Foreign Direct Investment, Globalized Agri-food Value Chains and Transformation

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Abstract:

We examine the determinants of participation and positioning in the Agriculture Globalized Value Chains (AGVC) with focus on role of foreign Direct Investment (FDI) in agriculture. Among the determinants, trade policies that are reflected in cost to trade play a significant role in AGVC engagement. FDI in agriculture affects AGVC structure correlating significantly with forward participation. FDI holds potential for enhancing value addition, technology diffusion, and market access. We then assess the effect of AGVC on production diversification in agriculture i.e., manifested in crop choices. A priori is unclear whether AGVC participation and positioning leads to greater specialization or diversification as there are forces in either direction. Our findings show that AGVC participation is associated with diversified agriculture. Moreover, the effect varies by positioning (backward and forward). The estimates using panel regression, Lewbel instrumental variable method and continuous treatment matching yielding dose response functions show these results to be robust. Results also vary regionally. East and Southeast Asia show the strongest association between AGVC and product diversification.

Keywords: Agri-food Global Value Chain (AGVC), product diversification, foreign direct investment in agriculture, Lewbel method, Uncertainty index

JEL Classification: Q10, F13, F15, E22, E23

1. Introduction

The rise of global value chains (GVCs) in recent decades has been affecting not only the manufacturing and services sector but increasingly the agricultural-food sector in both developed as well as low- and middle-income countries (LMICs). Agri-good GVC (AGVC) are considered important for outcomes such as structural transformation and growth in agricultural productivity (Greenville et al., 2017; Lim 2021, Montalbano and Nenci 2020). Structural transformation within agriculture comprising diverse crop choices is a precursor to larger structural change with shift into non-farm and industrial sectors (Johnson 2000; Reardon and Timmer 2007, Gollin et al 2002; Foster and Rosenzweig 2004; Emran and Shilpi 2012; Bustos et al 2016). It may not be possible to move to the stage of rapid productivity growth if crop diversification is postponed (Amare et al., 2018; Weinberger and Lumpkin, 2007; Birthal et al., 2015, Timmer 1992).

Crop choices are important for their effects on farm incomes, nutrition, and environmental sustainability (Birthal et al 2015; Govereh and Jayne 2003; Barghouti et al. 2004; Michler and Josephson 2017). Profitability of agriculture depends on diversification into crops and livestock that generate higher returns, better demand prospects compared to cereals, and into production for agri-business that can add value through processing and enhanced consumer appeal (Timmer 2009; Reardon and Timmer 2007).

Traditionally, in economics, agriculture was treated as a sector producing homogenous products with comparatively little value addition distinct from manufacturing and services. However, in recent decades, the agri-food sectors have undergone significant transformation and mimic the economic structure of manufacturing and services. Nowhere, the similarities are as stark as in trade including the emergence of GVCs. In GVCs, products cross international borders to supply foreign markets, it entails the sequence of dispersed activities in several countries involved in transforming raw materials into final consumer products, comprising production, marketing, distribution, and support to end users (Gereffi and Fernandez-Stark, 2011).

Studies show the important role of AGVC in technology adoption, agricultural productivity (Montalbano and Nenci 2020), and other outcomes such as sustainability of agriculture. Little is known, however, about how participation in AGVCs changes production choices in terms of diversification. We hypothesize that participation in GVC is associated with diversified agriculture and effects are likely to vary between upstreamness/downstreamness of participation i.e., positioning in AGVC and differ in the short versus long run.

Specialization based on comparative advantage within AGVC may result in lower diversification. Over time as investments, technology and flow of knowledge occur, that could usher in diversification. Upgrading processing capacity or reputation for quality could spur diversification. Such effects are more likely over the longer run. In principle, the direction and strength of relationship between production diversification and GVC is unclear and needs to be estimated. Prior to that, it is important to assess the determinants of participation and positioning in AGVC itself, particularly the role of FDI in agriculture to ease capital constraints for LMICs.

The agricultural sector tends to be heavily protected in most developing countries (Reardon and Timmer, 2007) because of which, AGVC growth may have been comparatively slow. Yet, as Barrett et al (2020) show, in recent times especially since the conclusion of the Uruguay Round Agreement on Agriculture in 1994, AGVCs have strengthened as a share of agricultural output. There is also a growing diversity of suppliers, especially from LMICs, and the rise of China as a key GVC hub within the sector (Greenville et al 2019). The "GVC revolution" has provided opportunities for small countries with limited capacities to engage in AGVCs and benefit from global trade (Minten et al., 2009; Swinnen and Vandeplas, 2014).

We look at AGVC participation across four broad regions Europe, East and Southeast Asia, North, South, and Central America to see how broad-based engagement in AGVC is (Annexure A1). Across sectors, Barrett et al (2020) show that exports of higher-value products in subsectors such as dairy, fruits, meat, seafood, and vegetables have been accompanied with significant GVC investments in logistical capacity and other investments.

Through GVCs, agri-food producers can gain access to broader international markets, allowing expansion of their customer base. This diversification of markets mitigates risks associated with market fluctuations and creates opportunities for sustained growth. Moreover, participation in AGVCs exposes the agri-food sector to advanced technologies, and knowledge transfer from international partners, suppliers, and customers. These factors can drive diversification, leading to adoption of more efficient and sustainable farming, improved processing techniques, and enhanced product quality.

Hence, taking part in AGVC can lead to both market and production diversification. AGVCs often involve higher-value processing and manufacturing activities, packaging, and branding. By shifting towards these value-added activities, agri-food producers can have larger value capture in the supply chain, enhancing competitiveness and profitability. This can expand the range of commodities produced and also enable production of finished or semi-finished products for exports, further integrating into AGVCs and affecting positioning. Greenville et al. (2019) identify two distinct pathways in value addition and involvement in AGVC, (i) downstream processing sectors, where domestic value is added to agriculture, and connections to trade and GVCs are established (backward GVC participation), (ii) Focus on primary products, where domestic value addition occurs at raw product level, and sector engages directly in trade and GVCs through export of these primary products, catering to foreign processing or final demand (forward GVC participation). The proponents of downstream value addition argue that it leads to higher overall returns compared to the export of primary products. Lim (2021) shows that upstream participation in AGVCs is associated with a more agrarian economy; implying that upstream (downstream) participation leads to more labor- (capital-) intensive agriculture which would be reflected also in production choices.

Though the level of participation varies across sectors and countries, agriculture primarily contributes to value chains as suppliers of raw materials for other production processes, while the food sector relies on sourcing inputs from global suppliers. The increased significance of global

agricultural trade has also changed AGVCs, with greater vertical coordination, supply base upgrading, and growing influence of multinational food companies (FDI) (Greenville et al., 2017). New players have emerged, such as commodity traders, and there is greater focus on branding and marketing. The "GVC revolution" has provided opportunities for small countries with limited capacities or resources to engage in AGVCs and benefit from global trade (Minten et al., 2009; Swinnen and Vandeplas, 2014).

Our paper also investigates how FDI facilitates these changes towards integration into AGVCs. Furthermore, the study contributes by investigating the variations in the effects of AGVC participation across different stages including inputs and machinery, primary production, logistics, and processing, which are connected with agri-food sector.

There has been a surge of literature examining the competitiveness of countries and industries by considering value-added production and integration into GVCs but disproportionately focused on manufacturing and services. The use of inter-country input-output tables and comprehensive matrices of bilateral trade flows has facilitated analysis of value-added trade and the calculation of new indicators. These aggregate analyses reveal that around half of the current agri-food trade can be classified as intermediate usage for global production processes (OECD, 2016).

Furthermore, these analyses demonstrate that, despite relatively low trade shares at global level across LMICs, there are instances of significant AGVC engagement. The agricultural sector in sub-Saharan Africa for example has a deep involvement in AGVC, with the importance of its international linkages increasing over time. However, this participation primarily occurs in the upstream stages and may be targeted towards specific markets like Europe (Balié et al., 2019).

This study utilizes the OECD-Trade in Value Added (TIVA) database (covering 1995 to 2018 across 66 countries) and tries to employ econometric approaches to assess determinants of participation and positioning in AGVC. The multivariate regression framework controls for several factors including indicators for business environment that can affect AGVC engagement. These

include trade barriers (natural and policy driven), measures of uncertainty developed at IMF to capture business environment along with digitization and governance indicators. Other controls include share of female employed in agriculture, climate footprints and productivity in agriculture.

In assessing participation and effects of GVC participation and positioning on outcomes, there clearly is an issue of endogeneity. We employ Lewbel two-step heteroscedasticity based IV estimator to address these concerns. Lewbel's (2012) approach exploits conditional second moments of endogenous variables, AGVC participation or FDI to circumvent endogeneity.[1] The core finding suggests a positive and significant relationship between FDI and GVC participation (elasticity 0.98) and positioning (elasticity 0.42). The results establish a positive and significant relationship between GVC and production diversification, with variations observed across different industry stages and regions.

The rest of the paper is organized as follows. Section 2 presents the data and methodology. Section 3 presents descriptive statistics. In Section 4, we present empirical findings on participation and positioning in AGVCs and its effect on outcome indicators. In Section 5, we assess heterogenous effects by sector. In Section 6 we conduct a robustness check using a generalized propensity score matching approach. Section 7 concludes with implications.

[1]Specifically, Lewbel (2012) shows that if first-stage errors, are heteroskedastic and at least a subset of elements of covariates are correlated with variances of these errors, then the model is identified. If these assumptions are satisfied by systems of equations where error correlations across equations arise due to an unobserved common factor (for crop choices and AGVC participation).

2. Data

We utilize the Trade in Value Added (TiVA) indicators published by OECD, to examine AGVC participation. TIVA indicators are derived from OECD's Inter-Country Input-Output (ICIO) tables covering 1995 to 2018. This database covers 66 countries, OECD members, European Union nations, ASEAN countries, and G20 members, with approximately 45 unique sectors, comprising agriculture, machinery, food and beverages, and manufacturing. The indicators offer insights into global production networks and supply chains that conventional trade statistics may not capture. We focus on all 66 countries regarding their AGVC credentials (participation and positioning).

We select 11 sectors out of 25 that are closely related to agri-food, aggregating them into 4 broad value-added stages. The "Input Stage"-Chemical and Chemical Products, Electricity, Gas, Steam and AC Supply, Machinery and Equipment, and Water Supply, Sewerage, Waste Management, and Remediation Activities, The "Primary Stage"- Agriculture, Hunting and Forestry, and Fishing and Aquaculture. The "Logistics/Supply Chain Stage" encompasses Air Transport, Land Transport and Transport via Pipelines, Warehousing and Support Activities for Transportation, and Water Transport. Finally, "Processing Stage" comprises Food, Beverages, and Tobacco industry.

We use other databases as well such as FAOSTAT[2], UNCTAD[3], World Uncertainty Index[4], Worldwide Governance Index[5], World Development Indicators[6], Tariff and Non-Tariff Measures Database[7] (Annexure A2).

