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Sustainable Agriculture Dynamics: Land Use, Competitiveness and Trade in BRICS

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Abstract: The study aims to examine how arable land use, global value chain participation, and agricultural product competitiveness impact the commodity terms of trade stability for Brazil, Russia, India, China, and South Africa. The panel fixed effects model chosen for the study can produce individual-specific time-invariant effects. The study used FGLS (Feasible Generalised Least Squares) to rectify heteroskedasticity and serial correlation. The findings revealed a significance for focus variables of the study such as arable land use, and global value chain participation in the short run when estimated using the fixed effects model and Feasible Generalised Least Squares during the study period. The study poses the question of resource constraints and the return of the scenarios postulated by Prebisch and Singer due to the loss of sustainable agriculture. This will put their competitiveness in agriculture in reverse gear. The study sheds new light on these dynamics using a unique competitiveness index such as the Lafay trade specialisation index. Understanding the relationships between land use, competitiveness and terms of trade will lead to the framing of better policies to ensure food security.

Keywords: Arable land, Competitiveness, Fixed Effects, Agriculture trade, Terms of trade

INTRODUCTION

Global food security is an alarming issue of the 21st century. It is due to the soaring food prices, population surge and the lack of infrastructure and land resources to support the need. At this juncture, trade plays a crucial role in maintaining the balance and flow of goods and services. In the global supply chains, commodity trade is activated by the hidden arable land use (Qiang *et al.* 2013; Tilman *et al.*, 2011). Overconsumption domestically and from global markets naturally puts a burden on the domestic arable land

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resources. The global economy is more integrated than ever today. It created an intensively correlated supply chain (Davis and Caldiera, 2010). In this context, it becomes more appropriate to discuss the role of arable land use.

BRICS came into existence in 2009. South Africa joined the BRIC in 2011. In 1990, BRICS only had 3 per cent of the global trade. It doubled by the start of the 21st century. In 2011, BRICS covered 19 percent of global exports and 16 % of global imports of goods and services.

Trade to GDP ratio is a key that separates BRICS. The trade-to-GDP ratio has shown an upward trend Since the 90s. Except for Brazil, the trade-to-GDP ratio increased in BRICS economies. In India, compared to 1990 levels, it doubled in 2011. In intra-BRICS trade in 2013, China is the largest trade partner for each of the BRICS economies. (ranges between 72 and 85 Percent). BRICS nations occupy about 26 per cent of the global landmass (Hathur & Dasgupta, 2013).

Among the BRICS economies, arable land use is highest in India (in terms of production and consumption-based arable land use) followed by Russia, Mainland China, Brazil and South Africa (Chen & Han, 2015). India possesses 157.01 million hectares of direct arable land use and for China, it is 107.22 million (Database - Eurostat, n.d.). In China, production-based arable land use is the highest. In Russia, for example, consumption-based arable land use is the dominant one. When it comes to gross export and import of global arable land use United States occupies the first position followed by Germany and China. Developing economies like India export considerable arable land use. India exports 4.05 million ha of intermediate arable land use to the European Union and 2.68 million ha of final arable land use. So, developing economies are predominantly suppliers of arable land use and developed economies receivers of the same (Chen & Han, 2015). It is worth mentioning that arable land use and global value chain participation hold a reciprocal relationship. The demand for foreign value added due to the integration by developing economies is a major reason for this relationship (Bia\low[1]s & Budzyñska, 2022). Overall BRICS economies play a dual as net suppliers and receivers of final and intermediate arable land use. In this context, the study assumes arable land use in these individual economies does not carry a major influence in determining the overall terms of trade (Ho). The study also assumes that the global value chain participation of BRICS economies did not play a significant role in influencing the terms of trade stability (Ho). Based on the background provided above, we would like to ask the following two questions: i) How does arable land use in individual BRICS economies impact the terms of trade scenario in the 21st century? ii) How does integration into value chains determine the terms of trade fluctuations in an integrated world?

