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Exploring FTAs, seafood exports, and SDGs: a gravity model analysis of Pakistan's seafood trade with China and regional partners

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This study examines the effects of Free Trade Agreements (FTAs) on Pakistan's seafood exports, specifically analyzing the China-Pakistan Free Trade Agreement (CP-FTA) and its stages, CP-FTAI and CP-FTAII. Using the gravity model (GM) of trade, it empirically analyzes the dynamics of seafood trade between Pakistan and its neighboring countries, aiming to provide insights into improving trade balance and export performance. The study employs three econometric approaches—Ordinary Least Squares (OLS), Fixed Effects Model (FEM), and Pseudo Poisson Maximum Likelihood (PPML) to ensure the robustness and reliability of the findings. The results reveal that Pakistan's seafood exports are significantly influenced by FTAs, particularly with Afghanistan, Sri Lanka, and Malaysia, while CPFTA-I shows a positive impact. However, CPFTA-II exhibit negative and insignificant relationship, indicating that external shocks, like the COVID-19 pandemic, have impacted trade dynamics. The results of this study are significantly relevant to multiple United Nations Sustainable Development Goals (SDGs). Notably, they contribute to SDG 8, which focuses on Decent Work and Economic Growth, by promoting trade-driven economic advancement. Furthermore, they support SDG 9, which pertains to Industry, Innovation, and Infrastructure, by facilitating infrastructure development through the China-Pakistan Economic Corridor (CPEC). Additionally, they align with SDG 12, which emphasizes Responsible Consumption and Production by advocating sustainable trade practices. The study recommends enhancing FTAs, improving infrastructure, and expanding trade with neighboring markets to optimize Pakistan's seafood export potential. Policymakers should focus on strengthening trade agreements, streamlining logistics, and integrating variables like security and exchange rates to develop more resilient and sustainable trade strategies, contributing to important SDGs.

KEYWORDS

FTAs, seafood exports, gravity model, Pakistan-China trade, SDGs

1 Introduction

Trade agreements are fundamental to any country's economic development plan. These agreements foster employment creation and poverty alleviation, enhancing national economic growth by mitigating or removing barriers to expanding international trade (Hasan et al., 2012; Le and Tran-Nam, 2018; Amna Intisar et al., 2020). For this reason, countries worldwide have been signing trade agreements to strengthen their trade and business ties (Couillard and Turkina, 2015; Hayakawa et al., 2024). Since 1990, regional trade agreements have gained popularity to pursue rapid economic growth and enhance cooperation. Statistics published by the World Trade Organization (WTO) show a significant increase in trade agreements from 15 (1980) to 490 (2019). Surprisingly, most of these agreements, 55%, endorsed regional trade (Haq et al., 2021). However, two schools of thought exist when the potential benefits of these agreements are debated. Proponents of regionalism maintain an optimistic perspective, viewing regional trade agreements as a means for nations to maximize the benefits of trade and improve economic integration (Moser and Rose, 2014; Barnekow and Kulkarni, 2017). Increased regional trade leads to economic stability and prosperity.

On the other hand, proponents of the pessimistic view argue that regional trade threatens trade liberalization and that the benefits of trade liberalization are minimized, affecting global welfare (Datta and Kouliavtsev, 2009; Dix-Carneiro and Kovak, 2017). The advantages of trade might differ based on particular objectives, policy approaches, bilateral relations, and the socioeconomic situation of a country (Barros and Martinez-Zarzoso, 2022). Moreover, trade distortions in the form of trade diversion or trade creation can harm local or global welfare at varying degrees of intensity (Baier and Bergstrand, 2004; Lambert and McKoy, 2009). In the contemporary economic landscape, regional Free Trade Agreements (FTAs) are prevalent globally, with Asia being no exception. Around 30% of world FTAs belong to Asian countries (Haq et al., 2021). Pakistan has signed FTAs with several regional countries, including Afghanistan (PA-FTA), China (CP-FTA), Sri Lanka (PSR-FTA), and Malaysia (PM-FTA), to enhance trade and foster economic convergence, which may also create opportunities for promoting sustainable trade practices (Uzair and Nawaz, 2020; Khan et al., 2021). The PM-FTA was signed in 2007 to enhance economic ties. However, Pakistan's exports to Malaysia have remained volatile, and the trade balance has not improved significantly (Khan et al., 2018). The PSR-FTA came into effect in 2005 and proved very beneficial for Pakistan as exports soared after the inception of this agreement. However, the PSR-FTA faces several challenges, such as political tensions, non-tariff barriers, and a lack of product diversification (Mahmood and Jongwanich, 2018). Furthermore, Pakistan has signed several trade agreements with Afghanistan, such as those in 1965 and 2010, which have played a crucial role in fostering economic interdependence despite their historically complex relations. However, trade between the two nations has faced challenges due to political tensions and transit-related issues (Shabir and Kazmi, 2007; Zingel, 2014). These FTAs have both pros and cons. The pros include trade enhancement, greater access to the market, sectoral benefits, and economic growth, whereas the cons include competitiveness issues, trade deficits, the negative impact of non-tariff barriers, and limited impact (Shabir and Kazmi, 2007; Haq et al., 2021; Akram et al., 2024; Khan et al., 2024).

Pakistan sustains unique trade and economic relations with China, in contrast to other regional nations, leading to the establishing of cooperation agreements (Hussain et al., 2020). The first phase of the China-Pakistan Free Trade Agreement (CP-FTAI), acknowledged in 2006, has been a hot topic among trade liberalization experts (Shah et al., 2022). Some researchers have criticized FTA's impact on Pakistan exports (Shabir and Kazmi, 2007; Haq et al., 2021). Pakistan is in a severe trade deficit situation with China. According to the available data, China exported goods and services to Pakistan, valued at 18.2 billion USD (2017). In contrast, Pakistan sold goods and services to China valued at 1.82 billion USD (2018) (Haq et al., 2021). Such studies identified numerous factors that contributed to the diminished efficacy of CP-FTA. The factors contributing to this scenario include China's financial supremacy, Pakistan's insufficient infrastructure to leverage the CP-FTAI discounts, a limited range of products, a vulnerable economy, and the repercussions of the 2008 global crisis on the CP-FTAI (Lateef et al., 2018; Shah et al., 2022; Abdul Kamal et al., 2022; Khan et al., 2024). Thus, following multiple negotiations, a second phase of this trade agreement, CP-FTAII, was concluded in 2019. The tariff rates have been reduced from 30% under CP-FTAI to 90% under CP-FTAII (Haq et al., 2021). CP-FTAII has entirely changed the pace of trade between Pakistan and China. Therefore, a thorough examination of the components of Pakistan's seafood trade within the framework of the CP-FTAI and CP-FTAII is essential.