[2] https://www.fao.org/faostat/en/#data
[3] https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx
[4] https://worlduncertaintyindex.com/data/
[5] https://info.worldbank.org/governance/wgi/
[6] https://databank.worldbank.org/source/world-development-indicators
[7] https://epingalert.org/en

2.1. Measures of AGVC

2.1.1. Measures of AGVC Participation

Hummels et al. (2001) introduced a way to measure participation in GVCs using Input-Output (IO) tables, for both direct value-added trade and indirect value-added trade going through other countries. However, this measure was susceptible to "double counting" when intermediate goods crossed borders multiple times (Koopman et al., 2011). To address this issue, we adopt the GVC participation measure proposed by Koopman et al. (2010), which considers all sources of value added in total exports and tries to address the problem of "double counting." GVCPI considers not only the value added generated directly by the country but also the value added generated in other countries involved in the supply chain.

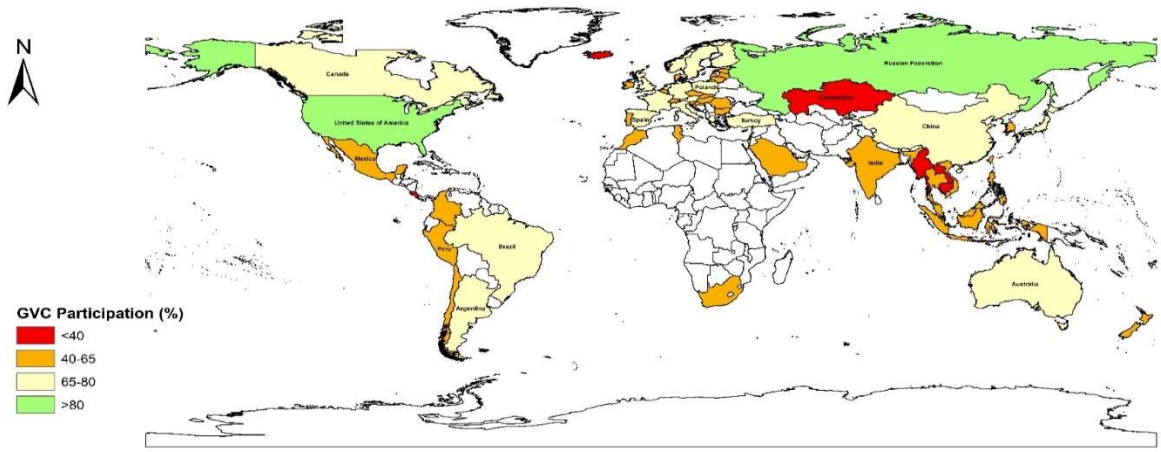
GVCPI is defined as:

$$GVCPI_{is} = \frac{FVA_{is}+DVX_{is}}{Gross\ Exports_i} \quad (1)$$

Where Domestic value added (DVA) refers to the value of exports created by domestic production factors. Foreign value added (FVA) is the value of exports that originates from imported inputs and indicates backward GVC participation. Domestic value added embedded in other countries' exports (DVX) refers to domestic value added in intermediate goods that are further re-exported by partner country. DVX is a component of forward GVC participation (upstream) (Lim 2021).

FVA_{is} represents foreign value added of sector "s" in country "i", DVX_{is} indicates indirect value added of sector "s" in country "i" and $Gross\ Exports_i$ refers to total exports of country "i". FVA_{is} measures imported intermediate input content of exports and measures "backward participation" whereas DVX_{is} adds the portion of exports used as inputs by another country in production of its exports. Figure 1 shows that AGVC participation is comparatively high in developed nations while the global south is catching up.

Figure 1: Distribution of AGVC participation



Source: TIVA Database
Note: Information on countries without color is unavailable and are grouped under "rest of the world." Additionally, due to map's small scale, some country names are not displayed.

2.1.2. Positioning in GVC

The position of a sector in GVCs is represented by the log difference of a country-sector's supply of intermediates used in other countries' exports to the use of imported intermediates in its own exports (Koopman et al., 2011).

$$Upstream_{is} = \log\left(1 + \frac{DVX_{is}}{Gross\ Exports_i}\right) - log\left(1 + \frac{FVA_{is}}{Gross\ Exports_i}\right) \quad (2)$$

An upstream sector participates in GVC by producing inputs for others. Thus, its indirect value-added exports (DVX) share of gross exports will be higher than its foreign value added (FVA) share. Conversely, a downstream sector in GVC uses intermediates from other countries to produce final goods, i.e., FVA share will be higher than its DVX share .

2.2. Outcome Indicators

Diversification is influenced by factors such as access to specific inputs, machinery, knowledge, and biophysical conditions. Price realization as well as its variability matter for farm choices. GVCs provide an avenue for improving economic and technical performance of farmers and firms, enabling them to compete in major products, explore niche markets for minor products, and

engage in product differentiation. To examine production diversification, a diversification index viz. Simpson index based on value of agri-food production is used. The Simpson Index is:

$$Agrifood\ Production\ Simpson\ Index = 1 - \sum_{i=1}^{n} P_i^2 \quad (3)$$

where, P_i is proportion of the i_{th} agri-food item in value of all agri-food commodities in reporting country. The Simpson index ranges between 0 and 1, where greater value implies higher diversification.

We also look at the role of FDI in the agri-food sector as a factor in participation and provisioning in AGVC. This indicator from FAOSTAT is tested for association with GVC participation and positioning as proposed in Barrett et al (2020). There is a reverse causality possible as well. GVCs itself can foster a favorable environment for FDI. GVCs facilitate the internationalization of domestic firms and facilitate interactions between multinational corporations (MNCs) and local manufacturers, through both backward and forward linkages.

2.3. Methodology

Two models, fixed effects (FE), and random effects (RE) panel regression models are employed to assess the effect of GVC on product diversification and FDI's role in GVC. Conducting a Hausman specification test, the FE model is judged appropriate i.e., supported by the data. FE estimator allows for elimination of individual- time invariant FE in through within transformation. However, even with this transformation, there may remain a correlation between the transformed lagged dependent variable and the transformed error term (Bond, 2002). In instances involving dynamic panel data, particularly when time-period is small, the FE estimators may lack consistency.

Alternative methods are then used, first involving standard external instrumental variables (IV). Often such IVs are either unavailable or are weak. In such cases, an alternative is to use the generalized method of moments (GMM) system estimation which is suitable when there is a

limited number of time periods and many observations within each period. It does not assume presence of enough instruments outside the core data set and provides reliable estimates using internal instruments (Roodman, 2009). However, even with the GMM system estimator, if the available valid instruments (such as lagged levels and lagged differences) are weak, it can result in significant bias akin to the traditional IV models with weak instruments (Bun and Windmeijer, 2010).

Currently, there are only ad-hoc methods for testing the strength of instruments when using GMM system estimator (Bazzi and Clemens, 2013). Lewbel (2012) introduced an alternative approach that has two advantages. First, within the GMM structure, it allows test of weak instruments in a traditional way. Second, it does not rely on instruments from outside and uses heteroscedasticity present in the data to generate valid instruments. The approach does not identify endogenous variables in the second stage based on traditional exclusion restrictions but achieves identification using higher moments. A standard over identification test can be used to evaluate validity of these assumptions. Potentially valid instruments are constructed by multiplying the heteroscedastic residuals from the first-stage regressions with a subset (or all) of the mean-centered exogenous variables, $(Z - \bar{Z})\hat{\varepsilon_1}$, where $\hat{\varepsilon_1}$ is the vector heteroscedastic residuals from the first-stage regressions, and $\bar{Z}$ is a vector of means of Z.

In this approach, instruments can be either weak or strong, depending on the degree of heteroscedasticity in the data. To detect heteroscedasticity, we use Breusch-Pagan test (Lewbel, 2012). To assess the strength of these generated instruments, we employ standard tests designed for weak instruments (Stock and Yogo, 2005). As the method may produce a mix of strong and weak instruments, it benefits to remove weak instruments from the set. To identify weak instruments, we check if the absolute value of the instrument's t-statistic is less than 1.96 in first-stage.

For our analyses, we use Stata-MP 18th version and employ “ivreg2h” command, which utilizes the two-step feasible generalized method of moments (GMM) estimation and compare the results with ordinary least squares with fixed effects (OLS-FE) (Lewbel, 2012).[8] To address any potential downward bias in standard errors due to serial correlation, we cluster by country pairs, as suggested by Angrist and Pischke (2009). Additionally, Petersen (2009) proposes clustering to avoid bias in standard errors when considering both the correlation of observations within clusters and within time periods. This is achieved by including time dummies. Further as test for robustness using continuous treatment matching, we estimate “Dose Response Function – Generalized Propensity Score Matching” which is estimated by a third-degree polynomial approximation.

3. Descriptive Statistics

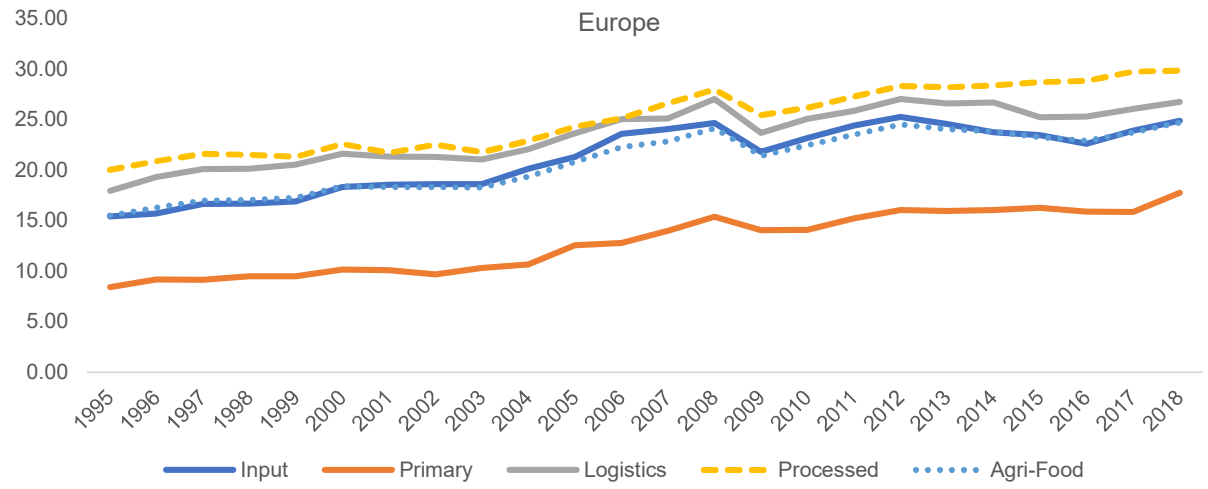
Between 1995 and 2018, there was an overall increase in average product diversification, except in Europe, where it declined slightly. In all regions there was intensification with greater usage of agricultural inputs, specifically fertilizers, that increased by more than 30% across all regions (except Europe). The usage of pesticides nearly doubled for North, South, and Central America with a marginal increase in East and Southeast Asia and a decline for Europe.

