



Agricultural export promotion through diversification of export basket: Evidence from panel data regression

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Abstract

The study aimed to determine the level of export diversification and its effect on agricultural exports across 57 countries over 11 years between 1996 and 2022. The study used data from World Bank and FAOSTAT. The study used panel data regression, Pearson correlation and tabulation of data to derive inferences. The study used Herfindahl-Hirschman Index as measure of concentration of export basket. Developed countries had diversified export basket. The effect of export concentration to agricultural export were significant with inverse-U shaped relationship. The optimum level of diversification was at export concentration index value of 0.513, which suggested that neither extreme concentration nor extreme diversification was desirable. The inverse-U relationship was also observed with per-capita income which suggested that too low or high per capita income can reduce the exportable surplus. The robustness of results was assessed by using lagged value of concentration index and using only subset of the panel data. The results were weakly robust thus limiting the uniform applicability of results across time and space. Based on the findings, it was suggested to have a balance between diversification and concentration while formulating export policies.

Keywords: agricultural exports; diversification, international trade, optimization

Abbreviations: CV, coefficient of variation; FAOSTAT, Food and Agriculture Organization Corporate Statistical Database; GDP, gross domestic product; H index, Herfindahl-Hirschman index; LCU, local currency unit; OLS, ordinary least squares; PCI, per-capita income; SD, standard deviation; USD, United States dollar; WTO, World Trade Organization

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1. Introduction

Agricultural exports are an important part of Global trade with nearly eight percentage of total exports in the World in the 2023-24, encompassing a vast array of products ranging from grains and fruits to meats and dairy. The Global agricultural exports were approximately valued at 1906 billion USD in 2023 with 39.6 percent growth compared to 1365 billion USD in 2013 highlighting the scope of agricultural exports (1). These exports play a pivotal role in shaping national economies in significant ways, such as economic growth, enhancing food security, stabilising foreign exchange earnings, generating employment, catalysing rural development, encouraging technology and innovation etc.

Cultivation of agricultural crops is linked to specific climatic conditions thereby ensuring that certain regions would specialize in the production and trade of the output of these crops. The concentration of few commodities in the export basket creates fluctuations in export revenue,

domestic price instability (2) and economic development (3). Further economic situation of farmers growing tradable agricultural commodities is at mercy of international commodity prices and trade measures. Also, export concentration resulted in inequitable distribution of trade benefits. While dominant exporters gained significant advantages, others often struggled to compete. Also, a concentrated export widened income disparities and limits opportunities for inclusive growth (4).

Another challenge lies in changing consumer preferences, which can rapidly shift demand patterns in global markets. Exporters with concentrated portfolios may struggle to adapt to these changes, resulting in loss of competitiveness and market share. For example, Sri Lanka heavily relied on bulk tea export. But the global market has shifted towards value-added tea products like tea bags, instant tea, and organic tea, moving away from bulk tea, resulting in loss of market share of Sri Lanka (5).

On the other hand, export diversification was associated buffer against external economic shocks (6), market volatil-

ity (7), job losses and poverty (8), lack of competitiveness of a sector and weakening competitive position of exporters and overall industrial decline (9). Also, diversification enabled countries to adapt to changing consumer preferences, ensuring that export portfolios remain aligned with global demand trends. Overall, export diversification was found to be a strategic pathway toward resilience, growth, and inclusive development, positioning countries to thrive in an increasingly interconnected global economy.

Apart from empirical findings, various economic thoughts and theories on exports existed. The Heckscher-Ohlin trade theory explained differences in production and export with the help of factor intensities and factor endowment (10-12). Thus, in respect of agriculture, climate, weather, and soil type were factor endowments which helps explain why certain nations can grow wide range of crops each year and in different season while others cannot. Also, factor intensities also decided the level of such production and consequent trade thereby explaining the export diversification. Thus, according to this theory, a country with diverse soil and climatic conditions and varying factor intensities can have diversified export basket of agricultural commodities.

In contrast, Ricardian theory of comparative advantage focused on export specialization, therefore, was not able to explain export diversification. Paul Krugman in his New Trade Theory introduced idea of product differentiation (13). The product differentiation helped explain why India being large tea producer simultaneously exports and imports different variety of tea to and from the World market. Thus, New Trade Theory explained enhanced possibilities for diversified trade basket. The product life cycle theory explained that a product coming out of innovation contribute to export diversification when it reaches maturity stage (10, 14).

Although a substantial amount of research had been done in last four decades on export diversification on aggregate exports from economy but literature on agricultural export diversification was neither substantial nor it could address the question of optimum export diversification. The country specific research had shed light on various aspects of the agricultural export diversification, but question regarding effect of it on agricultural export was not examined on Global scale. The cross-country examination could have provided robust results across different income groups and geographies. Therefore, this research approached to study agricultural export diversification and its effect on agricultural export on a global level by taking a sample of countries which aptly represented the World. The research questions which the study aimed to answer are as following:

1. Whether agricultural export diversification across the World was rising over the years?
2. Whether increasing agricultural export diversification had effect of increasing export revenue?
3. What is the optimum level of export diversification for agricultural commodities across the World?

Rest of the paper is organized with chapters on methodology which covers variables & data, sample countries, and analytical procedure followed by results and discussion and at the last conclusion.

