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Determinants, efficiency and potential of agri-food exports from Nigeria to the EU: Evidence from the stochastic frontier gravity model

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Abstract: This study uses an extended gravity model to examine the determinants, efficiency and potential of agri-food exports from Nigeria to the EU for the 1995–2019 period. It uses a stochastic frontier analysis (SFA) to estimate the extended gravity model. The results show that the economic size (GDP) of Nigeria and the EU countries, as well as bilateral distance, positively determine agri-food exports from Nigeria to the EU. Also, the results show that Nigeria's agri-food exports to the EU are negatively determined by the income (per capita GDP) of Nigeria and its EU trading countries, bilateral exchange rate and EU new member states (NMS). The results further show that Nigeria scores relatively low in terms of the efficiency of its agri-food exports to the EU countries. On a final note, the study shows that Nigeria's agri-food exports with the EU have a relatively large potential that has not been exploited. We document policy recommendations in this study.

Keywords: agri-food exports; EU; gravity model; Nigeria; stochastic frontier analysis

Nigeria is a leading oil-exporting country in Africa and one of the world's major oil-producing countries since its oil discovery in the early 1960s. Over the past four decades, oil revenues accounted for an average share of nearly 90% of the total merchandise export revenues. Meanwhile, revenues from non-oil exports have considerably dropped and accounted for an average share of less than 10% between 1995 and 2019 (NBS 2020). In this present decade, Nigeria has slumped into recession twice, mainly caused by the crash in global oil prices and the decline in Nigeria's oil production and exports. Thus, the Nigerian government has committed its economic development path to diversify its economy due to the frequent shocks of the drop in oil revenues that forced the country to take several measures to reduce the impact of its declining economy (Ding et al. 2020). This economic development path is aimed at increasing revenues from non-oil exports. There has been a gradual shift away from a growth path of over four decades of heavy reliance on oil revenues (Verter 2016; Verter and Bečvářová 2016).

The Nigerian government launched an economic policy document, called Economic Recovery and Growth Plan (ERGP) in 2017, to expand the economy and proactively reduce its dependence on oil revenues. The document emphasises the need to boost agricultural production and exports. Accordingly, Nigeria plans to expand investments in agriculture and projects

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to become a net exporter of vital agri-food products such as maise, cassava, rice, soya beans, groundnuts, vegetable oil, and cashew nuts (MBNP 2017). Undoubtedly, the agriculture sector in Nigeria remains vital for its economic progress. The industry is an important source of employment, non-oil exports, and foreign exchange earnings as well as ensures food security.

Although Nigeria's agricultural revenues and employment rate respectively dropped from 47.19% and 36.97% in 2002 to 21.2% and 35.57% in 2018, these values are still reasonable (World Bank 2020). Between 1995 and 2016, the food production index in Nigeria increased from 67.53 to 124.55; however, attaining food self-sufficiency and food security have continued to be an issue for the country, scoring 38 out of 100 in 2018 (Owoo 2020). Agricultural production in Nigeria has dropped significantly in recent times due to issues such as climate change, erratic rainfall, lack of modern agricultural inputs, low market access, farmer-herder crises, terrorism (causing severe damage to crops, livestock, and infrastructure), rapid urbanisation and industrialisation among others (Noubissi and Njangang 2020).

Similar to most African countries, Nigeria significantly depends on the European Union (EU) and other emerging economies to consume its agri-food products. Nigeria is the EU's leading trading partner in the West African region (UNCTAD 2020). According to the EU's ranking of the global leading agri-food trade partners in European Commission (2019a), Nigeria ranks as the 30th importing market (with EUR 962 million and 0.5% share of extra-EU) for the agri-food exported from the EU in 2019. Similarly, Nigeria ranks as 37 among exporting markets (with EUR 574 million, or 0.5% share of extra-EU) for the EU's agri-food in 2019.

The bilateral agri-food trade relations between Nigeria and the EU have considerable implications for Nigeria. For instance, the country has been widely open to severe competition from the EU concerning product safety, product quality, economies of scale, and price. The EU and Economic Community of West African States (ECOWAS) established a treaty, known as Economic Partnership Agreements (EPA), to reduce trade restrictions between EU and ECOWAS member countries. The EPA is considered a marching stone for strong capacity building, enhancing investments, ensuring specialisation, competitiveness, and trade performance in agri-food products (European Commission 2017). Despite the EU's efforts for the promised benefits to developing countries like Nigeria, including better access to EU markets and integration into a global economy, Nigeria remains the only ECOWAS member state that is yet to be a party to the EPA (European Commission 2019b). Nonetheless, under the generalised system of preferences and its support for trade initiatives aimed at Nigeria and other West African nations, the EU is committed to boosting trade-privileged market access for Nigerian agricultural products (European Commission 2019a).

Against this background, we are motivated to provide an empirical perspective on Nigeria's agri-food export trade flows to the EU. Our focus on Nigeria's agri-food exports with the EU is borne out of the idea that, over the past decades, the EU trading bloc has been the major destination for Nigeria's agri-food exports. To contribute novel knowledge to existing literature, we examine the determinants, efficiency and potential of agri-food exports from Nigeria to the EU. Through a literature survey, we realise that the focus of this research has not been previously given empirical attention. From a methodological point of view, we execute this research with the gravity model, which is yet to be applied in agri-food export trade literature in Nigeria. The gravity model is built on a sound theoretical foundation, and it has become popular in international trade literature due to its success in predicting trade flows among economies (Westerlund and Wilhelmsson 2011). Also, our application of the stochastic frontier analysis (SFA) offers a contribution to existing literature. To date, to the best of our knowledge, the SFA has been sparsely used in agri-food export trade literature, and its application appears to be missing in the Nigerian context. SFA is a parametric approach that has the capacity to measure efficiency and produce unbiased estimates in the presence of measurement error and stochastic disturbance (Ruggiero 2007).