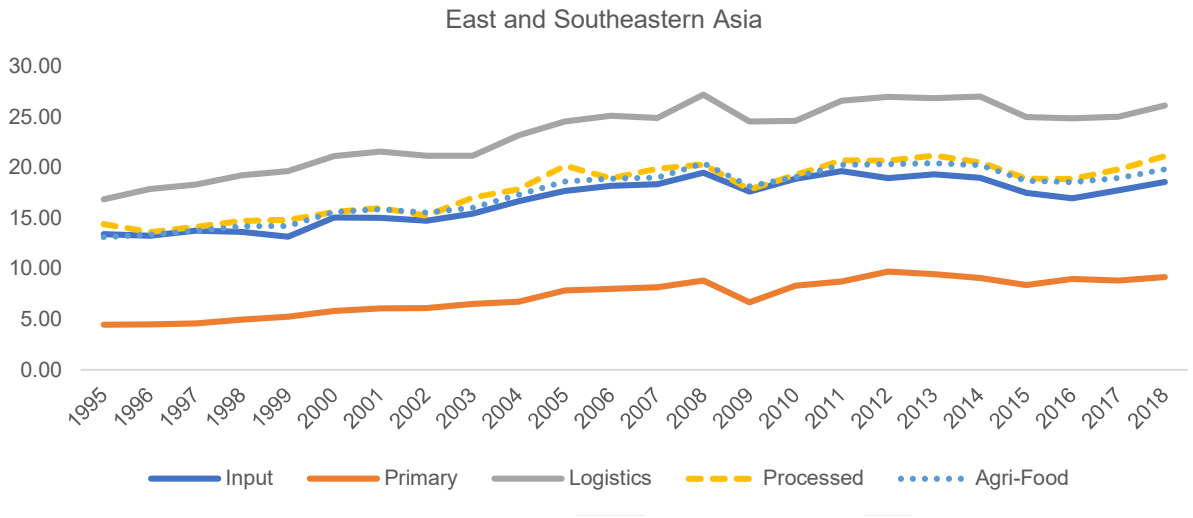
Furthermore, value added/worker, FDI inflows in agriculture, GDP per capita, and internet usage all exhibited an upward trajectory. Additionally, there was a significant decrease in share of emissions from agri-food sector. Import tariff rates demonstrated considerable volatility across multiple industries, including agriculture, fisheries, food and beverages, fertilizer, and machinery. In measuring the business environment, the uncertainty index faced by all regions displayed an increase in volatility.

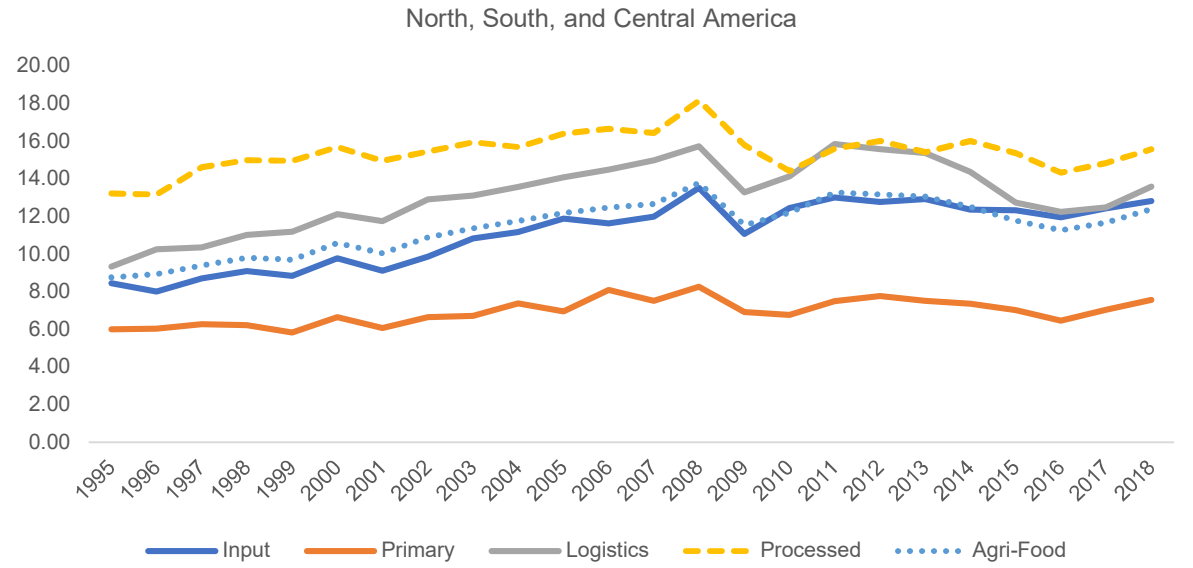
[8] We performed the analysis on high end computer using Amazon Web Services.

Figure 2 shows backward GVC (BGVCs) and highlights variation across stages of production in agri-food sector. The prominence of BGVCs is observed in all regions, indicating the significance of FVA in production of final goods. The prevalence increased from 1995 to 2018 with a slight dip during crisis periods of 2007-08. The share of BGVCs is relatively lower in primary producers, followed by input industries. However, this share has increased over time, indicating a shift towards greater participation in BGVCs. On the other hand, the intensity of involvement in processed and logistic industries is higher but exhibits considerable variability. Overall, these figures highlight the importance of FVA, the varying levels of participation across stages of production.

Figure 2: Backward GVC (%) – Region Wise




East and Southeastern Asia
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Input
Primary
Logistics
Processed
Agri-Food


North, South, and Central America
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
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1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Input
Primary
Logistics
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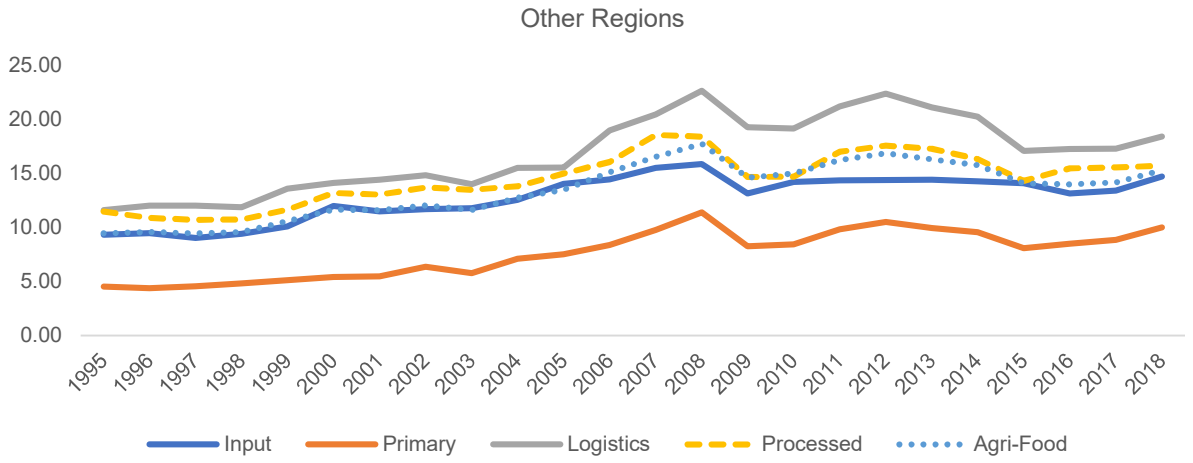
Agri-Food


Other Regions
25.00
20.00
15.00
10.00
5.00
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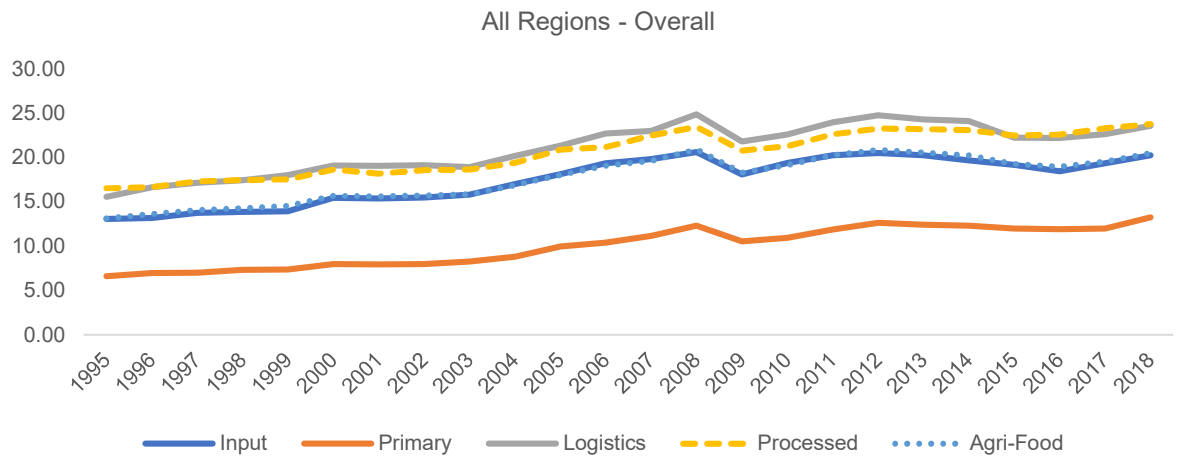
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Input
Primary
Logistics
Processed
Agri-Food



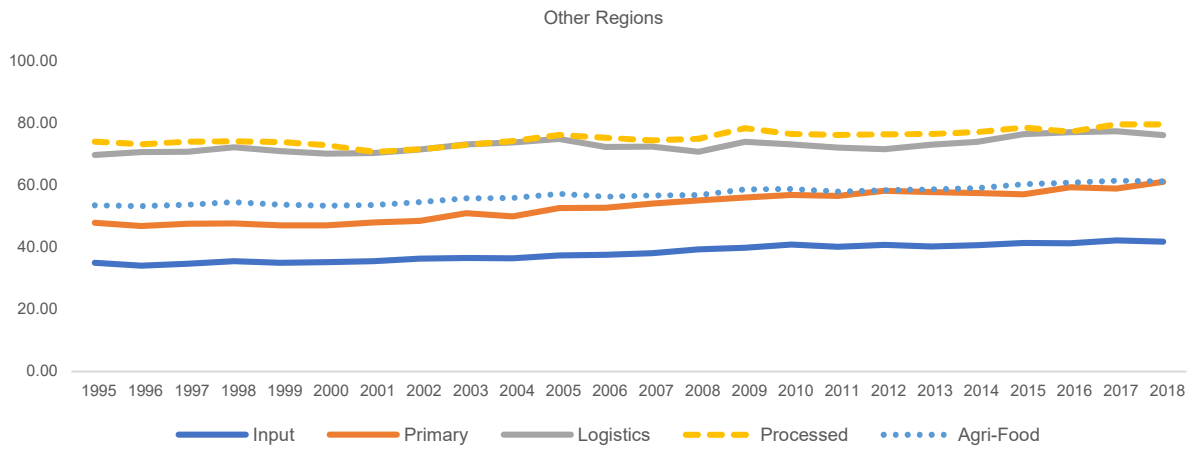
Source: OECD-TiVA 2021 Database
Note: Authors Calculation