2. Materials and Methods

The research focused on 57 countries across different continents, capturing global agricultural export trends over an 11-year period. Initially data were downloaded from FAO-STAT and World Bank for all countries. After merging data on different variables, countries were trimmed where missing observations were found on one or more variable and also ones which had negligible traded quantity over the years as these could later on become outliers. Time periods for which data were not available were also dropped. At the time of downloading data in 2024, data were available only till 2022. Sensitive years were excluded from data such as 2010, 2014, and 2020. The year 2010 witnessed major changes in global trade due to 2008 economic meltdown in US and 2014 witnessed sharp correction in global agricultural pace. The year 2020 marked the COVID-19 crisis which crippled the normal life as well as global trade. The years included in the study were 1996, 1998, 2000, 2002, 2005, 2006, 2008, 2012, 2016, 2018, and 2022. Focus was given around the year 2005, as it was the time by which most countries around the World had to abide by the norms set out in Uruguay round of conferences of the World Trade Organisation (WTO). By selecting this timeframe, the study ensures a comprehensive analysis of agricultural export dynamics and their variations over time. These specific years reflect diverse phases in global trade, coinciding with major economic events and policy shifts. The resulting data was balanced panel data wherein observations were available on all countries for all years. Finally, 57 countries were chosen from 198 countries. The list of these countries along with ISO codes were provided in Table 1.

The sample of countries that has been selected in the study provided a proper representation of the world as they have significant global share in the economic variables [Table 2].

The variables and its description and data sources are provided in Table 3. Frequency of all observation was annual.

The degree of agricultural export concentration was quantified using the Herfindahl-Hirschman Index (H Index). This index was calculated as the sum of squares of shares of individual commodity (calculated from trade matrix) in the total agricultural exports of a nation (15). The H Index ranges from zero to one, with low values indicating a more diversified export portfolio. A value close to zero reflects balanced sectoral contributions, while values near one indicate high export concentration dominated by a single commodity or item.

Table 1: ISO Codes of the 57 countries of involved in the study

Country	ISO Code	Country	ISO Code	Country	ISO Code	Country	ISO Code
Argentina	ARG	Algeria	DZA	Jordan	JOR	Philippines	PHL
Australia	AUS	Ecuador	ECU	Japan	JPN	Portugal	PRT
Austria	AUT	Spain	ESP	South Korea	KOR	Paraguay	PRY
Bolivia	BOL	Finland	FIN	Morocco	MAR	Romania	ROU
Brazil	BRA	France	FRA	Moldova	MDA	Singapore	SGP
Canada	CAN	United Kingdom	GBR	Madagascar	MDG	Slovenia	SVN
Switzerland	CHE	Greece	GRC	Mauritius	MUS	Sweden	SWE
China	CHN	Hong Kong	HKG	Malaysia	MYS	Thailand	THA
Cameroon	CMR	Honduras	HND	Nicaragua	NIC	Turkey	TUR
Colombia	COL	Hungary	HUN	Netherlands	NLD	Uruguay	URY
Costa Rica	CRI	Indonesia	IDN	Norway	NOR	United States	USA
Cyprus	CYP	India	IND	New Zealand	NZL	South Africa	ZAF
Czech Republic	CZE	Ireland	IRL	Pakistan	PAK		
Germany	DEU	Iceland	ISL	Panama	PAN		
Denmark	DNK	Italy	ITA	Peru	PER		

Table 2: Global Share of Selected Countries in Important Economic Variables (2022)

Variables	Global Share (%)
Global Agricultural Exports	80.18
Global Agricultural GDP	76.84
Global Gross Agricultural Production Value	82.12
Global Population	66.79

Table 3: Description of variables and Sources of data

Name of the Variable	Unit	Description	Source
Agricultural Export	1000 US Dollar	Value of exports from agricultural sector including livestock (current prices)	FAOSTAT (2024)
Real Agricultural GDP	Million US Dollar	Value Added (Agriculture, Forestry and Fishing), constant 2015 prices	FAOSTAT (2024)
Trade Matrix	1000 US Dollar	Item wise export value from reporting country to the whole World (Four-digit HS code) (current prices)	FAOSTAT (2024)
Real Per Capita Income	US Dollar	GDP per capita (constant 2015 prices)	World Bank (2025)
Exchange Rate		Standard local currency units per US Dollar (current prices)	FAOSTAT (2024)

The H Index is given by the formula

$$H_t^r = \sum_{i=1}^N (S_{it}^r)^2 = \sum_{i=1}^N \left(\frac{V_{it}^r}{\sum_{i=1}^N V_{it}^r} \right)^2 \quad (1)$$

V_{it}^r is the value of the i^{th} commodity export in the total export basket of the r^{th} country for the t^{th} year. N is the total number of agricultural commodities exported. Among the literatures reviewed, several research studies used Herfindahl Hirschman index as a measure of export diversification (17-22).

Data were analysed using descriptive statistics, correlation among variables, line charts and regression analysis. The panel data regression model was employed to examine the determinants of agricultural export performance. As considerable heterogeneity was found for the variables, use of logarithm was more suitable. The dependent variable was agricultural export value (Y), while independent vari-

ables included were agricultural export concentration index (X1: H Index), agricultural GDP (X2), Per-capita income (X3) and exchange rate (X4). Following panel data regression equation was used in the study

$$\log Y_{it} = \alpha_0 + \alpha_1 X_{1it} + \alpha_2 X_{1it}^2 + \alpha_3 \log X_{2it} + \alpha_4 \log X_{3it} + \alpha_5 (\log X_{3it})^2 + \alpha_6 \log X_{4it} + u_{it} \quad (2)$$

wherein the dependent variable and explanatory variables except for H Index were all in log form. Along with it, other research studies (17) also chosen to use a non-linear equation, where both H index and its squared term are included in the model as independent variables. The sign of coefficient of H index when used without its squared term is theoretically expected to be negative. The sign of coefficient of H index when used with its squared term is expected to be positive and sign of coefficient of its squared term negative.

