DOI: 10.28934/ea.2236 First Online: November 6, 2026

ORIGINAL SCIENTIFIC PAPER

Factors Associated with Agricultural Export Diversification: Panel-Data Evidence from Developed and Developing Countries

Milan Tomić[1]*

[1] Independent Researcher, Banja Luka, Bosnia and Herzegovina

ABSTRACT

This paper examines the factors associated with agricultural export diversification across countries and over time. The main objective is to assess whether economic development, market size, agricultural trade openness, domestic agricultural production diversification, foreign direct investment, exchange rate volatility and the COVID-19 shock are associated with differences in agricultural export diversification. Agricultural export diversification is measured by the normalized Herfindahl–Hirschman Index, based on agricultural product lines classified under the CPC system. The same HHI-based approach is applied to measure domestic agricultural production diversification, which allows the paper to link the structure of agricultural exports to the structure of domestic agricultural production. The empirical analysis is based on a country-year panel dataset covering 86 countries over the period 2010–2023. Pooled OLS, fixed-effects and random-effects models are estimated, while the preferred specification is selected using panel diagnostic tests and a Mundlak specification test. Robust standard errors clustered at the country level and temporal robustness checks are used to assess the stability of the findings. The results show that GDP per capita, population and the HHI-based index of domestic agricultural production structure are associated with agricultural export diversification. GDP per capita is included in both linear and squared form, and the results point to a nonlinear relationship between economic development and agricultural export diversification. Population is positively associated with agricultural export diversification, while the positive coefficient of the domestic agricultural production HHI indicates that a less diversified domestic production structure is associated with lower agricultural export diversification. The paper contributes to the limited literature on agricultural export diversification by using FAOSTAT-based HHI indicators and by examining factors associated with agricultural export diversification in a multi-country panel framework, with particular attention to the role of domestic agricultural production structure.

Keywords: *agricultural export diversification; Herfindahl–Hirschman Index; agricultural production diversification; international trade; panel-data models; fixed effects*

JEL Classification: F14, Q17, C23, O13, F43

INTRODUCTION

Agricultural export diversification is important for countries seeking to reduce their dependence on a narrow range of export products and strengthen the resilience of export earnings. Ali et al. (1991) examined whether changes in the export mix could support export

* E-mail: Milantm93@gmail.com

growth and stability. They cautioned that the benefits depend on price dynamics, comparative advantage and domestic production performance. Research on geographical diversification also shows that exporting to more destination markets can reduce agricultural export volatility (Wang & Liu, 2023). The policy relevance of this issue is also reflected in development initiatives that link agricultural competitiveness and export diversification with higher productivity, improved market access and stronger agri-food value chains (World Bank, 2020). The issue is especially important for developing countries, where agriculture frequently contributes substantially to employment, rural livelihoods and export earnings. When agricultural exports are concentrated in a small number of products, countries become more exposed to international price fluctuations, climate-related production shocks, changes in foreign demand and disruptions in logistics and supply chains. A more diversified agricultural export structure can reduce dependence on individual products, broaden export opportunities and strengthen the resilience of the agricultural sector to such shocks (Weber et al., 2022).

The broader literature examines export diversification as part of economic development and structural transformation. Diversification is generally associated with the accumulation of productive capabilities, broader participation in international markets and a gradual movement from narrow specialization towards more varied and complex production and export structures. However, the relationship between economic development and diversification may not be linear. Imbs and Wacziarg (2003) show that economies tend to diversify during development and reconcentrate at higher income levels. Cadot et al. (2011) identify a hump-shaped pattern of export diversification along the development path. When export diversification is measured inversely using a concentration index such as the HHI, greater diversification is reflected in lower index values. Most cross-country studies of the determinants of diversification examine total exports rather than agriculture as a separate sector (Alaya, 2012; Giri et al., 2019; Swathi & Sridharan, 2022). The agricultural literature remains more limited and frequently focuses on individual countries or regions, the measurement of diversification, or the identification of diversification opportunities (Djokoto, 2015; Samavong et al., 2021; Taylor & Francis, 2003; Weber et al., 2022). Consequently, less is known about the joint role of macroeconomic conditions, agricultural trade openness, foreign direct investment (FDI) and the domestic agricultural production structure in explaining changes in agricultural export diversification across a broad sample of countries. In particular, limited attention has been paid to whether a broader domestic agricultural production base is systematically associated with greater agricultural export diversification.

Against this background, the objective of this paper is to identify the macroeconomic and production-side factors associated with agricultural export diversification across countries and over time. The analysis uses an unbalanced panel of 86 developed and developing countries over the period 2010–2023. The analysis also examines whether the relationship between economic development and agricultural export diversification is nonlinear. Agricultural export diversification is measured using the normalised Herfindahl–Hirschman Index. The explanatory variables capture GDP per capita, market size, agricultural trade openness, agricultural foreign direct investment, the structure of domestic agricultural production, exchange-rate volatility and the COVID-19 period. To allow for nonlinearity, the empirical specification includes both the logarithm of GDP per capita and its squared term. The paper therefore tests whether agricultural export diversification follows a nonlinear development pattern similar to that identified in the broader export diversification literature. The empirical strategy relies primarily on country fixed effects with country-clustered robust standard errors, supplemented by alternative panel specifications and temporal robustness checks.

The contribution of this paper lies in examining the relationship between domestic agricultural production structure and agricultural export diversification within a common cross-country panel framework. Building on country-specific evidence, including Djokoto (2015), the analysis examines this relationship across a broad country sample. It accounts jointly for economic

development, market size, agricultural trade openness, agricultural foreign direct investment and macroeconomic shocks. Applying the same normalized HHI formula to production and export shares provides a consistent measurement framework for examining these two dimensions of agricultural structure.

The analysis also combines this production-side perspective with a nonlinear income specification. Country fixed effects allow the estimates to reflect changes within countries rather than only persistent differences between economies. The contribution therefore extends beyond selecting agriculture as the sector of interest. It concerns whether changes in domestic production structure remain associated with export diversification when development conditions and other relevant factors are considered jointly. These estimates provide evidence on conditional relationships, rather than identifying a causal effect of production diversification on export diversification.

The paper is structured as follows. The Literature Review section discusses the theoretical and empirical literature on export diversification and its main determinants. The Data and Methodology section presents the dataset, variables, construction of the HHI indicators and panel-data estimation strategy. The Results and Discussion section reports the baseline estimates, diagnostic tests, robustness checks and interpretation of the principal findings. The Conclusion summarizes the results and discusses their policy implications, limitations and directions for future research.

LITERATURE REVIEW

Export diversification is commonly analyzed as part of the broader process of economic development and structural transformation. This literature argues that countries develop by expanding productive capabilities, broadening the range of goods they produce and export, and gradually moving towards more complex export structures (Cadot et al., 2011; Giri et al., 2019; Hesse, 2008; Hidalgo et al., 2007; Parteka & Tamberi, 2013). Countries with broader productive capabilities are generally able to produce and export a wider range of goods, whereas countries with limited productive capacity tend to depend on a narrower export basket (Hausmann & Hidalgo, 2011; Hidalgo et al., 2007). Earlier contributions also emphasized the risks associated with export concentration and commodity dependence, particularly for economies exposed to external price shocks (Massell, 1964; Prebisch, 1950). In this context, low export diversification is associated with greater export instability, stronger exposure to terms-of-trade shocks and weaker growth prospects (Hesse, 2008).

Diversification indicators describe how export value is distributed across product lines. This study uses the normalized Herfindahl–Hirschman Index as an inverse measure of agricultural export diversification. Since the index is calculated from squared export shares, products with larger shares in total exports have a stronger influence on its value (Cadot et al., 2011, p. 591; United Nations Conference on Trade and Development, 2018, pp. 3–4). Higher HHI values indicate weaker diversification and greater dependence on a smaller number of agricultural product lines, while lower values indicate a more diversified export basket. The normalized HHI is used because it directly captures the degree of dependence on dominant agricultural export products.

