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Does the China–Pakistan free trade agreement benefit the vegetable exports of Pakistan? A gravity estimation

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In the backdrop of criticism that the China-Pakistan Free Trade Agreement has disproportionately favored China, particularly in agricultural trade, there has been a surge in Pakistan's imports, leading to a trade deficit. This study attempts to evaluate the impact of CPFTA 1&2 on the vegetable exports of Pakistan which is an important sector of the agricultural industry. A panel data set of Pakistan's vegetable exports to its trading partners from 2003 to 2021 was analyzed with the extensively used gravity model of trade. The vegetable export data was sourced from the International Trade Centre (ITC) which is based on the Pakistan Bureau of Statistics. The results suggest that the China-Pakistan Free Trade Agreement (CPFTA-I) has a positive association with Pakistan's vegetable exports to China. However, trade liberalization with Afghanistan, Sri Lanka, and Malaysia plays a more substantial role in driving Pakistan's vegetable exports. CPFTA-II has not had a measurable or statistically significant impact on the vegetable exports of Pakistan as this period was highly influenced by COVID-19. The results of colonialism variables show that Pakistan is exporting more to countries with the same colonial history. Moreover, the results of the geographical variable suggest that Pakistan should explore more close markets to expand vegetable exports. Policy implications suggest the need to reduce trade costs, leverage CPEC infrastructure, enrich trade relations with neighboring countries, and involve business professionals in policy negotiations.

KEYWORDS

trade liberalization, China–Pakistan Free Trade Agreement (CPFTA), gravity equation, vegetable trade, CPEC

1 Introduction

Trade liberalization is a crucial element of economic integration that removes or reduces restrictions and barriers to promote international trade. Trade liberalization by creating employment and eradicating poverty increases the country's economic growth (Yameogo and Omojolaibi, 2021). Over the last few decades countries across the globe are actively participating in free trade agreements to accelerate economic and trade activities. Following the same trend of economic integration, Pakistan tied itself to different trade agreements with China, Malaysia, Sri Lanka, Afghanistan, and Iran to promote trade and economic activities (MoC, 2022). Trade advantages can be diverse across nations, upon a country's particular set of interests, economic outlook, and diplomatic relationships (Irshad et al., 2018). In the context of trade liberalization, the China-Pakistan Free Trade Agreement (CPFTA) initially formed in

2006, is still debated, and a popular subject for researchers (Irshad and Xin, 2018; Lateef et al., 2018; Haq et al., 2021; Shah, 2021; Qiu et al., 2022). The impact of free trade agreements, however, on some particular sectors of Pakistan's economy, such as the agriculture sector, has widely drawn criticism (Barbalet et al., 2015; Irshad and Xin, 2018; Qiu, 2020; Butt et al., 2022). These studies discovered several reasons why CPFTA was less effective. These reasons include China's dominant economic position due to its diverse economy, Pakistan's insufficient grounding to exploit the concessions of CPFTA, Pakistan exporting only a few items, and Pakistan's fragile economy and global crises of 2008 occurring shortly after the establishment of CPFTA. Hence it becomes important to study the individual segments of the agriculture sector of Pakistan in the context of the China-Pakistan Free Trade Agreement.

The trade portfolio of China and Pakistan receives handsome contributions from their agriculture sector. China – Pakistan agricultural trade is primarily comprised of raw agricultural products, cotton, and cereals. However, additional trading sectors like vegetables and fruits have emerged over time and trade integration. In 2021, Pakistan's exports totalled USD 3.04 billion and the imports valued at USD 20.7 billion which created a huge trade deficit. In terms of agricultural trade with China, Pakistan's agricultural export was recorded at 4.19 percent of the total exported value to China in 2006. The agricultural exports of Pakistan continued its increase pace and reached 26 percent of the total trade with China in 2021. Vegetable is an important sector of agriculture in Pakistan (Manzoor et al., 2020; Abbas, 2022). As presented in Appendix Table A1, even with its agricultural capabilities, Pakistan's vegetable exports to the world were USD 313 million in 2021, while the imports were USD 946 million on the other hand China's vegetable exports were USD 10077 million and imports were 2,854 USD million (ITC, 2021). Table 1 shows the Pakistan's vegetable trade with China from 2003 to 2021. Though during this period Pakistan's total vegetable trade with China observed 21.6 percent growth. The surging imports of Pakistan have driven the vegetable trade deficit. In the background of the importance of vegetables in the agricultural sector of Pakistan and the trade deficit with China, this study adopts the gravity model of trade to evaluate the impact of China–Pakistan Trade Agreements CPFTA 1&2 on vegetable exports of Pakistan.