The purpose of including the exchange rate was to account for the fact that depreciation or devaluation of currency aids in export of the commodity. Thus, theoretically the expected sign of its coefficient was positive. The per-

capita income and its square were added to the model to account for the fact that increasing in per-capita income is linked with greater purchasing power which can lead to greater demand for the agricultural produce in domestic market leaving little exportable surplus in the country for international market. The purpose of including agricultural GDP was to account for the country's capacity for value addition in the agricultural sector. Higher the value-addition better are export opportunities. Thus, sign of its coefficient was expected to be positive.

The regressions, was performed on complete dataset and also by creating subset from the dataset, one with years 1996, 2006 and 2016, second with 1998, 2008 and 2018 and third with 1996, 1998, 2000, 2002. This also allows to check robustness of the results on equally spaced interval data and also on different time scales. Although, the problem with unequally spaced interval data is limited to dynamic panel data while the current specification is not dynamic one. Still robustness check allows for detecting "whether the given phenomenon is true in sub-periods".

A key limitation of the above specification can be from reverse causality or endogeneity. Since H index is constructed from the shares of commodities in total value of agricultural export which is dependent variable, it is possible that increase in total value of agricultural export can alter or influence the shares of the commodities in the export basket. Thus, introducing the reverse causality in the regression leading to biased and inconsistent regression estimates. This can also render the relationship between agricultural export value and H index a mechanical one. Thus, to overcome the endogeneity, an alternative is to replace the key independent variable by its lagged value which are not affected by the current year agricultural export performance. Accordingly, in subset regressions, lagged H index was used.

Four regression models were implemented:

Pooled Model: This model combined all observations without any transformation and estimated parameters using Ordinary Least Squares (OLS). It assumes that there is only single intercept for all countries and times. It assumes that there are no unobserved effects associated with country and year affecting the dependent variable which is principal focus of the panel data regression.

Fixed Effect Within Model: This model was estimated by using OLS on time-demeaned data wherein data is transformed by subtracting the mean of each variable for each country from its respective observations. This transformation removed the influence of time-invariant factors, resulting in a model that focused solely on within-country variations. This regression is suitable when there are large number of countries and small number of time periods available for estimation which is a case with current study. The absence of an intercept in the within model ensured that the estimation reflected relative changes rather than absolute levels. Subject and time fixed effects are said to be correcting for omitted variables in the regression equation which account for fixed factors like factor endowments important

in Heckscher-Ohlin trade theory (11). On a theoretical basis, fixed effects are better than random effect suited when subject fixed effects associated with the country characteristics are correlated with regressors.

Fixed Effect First Difference Model: When there is presence of autocorrelation in the residual of panel data regression, usually first difference removes the presence of such autocorrelation of first order. This model is used only when there are no time-invariant regressors. This model runs OLS regression by taking first difference on all variables in the model. Use of this model reduces the number of observations available for estimation. Its use is avoided when the distance between periods is not uniform. In this study, it is used only with subset regression.

Random Effect Model: It is a mixture of pooled and fixed effect model. Therefore, it is also called as "partial pooled model". While fixed effect model assumes presence of correlation between unobserved effects and regressors but random effect model assumes presence of no such correlation.

The R software version 4.2.2 (23) was used for panel data regression using "plm" package version 2.6-4 (24-25). The function plm was used to estimate the panel data regression equation. The correlation analysis was performed with the help of sjPlot package using tab_corr function.

2.1 Optimum amount of Export Diversification

The optimum amount of export diversification was worked out by taking partial derivative of the estimated regression equation and setting it equal to zero.

$$\frac{\partial \log Y_{it}}{\partial X_{1it}} = a + 2bX_{1it} = 0 \quad (3)$$

The resulting equation was solved for X_1 and it yielded the following.

$$X_{1it} = -\frac{a}{2b} \quad (4)$$

Thus, if the estimated equation has $a > 0$ and $b < 0$ then the optimum amount of X_1 would be positive. The approach used here was also used by (26). The satisfaction of second order conditions for a maximum was ensured by $b < 0$ and $a > 0$.

2.2 Model Diagnostic Tests

Various statistical tests were carried out ensure that the model specification used for the analysis are accurate, reliable, and robust. Angrist and Newey's test was used to detect misspecification in fixed effects panel data models by examining whether there are remaining systematic patterns in the residuals after the within transformation. It has null hypothesis that the within-transformed model is correctly specified. To perform this test, aneweytest function in plm package was used. Breusch-Godfrey/Wooldridge

Test was used for detecting serial correlation in panel data models that extends the traditional Breusch-Godfrey test to panel data context. The Breusch-Godfrey test was also used for this purpose by study (27). It has null hypothesis that no serial correlation up to order p (degrees of freedom) in error term. To perform this test, `pbgttest` function in `plm` package was used. Pesaran CD Test was used for detecting cross-sectional dependence in panel data that examines the correlation of residuals across different cross-sectional units. This was also used by a study (28) to detect the cross-sectional dependence. It has null hypothesis that no cross-sectional dependence (correlation between cross-sectional units is zero). To perform this test `pcdtest` function in `plm` package was used. To select between random and fixed effect, Hausman test, also referred to as Durbin-Wu-Hausman test, was conducted. The null hypothesis of this test is that random effect model is appropriate versus an alternative hypothesis that fixed effect model is appropriate. To perform this test `phtest` function in `plm` package was used. To detect the heteroscedasticity in residuals, Breusch-Pagan test performed using `bptest` function from `lmtest` package. To decide whether two-way effects are applicable, Lagrange multiplier test (given by Gourieroux, Holly and Monfort) was used with null hypothesis that there are no significant two-way effects. This test was performed using `plmtest` function in `plm` package. For all tests, if p -value of test statistic was less than five percent level of significance then null hypothesis was rejected.

