrated a positive link between economic complexity and export competitiveness. The study further noted that developing countries should produce high-value-added products and science-based manufacturing instead of exporting raw materials and simple manufacturing goods to enhance their complexity and competitiveness.

The studies about the importance of know-how in diversifying economic activities had intensively emphasized product relatedness. For instance, Hidalgo et al. (2007) proposed the idea of product space as a network of products that are likely to be co-exported. The purpose was to exhibit the probability that a nation enters or exits an export market depending on the country's number of related current exports of that industry. Likewise, the relatedness of economic activities occurs when two products have similar knowledge or inputs, which promotes export diversification since products share productive capabilities and knowledge diffusion (Hidalgo et al., 2018). Furthermore, Hausmann and Hidalgo (2011) modelled the network structure of economic output by assuming that products require a large number of non-tradable inputs or capabilities, and countries diverge in these capabilities. They observed that the expected diversification growth from the accumulation of capabilities is negligible for countries with few and significant for those with many capabilities. Using multiple gravity specifications, Jun et al. (2020) separated the relatedness of bilateral trade into three categories by applying bilateral trade data from 2000 to 2015. Firstly, product relatedness interrogates whether a country exports many similar products to a specific destination. Secondly, importer relatedness quests if a country exports similar products to the neighbours of the target destination. Thirdly, exporter relatedness asks whether a country's neighbours are already exporting the same product to the destination. The study found that common language and product relatedness describe aspects of knowledge relatedness, which are crucial for exchanging more sophisticated and differentiated products. Additionally, countries increase the exports of a product to a destination for the presence of any form of relatedness.

Besides the significance of productive structures for a country's trade performance, the literature on economic complexity thoroughly focused on other aspects of economic development. The link between economic complexity and income inequality was hugely investigated in previous studies (Hartmann et al., 2017; C.-C. Lee & Wang, 2021). The results demonstrate that countries that export less complex goods tend to have higher unequal income distribution than countries that export more complex and sophisticated products. This suggests that a complex product structure can mitigate income inequality. Moreover, Doğan et al. (2021) investigated the contribution of economic complexity to alleviating environmental degradation. The findings show that exporting more sophisticated products and renewable energy use might help reduce the environmental degradation problems in OECD countries. Similarly, Can and Gozgor (2017) found that a higher economic complexity suppresses CO_2 emissions in the long run. This means that as the country's level of complexity increases, it will induce CO_2 emissions to decline.

It is noteworthy that economic diversification enhances the productive capabilities of developing economies that boost growth, attract foreign enterprises, and reduce frequent output fluctuations. Güneri and Yalta (2021) applied the generalized method of moments (GMM) to explore the effects of economic complexity on output volatility. The findings show that economic complexity decreases output volatility and improves the country's productive structure to more sophisticated products. In addition, using ARDL and VECM, Khan et al. (2020) demonstrated the significance of FDI inflows by investigating the bidirectional causal relationship between economic complexity and foreign direct investment in China. The finding confirms that economic complexity and FDI have a long-run bidirectional and short-run unidirectional causal link.

The gravity model has long been the prime focus of international trade for analyzing trade patterns. Tinbergen (1962) pioneered the gravity-based models of trade which proposed that trade flow between any two countries depends positively on their respective economic sizes and adversely on the distance between them. Many contemporary studies have been done about the gravity models, including Anderson (1979), who suggested that gravity-based trade is fundamentally relevant to product differentiation by the trading countries and the love of variety by the consumer, which is the driving force of trade. Most recent studies that applied the gravity model of trade preferred panel data over cross-sectional because it considers better country-specific unobserved and time-invariant heterogeneity (Ahcar Olmos & Rodríguez-Barco, 2020). However, there was an evolution in the panel estimation techniques where most studies have used fixed and random effects (Baier & Bergstrand, 2007; Bussière et al., 2008; H. Lee & Park, 2007). At the same time, some others used these panel methods with Hausman-Taylor Method (HTM) (Abedini & Péridy, 2008). Based on econometric progress, estimating the gravity models necessitates a proper method that captures the theoretical constructs of multilateral resistances. Silva and Tenreyro (2006) suggested the use of non-linear estimators like PPML because of many benefits over other estimation techniques. It considers multilateral resistance terms; it deals with heteroscedasticity, which is inevitable in trade data; the frequency of zero trade flows, and the inconsistency of the OLS and the other estimators.

Despite the expanding recent literature, studies that figure out the link between economic complexity and trade performance still need to be included. Research on inclusive growth, environmental sustainability, and output fluctuations have been using economic complexity as an indicator to enhance sustainable development (Can & Gozgor, 2017; Doğan et al., 2021; Güneri & Yalta, 2021; Hartmann et al., 2017; Khan et al., 2020; C.-C. Lee & Wang, 2021). However, the literature disregarded the significance of productive knowledge and skills for advancing trade flows, even though their importance is expanding.

Given this backdrop, this study fills the gap in the literature in the following ways. First, this study extends the gravity trade model to analyze the effect of economic complexity on bilateral trade flows. For this purpose, sectoral trade data will be applied to observe the influence of know-how on the trade volume of three specific sectors. Second, we apply the PPML method to this extent, which recently became very common for trade flow analysis. Third, the study considers the role of FTAs on bilateral trade flows, particularly in some selected COMESA and East Asia countries. Thus, it could be useful to the policymakers of these emerging economies to understand the role of know-how in improving trade. Eminently, the study results will lead to inspecting their current economic complexity status to enhance the skills of their labour and productive structures to achieve better future economic growth.

2. Data and research methodology

2.1. Data

Economic Complexity Index (ECI) data are from MIT's Observatory of Economic Complexity. The estimations of this study were conducted using annual panel data from 27 countries between 1995 and 2019. The bilateral export data for the country pairs (CPs) are extracted from the UN COMTRADE database, where the data were organized based on the Standard International Trade Classification (SITC), revision 3. It consists of the exports of each pair where the exporter and the importer countries report their trade information every year. This study focuses on trade in three sectors: food and live animals, manufactured goods classified by material, and machinery and transport equipment. In addition, Table A1 in the Appendix presents the country pairs from the two regions selected for the study.

Most studies on the gravity model use Gross Domestic Product (GDP) and population to proxy for the economic sizes of the trading partners. The macroeconomic data of GDP (in current US dollars) and the population was obtained from World Bank's World Development Indicators Database. The geographical data on the bilateral distances between the most populated cities and cultural data for the common border, colonial ties, and shared language came from the GeoDist database CEPII (Mayer & Zignago, 2011). For the trade integration, the study included dummies for the existence of free trade agreement (FTA) between exporter and partner country, which is unity if there is any and 0 otherwise. Table 1 summarizes the variables, units of measurement, symbol, and sources of data.