The gravity model of trade hypothesizes that the volume of trade between two countries is positively associated with their economic sizes and inversely related to the distance between them. Trade flow is further influenced by factors including contiguity, colonial links, and the presence of trade agreements. The inclusion of various determinants allows for a comprehensive assessment of the factors shaping Pakistan's vegetable exports. Population size often serves as a proxy for market demand, whilst distance and contiguity capture the geographical barrier and proximity influence trade patterns. Moreover, historical colonial relations can exert lingering effects on trade relationships, further enhancing the depth of analysis.

Compared to the existing research, this study has three notable contributions. First, previous research mainly focused on general or sectoral trade however, to the best of our knowledge, no study focuses on the impact of Pakistan's free trade agreements on the commodity level. To our knowledge, this is the first empirical study using the gravity equation of trade to analyze Pakistan's vegetable exports to China. Second, as discussed earlier, vegetables among the crops of Pakistan hold an important position that requires attention to be placed in the right market to improve the balance of trade and foreign exchange earnings. So, our study contributes by offering detailed insight into vegetable trade which is not covered comprehensively in the existing literature. Third, since earlier studies solely focused on the first phase of CPFTA, a comprehensive study of the trade agreement gives decision-makers the knowledge to make informed decisions. For this reason, this is among the very first studies to take into account both CPFTA-I and CPFTA-II.

TABLE 1 Pakistan's vegetables exports to China (US Dollar Thousand).

Year	Exports	Imports	Trade	Deficit
2003	67	19,824	19,891	−19,757
2004	37	13,689	13,726	−13,652
2005	136	45,741	45,877	−45,605
2006	469	48,563	49,032	−48,094
2007	199	82,296	82,495	−82,097
2008	0	57,420	57,420	−57,420
2009	0	66,765	66,765	−66,765
2010	28	97,310	97,338	−97,282
2011	227	93,258	93,485	−93,031
2012	3,955	35,054	39,009	−31,099
2013	598	30,042	30,640	−29,444
2014	889	67,823	68,712	−66,934
2015	923	63,130	64,053	−62,207
2016	852	107,378	108,230	−106,526
2017	11	87,190	87,201	−87,179
2018	36	43,988	44,024	−43,952
2019	42	58,340	58,382	−58,298
2020	303	112,518	112,821	−112,215
2021	109	71,260	71,369	−71,151

The rest of this research is constructed as follows. Section 2 presents a brief literature review. Section 3 describes the material and methods, providing detailed information about the data sources and data structure, the gravity equation of trade, and the estimation techniques involved in the analysis. Section 4 presents the estimated results and discusses each variable under study. All the findings of the study are concluded in section five of this study.

2 Literature review

The primary objectives of the CPFTA were to safeguard the two-sided relationship between China and Pakistan and expand bilateral trade. The tariffs and restrictions were lifted from the 6,711 and 6,418 product lines for Pakistan and China, respectively. The products and product categories for which China removed or reduced barriers included textiles, seafood products, agriculture and livestock, and minerals. Pakistan reduced or removed tariffs on agrarian products such as fruits and vegetables, machinery, meat, and chemicals. However, Pakistan has yet not fully exploited the CPFTA and only enjoyed 3.3 percent of the tariff line (Hussain, 2017). The positive impact of CPFTA is more observable in the imports of

Pakistan from China, which has expanded the trade deficit of Pakistan with China (Xin et al., 2014; Ali, 2018; Baier et al., 2019; Qayyum and Nigar, 2020; Rahamdil et al., 2021; Shah et al., 2022). Since the CPFTA 2006, Pakistan's imports from China rose from USD 2.9 billion to USD 15.17 billion. This trade deficit is mainly caused by those products that were not imported before the implementation of CPFTA (Mukhtar and Hongdao, 2017). Despite the concessions made by China, Pakistan did not achieve all the benefits it hoped for from China because local businessmen and traders were not actively part of the negotiations (Mukhtar, 2019). The backdrop of criticism and the perception that CPFTA 2006 favored China more than that of Pakistan led to the negotiation of the second phase of the CPFTA. The second phase of the China-Pakistan Free Trade Agreement CPFTA-II, spanning from 2019 to 2024, was executed in 2019. The reductions and concessions on the tariff line were expanded in the CPFTA-II. In phase II of the CPFTA China has favored Pakistan by waiving tariffs on 313 export products of the interest of Pakistan (MoC, 2022). The tariff structure of the CPFTA-II is better than that of the CPFTA-I and presents considerable prospects to expand and diversify Pakistan's exports to China. The second phase of the CPFTA is not an independent agreement, instead, its evaluation should be intervened with the China-Pakistan Economic Corridor (CPEC) as the framework of CPEC has notably improved the connectivity between China and Pakistan. The fastest connected route across Khujarab Pass, which is both time and cost-effective, is expected to facilitate and expand bilateral trade (Alam et al., 2023a,b).