3. Results and Discussion

3.1 Descriptive Statistics

The table 4 presented descriptive statistics for various economic indicators involved in the study. The data indicated significant variability in these measures, reflecting substantial economic differences across the selected countries.

Agricultural GDP showed a wide range, from 81.25 million USD to 1,278,267 million USD, with an average of 35,040 million USD. The median GDP of 6,781 million USD was much lower than the mean, indicating a positively skewed distribution, where a few countries have very high GDP levels. The H Index, which measures product export concentration, had an average value of 0.117 with the minimum value of 0.020 and the maximum value of 0.808. The CV of 95.34 percent indicated moderate variability in the level of concentration. In the sample, 50 percent of the nations were below H index value of 0.08 indicating that half of countries in the sample had very high level of diversification. Only 25 percent of the countries falling between the third quartile and maximum value were having low to extremely low levels of diversification.

In the dataset, the nations which exhibited the least values of export concentration over the years were Hungary, Germany, China and Spain. As these countries were highly industrialiser; that most of the industrialized economies

tended to diversify their export basket. A study (17) observed that comparatively low levels of export concentration were associated with several of the rapidly growing nations from the East Asia, including China, Malaysia, Thailand, Taiwan (China), and the Korea. The Mauritius, Algeria, Madagascar and Cyprus were the nations with high H index values during the study period.

Exchange rates had extreme variability. The average country in the dataset had extremely depreciated currency as indicated by exchange rate of 394 LCU per USD. The highly depreciated currency levels indicate that these countries were having good reason to export products than use it in the domestic market.

For per capita income, the minimum value of 415 USD and the first quartile value 4,197 meant that bottom 25 percent of the sample nations were low income or lower middle-income countries according to World Bank's classification of 2015. The median value of 12,312 USD indicated the country which was at the centre belonged to upper middle-income countries. The third quartile and maximum value of per capita income were 36,399 USD and 97,317 USD respectively. From perusal of the data, it can be understood that half of the countries selected were high income countries which was also indicated by the average value of 21442 USD.

Agricultural exports exhibited notable variability, with a mean value of 13,325 thousand USD and a maximum of 193,638 thousand USD. The standard deviation of 22,580 thousand USD and a CV of 169.46 percent indicated significant variations across the countries. The minimum value of 4.12 thousand USD and the first quartile value of 1229 thousand USD showed that bottom 25 percent of the countries on this variable were low agricultural exporters.

Figure 1 provided the H index and agricultural export over the years. The agricultural exports were rising over the years while H index was declining except for the rise in H index values in some years. The mean H index value on the graph was between 2002 and 2005.

3.2 Correlation matrix of the variables

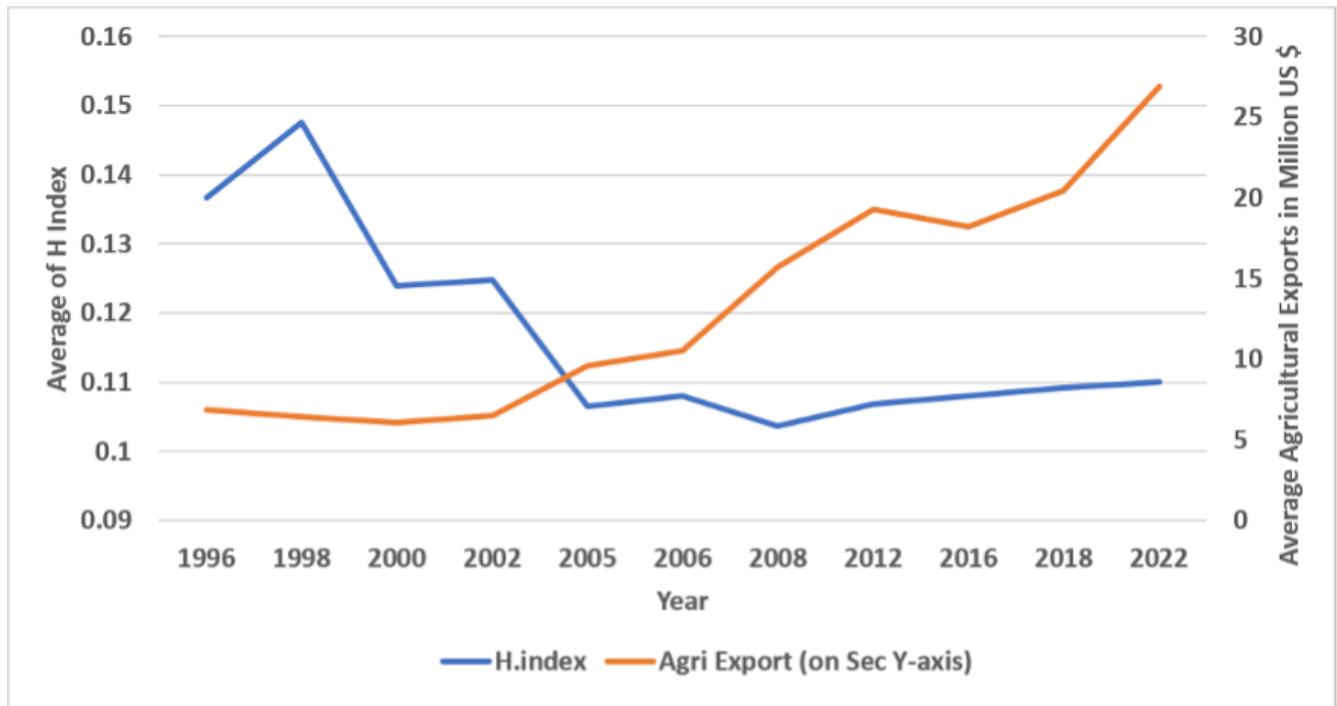
The agricultural GDP was negatively correlated with the H-index suggesting that higher agricultural GDP was associated with more diversified agricultural exports [Table 5]. Additionally, Agricultural GDP showed a significant positive correlation with agricultural export, indicating that the countries with higher agricultural GDP were associated with higher agricultural export values.