RELATED LITERATURE

The literature review focuses on the determinants addressed by the previous studies. Some of the variables have been studied in different contexts on multiple occasions. The variables such as REER (Real Effective Exchange Rates), world demand, and H-O(Hecksher-Ohlin) variables such as land, labour, and capital often dominate the literature concerning terms of trade. The commodity terms of trade stability are a new concept as we emphasized the theoretical framework based on Prebisch Singer's thesis. The studies related to terms of trade stability based on standard deviations are a frequently used strategy. However, in the present study, the coefficient of variation is taken in this situation. The study considered a few crops which stood out as the top export category for several years in the case of BRICS economies.

Erokhin *et al.* (2020) pointed out that stable value chains can facilitate developing countries to take leverage of their factor endowments. Nevertheless, the complex interplay of natural, technological, and economic factors on agricultural production and distribution poses a significant challenge. The study suggested transferring resources towards competitive products to safeguard the performance of marginally competitive products. Darity (1990) focussed on evaluating the model adopted by Ronald Findlay's analysis of the determinants of trade. The study did this specifically in the context of north-south models of trade and growth. The study considered long-run equilibrium (uniform international growth rates) and long-period equilibrium (uniform profit rates) scenarios. It accounted for capital mobility. The study focussed on the impact of aggregate demand, effective demand and income on the determination of terms of trade. The strategy was to consider the North as a Keynesian and Kaleckian economy. The study finds that North can increase its markup (profit margin) but end up with a deterioration in terms of trade. Barros (1991) used an identifiable vector autoregressive model to assess the spread of external price shocks in the Brazilian economy. The study intends to fill the gap in analysing the impact of shocks on agriculture relative prices of developing countries. They have done this specifically with how monetary and exchange rate shocks have interacted with external shocks to affect the prices of agriculture commodities upon domestic terms of trade. The paper concludes that external shocks do play a role in understanding money supply. The international price of food and exchange rates affect the Brazilian domestic terms of trade. Murshed (2018) used inflation as a factor to empirically analyse the determinants that impact inflation in Afghanistan. The cointegration is observed for variables such as inflation, exchange rates, terms of trade, money supply, economic growth, interest rate, trade openness, export, and import at first difference levels. The motive of the paper was to investigate terms of trade - inflation nexus from a multidimensional framework for the period 1980-2014. The study, therefore, analysed the TOT-INF nexus and found no causal association between INF and the explanatory variables in the long run. Thus, terms of trade and exports can be improved without a need to be wary of the spiking inflation rates. Variables linked to trade facilitation such as tariffs and protectionism were studied by Kutlina-Dimitrova & Lakatos(2017). However, such variables were excluded due to the tariff calculation problems that are encountered due to the common nature of tariffs for countries. Similarly, export diversification is suggested as an antidote to the concerns of export stability (Stanley & Bunnag, 2001) (Singer & al, 2002). The studies on determinants of terms of trade mainly revolved around individual determinants. Thus, carry more direct weightage. The theoretical base also considered variables such as prices of exports or imports, technology, infrastructure and so on. In the present study, certain variables were excluded for model specification. The variables evolving and more pertinent within a new world scenario as envisioned by the conceptual framework are selected to make the model more reliable (youth article library, 2013).

DATA & METHODOLOGY

The study will focus on BRICS (Brazil, Russian Federation, India, China, South Africa) economies as these countries possess a rich resource of arable land. The BRICS economies are primarily agriculture-based economies and the environmental decline such as on land will bear major consequences for them. The results of unit root tests (Levin) show a combination of level and first difference stationarity for the chosen variables. Therefore, cointegration is dropped as a long-term relationship cannot be established. A panel fixed effects model is utilised to study the short-term relationships among the chosen variables i.e. arable land use, commodity terms of trade stability and Lafay trade specialisation index and the other variables such as PPP GDP, GL Index, REER etc. The panel FGLS (Feasible generalised least squares) is conducted to correct for the heteroskedasticity and serial correlation occurrences in the fixed effects model. The choice of fixed effects is determined through the Hauseman test in Stata. The commodity terms of trade index stability are taken as the dependent variable for the analysis.

Commodity terms of trade stability are calculated by taking the coefficient of variation from the commodity terms of trade data collected from International financial statistics. Lafay index of trade specialisation is a competitiveness index which takes into account the reimport flows due to fragmentation in the production process.