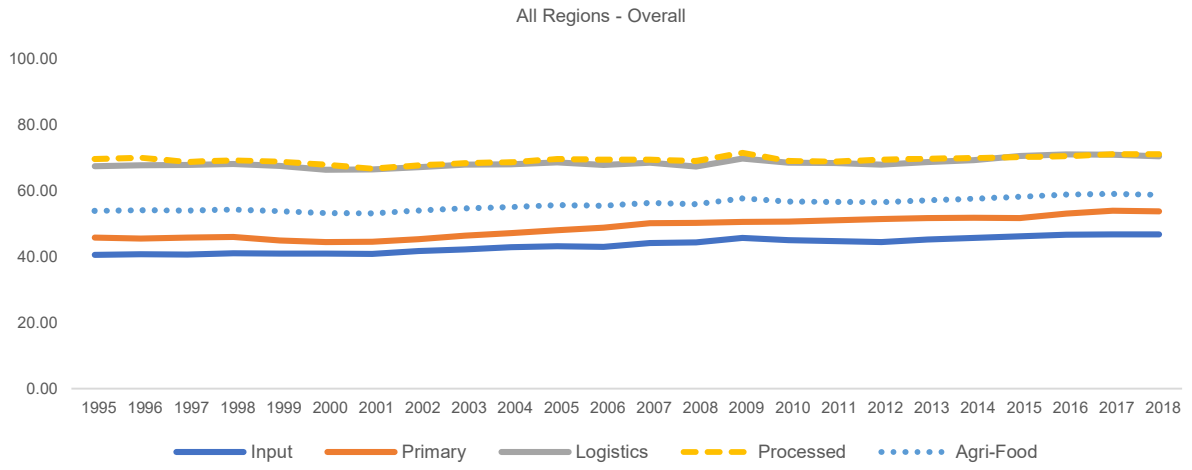
Figure 3 presents forward GVC (FGVCs), which are higher than BGVCs for all regions and industries. Across sectors, primary and processed sectors were more involved in upstream participation, the input and logistic sectors had more involvement in downstream. In simpler terms, primary sector (agriculture and fisheries) and the processed food sector tend to have more connections with suppliers forward in production process, while input and logistic sector (transportation and warehouses) have more connections with buyers in the backward stages of production. However, this engagement both upstream and downstream is not fixed to a particular stage; it can change over time based on domestic industries, global trade dynamics, product preferences, and country partners. Europe and North, South, and Central America exhibit significant FGVC participation across all stages. The North, South, and Central America region leads in all stages except the primary sector, with Europe, other regions, and East and Southeastern Asia following suit.

Such positioning in the GVC is expected because the food and beverage industry involves more processing, distribution, and processes like labeling, grading and certification which require inputs from suppliers in the chain. Positioning in GVC, level of downstream and upstream participation also varies across regions. European countries tend to have high participation in both FGVC as well as BGVC possibly due to European Union (EU) membership, while African countries have a

relatively higher share of FGVC participation. South and Southeast Asian countries show relatively high FGVC participation. Additionally, North America displays relatively high BGVC participation, while South America displays relatively high BGVC participation in both sectors (Lim and Kim 2022).

Figure 3: Forward GVC (%) – Region Wise

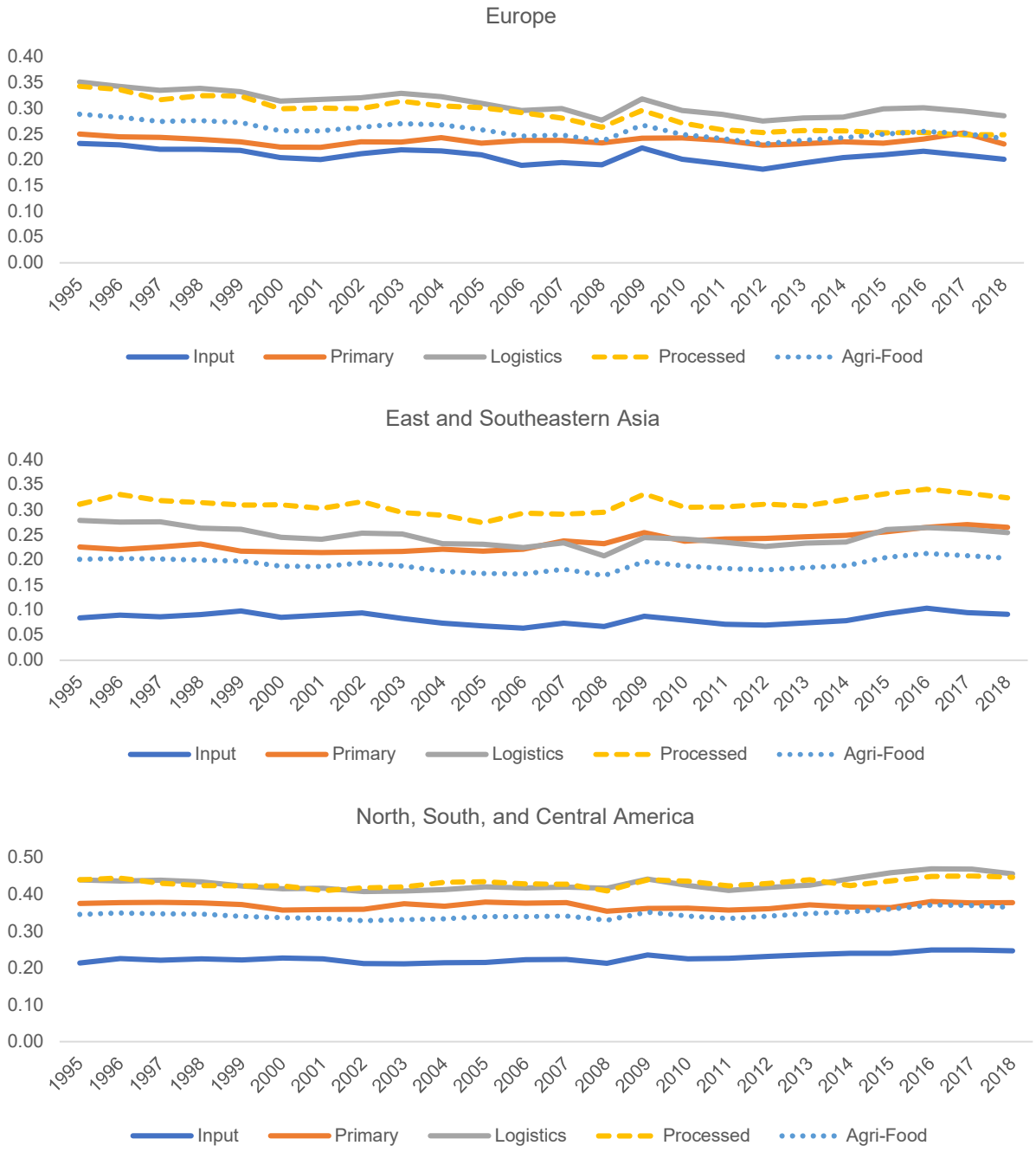


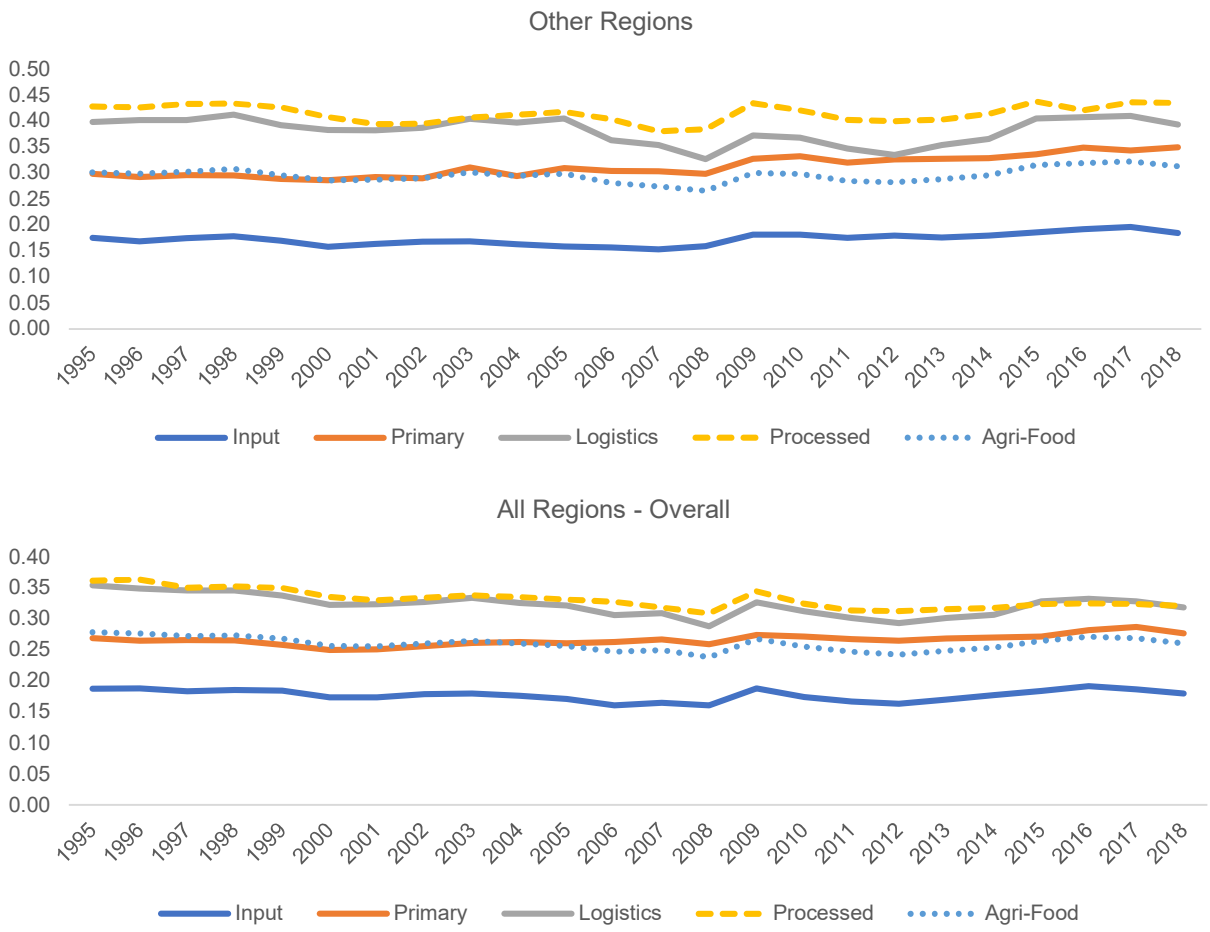


Source: OECD-TiVA 2021 Database
Note: Authors Calculation

Figure 4 shows GVC positioning, which indicates how specialized a country is in activities closer to final demand i.e., in terms of the number of production stages involved (Antras and Chor 2018). Processed and logistics sectors have higher scores on upstreamness compared to the input and primary sector in all regions. The positioning depends on the length of the production chains. Between 1995 and 2018, upstreamness of all sectors gradually decreased, indicating a trend towards more downstream activities. Europe stands out as being more volatile, with a greater shift towards downstreamness during this period. In contrast, North, South, and Central America primary and processed sectors remained relatively flat from 1995 to 2018.

Figure 4: GVC Positioning in log values [(upstream; positive slope) or (downstream; negative slope)] – Region Wise





Source: OECD-TiVA 2021 Database
Note: Authors Calculation

4. Econometric Analysis

4.1. Factors affecting AGVC and FDI's effects.

This section presents results on the determinants of participation (BGVC, FGVC, and GVC positioning) including FDI in agriculture, and its effect on production diversification. The first stage parameters reflect the factors affecting GVC participation and positioning (Table 1). In the second stage, we get parameters by choice of instruments i.e., system generated, or using lagged levels and differences of the regressors via a two-step generalized method of moments (GMM) estimator (Table 2).