Economic development, market size and productive capabilities feature prominently in empirical explanations of export diversification, while recent studies continue to examine their relevance using alternative empirical approaches (Bouberrima & Mostefai, 2025; Giri et al., 2019; Parteka & Tamberi, 2013; Vogel, 2025). GDP per capita is therefore widely used as a proxy for the broader development conditions under which countries accumulate productive capabilities and expand their export baskets into related products (Hausmann & Hidalgo, 2011; Hidalgo et al., 2007). However, the relationship between income and export diversification is not necessarily linear. Imbs and Wacziarg (2003) show that economies tend to diversify during the development process and reconcentrate at higher income levels. Similarly, Cadot et al. (2011) identify a hump-

shaped pattern of export diversification along the development path, where diversification initially increases with income but may decline after a certain threshold. Consistent with this approach, Giri et al. (2019) include both GDP per capita and its squared term among the core structural factors associated with export diversification. Hadjira and Zakane (2021) also apply a quadratic income specification. They report a negative coefficient for the linear GDP per capita term and a positive coefficient for its squared term. Wang (2024) provides further evidence of a nonlinear relationship between income and export diversification.

Population is included as a complementary proxy for domestic market size, labor availability and production scale. Larger economies may have broader production structures and greater potential to support a more diversified export basket. Hu et al. (2012) identify an S-shaped relationship between export diversity and economic size. Tomić and Stevandić (2024) use population as a market-size variable in a panel model of export diversification in OPEC countries.

Domestic agricultural production diversification is linked to export diversification through supply-side capabilities. Product-space research suggests that countries tend to expand into products related to capabilities already present in the economy (Hausmann & Hidalgo, 2011; Hidalgo et al., 2007). A broader domestic production base may therefore enlarge the set of agricultural products that can be supplied consistently to export markets. However, export capacity in agriculture also depends on product quality, certification and compliance with foreign-market standards. Paraušić et al. (2024) show that GLOBALG.A.P. certification is linked to stronger fruit and vegetable export performance in middle-income European countries. A more concentrated domestic agricultural production structure may limit the range of products that can be supplied competitively to export markets.

Trade openness and exchange-rate volatility are often discussed because market access and macroeconomic uncertainty can support or constrain entry into new export lines. Dennis and Shepherd (2011) link lower export and transport costs to export diversification. Agosin et al. (2012) show that openness can also reinforce specialization when countries expand exports in products where they already hold comparative advantages. Exchange-rate uncertainty can affect price competitiveness, expected returns, and exporters' planning horizons. Clark et al. (2004) and Tenreyro (2007) show that empirical evidence on exchange-rate volatility and trade flows is mixed. In diversification models, exchange-rate-related variables are often weak or insignificant. Fonchamnyo and Akame (2017) use a fractional logit model for Sub-Saharan African countries and report that the official exchange rate is not a statistically significant determinant of export diversification.

Foreign direct investment may affect export diversification through opposing channels. On the one hand, FDI can support diversification by transferring technology, managerial knowledge and information about foreign markets, as well as by reducing entry costs for domestic firms in non-traditional export activities (Alaya, 2012). On the other hand, its effect depends on absorptive capacity, domestic linkages and the sectoral allocation of investment. FDI directed towards activities with strong local linkages may expand productive capabilities, while investment concentrated in enclave or resource-based sectors may reinforce existing export patterns (Elhiraika & Mbate, 2014). Empirical evidence is also mixed. Fonchamnyo and Akame (2017) and Swathi and Sridharan (2022) find that FDI supports export diversification, whereas Giri et al. (2019) report that higher FDI may be associated with greater export specialization. Therefore, the expected sign of FDI is ambiguous.

The COVID-19 pandemic disrupted global trade, logistics and food supply chains in 2020 and 2021, providing a rationale for controlling for the pandemic period in the empirical model (Food and Agriculture Organization of the United Nations [FAO], 2020; Verschuur et al., 2021). Vukmirović and Nedeljković (2023) report uneven labor-income effects across sectors in Serbia during the pandemic, including agriculture, forestry and fishing. This supports treating COVID-19 as a broad economic and sectoral shock.

A key gap is that much of the literature examines diversification at the level of total exports rather than agriculture as a separate sector (Alaya, 2012; Giri et al., 2019; Parteka & Tamberi, 2013). Sector-specific agricultural evidence is more limited. Taylor and Francis (2003) analyze agricultural export diversification in Latin America and the Caribbean using disaggregated agricultural export data and entropy-based measures. Samavong et al. (2021) use the HHI to examine agricultural export diversification and concentration in Lao PDR. Djokoto (2015) combines FAOSTAT and UNCTADstat data with a Simpson diversification index for Ghana. Weber et al. (2022) assess agrifood diversification opportunities in Guyana using comparative-advantage, export-sophistication and proximity metrics. This paper links an HHI-based agricultural export diversification indicator to domestic agricultural production diversification. The export indicator is obtained from the Diversity Index Database and is calculated from FAOSTAT agricultural trade data (Tomić et al., 2026). FAOSTAT is also appropriate for the production side because it provides internationally comparable food and agriculture data covering crops, livestock and derived products (FAO, n.d.a).

DATA AND METHODOLOGY

This section presents the data, variables and empirical strategy used to examine the determinants of agricultural export diversification. The broader dataset covers the period 2010–2023, subject to data availability across countries and variables. In the preferred model specification, the effective regression sample includes 699 observations for 86 countries, of which 24 are classified as developed countries and 62 as developing countries. The classification follows the IMF World Economic Outlook country grouping, which distinguishes between advanced economies and emerging market and developing economies (International Monetary Fund, 2025). In this paper, these two groups are reported as developed countries and developing countries. The effective regression sample differs across specifications because panel estimations use only observations for which all model variables are available. This period is selected because it provides a recent and sufficiently long time frame for examining changes in agricultural export structures. It also includes the COVID-19 period, which is relevant for controlling for a major global disruption in trade and agricultural markets. The section first presents the variables and preliminary descriptive evidence. It then explains the panel-data estimation strategy, diagnostic tests and model-selection procedure used in the empirical analysis.

VARIABLE MEASUREMENT, DATA SOURCES AND MODEL SPECIFICATION

The analysis uses two distinct HHI-based indicators. The first measures the distribution of agricultural export value across products and serves as the dependent variable. The second measures the distribution of domestic agricultural production value across products and is included as an explanatory variable. Although both indicators use the same normalization formula, they describe different economic structures.

The agricultural export diversification indicator is obtained as a pre-calculated series from the Diversity Index Database through the Div Index platform (Tomić et al., 2026). The underlying export data come from the FAOSTAT Trade: Crops and livestock products domain (TCL), using the "Export value" series expressed in thousands of US dollars (FAO, n.d.b). The index is calculated from export values for agricultural product items classified under the Central Product Classification (CPC). FAOSTAT is therefore the primary source of the trade data, while the Div Index platform provides the calculated diversification indicator. The production indicator is constructed separately from product-level values reported in the FAOSTAT Value of Agricultural Production domain (FAO, n.d.d).

The normalized HHI index is calculated as follows:

$$H^* = \frac{\sum_k (S_k)^2 - 1/n}{1 - 1/n} \quad (1)$$

where S_k denotes the share of agricultural product k in total agricultural export value for the observed country and year. This share is calculated as $S_k = X_k / \sum_{\ell=1}^{n} X_\ell$, where X_k is the export value of product k, and n is the number of agricultural product items included in the calculation for that country and year. Each product share is squared, the squared shares are summed, and the resulting sum is normalized using Equation (1). For $n > 1$, the normalized HHI takes values between zero and one. A value of zero corresponds to equal export shares across the included products, while values closer to one indicate greater reliance on a small number of products. Lower index values therefore indicate greater agricultural export diversification.