The study is based on secondary data. Time series data was collected on agriculture exports (at HS-2 LEVEL) for 4 major agriculture products (HS 9,10,12,18)[1] from 1996 to 2020 from various sources such as the Commodity Trade Statistics Database (COMTRADE). Food and agriculture organization, Trade Statistics for International Business Development (ITC TRADE MAP), Eurostat, and World Integrated Trading Solutions (WITS) data were major databases utilised for the study. The Panel data will be framed due to the inclusion of multiple regions i.e., the BRICS economies. Our world in data is a major source for data on arable land (Ritchie & Roser, 2023).

Table I: Descriptive Statistics

	L.cocoa	*L.coffee*	*L.oilseeds*	*L.cereals*	*Arable_LU*
nobs	125.0	125.0	125.0	125.0	125.0
Min	-0.340948	-0.424505	-15.777140	-1.545591	0.084667
Max	0.120831	2.868246	7.066403	1.922582	0.861750
Mean	-0.041024	0.383313	0.468304	0.158980	0.317350
Med	-0.009879	0.051396	0.048012	0.048113	0.252020
Skew	-1.190456	1.432250	-2.086671	0.147874	1.257835
Kurt	1.097220	1.631471	22.035982	-0.193798	-0.093443
	REERCPI	*GVC_P_Index*	*World. Demand*		*CTOT_Stability*
nobs	125.0	125.0	125.0		125.0
Min	47.955592	0.000298	24092430.3		-2.093303
Max	130.045043	0.000811	2133605397.0		2.088319
Mean	89.891807	0.000472	342122893.6		-.0334199
Med	88.943413	0.000438	145247873.7		0.835398
Skew	0.014235	0.887768	2.346795		1.778989
Kurt	-0.205753	-0.210857	4.441652		2.181974
	G-L Index9	*G-L Index10*	*G-L Index12*		*G-L Index18*
nobs	125	125	125		125
Min	.0144302	.0004465	.0163028		.6444261
Max	.8346507	.9966072	.9842625		.268192
Mean	.2620987	.4143153	.3915934		.9990731

Source: Author's calculation.

EMPIRICAL FRAMEWORK AND TEST RESULTS

The analysis employs two commonly utilized panel data models, specifically pooled and fixed effect, chosen over random effects following the Hausman test. These models are applied to investigate the impact of determinants outlined in equation (ii) on the instability of commodity terms of trade within a panel of countries, such as BRICS, across time. In cases where these determinants influence terms of trade, a statistically significant coefficient with a positive direction is anticipated for each factor. Emphasis should be placed on the magnitude of β_5.

By knowing the magnitude of influence of arable land use we can better understand how it holds a role in influencing commodity terms of trade stability. This should alert the ongoing policy debates and inspire sustainable usage and production.

Two models are proposed based on the assumption of the error term

$$\beta_{it} = \beta_0 + \varepsilon_{it} \quad \text{(i)}$$

Equation (i) postulates that the residual terms encompass systematic (β0) and idiosyncratic ([it) elements. The former is explicatable through the model's inclination towards the latent individual (country) impact, while the latter adheres to a white noise mechanism and is independent of the regressors. The description of two-panel models is as delineated below:

(a) Pooled model: $\beta_i = \beta$ (there is no individual effect); (b) Fixed effect model: $E(\beta_i, Xi,t) \neq 0$ (individual effect is correlated with the regressors).X includes the independent variables.

$$\begin{aligned} lnCTOT_{it} &= \beta_i + \beta_1 lno1_{it} + \beta_2 lnc1_{it} + \beta_3 lnc2_{it} + \beta_4 \ln c3_{it} + \beta_5 lnarable_{it} + \\ &\beta_6 lnREER_{it} + \beta_7 \ln WD_{it} + \beta_8 lnGVC_{it} + \beta_9 lnPPPGDP_{it} + \beta_{10} lnGLIndex9_{it} + \\ &\beta_{11} lnGLIndex10_{it} + \beta_{12} lnGLIndex12_{it} + \beta_{13} lnGLIndex18_{it} + \varepsilon_{it} \end{aligned} \quad \text{(ii)}$$

Where *i* stands for BRICS countries, β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9, β_{10}, β_{11}, β_{12}, β_{13} are parameters to be estimated, β_i is the constant term, *t* denotes time, ε_{it} is the error term. All variables are expressed in logarithmic form.o1,c1,c2 and c3 indicates lafay index values of oilseeds, coffee, tea, mate and spices and cocoa and cocoa preparations, arable denotes arable land use per person, REER denotes Real Effective Exchange Rates, WD denotes World Demand, GVC is global value chain participation, PPPGDP represents purchasing power parity gross domestic product and GLINDEX 9,10,12&18 are the intra-industry trade indexes of oilseeds, coffee, tea, mate and spices and cocoa and cocoa preparations.