Brief overview of Nigeria's agri-food trade and its trade with the EU. Historically, Nigeria's leading agri-food trade partner is the EU. Table 1 shows that the EU's share in Nigeria's total food imports and exports have significantly declined from 40.4% and 72.1% to 25.0% and 41.2% between 1995 and 2019, respectively. This may be attributed to both parties' diversification of their market base, which caused a decrease in bilateral agri-food trade between the EU and Nigeria (Verter et al. 2020). Other factors include the boom of non-agriculture sectors such as oil and services industries and the accelerated increase in population over the years. However, the role of the EU in Nigeria's agri-foods export is still noteworthy. Total agri-food trade turnover between the EU and Ni-

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Table 1. Performance of Nigeria's agri-food sector and its trade with the EU

	1995	2000	2005	2010	2015	2019
Imports						
Overall imports (million USD)	8 221.50	8 721.30	20 753.96	44 235.27	44 487.40	55 263.00
Agri-food imports (million USD)	9 34.85	1 454.13	3 748.10	5 552.95	6 390.03	6 620.97
Agri-food imports from the EU (million USD)	377.80	619.14	1 190.00	1 056.17	1 290.78	1 658.20
Share of agri-food imports in overall imports (%)	11.37	16.67	18.06	12.55	14.36	11.98
Share of the EU in agri-food imports (%)	40.41	42.58	31.75	19.02	20.20	25.04
Exports						
Overall exports (million USD)	12 342.00	20 975.00	45 789.35	86 567.91	49 846.21	64 445.29
Agri-food export (million USD)	378.18	184.96	746.99	1 860.30	1 761.92	1 798.10
Agri-food exports to the EU (million USD)	272.70	121.26	380.77	700.88	807.09	741.36
Share of agri-food exports in overall exports (%)	3.06	0.88	1.63	2.15	3.53	2.79
Share of the EU in agri-food exports (%)	72.11	65.56	50.97	37.68	45.81	41.23
Trade						
Overall trade (million USD)	20 563.50	29 696.30	66 543.31	130 803.18	94 333.61	119 708.29
Overall trade balance (million USD)	4 120.50	12 253.70	25 035.39	42 332.64	5 358.81	9 182.29
Agri-food trade (million USD)	1 313.03	1 639.09	4 495.09	7 413.25	8 151.95	8 419.07
Agri-food trade balance (million USD)	–556.68	–1 269.17	–3 001.11	–3 692.65	–4 628.11	–4 822.86
Agri-food trade with the EU (million USD)	650.50	740.41	1 570.76	1 757.06	2 097.88	23 99.57
Agri-food trade balance with the EU (million USD)	–105.10	–497.88	–809.23	–355.29	–483.69	–916.84
Share of agri-food trade in overall trade (%)	6.39	5.52	6.76	5.67	8.64	7.03
Share of the EU in agri-food trade (%)	49.54	45.17	34.94	23.70	25.73	28.50

Source: Authors' calculation using data from the UNCTAD (2020)

geria has increased from USD 650.5 million in 1995 to USD 2.4 billion in 2019. Contrarily, agri-food exports fluctuated from USD 272.7 million in 1995 to their peak in 2013 with USD 1 125 million, before declining to USD 512 million in 2017, and then grew to USD 741.4 million in 2019. Sadly, Nigeria consistently recorded negative balances in its agri-food trade and its trade with the EU (Table 1).

Table 2 presents the imports and exports of Nigeria's agri-food products. In general, almost all the value of agri-food imports increased considerably. Nigeria's agri-food imports had increased from USD 225.43 million (24.1% of total agri-food imports) to USD 3 801.91 million (57.4% of total agri-food imports). A look at Table 2 shows that wheat is the Nigeria's largest agri-food import trade in the different periods, and the import trade had increased significantly from USD 153.32 million in 1995 to USD 1 949.04 million in 2019. Also, the table shows that the share of export commodities had fluctuated from 84.23% in 1995 to 91.89% in 2000 before falling to 77.51% in 2015 and then increased to 88.21% in 2019. The most notable commodity is spices exports which witnessed an increase from USD 1.69 million in 1995 to USD 56.62 million in 2005 and subsequently decreased to USD 37.1 million in 2019. However, in the case of cocoa, its export had increased significantly from USD 218 million in 1995 to USD 851.39 million in 2010 and then marginally dropped to USD 822.25 million in 2019.

Figure 1 shows the total agri-food imports and exports between Nigeria and the EU members from 1995–2019. The Netherlands is by far the most significant Nigeria's agri-food trading partner. Figure 1 also reveals that the agri-food trade between Nigeria and the Netherlands is valued at USD 544.42 million annually. The United Kingdom is the second-largest Nigeria's agri-food imports, with an annual estimated value of USD 195.93 million, followed by Ireland and France with a market value of USD 135.52 million and USD 104.12 million, respectively. In comparison, Germany is the second-largest destination of Nigeria's agri-food products with an annual value of USD 85.61 million, followed by France and the United Kingdom with USD 56.54 million and USD 46.6 million, respectively.

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Table 2. Imports and exports of Nigeria's major agri-food products

	1995	2000	2005	2010	2015	2019
Imports						
Alcoholic beverages (million USD)	17.35	19.37	31.81	120.48	196.47	132.07
Cereal preparations (million USD)	20.55	15.54	53.18	88.82	143.11	148.91
Edible products (million USD)	77.11	72.68	225.27	584.79	685.74	853.03
Feed stuff for animals (million USD)	5.62	9.28	11.12	83.08	82.58	96.93
Fish, dried, salted or in brine (million USD)	14.73	15.84	64.01	160.89	169.46	138.01
Milk, cream and milk products (million USD)	90.07	137.28	369.64	426.31	295.37	483.93
Wheat (million USD)	153.32	273.28	603.24	915.16	1568.47	1949.04
Total (million USD)	225.43	543.28	1358.25	2379.53	3141.20	3801.91
Share from total agri-food imports (%)	24.11	37.36	36.24	42.85	49.16	57.42
Exports						
Cocoa (million USD)	218.00	80.72	345.58	851.39	741.77	822.25
Crustaceans and invertebrates (million USD)	49.66	36.18	66.10	179.22	69.47	70.23
Fish, chilled or frozen (million USD)	4.00	2.28	2.70	1.78	6.41	3.71
Fixed vegetable oils (million USD)	7.17	2.95	3.06	0.73	10.39	19.37
Fruits and nuts (million USD)	26.16	10.80	146.96	104.79	152.54	317.92
Oil seeds and oleaginous fruits (million USD)	11.85	30.67	66.03	386.47	315.30	315.56
Spices (million USD)	1.69	3.17	56.62	40.13	69.85	37.10
Total (million USD)	318.52	166.77	687.05	1564.51	1365.73	1586.14
Share from total agri-food exports (%)	84.23	90.17	91.98	84.10	77.51	88.21