After defining the HHI-based dependent variable, the relationship between agricultural export diversification and its proposed determinants is specified using a panel-data model. Since GDP per capita enters the model in centered form, the centered logarithm of GDP per capita is first defined as follows:

$$g_{it} = ln(GDPpc_{it}) - \overline{\ln(GDP_{pc})} \quad (2)$$

where g_{it} denotes the centered logarithm of GDP per capita for country i in year t, while $\ln(GDP_{pc})$ denotes the arithmetic mean of the logarithm of GDP per capita used for centering. In this paper, the centering mean is calculated on the broader variable-construction sample before the final regression sample is obtained through listwise deletion. This is why the mean value of the centered GDP variable in the final regression sample reported in Table 2 is close to, but not exactly equal to, zero.

$$lnHHI_{it} = \alpha + \beta_1 g_{it} + \beta_2 {g_{it}}^2 + \beta_3 ln(AGOPEN_{it}) + \beta_4 ln(\mathrm{POP}_{it}) + \beta_5 ln(DIV_{it}) + \beta_6 ln(FDI_{it}) + \beta_7 ln(VOL_{it}) + \beta_8 COVID_t + \mu_i + \varepsilon_{it} \quad (3)$$

In equation (3), i denotes country and t denotes year. The term μ_i captures unobserved country-specific effects, while ε_{it} is the idiosyncratic error term. GDP per capita is expressed through the centered logarithmic variable g_{it}, while g_{it}^2 represents its squared term and is included to test for a possible nonlinear relationship between economic development and agricultural export diversification. Annual time effects are tested in additional specifications in order to examine whether common year-specific shocks add explanatory power to the model. Since HHI and DIV are HHI-based inverse indicators of diversification, lower values indicate greater diversification, while higher values indicate a narrower agricultural export or production structure. The normalized HHI index is used to improve comparability across countries and years, especially when the number of active export product lines differs across observations.

Table 1 provides a visual summary of the empirical model by showing the dependent variable, explanatory variables, their role in the model and the corresponding data sources.

Table 1. Visual representation of the empirical model

Model component	Variable	Measurement / role in the model	Data source
Agricultural export diversification	HHI	Logarithm of the normalized HHI index of agricultural exports	Div Index platform (Tomić et al., 2026), based on FAOSTAT Trade: Crops and livestock products (FAO, n.d.b)
Economic development	GDP, GDP^2	Centred logarithm of GDP per capita and its squared term	World Development Indicators
Agricultural trade integration	AGOPEN	Logarithm of agricultural exports plus agricultural imports relative to GDP	FAOSTAT
Market size and production scale	POP	Logarithm of total population	World Development Indicators
Domestic agricultural production structure	DIV	Logarithm of the normalised HHI index of domestic agricultural production	Author's calculations based on FAOSTAT Value of Agricultural Production (FAO, n.d.d)
Agricultural foreign direct investment	FDI	Logarithm of foreign direct investment in agriculture	FAOSTAT
Exchange rate volatility	VOL	Logarithm of annual volatility of monthly exchange rates	International Monetary Fund
External shock	COVID	Dummy variable equal to one for 2020 and 2021, and zero otherwise	Author's specification

Source: Author's illustration.

After this visual overview, the variables included in the empirical specification are described in more detail. The empirical model includes one dependent variable and eight explanatory variables. The dependent variable ($lnHHI$) is the logarithm of the normalized HHI index of agricultural exports, obtained from the Diversity Index Database through the Div Index platform (Tomić et al., 2026). GDP per capita ($lnGDPpc$) is measured in constant 2015 US dollars and is obtained from the World Development Indicators database (World Bank, n.d.a). It is included as a proxy for economic development, productive capacity and structural transformation (Agosin et al., 2012; Parteka & Tamberi, 2013; Swathi & Sridharan, 2022). In the model, GDP per capita enters in both linear and squared form in order to test for a possible nonlinear relationship between economic development and agricultural export diversification. A similar approach, based on the inclusion of GDP per capita and its squared term in export diversification models, has been applied in previous studies (Cadot et al., 2011; Giri et al., 2019; Hadjira & Zakane, 2021; Wang, 2024). The logarithm of GDP per capita is centered before constructing the squared term in order to reduce the mechanical correlation between the linear and quadratic terms and to improve the interpretability of the estimated coefficients. Since the dependent variable is an HHI-based measure of export diversification, a negative coefficient is expected for the GDP term, while a positive coefficient is expected for the squared GDP term.

Agricultural trade openness ($lnAGOPEN$) is calculated specifically for this paper as the ratio of agricultural imports and exports to GDP. Agricultural import and export data are obtained from the FAOSTAT trade domain for crops and livestock products, while GDP data used in the denominator are obtained from the FAOSTAT Macro Indicators domain (FAO, n.d.b; FAO, n.d.c). This sector-specific measure is more appropriate than general trade openness because it captures the degree of external integration of the agricultural sector rather than the openness of the whole economy. Its expected sign is ambiguous, since agricultural openness may support market access and export diversification, but may also reinforce specialization in a narrower set of agricultural products (Agosin et al., 2012; Alaya, 2012). Population ($lnPOP$), obtained from the World Development Indicators database (World Bank, n.d.b), is used as a proxy for domestic market size

and production scale. A negative coefficient is expected because larger countries may have a broader production base (Parteka & Tamberi, 2013; Swathi & Sridharan, 2022).

The HHI-based measure of domestic agricultural production diversification is constructed from the FAOSTAT Value of Agricultural Production domain (QV), using gross production values expressed in constant 2014–2016 international dollars (FAO, n.d.d). The corresponding FAOSTAT series is "Gross Production Value (constant 2014–2016 thousand I$)." This series was preferred to the current-price alternative because it provides more complete country-year coverage for the sample used in the analysis. For each country and year, each product's share is calculated by dividing its gross production value by the sum of gross production values across the product items included in the calculation. These production-value shares are then squared, summed and normalized using Equation (1). For this indicator, n denotes the number of product items included in the production calculation for the observed country and year. The resulting index enters the model in natural logarithmic form. Lower values of this variable indicate a more diversified domestic production structure. Since a broader domestic production base may support a broader export basket, a positive coefficient is expected. Higher production concentration should be associated with higher agricultural export HHI values (Djokoto, 2015; Osakwe & Kilolo, 2018; Samavong et al., 2021).

Foreign direct investment ($lnFDI$), obtained from the FAOSTAT database, is included as a proxy for international capital inflows, technology transfer and potential spillover effects in the agricultural sector (FAO, n.d.e). Its expected sign is ambiguous. On the one hand, FDI may support export diversification by facilitating technology transfer, improving production capacity and expanding access to foreign markets. On the other hand, FDI may reinforce specialization if investment is concentrated in a limited number of agricultural products or resource-based activities. Previous studies have also included FDI as an explanatory variable in export diversification models (Alaya, 2012; Elhiraika & Mbate, 2014; Fonchamnyo & Akame, 2017; Giri et al., 2019; Swathi & Sridharan, 2022). Exchange rate volatility ($lnVOL$) is calculated as the annual volatility of monthly exchange rates using IMF data (International Monetary Fund, n.d.) and captures macroeconomic instability. Higher volatility may discourage entry into new export products and increase concentration, so a positive coefficient is expected (Agosin et al., 2012; Clark et al., 2004). The COVID-19 dummy equals one for 2020 and 2021 and zero otherwise. All continuous variables are expressed in logarithmic form, while the COVID-19 dummy is not log-transformed.

DESCRIPTIVE STATISTICS AND CORRELATION ANALYSIS

The empirical analysis begins with a descriptive overview of the variables included in the preferred model specification. This step provides initial information on the distribution of the HHI-based indicator of agricultural export diversification and on the variation of the explanatory variables across countries and years. Table 2 reports descriptive statistics for the effective estimation sample, which includes observations for which all variables used in the model are available.

Table 2. Descriptive statistics of variables used in the analysis

Variable	N	Mean	SD	Min	Max
HHI	699	-2.377	0.773	-4.060	-0.306
GDP	699	-0.025	1.169	-2.541	2.619
GDP^2	699	1.365	1.587	0.000	6.857
AGOPEN	699	-0.058	0.479	-1.317	0.925
POP	699	16.753	1.647	12.381	21.069
DIV	699	-2.414	0.574	-3.546	-0.949
FDI	699	3.109	2.187	-12.206	9.533

Variable	N	Mean	SD	Min	Max
VOL	699	-4.408	1.167	-9.763	0.365
COVID	699	0.110	0.313	0	1

Source: Author's calculations.