The fisheries sector substantially influences Pakistan's economic development, which generates an annual export revenue of approximately 400 million USD. Seafood export products include frozen, fresh, chilled, salted, and smoked products and are destined for diverse countries of the world, such as China, Vietnam, and Thailand (Sharif et al., 2014; Shah et al., 2017; Mohsin et al., 2024). China is a major importer of Pakistani seafood products (Mohsin et al., 2018). Trade between these countries increased enormously after CP-FTAI. Under the auspicious CP-FTAI in 2015, the trade value amounted to 20 billion USD, with an annual average increase of 18.8% in trade volume (CPEC, 2017; The News, 2015). Published literature also claims the positive impact of China Pakistan Economic Corridor (CPEC) and China's accession to the WTO on enhancing trade between these two countries (Wang, 2003; Zhao and Wang, 2009; Rehman et al., 2018). CPEC has caused trade enhancement between China and Pakistan through infrastructure development, optimization of the trade route, and regional integration. Moreover, WTO accession has led to trade liberalization and market access, leading to stronger trade relations (Kousar et al., 2018; Khetran and Khalid, 2019; McCartney, 2020; Kumar et al., 2022; Alam et al., 2023).

However, several researchers have also highlighted the negative impacts of FTAs signed by Pakistan and blame FTAs for the trade deficit situation in Pakistan (Haq et al., 2021; Shah et al., 2022). However, this situation should vary sector by sector. Some sectors

may have a trade surplus situation for Pakistan. The published literature does not report the impact of FTAs on the seafood trade from Pakistan. Instead, it focuses on other sectors such as transportation, vegetable exports, textiles, etc (Naz et al., 2018; Shah et al., 2022; Khan et al., 2024). Thus, studying the Pakistani seafood sector in this context is imperative.

Typically, the gravity model (GM) of trade explains how country size and distance influence trade patterns (Natale et al., 2015; Herianingrum et al., 2024). According to this model, the size of an economy is positively correlated with the volume of trade, whereas distance is negatively correlated with the volume of trade (Kabir et al., 2017). However, trade agreements, colonial ties, and proximity further influence trade volume (Berthou and Ehrhart, 2017; Freeman and Pienknagura, 2019). Therefore, a thorough investigation into the factors impacting Pakistan's seafood exports can be conducted by employing diverse variables. Consumer demand is frequently approximated by population density, geographical constraints can be determined by distance, and trading patterns are influenced by closeness (Clark, 2007; Bailey et al., 2021; Habyarimana, 2024). Furthermore, prior colonial interactions may have long-term repercussions on trading, increasing the complexity of research (Head et al., 2010; Berthou and Ehrhart, 2017).

Although published online literature documents the impact of FTAs on Pakistan trade, it confers several research gaps. For instance, the predominant focus of this literature has been on either broad or sector-specific trade (Lateef et al., 2018; Khan et al., 2024). Based on our current understanding, research is deficient regarding the influence of FTAs on commodity levels. Using GM, this study empirically investigates the dynamics of seafood trade between Pakistan and neighboring countries with which it has signed FTAs, particularly with China. This study is the first to comprehensively examine both CP-FTAI and CP-FTAII. The seafood trade in Pakistan holds significant importance, requiring diligent consideration of competitive positioning to enhance the trade balance and foreign exchange earnings. Moreover, decision-makers may benefit from a comprehensive analysis of FTAs using sophisticated GM. Thus, this study has several important objectives. First, this study assesses the impact of FTAs on Pakistan's seafood exports. Second, it aims to understand the trade dynamics of the seafood sector, highlighting how FTAs can affect trade balance and export performance in the context of GM. Third, it offers reliable outcomes which can direct decision-makers to make strategic trade policies by considering the practical impacts of FTAs. Moreover, this study paves the way to achieve crucial United Nations Sustainable Development Goals (SDGs), including SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production).

2 Literature review

Most of the pioneering studies related to seafood revolve around the topics of food insecurity, seafood contamination, and the identification of new species (Yıldırım and Yıldırım, 2021; Davis et al., 2023; Gong et al., 2024; Ward et al., 2024; Yıldırım et al., 2024). The CP-FTA promoted economic ties between partner countries by enhancing trade opportunities. The levies and limitations were lifted from 6,711 Pakistani and 6,418 Chinese product categories. Textiles, seafood, and agriculture were among the product categories and goods for which China eliminated or lowered tariffs. The tariffs Pakistan imposed on agricultural goods, including fruits and vegetables, equipment, meat, and chemicals, were either decreased or eliminated. Pakistan only uses 3.3% of the CP-FTA pricing line (Hussain, 2017). Pakistan's trade imbalance with China has increased due to CP-FTA's beneficial effect on Chinese imports (Uzair and Nawaz, 2020; Shah et al., 2022). FTAs have more potential to increase agricultural trade between Pakistan and China compared to manufactured products (Mahmood and Jongwanich, 2018). Pakistan's trade with China has grown enormously, amounting to 15.17 billion USD since the CP-FTA was signed in 2006. The primary factor contributing to this trade deficit is the influx of goods not imported before CP-FTA (Mukhtar and Hongdao, 2017). Pakistan did not attain the full spectrum of advantages it had anticipated from China, even though China extended certain concessions to offer Pakistan some benefits.

The CP-FTAII was negotiated amidst the prevailing notion that the CP-FTAI disproportionately benefited China at the expense of Pakistan. The tariff line concessions and reductions previously offered were expanded as part of the CPFTA-II. China has supported Pakistan in CPFTA-II by removing duties on 313 Pakistani export goods (MoC, 2022). Thus, the CPFTA-II offers more favorable tariffs. Moreover, it gives Pakistan much room to grow and change the kinds of goods it sells to China. The connectivity between China and Pakistan has considerably increased due to the commencement of the CPEC. Thus, CPEC profoundly influences and is closely affiliated with CP-FTAII. The fastest and most efficient way through the Khujarab Pass is expected to make trade between the two countries more efficient (Alam et al., 2023).

Studies on CP-FTA implications is often contradictory, particularly investigations employing GM. Irshad et al. (2018) investigated the trade opportunities between Pakistan and China. These researchers employed EGLS, Pseudo Poisson Maximum Likelihood (PPML), and the Tobit model in their analysis, and most of their findings align with the principles of GM. Their findings indicate that the CP-FTA has not succeeded in its objective of augmenting Pakistan's exports. Abbas (2018) employed GM and found that FTAs have a positive impact on imports, whereas they have a negative impact on exports from Pakistan. The GM and the PPML methods were used by Lateef et al. (2018) to look into how CP-FTA affected trade in agriculture between the partner countries. According to their research, China's agricultural exports have not increased due to the CP-FTA, despite its impact on trade creation. To examine agricultural trends before and after the CP-TFA, Qayyum and Nigar (2020) used a variety of econometric indicators. It is evident from their investigation that China has a major edge in bilateral trade. It is possible, however, to reduce Pakistan's trade deficit significantly by exporting agricultural products.

Furthermore, Lateef et al. (2017) investigated CP-FTAs employing a PPML estimator to analyze the GM. For their study, they used comprehensive data collection from 110 countries that Pakistan exported to between the years 2001 and 2014. The findings demonstrate that the number of agricultural trade transactions has greatly grown due to the CP-FTA. Stakeholders and decision-makers in China and Pakistan must understand the effects of CP-FTAs on certain agricultural products.