Source: Authors' calculation using data from the UNCTAD (2020)

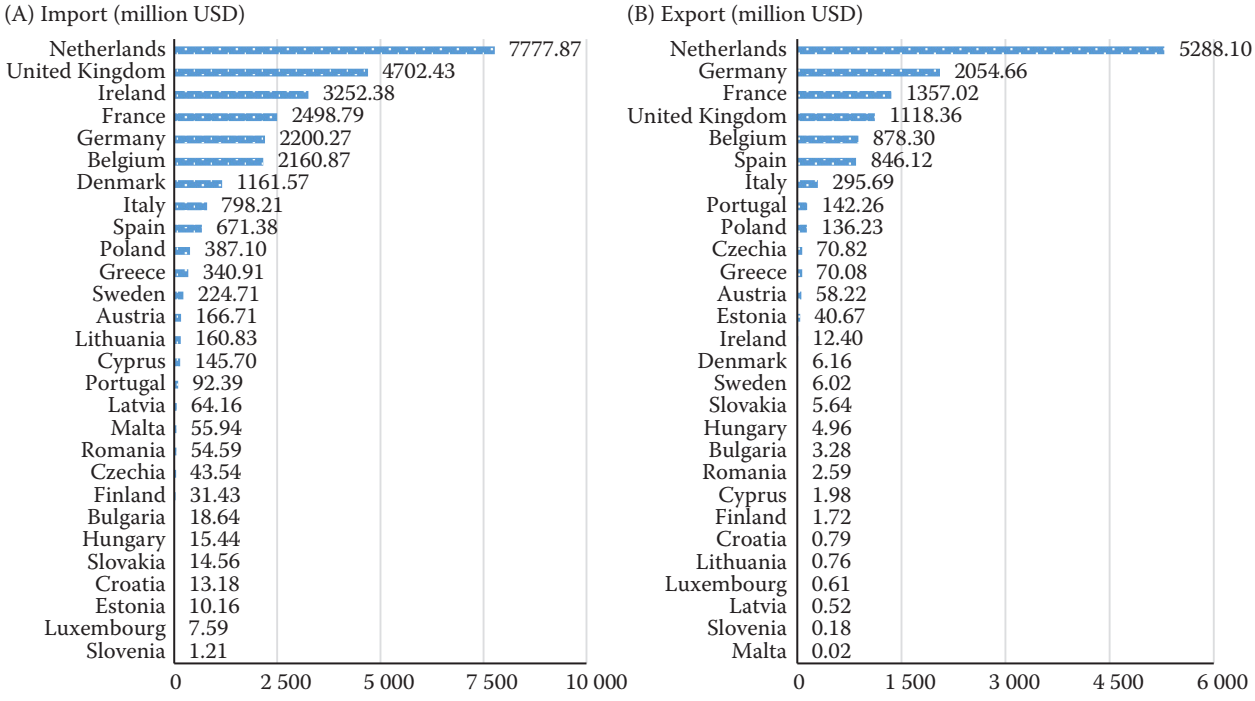

Figure 1. Total agri-food trade between Nigeria and the EU for the period 1995–2019

Source: Authors' computation using data from UNCTAD (2020)

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Top Nigeria's agri-food products export destinations in the EU. Based on Nigeria's total agri-food export values with the EU between 1995 and 2019, the top trading partners' rank is shown in Figure 2. Revealing that Nigeria's top ten agri-food destinations are as follows: the Netherlands (42.63%), Germany (16.56%), France (10.94%), United Kingdom (9.02%), Belgium (7.08%), Spain (6.82%), Italy (2.38%), Portugal (1.15%), Poland (1.33%), and the Czechia (0.57%). Figure 2 also reveals that the export flows between Nigeria and these countries accounted for 98.4% of Nigeria's total agri-food export trade flows to the EU market. The annual average export flow between Nigeria and its top ten major destinations is valued at USD 507.82 million. Figure 3 illustrates the Nigerian agri-food exports trends to its ten largest regular partners between 1995 and 2019. Figure 3 also shows that Nigeria's agri-food export trade with the Netherlands reached the highest point in 2013 with a value of USD 762.33 million. However, the values dropped before it rebound in 2016.

Review of related empirical studies. Traditionally, the determinants of trade flows are explained based on the gravity model (Tinbergen 1962; Anderson 1979). Several studies have used the gravity model to determine the factors affecting agricultural export flows (Assem et al. 2010; Atif et al. 2016; Barma 2017; Braha et al. 2017). For instance, Assem et al. (2010) focus on Egyptian agricultural exports' determinants over the 1994–2008 period. Using the fixed and random effects estimation techniques, they show that GDP and exchange rate boost agricultural exports while GDP per capita and bilateral distance adversely affect agricultural exports. Atif et al. (2016), using the stochastic form of the gravity model to examine the determinants and potential of agricultural exports in Pakistan over the period 1995–2014. The study shows that