As shown in Table 2, the effective estimation sample consists of 699 observations. The mean value of the HHI-based indicator is −2.377, with a standard deviation of 0.773. Since the dependent variable is expressed in logarithmic form, negative values reflect the transformation of the normalized HHI index. Although the initial number of available observations differed across variables, the final sample was restricted to observations for which all model variables were simultaneously available. The highest initial number of observations was available for HHI, with 2,567 observations, while the lowest was available for the agricultural FDI variable, with 827 observations. Despite reducing the effective sample size, FDI is retained in the preferred specification because it captures an economically relevant channel of international capital inflows, technology transfer and sectoral restructuring in agriculture, whose omission could leave an important determinant of export diversification uncontrolled. After applying the complete-case requirement for the preferred model, the final sample was reduced to 699 observations.

After describing the distribution of the variables, the next step is to examine preliminary associations among the regressors. Table 3 reports pairwise correlations among the explanatory variables included in the preferred model specification. These correlations should not be interpreted as causal relationships, but they provide useful initial evidence on the relationships among the explanatory variables. They also help identify whether some explanatory variables may be strongly correlated before moving to the panel regressions.

Table 3. Pairwise correlation matrix of explanatory variables

Variable	GDP	GDP^2	AGOPEN	POP	DIV	FDI	VOL	COVID
GDP	1.000							
GDP^2	-0.025	1.000						
AGOPEN	-0.081	-0.251	1.000					
POP	-0.116	-0.012	-0.537	1.000				
DIV	0.037	0.091	0.272	-0.355	1.000			
FDI	0.035	-0.050	-0.166	0.375	-0.038	1.000		
VOL	0.326	-0.029	-0.132	-0.042	-0.083	0.051	1.000	
COVID	-0.031	-0.001	-0.040	0.037	-0.026	-0.035	-0.050	1.000

Source: Author's calculations.

Table 3 reports the pairwise correlation matrix for the explanatory variables included in the preferred model specification. The correlation coefficients are generally low to moderate, indicating no strong pairwise association among the regressors. The highest correlation is observed between agricultural trade openness and population, with a coefficient of −0.537, while all remaining correlations are below this value in absolute terms. The correlation between GDP and GDP^2 is very low, which confirms that centering the GDP variable substantially reduced the mechanical correlation between the linear and squared terms. Since pairwise correlations provide only a preliminary indication of multicollinearity, the analysis is further complemented by the variance inflation factor, which is reported later in the diagnostic tests table. The VIF results remain below conventional critical thresholds, indicating that multicollinearity does not represent a serious problem for the estimated models.

Although these descriptive results provide useful preliminary insights, they do not account for unobserved country-specific heterogeneity or the panel structure of the data. Therefore, the next subsection presents the panel-data estimation strategy and the diagnostic tests used to select the preferred model.

PANEL DATA ESTIMATION STRATEGY AND DIAGNOSTIC TESTING

The empirical analysis is based on panel-data models. The pooled OLS model is first estimated as an initial reference specification. Fixed-effects and random-effects models are then used to account for the panel structure of the data (Wooldridge, 2010). The relevance of unobserved country-specific heterogeneity is assessed through tests of individual effects in the fixed-effects framework and through the LM test in the random-effects framework. This is important because ignoring country-specific effects may lead to inappropriate reliance on a pooled model with constant parameters.

The joint relevance of time effects is examined through tests of annual effects. These tests show whether common shocks in specific years add explanatory power to the model. The functional form of the pooled specification is checked using Ramsey's RESET test (Ramsey, 1969). This is important because functional-form misspecification may lead to biased estimates and misleading inference.

Several diagnostic tests are used to evaluate the reliability of statistical inference. Heteroskedasticity is examined using White's test (White, 1980) in the pooled OLS model. It is also examined using the modified Wald test after fixed-effects estimation (Baum, 2001) and the Baltagi, Bresson, and Pirotte LM test in the random-effects framework (Baltagi et al., 2006). This is important because heteroskedasticity may lead to inefficient estimates and biased standard errors. Where diagnostic tests indicate heteroskedasticity or within-country correlation in the error term, statistical inference is based on robust standard errors clustered at the country level.

Serial correlation is tested because autocorrelated errors can distort statistical inference in panel models. In the fixed-effects specification, serial correlation is assessed using the Wooldridge test for autocorrelation in panel data (Drukker, 2003; Wooldridge, 2010). In the random-effects framework, it is examined using the ALM test (Baltagi & Li, 1991, 1995). Cross-sectional dependence is examined using Pesaran's CD test (Pesaran, 2004). This is important because countries may be affected by common global shocks, regional spillovers or synchronized movements in trade and agricultural markets. If cross-sectional dependence is present and ignored, standard errors may be biased and statistical inference may become unreliable. The test is suitable for panels with a larger number of cross-sectional units than time periods.

The choice between fixed and random effects is based on the Mundlak specification test (Mundlak, 1978). The classical Hausman test evaluates whether unobserved individual effects are correlated with the regressors (Hausman, 1978). The Mundlak specification provides a robust alternative by augmenting the random-effects model with unit-level means of time-varying regressors and testing their joint significance. Rejection of the Mundlak specification test indicates that the random-effects assumption is not supported and that the fixed-effects estimator is more appropriate. Multicollinearity is assessed using the variance inflation factor, with values below the commonly used thresholds of 5 or 10 interpreted as providing no indication of serious multicollinearity (James et al., 2013).

Potential endogeneity should be considered when interpreting the estimates. A broader domestic production base may support agricultural export diversification, but changes in export demand may also encourage producers to alter their product mix. Unobserved time-varying factors, including commodity-price movements, weather shocks and changes in agricultural policy, may influence both production and export structure. Measurement error in the explanatory variables provides another potential source of endogeneity.

Country fixed effects account for time-invariant national characteristics, but consistent estimation still requires strict exogeneity of the regressors with respect to the idiosyncratic error term (Wooldridge, 2010). Country-clustered standard errors allow for heteroskedasticity and within-country error correlation, but they do not correct bias arising from reverse causality or omitted time-varying factors. The estimates are therefore interpreted as conditional within-country associations rather than causal effects. Establishing causality would require additional

identifying assumptions and an appropriate empirical design beyond the scope of the current analysis.

After defining the variables and presenting the panel-data estimation strategy, the analysis proceeds to the regression results. The main objective is to identify which macroeconomic and production-side factors are associated with agricultural export diversification after controlling for unobserved country-specific heterogeneity. The baseline and temporal robustness estimates are reported in Table 4, while additional model-selection and diagnostic results are presented in Appendix Table A1.

RESULTS AND DISCUSSION

This section presents and discusses the panel-data results on the determinants of agricultural export diversification. The analysis first focuses on the baseline and robustness estimates reported in Table 4. The main objective is to examine whether economic development, market size and the structure of domestic agricultural production are systematically associated with agricultural export diversification after controlling for unobserved country-specific heterogeneity. The discussion then relates the main findings to previous empirical literature and highlights the sector-specific contribution of the results.

Table 4. Baseline and robustness estimates of the determinants of agricultural export diversification

	OLS	**Robust FE**	**Robust RE**	**Robust FE 2011–2023**	**Robust FE 2010–2022**
GDP	**-.364*** **	**-.464*** **	**-.463*** **	**-.569*** **	**-.452** **
	(.019)	**(.167)**	**(.051)**	**(.174)**	**(.172)**
GDP^2	**-.056*** **	**.216** **	**.091** **	**.190** **	**.206** **
	(.013)	**(.092)**	**(.043)**	**(.095)**	**(.093)**
AGOPEN	**-.531*** **	-.099	**-.210***	-.151	-.088
	(.056)	(.137)	**(.118)**	(.138)	(.138)
POP	**-.105*** **	**-.735** **	**-.089** **	**-.741** **	**-.734** **
	(.017)	**(.326)**	**(.044)**	**(.330)**	**(.331)**
DIV	**.632*** **	**.581*** **	**.549*** **	**.552*** **	**.605*** **
	(.039)	**(.128)**	**(.098)**	**(.131)**	**(.131)**
FDI	-.011	.002	.003	.002	.005
	(.010)	(.008)	(.008)	(.008)	(.008)
VOL	.013	.018	.026	.027	.014
	(.019)	(.016)	(.018)	(.017)	(.017)
COVID	.100	.025	-.011	.028	.018
	(.066)	(.025)	(.031)	(.025)	(.026)
Constant	**1.040*** **	**11.100** **	.365	**11.227** **	**11.131** **
	(.279)	**(5.459)**	(.704)	**(5.529)**	**(5.516)**
Observations	699	699	699	635	681
Number of groups	86	86	86	82	86
Individual effects		F (85, 605) = 45.27 p < 0.001	$chibar^2(01)$ = 2015.77 p < 0.001	F (81, 545) = 45.96 p < 0.001	F (85, 587) = 45.15 p < 0.001
Model significance	F (8, 690) = 85.82 p < 0.001	F (8, 85) = 11.00 p < 0.001	Wald $\chi^2(8)$ = 119.76 p < 0.001	F (8, 81) = 12.54 p < 0.001	F (8, 85) = 10.31 p < 0.001
Ramsey RESET test	F (3, 687) = 49.88 p < 0.001				
Mundlak specification test		$\chi^2(7)$ = 23.58 p = 0.001			
Mean VIF	1.30	1.30	1.30	1.30	1.30