The equation denoted as (ii) represents a linear unobserved effects panel data model. Within panel data models, it is frequent to encounter the presence of autocorrelation and heteroskedasticity in the residuals. We used Cross-sectional time-series FGLS regression which is robust to groupwise heteroskedasticity and time series autocorrelation to achieve more efficient and consistent estimates (Hoechle, 2007). The Hausman test is used to choose between fixed effects and random effects models (Chiu *et al.*, 2011). The results from fixed effects are reported for inference purposes.

We initially conducted an analysis using the combined model and presented the outcomes in Table II. The statistical findings indicate a rejection of the null hypothesis regarding the lack of individual effect. In the pooled OLS, the rho value i.e. 0 suggests the absence of autocorrelation in the model. This is also evident from the results of the Hausman test where RE is rejected and fixed effects are accepted. The examination for heteroskedasticity provides indications contradicting the null hypothesis of absence of heteroskedasticity (p-value lower than 0.05). The examination using the Modified Wald test for the regression model with fixed effects revealed the existence of heteroskedasticity at the group level. Furthermore, the assessment conducted with the Wooldridge test for autocorrelation in panel data indicates the existence of serial correlation within the fixed effects model. Consequently, we proceed with the execution of unrestricted fixed effects employing FGLS estimators to ascertain unbiased estimations. The outcomes are documented in Table III.

If we compare the pooled model and fixed effects model (without FGLS), few estimates changed the sign. Further, t-statistics also reveal that only a few values remained significant for the fixed effects model compared to the pooled model. For instance, the log of Lafay value of oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit, industrial or medicinal plants; straw and fodder (o1) are showing an inverse relationship in the coefficient (-.1304287) and also at significant at 1%. However, it became a direct relation in the coefficient and insignificant for the fixed effects model. Also, some of the major focus variables of the study such as arable land use (also in the pooled model), and GVC participation index remained significant at 1% and 5% respectively in the fixed effects model.

The Hausman test is performed to decide whether a random or fixed effects model is more suitable. The null hypothesis is that the individual effect is correlated with regressors ($E(\beta_i, X_{i,t}) \neq 0$) against the alternate hypothesis when they are uncorrelated (Chiu *et al.*, 2011). The test results in Table III suggest that there is a correlation between regressors and therefore fixed effects model is more suitable to adopt.

To further test for heteroskedasticity, a likelihood ratio test is adopted. The null hypothesis was homoskedasticity is nested within heteroskedasticity in the model. This is used to compare a model that assumes homoskedasticity (constant variance of residuals) against a model that allows for heteroskedasticity (varying variance of residuals). The high p-value (0.9982) shows that we cannot reject the null hypothesis of homoskedasticity. In practical terms, it means that based on the LR test, introducing heteroskedasticity does not lead to statistical significance compared to the simpler assumption of homoskedasticity.

Table II: Pooled Model OLS

	Estimate	*Std. Error*	*t-value*	*Pr(> |t|)*
o1[2]	-.1304287	.0321313	-4.06	0.000***
c1[3]	-.4560851	.1264744	-3.61	0.000***
c2[4]	.1542376	.1040565	1.48	0.138
c3[5]	-3.266277	.9005729	-3.63	0.000***
lnArable_LU	.6783848	.0915536	7.41	0.000***
lnREERCPI	.860511	.2838466	3.03	0.002***
lnGVC_P_Index	-1.099657	.2634308	-4.17	0.000***
lnWorldDemand	-.1037217	.0702556	-1.48	0.140
lnPPPGDP	.2123347	.08857	2.40	0.017**
lnGLindex9	-.5050075	.0824791	-6.12	0.000***
lnGLindex10	-.0733993	.031303	-2.34	0.019**
lnGLindex12	.0871019	.0813365	1.07	0.284
lnGLindex18	-.4315156	.1679386	-2.57	0.010**
_cons	11.90374	5.803922	2.05	0.040**
rho	0 (fraction of variance due to u_i)			

(a) Balanced Panel: n = 5, T = 25, N = 125.