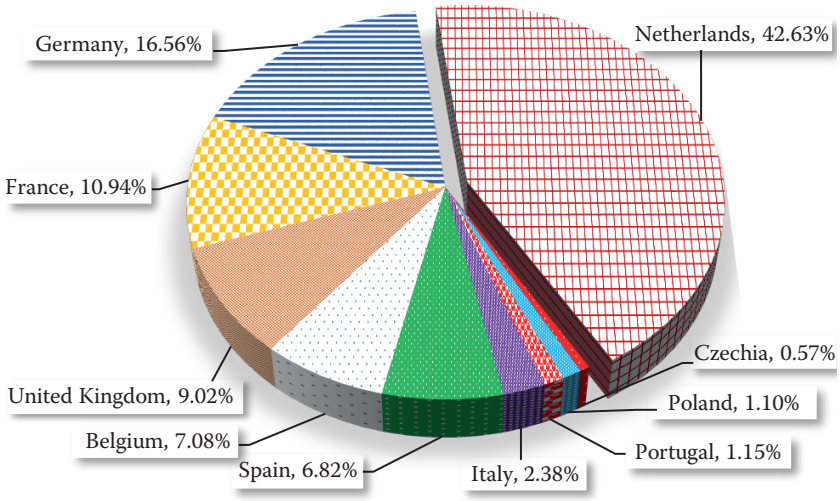

Figure 2. Average share of top ten Nigeria's agri-food exports destinations for the period 1995–2019

Source: Authors' computation using data from the UNCTAD (2020)

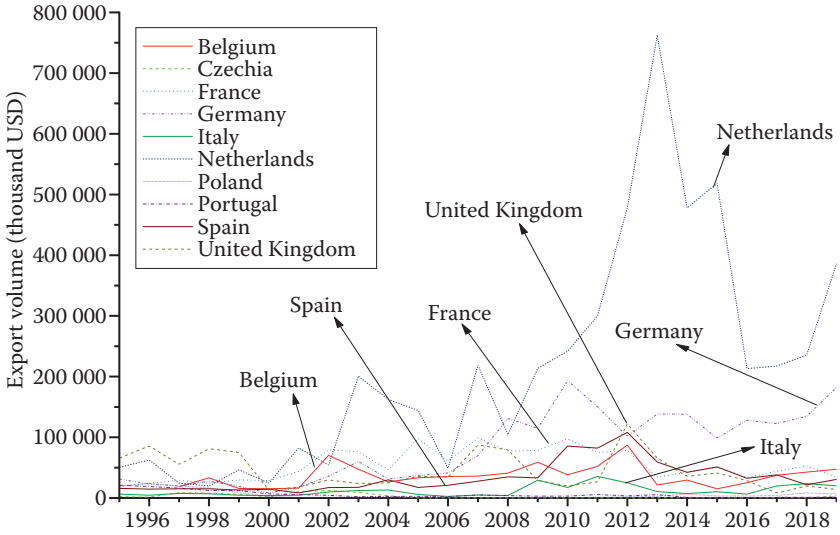

Figure 3. Export trend of top ten Nigeria's major destinations of agri-food products for the period 1995–2019

Source: Authors' computation using data from UNCTAD (2020)

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the exchange rate policy and tariff rate determine Pakistan agricultural export. The study further reveals that Pakistan has a substantial untapped export potential with its trading partners, especially with its neighbouring countries. In similar vein, Barma (2017) investigates the factors influencing agricultural export flows from India to 112 countries for the 2000–2013 period. The author confirms that, while agricultural export is limited by bilateral distance, landlocked and contiguity, it is stimulated by the GDP of trading countries and population. Utilising the pseudo Poisson maximum likelihood, Braha et al. (2017) reveal that Albania's agricultural export during the 1996–2013 period is determined by geographical distance, exchange rate, price stability, and trade liberalisation.

A group of studies have also used the gravity model to empirically understand agri-food exports. The main determinants of the Italian agri-food exports to non-EU Mediterranean partner countries are examined by Crescimanno et al. (2013), using a 1996–2010 panel dataset. The study shows a variety of positively associated factors with the Italian agri-food exports, such as the income of partner countries, geographical proximity, colonial and historical relations and the lack of importance of the agricultural sector in some partner countries. Sapa and Droždz (2019) explore the factors affecting Poland's agri-food exports to non-EU countries for the period 2000–2016. The findings show that GDP and agricultural value-added stimulate trade between Poland and the non-EU countries. Meanwhile, the negative impact of geographical distance and historical condition of Poland are observed.

Although, we find few studies on Nigeria's agri-food trade (Onogwu 2014; Zdráhal et al. 2019; Verter et al. 2020). However, to the best of our knowledge, there seems to be no existing study that uses the gravity model to evaluate the determinants, efficiency and potential of Nigeria's agri-food exports to trading countries through a stochastic frontier analytical approach. Therefore, our study is designed to fill this research gap.

MATERIAL AND METHODS

Model. To identify the determinants of agri-food exports from Nigeria to the EU, we employ the gravity model that determines bilateral trade flows based on the economic size and distance between two countries. The seminal work of Tinbergen (1962) led to the development of the gravity model in international trade literature. Anderson (1979) largely investigates the model with the expectations that bilateral trade between two countries is positively determined by each country's GDP, and inversely determined by the distance between them.

The gravity model in its baseline form can be expressed as follows:

$$Trade_{ij} = \alpha \frac{GDP_i . GDP_j}{Dis_{ij}} \tag{1}$$

where: $Trade_{ij}$ – value of the bilateral trade between the country i and j, in this study Nigeria and the EU-28 members; GDP_i, GDP_j – gross domestic product (GDP) of Nigeria and that of its EU importing countries, respectively; Dis_{ij} – distance between the two countries; α – constant of proportionality.

Taking the natural logarithm of Equation (1), we obtain the linear form of the equation, in our case, it can be expressed for the Nigerian agri-food exports as follows:

$$\begin{aligned} \ln\left(AGRFEX_{ijt}\right) = \beta_0 + \beta_1 \ln\left(GDP_{it}\right) + \\ + \beta_2 \ln\left(GDP_{jt}\right) + \beta_3 \ln\left(Dis_{ij}\right) + \varepsilon_{ijt} \end{aligned} \tag{2}$$

where: $AGRFEX_{ijt}$ – value of agri-food exports from Nigeria to its trading partners; j = 1, 2, …, 28 is for trading partners and t = 1995, 1996, …, 2019 annual series; ε_{ijt} – double-sided error term.