The prevailing literature has a contradiction on the effect of the China-Pakistan Free Trade Agreements. For instance, Irshad and Xin (2018) utilized the gravity model of trade and studied the Pakistan-China trade potential from 1992 to 2015. Most of their study results obtained from different techniques like EGLS, PPML Tobit model, etc. are aligned with the theory of gravity however they argue that free trade agreement has a negative impact on bilateral trade. More specifically their results reveal that CPFTA is not successful in achieving its goal of improving the exports of Pakistan. Lateef et al. (2018) preferred the gravity model with the PPML technique and studied the impact of CPFTA on the bilateral agricultural trade between China and Pakistan. Their research argues that although CPFTA has a trade creation effect this agreement has not boosted the agricultural exports of China. Qayyum and Nigar (2020) used various econometric indices to analyze the pre and post-CPFTA trends in the agriculture sector. According to their results, the bilateral trade between China and Pakistan is more tilted towards China. Further, they argue that trade in agricultural products can contribute to reducing the trade deficit of Pakistan. In the same context, Lateef et al. (2017) analyzed the gravity equation with a PPML estimator to evaluate CPFTA. Their research used a large data set of 110 export partner countries of Pakistan from 2001 to 2014. The results show that CPFTA has significantly increased the volume of agricultural trade. Overall the current papers provide a broad picture of CPFTA's effect on the agricultural trade between China and Pakistan and there is an obvious lack of study for certain agricultural commodities. Decision-makers and stakeholders in both China and Pakistan need to know how the CPFTA 1 and 2 impact specific agricultural commodities. This paper will help decision-makers and stockholders to better understand the obstacle and will aid in figuring out where to focus efforts to fully exploit trade liberalization.

3 Materials and methods

In this section, we present how we conducted this study and the tools we used. First, we explain the basic idea of the gravity equation. Second, we describe our derived model for the vegetable exports of Pakistan. Third, we provide the detailed protocol involved in the estimation of our model. Finally, we give information about the data source and summarize the main characteristics of the data.

3.1 Gravity equation

Newton's Law of gravitation serves as the foundation for the gravity model of trade. Tinbergen (1962) and Pöyhönen (1963) introduced the concept of Newton's Law of Gravitation to international trade. The main theme of the model is that trade between countries is directly proportional to the economic masses of the countries and inversely proportional to the trade cost between them. In general, a country's GDP represents its economy or economic size (Markusen, 2013), whereas distance and trade barriers indicate the cost of trade between them. Hence the gravity equation of trade states that "the volume of trade between countries is directly proportional to the GDP of countries and inversely proportional to the distance between them" (Tinbergen, 1962; Linnemann, 1966). The gravity model of trade is widely preferred to measure the trade flow between any two counties or regions (Caporale et al., 2015). Gravity stands as a 'celebrity' in economic modeling, witnessed by its widespread utilization in international trade (Yotov, 2022). Mathematically the gravity equation of trade is expressed as follows in Equation 1:

$$X_{ij} = A\left(Y_i Y_j\right) / D_{ij} \tag{1}$$

Where i and j, respectively, represent exporting and importing countries, X_{ij} refers to the bilateral trade volume between i and j, A is the constant and Y_i represents the GDP of the country i,Y_j represents the GDP of country j, D_{ij} is the cost of transportation and distance between the two countries, i.e., i and j.

The gravity equation is transformed to logarithmic form to get the linear version as follows in Equation 2:

$$LnX_{ij} = \beta_0 + \beta_1 LnY_i + \beta_2 Y_j - \beta_3 LnD_{ij} \tag{2}$$

By adding the stochastic term, we get the final version of the simple gravity model of trade as follows in Equation 3:

$$LnX_{ij} = \beta_0 + \beta_1 LnY_i + \beta_2 Y_j - \beta_3 LnD_{ij} + \varepsilon_{ij} \tag{3}$$

Once we develop the model where the independent variables GDP's of the countries and the distance explains the dependent variable then it is possible to incorporate other control variables that are expected to explain the dependent variable. In Equation 4, γLnX captures all the control variables that possibly affect the bilateral trade.

$$LnX_{ij} = LnA + \alpha Ln\left(Y_i * Y_j\right) - \beta LnD_{ij} + \gamma LnX + \varepsilon_{ij} \tag{4}$$

Anderson and Van Wincoop (2003) incorporated the multilateral resistance term into the model which capture the general equilibrium effect of the trade barriers. The MR gives bilateral trading partners the ability to have their exports influenced by the demand of other countries for their products and alternative suppliers for their imports. The average trade barrier between two trading nations is known as the MR. This indicates that relative adjustments in trade barriers between paired nations relative to other trading partners may result in a reduction in bilateral trade volumes. Structural gravity is another name for the underlying theory of the gravity model, which incorporates the MR term as given in Equation 5:

$$X_{ij} = \frac{Y_i Y_j}{Yw}\left(\frac{t_{ij}}{\prod i \prod j}\right)^{1-\sigma} \quad (5)$$