(b) Significance Codes: *** 1% significance level; ** 5% significance level; * 10% significance level.

(c) Multiple R-squared: 0.8442. d) Wald chi2(13) = 601.49, Prob > chi2 = 0.0000

Table III: Hauseman Test

Test of H0: Difference in coefficients not systematic
chi2(4) = (b-B)'[(V_b-V_B) ^ (-1)] (b-B) = 87.86
Prob > chi2 = 0.0000
(V_b-V_B is not positive definite)

To provide a clear comparison of the outcomes and to understand the influence of FGLS on the fixed effects model, both fixed effects model results (with and without FGLS) are reported here. In the original fixed effects model, the competitiveness variables i.e. o1, c1(coffee, tea, mate and spices), c2(cereals), and c3(Cocoa) showed no significance except for c2 (at 5% level). Except for o1 and c3, the coefficients are negative for c1 and c2. Now for FGLS estimation, o1, c1 and c3 are significant at 1% level (except c2). The arable land use has a positive value coefficient and is significant at a 1% level for both fixed effects models with or without FGLS. Global value chain participation is significant at a 5% level but negative at the coefficient. Apart from these emerging variables which demonstrate a strong influence on commodity terms of trade stability of BRICS economies, GDP PPP, and Grubel-Lloyd or intra-industry trade indexes (9 & 18) seem to have an influence at 5% and 1% respectively. The results however indicate the crucial role played by resource constraint which can happen due to short-term impacts of arable land use. The value chain participation is calculated without a sectoral difference. Yet as an emerging and recognised determinant, it can prove to be critical. Therefore, we reject both the null hypotheses i.e. arable land has no significance in terms of trade stability (Ho) and global value chain participation can't impact terms of trade stability (Ho). The common AR (1) coefficient for all panel's value i.e. (0.642) indicates that a single autocorrelation coefficient is assumed for all panels (rdrr.io, 2024). The value of 0.6 falls between the rho autocorrelation coefficient range which is between -1 to 1, where 1 indicates high autocorrelation and 0 indicates no autocorrelation.

Table IV: Fixed Effects Model

	Coefficient	*Std. err.*	*t*	*P>|t|*
o1	.0075876	.0184557	0.41	0.682
c1	-.0615205	.0695797	-0.88	0.379
c2	-.1065821	.0565555	-1.88	0.062*
c3	.0649196	.6803033	0.10	0.924
lnArable_LU	3.173983	.4178292	7.60	0.000***
lnREERCPI	-.0844907	.1582267	-0.53	0.594
lnGVC_P_Index	-.364519	.1591964	-2.29	0.024**
lnWorldDemand	.0869715	.0619441	1.40	0.163
lnPPPGDP	-.2346856	.0791597	-2.96	0.004***
lnGLindex9	-.0338152	.0598248	-0.57	0.573
lnGLindex10	.0068568	.0163025	0.42	0.675
lnGLindex12	.1524663	.0493905	3.09	0.003***
lnGLindex18	-.1745529	.1003457	-1.74	0.085 *

(a) Balanced Panel: n = 5, T = 25, N = 125.

(b) Significance Codes: *** 1% significance level; ** 5% significance level; * 10% significance level.

(c) Multiple R-squared: 0.2581, F(13,107) = 28.45

In addition to the above tests, a random coefficient test (xtrc) was performed to see whether the estimates are intercept changing and slope changing. The test showed both possibilities therefore a group-specific estimation is performed. The results indicated that significant levels are different across all the cross-sections and hence slope is changing across cross-sections. If there is heteroskedasticity, slopes are supposed to remain constant. However, heteroskedasticity could be due to other possibilities like varying standard errors or time series heteroskedasticity. Therefore, to correct for the groupwise heteroskedasticity and time series autocorrelation,