3 Materials and methods

3.1 Gravity equation and study model

This study employs a systematic research framework, as illustrated in Figure 1. Numerous economists have proposed theories explaining bilateral trade flows between nations. The Heckscher-Ohlin Theory, the New Trade Theory, the Product Life Cycle Theory, the Comparative Advantage Theory, and the GM are all widely recognized theories of trade (Mathur, 2000; Angulo Bustinza, 2024). Among these theories, GM stands as a celebrity to explain trade flows comprehensively between countries (Van Bergeijk and Brakman, 2010). An American economist, Walter Isard, introduced GM in 1954. GM is based on the logic proposed by Newton in his world-famous Law of Gravity. Afterwards, many economists modified GM differently (Capoani, 2023). Few economists, such as McCallum, Anderson, and van Wincoop, integrated GM with trade barriers. Later, Krugman, Tranos, and Nijkamp combined imperfect competition, geographical barriers, and infrastructure with GM (Capoani, 2021). GM relies on two important trade determining factors, i.e., the economic size of a country and the cost of a trade. These two factors are critical for understanding bilateral trade flows. According to GM, a positive relationship exists between a country's economic scale and trade. On the other hand, the cost of trade and trade has a negative relationship (Gopinath and Echeverria, 2004; Yamarik and Ghosh, 2005). This means that trade increases with the increase in the economic size of countries. Meanwhile, trade decreases with the increase in trade costs.

This concept of understanding bilateral trade patterns is very famous in the economic world, and many studies render this theory to explore their particular trade patterns (Khan et al., 2024). A plethora of literature supports this theory (Van Bergeijk and Brakman, 2010; Kabir et al., 2017). However, sometimes deviation also occurs (Khan et al., 2024). In scientific studies, proxies are mostly used to measure the economic size as well as trade cost. Gross domestic product (GDP) is usually considered suitable to represent economic size. On the other hand, trade cost is frequently represented by the distance between countries. Mathematically, GM can be represented as follows (Equation 1):

$$Txy = P(QxQj)/Dxy \tag{1}$$

Above equality expresses bilateral trade, Txy, between two countries. Moreover, x and y denote exporting (origin) and importing (destination) countries in that order. Furthermore, P and Q stand for constant and GDP of the respective country, x or y. On the other hand, Dxy symbolizes distance or transportation costs between the trading countries. It is possible to express GM in terms of logarithmic linear form, as follows (Equation 2):

$$LnTxy = \alpha 0 + \alpha 1 LnQx + \alpha 2 Qy - \alpha 3 LnDxy \tag{2}$$

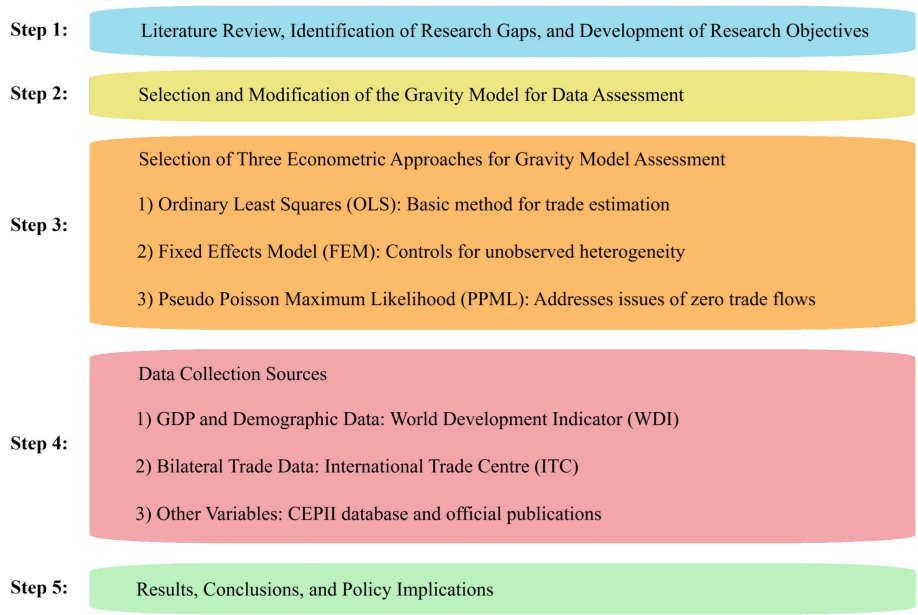

FIGURE 1
Chronological steps to conduct this study.

To deal with uncertainty, we add stochastic variable, δxy, as follows (Equation 3):

$$LnTxy = \alpha 0 + \alpha 1 LnQx + \alpha 2 Qy - \alpha 3 LnDxy + \delta xy \quad (3)$$

It is pertinent to mention that in this study, GDP and distance are considered independent and dependent variables, respectively. Moreover, GDP is represented by nominal GDP. Control variables can be incorporated in the above equation to elaborate the distance variable. Thus, the following equation includes control variables (Equation 4):

$$LnTxy = LnP + \alpha Ln(Qx*Qj) - \beta LnDxy + \gamma LnT + \delta xy \quad (4)$$

The last part of this equation, γLnT, denotes control variables. As aforementioned, several economists have created diverse versions of GM. One of these versions is very popular and termed as multilateral resistance (MR). This version, originally presented by Anderson and Van Wincoop (2003), explains bilateral trade under the influence of demand from other countries. This demand from alternative suppliers or other countries impacts trade flow between trade partners. Thus, MR explains the barriers that a country experiences while trading with other countries. This implies that changes in trade barriers may impact bilateral trade, resulting in reduced trade quantities. The concept of MR is frequently integrated with GM to understand trade under the influence of the combined effect of trade barriers with all trading countries (Jie and Xuezhi, 2017). This integration of MR with GM can be expressed as follows (Equation 5):

$$Txy = \frac{QxQy}{Qw}\left(\frac{TCxy}{\Gamma x \Gamma y}\right)^{1-\sigma} \quad (5)$$

In the above equation, most of the variables have been explained earlier. However, some are new and needs explanation such as, Qw denotes the GDP of the world. On the other hand, TC represents trade costs between the trading countries. The variable Γx stands for the MR of the exporting whereas the variable Γy represents the MR of the importing country. Thus, the variables Γx and Γy, as a trade cost function, collectively represent all of the variables resisting trade. Finally, the variable σ symbolizes substitution elasticity of the traded products. The value of this variable is assumed to be greater than 1 and is fixed for this analysis. The use of fixed effects of exporters as well as importers for a country is a popular way to analyze bilateral trade indices. The equation with the inclusion of CP-FTAI is as follows (Equation 6):

$$LnTxy = \alpha 0 + \alpha 1 LnGDPx + \alpha 2 LnGDPy + \alpha 3 LnHumPopx + \alpha 4 LnHumpopy + \alpha 5 LnDistxy + \alpha 6 CP - FTAI + \alpha 7 PM - FTA + \alpha 8 PA - FTA + \alpha 9 PSR - FTA + \alpha 10 MutBor + \alpha 11 ComCol + \alpha 12 Coloni + \alpha 13 CommLan + \delta xy \quad (6)$$

The equation with the inclusion of CP-FTAI and CP-FTAII is as follows (Equation 7):

$$LnTxy = \alpha 0 + \alpha 1 LnGDPx + \alpha 2 LnGDPy + \alpha 3 LnHumPopx + \alpha 4 LnHumpopy + \alpha 5 LnDistxy + \alpha 6 CP - FTAI + \alpha 7 CP - FTAII + \alpha 8 PM - FTA + \alpha 9 PA - FTA + \alpha 10 PSR - FTA + \alpha 11 MutBor + \alpha 12 ComCol + \alpha 13 Coloni + \alpha 14 CommLan + \delta xy \quad (7)$$

In order to meet this study's objectives, GM was modified. GM equation was incorporated with various variables such as Human Population (Hum. Pop.), GDP, Distance (Dist.), FTAs (binary variable), Mutual Border (Mut. Bor.), Common Colony (Comm. Col.), Colonizer (Coloni.), and Common Language (Comm. Lan.). These variables can be categorized into four types. First, dependent variables are represented by trade flows. Second, proxy variables such as GDP are used to calculate economic size and distance for transportation costs. Third, binary variables such as Mut. Bor., Comm. Col., Coloni., and Comm. Lan. Fourth, FTAs between countries.