Table 1. Variables, measurement, and data sources

Variables	Symbol	Measurement	Data Source
Exports of agricultural goods	X_{AGR}	The nominal value of bilateral exports	UN COMTRADE
Exports of manufactured products	X_{MANUF}	The nominal value of bilateral exports	UN COMTRADE
Exports of machinery and transport equipment	X_{MACH}	The nominal value of bilateral exports	UN COMTRADE
Gross Domestic Product	GDP	The nominal value of GDP (millions $)	WDI
Population	POP	Population, total (millions)	WDI
Distance	DIST	The geographical distance between capital cities of countries (thousands of kilometers)	CEPII
Contiguity	CONTIG	1 = countries share borders, 0 otherwise	CEPII
Common language	LANG	1 = countries share a common language, 0 otherwise	CEPII
Colony	COL	1 = colonial history exists, 0 otherwise	CEPII
Economic complexity	ECI	Economic complexity index	OEC
Free Trade Agreement	FTA	Unity if two countries share FTA, 0 otherwise	WTO

2.2. Economic Complexity Index (ECI)

To quantify the impact of economic sophistication and diversity of products on the trade flows of the selected countries, we use the Economic Complexity Index (ECI) constructed by Simoes and Hidalgo (2011). ECI combines data on the diversity of a country (the number of products it exports) and the uniqueness of its products (the number of other countries that can export that good) to measure the complexity of a country's export structure by considering the amount of productive knowledge associated with each product. The perception behind the use of ECI is that those complex economies are the exporters of diversified and unique products that very few other countries can make these sophisticated products. In contrast, less complex economies are familiar with the export of ubiquitous products.

ECI is calculated from export data linking countries to the goods in which they have Revealed Comparative Advantages (RCA) (Hidalgo & Hausmann, 2009). RCA is defined as the ratio of a country's exports in a particular product category to its share in total merchandise exports (Balassa & Noland, 1989). The RCA of a country c in a product p formula was derived using the Balassa index:

$$RCA_{cp} = \frac{X_{cp} / \Sigma_{p'} X_{cp'}}{\Sigma_{c'} X_{c'p} / \Sigma_{c'p'} X_{c'p'}}, \tag{1}$$

where X_{cp} is country c's exports of product p. Let M_{cp} be a matrix summarizing the export of product (p) by country (c). Usually, M_{cp} is defined as $M_{cp} = 1$ when a country's output in a good has a revealed comparative advantage (RCA) larger than what is expected for a country of the same size and a product with the same total output.

$$M_{cp} = 1 \text{ if } RCA_{cp} \geq 1; \tag{2}$$

$$M_{cp} = 0 \text{ if } RCA_{cp} < 1. \tag{3}$$

The M_{cp} matrix allows to describe the diversity of a country as the complexity K of country c to be K_c which is the number of goods that are exported by a country with comparative advantage. On the other hand, the ubiquity of a product as the complexity K of a product p to be K_p which is the number of other countries that export that good with comparative advantage.

$$\text{Diversity: } K_c^{(0)} = \sum_p M_{cp}; \tag{4}$$

$$\text{Ubiquity: } K_p^{(0)} = \sum_c M_{cp}. \tag{5}$$

Subsequently, the ubiquitousness of a product is described by a matrix that links countries that export similar products and normalized by the diversity of a country:

$$\widetilde{M}_{cc'} = \frac{1}{K_{c,0}} \sum_p \frac{M_{cp} M_{c'p}}{K_{p,0}}. \tag{6}$$

Formally, the Economic Complexity metric will be defined as follows:

$$ECI_c = \frac{K_c - \langle K \rangle}{std(K)}. \tag{7}$$

This equation indicates that the economic complexity index of country c where K_c is the eigenvector of $\widetilde{M}_{cc'}$ associated with the second largest eigenvalue – the vector associated with the largest eigenvalue is a vector of ones. In addition, $\langle K \rangle$ is an average and $std(K)$ represents the standard deviation of the complexity of a country (Caldarelli et al., 2012; Hausmann et al., 2014).

2.3. Model specification

We employ a structural gravity model of international trade that links trade flows directly with economic size and inversely with trade costs, as suggested by Tinbergen (1962). In its most fundamental form, the gravity model is written as follows:

$$lnX_{ij} = \beta_0 + \beta_1 lnGDP_i + \beta_2 lnGDP_j + \beta_3 ln\tau_{ij} + e_{ij}, \tag{8}$$

where X_{ij} indicates bilateral exports from the exporter country i to the importer country j,

GDP_i and GDP_j is the gross domestic product of the trading countries, τ_{ij} represents trade costs of the trade partners which can further be expanded as shown in Eq. (9):

$$ln\tau_{ij} = lnDIST_{ij} + lnCONTIG_{ij} + lnLANG_{ij} + lnCOL_{ij}, \quad (9)$$

where $DIST_{ij}$ is the geographical distance between countries as an observable proxy for trade costs, $CONTIG_{ij}$ measures whether there is a common border between the two trading partners, $LANG_{ij}$ captures the possibility of the use of a common language, while COL_{ij} captures whether the trading partners have colonial ties and e_{ij} is a random error term. The *ln* denotes variables in natural log form, the β_0 term is a regression constant, and the other β terms are coefficients to be estimated. Instead of the structural gravity model, some studies in the literature extended the gravity model to analyze the effect of trade policies. Therefore, this study adds to the basic gravity model ECI variable as a measurement of the economy's productive capacity, which determines its export baskets. Furthermore, to remark on the economic sizes of the trade partners' export volume, the population (POP) of the trading partners is included. A dummy variable will be used to capture the effect of FTAs on trade flows. The following model is obtained:

$$lnX_{ijt} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{jt} + \beta_3 lnPOP_{it} + \beta_4 lnPOP_{jt} + \beta_5 lnDIST_{ij} + \beta_6 CONTIG_{ij} + \beta_7 LANG_{ij} + \beta_8 COL_{ij} + \beta_9 ECI_{it} + \beta_{10} ECI_{jt} + \beta_{11} FTA_{ijt} + e_{ijt}, \quad (10)$$

where ECI_{it}, ECI_{jt}, POP_{it} and POP_{jt} measure the economic complexities and population of country *i* and country *j*. FTA_{ij} is binary variable that is unity if the pairs have membership of the same free trade agreement and 0 otherwise.

Because the number of countries in our panel data exceeds the period, stationarity and spurious regression are of no concern for this study (Dadakas et al., 2020). We employ the Poisson pseudo maximum likelihood (PPML) estimator for our analysis as the most efficient and correctly specified approach suggested by Silva and Tenreyro (2006). Since the PPML regression utilizes an exponential function, Eq. (10) is transformed as follows:

$$X_{ijt} = exp\ (\beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{jt} + \beta_3 lnPOP_{it} + \beta_4 lnPOP_{jt} + \beta_5 lnDIST_{ij} + \beta_6 CONTIG_{ij} + \beta_7 LANG_{ij} + \beta_8 COL_{ij} + \beta_9 ECI_{it} + \beta_{10} ECI_{jt} + \beta_{11} FTA_{ij}) \times e_{ijt}. \quad (11)$$

Piermartini and Yotov (2016) proposed that the multiplicative form of the PPML for the estimation of the structural gravity can take into account heteroscedasticity problems and zero trade flows frequent in trade data. The PPML with its additive property, ensures that the fixed effects are consistent with the structural terms, the multilateral resistances (Arvis & Shepherd, 2013; Fally, 2015).