Agricultural input use is positively associated with GVC participation. Within GVCs, agricultural inputs that are produced in different countries. often cross borders to be used in intermediate and

processed goods It requires coordination among farmers, processors, traders, and retailers that may be driven by the end buyers like supermarkets and food processors, or by the suppliers at the beginning (upstream), such as farmers or farmer cooperatives (Swinnen and Maertens, 2007; Reardon et al. 2003).

Agriculture value added/worker is positively associated with BGVC and FDI (0.3) (table 1).[9] FGVC, and GVC participation which reflect the increased demand for skilled labor in downstream as well as upstream stages of GVC. The study by Farole et al (2018) also finds greater return to skilled labor being correlated with GVC on the buying side. Our study adds that demand for skilled labor extends to the selling side as well.

Globally, the proportion of women employed in agriculture has declined from 42% in 1991 to 25% in 2021.[10] The major factor is comparatively low wage and working conditions in farm and non-farm sector. Women prefer to engage in services such as health and education (Alon et al., 2020, Roy, et al., 2022 and Saroj et al.,2022). Table 1 shows share of female employment in agriculture being negatively associated with FGVC. In some regions, disadvantage for women could be compounded by skill deficit, low access to capital which may hamper accessing jobs in GVC. The advantages of women participation in GVCs might be on the extensive margin i.e., higher number of jobs rather than new opportunities created in high paying jobs in processing or manufacturing sector (Bamber and Staritz, 2016).

Humans caused 16.5 billion tons GHG emission that originated from agri-food systems, 7.2 billion tons came from within farm gate, 3.5 billion tons from land use change, and 5.8 billion tons from supply-chain processes.[11] Table 1 shows negative association between emissions and AGVC participation. Environmental footprints primarily lie in purchases, materials and services required

[9] Number in parenthesis represents elasticity.
[10] World Development Indicator - https://data.worldbank.org/indicator/SL.AGR.EMPL.FE.ZS
11 FAO Statistics, 2019 - https://www.fao.org/faostat/en/#data

for production or consumption which fall in the upstream or forward linkages (Berners-Lee et al. 2011).

Important trade barriers comprise tariffs, transportation cost, border costs(taxes/fees), insurance cost and hidden barriers like lack of trust.[12] The trade cost amplifies as products go from one segment to other in the value chain, as trade cost accumulate. It is reflected in our result, the coefficient of cost to trade is positive and significant in FGVC, GVC participation and GVC positioning. In contrast, the coefficient of cost to trade is negative for BGVC (8.8) as well as FDI (0.3) which gives boost to production for primary rather than final products. In an ideal scenario, the cost to trade should be lower for upstream for better integration into GVC. Hummels and Schaur (2013) demonstrate that industries in which GVCs play a significant role tend to be highly affected by time and cost to trade.

Trade policy volatility can be a major impediment to trade and GVC participation. When tariffs are imposed, it leads to higher input costs for the domestic producers. Taking India as an example, the average tariff imposed on agricultural commodities is higher than for example Viet Nam and other countries resulting in high input costs and it reflects in GVC participation. We find statistically significant negative coefficient of tariff imposed for BGVC (3.7) when production process could be comparatively dependent on foreign inputs. In BGVC, producers pay tariffs on their imported inputs and may further face tariffs on exports. Hence producers may want to position in BGVC, far away from the final product to avoid tariff escalation. However, for FDI (0.5), we find a positive coefficient of tariff, possibly providing foreign businesses an advantage by limiting competition.

In understanding GVCs and economic development, institutions have been recognized as crucial factors (North, 1990; Knack and Keefer, 1997; Acemoglu et al., 2001, 2005). As GVCs extend across borders, institutions across countries in rule of law, corruption, regulation, and politics

[12]Trade Costs Dataset by the World Bank provides estimates of bilateral trade costs in agriculture and manufactured goods. It is built on trade and production data collected in over 200 countries. Symmetric bilateral trade costs are computed using the Inverse Gravity Framework (Novy 2009), which estimates trade costs for each country pair using bilateral trade and gross national output.

affect GVC. Kaufmann et al (2010) developed Governance Indicators comprising voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption and show that agri-food sector tends to have greater involvement in GVCs and FDI where institutions are stronger.

Our results also indicate a positive association between GDP/capita with AGVC participation as well as FDI in the agri-food sector. Higher GDP/capita may help in access to technology, skills, and income to meet the cost of imports of raw materials (Felice and Tajoli 2021; Kazunobu and Hiroshi 2021).

On the infrastructure side, digital economy has opened prospects for small firms, agri-food traders, processors, and farmers. Digitization has brought significant changes in resource allocation reducing trade cost and addressing information asymmetry in agri-food trade (Pan et al., 2022). It can help GVC by facilitating connection with international and domestic markets through reduction in cost to trade. We do find a positive association between internet penetration and BGVC participation. Whereas in FGVC it is the opposite possibly due to higher non-agriculture GVC participation with rise in internet penetration and higher costs of internet usage in countries that could impede small businesses and farmers from harnessing benefits of the internet for FGVC participation when profit margins are thin.

The frequent disruptions and unexpected events resulting in increased uncertainty has caused shifts in global trade flows and even led to reversals in trade diplomacy e.g., during Global Financial Crisis, Covid, Russia-Ukraine War. We use the World Uncertainty Index for both the reporting as well as partner country to assess how uncertainty affects AGVC participation and FDI in agriculture.

Results indicate a positive association between BGVC participation in agri-food sector and index of uncertainty in reporting country. While trading, with greater uncertainty in partner country

relative to reporting country, firms or agri-food producers may choose the upstream segment of the value chain as greater investment characterizes downstream activities. The same holds if uncertainty is higher for reporting country relative to partner countries. In this context, the partnering country aims to engage with trading partners that offer reduced levels of uncertainty. Expectedly, there is a negative association between the world uncertainty index and FDI including in the agri-food sector.

Table 1: Factors affecting BGVC, FGVC, GVC Participation, GVC Positioning and FDI– Estimates from first stage of Lewbel Method

Variables	BGVC	FGVC	GVC Participation	GVC Positioning	FDI
	Coef	Coef	Coef	Coef	Coef
Input use (tons/ha)	0.024***	0.002***	0.001***	0.001***	0.084***
	(0.003)	(0.001)	(0.000)	(0.000)	(0.039)
Agriculture value added/worker	0.060***	0.035***	0.023***	0.016***	0.003***
	(0.010)	(0.002)	(0.002)	(0.002)	(0.000)
Share of female in agriculture	-0.075***	-0.046***	0.030***	0.030***	0.204***
	(0.009)	(0.002)	(0.002)	(0.002)	(0.034)
Emission share agri-food systems	-0.045***	-0.029***	-0.020***	-0.015***	-0.006***
	(0.006)	(0.001)	(0.001)	(0.001)	(0.001)
Cost to trade	-0.088***	0.021***	0.016***	0.014***	-0.003**
	(0.002)	(0.000)	(0.000)	(0.000)	(0.001)
Tariff	-0.037***	0.008***	0.006***	0.004***	0.005***
	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
Voice/accountability index	0.030***	0.002***	0.001***	0.001***	0.001***
	(0.008)	(0.000)	(0.000)	(0.000)	(0.000)
Political stability index	-0.038***	0.036***	0.033***	0.023***	-0.001***
	(0.007)	(0.014)	(0.013)	(0.012)	(0.000)
Government effectiveness index	-0.012	0.015	0.017	0.014	-0.002***
	(0.014)	(0.010)	(0.010)	(0.011)	(0.000)
Regulatory quality index	0.055***	-0.000	-0.000	-0.000	-0.899***
	(0.013)	(0.000)	(0.000)	(0.000)	(0.026)
Rule of law index	-0.066***	0.001***	0.001***	0.001***	0.479***
	(0.014)	(0.000)	(0.000)	(0.000)	(0.030)
Control of corruption index	-0.031***	0.001***	0.001***	0.001***	0.001***
	(0.008)	(0.000)	(0.000)	(0.000)	(0.000)
GDP per capita	0.091***	0.001***	0.002***	0.001***	0.001***
	(0.010)	(0.000)	(0.000)	(0.000)	(0.000)
internet penetration	0.033***	-0.002***	-0.002***	-0.002***	-0.074***
	(0.002)	(0.001)	(0.000)	(0.000)	(0.004)
WUI — Partner Country	0.245***	0.038***	0.030***	0.027***	0.012
	(0.026)	(0.005)	(0.004)	(0.004)	(0.023)
WUI — Reporting Country	0.048***	-0.022***	-0.014***	-0.012***	-0.356***
	(0.011)	(0.002)	(0.002)	(0.002)	(0.024)
Observations	17.424	17.424	17.424	17.424	17.424
R-squared	0.827	0.458	0.722	0.358	0.425
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Region-wise factors affecting BGVC, FGVC, GVC Participation, GVC Positioning and FDI are not reported due to brevity, are available upon request.

4.2. GVCs and outcomes

Above, we assessed factors affecting AGVC participation including FDI in agri-food sector based on the first stage of Lewbel method. In this section, we assess the effect of GVCs on outcomes viz. production diversification (Tables 2 and 3). Columns M1-M4 report coefficients from Lewbel method, M1 presents “generated instruments” whereas M2-M4 present coefficient from 2-step GMM estimation (lagged instruments) and M5 reports the results from panel fixed effects method post Hausman test.

The specifications control for country, time and industry fixed effects, and other covariates such as world policy (trade) uncertainty index, input cost, agricultural value added/worker, female employment share in agriculture, emission share in agri-food systems, cost to trade, tariff imposed, governance index (voice and accountability, political stability, government effectiveness, regulatory quality, rule of law and control of corruption) and digitization (percentage of individuals using internet) with country pair wise clustering to account for variations related to unobservable factors.

4.2.1. GVCs and Production Diversification

Our estimates in table 2 indicate a positive and statistically significant association between product diversification and AGVC participation with the association is most pronounced in East and Southeast Asia, followed by North, South, and Central America, Europe, and other regions. If participating in AGVC brings income growth through both backward and forward linkages, farmers may tend to diversify their crop selection, access to inputs, and food preferences. Diversifying crop selection enhances nutrition sensitivity (shifting to nutri-cereals) by boosting dietary variety and agricultural output. Also, there are changes in attributes of demand comprising safety, quality, health, and convenience. These factors collectively affect the spillovers and the potential for crop diversification associated with AGVC participation particularly for firms positioned upstream in value chain (Nadvi, 2004; Montalbano and Nenci, 2020).

Several studies have argued for forward integration expanding activities upstream and enhancing the competitiveness and resilience of producers. Considered as a form of vertical integration, this aims at reducing risk and increasing income of value chain actors. There could also be engagement in functions, or activities further downstream. This strategy is often categorized as vertical diversification, involving the expansion of production activities to include processing and packaging within the value chain (Gibbon, 2001; Humphrey and Schmitz, 2002; Barghouti et al., 2004; Sexton et al., 2007; Aneani et al., 2011; Chang and Iseppi, 2012; Kray et al., 2018; Del Prete and Rungi, 2020). Small farmers in developing countries may find crop diversification a comparatively feasible option over forward integration because of challenges in resource-constrained settings.