It is important to mention that *Ln* is the natural logarithm of the respective variables in all the above equalities. The variables x and y correspondingly denote Pakistan and other trading countries. It is pertinent to mention that GDP and distance coefficients are believed to have positive and negative values in that order. The variable Mut. Bor. represents the distance between the trading nations, highlighting trade costs and hence believed to impact trade significantly. The statistical data of this variable was obtained by exploring the CEPII database. On the other hand, the variable, Comm. Lan., is assumed to have a significant and positive impact on trade. Since Comm. Lan. can help with effective communication, more trade is expected with a similar spoken language. The numerical data for this variable was also collected by digging CEPII online datasets. FTAs are assumed to have a positive impact on the seafood trade. FTAs were given two values, 1 or 0. 1 represents the condition when countries have an FTA with Pakistan. Otherwise, it was given 0. Data about four FTAs was employed in this study to explore FTAs and trade relations. CP-FTA was given special consideration. The variable, Coloni., is also believed to impact trade significantly. Finally, the variable, Hum. Pop, control demand and is believed to impact trade considerably.

3.2 Data collection and assessment

Various online data repositories were explored to fetch data for this study. This study intends to investigate FTA's impact on regional and bilateral trade through GM. Thus, Pakistan is considered a country of origin, whereas other trade partner countries are considered destination countries. Seafood exports, a dependent variable, from Pakistan are represented by their annual value. The list of countries to which Pakistan exports its seafood products is shown in Appendix 1. This study takes into account the Harmonized System (HS) classification. It uses a two-digit HS-code 03, exclusive to "Fish and Crustaceans, Molluscs and other Aquatic Invertebrates". A comprehensive list of the HS-03 commodities can be found in Appendix 2. Bilateral trade statistics from 2004 to 2023 were sought from the online data repository of the ITC.

GDP was considered as a proxy for the size of an economy. According to GM, seafood exports should be positively impacted by the GDP of trading countries. The WDI serves as a basis for each country's GDP and demographic statistics in the present study. The market size of a country is reflected by its population. The trade between countries is anticipated to increase as the market size

increases. The Coloni. variable was considered 1 when there was a historical colonial relationship between the two countries. On the other hand, the Com. Col. variable considered 1 when both nations were subjected to colonization by the same colonial authority. Only the United Kingdom shared a colonizer among all the sample countries. According to our understanding, published literature and the collected statistics indicate that China, Sri Lanka, Malaysia, and Afghanistan established ancient tribute trade. The data of the two variables Comm. Col. and Coloni. was mined through the online statistical repository of CEPII.

In this study, three different econometric methods were used to check the consistency of our models with GM. The purpose of using multiple statistical approaches was to compare and obtain reliable results. The first model we selected for this study was OLS. The OLS method is capable of performing regression analysis simply and efficiently. The results of OLS are considered very accurate, as this statistical technique produces impartial estimates under homoscedasticity conditions. The ability to analyze large data sets and the easily interpretable results make OLS very commonly used in scientific analysis (Gomez-Herrera, 2013). To consider the OLS results valid, certain criteria were applied that were consistent with the published literature. This criterion meets the three important required correlation conditions: error term, homoscedasticity, and multicollinearity (Burton, 2021).

If variances are homogenized, OLS outputs are considered biased in their estimates (Greenwald, 1983). GM is generally used in conjunction with FEM. Typically, GM estimations alone do not capture unvarying variables related to both importers and exporters. The use of FEM is recommended in the published literature to address biases and control for endogeneity of variables (Shepherd, 2013). In this study, we have used FEM, which accounts for all unobserved factors that could influence seafood trade in Pakistan. As a result, the estimated coefficients are more reliable for drawing dependable conclusions. Frequently, no trade data are reported for a certain product between trading countries. To address this issue, the published literature has emphasized the use of PPML over OLS and FEM techniques. The PPML technique is an excellent statistical method for dealing with heteroscedasticity and producing unbiased results. Moreover, PPML estimators are not affected by the inclusion or exclusion of zero trade data, thus yielding reliable results. These advantages make the PPML technique an ideal statistical tool (Larson et al., 2018).

The PPML technique can address common trade issues by producing more effective estimates of various variables (Afesorgbor, 2017; Islam et al., 2024). However, it is important to note that, according to the published scientific literature, GM has several limitations regarding its assessment methods and model specifications (Shepherd, 2013). For instance, sometimes various OLS assumptions are not met, leading to unreliable results. The OLS method relies on reported data; thus, it does not handle anomalies associated with the data. Moreover, the OLS technique cannot deal with complicated situations or nonlinear relationships (Briggs and MacCallum, 2003; Zdaniuk, 2023).

4 Results and discussion

The findings and a discussion of this study are presented in this section. Seafood trade is one of Pakistan's few leading sectors, and it has a trade surplus with the World. This sector significantly strengthens the developing national economy by contributing massive export revenue. According to the statistics, in 2023, seafood products worth 467,110 thousand USD were sold worldwide (Figure 2). Detailed seafood trade statistics of Pakistan with the World are presented in Appendix 3a and Appendix 3b. Table 1 presents Pakistan's seafood trade statistics with China over 19 years, from 2005 to 2023. HS code-wise seafood trade between Pakistan and China is elaborated in Appendix 4a and Appendix 4b. Over the years, Pakistan's seafood exports to China have shown a consistent upward trend, with significant growth in recent years, particularly after 2017. Exports grew from 28,273 thousand USD in 2005 to 220,708 thousand USD in 2023. According to the published literature, various cooperation projects, particularly CP-FTA and

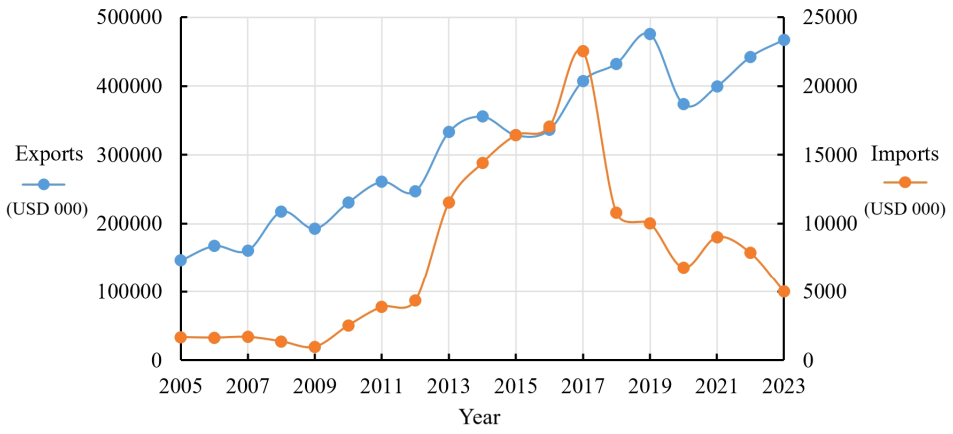

FIGURE 2
Pakistan's seafood exports and imports from the world.