3. Results and discussion

3.1. Evolution of complexity and world rankings of the selected countries

This section presents the evolution of economic complexities of the countries in our sample during the last decade. As indicated in Table 2, most of the countries in our sample performed well from 2009 to 2019. The entire economies in East Asia showed positive development, and most COMESA countries grew their world rankings and complexity indices during the decade. However, several countries showed a decline in their complexity rankings.

Table 2. The progress of economic complexity and world rankings 2009–2019
(source: authors' calculation using data from OEC, 2020)

Country/Region	World Rank		ECI		Δ World Rank	Δ ECI
	2009	2019	2009	2019	(2009–2019)	(2009–2019)
East Asia						
Japan	1	1	2.27	2.28	0	0.01
South Korea	12	5	1.61	1.95	7	0.34
Singapore	11	6	1.63	1.82	5	0.19
Malaysia	31	25	0.95	1.13	6	0.18
Hong Kong	40	28	0.7	1.06	12	0.36
China	36	29	0.78	1.06	7	0.28
Thailand	44	31	0.6	1.05	13	0.45
Philippines	61	42	0.28	0.68	19	0.4
Viet Nam	93	67	–0.3	0.11	26	0.4
Indonesia	83	69	–0.2	0.08	14	0.25
Cambodia	144	119	–1.4	–0.73	25	0.68
Laos	140	125	–1.3	–0.82	15	0.44
COMESA						
Egypt	89	75	–0.2	0.003	14	0.2
Mauritius	103	84	–0.6	–0.19	19	0.36
Tunisia	77	62	–0.1	0.22	15	0.27
Kenya	100	96	–0.4	–0.4	4	0.01
Tanzania	122	103	–0.8	–0.51	19	0.28
Malawi	146	108	–1.5	–0.57	38	0.88
Zambia	110	111	–0.6	–0.63	–1	0.01
Ethiopia	117	116	–0.8	–0.72	1	0.03
Zimbabwe	96	117	–0.3	–0.72	–21	–0.4
Uganda	104	122	–0.6	–0.77	–18	–0.21
Somalia	67	135	0.1	–1.09	–68	–1.19
Madagascar	135	136	–1.1	–1.09	–1	0.05
Libya	105	142	–0.6	–1.25	–37	–0.67
Sudan	154	146	–2.1	–1.4	8	0.74
D. R Congo	147	152	–1.6	–1.66	–5	–0.1

Some countries in East Asia made massive progress by moving from very low complex rankings. For example, in 2009, Thailand and the Philippines had complexity indices of 0.6 and 0.28, respectively. Thailand's complexity index grew substantially to 1.05, which raised its world ranking from 44th to 31st in 2019. The Philippines made similar progress of change in the complexity index by 0.40, that took its global rank to 42nd from 61st. In 2009, Viet Nam and Indonesia had negative complexity indices of –0.3 and –0.2 that reflected lower world ranks, 93rd and 83rd, respectively. In 2019, these economies transformed to have better complexity of 0.11 and 0.08, which rose to better ranks 67th and 69th, respectively. Cambodia and Laos are the lowest complex economies in ASEAN, but they developed their indices that were the initial period –1.4 and –1.3, with a world ranking of 144th and 140th, respectively. Hence, in 2019, they made tremendous progress that increased their complexity indices by 0.68 and 0.44, with higher global rankings of 119th and 125th, respectively.

Although other economies such as South Korea, Singapore, Malaysia, Hong Kong, and China had complexity indices greater than one, they exhibited little progress compared to other countries. Malaysia, Singapore, and China showed subtle change during the decade since they made slow complexity positive change that was, on average, 0.22. In relation to, South Korea and Hong Kong, grew in complexity by 0.34 and 0.36, respectively. This progress takes South Korea from 12th to 5th while Hong Kong moved from 40th to 28th. Japan was the only economy with the same rank and economic complexity index over the period.

Despite COMESA countries being considered the least complex economies, most of them substantially improved their production capabilities. In 2009, Somalia was the only country in the region that had a complexity index greater than 0. Still, at the end of the decade, the country exhibited the most significant complexity decline from 0.1 to –1.09, and its world ranking dropped from 67th to 135th. Similarly, although Libya and Zimbabwe had very low complexity in 2009, they faced a considerable loss in their complexity indices and rankings at the end of the decade. Libya's complexity index dropped from –0.6 to –1.25, and its world rank declined from 105th to 142nd, while Zimbabwe's complexity declined by –0.4, lowering its rank by 21 below where it was in 2009. Uganda and D.R Congo decreased their complexities by –0.21 and –0.1, respectively, dropping their rankings by 18 and 5 lower than in 2009.

On the other hand, Mauritius, Malawi, and Sudan have experienced the highest complexity growth of 0.36, 0.88, and 0.74, respectively. Even though they exhibited the most considerable progress throughout our sample countries and improved their productive capabilities, these countries are still at the bottom of the global ranking. This shifted Mauritius from 103rd to 84th, Malawi moved from 146th to 108th, while Sudan, one of the lowest complex economies, improved its index to –1.4 from –2.1. Other countries such as Kenya, Zambia, Ethiopia, and Madagascar had effectively stagnated by 0.01, 0.01, 0.03, and 0.05, indicating comparatively low improvement of their respective complexity levels and rankings. Throughout the decade, Egypt, Tunisia, and Tanzania grew their complexities by 0.2, 0.27, and 0.28, respectively. However, in 2019, Tunisia and Egypt became the only countries with complexity indices larger than 0, which are 0.22 and 0.003, respectively. This made them among the highest complex economies in the region.

3.2. Descriptive statistics of the variables

This section discusses the descriptive analysis of the variables in the current study, as shown in Table 3. We classified the summary statistics based on the geographical regions of East Asia and COMESA. In general, the export value of East Asia economies was more extensive than that of COMESA. The mean of the export values of machinery and transport equipment is the highest among the other sectors across the two regions since it is associated with a vast accumulation of capabilities that make it the highest value-added product. It has a mean value of USD 5,910 million in East Asia compared to 3.594 in COMESA. Moreover, the mean value of the bilateral exports of manufactured goods is USD 1,540 million in East Asia, whereas the value is USD 11.400 million in COMESA economies. The mean value of the exports of agricultural goods between East Asia countries is USD 405 million, while the value is USD 12.400 million in COMESA. In addition, the exports of machinery and transport equipment had the highest maximum value of USD 248,000 million in East Asia countries, even though agricultural exports had the highest maximum value of USD 1,280 million in COMESA economies. The different export commodities can be observed in that