Table 2: GVCs and Production Diversification

Outcome Variable →	**Production Diversification**				
	Lewbel Method				**OLS – Fixed Effects Model**
Models →	**Generated Instruments**	**2-Step GMM Estimation (Lagged Instruments)**			
	M1	**M2**	**M3**	**M4**	**M5**
All Regions					
Backward GVC	0.042*** (0.004)	0.714*** (0.056)	0.020*** (0.002)	0.022*** (0.002)	0.017*** (0.001)
Forward GVC	0.024 (0.015)	0.313*** (0.352)	0.016** (0.008)	0.002 (0.008)	0.090*** (0.007)
GVC Participation	0.000 (0.000)	0.015*** (0.004)	0.000* (0.000)	0.000 (0.000)	0.001*** (0.000)
GVC Positioning	0.001** (0.000)	0.018*** (0.005)	0.000* (0.000)	0.000 (0.000)	0.001*** (0.000)
Europe					
Backward GVC	0.005 (0.003)	0.380*** (0.044)	0.001 (0.002)	0.006*** (0.002)	0.041*** (0.002)
Forward GVC	0.048*** (0.005)	0.876*** (0.396)	0.013* (0.008)	0.011 (0.008)	0.024*** (0.008)
GVC Participation	0.001*** (0.000)	0.021*** (0.004)	0.000* (0.000)	0.000* (0.000)	0.000*** (0.000)
GVC Positioning	0.000 (0.000)	0.026*** (0.006)	0.000 (0.000)	0.000 (0.000)	0.001*** (0.000)
East and Southeastern Asia					
Backward GVC	0.052*** (0.012)	0.877*** (0.078)	0.032*** (0.006)	0.004 (0.004)	0.119*** (0.004)
Forward GVC	0.090*** (0.007)	0.269*** (1.008)	0.013 (0.022)	0.032 (0.020)	0.080*** (0.019)
GVC Participation	0.001*** (0.000)	0.092*** (0.013)	0.000 (0.000)	0.000 (0.000)	0.001** (0.000)
GVC Positioning	0.001 (0.001)	0.131*** (0.017)	0.000 (0.000)	0.000 (0.000)	0.002*** (0.000)
North, South, and Central America					
Backward GVC	0.006	0.312***	0.004	0.010***	0.031***

Outcome Variable →	Production Diversification				
	Lewbel Method				OLS – Fixed Effects Model
Models →	Generated Instruments	2-Step GMM Estimation (Lagged Instruments)			
	M1	M2	M3	M4	M5
All Regions					
	(0.005)	(0.019)	(0.003)	(0.001)	(0.003)
Forward GVC	0.048***	0.167***	0.029***	0.030***	0.119***
	(0.005)	(0.319)	(0.011)	(0.010)	(0.013)
GVC Participation	0.001***	0.017***	0.000**	0.000***	0.001***
	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)
GVC Positioning	0.001**	0.021***	0.000**	0.001***	0.002***
	(0.000)	(0.005)	(0.000)	(0.000)	(0.000)
Other Region					
Backward GVC	0.008	0.116***	0.017***	0.018***	0.001
	(0.005)	(0.011)	(0.004)	(0.002)	(0.003)
Forward GVC	0.090***	0.753	0.028**	0.040***	0.023*
	(0.007)	(0.498)	(0.014)	(0.014)	(0.012)
GVC Participation	0.001***	0.007	0.000**	0.001***	0.000**
	(0.000)	(0.006)	(0.000)	(0.000)	(0.000)
GVC Positioning	0.001**	0.006	0.001**	0.001***	0.001**
	(0.000)	(0.008)	(0.000)	(0.000)	(0.000)
Control Variable and Fixed Effect					
Control Variables	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: M1 – Lewbel generated instruments; **M2** – Standard IV; **M3** – Generated Instruments; **M4**- Generated and Standard IV, **M5** – Fixed Effects; **Controls:** World policy (trade) uncertainty index, input cost, agricultural value added per worker, female employment share in agriculture, emission share in agri-food systems, cost to trade, tariff imposed, governance index (voice and accountability, political stability, government effectiveness, regulatory quality, rule of law and control of corruption) digitization (%age using internet).

4.2.2. FDI and AGVCs

FDI in agriculture may affect the structure and organization of AGVCs. FDI growth in agri-food sector has been driven primarily by policy changes, such as the liberalization of investment, trade, and reduction in trade-distorting agricultural subsidies after the Uruguay round. These changes have enabled countries to access a wider range of imported intermediate inputs (Greenville et al 2019; OECD, 2019).

Furthermore, proliferation of public and private standards has played a role in promoting trade by addressing information gaps between trading partners and focusing on aspects such as food quality, safety, ethics, and environmental concerns (Maertens and Swinnen, 2008; Swinnen and Vandeplas, 2009). The impact of FDI on AGVCs however may depend on the nature of investment, including whether the production requires imported intermediate inputs and whether

the final goods or intermediates produced are destined for exports. These factors determine the extent to which FDI influences the flow of goods, services, and technologies within the agri-food GVCs.

Table 3 shows a positive and statistically significant relationship between FDI and AGVCs. Notably, the findings particularly show the association with FGVC, which involves integration of value added from exports into third-country exports. This underscores the pivotal role played by FDI in bolstering productivity and enabling upstream industries in international trade. Conversely, the association between FDI and BGVC participation, which entails the utilization of imports in the production of exports, exhibits a more complex relationship in terms of getting long term investment and requires continuous process in maintaining the standards in agri-food sector. On average FDI in the agri-food sector seems to promote exports to industries further along the value chain, resulting in increased integration within AGVCs.

The results on FDI and GVCs also support some of the earlier findings in the literature such as Kowalski et al. (2015) who also observe a positive and significant relationship between FDI openness and participation in both backward and forward stages of AGVC. FDI, when targeted towards establishing export-processing facilities, can stimulate backward linkages while when aimed at accessing natural resources can promote forward linkages. FDI presents with the opportunity to engage in GVCs, amplify domestic value added, and harness the benefits of knowledge transfer, technology diffusion, and enhanced market access by capitalizing on the potential synergies between FDI and GVCs, there can be multiplier effects.

Table 3: FDI and GVCs

Outcome Variables →		BGVC		FGVC		GVC Participation		GVC Positioning	
Models		**Coef**	**SE**	**Coef**	**SE**	**Coef**	**SE**	**Coef**	**SE**
All Regions									
Generated Instruments	M1	0.000	(0.000)	0.001***	(0.000)	0.001***	(0.000)	0.000***	(0.000)
2-Step GMM	M2	0.337***	(0.047)	0.970***	(0.268)	0.982***	(0.265)	0.417**	(0.194)
Estimation (Lagged	M3	0.013***	(0.005)	0.103*	(0.061)	0.108*	(0.060)	0.044	(0.044)
Instruments)	M4	0.015***	(0.005)	0.142**	(0.060)	0.148**	(0.060)	0.066	(0.044)
OLS – Fixed Effects Model	M5	0.015***	(0.001)	0.113***	(0.022)	0.113***	(0.022)	0.068***	(0.015)
Europe									
Generated Instruments	M1	0.000	(0.000)	0.001***	(0.000)	0.001***	(0.000)	0.000***	(0.000)
2-Step GMM	M2	0.156***	(0.058)	0.483	(0.417)	0.687	(0.422)	0.073	(0.304)
Estimation (Lagged	M3	0.003	(0.010)	0.099	(0.082)	0.095	(0.080)	0.039	(0.062)
Instruments)	M4	0.001	(0.009)	0.044	(0.081)	0.037	(0.079)	0.006	(0.061)
OLS – Fixed Effects Model	M5	0.009***	(0.001)	0.159***	(0.032)	0.158***	(0.032)	0.098***	(0.022)
East and Southeastern Asia									
Generated Instruments	M1	0.000	(0.000)	0.003***	(0.000)	0.003***	(0.000)	0.002***	(0.000)
2-Step GMM	M2	0.084*	(0.045)	1.181***	(0.295)	1.158***	(0.292)	0.634***	(0.215)
Estimation (Lagged	M3	0.004	(0.009)	0.287***	(0.102)	0.282***	(0.101)	0.171**	(0.074)
Instruments)	M4	0.004	(0.009)	0.365***	(0.105)	0.355***	(0.104)	0.226***	(0.075)
OLS – Fixed Effects Model	M5	0.010***	(0.001)	0.107***	(0.041)	0.108***	(0.041)	0.072**	(0.029)
North, South, and Central America									
Generated Instruments	M1	0.000	(0.000)	0.001***	(0.000)	0.001***	(0.000)	0.000***	(0.000)
2-Step GMM	M2	0.253***	(0.044)	1.110*	(0.600)	1.224**	(0.606)	0.642*	(0.426)
Estimation (Lagged	M3	0.022*	(0.011)	0.013	(0.201)	0.010	(0.202)	0.063	(0.142)
Instruments)	M4	0.028**	(0.011)	0.111	(0.196)	0.139	(0.197)	0.023	(0.138)
OLS – Fixed Effects Model	M5	0.008***	(0.002)	0.070	(0.098)	0.072	(0.098)	0.057	(0.068)
Other Region									
Generated Instruments	M1	0.000	(0.000)	0.001***	(0.000)	0.001***	(0.000)	0.000***	(0.000)
2-Step GMM	M2	0.051	(0.041)	2.422***	(0.438)	2.389***	(0.436)	1.585***	(0.310)
Estimation (Lagged	M3	0.020**	(0.010)	0.076	(0.214)	0.083	(0.212)	0.039	(0.150)
Instruments)	M4	0.021**	(0.010)	0.085	(0.205)	0.077	(0.204)	0.068	(0.144)
OLS – Fixed Effects Model	M5	0.031***	(0.002)	0.279***	(0.077)	0.276***	(0.077)	0.178***	(0.054)
Control Variables		Yes		Yes		Yes		Yes	
Country FE		Yes		Yes		Yes		Yes	
Year FE		Yes		Yes		Yes		Yes	
Industry FE		Yes		Yes		Yes		Yes	

Source: Author's calculations

Note: M1 – Lewbel generated instruments; **M2** – Standard IV; **M3** – Generated Instruments; **M4**- Generated and Standard IV, M5 – Fixed Effects; **Control variables:** Same as table 2

5. Heterogeneous Effects by Stages of Value Chain

To account for heterogeneity across industries, we estimate the above relationships viz. input, primary, logistics, and processed levels. Using the Lewbel method, for brevity tables 4 and 5 present only the results of system-generated instruments unlike Tables 2 and 3. In Table 4 and 5, notable differences in coefficients exist compared to Tables 2 and 3. In the case of the processed-segment, we find a negative coefficient associated with BGVC and crop diversification. This implies that domestic policies, such as farm subsidies and support prices for staple foods, may play a role in determining the extent of diversification.