Where, where Yw represents world GDP, $Y_i$and$Y_j$are the GDP of countries j and i respectively, X_{ij} shows the exports from country i to destination j, tij represents the transaction costs of products export from country i to j, σ is the elasticity of substitution between all products. The basic assumption is to take a fixed value of $\sigma > 1$ to account for a preference for a variation of commodities thus a commodity can be substituted for other similar goods. ÷ $j$is the multilateral resistance term (MRT) (representing the trade costs of country j as a function of all trading partners i and their import demand).÷ i represents the inward multilateral resistance and is, therefore, a function of the trade cost of i (the importer) to all trading partners j. Unobserved trade barriers that are challenging to assess or include in the model are taken into consideration by these two variables. Country-fixed effects for importers and exporters and year-fixed effects are the most widely used and accepted approaches to account for these indicators (Feenstra, 2002).

3.2 The model

We settled our model for Pakistan's vegetable exports. The standard gravity equation is augmented by adding population, binary variable for the trade agreements with the importers, common language, common border (contiguity), common colony, and colonizer.

$$\begin{aligned} LnX_{ij} = {} & \beta_0 + \beta_1 LnGDP_i + \beta_2 LnGDP_j + \beta_3 LnD_{ij} \\ & + \beta_4 Lnpop_i + \beta_5 Lnpop_j + \beta_6 comlan_{ij} + \beta_7 contig \\ & + \beta_8 Comcol + \beta_9 Col + \beta_{10}\text{PAFTA} + \beta_{11}\text{PIFTA} \\ & + \beta_{12}\text{PSFTA} + \beta_{13}\text{PMFTA} + \beta_{14}\text{CPFTA} + \varepsilon_{ij} \end{aligned} \quad (6)$$

$$\begin{aligned} LnX_{ij} = {} & \beta_0 + \beta_1 LnGDP_i + \beta_2 LnGDP_j + \beta_3 LnD_{ij} \\ & + \beta_4 Lnpop_i + \beta_5 Lnpop_j + \beta_6 comlan_{ij} + \beta_7 contig \\ & + \beta_8 Comcol + \beta_9 Col + \beta_{10}\text{PAFTA} + \beta_{11}\text{PIFTA} \\ & + \beta_{12}\text{PSFTA} + \beta_{13}\text{PMFTA} + \beta_{14}\text{CPFTA} \\ & + \beta_{15}\text{CPFTA}_2 + \varepsilon_{ij} \end{aligned} \quad (7)$$

Where the $LnGDP_i$ and $LnGDP_j$ represent the natural logarithm of the GDP of Pakistan and the partner countries, respectively. The GDP of both origin countries and destination countries is expected to have positive signs. LnD_{ij} is the natural logarithm of the distance between the origin country (Pakistan) and destination countries. The coefficient of distance is expected to have a negative sign. $Lnpop_i$ and $Lnpop_j$ is the natural logarithm of the population of origin and destination countries, respectively. Common language is a binary variable used in the study which takes the value of one if the origin and partner countries are sharing an official common language otherwise zero. Common language is anticipated to have a positive impact on trade between countries by reducing the communication gap. The data for the common language is sourced from CEPII. A common border is a binary variable that takes the value of one if the countries sharing the border with the sourced country otherwise zero. Common border (contiguity) is expected to have a positive relation to the trade between them as it reduces the trade cost in terms of distance. The data for the common border is sourced from CEPII. Trade agreement is a dummy variable and takes the value of one if the countries have joined an agreement otherwise zero. In this study, we have added five trade agreements to the model. PAFTA represents the Pakistan trade agreement with Afghanistan, while PIFTA represents the preferential trade agreement with Iran in southwest Pakistan. Three bilateral free trade agreements with China, Sri Lanka, and Malaysia are represented with CPFTA, CPFTA_2, PSFTA, and PMFTA, respectively. However, we will mainly focus on Pakistan's free trade agreements with China. Trade agreements are anticipated to have a positive impact on the vegetable exports of Pakistan.

3.3 Estimation protocol

In line with the previous studies, we employed various econometric approaches to investigate whether our model is consistent with the gravity theory of trade. We preferred Ordinary Least Square (OLS), Fixed effect (FE), and Pseudo Poisson Maximum Likelihood (PPML) to reach reliable results. However, researchers have identified several weaknesses in the specification and estimation techniques of the gravity model of trade.