	OLS	Robust FE	Robust RE	Robust FE 2011–2023	Robust FE 2010–2022
R-squared	$R^2 = 0.498$ $R^2_{adj} = 0.492$	$R^2_w = 0.285$ $R^2_b = 0.141$ $R^2_o = 0.174$	$R^2_w = 0.252$ $R^2_b = 0.463$ $R^2_o = 0.414$	$R^2_w = 0.268$ $R^2_b = 0.188$ $R^2_o = 0.208$	$R^2_w = 0.279$ $R^2_b = 0.141$ $R^2_o = 0.170$

Source: Author's calculations.

*Note: Values in parentheses are robust standard errors. ***, ** and * indicate coefficients statistically significant at the 1%, 5% and 10% levels, respectively.*

Table 4 reports the baseline and robustness estimates for agricultural export diversification. The dependent variable is the logarithm of the normalized HHI, which is used as an inverse indicator of diversification. Therefore, lower values of HHI indicate a higher level of agricultural export diversification. The pooled OLS model is reported only as an initial reference specification. The tests of country effects indicate that unobserved country-specific heterogeneity is statistically relevant and that pooled OLS does not adequately account for cross-country differences. The Mundlak specification test rejects the random-effects restrictions, suggesting that unobserved country-specific characteristics are correlated with the explanatory variables (Mundlak, 1978; Wooldridge, 2010). The test has seven degrees of freedom because it tests the joint significance of the unit-level means of seven time-varying country-specific regressors, while time effects are not included in this joint test because they capture common year-specific shocks. The analysis therefore uses country fixed effects with country-clustered robust standard errors. The explanatory variables are jointly statistically significant. The reported VIF value of 1.30 is well below the commonly used thresholds of 5 or 10 and provides no indication of serious multicollinearity (James et al., 2013). Since such thresholds are diagnostic conventions rather than universal decision rules, this result should be interpreted as evidence against serious multicollinearity rather than as proof that collinearity is entirely absent (Jeng, 2023).

The possible role of annual effects is examined in Appendix Table A1, which reports the full-sample two-way specifications and joint tests of year indicators. These results are treated as auxiliary evidence because the Mundlak specification test selects the fixed-effects framework, while the diagnostic tests indicate heteroskedasticity and within-country serial correlation. In the country-clustered TWFE specification, the year indicators are not jointly statistically significant, $F(13, 85) = 1.59$, $p = 0.103$. Although the conventional TWFE test produces a different conclusion, clustered inference is preferred because the diagnostic tests indicate heteroskedasticity and within-country serial correlation. The one-way country fixed-effects model with country-clustered robust standard errors is therefore retained as the baseline specification. The COVID-19 dummy is retained in this model as a direct control for the pandemic period, whereas it is absorbed by the full set of year effects in the auxiliary two-way specifications.

The diagnostic tests reported in Appendix Table A1 further support this estimation strategy. The Ramsey RESET test indicates possible misspecification in the pooled OLS model (Ramsey, 1969). White's test, the Modified Wald tests and the LM tests for the random-effects specifications indicate heteroskedasticity in the error structure (Baltagi et al., 2006; White, 1980). The Wooldridge and adjusted LM autocorrelation tests also indicate within-country serial correlation (Baltagi & Li, 1991, 1995; Drukker, 2003; Wooldridge, 2010). By contrast, the Pesaran CD tests do not provide evidence of residual dependence across countries (Pesaran, 2004). Taken together, these results justify the use of country-clustered robust standard errors in the preferred model. The last two columns of Table 4 assess temporal robustness. The 2011–2023 specification excludes the initial year, while the 2010–2022 specification excludes the final year. The principal results remain stable. The linear GDP per capita term is negative, its squared term is positive, population remains negative, and the HHI-based domestic agricultural production diversification variable remains positive, with all four variables statistically significant. Given the inverse HHI interpretation, these results indicate that income, market size and a more diversified domestic agricultural production structure are systematically associated with higher agricultural export

diversification. Agricultural trade openness, foreign direct investment in agriculture, exchange-rate volatility and the COVID-19 dummy remain statistically insignificant in both robust FE checks. These findings support the conclusion that the main results are not driven by the inclusion of either boundary year. The interpretation of individual coefficients therefore focuses on the preferred full-sample robust fixed-effects model.

INTERPRETATION OF KEY DETERMINANTS

The baseline fixed-effects estimates show statistically significant coefficients for both income terms, population and domestic agricultural production structure. Most previous panel studies examine total exports rather than agriculture. Their findings provide broader context for interpreting the links between development, market size, investment, productive capacity and agricultural export diversification.

The linear and squared income terms must be interpreted jointly. Their negative and positive coefficients, respectively, are consistent with an association in which agricultural export diversification initially increases with income, while this relationship weakens and may reverse at higher income levels. This pattern is related to the broader diversification literature discussed by Imbs and Wacziarg (2003) and Cadot et al. (2011). However, the coefficient signs and statistical significance alone do not establish the shape of the relationship throughout the observed income range.

One possible explanation is that rising income supports the accumulation of capabilities needed to produce and export additional agricultural products. Improvements in skills, production technology and supporting services may make previously unviable export activities feasible. At higher development levels, agricultural resources may instead become increasingly allocated to selected activities in which producers are more competitive. Such specialization could increase the export HHI even alongside improvements in productivity or product quality. These mechanisms provide possible interpretations of the nonlinear estimates, but are not separately identified by the model. A more precise confirmation of the turning point and the exact shape of this relationship would require additional tests.

Population has a negative and statistically significant coefficient. In the fixed-effects model, population growth within a country is associated with a reduction in the export HHI, conditional on the included controls. This is consistent with market-size explanations of diversification discussed by Parteka and Tamberi (2013). A larger domestic market may sustain a wider range of agricultural activities and make specialized processing, grading and storage services commercially viable. These services may also help producers supply foreign markets. However, population is only a proxy for these conditions, and the model does not separately identify changes in labor availability, domestic demand or supporting services.

The coefficient of DIV is positive and statistically significant across all specifications. The production HHI is calculated using each product's share in gross agricultural production value, measured in constant 2014–2016 international dollars. Higher values therefore indicate a less diversified domestic agricultural production structure. Since the dependent variable is also HHI-based, the positive coefficient means that a less diversified domestic production structure is associated with lower agricultural export diversification. Conversely, a broader domestic agricultural production base is associated with a more diversified agricultural export structure. This is the most sector-specific result in the model because it directly links the composition of domestic agricultural production with the composition of agricultural exports.

A broader production base may increase the range of products for which exporters can obtain a reliable domestic supply. Related agricultural activities may also share inputs, knowledge, storage facilities and processing services, potentially reducing the costs of developing additional export lines. Conversely, when production is dominated by a few products, improved foreign-market access may primarily expand those existing export lines rather than broaden the export

basket. The production structure therefore provides a possible explanation for why greater trade integration does not necessarily coincide with greater diversification.

Djokoto (2015) provides related evidence for Ghana, showing that agricultural production and export structures tend to move in the same direction after other factors are considered. Samavong et al. (2021) show that agricultural exports in Lao PDR remain highly concentrated and that limited production and processing capacity constrain diversification. Similarly, Osakwe and Kilolo (2018) identify weak domestic production structures as an important constraint on export diversification in developing countries. The association therefore points to the relevance of domestic supply conditions alongside access to foreign markets. In the baseline fixed-effects specification, a 1% reduction in the production HHI is associated with an approximately 0.58% reduction in the export HHI, holding the other regressors constant.