The H-index was negatively correlated with agricultural GDP, per capita income and agricultural export. It implies that countries with more diversified agricultural exports were associated with higher agricultural GDP, higher per capita income, and higher agricultural export values. This negative correlation between agricultural exports and H index can be clearly visualised in Figure 1.

Exchange rate had no significant correlations with the other indicators, indicating no linear association with agricultural GDP, or agricultural export in the sample countries.

Table 4: Summary Statistics of the Variables

	Real Agri GDP (Million USD)	H index	Exchange Rate (LCU/US \$)	Real Per Capita Income (US \$)	Agri Export (Thousand USD)
Minimum	81.25	0.020	0.08	415	4.12
1st Quartile	2683	0.046	1.00	4197	1229
Median	6781	0.080	5.80	12313	4346
Mean	35040	0.117	393.81	21442	13325
3rd Quartile	26121	0.146	40.17	36399	14425
Maximum	1278267	0.808	14850	97317	193638
SD	111 411	0.112	1576	20541	22598
CV (%)	317.95	95.54	400.18	95.80	169.59

**Figure 1:** Agricultural export and export concentration index over the year for sample countries. *Note: Based on mean values calculated from 627 observations (57 countries and 11 years).***Table 5:** Correlation matrix of the variables in the study

	Agricultural GDP	H index	Exchange Rate	Per capita income	Agricultural Export
Agri.GDP		-0.137*** (0.001)	0.033 (0.403)	-0.114*** (0.004)	0.304*** (<.001)
H index	-0.137*** (0.001)		0.188*** (<.001)	-0.352*** (<.001)	-0.250*** (<.001)
Exchange Rate	0.033 (0.403)	0.188*** (<.001)		-0.200*** (<.001)	0.001 (0.976)
Per capita income	-0.114*** (.004)	-0.352*** (<.001)	-0.200*** (<.001)		0.282*** (<.001)
Agri Export	0.304*** (<.001)	-0.250*** (<.001)	0.001 (0.976)	0.282*** (<.001)	

Note: Correlation coefficient based on raw data calculated from 627 observations (57 countries and 11 years), Figures in parentheses are p values of t test statistic.

Significance Code: *** p < 0.001, ** p < 0.01, * p < 0.05

Note: Based on raw data calculated from 627 observations (57 countries and 11 years)

Per-capita income was negatively correlated with the H-index, suggesting that high per capita income was associated with more diversified agricultural exports. It was also positively correlated with agricultural export, indicating that countries with high per-capita income also have high agricultural export values. A study (17) also found a negative correlation between GDP per capita and H index with

correlation coefficient of – 0.51.

3.3 Effect of export diversification on agricultural export

The Table 6 presents the results of regression analysis for determinants of agricultural exports. To decide the

suitability of model and standard tests were conducted results of which are reported in Table 7. Fixed effect within model was found to be suitable model based on Angrist and Newey's test and Hausman test. Heteroscedasticity consistent cluster-robust standard errors, clustered at the country level were used due to presence of serial correlation, cross-sectional dependence and heteroscedasticity in error terms.

Among all the regressors included in the model, H index and its squared terms were the principal focus of the study. The H index had negative and statistically significant coefficient in pooled model which can be interpreted as negative effect of higher H index values on agricultural exports. However, the coefficient of squared H Index was not statistically significant. Thus, product specialization was found to be hurting the agricultural exports.

In the within model, the coefficient of H Index coefficient was positive, while the coefficient of its squared term was negative. Both coefficients were statistically significantly different from zero. Using these coefficients the optimum level of agricultural export concentration was worked out; the optimum level was at H index equal to 0.513 which corresponded to the maximum agricultural exports [Figure 2]. The optimum level of 0.513 was analogous to study (26) where the critical value of concentration, expressed in Commodity Concentration Index (CCI), was found out to be 51.4 percent. The plot of agricultural export against H index was hump or inverted-U shaped which indicated that neither excessive export concentration nor excessive export diversification was an ideal condition for maximizing the agricultural exports.

The reason for export diversification to have negative effect after a critical point could be explained by product life cycle theory. According to this theory, new product innovations can contribute to exports only at maturity stage after being domestically accepted (13-14). Therefore, for innovative products hitting export markets it takes time for these products to be find acceptance in their destination countries. Thus, extent of export revenue associated with such products in the initial period would be low. Thus, the most diversified export basket containing new innovative products may have lower export revenue.

In quite contrast, the overly concentrated export basket can have lower export earnings due to saturation effects. The demand for an individual product gets saturated when consumed in sufficient quantity. No matter how cheap the product is offered by exporter after saturation point, the demand would be zero. This explains why countries with few products, having concentrated export basket, earned less export revenue. Also, as per Engel's hypothesis, the consumers tend to spend lower share on food and other necessities once their income rises. Thus, over the years, with increase in income, consumers would spend less on a given food item unless it qualifies as luxury (29). This also explains the lower export earnings from a concentrated basket. Also, exporting nations with concentrated export

basket risk losing markets with shift in consumption trends (5).