The estimations of Ordinary Least Square OLS regression drop zero bilateral trade (exports in our case). For instance, in our data, 73% of the data set exhibits positive while 27% are zero trade/exports. OLS outcomes will be only reliable if they fulfill the general required conditions of multicollinearity, homoscedasticity, and error term correlation with any independent variable. if there is heteroskedasticity in the data then the OLS estimations remain biased (Silva and Tenreyro, 2006; Gómez-Herrera, 2013). The gravity equation of trade traditionally estimated with the fixed effects model does not account for exporter and importer invariant variables (Barbalet et al., 2015; Prehn et al., 2016) To address the endogeneity problem in the model recent studies have suggested the fixed effect model as the fixed effect model helps to address the biases arise from the unobserved time-specific effects. By including fixed effects in the model, we essentially capture the country-specific unobserved factors that might influence trade but are not directly included in the model. The fixed effect approach improves the reliability of the estimated coefficient.

In international trade data, it is common to observe zero values indicating no trade between a pair of countries or for a certain product (Sun and Reed, 2010; Philippidis et al., 2013; Timsina and Culas, 2022). For instance, our model is true only if Xij > 0, Xij = 0 indicates

that there is no trade between countries, and the log of zero is not defined. To address the heteroskedasticity and the zero-trade issue literature has widely criticized the OLS, Fixed and Random effects model, and preferred PPML technique (Silva and Tenreyro, 2006; Braha et al., 2018; Brodzicki and Uminski, 2018; Irshad and Xin, 2018; Correia et al., 2020; Yusuf et al., 2021; Santos Silva and Tenreyro, 2022). PPML has several advantages over other estimators and effectively addresses the common issue in trade analysis (Anderson and Yotov, 2016; Yotov et al., 2016). Hence, we rely on the results of estimates obtained from the PPML technique.

3.4 Data

We extracted and compiled data from multiple sources. Vegetable exports are the dependent variable which is the annual export value from the origin country (Pakistan) i to country j which is the destination country. Appendix Table A2 presents the list of Pakistan's vegetable export destinations. This study is based on 2-digit HS classification code 07 within the Harmonized System of Commodity Classification specifically pertaining to "Edible Vegetables Certain Roots and Tuber." Appendix Table A3 presents a detailed description of the products under HS-07. The data spanning from 2003 to 2021 is sourced from the International Trade Centre (ITC) database. Gross domestic product is a measure of the country's economic size. According to the basic gravity equation of trade GDP of both the origin and destination country is expected to positive impact on the exports of vegetables (dependent variable). GDP data in this study is sourced from the World Development Indicator (WDI). Population describes the strength of the country's market. It is expected that the greater the market size the greater will be trade among them. The data on the population of the countries is obtained from the World Development Indicator (WDI). The binary variable Colony has a value of one if the two nations have ever had a colonial connection in the past while the Comcol takes the value of one if the pair of nations were colonized by the same colonial power. The United Kingdom was the only country to have a common colonizer with other countries in the dataset. For the Colony variable, our dataset reveals that the United Arab Emirates, Bangladesh, Bahrain, Brunei Darussalam, Hong Kong, China, India, Kenya, Kuwait, Sri Lanka, Maldives, Myanmar, Malaysia, Qatar, Singapore, Tanzania, and Uganda have historical colonial relations. The data for the history variables Colony and Comcol are sourced from the CEPII database.

Table 2 presents the summary statistics of the data. Exports are often defined as the goods and services that a country sells to other countries. There are 843 observations of exports in our data set. The average value of the exports over these observations is around 3670.79. The standard deviation is relatively high, which explains the significant difference in the exports among countries. The minimum export value is zero which indicates that some countries have no export record for some period.

GDP is the measure of the economic output or total value of goods and services produced within the borders of a country. There are 854 observations of the GDP for Pakistan's vegetable export destination countries. The large standard deviation suggests substantial variability in the economic masses of the destination countries. There are 855 observations for the population of both origin and destination countries. The high standard deviation in the population of the destination countries explains the significant variation in the population of countries. The distance represents the geographical distance between Pakistan and the destination countries involved in trade. The average distance is around 5,092.16 kilometers, with a standard deviation of 3422.59 kilometers. The distance between the trading partners shows high variation. The shortest distance is 373.6 kilometers, while the largest distance observed in our data set is around 15,622 kilometers. CPFTA, PMFTA, PSFTA, PIFTA, and PAFTA are binary variables that represent that represent trade policies. They are crucial indicators that can influence trade with trading partners. Contiguity represents the closeness of origin and partner countries. Contiguity by reducing the trade cost can influence the trade. Common language is a binary variable and is expected to potentially enhance bilateral trade.

TABLE 2 Descriptive Statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
exports	843	3670.696	13975.19	0	165,314
gdp_d	854	1.16E+12	2.88E+12	1.05E+09	2.33E+13
gdp_o	855	2.26E+11	8.43E+10	9.18E+10	3.56E+11
pop_o	855	2.00E+08	1.93E+07	1.67E+08	2.31E+08
pop_d	855	1.11E+08	2.68E+08	297,226	1.41E+09
dist	855	5092.159	3422.593	374.652	15622.2
CPFTA	855	0.018714	0.13559	0	1
PMFTA	855	0.022222	0.147492	0	1
PSFTA	855	0.019883	0.13968	0	1
PIFTA	855	0.022222	0.147492	0	1
PAFTA	855	0.022222	0.147492	0	1
contig	855	0.088889	0.28475	0	1
comlang_off	855	0.266667	0.442476	0	1
comcol	855	0.355556	0.478962	0	1
colony	855	0.022222	0.147492	0	1

"Obs" means observations and "std.dev." means standard deviation.