No statistically significant within-country association is detected between agricultural trade openness and export diversification. This holds in the full-sample fixed-effects model and both temporal robustness checks. Greater openness may facilitate access to foreign markets, but it may also reinforce specialization in existing products. Agosin et al. (2012) highlight the specialization channel, whereas Alaya (2012) finds that openness can support diversification in some country contexts.

Agricultural FDI is also statistically insignificant in these three specifications. Foreign investment may promote diversification through technology transfer, managerial knowledge, information about foreign markets and spillovers to domestic firms. Investment concentrated in established or resource-based sectors may instead reinforce existing comparative advantages (Alaya, 2012; Giri et al., 2019). Fonchamnyo and Akame (2017) and Swathi and Sridharan (2022) report a diversifying role for FDI. Elhiraika and Mbate (2014) emphasize the importance of domestic capabilities, public investment, human capital and institutions. The lack of statistical significance does not imply that all forms of foreign investment are irrelevant. Their relevance may depend on the activities receiving investment, such as agriculture, agro-processing, storage, logistics, technology or non-traditional exports. Linkages with domestic producers may also matter.

Exchange-rate volatility and the COVID-19 dummy are also statistically insignificant in the baseline model. These estimates do not establish that exchange-rate uncertainty or the pandemic were irrelevant to agricultural trade. A shock may change total export earnings without substantially changing the relative product shares captured by the HHI. Moreover, the common pandemic indicator cannot distinguish differences in the timing, severity or sectoral composition of disruptions across countries.

The inclusion of developed and developing countries also raises the possibility that these relationships differ across development levels. The quadratic income specification allows the estimated association with income to vary along the income range, but it does not establish that the two country groups follow different relationships. The model uses a common set of slope coefficients, while country fixed effects account for persistent differences in levels. In developing economies, diversification may depend more strongly on overcoming basic production and market-entry constraints. In developed economies, changes may be more closely related to processing, quality upgrading and specialization in selected competitive activities. These are possible differences rather than results established by the current estimates. Future research could examine them through interactions with development-group indicators or separate group-specific models, subject to sufficient observations and within-country variation.

CONCLUSION

This paper examined the factors associated with agricultural export diversification using pooled OLS, fixed-effects, random-effects and auxiliary two-way panel specifications, together with temporal robustness checks. The tests of individual effects and the Mundlak specification test

support the country fixed-effects estimator, while the heteroskedasticity and serial-correlation diagnostics support the use of country-clustered robust standard errors. The Pesaran CD tests do not provide evidence of residual cross-sectional dependence. Accordingly, the one-way robust fixed-effects model is used as the preferred specification, and the reported relationships are interpreted as conditional associations rather than causal effects.

The results indicate that economic development is nonlinearly associated with agricultural export diversification. The negative linear GDP per capita coefficient and the positive squared coefficient suggest that higher income is initially associated with greater agricultural export diversification, while this effect may weaken at higher income levels. This result points to a possible hump-shaped relationship between income and agricultural export diversification. However, the signs and significance of the two GDP terms should not be interpreted as definitive proof of the exact shape of this relationship. A more precise confirmation would require additional tests of the turning point and the slopes across the observed income range.

Population is positively associated with agricultural export diversification, since its negative coefficient in the HHI-based model implies lower HHI values. This suggests that market size, labor availability and production scale may support a broader agricultural export structure. The most sector-specific result is the relationship between domestic agricultural production structure and agricultural export diversification. Countries with a broader domestic agricultural production base tend to have more diversified agricultural exports, while a narrower domestic production base is associated with a less diversified export structure. These principal findings remain stable when either 2010 or 2023 is excluded from the estimation period. Agricultural trade openness, foreign direct investment in agriculture, exchange-rate volatility and the COVID-19 dummy are not statistically significant in the preferred model. The association between domestic production structure and export diversification points to the importance of supporting commercially viable additions to the agricultural production base. This need not involve promoting all products equally. Support could instead focus on activities that build on existing production capabilities and have realistic market opportunities.

Relevant measures include technical assistance for producers entering related activities, cooperation among producers to assemble reliable export volumes, and shared access to storage, grading and processing facilities. Assistance with certification and compliance with foreign-market standards may help translate a broader production base into additional export opportunities. For smaller economies, producer coordination may partly compensate for limited domestic scale. Export-diversification programs should therefore be assessed not only through growth in total export value, but also through the development and continued participation of additional product lines. These recommendations follow from the supply-side interpretation of the estimates and the literature reviewed, rather than from causal evaluations of individual policy instruments.

This study has several limitations. The set of explanatory variables is constrained by the availability of internationally comparable annual data. The model does not directly include institutional and regulatory quality, legal enforcement, human capital, agricultural research and innovation, or agriculture-specific infrastructure such as irrigation, rural roads, storage and cold-chain capacity. It also does not explicitly control for international agricultural commodity prices, agricultural terms-of-trade shocks, fertilizer and other input prices, extreme weather events or longer-term climate pressures. The static fixed-effects framework cannot fully address persistence, reverse causality or other sources of endogeneity, while the quadratic specification alone is not sufficient to establish a definitive nonlinear income-diversification pattern.

Future research should incorporate omitted institutional, regulatory, price, climate and agriculture-specific infrastructure variables, including indicators related to irrigation, rural roads, storage capacity, cold chains, research and innovation, and compliance with international quality standards. Dynamic panel estimators, including the Arellano–Bond difference GMM and system GMM approaches, could be used to examine persistence and potential endogeneity, with careful

restriction of the instrument set (Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998). The nonlinear income relationship should also be evaluated more formally. Non-parametric and semi-parametric approaches, including local-polynomial estimates, spline regressions and threshold models, could provide additional evidence on whether the nonlinear relationship between development and export diversification, already identified in the broader export diversification literature, can also be confirmed in the specific case of agricultural export diversification. Further research could also assess whether the relationships differ between developed and developing countries, rather than imposing common slope coefficients across the full sample.

REFERENCES

Agosin, M. R., Alvarez, R., & Bravo-Ortega, C. (2012). Determinants of export diversification around the world: 1962–2000. *The World Economy, 35*(3), 295–315. https://doi.org/10.1111/j.1467-9701.2011.01395.x

Alaya, M. (2012). *The determinants of MENA export diversification: An empirical analysis* (ERF Working Paper No. 709). Economic Research Forum.

Ali, R., Alwang, J., & Siegel, P. B. (1991). *Is export diversification the best way to achieve export growth and stability? A look at three African countries* (Policy Research Working Paper No. 729). World Bank.

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies, 58*(2), 277–297. https://doi.org/10.2307/2297968

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics, 68*(1), 29–51. https://doi.org/10.1016/0304-4076(94)01642-D

Baltagi, B. H., & Li, Q. (1991). A joint test for serial correlation and random individual effects. *Statistics & Probability Letters, 11*(3), 277–280. https://doi.org/10.1016/0167-7152(91)90156-L

Baltagi, B. H., & Li, Q. (1995). Testing AR (1) against MA(1) disturbances in an error component model. *Journal of Econometrics, 68*(1), 133–151. https://doi.org/10.1016/0304-4076(94)01646-H

Baltagi, B. H., Bresson, G., & Pirotte, A. (2006). Joint LM test for homoskedasticity in a one-way error component model. *Journal of Econometrics, 134*(2), 401–417. https://doi.org/10.1016/j.jeconom.2005.06.029

Baum, C. F. (2001). Residual diagnostics for cross-section time series regression models. *The Stata Journal, 1*(1), 101–104. https://doi.org/10.1177/1536867X0100100108

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel-data models. *Journal of Econometrics, 87*(1), 115–143. https://doi.org/10.1016/S0304-4076(98)00009-8

Bouberrima, C., & Mostefai, Y. (2025). Economic determinants of export diversification in Algeria: An empirical analysis through quantile regression. *Economic Analysis: Applied Research in Emerging Markets, 58*(2), 73–86. https://doi.org/10.28934/ea.2009

Cadot, O., Carrère, C., & Strauss-Kahn, V. (2011). Export diversification: What's behind the hump? *The Review of Economics and Statistics, 93*(2), 590–605. https://doi.org/10.1162/REST_a_00078

Clark, P. B., Tamirisa, N. T., Wei, S.-J., Sadikov, A. M., & Zeng, L. (2004). *A new look at exchange rate volatility and trade flows* (IMF Occasional Paper No. 235). International Monetary Fund. https://doi.org/10.5089/9781589063587.084

Dennis, A., & Shepherd, B. (2011). Trade facilitation and export diversification. *The World Economy, 34*(1), 101–122. https://doi.org/10.1111/j.1467-9701.2010.01303.x

Djokoto, J. G. (2015). *Agricultural production structure and export diversification in Ghana* [Conference paper]. Regional Conference on Market Dynamics in the Sahel and West Africa.