We extend the traditional gravity model by separating the demand and supply-side factors and incorporating exports stimulating [the exchange rate and EU-new member state (NMS)] and resisting (distance, language, and landlocked) variables identified from the literature. Thus, the model becomes:

$$\begin{aligned} \ln(AGRFEX_{ijt}) = \beta_0 + \beta_1 \ln(GDP_{it}) + \\ + \beta_2 \ln\left(GDP_{jt}\right) + \beta_3 \ln(pcGDP_{it}) + \\ + \beta_4 \ln(pcGDP_{jt}) + \beta_5 \ln(Dis_{ij}) + \\ + \beta_6 \ln(Ex_{ijt}) + \gamma_1 (EU\text{-}NMS_j) + \\ + \gamma_2 (Language_{ij}) + \gamma_3 (Landlocked_j) + \zeta_{ijt} \end{aligned} \tag{3}$$

where: $\ln(AGRFEX_{ijt})$ – log of the value of Nigeria's agri-food exports in USD 1 000; $\ln(GDP_{it})$ – log of Nigeria's GDP in USD; $\ln(GDP_{jt})$ – log of trading partners' GDP in USD; $\ln(pcGDP_{it})$ – log of Nigeria's per capita GDP in USD; $\ln(pcGDP_{jt})$ – log of trading partners' per capita GDP in USD, $\ln(Dis_{it})$ – log of the value of distance in kilometres between Nigeria's capital, Abuja and its trading partner countries' capital; $\ln(EX_{ijt})$ – log of the

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value of the exchange rate of Nigeria in Naira; $EU\text{-}NMS_j$ – dummy variable with a value of 1 for the countries that joined the EU before 1995 and from the year new member joins, otherwise 0. EU-2004 (Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia), EU-2007 (Bulgaria and Romania), and EU-2013 (Croatia); $Language_{ij}$ – dummy variable with a value of 1 if the partners share the same official language with Nigeria, otherwise 0; $Landlocked_j$ – dummy variable with a value of 1 if countries do not have sea border, otherwise 0; ζ_{ijt} – Stochastic error term, random, non-systematic term, a random 'disturbance'.

The stochastic frontier gravity model (SFGM). Aigner et al. (1977) and Meeusen and Van Den Broeck (1977) individually develop the gravity equation using SFA in production economics. This method suggests that the estimations of the maximum level of output and a production possibility frontier (PPF) can be reached from a given level of inputs. A firm/industry operating below the frontier output is considered a technically inefficient firm, indicating a shortfall between the observed and the maximum possible output levels. In contrast, technically efficient operates on the PPF such that observed and frontier levels of output correspond. Hence, the former refers to the opportunity for additional expansion of output. Thus, the technically inefficient production function refers to the degree to which actual output falls short of potential output. Similarly, in the case of exports, SFA can be used to define export frontier whereby inefficient export performance refers to the degree to which actual export falls short of the maximal potential export. Kalirajan (2007) introduces the SFA in the gravity equation to explain trade partners' variations in trade. The trade frontiers estimated through this approach give liberty in taking the optimal trade level among the countries in the analysis. These bilateral trade frontiers are influenced by positive or negative error terms formed within the model. This allows the randomly created trade frontier to differ according to the given deterministic part of the gravity model. The observed magnitude of trade afterwards can be matched against the predicted frontier values of trading nation partners to analyse the maximum size of the trade.

Belotti et al. (2013) and Kalirajan (2007) suggest the significance of applying the SFGM in international trade analysis as follows. First, it can offer information on exports' efficiency and potential. Second, it can be applied even if a model has not adequate information about the omitted variables. Third, it separates the analysis from the white noise term, and it estimates the effect of the economic distance term, which may cause non-normality and heteroskedasticity. The inclusion of SFA in the gravity model permits estimation of exports potential at a bilateral level. These export frontier quantities are influenced by a random error that may either be positive or negative and, consequently, permit stochastic frontier exports to fluctuate around the model's deterministic part (Ravishankar and Stack 2014; Atif et al. 2016). Therefore, the strong theoretical and policy relevance of SFA results provide a decent justification for its use. After incorporating SFA into our extended gravity model in Equation (3), it is transformed into SFGM as follows:

$$\begin{aligned}\ln AGRFEX_{ijt} = {} & \beta_0 + \beta_1 \ln(GDP_{it}) + \\ & + \beta_2 \ln\left(GDP_{jt}\right) + \beta_3 \ln(pcGDP_{it}) + \\ & + \beta_4 \ln(pcGDP_{jt}) + \beta_5 \ln(Dis_{ij}) + \\ & + \beta_6 \ln(Ex_{ijt}) + \gamma_1(EU\text{-}NMS_j) + \\ & + \gamma_2(Language_{ij}) + \gamma_3(Landlocked_j) + \\ & + \varepsilon_{ijt} - V_{ijt}\end{aligned} \tag{4}$$

where: V_{ijt} – one-sided error-term truncated at zero.