China Pakistan Economic Corridor (CPEC), between Pakistan and China have boosted regional seafood trade between these two countries (Mohsin et al., 2018; Ali et al., 2020). Moreover, import bans from the US, EU, and Saudi Arabia have substantially diverted Pakistan's seafood exported to China (Mehak, 2024). On the other hand, import data shows relatively low import figures compared to exports, with imports fluctuating but remaining under 150 thousand USD/year. For example 2005, there were no imports, and in 2020, imports were recorded at just 3 thousand USD. Unfortunately, fish consumption in Pakistan, 2 kg/year/person, is far lower than the world average, 17 kg/year/person, resulting in almost no need to import seafood for local consumption (Memon, 2017; Mohsin et al., 2018).

The fisheries sector in Pakistan is confronted with the major issues of by-catch and high discard rate. Most consumable fish is preferred to be exported to other countries to earn exchange revenue (Rehman et al., 2019; Mehak et al., 2023). Furthermore, the trade balance consistently shows a surplus, with the surplus amount increasing over time, particularly in the latter years. For instance, in 2005, the trade balance was 28,273 thousand USD, which grew to 161,203 thousand USD by 2023, reflecting Pakistan's growing seafood export sector. Furthermore, total trade volumes have steadily increased from 28,273 thousand USD in 2005 to 220,776 thousand USD in 2023. These trade statistics represent prospering trade relations with China, with Pakistan as a dominant country in the seafood trade sector. Several researchers have concluded similar results debating good relations between Pakistan and China and the increasing magnitude and pace of trade between these two countries (Irshad et al., 2018; Masood et al., 2023). Several reasons are reported in the scientific literature for this increased seafood trade between Pakistan and China. These reasons include rising seafood demand from China, conducive trade relations, and strategic development cooperation (Mohsin et al., 2018; Crona et al., 2020; Shah et al., 2022). Rising seafood demand from China can be correlated to its growing GDP. As countries grow their GDP, they tend to import more products to meet local demand. Scientific studies have reported a positive correlation between seafood consumption and economic development (Clark and Longo, 2019; Han et al., 2022). Thus, the prospering GDP of China has a promising impact on seafood exports from Pakistan. Table 2 elaborates on explanatory variables and describes their expected sign by GM.

TABLE 1 Pakistan's seafood trade statistics with China.

Year	Exp.	Imp.	Tra. Bal.	Tot. Tra.
2005	28273	0	28273	28273
2006	24638	1	24637	24639
2007	29660	3	29657	29663
2008	40280	12	40268	40292
2009	47014	133	46881	47147
2010	63099	57	63042	63156
2011	41322	17	41305	41339
2012	39504	112	39392	39616
2013	35779	36	35743	35815
2014	55210	74	55136	55284
2015	46168	26	46142	46194
2016	47995	17	47978	48012
2017	60190	137	60053	60327
2018	91781	129	91652	91910
2019	135807	32	135775	135839
2020	134053	3	134050	134056
2021	161217	14	161203	161231
2022	189256	41	189215	189297
2023	220708	68	220640	220776

"Exp." means Exports, "Imp." means Imports, "Tra. Bal." means Trade Balance, "Tot. Tra." means Total Trade.

Table 3 provides a summary of the key statistics. The total number of observations is 1,216. Exports range from 0 to 94,805 thousand USD, with a mean value of 1,531.84 thousand USD. The S.D. of 7,351.15 indicates considerable variability in the export data. The value of the Human Population (Pakistan) ranges from 174 million (1.74E+08) to 240 million (2.40E+08) (Figure 3). The mean population is approximately 207 million (2.07E+08), with a S.D. of 19.8 million (1.98E+07). On the other hand, Human Population (Other Countries) ranges from 19.7 million (1.97E+07) to 1.41 billion (1.41E+09), with a mean population of 363 million (3.63E+08) and a S.D. of 584 million (5.84E+08). Pakistan's GDP across observations ranges from 578 billion (5.78E+11) to 1.49 trillion (1.49E+12), with a mean GDP of approximately 962 billion (9.62E+11) and a S.D. of 269 billion (2.69E+11). It is pertinent to mention that during two years, 2020 (-1.27409) and 2023 (-0.00486), Pakistan experienced negative GDP growth showed (Figure 4). A decrease in GDP impacts people's disposable income, thus affecting the production and trade of products. On the other hand, even in recent years, statistics show that Pakistan has exported more seafood products to other countries. This happened quite possibly due to other reasons, including illegal, destructive fishing, small mesh size, and catching during the closed season (Khan and Khan, 2011; Kalhoro et al., 2024). Whereas the GDP of other countries ranges from 26.3 billion (2.63E+10) to 34.6 trillion (3.46E+13), with a mean GDP of 4.86 trillion (4.86E+12) and an S.D. of 8.77 trillion (8.77E+12), indicating a wide variation in the economic sizes of the countries involved in the study.

The geographical distance between Pakistan and the other countries varies from 476 km to 4,513 km, with a mean distance of approximately 2,594.5 km and a S.D. of 1,668.28 km. The results for the distance variable are consistent across the two equations. In Equations 6, 7, the distance variable consistently shows a statistically significant negative relationship with trade flows. Specifically, the OLS and FEM estimates for distance are nearly identical, with coefficients of -3.537 and -3.569, respectively, both of which are statistically significant at the 1% level. This indicates that as the distance between Pakistan and its trading partners increases,

TABLE 2 Description of explanatory variables.