Table 4: GVCs on production diversification by stages

Outcome Indicator →	**Production Diversification**			
Stages of Value Chains	**Inputs**	**Primary**	**Logistics**	**Processed**
All Regions				
BGVC	-0.043***	-0.031***	-0.002	-0.012***
	(0.004)	(0.004)	(0.002)	(0.003)
FGVC	0.040***	-0.041**	0.070***	0.110***
	(0.011)	(0.019)	(0.012)	(0.021)
GVC Participation	0.030***	-0.056***	0.049***	0.075***
	(0.011)	(0.019)	(0.012)	(0.021)
GVC Positioning	0.045***	-0.065**	0.098***	0.130***
	(0.016)	(0.028)	(0.017)	(0.029)
Europe				
BGVC	-0.022***	-0.007	-0.019***	-0.003
	(0.003)	(0.004)	(0.002)	(0.003)
FGVC	-0.036***	0.009	0.060***	-0.001
	(0.010)	(0.018)	(0.010)	(0.017)
GVC Participation	-0.023**	0.015	0.041***	0.032*
	(0.010)	(0.018)	(0.010)	(0.018)
GVC Positioning	-0.054***	0.027	0.075***	-0.004
	(0.014)	(0.026)	(0.014)	(0.024)
East and Southeastern Asia				
BGVC	-0.003	0.017***	0.039***	0.020***
	(0.005)	(0.005)	(0.003)	(0.003)
FGVC	0.110***	0.054*	0.042	0.189***
	(0.030)	(0.032)	(0.026)	(0.034)
GVC Participation	0.057*	0.025	-0.023	0.053
	(0.031)	(0.034)	(0.028)	(0.039)
GVC Positioning	0.177***	0.042	0.063*	0.256***
	(0.049)	(0.047)	(0.038)	(0.047)
North, South, and Central America				
BGVC	-0.022***	-0.019***	0.000	0.001
	(0.002)	(0.002)	(0.000)	(0.000)
FGVC	-0.051**	-0.094***	0.001	-0.009
	(0.026)	(0.026)	(0.013)	(0.018)
GVC Participation	-0.045*	-0.040	0.030**	-0.037*
	(0.027)	(0.028)	(0.015)	(0.019)
GVC Positioning	-0.086**	-0.136***	0.005	0.008
	(0.038)	(0.037)	(0.019)	(0.024)

Outcome Indicator →	Production Diversification			
Stages of Value Chains	**Inputs**	**Primary**	**Logistics**	**Processed**
Other Region				
BGVC	-0.012***	-0.026***	0.007***	0.019***
	(0.001)	(0.002)	(0.001)	(0.003)
FGVC	0.085***	-0.228***	0.083***	0.154***
	(0.017)	(0.038)	(0.018)	(0.028)
GVC Participation	0.031	-0.059	0.061***	0.075**
	(0.020)	(0.043)	(0.019)	(0.031)
GVC Positioning	0.103***	-0.332***	0.113***	0.210***
	(0.024)	(0.057)	(0.024)	(0.038)

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

In primary based industry (agriculture and fisheries), we find a negative coefficient associated with FDI and FGVC participation. This is likely due to limited investment in these sectors where large investments could be required. If the cost of imported intermediates were to increase due to high tariffs in the primary sector, it can hinder FDI (Table 5). The differences in estimates across regions may reflect the influence of domestic policies across regions.

Table 5: FDI on measures of GVCs

Outcome Indicators →	Measures of GVCs			
Stages of Value Chains→	**Inputs**	**Primary**	**Logistics**	**Processed**
All Regions				
BGVC	-0.001	-0.001	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
FGVC	0.009	-0.048*	0.033*	0.079***
	(0.013)	(0.025)	(0.018)	(0.029)
GVC Participation	0.007	-0.049*	0.032*	0.079***
	(0.013)	(0.025)	(0.017)	(0.029)
GVC Positioning	0.005***	-0.001	0.006**	0.015***
	(0.002)	(0.004)	(0.003)	(0.004)
Europe				
BGVC	0.001	-0.002	0.002***	0.001
	(0.001)	(0.002)	(0.001)	(0.001)
FGVC	-0.001***	-0.000	-0.000***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
GVC Participation	-0.001***	-0.000	-0.000***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
GVC Positioning	-0.001***	-0.000	-0.000***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
East and Southeastern Asia				
BGVC	-0.013***	0.001	-0.005***	-0.005
	(0.002)	(0.003)	(0.002)	(0.005)
FGVC	0.001***	0.007***	0.001***	0.001
	(0.000)	(0.001)	(0.000)	(0.001)
GVC Participation	0.001***	0.007***	0.001***	0.001
	(0.000)	(0.001)	(0.000)	(0.001)
GVC Positioning	0.001**	0.005***	0.001***	0.001
	(0.000)	(0.001)	(0.000)	(0.000)
North, South, and Central America				
BGVC	0.005	-0.002	0.001	0.004
	(0.003)	(0.005)	(0.003)	(0.003)

Outcome Indicators →	Measures of GVCs			
Stages of Value Chains→	**Inputs**	**Primary**	**Logistics**	**Processed**
All Regions				
FGVC	-0.002**	-0.001	0.000	-0.001
	(0.001)	(0.001)	(0.000)	(0.001)
GVC Participation	-0.002**	-0.001	0.000	-0.001
	(0.001)	(0.001)	(0.000)	(0.001)
GVC Positioning	-0.001**	-0.000	0.000	-0.000
	(0.000)	(0.001)	(0.000)	(0.000)
Other Region				
BGVC	0.005*	-0.010***	-0.000	-0.004
	(0.003)	(0.004)	(0.003)	(0.003)
FGVC	-0.000	-0.002**	0.001	0.000
	(0.001)	(0.001)	(0.000)	(0.001)
GVC Participation	-0.000	-0.002**	0.001	0.000
	(0.001)	(0.001)	(0.000)	(0.001)
GVC Positioning	-0.000	-0.001**	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Note: Coefficient based on Lewbel generated instruments

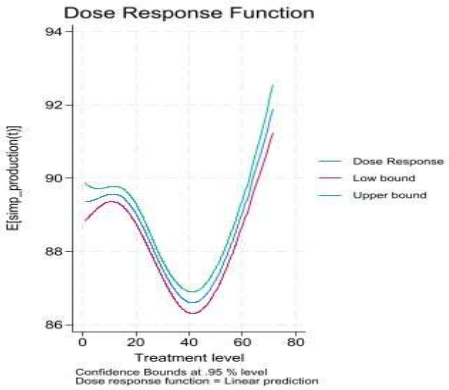
6. Robustness Check – Dose Response Function

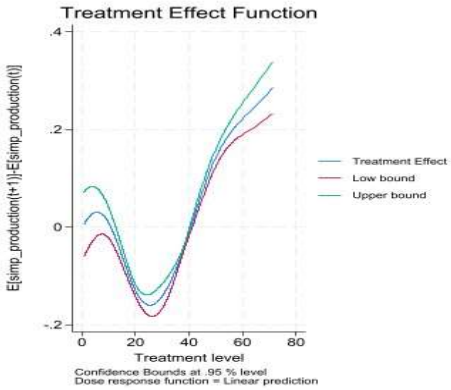
A concern in using System GMM and fixed effects may be the reliance only on internal instruments. As a test of robustness, we employ generalized propensity score (GPS) matching methods and estimate the dose response function (DRF) (Rosenbaum and Rubin, 1983; Imbens, 2001; Hirano and Imbens, 2004).

Examining the DRFs for various ranges of GVC measures, we observe that product diversification displays an upward trend after surpassing specific thresholds (Figure 5). The positioning of GVCs within the value chain emerges as a critical factor, and significant shifts in GVC measures can yield substantial effects on production diversification. Noteworthy aspects of the DRFs include their relatively precise estimation, as evidenced by the narrow confidence intervals. However, at higher or lower levels of GVC measures where observations are limited, the DRFs exhibit wider intervals due to fewer observations.

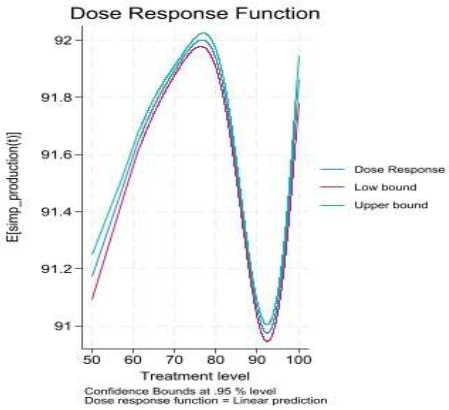
Figure 5: GVCs on Production Diversification– Dose Response Function

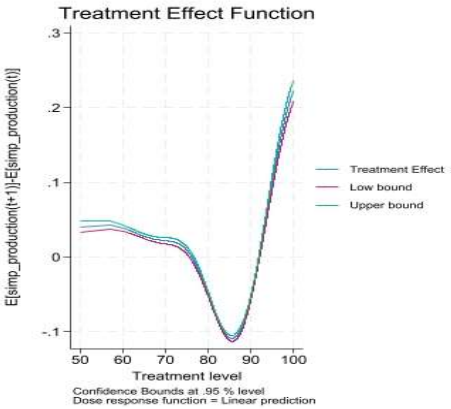
BGVC



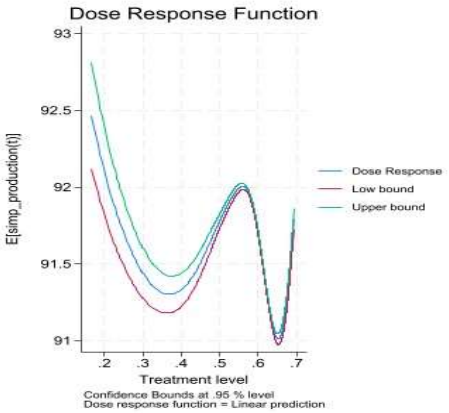


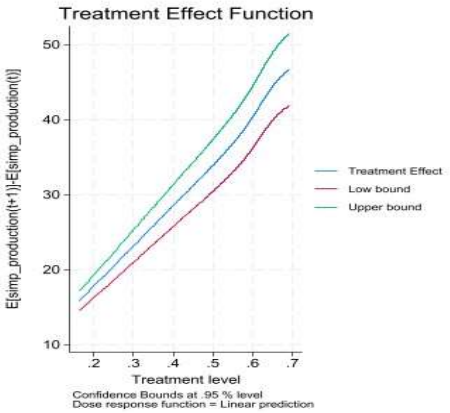
FGVC





GVC Positioning





7. Conclusion and Policy Implications

Over the past few decades, production processes where goods typically embody value added from multiple countries of origin, enroute to final consumption, the phenomenon of GVC are also affecting the agri-food sector. Often it is assumed that low-income countries are not able to integrate in AGVC and are unable to reap benefits of the changing nature of the international trading system. In this paper we investigated the determinants of country's participation in AGVCs. AGVCs are comparatively less studied relative to manufacturing and services where the focus has been on measurement of participation and association with outcomes like agricultural productivity, role of GVC in structural transformation. We first econometrically estimate the effects of several determinants of AGVC participation related to characteristics of agriculture (level of intensification), policies, and the institutional environment (rule of law, risk, and uncertainty. Using fixed-effect regression analysis, and methods to address potential endogeneity issues this paper examines the factors that influence the various measures of AGVC participation and positioning for the global sample of countries included in the TIVA database.