Table 3. Descriptive statistics of the variables

Variable	Mean	Std. dev.	Minimum	Maximum	Observations
East Asia					
X_{AGR}	405	960	0.000	10,800	2,933
X_{MANUF}	1,540	3,490	0.000	26,400	3,171
X_{MACH}	5,910	18,700	0.000	248,000	3,124
GDP_i	1,160,000	2,150,000	2,660	11,500,000	3,300
GDP_j	1,160,000	2,150,000	2,660	11,500,000	3,300
POP_i	169	352	3.525	1,400	3,289
POP_j	169	352	3.525	1,400	3,289
DIST	2,627	1,899	316	5,791.63	3,275
CONTIG	0.167	0.373	0.000	1	3,300
LANG	0.129	0.335	0.000	1	3,300
COL	0.076	0.265	0.000	1	3,300
ECI_i	0.496	1.005	−1.581	2.464	2,970
ECI_j	0.496	1.005	−1.581	2.464	2,970
FTA	1	0.000	1	1	3,300
COMESA					
X_{AGR}	12.400	45.700	0.000	1280	2,713
X_{MANUF}	11.400	37.200	0.000	623	2,918
X_{MACH}	3.594	13.300	0.000	355	2,908
GDP_i	35,400	47,700	865	302,000	5,180
GDP_j	35,400	47,700	865	302,000	5,180
POP_i	30.300	26.200	1.122	112	5,250
POP_j	30.300	26.200	1.122	112	5,250
DIST	3,114	1,763.412	376	8,054	5,250
CONTIG	0.162	0.368	0.000	1	5,250
LANG	0.495	0.500	0.000	1	5,250
COL	0.367	0.482	0.000	1	5,250
ECI_i	−0.697	0.516	−2.229	0.526	4,186
ECI_j	−0.696	0.516	−2.229	0.526	4,181
FTA	1	0.000	1	1	5,250

Notes: Author's estimates. Mean values for exports, GDPs and population are presented in millions.

agricultural products are the lowest traded, while manufactured goods by material exports have been traded more frequently than other product communities. Minimum zero trade flows occur when two countries do not trade for a particular year. The standard deviation of the export data is high, indicating that in trade analysis, the data is wide across countries and sectors due to the frequency of zero trade flows, leading to a heterogeneity problem. This necessitates the use of the PPML estimator, as suggested by previous studies (Piermartini & Yotov, 2016; Silva & Tenreyro, 2006).

In addition, the average value of the GDP for the exporter and importer is USD 1,160 billion in East Asia countries. The minimum GDP value was USD 2,660 million, and the maximum was 11.5 trillion. However, the mean GDP in the COMESA economies is USD 35,400 million, whereas the maximum and minimum values are USD 302,000 million and USD 865 million, respectively. This indicates the wider income gap between the countries in the two regions. Moreover, the average population in East Asia is 169 million compared to the COMESA, which has a mean of 30.3 million people. The least-populated nation in East Asia has 3.525 million people, whereas the highest-populated country has 1.40 billion people. In COMESA, the minimum value of the population is 1.122 million people, and the maximum is 112 million people. On the other hand, the average distance between the capital cities of the trading partners in East Asia is 2,627 km, which is much lower than that of COMESA trading partners, 3114 km. We use dummy variables equal to unity for countries with the same border, common official language, and colonial history. We observed from Table 3 that the mean of the common border is 0.167 and 0.162 for East Asia and COMESA nations, respectively. Furthermore, nearly half of the trading partners in COMESA have a common language (0.495) and common colonial ties (0.367), which theoretically enhances trade flows between the trading partners through reduced transaction costs. However, the average of the countries with language ties in East Asia is low (0.129), as well as those with common colonial links (0.076).

The average value of economic complexity in East Asia is 0.496, whereas the standard deviation is 1.005. The wide variability between the maximum of 2.464., extremely complex, and the minimum of –1.581, least complex, indicates the development gap between the region's highest and lowest complex economies. In COMESA, the mean value of the ECI is –0.697. This low value reveals that lower productive structures and insufficient accumulation of capabilities characterize a higher proportion of the countries in the region. The least complex economy in the region had an ECI of –2.229, while the most complex economies in COMESA have an economic complexity of 0.526. Additionally, the FTA dummy is one if there was an agreement in place between countries in COMESA or East Asia during a specific year. Dadakas et al. (2020) suggested that using a single dummy variable to capture the effect of several RTAs was econometrically valid. The average value for the FTA for both regions is 1, which indicates that countries in the same region had regional trade agreements.

3.3. Gravity model estimates of the PPML: regional groups

This section presents the gravity model estimates based on COMESA and East Asia regions, as presented in Table 4. Most of the explanatory variables exhibited significant results across the panels. We found that the GDPs of the exporter and importer countries were positively associated with various export commodities across regional groups. For COMESA countries, a percentage increase in the exporters' GDP increases exports of agricultural products, manufactured goods, and machinery and transport equipment by 2.621%, 1.092%, and 0.979%, respectively. However, the exporters' income elasticities are lower for East Asia countries compared to their trading partners in COMESA. A 1% rise in the exporter's GDP raises the exports of agricultural products (0.501%), manufactured goods (0.709%), and machinery and transport equipment (0.928), respectively. Moreover, the importer's GDP was positive and significant for all panels except the East Asia manufactured exports. It is notable that the elasticities of the importer's GDP were higher for the exports of manufactured products and

Table 4. Gravity model estimates of bilateral exports using PPML by region

Variables	COMESA			East Asia		
	X_{AGR}	X_{MANUF}	X_{MACH}	X_{AGR}	X_{MANUF}	X_{MACH}
C	7.298 (5.925)	−7.654 (5.602)	−11.640 (7.162)	1.119 (7.640)	8.091*** (3.030)	57.877*** (6.405)
$lnGD_Pi$	2.621*** (0.457)	1.092** (0.430)	0.979* (0.517)	0.501*** (0.074)	0.709*** (0.072)	0.928*** (0.110)
$lnGDP_j$	0.685*** (0.247)	1.613*** (0.240)	1.464*** (0.344)	0.730*** (0.176)	−0.231 (0.360)	0.694*** (0.082)
$lnPOP_i$	−2.579** (1.046)	−0.502 (0.899)	−0.417 (1.066)	−0.094 (0.292)	−1.437*** (0.395)	−1.552*** (0.321)
$lnPOP_j$	−0.440 (0.663)	−1.367** (0.684)	−0.991 (0.734)	−0.467 (0.415)	1.606 (1.214)	−2.747*** (0.271)
lnDIST	−2.539*** (0.150)	−1.441*** (0.100)	−1.169*** (0.166)	−0.667*** (0.029)	−0.414*** (0.005)	−0.310*** (0.028)
CONTIG	0.055 (0.205)	1.294*** (0.178)	1.282*** (0.251)	0.643*** (0.056)	0.979*** (0.130)	1.123*** (0.043)
LANG	−1.166*** (0.131)	0.160 (0.161)	−0.126 (0.154)	0.587*** (0.070)	0.563* (0.309)	0.479*** (0.059)
COL	−0.967*** (0.198)	−1.728*** (0.286)	−0.506** (0.207)	−0.114 (0.074)	−0.235 (0.368)	−0.115 (0.091)
ECI_i	0.034 (0.209)	0.280 (0.231)	0.802*** (0.292)	0.014 (0.084)	0.250*** (0.080)	0.647*** (0.106)
ECI_j	−0.618*** (0.123)	−0.833*** (0.142)	−0.650*** (0.149)	0.671*** (0.107)	0.538*** (0.073)	0.373*** (0.080)
R^2	0.790	0.754	0.705	0.883	0.886	0.935
Observations	1,917	2,104	2,111	2,658	2,682	2,693
No. of pairs	105	105	105	66	66	66
Fixed effects	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT
RESET Test (p-value)	0.296	0.273	0.022	0.151	0.000	0.031