Expla. Varia.	Des.	Exp. Sign	Reason
Hum. Pop.	Total number of people living in a country at a given time	+ve	Larger domestic markets, increased production capacity, and greater trade partner attraction
GDP	Total monetary value of all goods and services produced within a country over a specified period	+ve	GDP association with higher production capacity, greater market demand, economic influence, and trade diversification
Dist.	Geographical separation between two countries	-ve	higher transportation costs, longer shipping times, logistical challenges, and reduced trade frequency
CP-FTA	Bilateral deal to reduce tariffs and enhance trade	+ve	Tariff reductions, improved market access, enhanced trade facilitation, increased investment, stronger bilateral ties, and economic diversification
PM-FTA	Bilateral deal to reduce tariffs and enhance trade	+ve	Tariff cuts, better market access, trade facilitation, and increased investment
PA-FTA	Bilateral deal to reduce tariffs and enhance trade	+ve	Tariff reductions, improved market access, enhanced trade facilitation, and regional economic integration
PSR-FTA	Bilateral deal to reduce tariffs and enhance trade	+ve	Tariff reductions, improved market access, simplified trade procedures, stronger bilateral relations
Mut. Bor.	Shared land boundary between two countries	+ve	Reduced transportation costs, easier logistics, increased trade frequency, and stronger economic ties
Comm. Col.	Two countries that were once part of the same colonial empire	+ve	Shared language, legal systems, and historical ties
Coloni.	A country that establishes control over another territory	-ve	Historical conflicts, trade barriers, different economic and cultural environment
Comm. Lan.	Language shared by two or more countries, often used for trsade	+ve	Transaction costs, easier business relationships, cultural similarities, and fewer barriers to market entry

"Expla. Varia." means Explanatory Variables, "Des." means Description, "Exp. sign" means Expected Sign.

trade tends to decrease, in line with the expectations of the Gravity Model (Borchert and Yotov, 2017; Wu et al., 2020). The PPML estimates, which account for heteroscedasticity and zero trade flows, are lower in magnitude, with a coefficient of -0.867, but still statistically significant at the 1% level. This suggests that while the effect of distance on trade is reduced when these complexities are considered, the negative relationship remains robust. Notably, including CP-FTAII in Equation 7 does not significantly alter the effect of distance on trade. Significant infrastructure development in Pakistan has been due to CP-FTAI, CP-FTAII, and CPEC (Mohsin et al., 2018; Mehak, 2024). However, there are still several shortcomings that need to be overcome. Swift transport can reduce the cost of trade and enhance trade volume between Pakistan and China (Mehak, 2024).

All of the FTAs represent binary variables (0 or 1), highlighting the presence of specific FTAs. Their mean values are very low, ranging from 0.021457 for CP-FTA to 0.092547 for PA-FTA. This indicates the limited presence of these agreements across the observations. Moreover, mutual border, a binary variable, exhibited a mean value of 0.033333 and an S.D. value of 0.16543. The mean value, 0.154265, of another binary variable, common colony, represents a relatively small proportion of colonial history observations. The S.D. value of this variable is 0.42945. Furthermore, the colonizer variable has a mean value of 0.33333 and an S.D. of 0.16543. This means a small percentage of observations that involve colonial relations between the countries. Lastly, the common language variable has a mean value of 0.365414 and an S.D. of 0.48512. This variable represents the moderate occurrence of a common language in the countries involved in this study.

A comparison of OLS, FEM and PPML results along with their corresponding intercept values for GM using Equations 6, 7 are listed in Tables 4, 5, respectively. The results of OLS, FEM, and PPML for the GDP variable by using Equations 6, 7 show a consistent and statistically significant positive relationship with trade flows. In both equations, the OLS and FEM estimates for the GDP coefficient are relatively similar, with values of 2.492 and 2.657 for Equation 6 and 2.494 and 2.660 for Equation 7, respectively, and both are statistically significant at the 1% level. This indicates that, according to OLS and FEM, GDP has a strong positive effect on trade. This result is supported by the published literature (Khayat, 2019; Zhang et al., 2022). However, the PPML estimates are considerably lower (0.686) for both equations, suggesting that accounting for heteroscedasticity and zero trade flows reduces the magnitude of the GDP-trade relationship, though the effect remains statistically significant at the 1% level. The similarity in results between Equations 6, 7 indicates that the inclusion of CP-FTAII does not significantly alter the GDP coefficient. This suggests a stable and robust relationship between GDP and trade flows in the context of Pakistan's trade with neighboring countries, including China. Our results align with the published literature, which also documents a positive relationship between GDP and trade (Khayat, 2019).

The results for the Hum. Pop. variable show a consistent negative relationship with trade flows. In both Equations 6, 7, the OLS estimates for the Hum. Pop (Ori.) are significant and negative,

TABLE 3 Summary of the key study statistics.

Variable		Cross-Section				Time-Series			
	Obs.	Min.	Max.	S.D.	Mean	Min.	Min.	S.D.	Mean
Exports	1216	0	220708	7351.15	1531.84	0	94805	7351.15	1531.84
Human Pop Pak	1216	1.74E+08	2.40E+08	1.98E+07	2.07E+08	1.74E+08	2.40E+08	1.98E+07	2.07E+08
Human Pop Other C	1216	1.97E+07	1.41E+09	5.84E+08	3.63E+08	1.97E+07	1.41E+09	5.84E+08	3.63E+08
GDP Pak	1216	1.45E+11	3.74E+11	7.21E+10	2.67E+11	1.45E+11	3.74E+11	7.21E+10	2.67E+11
GDP Other C	1216	2.63E+10	3.46E+13	8.77E+12	4.86E+12	2.63E+10	3.46E+13	8.77E+12	4.86E+12
Distance	1216	476	4513	1668.28	2594.5	476	4513	1668.28	2594.5
CP-FTA	1216	0	1	0.14618	0.021457	0	1	0.14618	0.021457
PM-FTA	1216	0	1	0.16543	0.033333	0	1	0.16543	0.033333
PA-FTA	1216	0	1	0.31759	0.092547	0	1	0.31759	0.092547
PSR-FTA	1216	0	1	0.16543	0.033333	0	1	0.16543	0.033333
Mutual Border	1216	0	1	0.16543	0.033333	0	1	0.16543	0.033333
Common Colony	1216	0	1	0.42945	0.154265	0	1	0.42945	0.154265
Colonizer	1216	0	1	0.16543	0.033333	0	1	0.16543	0.033333
Common Language	1216	0	1	0.48512	0.365414	0	1	0.48512	0.365414

"Obs." means Observations, "Min." means Minimum, "Max." means Maximum, "S.D." means Standard Deviation.

with values of -6.642 and -6.613, respectively. In contrast, the PPML estimates are smaller at -3.112 and -3.103 but still statistically significant. The FEM model omits the origin country's population, so no estimate is provided. For the Hum. Pop. (Dest.), the OLS and FEM estimates are consistent at around -2.13, and the PPML estimate is -0.478, with a smaller magnitude. The inclusion of CP-FTAII in Equation 7 does not substantially alter the results, indicating that the effect of population on trade is robust across both equations and models.

The results for the CP-FTA show a strong positive and statistically significant relationship with trade flows in both Equations 6, 7. In Equation 6, the OLS estimate for CP-FTA is 6.974, the FEM estimate is 7.103, and the PPML estimate is 1.565, all significant at the 1% level. These results indicate that the first phase of the CP-FTA has a substantial positive impact on trade between Pakistan and its trading partners. In Equation 7, which includes both phases of the CP-FTA, the estimates for CP-FTAI are 6.998 (OLS), 7.563 (FEM), and 1.521 (PPML), while the estimates for CP-FTAII are 7.167 (OLS), 7.426 (FEM), and 2.015 (PPML), all statistically significant at the 1% level. These results suggest CP-FTAII has an even stronger positive effect on trade flows than CP-FTAI.