The Per Capita Income (PCI) and its squared term also gave interesting results in both the model. In pooled model, the positive coefficient for log (PCI) indicated that higher income levels positively influenced agricultural exports. However, the squared term was not significant, suggesting that in absence of fixed effects the relationship was linear in nature. However, in the within model, the PCI coefficient was positive, while for the squared term the coefficient was negative. In both the models the coefficients were statistically significantly different from zero. At median level of PCI (USD 12,313) the elasticity of agricultural exports with respect to PCI was 1.59. Thus, one percent increase in per-capita income was associated with 1.59 growth in export revenue.

This result is supported by study (30) who argued that as income increases the economies become more diversified but at later stages these countries tend to concentrate their export basket; the same effect is visible here where at high levels of per-capita income, export earnings have declined. (22) observed that the low-income countries had higher export concentration. A study (17) observed that the Sub-Saharan African nations with a highly concentrated export basket had witnessed a number of underwhelming growth performances during 1961 to 2000. A study (31) reported that inverted-U (hump shaped) relationship was a natural outcome of diversification based on Heckscher-Ohlin theory of trade.

The level of optimum per capita income worked out by using the coefficients from within model was USD 23,897 which is higher than the median but was close to the mean level of income for countries in the dataset. Thus, the highest level of exports was possible for a high-income country. The Figure 3 illustrates the relationship between the per capita income and agricultural exports. The data points formed an inverse U-shaped curve, indicating that agricultural exports initially increase with rising per capita income but begin to decline after reaching a certain income level. The peak of the curve, marked by a vertical red line at a per capita income of USD 23,897, signifies the optimal income level for maximizing agricultural exports.

Regarding exchange rate, its logarithm in pooled model had negative and significant coefficient indicating that appreciation of the exchange rate reduces export competitiveness. While in the within model, the coefficient was positive and significant suggesting that exchange rate depreciation can improve agricultural exports over time. One percent depreciation of exchange rate was associated with 0.101 percent increase in agricultural exports. A study (21) found that depreciation of exchange rate had positive effect on export diversification.

Log of agricultural GDP had statistically significant positive coefficient in both the models. One percent increase in agricultural GDP on average was associated with 0.281 percent increase in the agricultural exports. Thus, greater value

Table 6: Results of panel data regression for both pooled, within and random model

Dependent Variable: log (Agricultural Exports)			
Particulars	Pooled@	Within\$	Random\$
Intercept/Constant	2.54 [1.06]	-	-1.46 [-0.564]
H index	-3.78 ** [-3.12]	2.39 *** [3.8]	1.99 ** [2.73]
H index2	3.43 [1.88]	-2.32 ** [-2.79]	-2 * [-2.07]
Log (Agri GDP)	0.613 *** [20.8]	0.281 ** [3.02]	0.701 *** [9.83]
Log (PCI)	1.25 * [2.4]	2.68 *** [4.61]	1.16 [1.93]
Log (PCI)2	-0.0451 [-1.58]	-0.133 *** [-4.00]	-0.01 [-0.298]
Log (Exchange Rate)	-0.0614 ** [-2.8]	0.101 * [2.41]	0.121 ** [3.10]
Country fixed effects	No	Yes	Yes
Time fixed effects	No	Yes	Yes
Number of countries	57	57	57
Number of years	11	11	11
Number of observations	627	627	627
R2	0.562	0.149	0.341
F-statistic/Chisquare	132.384	16.134	320.572
Degrees of Freedom	620	554	6
p-value of F-statistic	< 2.22e-16	< 2.22e-16	< 2.22e-16

Significance Code: *** p < 0.001, ** p < 0.01, * p < 0.05, Figures within parentheses are t-test statistic based on heteroscedasticity consistent clustered standard errors, clustered by country, @ using Beck and Katz standard errors i.e. Panel Corrected Standard Error (PCSE), \$ using Heteroscedasticity consistent cluster-robust standard errors clustered at the country level.

Table 7: Model Diagnostic Tests

Name of the Test	Null Hypothesis (H0)	Test Statistics	p-Value	Result
Angrist and Newey's test of within mode	Within specification is appropriate.	-74.578	1	Within model applies as the null hypothesis is not rejected
Breusch-Godfrey/Wooldridge test for serial correlation in panel models	No serial correlation in the model.	127.97	< 2.2e-16	Null hypothesis is rejected.; there is serial correlation in the model.
Pesaran CD test for cross-sectional dependence in panels	No cross-sectional dependence.	12.42	< 2.2e-16	Cross-sectional dependence is detected in the model.; null hypothesis is rejected.
Breush Pagan test for heteroscedasticity in residuals	No heteroscedasticity in residuals of panel data regression.	135.49	< 2.2e-16	Null hypothesis was rejected and there is presence of heteroscedasticity in residuals.
Hausman Test	Random effect model is consistent.	131.76	< 2.2e-16	Null hypothesis is rejected and hence fixed effect model is appropriate.
Lagrange Multiplier Test - two-ways effects	No significant two-way effects.	2045.2	< 2.2e-16	Significant two-way effects detected.

addition in agricultural sector was associated with greater exportable surplus. Similarly, a study (11) in study of 18 agricultural commodities over 161 countries used log of exporter production to account for exportable surplus as factor affecting log of export. In this regression, the coefficient of log of export production was positive and significant.

The values of F statistic were 132.384 and 16.1342 for pooled and within model respectively. The reported p values of F statistic were less than five percent level of significance, thus, all parameters were jointly significant in both the models. The values of R2 suggested that 56.2 percent of variations in agricultural exports were explained by independent variables in pooled model. While in within model, 14.9 percent variations in agricultural export could

be explained by the independent variables. The contrasting results between the pooled model and the within model can be attributed to within model using only within country variation.