Equations (3–4) are alike except that the error term ζ_{ijt} is separated into ε_{ijt} and V_{ijt} in Equation (4). The ε_{ijt} (double-sided error term) is indicating a statistical noise because of estimation errors with an assumption of $N(O \sim \sigma^2 e)$. The V_{ijt} is independent of ε_{ijt} and regressors, and it is a positive random variable which measures the exports' inefficiency, and its value may vary between 0 and 1. Thus, there is no statistical error, and the effect of omitting variables is little. When it takes a value other than 0 (that is; V_{ijt} is less than or equal to 1). It indicates that the effects of omitting variables are significant, which could impede exports. Therefore, V_{ijt} denotes deviance from the optimal export level. This may take place due to the multilateral resistance (MTR) that is quite difficult to quantify and result in inefficient exports' performance. Equation (4) can be considered as pooled frontier, and the values of the parameters may be estimated via the maximum likelihood method. Among other things, the gravity model parameters calculated for the composed error term variance $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and the ratio of the standard deviation of the inefficiency component to the standard deviation of the random error component $\lambda = \sigma_u^2 \big/ \sigma^2$, are also generated. The latter assesses the degree of inefficiency relative to the random error and, when statistically significant, justifies the use of the SFA approach. A further test for the existence of technical efficiency

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$$E\left[\exp\left(-V_{ijt}\right)|e_{ijt}+V_{ijt}\right]=\frac{1-\phi\left[\sigma_{*}+\Upsilon\left(e_{ijt}+V_{ijt}\right)/\sigma_{*}\right]}{1-\phi\Upsilon\left(e_{ijt}+V_{ijt}\right)/\sigma_{*}}x\ \exp\left[\Upsilon\left(e_{ijt}+V_{ijt}\right)+\frac{\sigma_{*}^{2}}{2}\right] \quad (5)$$

where: E – efficiency; $\phi(.)$ – density function; σ_{*} – cumulative distribution function; Υ – estimated efficiency

(TE) in the model is undertaken via a one-sided likelihood ratio (LR) test of the null hypothesis $H_0: \sigma_u^2 = 0$, against the alternative $H_0: \sigma_u^2 > 0$. The rejection of this hypothesis may confirm the appropriateness of SFA, and a failure to reject the hypothesis suggests the SFA model decreases to an ordinary least square (OLS) model. In this study, we follow the method suggested by Battese and Coelli (1988) to calculate the TE. Thus, the equation can be written as in Equation (5).

The estimated efficiency (Υ) from Equation (5) can vary from 0 to 1. Here, the efficiency score, which equals 0, indicates inefficiency, and more trade is possible with the given determinates of trade in Equation (4). Furthermore, the efficiency score of 1 is proof of excellent efficiency, and actual trade corresponds precisely to the potential trade.

Data. The panel dataset consists of bilateral agri-food exports from Nigeria to the EU-28 countries for the 1995–2019 period. Bilateral agri-food exports data are obtained from UNCTAD (2020). Data on GDP and per capita GDP (current USD) are obtained from the World Development Indicators (WDI) (World Bank 2020). The geographical distance between Nigeria's capital city and the EU countries' (importers') capital city is derived using a distance calculator. Bilateral exchange rates are official exchange rates in local currency units (Naira) per importers' currency, and they are sourced from UNCTAD (2020). Regarding our dummy variables, the EU-NMS is sourced from EU Portal (2020), while common language and landlocked is obtained from Research and Expertise on the World Economy database (CEPII 2020).

Table 3. Sources of data used in the study

Variable	Unit	Source
$AGRFEX_{ijt}$	USD 1 000	UNCTAD (2020)
GDP_{it}	USD	World Bank (2020)
GDP_{jt}	USD	World Bank (2020)
$pcGDP_{it}$	USD	World Bank (2020)
$pcGDP_{jt}$	USD	World Bank (2020)
Dis_{it}	kilometres	Time and Date (2020)
EX_{ijt}	Naira (₦)	UNCTAD (2020)
EU-NMS	binary	EU Portal (2020)
$Language_{ij}$	binary	CEPII (2020)
$Landlocked_{j}$	binary	CEPII (2020)

$AGRFEX_{ijt}$ – agri-food export; GDP_{it} – gross domestic product of exporter; GDP_{jt} – gross domestic product of importer; $pcGDP_{it}$ – per capita gross domestic product of exporter; $pcGDP_{jt}$ – per capita gross domestic product of importer; Dis_{it} – distance; EX_{ijt} – exchange rate; *EU-NMS* – EU new member state; $Language_{ij}$ – language; $Landlocked_{j}$ – landlocked; UNCTAD – United Nations Conference on Trade and Development; CEPII – French Centre for Research and Expertise on the World Economy

Source: Authors' collected from UNCTAD (2020), World Bank (2020) and CEPII (2020)

Table 3 presents the descriptive statistics of the data used in this study. Among the variables, agri-food exports, ln($AGRFEX_{ijt}$), has the highest standard deviation statistic of 3.6951, and this indicates that its deviation from its mean is the largest. This suggests that, relative to other variables, ln($AGRFEX_{ijt}$) appears to experience the highest variation/volatility over the 1995–2019 period.

RESULTS AND DISCUSSION

Determinants of agri-food exports from Nigeria to EU countries. Table 4 shows the determinants of agri-food exports from Nigeria to the EU using the SFGM. We conduct some diagnostics to confirm the suitability of the SFGM. In rejecting the null hypothesis $H_0: \sigma_u^2 = 0$ in favour of the alternative hypothesis $H_0: \sigma_u^2 > 0$, the λ values (the ratio of the standard deviation of inefficiency to the standard deviation of the random error component of the composed error term σ_u^2/σ^2) indicate the suitability of the SFA across our estimated models. The LR test further supports this result.

The estimated results are based on three different time-invariant models developed by Greene (2005). Based on the gravity model estimates, the positive and statistically significant coefficients on the GDP of importing countries (GDP_{jt}) and Nigeria's GDP suggest that a larger economic size encourages agri-food export flows from Nigeria to the EU. However, the magnitude of GDP_{it} is relatively lower as compared to GDP_{jt}. Therefore, the supply response with any change in Nigeria's GDP is lower than the demand response due to a change in the GDP_{jt}. This result has an interesting implication for Nigeria. It shows the

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Table 4. Summary statistics of the variables used in the model

Variable	Mean	SD	Min.	Max.	Observations
$\ln(AGRFEX_{ijt})$	6.1898	3.6951	–3.9120	13.5441	625
$\ln(GDP_{it})$	25.9665	0.8746	24.5089	27.0663	700
$\ln(GDP_{jt})$	25.7438	1.7024	21.9587	29.0046	700
$\ln(pcGDP_{it})$	7.1619	0.7005	6.0117	8.0780	700
$\ln(pcGDP_{jt})$	9.8853	0.8715	7.2163	11.6854	700
$\ln(Dis_{it})$	8.4102	0.1562	8.0249	8.6749	700
$\ln(EX_{ijt})$	–4.4658	1.3798	–6.8180	1.0205	700
$EU\text{-}NMS_{j}$	0.8229	0.3821	0.0000	1.0000	700
$Language_{ij}$	0.1071	0.3095	0.0000	1.0000	700
$Landlocked_{j}$	0.1785	0.3833	0.0000	1.0000	700