Table V: Feasible Generalised Least Squares Method Results

	Estimates	*Std. error.*	*z*	*P>|z|*
o1	-.0822684	.0230599	-3.57	0.000***
c1	-.3063293	.1016739	-3.01	0.003***
c2	.0196681	.0715489	0.27	0.783
c3	-2.458815	.7668999	-3.21	0.001***
lnArable_LandUse	.6995637	.0945634	7.40	0.000***
lnREERCPI	.1508866	.2375018	0.64	0.525
lnGVC_P_Index	-.4443159	.2040533	-2.18	0.029**
lnWorldDemand	.0202871	.0683185	0.30	0.767
lnPPPGDP	.1801228	.0793909	2.27	0.023**
lnGLindex9	-.2680788	.0727028	-3.69	0.000***
lnGLindex10	-.0277544	.0215962	-1.29	0.199
lnGLindex12	.0511962	.0618149	0.83	0.408
lnGLindex18	-.2982683	.1148195	-2.60	0.009***
_cons	13.02644	5.136467	2.54	0.011**

Correlation: common AR (1) coefficient for all panels - (0.6429)

Wald chi2(13) = 219.32

Prob > chi2 = 0.0000

Table VI: Cross-sectional dependency test

Pesaran's test of cross-sectional independence = 0.644, Pr = 0.5195
Average absolute value of the off-diagonal elements = 0.404

FGLS must be performed (Noman Arshed, 2022). The Pesaran's test of cross-sectional independence and the average absolute value of the off-diagonal elements are used to assess the possibility of cross-sectional dependency. The null hypothesis was that there is cross-sectional independence. The p-value of 0.5195 is larger than the significance level of 0.05. This indicates that there is not enough indication to discard the null hypothesis of cross-sectional independence. Thus, there is no strong cross-sectional dependence in the data.

CONCLUSION AND RECOMMENDATIONS

The ecological shift to a resource-constrained production and consumption system will supersede the competitiveness and diversification angles envisaged in the modern economy today. The change of this nature will be spearheaded by the decline of arable land, the land required for cultivation in both underdeveloped and developing economies. The BRICS nations stand at the threshold of too many resources related issues particularly related to land and climate change. The arable land required to produce a fixed quantity of crops has also declined steeply since the 1960s. This is calculated using the crop production index which is the total of products or crops (minus crops used for animal feed), weighted by commodity prices. (Ritchie &Roser, 2024). The shift to intensive agriculture is pivotal in keeping the yield and production stable despite the lesser use of land over the years. (Lambin & Meyfroidt, 2011)

The specific factor model in Economics discusses the changes in trade patterns over some time due to the demand for land and products grown on a particular piece of land. The kind of sector-specific shocks due to certain factors such as land is a key feature of this model. Similarly, Prebisch Singer's thesis also points out the drawback of developing economies which is their export of primary commodities. This will lead to a secular deterioration in terms of trade due to the incompetency of developed economies and their export of manufactured products. However, this form of decline could be anticipated based on agriculture production decline, land degradation or loss of arable land in the 21st century. The factors which are specific to primary production such as agricultural land may face challenges in adjusting to changing global economic conditions. The empirical model presents results which resonate with the deeper theoretical sentiments outlined here. In the FGLS model, arable land use in the BRICS shows positive coefficients and significance at a 1% level. There are mixed results when we compare fixed effects estimates for Lafay competitiveness values of four chosen commodities (HS-9, HS-10, HS-12, HS-18).[6] Coffee, tea, mate and spices, Cereals, and Cocoa are significant at a 1% level. This is in contrast to the results of the fixed effects model (without FGLS) where only Oilseeds showed significance. Again, significance at the 5% level is obtained for GVC participation and GDP PPP effect on commodity terms of trade stability. The results are made robust to the disturbances that are heteroscedastic, contemporaneously cross-sectionally correlated and autocorrelated of the type AR (1).

It is important to acknowledge the critical role played by land particularly due to the results presented here and the alarming rate of land degradation visible in the world. The findings connect with the changes in trade patterns and their impact on crops grown cited in the specific factor model. As the world is embracing fragmented production processes more and more due to global value chain prominence, the 5% significance level shown is an important indication of influences beyond production and land that can impact stability and trade dynamics. The policy implications could range from diversification in terms of crop production to sustainable land use. The conservation of arable land and the emphasis on alternate forms of farming is a possible solution to the resource problem. Future research should look into the crop-specific implications of arable land changes on competitiveness and trade.