Notes: The dependent variable for all models is the export value from country i to j. X_{AGR}, X_{MANUF}, and X_{MACH} indicate the exports of agricultural goods, manufactured products, and machinery and transport equipment, respectively. Values in parenthesis are standard errors. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. ET and IT are the importer and exporter time fixed effects included in all models.

machinery and transport equipment, while it was lower for the agricultural exports. Similarly, other studies confirmed from the various regions that the exporter and import GDPs enhance the bilateral exports between members of particular regions (Ekanayake et al., 2010; Luqman et al., 2016; Zainuddin et al., 2020). Contrary to the expectations, the population of exporters and importers exhibited that they are negatively related to various exports in some panels, even though it was insignificant for most of the panels. These results are consistent with earlier research by Mátyás (1997), who found that trading populations of countries had a negative and significant impact on trade flow. On the other hand, our findings run counter to recent research by Zainuddin et al. (2020).

The findings also indicate that geographical distance is negative and statistically significant for all panels. The exports of COMESA and East Asia's agricultural goods are more sensitive to the distance between the trading partners. It is noteworthy that the distance elasticity of the export of machinery and transport equipment is lower for both regions, which shows that the export of more capital-intensive products is less sensitive to distance than agricultural and basic manufactured goods. These findings are consistent with the predictions of the gravity model literature that greater distances raise transportation costs and reduce trade (Brodzicki & Uminski, 2018; Dadakas et al., 2020). In addition, the outcomes indicate that common borders have favourable and statistically significant effects on exports for all panels across regions, except the export of agricultural goods. Likewise, Zainuddin et al. (2020) and Ekanayake et al. (2010) support our findings that a common border contributes to higher bilateral exports. This indicates that countries with shared borders have higher bilateral trade flows due to lower transportation costs. Furthermore, the results suggest that a common language significantly improves the exports of various commodities between East Asia countries. This is in line with the findings of Dadakas et al. (2020) and Frede and Yetkiner (2017), which indicates that countries with common language trade more than others. However, the common language dummy was only significant and negatively influenced agricultural goods exports for countries that share a language in COMESA. Moreover, colonial ties reduce the exports of agricultural products, manufactured goods, and machinery and transport equipment in COMESA, even though it does not significantly influence the variety of exports of East Asia nations. This result is against the gravity model literature that asserts when countries have a common colonial history, they are expected to have greater bilateral trade volume (Ekanayake et al., 2010; Gupta et al., 2019).

The results indicate that the effect of economic complexity varies across regions and export commodities. For instance, the exporter's economic complexity indicates that it increases the exports of machinery and transport equipment by 0.802% (COMESA) and 0.647% (East Asia). Additionally, the exporter's ECI was significant for the exports of manufactured goods in East Asia, even though it does not significantly affect the exports of agricultural products for both regions. On the other hand, the importer's economic complexity enhances the exports of all export groups for East Asia. A percentage increase in the importer's ECI enhances exports of agricultural goods (0.671%), manufactured goods (0.538%) and machinery and transport equipment (0.373%). In contrast, the importer's ECI negatively influences the export of all commodities in COMESA. It notable that in models with time-varying ET/IT FEs included in the regressions of each region, the FTA coefficients are not estimable.

3.4. Gravity model estimates of the PPML: income groups

To understand how economic complexity affects the exports of countries with various income levels, we classified the economies in our sample into different income groups, namely: low-income (LI), lower-middle-income (LMI), upper-middle-income (UMI), and high-income (HI) countries. The estimates of the bilateral exports are presented in Table 5. The GDP of the exporting and importing nations are positive and significantly related to different kinds of exports for various income groups. A percentage increase in the exporter's GDP substantially enhances the exports of agricultural commodities for LI, LMI, and UMI countries by 1.455%, 0.760%, and 0.434%, respectively. The exporter's GDP enhances the trade of manufactured exports of LMI by 1.196%, while the coefficient of other income groups was found to be insignificant. Remarkably, the exporter's GDP enhances machinery and transport equipment exports for all income groups. In addition, the expansion of the GDP of the destination county enhances the exports of agricultural goods for LI (0.642%), LMI (1.401%), and UMI countries (1.182%). The increase in the GDP of the importer enhances the exports of manufactured products only for LI and LMI countries by 2.533% and 0.851%, respectively. Additionally, the rise in the destination countries' income improves the exports of machinery and transport equipment for LMI, UMI, and HI countries. According to Brodzicki and Uminski (2018), trading partners' economic similarities are correlated with the intensity of their trade relationships, which strongly supports Linder's Hypothesis. Moreover, the population of the origin and destination countries have shown mixed findings across the income groups. For instance, the increase in population was found to negatively affect the exports of various products for LMI and UMI countries, while it was insignificant for LI and HI countries. On the other hand, an increase in the population of destination countries increases the exports of agricultural and manufactured commodities for HI countries. In addition, it reduces the exports of agricultural products while not significantly affecting the manufactured goods exports for LI and LMI countries. Luqman et al. (2016) validated the positive effects of population on trade flows, which demonstrates the domestic market's desire for a variety of products. However, the majority of the literature indicated that there are contradicting impacts of population on bilateral trade flows (Brada & Mendez, 1993; Mátyás, 1997).