$AGRFEX_{ijt}$ – agri-food export; GDP_{it} – gross domestic product of exporter; GDP_{jt} – gross domestic product of importer; $pcGDP_{it}$ – per capita gross domestic product of exporter; $pcGDP_{jt}$ – per capita gross domestic product of importer; Dis_{it} – distance; EX_{ijt} – exchange rate; *EU-NMS* – EU new member state; $Language_{ij}$ – language; $Landlocked_{j}$ – landlocked
Source: Authors' computation; the sources of data are available in Table 3

greater power of adjustments of the supply of agri-food exports in reaction to any change in demand from importing countries to maintain agri-food exports equilibrium condition. Moreover, the coefficients show that a 1% increase in GDP_{it} and GDP_{jt} increases agri-food exports by 1.50% and 1.97%, respectively. The negative coefficients of per capita GDP (income) for both importers and exporter suggest that Nigeria's agri-food export with the EU follows the Linder hypothesis (Linder 1961). This hypothesis assumes that countries with similar income levels would have a similar demand and supply ability. Many prior studies also support the fundamental assumption of this hypothesis (Choi 2002; Sevela 2002; Kea et al. 2019).

Distance is used as a trade cost in the gravity literature (Anderson 1979). Therefore, as a trade resistance factor, distance is expected to reduce bilateral agri-food exports. However, in our analysis, distance has a positive and statistically significant impact at 5% level on Nigeria's agri-food exports with the EU, only in our baseline model. This finding contradicts prior studies (Castillo et al. 2016; Jambor et al. 2016; Osabuohien et al. 2019). Distance in agricultural trade reflects transportation costs as well as the differences in climatic and cultivation conditions between trading partners. The farther apart two countries are from each other, the greater the difference in factor endowments, which results in a higher difference in products manufactured and motivates more bilateral trade relations between these countries (Dreyer 2014).

The EX_{ijt}, which indicates the exchange rate, is negative and statistically significant at the 1% level in all models. The coefficient reveals that a 1% increment of EX_{ijt} decreases Nigeria's agri-food export flows by 0.5%. This finding supports Braha et al. (2017) for Albania and Shahriar et al. (2019) for China. This finding suggests that Nigeria needs to maintain or depreciate its exchange rates with EU countries because appreciation in the exchange rates would result in a fall in foreign exchange earnings from its agri-food exports. Igue and Ogunleye (2014) argue that exchange rate appreciation is an obstacle to agri-food trade.

We include three dummy variables to capture the EU-NMS, common language and landlocked effects. While the language and landlocked dummy variables remain statistically insignificant in all models, the negative and statistically significant coefficients on the $EU\text{-}NMS_{j}$ dummy variable suggest that Nigeria's agri-food export flows decrease for the countries that joined the EU at a time during the study period, that is, 1995 and years beyond. This finding contradicts prior literature (for instance, Ravishankar and Stack 2014; Balogh and Leitão 2019).

Efficiency and potential of agri-food exports of Nigeria to the EU. The average TE and export potential scores for each EU trading country are associated with the preferred stochastic frontier model specification (Model 1), and they are shown in Tables 5–6, respectively. In Table 5, the estimated results indicate that none of the countries is 100% efficient. Precisely, all the countries yield an efficiency score below 50%. On average (1995–2019), all countries' TE was 38.96%, revealing that Nigeria has a potential of 61.04% to expand its agri-food exports to the

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Table 5. The stochastic frontier gravity model (SFGM) estimates

Variable	Model 1			Model 2			Model 3		
	coefficient	SD	*Z*-statistic	coefficient	SD	*Z*-statistic	coefficient	SD	*Z*-statistic
$\ln(GDP_{it})$	1.5342**	0.6489	2.3600	1.4676**	0.6769	2.1700	0.6775	0.9433	0.7200
$\ln(GDP_{jt})$	2.0011***	0.1210	16.5400	1.9304***	0.1635	11.8100	1.9856***	0.3607	5.5100
$\ln(pcGDP_{it})$	–1.8651**	0.7905	–2.3600	–1.7137**	0.8189	–2.0900	–0.9060	1.1137	–0.8100
$\ln(pcGDP_{jt})$	–1.9782***	0.3293	–6.0100	–2.1702***	0.3096	–7.0100	–2.1846***	0.4089	–5.3400
$\ln(Dis_{it})$	2.5403**	1.0966	2.3200	1.0043	1.2057	0.8300	5.9202	4.5920	1.2900
$\ln(EX_{ijt})$	–0.3902***	0.1372	–2.8400	–0.4625***	0.1404	–3.2900	–0.6400***	0.2190	–2.9200
$EU\text{-}NMS_j$	–1.1026***	0.2878	–3.8400	–0.9617***	0.2858	–3.3700	–0.5002*	0.2950	–1.7000
$Language_{ij}$	0.8473	0.5340	1.5900	0.4440	0.6202	0.0700	–2.1995	2.0192	–1.0900
$Landlocked_j$	0.2782	0.6735	0.4100	–0.3690	0.5578	–0.6600	–1.3579	1.0372	–1.3100
Constant	–73.6760***	14.1730	–5.2000	–56.1140***	15.0540	–3.7300	–83.2645***	40.9840	–2.0300
Λ		0.9995			0.5282			0.8736	
LR		471.2139			465.9203			433.4743	