Notes

1. HS-9 denotes coffee, tea, mate and spices, HS-10 denotes cereals, HS-12 denotes oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit, industrial or medicinal plants; straw and fodder & HS-18 denotes cocoa and cocoa preparations
2. O1-oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit, industrial or medicinal plants; straw and fodder,
3. C1-coffee, tea, mate and spices
4. C2- cereals
5. C3- cocoa and cocoa preparations
6. HS-9 denotes coffee, tea, mate and spices, HS-10 denotes cereals, HS-12 denotes oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit, industrial or medicinal plants; straw and fodder & HS-18 denotes cocoa and cocoa preparations
7. Here again, the terms of trade stability for the period (1996-2020) in the BRICS is calculated using the formula: (Average/Standard deviation) *100. This form of segmented analysis is helpful to understand the changes more flexibly.
8. It is further divided by the average population for the same year. The GDP PPP can be used to represent the standard of living and economic performance of the country and can demonstrate an influence on terms of trade stability over time.

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APPENDIX

Theoretical/Conceptual Framework

Hechsher Ohlin's theory elaborates on how countries with abundant resources will export goods that make intensive use of those factors of production. A country rich in labour would export labour-intensive goods. The H-O theory emphasizes comparative advantage entrenched in factor endowments. The specific factors model is critical to the study focus areas, and so is the Prebisch-Singer thesis. The specific factors model implies that due to changes in trade patterns or economic shocks, the specific factors in certain industries are more adversely affected than others (Social Sci LibreTexts, 2020). It also points out that the mobility of factors across sectors is limited in the short run. On the other hand, the Prebisch-Singer thesis proposed in the mid-20th century a long-term decline in the terms of trade for primary commodity-exporting countries relative to manufactured goods-exporting countries. The fragmentation theory provides a different view of trade due to the fragmented production across countries in the value chains. The global value chain integration and participation is a reason for the inclusion of a trade specialisation index like the Lafay index for agri-food trade competitiveness in the current study. The origins of the New Trade Theory can be traced back to the 1980s, although Paul Krugman's formalization of the theory occurred in 2007. In addition to comparative advantage, this theory emphasizes the significance of economies of scale and network effects in shaping trade patterns. A country can accumulate an advantage because of scale economies and first-mover advantages, leading to monopolistic competition. On the other hand, intra-industry trade revolves around the idea of trade in similar but differentiated goods with each other. The theory emphasizes economies of scale and consumer preference for variety in consumption. Developed economies often take part in intra-industry trade. The differentiation is the source of trade even without traditional comparative advantage. The Lafay index is a measure that examines specialisation patterns and the extent of intra-industry trade. The terms of trade are in terms of commodity terms of trade. The formula for the same is as follows: The commodity terms of trade are determined by dividing a country's export price index by its import price index and multiplying the result by 100. This calculation yields a percentage that reflects the relative price of a country's exports compared to its imports. An increasing terms of trade value signifies an enhancement in the country's capacity to acquire more imports with a fixed quantity of exports. The formula for calculating the terms of trade is:

$$\text{Commodity Terms of Trade (TOT)}^{7} = (P\text{exports} \ / P\text{imports}) \times 100 \qquad \text{(iii)}$$

Where:

- Pexports = Price index of exports
- Pimports = Price index of imports

GDP PPP denotes the aggregate value in terms of purchasing power parity of final goods and services generated within a specific timeframe[8]. The impact of PPP on terms of trade can be observed through its influence on the relative prices of goods and services among different nations, consequently affecting the export and import price indices (Investopedia, 2024). When a nation's GDP PPP increases, it indicates a rise in the relative costs of products and services compared to other nations. Global involvement in value chains may also impact a nation's terms of trade by potentially modifying the relative prices of goods and services among various countries. For instance, engaging in global value chains by importing foreign inputs for the production of exported goods and services (backward participation) could result in an escalation of the import price index, leading to a decline in trade terms. Conversely, involvement in global value chains by exporting domestically sourced inputs to downstream partners (forward participation) might cause an upsurge in the export price index, thereby enhancing trade terms (Christophe *et al.*, 2017).