To test the robustness of the results of regression analysis, subset regression was run for 1996, 2006 and 2016 wherein the distance between succeeding years is fixed, i.e., one decade. Result of this subset regression is presented in Table 8. Compared to previous regression reported in Table 6, here lag of H index is used which is more robust than using only H index. Here, one additional model is included that is first difference model to overcome any bias emanating from common trend present between agricultural exports and H index. The sign of coefficient of H index is negative

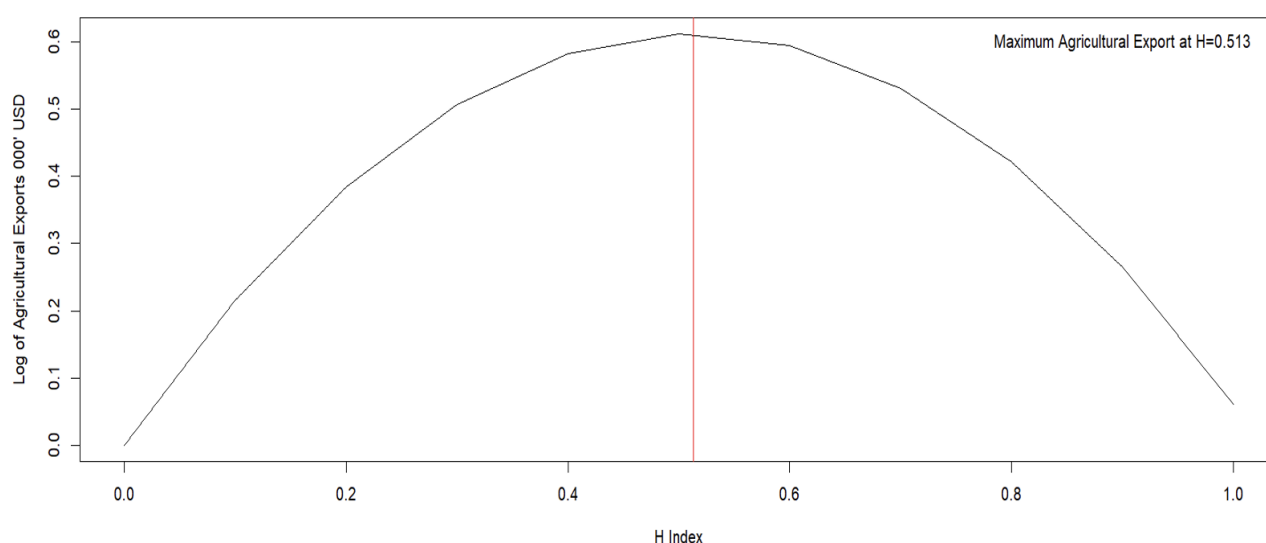


Figure 2: Effect of agricultural export concentration on agricultural exports. *Note: Prepared using the coefficients of H index in the fixed-effect panel-data regression using 627 observations.*

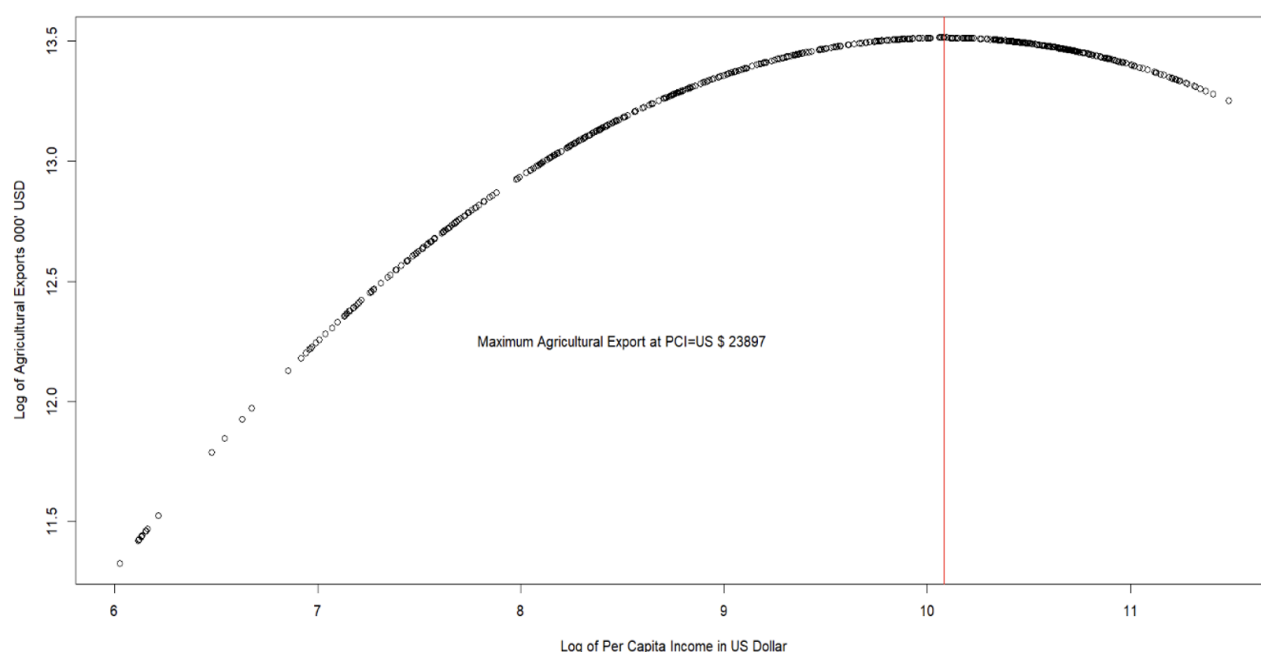


Figure 3: Effect of per capita income on agricultural export. *Note: Prepared using the coefficient of per-capita income in the fixed-effect panel-data regression using 627 observations.*

indicating that increasing concentration hurts agricultural exports. The coefficient was significant in both within and first difference model, both are fixed effect models. The increase in agricultural GDP had significant positive effect on agricultural exports regardless of model selected.