Time-invariant factors have a significant effect on trade across income groups. The outcomes show that geographical distance is negatively associated with different kinds of export for all income groups, except the export of manufactured goods and machinery and transport equipment for LI and HI countries, respectively, which was insignificant. The findings show that the greater the distance between trading partners, the lower the bilateral exports of agricultural goods for LI (−2.206%), LMI (−0.675%), UMI (−0.711%), and HI countries (−1.133%). Primarily, LI countries' various types of exports decline as the distance between trading partners is higher, indicating that geographical distance is a barrier to the trade of these economies. However, the various exports of UMI countries are less sensitive to the geographical distance of trading nations compared to other income groups. Correspondingly, Narayan and Nguyen (2016) discovered that Vietnam's trade is more sensitive to distance with richer trading partners than with low-income trading partners. Furthermore, contingency has a favourable and significant effect on most of the traded goods across different income levels except for the exports of LI countries. The magnitude of the effect of the common border on disaggregated export is larger for HI compared to other LMI and UMI countries. For HI economies, when the countries share a border, the exports of agricultural commodities, manufactured goods, and machinery and transport equipment increase by 1.708%, 1.965%, and 2.084%, respectively. Additionally, the existence of a common language enhances the bilateral exports of upper-middle-income and HI countries. The extent of the

Table 5. Gravity model estimates of bilateral exports using PPML by income

Income level	Low-income nations			Lower-middle income nations			Upper middle-income nations			High-income nations		
	X_{AGR}	$X_{MANUF.}$	$X_{MACH.}$	X_{AGR}	$X_{MANUF.}$	$X_{MACH.}$	X_{AGR}	$X_{MANUF.}$	$X_{MACH.}$	X_{AGR}	$X_{MANUF.}$	$X_{MACH.}$
C	−5.276	−20.290***	29.97***	8.918	59.265***	123.5***	4.198	41.358***	92.511***	−14.781	23.180**	37.283***
	(8.754)	(7.638)	(3.969)	(7.032)	(14.62)	(15.334)	(9.346)	(6.177)	(8.945)	(14.92)	(9.77)	(8.166)
$lnGDP_i$	1.455***	−0.178	3.925***	0.760***	1.196***	2.811***	0.434***	0.083	0.754***	0.071	−0.344	0.672*
	(0.497)	(0.539)	(0.862)	(0.178)	(0.126)	(0.333)	(0.079)	(0.293)	(0.138)	(0.483)	(0.433)	(0.354)
$lnGDP_j$	0.642*	2.533***	0.110	1.401***	0.851**	1.153***	1.182***	1.182	1.036***	0.079	−0.182	0.805***
	(0.379)	(0.09)	(1.079)	(0.151)	(0.345)	(0.374)	(0.15)	(0.938)	(0.162)	(0.258)	(0.119)	(0.093)
$lnPOP_i$	1.690	−0.028	−5.910*	−1.190**	−4.916***	−8.265***	−0.801*	−3.712***	−3.829***	0.555	0.127	−0.389
	(1.082)	(1.086)	(3.458)	(0.579)	(0.311)	(1.098)	(0.445)	(0.075)	(0.358)	(0.964)	(0.837)	(0.700)
$lnPOP_j$	−2.402***	−1.002	0.525**	−1.204***	0.146	−2.762***	−0.450	1.351	−2.332***	1.507**	0.734**	−2.587***
	(0.778)	(0.809)	(0.248)	(0.409)	(0.199)	(0.708)	(0.38)	(1.159)	(0.382)	(0.735)	(0.349)	(0.317)
lnDIST	−2.206***	−0.876	−2.528*	−0.675***	−0.771***	−1.017***	−0.711***	−0.469***	−0.556***	−1.133***	−0.525***	−0.015
	(0.163)	(2.159)	(1.462)	(0.054)	(0.084)	(0.07)	(0.036)	(0.075)	(0.032)	(0.072)	(0.045)	(0.043)
CONTIG	0.291	2.841	−0.554	0.707***	0.566***	0.131	0.515***	0.459***	0.642***	1.708***	1.965***	2.084***
	(0.275)	(2.795)	(1.237)	(0.069)	(0.007)	(0.199)	(0.058)	(0.094)	(0.047)	(0.181)	(0.082)	(0.076)
LANG	−0.525**	0.000	−1.322	0.080	−0.130	0.599***	0.974***	0.350*	0.864***	1.032***	0.443***	−0.416***
	(0.247)	(0.602)	(1.025)	(0.076)	(0.252)	(0.109)	(0.074)	(0.194)	(0.07)	(0.133)	(0.096)	(0.093)
COL	1.292***	2.552***	1.309***	0.318***	0.765***	0.931***	0.641***	−0.256	−0.588***	−2.045***	−1.153***	0.534**
	(0.18)	(0.922)	(0.324)	(0.123)	(0.194)	(0.210)	(0.095)	(0.28)	(0.084)	(0.152)	(0.186)	(0.137)
ECI_i	−0.307	0.442***	1.036***	0.236**	1.604***	0.626***	0.138	1.003***	0.825***	−0.067	0.317*	0.656***
	(0.241)	(0.032)	(0.154)	(0.109)	(0.049)	(0.209)	(0.1)	(0.141)	(0.179)	(0.185)	(0.167)	(0.138)
ECI_j	−0.496*	0.233	−0.889	0.171*	−0.246	0.430***	0.352***	0.008	0.495***	1.013***	0.715***	0.181*
	(0.263)	(1.006)	(0.639)	(0.101)	(0.217)	(0.203)	(0.103)	(0.263)	(0.103)	(0.218)	(0.106)	(0.09)
FTA				1.603***	1.909***	1.934***	0.807***	1.311***	1.34***			
				(0.092)	(0.058)	(0.151)	(0.108)	(0.188)	(0.176)			
R^2	0.741	0.854	0.683	0.926	0.904	0.927	0.968	0.962	0.983	0.898	0.949	0.957
Observations	1623	1782	1729	3414	3759	3452	2042	2166	2159	1,764	2082	2095
No. of pairs	104	104	104	130	130	130	65	65	65	52	52	52
Fixed effects	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT	ET, IT
RESET Test	0.144	0.928	0.098	0.66	0.67	0.167	0.202	0.014	0.901	0.815	0.752	0.106

Notes: The dependent variable for all models is the export value from country i to j. X_{AGR}, X_{MANUF}, and X_{MACH} indicate the exports of agricultural goods, manufactured products, and machinery and transport equipment, respectively. Values in parenthesis are standard errors. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. ET and IT are the importer and exporter time fixed effects included in all models.

export increase is more remarkable for agricultural products than other goods. However, the effect of a common language on most of the different kinds of exports by the LI and LMI countries was statistically insignificant. The study also found that the existence of a common colony enhances the bilateral exports of LI and LMI countries. For example, a percentage increase in the colonial ties between trading partners enhances the exports of agricultural products of LI and LMI countries by 1.292% and 0.318%, respectively. Moreover, common colony increases substantially the exports of machinery and transport equipment for all income groups, except the UMI countries, which exhibited a negative and significant coefficient. It also increases the exports of manufactured products of LI and LMI countries.