Drukker, D. M. (2003). Testing for serial correlation in linear panel-data models. *The Stata Journal, 3*(2), 168–177. https://doi.org/10.1177/1536867X0300300206

Elhiraika, A. B., & Mbate, M. M. (2014). Assessing the determinants of export diversification in Africa. *Applied Econometrics and International Development, 14*(1), 147–160.

Fonchamnyo, D. C., & Akame, A. R. (2017). Determinants of export diversification in Sub-Sahara African region: A fractionalized logit estimation model. *Journal of Economics and Finance, 41*(2), 330–342. https://doi.org/10.1007/s12197-016-9352-z

Food and Agriculture Organization of the United Nations. (2020). *COVID-19 and the risk to food supply chains: How to respond?* https://doi.org/10.4060/ca8388en

Food and Agriculture Organization of the United Nations. (n.d.a). *FAOSTAT: Crops and livestock products* [Data set]. Retrieved May 8, 2026, from https://www.fao.org/faostat/en/#data/QCL

Food and Agriculture Organization of the United Nations. (n.d.b). *FAOSTAT: Trade: Crops and livestock products* [Data set]. Retrieved May 8, 2026, from https://www.fao.org/faostat/en/#data/TCL

Food and Agriculture Organization of the United Nations. (n.d.c). *FAOSTAT: Macro Indicators* [Data set]. Retrieved May 8, 2026, from https://www.fao.org/faostat/en/#data/MK

Food and Agriculture Organization of the United Nations. (n.d.d). FAOSTAT: Value of Agricultural Production [Data set]. Retrieved May 8, 2026, from https://www.fao.org/faostat/en/#data/QV

Food and Agriculture Organization of the United Nations. (n.d.e). *FAOSTAT: Foreign Direct Investment (FDI)* [Data set]. Retrieved May 8, 2026, from https://www.fao.org/faostat/en/#data/FDI

Giri, R., Quayyum, S. N., & Yin, R. (2019). *Understanding export diversification: Key drivers and policy implications* (IMF Working Paper No. 19/105). International Monetary Fund. https://doi.org/10.5089/9781498313087.001

Hadjira, A., & Zakane, A. (2021). Determinants of export diversification: An empirical study, the case of developing and emerging countries during the period 1996–2017. *Revue d'Economie et de Statistique Appliquée, 18*(1), 7–15.

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica, 46*(6), 1251–1271. https://doi.org/10.2307/1913827

Hausmann, R., & Hidalgo, C. A. (2011). The network structure of economic output. *Journal of Economic Growth, 16*(4), 309–342. https://doi.org/10.1007/s10887-011-9071-4

Hesse, H. (2008). *Export diversification and economic growth* (Commission on Growth and Development Working Paper No. 21). World Bank. https://hdl.handle.net/10986/28040

Hidalgo, C. A., Klinger, B., Barabási, A.-L., & Hausmann, R. (2007). The product space conditions the development of nations. *Science, 317*(5837), 482–487. https://doi.org/10.1126/science.1144581

Hu, L., Tian, K., Wang, X., & Zhang, J. (2012). The "S" curve relationship between export diversity and economic size of countries. *Physica A: Statistical Mechanics and Its Applications, 391*(3), 731–739. https://doi.org/10.1016/j.physa.2011.08.048

Imbs, J., & Wacziarg, R. (2003). Stages of diversification. *American Economic Review, 93*(1), 63–86. https://doi.org/10.1257/000282803321455160

International Monetary Fund. (2025). *World Economic Outlook database, April 2025: Groups and aggregates information* [Data set]. https://www.imf.org/en/publications/weo/weo-database/2025/april/groups-and-aggregates

International Monetary Fund. (n.d.). *Exchange Rate (ER)* [Data set]. IMF Data. Retrieved May 8, 2026, from https://data.imf.org/

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). *An introduction to statistical learning: With applications in R*. Springer. https://doi.org/10.1007/978-1-4614-7138-7

Jeng, C.-C. (2023). Why a variance inflation factor of 10 is not an ideal cutoff for multicollinearity diagnostics. *Journal of Educational Research, 57*(2), 67–92. https://doi.org/10.53106/199044282023105702004

Massell, B. F. (1964). Export concentration and fluctuations in export earnings: A cross-section analysis. *The American Economic Review, 54*(2), 47–63.

Mundlak, Y. (1978). On the pooling of time series and cross section data. *Econometrica, 46*(1), 69–85. https://doi.org/10.2307/1913646

Osakwe, P. N., & Kilolo, J. M. (2018). *What drives export diversification? New evidence from a panel of developing countries* (UNCTAD Research Paper No. 3). United Nations Conference on Trade and Development. https://unctad.org/publication/what-drives-export-diversification-new-evidence-panel-developing-countries

Paraušić, V., Kljajić, N., & Domazet, I. (2024). Farming standards as a catalyst of green agriculture and food export: Middle income European countries case study. *Economic Analysis: Applied Research in Emerging Markets, 57*(3), 52–69. https://doi.org/10.28934/ea.24.57.3.pp52-69

Parteka, A., & Tamberi, M. (2013). What determines export diversification in the development process? Empirical assessment. *The World Economy, 36*(6), 807–826. https://doi.org/10.1111/twec.12064

Pesaran, M. H. (2004). *General diagnostic tests for cross section dependence in panels* (Cambridge Working Papers in Economics No. 0435). University of Cambridge. https://doi.org/10.2139/ssrn.572504

Prebisch, R. (1950). *The economic development of Latin America and its principal problems* (E/CN.12/89/Rev.1). United Nations.

Ramsey, J. B. (1969). Tests for specification errors in classical linear least-squares regression analysis. *Journal of the Royal Statistical Society: Series B (Methodological), 31*(2), 350–371. https://doi.org/10.1111/j.2517-6161.1969.tb00796.x

Samavong, C., Songvilay, L., Soutthanilaxay, V., & Phommavong, C. (2021). *Agricultural export diversification in Lao PDR* (MRI Working Paper Series No. 007/Oct 2021). Macroeconomic Research Institute.

Swathi, M., & Sridharan, P. (2022). Determinants of export diversification: Evidence from fractional logit estimation model. *Foreign Trade Review, 57*(2), 160–177. https://doi.org/10.1177/00157325211072922

Taylor, T. G., & Francis, B. (2003). Agricultural export diversification in Latin America and the Caribbean. *Journal of Agricultural and Applied Economics, 35*(Supplement), 1–11. https://doi.org/10.22004/ag.econ.43284

Tenreyro, S. (2007). On the trade impact of nominal exchange rate volatility. *Journal of Development Economics, 82*(2), 485–508. https://doi.org/10.1016/j.jdeveco.2006.03.007

Tomić, M., & Stevandić, S. (2024). Export diversification in OPEC countries: A panel data approach. *KNOWLEDGE - International Journal, 65*(1), 57–63. https://ojs.ikm.mk/index.php/kij/article/view/6974

Tomić, M., Stevandić, S., & Antonijević, M. (2026). Indicators of export diversification and their role in international trade. *Ekonomske ideje i praksa*, (62), 79–102. https://doi.org/10.54318/eip.2026.mt.421

United Nations Conference on Trade and Development. (2018). *Export diversification and employment* (UNCTAD/ALDC/2018/3). United Nations.