While CP-FTA results dominate the analysis, other FTAs, such as the PSR-FTA, PA-FTA, and PM-FTA, also show positive and

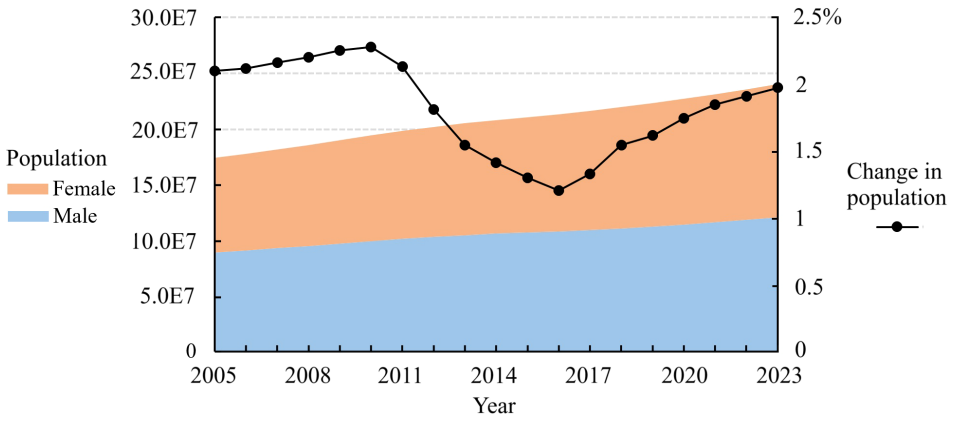

FIGURE 3
Human population dynamics in Pakistan.

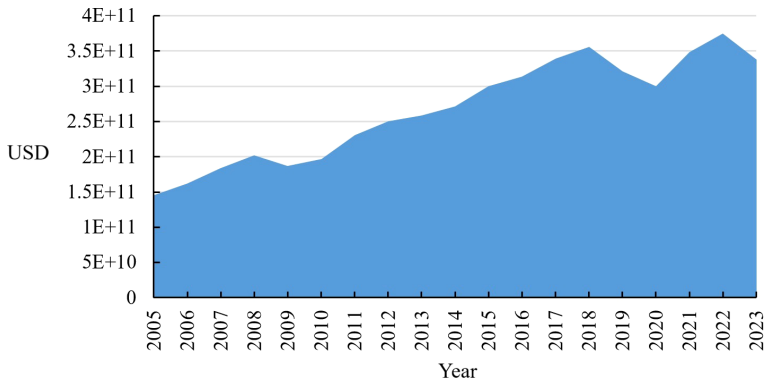

FIGURE 4
Nominal GDP of Pakistan.

statistically significant effects, although their magnitudes are smaller. For instance, PSR-FTA shows OLS estimates of 2.451 (Equation 6) and 2.453 (Equation 7), PA-FTA shows 3.679 (OLS) and 3.678 (OLS), and PM-FTA shows 6.763 (OLS) for both the equations. These estimates are statistically significant at the 1% level, though their impact on trade is smaller than that of the CP-FTAs. For the variable Mut. Bor. the results are consistent across both equations. In Equation 6, the OLS estimate is -2.384, FEM is -2.581, and PPML is -0.623, all statistically significant at the 1% level. These results suggest that sharing a mutual border between Pakistan and its trading partners has a negative impact on trade, with the effect being more pronounced in the FEM and OLS models than in the PPML model. In Equation 7, the results are nearly identical, with OLS at -2.384, FEM at -2.582, and PPML at -0.623, again all statistically significant at the 1% level.

The results of the variable Comm. Col. show a significant positive relationship with trade. The OLS estimate is 2.011 in Equation 6 and 2.010 in Equation 7, with FEM estimates of 2.032 and 2.033 and PPML estimates of 1.031 in both equations. These estimates are all statistically significant at the 1% level, indicating that a common colonial history between Pakistan and its trading partners fosters trade, with the PPML estimates being slightly smaller than the OLS and FEM estimates. The Coloni. variable also shows a positive and significant effect on trade flows. In Equation 6, the OLS estimate is 3.142, FEM is 3.102, and PPML is 0.417, all statistically significant. In Equation 7, the estimates are

TABLE 4 A comparison of OLS, FEM and PPML results for GM using Equation 6.

Ind. Variab.	OLS	FEM	PPML
Intercept	7.385*** (1.025)	7.310*** (1.025)	6.865*** (0.931)
Ln Exp. GDP	2.492*** (0.061)	2.657*** (0.061)	0.686*** (0.035)
Ln Imp. GDP	1.234*** (0.054)	1.312*** (0.058)	0.345*** (0.029)
Ln Hum. Pop. (Ori.)	−6.642*** (0.861)	Omitted	−3.112*** (0.345)
Ln Hum. Pop. (Dest.)	−2.133*** (0.101)	−2.143*** (0.101)	−0.478*** (0.084)
Ln Dist.	−3.537*** (0.221)	−3.569*** (0.218)	−0.867*** (0.218)
CP-FTA	6.974*** (0.668)	7.103*** (0.655)	1.565*** (0.274)
PSR-FTA	2.451** (0.804)	2.688** (0.804)	0.715* (0.238)
PA-FTA	3.679*** (0.621)	3.661*** (0.614)	1.054*** (0.265)
PM-FTA	6.763*** (0.649)	6.856*** (0.643)	1.228*** (0.097)
Mut. Bor.	−2.384*** (0.621)	−2.581*** (0.615)	−0.623*** (0.269)
Com. Col.	2.011*** (0.341)	2.032*** (0.339)	1.031*** (0.074)
Coloni	3.142*** (0.635)	3.102*** (0.631)	0.417*** (0.085)
Count. Lan.	−0.132 (0.621)	−0.114 (0.616)	0.117 (0.057)
R^2	0.705	0.713	0.694
Obs.	1216	1216	1216

*, **, and *** represent the significance at 10, 5, and 1% significance levels respectively; the values in the parentheses are standard errors.

TABLE 5 A comparison of OLS, FEM and PPML results for GM using Equation 7.

Ind. Variab.	OLS	FEM	PPML
Intercept	7.412*** (1.035)	7.338*** (1.023)	6.876*** (0.940)
Ln Exp. GDP	2.494*** (0.061)	2.660*** (0.061)	0.686*** (0.035)
Ln Imp. GDP	1.234*** (0.054)	1.312*** (0.058)	0.345*** (0.029)
Ln Hum. Pop. (Ori.)	−6.613*** (0.863)	Omitted	−3.103*** (0.345)
Ln Hum. Pop. (Dest.)	−2.135*** (0.101)	−2.143*** (0.101)	−0.478*** (0.084)
Ln Dist.	−3.537*** (0.221)	−3.570*** (0.218)	−0.867*** (0.218)
CP-FTAI	6.998*** (0.721)	7.563*** (0.789)	1.521*** (0.286)
CP-FTAII	7.167*** (0.645)	7.426*** (0.663)	2.015*** (0.318)
PM-FTA	6.763*** (0.649)	6.857*** (0.643)	1.228*** (0.097)
PA-FTA	3.678*** (0.621)	3.671*** (0.614)	1.054*** (0.265)
PSR-FTA	2.453** (0.804)	2.687** (0.803)	0.715* (0.238)
Mut. Bor.	−2.384*** (0.621)	−2.582*** (0.615)	−0.623*** (0.269)
Com. Col.	2.010*** (0.341)	2.033*** (0.338)	1.031*** (0.074)
Coloni	3.142*** (0.636)	3.106*** (0.633)	0.416*** (0.085)
Count. Lan.	−0.132 (0.621)	−0.113 (0.615)	0.117 (0.057)
R^2	0.706	0.714	0.694
Obs.	1216	1216	1216

*, **, and *** represent the significance at 10, 5, and 1% significance levels respectively; the values in the parentheses are standard errors.

similar, with OLS at 3.142, FEM at 3.106, and PPML at 0.416. These results suggest that the historical presence of a colonizer significantly enhances trade, although the magnitude of the effect is reduced in the PPML model.