The most remarkable results of the study indicate that economic complexity improves the bilateral exports of most goods across different income groups. An improvement in the economic complexity of the exporting countries enhances the export of manufactured products for all income groups. For instance, a percentage increase in the economic complexity of the origin country increases the export of manufactured goods for LI (0.442%), LMI (1.604%), UMI (1.003%), and HI nations (0.317%). In addition, the advancement in the country's productive capabilities substantially improves the export of machinery and transport equipment. A percentage increase in economic complexity raises machinery and transport equipment exports by 1.036%, 0.626%, 0.825%, and 0.656% for LI, LMI, UMI, and HI nations, respectively. However, the coefficient of economic complexity of the exporter country was insignificant in influencing the agricultural exports of countries across various income groups, except for the agricultural exports of LMI countries. These results support the idea that most high-value-added items are situated in a core with dense connectivity, whereas basic products are situated in a region with less connectedness (Hidalgo et al., 2007). It is notable that economic complexity has a substantial influence on different kinds of exports of LMI and UMI countries. On the other hand, the economic complexity of the destination country affects the export of various products based on income groups. For HI countries, a percentage increase in the economic complexity of the importer country increases the export of agricultural goods, manufactured products, and machinery and transport equipment by 1.013%, 0.715%, and 1.81%, respectively. In contrast, for LI countries, the outcomes show that the importers' economic complexity hampers agricultural goods exports while it was insignificant for other exports. Moreover, the improvement in the economic complexity of the destination country enhances the exports of agricultural and machinery and transport equipment of the LMI and UMI countries. Additionally, the results indicate that the FTA is positive and statistically significant for the diverse export commodities in LMI and UMI economies. The size of impact of FTA on bilateral exports is larger in LMI countries. This is in line with most gravity trade model literature that demonstrates trade volume increases with the presence of regional trade agreements (Baier & Bergstrand, 2007; Frede & Yetkiner, 2017; Gupta et al., 2019). Due to the higher degree of protection on agricultural products, some studies noted that FTAs increased agricultural and food exports (Jean & Bureau, 2015). Even though FTAs increase the bilateral exports of agricultural goods, these products are still restricted compared to non-agricultural products in many developing countries (Grant & Lambert, 2008).

3.5. Gravity model estimates of the PPML: all groups

The findings in the earlier sections were based on income or geographic categories. To estimate the magnitude of the impacts of economic complexity on bilateral trade for the all-country panels, we integrate all 27 trading partners in COMESA and East Asia into a single model. We implemented the PPML estimator by using separate specifications for different export commodities. In general, as shown in Table 6, regression results align with the expectation from the gravity model estimations in the literature for all the models employed. Almost all coefficients exhibited the expected signs. The results also confirm the robustness of our outcomes for the regional and income groups.

Table 6. Gravity model estimates of bilateral exports using PPML for all groups

Variables	X_{AGR}	X_{MANUF}	X_{MACH}
C	–17.302*** (5.429)	–15.534*** (5.451)	49.834*** (1.107)
$lnGDP_i$	0.490*** (0.072)	0.763*** (0.066)	0.932*** (0.005)
$lnGDP_j$	0.789*** (0.163)	–0.110 (0.373)	0.730*** (0.116)
$lnPOP_i$	0.210 (0.252)	–0.598 (0.599)	–1.602*** (0.415)
$lnPOP_j$	0.095 (0.351)	1.751* (0.971)	–2.435*** (0.402)
lnDIST	–0.685*** (0.028)	–0.430*** (0.018)	–0.310* (0.185)
CONTIG	0.655*** (0.055)	0.958*** (0.138)	1.123*** (0.309)
LANG	0.578*** (0.066)	0.501 (0.331)	0.453* (0.269)
COL	–0.116* (0.067)	–0.263 (0.304)	–0.116 (0.497)
ECI_i	0.039 (0.078)	0.137*** (0.045)	0.658*** (0.038)
ECI_j	0.442*** (0.087)	0.362*** (0.091)	0.281** (0.115)
FTA	1.503*** (0.060)	0.775*** (0.120)	2.271*** (0.480)
R^2	0.924	0.927	0.962
Observations	8,843	9,789	9,435
No. of pairs	351	351	351
Fixed effects	ET, IT	ET, IT	ET, IT
RESET Test (pvalue)	0.496	0.111	0.055

Notes: The dependent variable for all models is the export value from country i to j. X_{AGR}, X_{MANUF}, and X_{MACH} indicate the exports of agricultural goods, manufactured products, and machinery and transport equipment, respectively. Values in parenthesis are standard errors. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. ET and IT are the importer and exporter time fixed effects included in all models.

The GDPs of the exporter have significant and positive coefficients to affect the export of various products. At the same time, the importer GDP follows the same path for most of the coefficients, except for the trade of manufactured goods, which displayed insignificant outcomes. For instance, with a 1% increase in the income of the exporting nation, the export of agricultural commodities, manufactured goods, and machinery and transport equipment expanded by 0.490%, 0.763%, and 0.932%, respectively. Similarly, a percentage expansion in the importer's GDP enhances the bilateral exports of agricultural goods (0.789%) and machinery and transport equipment (0.730%). Comprehensively, these results indicate that income is crucial for bilateral export flows. This can be interpreted that as the economic size of the trading partners is large, the trade volume increases, which is consistent with the gravity model predictions. Additionally, the significance and the signs of population coefficients vary for each model. Surprisingly, the population of the exporter and importer were insignificant for the trade of agricultural goods, while it was negatively and significantly affecting the exports of machinery and transport equipment. In contrast, the population of the importer has a positive and significant effect on the exports of manufactured goods.

The findings also confirm that distance is a barrier to the bilateral trade flows for all export varieties, which implies that higher transportation costs of distant economies lead to less trade. The export of agricultural products had the highest responsiveness to the bilateral distances between trading nations, while the export of machinery and transport equipment had the least. For instance, a percentage increase in the geographical distances between countries will reduce bilateral trade of agricultural products (–0.685%), manufactured goods (–0.430%), and machinery and transport equipment (–0.310%). This indicates that the export of primary products declines with distance, whereas the export of highly industrialized products is less responsive to distance. Moreover, the findings indicate that a common border enhances trade, as all the models show high positive coefficients and significant results. With a 1% increase in the contingency between countries, the bilateral exports of agricultural products, manufactured goods, and machinery and transport equipment increase by 0.655%, 0.958%, and 1.123%, respectively. This implies that the trade flows between countries with a common border are higher than others. Similarly, common language enhances bilateral trade, as the gravity model expects. The magnitude of the effect of a common language on trade flows is higher when exporting agricultural goods, which increases by 0.578% compared to other products. Contrary to expectations, a common colony has a detrimental effect on bilateral trade flows of agricultural goods, while it exhibited negligible effects on other export commodities. Furthermore, the coefficients of FTA had positive and significant effects on the different kinds of exports. The expansion in the FTAs increases the bilateral exports of machinery and transport equipment more than other product commodities. This indicates that enhancing FTAs is more crucial for exporting highly sophisticated products.