4 Results and discussion

The objective is to investigate whether the trade agreements between China and Pakistan affect the vegetable exports of Pakistan. In this section, we provide the findings of our study and engage in an in-depth discussion of our results. Through this part of the study, we hope to provide a complete knowledge of the data and the insight it provides into Pakistan's vegetable exports under trade liberalization.

As presented in Table 3, which is calculated based on Equation 6, we compare the results obtained from different methods to reach reliable and robust outcomes. The Hausman test suggests the FE model, as $X^2 = 28.54$ with 5 degrees of freedom, and given the p-value 0.000 we reject the null hypothesis. Despite our reliance on PPML estimation, both the OLS and FE offer support and contribute to the robustness of our findings. The results obtained from the three models are to some degree resembling. We find consistency in the pattern of estimates obtained, as none of the parameters exhibit a change in the sign. We find that overall, the outcomes of each model are in line with

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TABLE 3 Gravity estimations for Equation (6) with OLS, fixed effects, and PPML.

Independent variables	OLS	FE	PPML
lnprgdp	1.383***	1.422***	0.474***
	(0.057)	(0.057)	(0.024)
lnpop_d	−1.023***	−1.037***	−0.343***
	(0.058)	(0.058)	(0.028)
lnpop_o	−5.751***	Omitted	−2.089***
	(0.853)		(0.233)
lndistcap	−2.315***	−2.357***	−0.754***
	(0.164)	(0.162)	(0.065)
contig	−2.249***	−2.446***	−0.596*
	(0.617)	(0.61)	(0.275)
comlang_off	−0.043	−0.016	0.018
	(0.214)	(0.211)	(0.073)
colony	2.681***	2.605***	0.396***
	(0.526)	(0.520)	(0.063)
comcol	1.149***	1.187***	0.186*
	(0.224)	(0.222)	(0.075)
PAFTA	7.871***	8.098***	1.472***
	(0.778)	(0.769)	(0.241)
PIFTA	0.513	0.696	0.229
	(0.741)	(0.733)	(0.344)
PSFTA	5.856***	5.942***	1.317***
	(0.538)	(0.532)	(0.089)
PMFTA	4.568***	4.550***	1.011***
	(0.523)	(0.516)	(0.086)
CPFTA	2.321**	2.547***	0.662*
	(0.764)	(0.756)	(0.277)
Constant	77.948***	−33.390***	28.373***
	(15.336)	(2.816)	(4.15)
R-squared	0.621	0.630	0.609
Observations	855	855	855

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

TABLE 4 Gravity estimations for Equation (7) with OLS, fixed effects, and PPML.

Independent variables	OLS	FE	PPML
lnprgdp	1.384***	1.424***	0.474***
	(0.057)	(0.057)	(0.024)
lnpop_d	−1.023***	−1.038***	−0.343***
	(0.058)	(0.058)	(0.028)
lnpop_o	−5.722***	Omitted	−2.080***
	(0.855)		(0.233)
lndistcap	−2.315***	−2.358***	−0.754***
	(0.164)	(0.162)	(0.065)
contig	−2.248***	−2.449***	−0.596*
	(0.617)	(0.61)	(0.275)
comlang_off	−0.043	−0.015	0.018
	(0.214)	(0.211)	(0.073)
colony	2.681***	2.602***	0.395***
	(0.527)	(0.520)	(0.063)
comcol	1.149***	1.188***	0.186*
	(0.225)	(0.222)	(0.075)
PAFTA	7.870***	8.103***	1.472***
	(0.778)	(0.769)	(0.241)
PIFTA	0.512	0.698	0.229
	(0.742)	(0.732)	(0.344)
PSFTA	5.856***	5.943***	1.317***
	(0.538)	(0.531)	(0.089)
PMFTA	4.568***	4.549***	1.011***
	(0.523)	(0.516)	(0.086)
CPFTA	2.464**	2.836***	0.708*
	(0.804)	(0.797)	(0.288)
CPFTA_2	−0.776	−1.534	−0.228
	(1.353)	(1.346)	(0.188)
Constant	77.400***	−33.444***	28.193***
	(15.372)	(2.816)	(4.159)
R2	0.621	0.631	0.609
Observations	855	855	855

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

the gravity theory of trade as the coefficient of GDP and distance variable have the desired signs (Wang, 2016; Shahriar et al., 2019; Dadakas et al., 2020).