Descriptively as well as through estimations we find significant heterogeneity by countries and regions. Outside of developed countries, there is comparatively high participation of east and southeast Asia in AGVC. Notwithstanding the variation, our trend analysis shows sustained trajectory (comparatively steep for BGVC for developing countries). Trade barriers on inputs as well as outputs play a disproportionately large role in both participation and positioning in AGVC. Cost to trade because of infrastructure and institutions are assessed to play a large role in AGVC participation. Hence, systems that reduce costs to trade (including risk reduction are associated with greater engagement in AGVC. In developing countries, capital constraints necessitate foreign investment to play a role in GVC engagement. Our results show a significant association of FDI in agriculture and engagement in AGVC more so for developing countries.

This paper is the first to investigate the relationship between the extent of a country's participation in AGVC and production diversification in agriculture. Both FGVC and BGVC are robustly associated with diversified agriculture. Using panel data from 66 countries for the period 1995-2018, we find that economies with their levels of development position themselves in GVC differently over time. Our results are robust, addressing concerns of endogeneity using multiple methods comprising System GMM, Instrument variable methods and continuous treatment matching.

The findings in this study can help inform agricultural trade policy in two ways. First, policy makers may wish to focus on participation in GVC to bring about increases in productivity by allocating resources efficiently and accessing inputs. Towards this trade policy openness on both inputs and outputs i.e., orthodox opening as opposed to heterodox opening is important. Also, reduction in cost to trade through digitization can be important for GVC engagement. Trade reforms that result in GVC participation can play a role in driving outcomes like production diversification that is much needed in several developing countries for various reasons including their structural transformation process and for a sustainable food system. Aggregate indicators of GVC participation show importance of country, industry and stages in value chain characteristics, and thus further context-specific case studies and analyses are needed.

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Annexure

Table A1: Region Wise Country

Region	# of Countries	Country Names
Europe	32	Austria; Belgium; Bulgaria; Croatia; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Iceland; Ireland; Italy; Latvia; Lithuania; Luxembourg; Malta; Netherlands; Norway; Poland; Portugal; Romania; Russian Federation; Slovak Republic; Slovenia; Spain; Sweden; Switzerland; and United Kingdom
East and Southeastern Asia	15	Brunei Darussalam; Cambodia; China; Chinese Taipei; Hong Kong; Indonesia; Japan; Korea; Laos PDR; Malaysia; Myanmar; Philippines; Singapore; Thailand; and Viet Nam
North, South, and Central America	9	Argentina; Brazil; Canada; Chile; Colombia; Costa Rica; Mexico; Peru; and United States
Other Region	10	Australia; India; Israel; Kazakhstan; Morocco; New Zealand; Saudi Arabia; South Africa; Tunisia; and Turkey

Source: TiVA Database

Table A2: Detailed descriptive statistics of the indicators for three time periods 1995, 2006 and 2018

	All Region			Europe			East and Southeastern Asia			North, South, and Central America			Other Region		
	1995	2006	2018	1995	2006	2018	1995	2006	2018	1995	2006	2018	1995	2006	2018
Simpson Index - Based on Production (Q)	90.5	90.3	89.8	92.4	91.7	90.2	86.8	87.1	87.6	89.4	89.8	89.9	91.2	90.8	91.8
Simpson Index - Based on Area (ha)	83.1	83.1	82.6	83.4	82.8	80.2	79.1	80.8	81.9	88.8	88.4	88.8	82.9	83.0	85.8
Simpson Index - Based on Production Value ($)	88.2	87.7	87.2	89.4	88.1	87.8	85.6	86.4	85.9	88.6	88.1	87.3	88.1	87.8	87.3
Agr Use - Nitrogen (t/ha)	4005	4787	5027	5197	5821	6154	4382	59199	57042	14291.	16780.	23007.	1943	2578	2857
	1.6	6.2	2.7	0.1	6.1	6.8	5.3	.8	.6	3	1	5	6.0	9.4	9.0
Agr Use - Phosphate (t/ha)	1641	1924	1746	1745	1704	1423	2447	35679	33378	5681.3	8053.0	9863.9	1068	1168	1076
	9.8	2.5	4.9	6.8	7.5	5.6	6.2	.9	.4				1.6	1.2	9.2
Agr Use - Potash (t/ha)	1642	1978	2049	1883	1912	1794	2374	33760	38936	5292.9	10058.	10792.	7737	9685	9728
	1.4	4.4	7.0	1.6	4.3	8.2	5.9	.4	.9		9	0	.6	.6	.2
Agr Use - NPK (t/ha)	7289	8690	8823	8825	9438	9373	9204	12864	12935	25265.	34892.	43663.	3785	4715	4907
	2.8	3.1	4.6	8.5	7.8	0.6	7.4	0.1	8.0	5	0	4	5.2	6.3	6.3
Agr Use - Insecticides (t/ha)	507.	482.	469.	310.	216.	240.	1383	1334.	1292.	96.5	218.9	170.6	195.	295.	233.
	8	7	0	6	5	8	.1	2	1				8	0	5
Agr Use - Herbicides (t/ha)	579.	759.	800.	539.	659.	593.	1134	1361.	1607.	248.7	653.7	670.2	175.	272.	365.
	7	6	2	3	5	9	.0	3	9				2	5	4
Agr Use - Pesticides (t/ha)	2154	2357	2426	2317	2141	2117	3789	3925.	4228.	526.3	1489.6	1528.6	641.	1479	1519
	.0	.4	.5	.9	.0	.8	.3	3	4				6	.0	.3
Agr Use - Pest+Inst+Herb (t/ha)	3241	3599	3695	3167	3017	2952	6306	6620.	7128.	871.6	2362.3	2369.4	1012	2046	2118
	.5	.7	.7	.8	.0	.6	.4	8	4				.5	.6	.3
Agriculture value added per worker (constant 2015 US$)	2002	2592	5484	1808	2616	3800	1175	16330	16831	44405.	39513.	202003	1671	2732	3332
	5.3	6.1	4.6	0.1	5.1	0.8	4.7	.6	.7	8	2	.9	3.3	6.0	0.9
Share of Employment in Agr - Female	18.1	13.9	9.8	9.2	5.6	3.3	35.6	27.7	19.7	8.8	7.6	6.7	28.8	25.6	18.2
FDI Inflows in Millions (USD)	5976	2044	1975	3983	2156	1086	1021	12571	28052	10151.	40184.	42260.	2236	1089	1554
	.7	4.9	9.0	.4	7.3	0.9	7.2	.2	.3	8	8	3	.8	7.5	1.6
Emissions Intensity - AgrFood- Kg CO2eq/kg product	210.	147.	150.	226.	134.	120.	244.	177.1	162.0	150.6	149.6	213.5	162.	144.	168.
	7	6	1	8	2	8	6						2	7	8
Emissions Share - Agrifood Systems - CO2eq	45.0	41.6	36.7	37.6	39.9	33.9	55.6	41.3	35.0	61.2	56.1	55.5	38.3	34.6	31.0
Temperature Change in Degree Celsius	0.7	0.9	1.5	0.9	1.0	2.0	0.5	0.7	1.1	0.6	0.9	0.8	0.5	0.9	1.3
Agri - Comprehensive Trade Cost	114.	216.	191.	117.	222.	186.	82.7	193.3	188.4	138.0	215.1	190.8	131.	236.	213.
	6	8	5	8	0	3							1	5	2
Agri - Geometric Avg Tariff	0.2	0.9	0.9	0.2	0.9	1.0	0.2	0.8	0.9	0.4	0.9	1.0	0.1	1.0	1.0
Agri - Additional Cost other than Tariff	33.8	189.	174.	33.0	197.	174.	27.1	164.1	161.4	70.4	187.9	179.0	13.5	202.	189.
		5	3		9	3								4	6
Voice and Accountability Index (%)	66.3	65.4	65.5	82.4	84.1	81.7	41.1	34.7	38.4	64.6	67.4	68.5	54.0	49.5	51.5
Political Stability and Absence of Violence/Terrorism Index (%)	64.7	60.8	59.1	79.6	75.0	71.2	56.5	50.8	54.3	49.1	45.6	47.2	43.6	44.2	38.3
Government Effectiveness Index (%)	70.6	71.7	73.4	81.1	81.5	81.9	54.6	61.5	67.1	67.0	61.2	61.6	64.4	65.2	66.0
Regulatory Quality Index (%)	71.8	72.2	73.3	81.0	83.8	83.3	58.4	55.6	62.0	72.9	66.4	69.1	61.6	65.0	62.3
Rule of Law Index (%)	67.9	67.6	69.7	79.8	80.5	80.9	52.7	50.4	58.4	57.8	58.3	58.5	61.8	60.3	60.8
Control of Corruption Index (%)	67.4	67.4	67.8	77.4	79.6	77.9	52.8	46.6	55.8	64.3	65.5	57.8	60.3	61.3	62.3
Applied Tariff Faced - Agr Component	9.1	10.2	4.8	9.6	10.9	6.3	5.1	5.3	2.4	11.4	13.8	4.0	11.2	12.2	4.6
Applied Tariff Faced - Fish Component	7.4	4.9	2.8	7.3	4.7	2.6	6.7	3.8	2.5	10.1	6.5	3.5	6.3	5.6	3.4
Applied Tariff Faced - Food & Beverages Component	16.1	14.0	7.5	17.7	14.9	9.3	9.2	8.8	4.2	18.9	17.7	6.6	18.7	15.4	7.7
Applied Tariff Faced - Fertilizer Component	3.5	3.3	1.7	3.7	3.3	1.9	2.9	3.0	1.4	4.0	3.7	1.8	3.6	3.8	1.7
Applied Tariff Faced - Machinery Component	2.4	1.9	1.0	2.7	2.2	1.4	1.5	1.2	0.6	2.5	2.0	0.7	2.5	2.0	0.9

	All Region			Europe			East and Southeastern Asia			North, South, and Central America			Other Region		
	1995	2006	2018	1995	2006	2018	1995	2006	2018	1995	2006	2018	1995	2006	2018
GDP Per Capita - Current Price USD	1354	2195	2948	1804	3114	3963	1077	13115	19540	8727.5	14355.6	20224.1	7616.9	1265	2023
% of Individuals using internet	3.1	3.6	0.6	6.0	0.1	2.9	7.1	.9	.9					1.8	3.2
Inflation Rate	2.8	42.8	76.6	2.3	55.5	84.0	5.8	33.0	65.6	1.6	34.0	73.9	0.9	24.7	71.7
Number of Products Traded	17.3	4.0	2.6	16.7	3.3	2.0	7.7	5.1	2.4	19.1	4.1	2.8	32.0	4.5	4.7
World Uncertainty Index – Reporting Countries (%)	221.9	230.6	235.5	231.4	236.9	240.4	194.9	210.3	221.1	227.2	238.0	236.1	227.6	234.0	241.0
Trading with Uncertainty Partner – Based on WUR of Partner Countries (%)	8.4	10.3	17.7	8.4	10.3	17.7	8.5	10.3	17.9	8.3	10.1	17.3	8.4	10.3	17.5
	36.8	37.6	38.5	33.0	36.0	36.4	41.1	39.1	62.8	37.7	28.5	14.0	41.7	48.9	30.5

Source: FAOSTAT, UNCTAD Stats, World Uncertainty Index, Worldwide Governance Index, World Development Indicators, Tariff and Non-Tariff Measures Database from e-ping