The considerably striking result of the current study was observed from the variable of economic complexity. Overall, the estimated findings show that the ECI of the exporter and importer has a favourable contribution to the bilateral trade flows of the selected economies. For instance, the coefficients of the exporter and importer ECI were positive and significant to exporting machinery and transport equipment. The effect is higher for the exporter's ECI, where a 1% increase in complexity of the exporting country leads to a 0.658% surge in its export of that sector compared to a 0.281% rise for the importer's export performance. This can be interpreted that machinery and transport equipment are complex products that demand greater production capabilities and vast quantities of knowledge across networks of people (CID, 2013; Erkan & Yildirimci, 2015). Besides, not only the ECI of the exporter is necessary for bilateral trade but also the importer's ECI because of the growing significance of intra-industry trade in intermediate goods (Lüthje, 2001). However, Luqman et al. (2016) demonstrated that most gravity trade analysis mainly emphasizes inter-industry trade. Moreover, the exports of manufactured goods classified by material exhibited positive and significant results for exporter and destination countries. When the exporter's ECI increases by 1%, it will induce the exports of these products to grow by 0.137% compared to a rise of 0.362% for the importer. The developing countries in COMESA and East Asia are characterized by the production of fundamental manufacturing activities, which are not associated with a more significant accumulation of capabilities. Notably, the exports of manufactured products contribute lower than that of machinery and transport equipment due to the less complexity. Furthermore, the study showed mixed results for the link between economic complexity and the export of agricultural goods. The coefficient of the exporter was insignificant, while the destination country's ECI was positive and significant. This exhibits the fact that agricultural products are the least complex products since they need a smaller network of capabilities and less productive knowledge. To sum up, the empirical findings of this study indicate that economic complexity is crucial for exporting complex products such as machinery and transport equipment and manufactured products by material. However, agricultural goods need less accumulation of capabilities and can be produced by almost every country, making the product less unique and inclusive.

The R^2 is high for the various models, which strengthens our estimation technique's reliability. The Ramsey RESET test has also been used to check the accuracy of the functional form of all models. The outcomes show that the models do not suffer from any omitted variables. Moreover, it is noteworthy that the current study employs the PPML technique for the estimation. It includes fixed effects for the exporter, importer, and times dummies. Besides, it has robust standard errors that control for heteroscedasticity and serial correlation of unknown form.

Conclusions and policy implications

The export patterns of a specific country are determined by its production capacity, which also forecasts future economic growth. The prior literature gave less attention to emphasize the importance of economic sophistication and diversification of exports for trade flows among nations. Thus, this study aims to examine the contribution of economic complexity on bilateral trade flows using the gravity model of trade during the period 1995–2019. Since economic complexity does not influence the export of different sectors equivalently, the study considered the export of three products: machinery and transport equipment, manufactured goods, and agricultural output. The sample comprises 27 countries, mainly from COMESA and East Asia, which were categorized based on the geographical location and income level of countries. The empirical estimations of the study applied the Poisson pseudo maximum likelihood (PPML) estimator with multi-way fixed effects since the literature suggests that it is the most efficient technique for gravity estimation. The use of nonlinear estimators such as PPML could produce reliable results because trade data commonly face the presence of heteroscedasticity and the OLS estimator is inconsistent (Silva & Tenreyro, 2006). The robustness of the results of the study was confirmed for various econometric specifications.

The overall findings from the estimation are consistent with the expectations of the gravity model variables. The study confirmed that exporter and importer country GDPs enhance bilateral exports across the regions. Furthermore, economic similarities between trading partners encourage bilateral exports among countries of different income levels. This is consistent with the Linder trade hypothesis, which holds that two nations may trade more often if their factor endowments are similar. In addition, compared to machinery and transport equipment exports, agricultural exports from COMESA and East Asia are more responsive to the distance between trading partners. Common borders and language improve the bilateral exports between countries, even though colonial ties improve the bilateral exports of LI and LMI nations. The study's findings confirm the gravity model literature that suggests that regional trade agreements enhance trade volume.

The most striking evidence from this study highlights that economic complexity is crucial for the bilateral exports of trading economies based on regions and income levels. The exports of machinery and transport equipment alongside manufactured goods of both the exporting and the destination countries displayed favourable to the enhancement of economic complexity. These products have a higher value since a greater web of knowledge interaction accompanies their production. Conversely, the estimates did not present enough evidence that economic complexity is necessary for agricultural production, which is not associated with a high accumulation of capabilities. A large part of the emerging economies is less competitive and least diversified, distinctly to the COMESA economies. It is noteworthy that these countries have excessive reliance on the agriculture sector, making their exports have low values. This caused their intra-regional trade to be inadequate due to the lack of differences in the products' revealed comparative advantages.

This study is the first step in improving our understanding of the importance of economic complexity for trade flows. The complexity levels of most economies in our sample have increased during the study period. However, they need to shift their export structure towards high-value and more complex products. Based on the findings of the study, several policy recommendations can be drawn. First, COMESA and East Asia countries should engage in more sophisticated Research and Development (R&D) that will lead to more innovation, technological advancement and diversified export structure. Policymakers should develop an environment that supports a broader range of productive activities, with an emphasis on activities of export diversification. Since agriculture makes up most of these countries' exports, governments should support rural diversification by fostering microcredit, essential rural services, accessibility to education, and improved infrastructure. Second, the encouragement of policies that attract multinational companies from advanced economies. This will raise the skills of the labour force and the productivity of particular sectors through the facilitation of knowledge transfer and high-tech capital goods from developed nations to emerging economies. Importing capital goods can enable less developed economies to grow their capacity to acquire the most sophisticated technology and provide a basis for creating a variety of less inclusive commodities. The involvement in the value chain can even be improved. Third, the countries should improve their production capabilities using the existing production network. The development of new high complex products could be unattainable for less sophisticated economies given their current export structure. However, each product is more likely to have other products that need similar capabilities to export. Therefore, focusing on these kinds of products in the network can improve the complexity of developing economies. Fourth, industrial policies need to be established because they are the most effective means of achieving structural transformation. By implementing sound industrial strategies, nations may upgrade their production capacities and expand their exports of high-value-added goods. Policies should encourage industrial upgrading, which is the gradual transition toward greater productive operations at the firm and national levels.

Future research should further focus on the determinants of the economic complexity of developing countries. This gives helpful insight into cross-country differences in productive knowledge. Moreover, one limitation of this study that future studies should concentrate on is that it should have considered the case of the developed countries. A comparison of the complexities of emerging and advanced economies is also notable.

Author contributions

Abdikafi Hassan Abdi, Mohd Azlan Shah Zaidi and Zulkefly Abdul Karim have contributed significantly to the writing of this article. They conceived the study and were responsible for the design and development of the data analysis. Abdikafi Hassan Abdi was responsible for data collection and analysis. Abdikafi Hassan Abdi, Mohd Azlan Shah Zaidi were responsible for data interpretation. Abdikafi Hassan Abdi wrote the first draft of the article while Mohd Azlan Shah Zaidi and Zulkefly Abdul Karim reviewed and edited the article.

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APPENDIX

Table A1. List of country pairs (CPs) in the study

COMESA	EAST ASIA
D.R. Congo	Cambodia
Egypt	China
Ethiopia	Hong Kong
Kenya	Indonesia
Libya	Japan
Madagascar	Laos
Malawi	Malaysia
Mauritius	Philippines
Somalia	Singapore
Sudan	South Korea
Tanzania	Thailand
Tunisia	Vietnam
Uganda	
Zambia	
Zimbabwe	