Verschuur, J., Koks, E. E., & Hall, J. W. (2021). Observed impacts of the COVID-19 pandemic on global trade. *Nature Human Behaviour, 5*(3), 305–307. https://doi.org/10.1038/s41562-021-01060-5

Vogel, T. (2025). Combining the pieces: Identifying key determinants of export diversification in Africa amidst model uncertainty. *Review of World Economics, 161*(1), 257–307. https://doi.org/10.1007/s10290-024-00568-y

Vukmirović, V., & Nedeljković, B. (2023). How has COVID-19 affected labor income in Serbia? An exploration of gender, education, the possibility to work from home, and the employment sector differences. *Economic Analysis: Applied Research in Emerging Markets, 56*(2), 54–67. https://doi.org/10.28934/ea.23.56.2.pp54-67

Wang, C. (2024). *Trade barrier effect on European Union member states export diversification from 1995 to 2022* [Master's thesis, Utrecht University]. Utrecht University Student Theses Repository. https://studenttheses.uu.nl/handle/20.500.12932/47534

Wang, Z., & Liu, H. (2023). Can export market diversification mitigate agricultural export volatility? A trade network perspective. *Emerging Markets Finance and Trade, 59*(7), 2234–2251. https://doi.org/10.1080/1540496X.2023.2171725

Weber, R., Bubbico, A., & Morales Opazo, C. (2022). *Diversification perspectives of Guyana's agrifood sector* (FAO Agricultural Development Economics Working Paper No. 22-07). Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cc1330en

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica, 48*(4), 817–838. https://doi.org/10.2307/1912934

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data* (2nd ed.). MIT Press.

World Bank. (2020). *Benin: Agricultural competitiveness and export diversification project* (Project Appraisal Document, Report No. PAD3329). World Bank.

World Bank. (n.d.a). *GDP per capita (constant 2015 US$)* [Data set]. World Development Indicators. Retrieved May 8, 2026, from https://data.worldbank.org/indicator/NY.GDP.PCAP.KD

World Bank. (n.d.b). *Population, total* [Data set]. World Development Indicators. Retrieved May 8, 2026, from https://data.worldbank.org/indicator/SP.POP.TOTL

Article history:	Received: 2.7.2026
	Revised: 15.10.2026
	Accepted: 29.10.2026

APPENDIX

Appendix Table A1. Alternative panel specifications and diagnostic tests for agricultural export diversification

	Pooled OLS-TE	**FE**	**TWFE**	**TWFE clustered SE**	**RE**	**TWRE**
GDP	**-.365*** (.019)**	**-.464*** (.096)**	**-.565*** (.147)**	**-.565** (.272)**	**-.463*** (.039)**	**-.425*** (.042)**
GDP^2	**-.055*** (.014)**	**.216*** (.046)**	**.185*** (.050)**	**.185** (.092)**	**.091*** (.026)**	**.080*** (.026)**
AGOPEN	**-.539*** (.056)**	-.099 (.067)	**-.187** (.075)**	-.187 (.149)	**-.210*** (.063)**	**-.252*** (.068)**
POP	**-.108*** (.017)**	**-.735*** (.199)**	**-.915*** (.249)**	**-.915** (.352)**	**-.089** (.037)**	**-.080** (.038)**
DIV	**.633*** (.040)**	**.581*** (.077)**	**.606*** (.077)**	**.606*** (.125)**	**.549*** (.064)**	**.565*** (.064)**
FDI	-.011 (.010)	.002 (.006)	.0009 (.006)	.0009 (.008)	.003 (.006)	.002 (.006)
VOL	.014 (.019)	.018 (.011)	**.020* (.011)**	.020 (.016)	**.026** (.011)**	**.0276** (.011)**
COVID		.025 (.029)			-.011 (.029)	
Constant	**1.046*** (.286)**	**11.100*** (3.395)**	**14.154*** (4.225)**	**14.154** (5.898)**	.365 (.626)	.273 (.637)
Observations	699	699	699	699	699	699
Number of groups	86	86	86	86	86	86
Individual effects		F (85, 605) = 45.27 p < 0.001	F (85, 593) = 45.91 p < 0.001	F (85, 593) = 45.91 p < 0.001	$chibar^2(01)$ = 2015.77 p < 0.001	$chibar^2(01)$ = 2037.19 p < 0.001
Time effects	F (13, 678) = 0.91 p = 0.537		F (13, 593) = 2.09 p = 0.013	F (13, 85) = 1.59 p = 0.103		$\chi^2(13)$ = 32.87 p = 0.002
Model significance	F (20, 678) = 34.69 p < 0.001	F (8,605) = 30.22 p < 0.001	F (20,593) = 13.69 p < 0.001	F (20,85) = 7.31 p < 0.001	Wald $\chi^2(8)$ = 268.39 p < 0.001	Wald $\chi^2(20)$ = 308.45 p < 0.001
White's test	$\chi^2(138)$ = 205.58 p < 0.001					
Modified Wald test		$\chi^2(86)$ = 4.6×10^6 p < 0.001	$\chi^2(86)$ = 39540.10 p < 0.001	$\chi^2(86)$ = 39540.10 p < 0.001		
LM heteroskedasticity test					$\chi^2(13)$ = 198.651 p < 0.001	$\chi^2(27)$ = 191.358 p < 0.001
Wooldridge test		F (1, 71) = 32.017 p < 0.001	F (1, 71) = 35.250 p < 0.001	F (1, 71) = 35.250 p < 0.001		
ALM autocorrelation test					$\chi^2(1)$ = 8.33 p = 0.004	$\chi^2(1)$ = 9.01 p = 0.003
Ramsey RESET test	F (3, 675) = 47.52 p < 0.001					
Pesaran CD test		CD = 1.01 p = 0.314	CD = -0.21 p = 0.836	CD = -0.21 p = 0.836	CD = 1.36 p = 0.174	CD = 0.01 p = 0.990
Mean VIF	1.55	1.30	1.55	1.55	1.30	1.55
R-squared	$R^2 = 0.505$ $R^2_{adj} = 0.491$	$R^2_w = 0.285$ $R^2_b = 0.141$ $R^2_o = 0.174$	$R^2_w = 0.315$ $R^2_b = 0.150$ $R^2_o = 0.174$	$R^2_w = 0.315$ $R^2_b = 0.150$ $R^2_o = 0.174$	$R^2_w = 0.252$ $R^2_b = 0.463$ $R^2_o = 0.414$	$R^2_w = 0.282$ $R^2_b = 0.472$ $R^2_o = 0.428$

Source: Author's calculations.

*Note: Values in parentheses are standard errors. ***, ** and * indicate coefficients statistically significant at the 1%, 5% and 10% levels, respectively.*

Appendix Table A2. Countries included in the preferred fixed-effects model

Developed countries				
Australia	Austria	Belgium	Croatia	Czechia
Estonia	France	Germany	Greece	Iceland
Israel	Italy	Japan	Latvia	Lithuania
New Zealand	Norway	Portugal	Republic of Korea	Slovakia
Slovenia	Spain	Sweden	United Kingdom of Great Britain and Northern Ireland	
Developing countries				
Albania	Algeria	Argentina	Armenia	Bangladesh
Bhutan	Bolivia (Plurinational State of)	Bosnia and Herzegovina	Brazil	Bulgaria
Cambodia	Chile	China, mainland	Colombia	Costa Rica
Côte d'Ivoire	Egypt	Georgia	Ghana	Guatemala
Honduras	Hungary	Indonesia	Iran (Islamic Republic of)	Kazakhstan
Kenya	Kyrgyzstan	Lao People's Democratic Republic	Madagascar	Malawi
Malaysia	Mauritius	Mexico	Mongolia	Morocco
Mozambique	Myanmar	Nepal	Nicaragua	Nigeria
North Macedonia	Pakistan	Paraguay	Peru	Philippines
Poland	Romania	Russian Federation	Rwanda	Serbia
Tajikistan	Thailand	Tunisia	Türkiye	Uganda
Ukraine	United Republic of Tanzania	Uruguay	Uzbekistan	Vanuatu
Viet Nam	Zambia			

Source: Author's calculations based on the preferred model estimation sample and IMF World Economic Outlook country grouping.