The value chain participation index is calculated as:

$$(DVX+FVA)/GROSS\ EXPORTS \quad \text{(iv)}$$

where DVX is a domestic value added in exports and FVA is a foreign value added.

Arable land use- refers to the amount of cultivable land reserved for agricultural purposes per individual within a given population. There are several studies which emphasise arable land and its growing impact on trade (Wu *et al.*, 2018) (Chen & Han, 2015) (Han & Chen, 2018) (Schwarzmueller & Kastner, 2022). The loss of arable land will be a critical issue in the context of resource depletion and trade dynamics in competition for land. Arable land use (hectares per person) is treated as an independent variable here.

World demand- can affect the prices of exported and imported goods. It could in turn affect the terms of trade. For instance, if there is high demand for a country's exports, the prices of those goods may surge. It leads to an improvement in the country's terms of trade. Conversely, if there is low demand for a country's imports, the prices of those goods may decrease. This would lead to an improvement in the country's terms of trade (Investopedia, 2023).

In addition to the above determinants Lafay trade specialisation index is considered to study their impact (oilseeds, cocoa, coffee, cereals) on terms of trade. These commodities are major export categories in the BRICS (Algieri *et al.*, 2022). The above-mentioned commodities are chosen due to their significance within the BRICS framework. Brazil, China and India are major producers of oilseeds in BRICS. Brazil is a major producer of Coffee, accounting for around 35% of its production. Brazil also has better Cocoa production. India is also a major producer of Coffee, tea, and spices among BRICS and in the world as well (Ren *et al.*, 2020).

$$LFI = 100(x_j - m_j / x_j + m_j - \sum_{j=1}^{N}(x_j - m_j) / \sum_{j=1}^{N}(x_j + m_j)) * (x_j + m_j) / \sum_{j=1}^{N}(x_j + m_j) \quad \text{(v)}$$

m_j represents the products that BRICS nations import globally while x_j denotes their exports. N signifies the quantity of goods traded. Moreover, a positive LF value suggests an edge, in the product indicating a significant level of specialization. Conversely a negative value implies dependence, on imports.

Finally, Grubel Lloyd index is calculated as follows:

$$SIIT = 1 - \frac{|\Sigma_d x_{isd} - \Sigma_d m_i ds|}{|\Sigma_d x_{isd} + \Sigma_d m_{ids}|}$$

where **s** is the country of interest, **d** is the group of all other countries in the world, **i** is the sector of interest, **x** is the product export flow, and **m** the product import flow. The numerator is the absolute value of difference between total exports and total imports in sector **i**. The denominator is the sum of the total exports and imports in sector **i**.

The comparative advantage due to differences in specific factor endowments is a key feature of Hecksher Ohlin's theorem. Two resource-based theories (Dutch disease and Prebish Singer's thesis) point out the perils of the burdensome nature of certain internal advantages. It could be a natural resource like land or commodity. In a world where resource constraints are perpetuated due to environmental changes, the use and availability of arable land will be a contentious issue. In so many ways, land occupies a central position in the resource debates. If a particular area disappears due to degradation, the multifunctional aspects of land increase (Fao,2024) This is due to the differentiation in agriculture or diversification. As per many studies, these kinds of improvisations play a role in maintaining export stability. The basic argument is that reliance on a particular endowment like land could become a liability due to the inability to accommodate large-scale production.

The decline of land resources could potentially lead to a decline in competitiveness and production. It could lead to an overall deterioration in terms of trade or agriculture terms of trade (Prebisch Singer thesis). The decline of agricultural land and ecological factors is a powerful driver of primary commodity prices and terms of trade (Geronimi & Taranco, 2018). Arable land is also temporary meadows, and pastures but used for cultivation of crops.

The present study set the agenda on the determinants which are long-standing and relevant for a resource-constrained and highly integrated world where location seems to be disappearing due to the fragmented nature of the production process. The resource problems like loss of arable land should be considered along with dynamic changes in the global trade environment such as value chain participation and demand for 'variety', especially for agrifood commodities perpetuated by a rise in per capita income and trade.