The results obtained from the OLS and FE model are almost similar. Most of the signs of the coefficients are positive and significant except for the common language and population that unexpectedly have a negative coefficient.

Concerning the trade agreements that Pakistan has with the trading partners, the results obtained from various methods show a positive and significant coefficient except the PIFTA which we refer to as the Pakistan trade agreement with the neighbor country Iran. Focusing on the agreement with China the estimated results from different models are somehow similar except the PPML. An increase or improvement of 1 % in the free trade agreement is associated with a 2.3 percent increase in vegetable exports in Pakistan. The results obtained from Equation 7 presented in Table 4 show that the coefficient of CPFTA_2 refers to the second phase of China Pakistan Free Trade Agreement has a negative and insignificant coefficient. The second phase of the CPFTA in conjunction with the CPEC's improved infrastructure is expected to have a trade creation. The negative coefficient could imply that CPFTA_2 has counterintuitive effects on Pakistan vegetable exports. However, statistically, no significance makes it hard to explain. The insignificance can be due to a small sample size, some external factors, and unaccounted variables in the model. Hence, we argue

that COVID-19 started in 2019 as an external factor that led to extensive disruption in the global supply chain resulting reduction in exports.

The OLS coefficient obtained for PAFTA is 7.871 with a standard error of 0.778 suggesting a highly significant and positive effect on the vegetable exports of Pakistan. The positive and significant results obtained from the fixed effect model reinforce the findings obtained from OLS. The coefficient obtained from PPML also confirms the positive association of PAFTA with the vegetable exports of Pakistan, though with a lower magnitude in comparison with OLS and FE estimations. With a standard deviation of 0.538 and an OLS coefficient of 5.856, the PSFTA appears to have had a highly significant and positive effect on the vegetable exports of Pakistan. The positive and significant coefficient obtained from the fixed effect model supports the findings obtained from OLS. The coefficient obtained from PPML also confirms the positive association of PSFTA with the vegetable exports of Pakistan but with a lesser magnitude than OLS and FE estimations. The OLS coefficient of PMFTA is 4.568 with a standard of 0.523, which indicates a highly significant and positive effect on the vegetable exports of Pakistan. The positive and significant results obtained from the fixed effect model underpin the findings obtained from OLS. The coefficient obtained from PPML also confirms the positive association of PMFTA with the vegetable exports of Pakistan, though with a lower magnitude in comparison with OLS and FE estimations. Our results are consistent with the findings of (Alam, 2018). Pakistan's trade agreements with China, Afghanistan, Sri Lanka, and Malaysia show consistently positive and significant coefficients across various estimations. However, the larger, positive, and statistically more significant coefficient of trade agreements with Afghanistan, Sri Lanka, and Malaysia suggests a higher association with Pakistan's vegetable exports.

GDP reflects the production potential of the exporting country and the importing country's purchasing power (Frankel, 1997). The positive and significant coefficient of the GPD explains that the countries with larger economic mass resulting in higher income, have more potential to import products (Ekanayake et al., 2010; Fadeyi et al., 2014; Karemera et al., 2015; Irshad and Xin, 2018; Lateef et al., 2018). According to the outcomes of this study, a 1 % increase in the economic mass of the trading partner countries is associated with a 1.3 percent increase in the vegetable exports of Pakistan. Distance as a proxy of trade cost between countries plays a significant role. In this study, the coefficient of the distance is negative and statistically significant. An increase of 1 % in the distance is associated with a 2.3 percent decrease in the exports of vegetables. Similar results for distance were observed in some research (Shuai, 2010; Fadeyi et al., 2014; Abbas and Waheed, 2015; Salim and Mahmood, 2015; Atif et al., 2017; Lateef et al., 2018). The outcomes suggest that Pakistan should place its vegetable products in the nearest market to surge exports. The negative and significant coefficient of the population of the destination countries expresses that countries having larger populations import fewer agricultural products as a vast number of people are engaged in rural areas in the agriculture sector making the country self-sufficient in the production of agricultural products. Parallel results have been reported by (Yeo and Deng, 2019).

The geographical variable contiguity has a negative and significant coefficient. We quantify the coefficient of the dummy variable contiguity as (exp [0.59]-1*100) which infers that Pakistan's exports to its contiguous countries are comparatively lower. Our findings demonstrate robust alignment with the results reported by (Iqbal, 2016; Iqbal and Nosheen, 2020). Although it looks counterintuitive, there could be various reasons for the negative contiguity coefficient, including infrastructure problems, political or economic barriers, linguistic and cultural differences, and security concerns. The variables representing the colonial relations, Colony and Comcol exhibit positive and statistically significant coefficients. The coefficient is quantified in the same manner as for dummy variables. This implies that colonial ties are likely to exert a meaningful impact on the vegetable exports of Pakistan. The results of the colonial links correspond with the outcomes of (Iqbal and Nosheen, 2020). Generally, a common language facilitates trade with partner countries. However, in our study the coefficient of variable common language is negative. The findings are consistent with the outcomes of (Atif et al., 2017). The negative and significant coefficient of the common language can be supported by the fact that Pakistan is exporting more to the neighboring countries and for these countries the official languages are different. China in the north of Pakistan has Mandarin-Chinese while Afghanistan in the west has Pashtu and Dari as its official languages. Iran in the southwest of Pakistan has Persian as its official language. These facts about the common language make this variable negative and statistically significant.