***$P < 0.01$, **$P < 0.05$, *$P < 0.1$; number of observations for all models = 625; GDP_{it} – gross domestic product of exporter; GDP_{jt} – gross domestic product of importer; $pcGDP_{it}$ – per capita gross domestic product of exporter; $pcGDP_{jt}$ – per capita gross domestic product of importer; Dis_{it} – distance; EX_{ijt} – exchange rate; *EU-NMS* – EU new member state; $Language_{ij}$ – language; $Landlocked_j$ – landlocked; Λ – random error component; *LR* – likelihood ratio

Source: Authors' computation; the sources of data are available in Table 3

EU market. In other words, Nigeria is performing suboptimally in terms of its agri-food export trade with its EU trading partners, and there is also a vast potential to increase export with these countries. For example, Lithuania, Latvia, Luxembourg, Slovenia, and Malta are the least efficient countries with 16.4, 17.88, 21.27, 23.12, and 25.78%, respectively, revealing that Nigeria has a substantial untapped export potential with these countries [Lithuania (83.6%), Latvia (82.12%), Luxembourg (78.73%), Slovenia (76.88%), and Malta (74.22%)]. The countries with higher efficiency scores are the Netherlands (47.54%), Spain (46.33%), France (46.10%), Italy (45.12%), Germany (44.61%). In addition, among the EU-NMS, Poland, Estonia, and Czechia have a relatively high-efficiency score compared with other new members with 41.68, 40.03, and 39.03%, respectively.

Table 6. TE scores of Nigeria's agri-food exports with the EU

Country	TE	Country	TE
Netherlands	47.54	Sweden	38.82
Spain	46.33	Hungary	35.96
France	46.10	Slovakia	35.58
Italy	45.12	Denmark	34.71
Germany	44.61	Bulgaria	34.02
United Kingdom	44.22	Finland	33.73
Belgium	43.56	Cyprus	32.25
Austria	43.50	Croatia	31.41
Poland	41.68	Romania	29.65
Portugal	41.54	Malta	25.78
Estonia	40.03	Slovenia	23.12
Greece	39.59	Luxembourg	21.27
Czechia	39.50	Latvia	17.88
Ireland	39.33	Lithuania	16.40

TE – technical efficiency

Source: Authors' computation based on the maximum likelihood estimates of the SFGM (Model 1)

Nigeria's efforts to expand agri-food exports should focus on those countries where a high export potential is calculated, especially with large partners such as the United Kingdom, Germany, France, Italy, Poland. Table 7 reveals that the country with the highest potential is the United Kingdom. This potential may be due to the market size, common language, and colonial links. With the Netherlands, Belgium, Portugal, Czechia, and Greece being among the largest exporting destinations and representing relatively large markets, agri-food exports expansion efforts should also focus on agreements that can enhance Nigeria's agri-food exports with these countries. The top three EU-NMS with the highest export potential are Poland, Romania, and Bulgaria. On average, between 1995 and 2019, Nigeria had an untapped export potential of 207.26 with

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Table 7. Export potential of Nigeria's agri-food exports with the EU

Country	Export potential	Country	Export potential
United Kingdom	12.81	Czechia	7.31
Germany	12.46	Ireland	7.29
France	11.64	Finland	7.25
Italy	11.06	Slovakia	7.20
Poland	10.73	Lithuania	6.29
Spain	10.39	Hungary	6.23
Romania	9.40	Denmark	6.19
Netherlands	9.08	Croatia	5.89
Belgium	8.10	Latvia	5.61
Austria	7.73	Slovenia	4.75
Greece	7.44	Estonia	4.34
Sweden	7.42	Cyprus	2.55
Portugal	7.40	Luxembourg	1.89
Bulgaria	7.33	Malta	1.49

Source: Authors' computation based on the true random effects model (TRE) (Model 1)

the EU. Nigeria's agri-food exports with the EU are less than the optimal level in all the EU members.

CONCLUSION

Occasioned by the dwindling demand for Nigeria's oil exports and the crash in global oil prices in recent years, the Nigerian government has been motivated to boost its non-oil export base, particularly agri-food exports. On the back of the aforementioned, we take a holistic perspective to understand Nigeria's agri-food export trading with the EU, Nigeria's major trading bloc for its agri-food exports, over the period between 1995 and 2019. This perspective offers insights into the determinants, efficiency and potential of agri-food exports from Nigeria to the EU. As a result, we augment extant literature with our novel findings. Relying on an extended gravity model and the SFA, we provide the following findings. First, the GDP (economic size) of Nigeria and its EU trading partners stimulate agri-food exporting from Nigeria to the EU. Second, the bilateral distance between Nigeria's capital and that of its EU trading countries positively determines the volume of Nigeria's agri-food export trade that flows to the EU trading countries. Third, the per capita GDP (income) of both Nigeria and the EU countries dissuade agri-food exports from Nigeria to the EU. Fourth, Nigeria's agri-food export trade is negatively associated with the exchange rate and EU-NMS. Fifth, Nigeria's agri-food exports to the EU countries are largely inefficient. Lastly, there is a relatively large potential of Nigeria's agri-food exports with the EU that is yet to be exploited.

Based on the findings, we offer recommendations that give policy directions for Nigeria to boost its agri-food export trade flows to the EU. By implementing economic policy reforms aimed at increasing the economic size of Nigeria, the promotion of its agri-food exports to the EU is feasible. For instance, as a strategy, the Nigerian government should promote the ease of doing business in order to improve the soundness of the investment environment, which would resultantly stimulate further domestic production. Also, depreciation of the Naira against the currencies of its EU trading countries would promote the exportation of agri-food products from Nigeria to the EU. Finally, Nigeria's agri-food export sector would benefit more from increasing its agri-food products to EU countries with observed higher export potential. We acknowledge that our study is limited to Nigeria's agri-food exports with the EU members only. Therefore, the results cannot be applied to the Nigerian agri-food sector as a whole. Future studies may add novelty to the existing body of knowledge by focusing on the agri-food exports of Nigeria with non-EU trading countries or both EU and non-EU trading countries. Similarly, they may consider a reverse case of our study by examining the determinants, efficiency and potential of agri-food exports of EU trading countries to Nigeria.

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