The Comm. Lan. variable shows less consistency in its effect on trade. In both Equations 6, 7, the OLS estimates for Comm. Lan. are negative (-0.132 in Equation 6 and -0.132 in Equation 7), but neither estimate is statistically significant. Similarly, the FEM estimates are also negative (-0.114 in Equation 6 and -0.113 in Equation 7), but again, they are not statistically significant. However, the PPML estimates for Comm. Lan. are positive (0.117) in both equations and statistically significant at the 5% level. This suggests that a shared language between countries can promote trade, but the effect is only significant in the PPML model. In Pakistan, Urdu is the official spoken language. Where its trading partner countries considered in this study use different official languages. In Iran, Persian is the official language. On the other hand, in Malaysia, Malay is the official language. Moreover, the official languages of China and Sri Lanka are Chinese and Sinhala or Tamil, respectively. The online literature supports the negative coefficients of Common Language in this study (Arif et al., 2017). Language barriers can be reduced by using effective communication to promote trade between countries (Melitz, 2008).

Reiterating the relevance of GM, the results are consistent across different estimating methods. The notable and positive coefficients of FTAs underscore the significance of trade agreements in enhancing seafood exports. Some insignificant coefficients, such as CP-FTAII, may be attributed to external influences, such as the COVID-19 epidemic. This emphasizes the importance of accounting for external shocks and unforeseen events to produce more precise forecasts and policy recommendations. The distance and contiguity variables have negative coefficients, indicating a strong relationship between geographical closeness and trade facilitation. Thus, policymakers should prioritize programs that strengthen the current FTA and negotiate new ones to boost seafood exports. Investing in infrastructure, eliminating trade barriers, and expanding markets is crucial to optimize trade opportunities. Considering geographical proximity, exporters should focus on opportunities in nearby markets rather than relying on areas further away. In the presence of disruptive external forces e.g. pandemics, the export industry must employ resilient strategies to mitigate risks. Moreover, implementing evidence-based trade policies requires close cooperation among research institutions, industry players, and the government.

The above results demonstrate consistency across different estimation methods, including OLS, FEM, and PPML, which confirms the reliability of the key relationships identified in this study. Specifically, the statistically significant positive effects of GDP, FTAs, and geographical proximity on seafood trade flows remain robust across all models. Additionally, the negative relationship between distance and trade, as well as the strong impact of FTAs, further supports the stability of the conclusions. This study acknowledges potential external influences, such as the COVID-19 pandemic, which could have affected trade patterns, but the core findings remain resilient despite these disruptions. This robustness check enhances the credibility of the study's results and ensures that the observed trends in seafood trade are not contingent upon specific model assumptions or external shocks.

Moreover, it is pertinent to mention that trade elasticities may differ across countries. The consistency of our results across OLS, FEM, and PPML estimations supports the validity of the uniform elasticity assumption in this context.

The positive impact of FTAs on Pakistan's seafood exports directly contributes to SDG 8 by promoting trade-driven economic growth and employment opportunities in the seafood sector. Specifically, enhancing FTAs, coupled with infrastructure development through projects like CPEC, supports SDG 9 by boosting the efficiency and sustainability of trade networks. Moreover, the study advocates for sustainable fishing practices that align with SDG 12, ensuring that the growth in seafood exports does not lead to overfishing or environmental degradation. Policymakers should also focus on measurable outcomes, such as increasing the volume of seafood exports by a certain percentage or reducing trade costs by improving logistics infrastructure, to directly contribute to these SDGs. Further research could investigate the specific impact of these recommendations, including quantifiable improvements in trade volumes, infrastructure quality, and sustainable production practices, to track progress toward achieving the relevant SDGs.

4.1 Implications

The findings of this study have several practical implications. This study suggests strengthening and expanding FTAs to boost Pakistan's seafood exports. Moreover, improving infrastructure, especially transport networks, can reduce trade costs and enhance efficiency. Policymakers should address external shocks, such as pandemics, with risk management strategies. In addition, sustainable fishing practices should be prioritized to align with global standards and improve competitiveness. Furthermore, expanding regional trade networks and diversifying markets will help reduce reliance on distant countries and support Pakistan's economic growth.

4.2 Limitations

Due to the focus of this study on seafood exports, it cannot accurately reflect Pakistan's broader trading relationships. Including real transportation costs instead of distance could improve the model and help people understand it better. Furthermore, it was not possible to consider Pakistan's political stability, which is an essential factor in establishing trade links within the country. Some deviations in the results should be verified and explored in terms of their potential causes. Moreover, this research does not consider the currency exchange rate and security issues, which are factors that play a role in establishing prices and have the potential to influence the flow of trade. In addition, the COVID-19 pandemic could have contributed to the negative and insignificant relationship observed in CP-FTAII. This is likely due to disruptions in global supply chains, changes in demand, and general uncertainty in the global trade environment during the pandemic. Therefore, future studies could explore the quantitative effects of external shocks more explicitly.

5 Conclusion

This study highlights the positive impact of CP-FTA on Pakistan's seafood exports It finds that proximity to markets and historical colonial ties play significant roles in trade patterns, with a negative correlation between geographical distance and exports. The study recommends reducing trade costs by improving logistics, supporting CPEC infrastructure, strengthening business ties with neighboring countries, and expanding trade partnerships. These findings align with several key SDGs 8, 9 and 12. Future research could include variables that impact trade, such as tariff structures, product diversity, marine-sector-specific indicators, sanitary and phytosanitary measures, and technological advancements. More advanced econometric methods could be used in future studies to enhance the gravity model. Researchers could explore different methods that might help them understand global trade dynamics more deeply. This study also recognizes the importance of considering external shocks, such as the COVID-19 pandemic, which can disrupt trade dynamics and affect the stability of exports. While the gravity model provides valuable insights, future research could explore more granular factors, such as tariff structures, robustness checks by excluding the COVID years, product diversification, and technological advancements, to gain a deeper understanding of global trade patterns. Additionally, testing different econometric methods and expanding the range of variables could further refine the model and its predictions. Policymakers are encouraged to focus on resilient trade strategies, strengthen FTAs, diversify markets, and improve infrastructure to safeguard exports against future disruptions. Finally, fostering public-private partnerships and supporting R&D initiatives will ensure that Pakistan remains a competitive and sustainable player in the global seafood export market.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

YX: Investigation, Methodology, Writing – original draft. HY: Resources, Supervision, Validation, Writing – review & editing. MM: Conceptualization, Data curation, Methodology, Writing – review & editing. AM: Data curation, Formal Analysis, Resources, Writing – review & editing. CY: Data curation, Resources, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2025.1553780/full#supplementary-material

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