Table 9 provided the result of panel data regression for subset 1998, 2008 and 2018. The coefficient of H index had positive sign in contrast to the results of the first subset but it was not significant. Similar case was there in results

presented in Table 10 for 1996, 1998, 2000 and 2002. Thus, results of Table 8, 9 and 10 highlight the problem of weak robustness meaning that such results may not be applicable to all countries and all years consistently. This could be an effect of large gaps between successive periods in first and second subset regression. Also lack of robustness is supported by Figure 1 wherein increase in H index value was accompanied by increase in exports.

Table 8: Results of panel data regression for determinants of agricultural exports for subset of 1996, 2006 and 2016

	Pooled	Within	First Difference	Random
(Intercept)	1.85 [0.42]		0.47 *** [9.17]	4.77 [0.4]
lag(H Index)	-0.98 [-1.16]	-1.04 ** [-2.78]	-1.18 *** [-3.43]	-0.1 [-0.84]
log(Agricultural GDP)	0.62 *** [11.6]	0.43 * [2.35]	0.45 * [2.33]	0.561 * [1.98]
log(Per capita income)	1.31 [1.33]	0.78 [0.72]	1.02 [1.36]	0.83 [0.3]
log(Per capita income)2	-0.05 [-0.86]	-0.04 [-0.64]	-0.06 [-1.43]	-0.02 [-0.16]
log(Exchange Rate)	-0.08 [-1.95]	0.11 [1.39]	-0.01 [-0.15]	-0.01 [-0.08]
N	170	170	113	170
R2	0.56	0.16	0.16	0.55

Note: *** p < 0.001; ** p < 0.01; * p < 0.05, Figures within parentheses are t-test statistic based on heteroscedasticity consistent clustered standard errors, clustered by country and for pooled model based on Beck and Katz standard errors

Table 9: Results of panel data regression for determinants of agricultural exports for subset of 1998, 2008 and 2018

	Pooled	Within	First Difference	Random
(Intercept)	-1.37 [-0.28]		0.5 *** [7.75]	-5.56 [-0.48]
lag(H Index)	-0.21 [-0.24]	0.33 [0.72]	1.12 [1.61]	0.37 [0.36]
log(Agricultural GDP)	0.67 *** [11.6]	0.13 [0.51]	0.16 [0.73]	0.57 * [2.31]
log(Per capita income)	1.82 [1.69]	4.32 ** [2.79]	4.2 * [2.03]	2.93 [1.1]
log(Per capita income)2	-0.07 [-1.18]	-0.22 * [-2.48]	-0.19 [-1.78]	-0.13 [-0.88]
log(Exchange Rate)	-0.07 [-1.57]	0.19 [1.44]	-0.1 [-0.78]	-0.003 [-0.02]
N	170	170	113	170
R2	0.55	0.18	0.19	0.54

Note: *** p < 0.001; ** p < 0.01; * p < 0.05, Figures within parentheses are t-test statistic based on heteroscedasticity consistent clustered standard errors, clustered by country and for pooled model based on Beck and Katz standard errors.

Table 10: Results of panel data regression for determinants of agricultural exports for subset of 1996, 1998, 2000 and 2002

	Pooled	Within	First Difference	Random
(Intercept)	0.743 [0.19]		-0.10 [-1.62]	-0.66 [-0.05]
lag(H Index)	-0.55 [-0.90]	0.25 [0.74]	0.95 [1.38]	0.05 [0.06]
log(Agricultural GDP)	0.67 *** [12.9]	0.33 [0.10]	0.05 [0.26]	0.63 *** [3.45]
log(Per capita income)	1.47 [1.7]	3.33 [1.13]	6.71 ** [3.25]	1.71 [0.54]
log(Per capita income)2	-0.06 [-1.17]	-0.14 [-0.88]	-0.31 ** [-2.92]	-0.07 [-0.39]
log(Exchange Rate)	-0.11 ** [-3.08]	0.09 [0.67]	0.24 [1.96]	-0.08 [-0.68]
N	227	227	170	227
R2	0.57	0.03	0.05	0.57

Note: *** p < 0.001; ** p < 0.01; * p < 0.05, Figures within parentheses are t-test statistic based on heteroscedasticity consistent clustered standard errors, clustered by country and for pooled model based on Beck and Katz standard errors.

4. Conclusion

The study revealed that barring few exceptions, most industrialised countries such as USA, China, Spain, Germany

had very low values of concentration index i.e. their export basket had been more diversified over the years. Many less

developed and developing countries such as Madagascar, Cameroon, Mauritius, Algeria had higher values of concentration index i.e. their export basket was relatively more concentrated. The effect of concentration of export basket on agricultural export was significant and inverse-U shaped relationship was observed. The optimum level of diversification was at H Index value of 0.513, which suggested that neither extreme concentration nor extreme diversification was desirable. The inverse-U relationship was also observed with per-capita income which suggested that too low or high per capita income can reduce the exportable surplus. However, the results had weak robustness meaning that this result may not be applicable to all countries at all times. Finally, it can be concluded that the economies need to plan their agricultural exports in a such a way the export basket is optimally diversified.

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Authors' contributions

GKV carried out the conceptualization of the study. SS collected the data and processed it. GKV and SS together analyzed it. The initial draft of the manuscript was prepared by SS and final version of the manuscript was prepared by GKV. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical issues

None.

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Data availability

All data sources have been authentically declared in the manuscript and are publicly available.

Code availability

The code is not publicly available but may be provided by the authors upon request.

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