The aforementioned findings and discussion offer several theoretical and practical implications for understanding the determinants of vegetable exports in Pakistan and broader implications for international trade theories. The consistency of the findings across various estimation techniques reiterates the applicability of the gravity model of trade. The positive coefficients of GDP and distance variables are in line with the theoretical expectation of the model, indicating that economic mass and trade costs significantly influence trade flow. The positive and significant coefficients of the trade agreements highlight the importance of trade agreements in enhancing vegetable exports. The insignificance of certain coefficients such as CPFTA_2 is attributed to external factors like the COVID-19 pandemic. This emphasizes how trade modeling needs to account for exogenous shocks and unanticipated events to provide more accurate predictions and policy recommendations. The negative coefficient of distance and contiguity variables indicates the significance of geographical proximity in facilitating trade. The negative coefficient of language variable challenges the conventional notion that common language facilitates trade and highlights the role of cultural and linguistic factors in shaping trade patterns.

The finding's practical implications include that policymakers should prioritize initiatives aimed at strengthening existing trade agreements and negotiating new agreements to promote vegetable exports. Furthermore, efforts to improve infrastructure, address trade barriers, and enhance market access can help capitalize on trade opportunities. Given the importance of geographic proximity in trade, exports should explore opportunities in neighboring markets and reduce reliance on distant markets. Given the disruptive effects of external factors such as pandemic, exporters should resilience strategies to mitigate risks and adapt to changing market conditions. Collaborative efforts between government, industry stakeholders, and research institutions are essential for implementing evidence-based trade policies."

5 Conclusion and policy implications

The following conclusions can be drawn from the above analysis. First, although the first phase of CPFTA has a positive association with

Pakistan's vegetable exports, there has been a discernible rise in imports from China, resulting in a trade deficit. The free trade agreements with Malaysia, Afghanistan, and Sri Lanka are more efficient in export promotion. Second, the second phase of the CPFTA shows a negative and insignificant association with vegetable exports in Pakistan. However, we argue that this period of the CPFTA-II was mainly influenced by COVID-19, as that period was declared a pandemic by the World Health Organization and borders were restricted aimed prevention of the spread of contiguous disease. The negative association of geographical distance with vegetable exports led us to the conclusion that closer markets are necessary for expanding Pakistan's vegetable exports. Based on the findings of the common official language we conclude that Pakistan is trading more with countries whose official language is different from English. Pakistan is exporting more to countries that have the same historical colonial links. Finally, based on the study findings we give the following policy implications.

Based on these conclusions, several suggestions can be made. First, reduce trade costs, such as simplifying, logistics and transportation routes to reduce transportation costs and transit time. The CPEC infrastructure can aid in the process of connectivity. Aimed expanded exports of perishable goods, in our case vegetables, Pakistan's government should promote the CPEC route in conjunction with the free trade agreements. Business professionals are the key stockholders of the country's domestic and international trade. Therefore, they must be active participants in such policy negotiations in the future. Second, Pakistan needs to enrich trade relations with neighboring countries. Third, expand trade channels and establish more trading partners. Forthcoming research can extend our study by considering more disaggregated commodities to explain the nature of trade under trade liberalization in conjunction with the CPEC.

While this study provides valuable insight into the vegetable exports of Pakistan under trade liberalization, there are a few limitations to note. The focuses of this study are the vegetable exports which may not represent the overall trade relations of Pakistan. Instead of distance actual transportation costs may enhance the model and provide a better understanding. We could not consider political stability in Pakistan which is important in trade relations. This study does not account for the currency exchange rate which is a factor in determining the price and might influent trade flow. To gain a more comprehensive understanding, incorporation of additional variables is required. Further studies could incorporate factors that influence trade such as political stability, exchange rate, security, technological advancement, etc. Future research could enhance the gravity model with more advanced econometric techniques and machine-learning approaches. Researchers could explore alternative techniques that could offer more comprehensive insight into international trade dynamics.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found here: https://www.trademap.org/Index.aspx and https://databank.worldbank.org/.

Author contributions

HK: Data curation, Methodology, Writing – original draft, Writing – review & editing. YC: Conceptualization, Funding acquisition, Supervision, Writing – review & editing. LL: 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.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1362910/full#supplementary-material

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