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A method for estimating global trade in value added within agriculture and food value chains

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A METHOD FOR ESTIMATING GLOBAL TRADE IN VALUE ADDED WITHIN AGRICULTURE AND FOOD VALUE CHAINS

Jared Greenville, Kentaro Kawasaki and Raphaël Beaujeu
Organisation for Economic Co-operation and Development

Global Value Chains (GVCs) have transformed production across a broad range of goods and services worldwide. Although the development of GVCs has occurred in agro-food sectors alongside other sectors, less is known about the trade that occurs within agro-food GVCs due to limited information on flows of trade in value added. This study develops an approach to calculate disaggregated indicators of GVC participation in agro-food sectors in both developed and developing countries. Specifically, the approach exploits the Global Trade Analysis Project (GTAP) database to construct an inter-country input-output (ICIO) table for the year 2011. The resulting ICIO is used to compute indicators of GVC participation based on the concept of vertical specialisation – forward and backward participation – across 20 agro-food sectors in 70 countries and/or regions. Estimates of domestic value added in exports and final demand or agro-food products, including the contribution of all industries, are also presented.

Keywords: Agriculture; Global Value Chain; GTAP; Multi-Regional Input Output.

JEL Classification: F14, F60, Q17

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Executive Summary

A significant literature has been developed exploring agricultural value chains at a micro level for individual products and for individual countries. Despite this, there has been little analysis of trade flows within global agro-food value chains for agricultural products. That is, the trade related aspects of value chains that cross international borders. The underlying reason for this has been a lack of data on trade in value added – the necessary input for this type of analysis – for individual agricultural and food sectors. So far, global information on trade in value added has only collected data at an aggregated level – for agriculture and food processing as broad sectors.

The differences that exist between individual agro-food and other sectors, suggest a need to address the gaps limiting current understanding of agro-food global value chains (GVCs). Better information on how policies influence participation in GVCs, and identifying what contributes to obtaining greater benefits from GVC participation to economies will be important for future agro-food trade reforms at the multilateral, regional and bilateral level.

This study seeks to fill some of the information gaps that surround agro-food GVCs. Specifically, it sets out an approach using the Global Trade Analysis Project (GTAP) database to identify trade in value added across 20 agro-food sectors in 70 countries. From this data, the study constructs an inter-country input-output (ICIO) table which can be used to calculate disaggregated indicators of GVC participation in agro-food sectors in both developed and developing countries. This is done for the 2011 base year of the version 9 GTAP database. The resulting ICIO is used to compute indicators of GVC participation based estimates related to the concept of vertical specialisation – those of forward and backward participation in GVCs.

The results from the trade in value added data estimated reveal that agro-food trade measured in gross value terms is significantly greater than trade measured in value added terms. This held for all countries and all agro-food products examined. Trade in value added (from all sources) is generally around half that of trade measured in gross value terms. However, there is considerable variation. For example, in 2011 for gross export values of around USD 10 000 million, trade in value added terms varies between USD 1 300 million and USD 3 400 million. Across agro-food products, considerable variation exists in the difference between trade in value added and gross values. As expected, for less processed products, gross trade flows better approximate the trade in value added – for example, much of the gross value in vegetable, fruits and nuts trade is trade in value added (a share closer to 100%). On the other hand, for products which involve a greater level of processing, such as processed rice and dairy, trade in value added is only a small proportion of the gross trade value observed.

On GVC participation, the estimates confirm that significant differences exist in participation between different agro-food sub-sectors. While the general observations related to agricultural sectors supplying into GVCs and food sectors buying from them are generally maintained, significant variance is seen in average participation across sub-sectors. As such, for individual countries, much of the differences in GVC participation at the aggregate level are likely to be explained by differences in industry mix, which for agriculture is largely driven by climatic and geographic factors rather than policy factors. That said, the results also point to significant variation in GVC participation within individual sub-sectors across countries suggesting policy is playing a role. The effect of this is explored in the second paper in this series.

1. Introduction

1.1. Why this study?

Notwithstanding the significant literature on value chains at a micro level, there has been little analysis of trade flows within global agro-food value chains for agricultural products. The underlying reason for this has been a lack of data on trade in value added for individual agricultural and food sectors. So far, global information on trade in value added, such as the OECD-WTO's (2013) Trade in Value Added (TiVA) database,[1] has only collected data at an aggregated level – for agriculture and food processing as broad sectors.

The possible differences between individual agro-food and other sectors, suggest a need to address the gaps limiting current understanding of agro-food global value chains (GVCs). Better information on how policies influence participation in GVCs, and identifying what contributes to obtaining greater benefits from GVC participation will be important for future agro-food trade reforms at the multilateral, regional and bilateral level.

This study seeks to begin to fill some of the information gaps that surround agro-food GVCs. Specifically, this paper sets out an approach using the Global Trade Analysis Project (GTAP) database to identify trade in value added across 20 agro-food sectors in 70 countries, thereby constructing an inter-country input-output (ICIO) table and enabling the calculation of disaggregated indicators of GVC participation in agro-food sectors in both developed and developing countries.

1.2. How are global value chains measured and described?

Trade flows, in particular, trade values, are composed of a range of inputs. The value of a given product represents the combination of a number of inputs, some of which would have been sourced locally (such as labour, capital and locally produced intermediates) and some that would have been imported (such as intermediate inputs and their embodied labour and capital). Understanding GVCs requires unpacking these various elements so that for any given product traded, the amount of transformation that has occurred locally can be identified. That is, the approach allows the trade in *value added* to be estimated. For example, the joint OECD-WTO (2013) Trade in Value-Added (TiVA) database measures trade flows in terms of the value that is added domestically (labour compensation, other taxes on production and operating surplus, or profits) by a country in the production of any good or service that is exported.

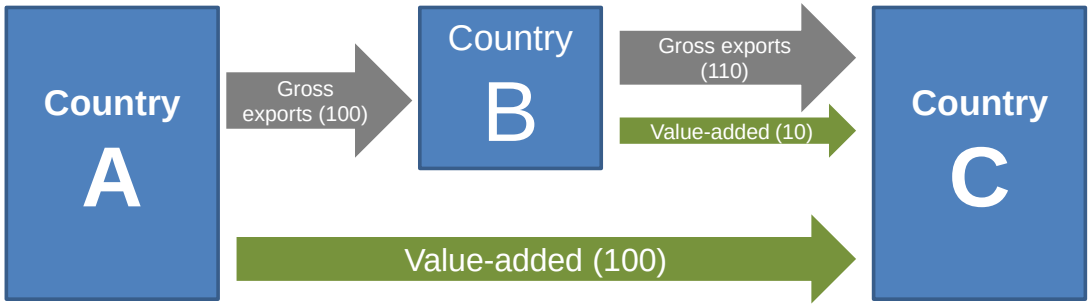
The difference between conventional trade flows and trade in value added is shown in Figure 1.1. In this simple example, Country A exports $100 worth of goods, produced entirely domestically, to Country B. Country B then further processes these goods before exporting them to Country C where they are consumed. In doing so, Country B adds value of $10 to the goods and so exports $110 worth of goods to Country C. Conventional measures of trade show total global exports and imports of $210 but only $110 of value-added has been generated in their production. Conventional measures also show that Country C has a trade deficit of $110 with Country B, and no trade at all with Country A, despite the fact that Country A is the chief beneficiary of Country C's consumption.

Through tracking value added flows instead of absolute flows, it is possible to decompose trade into its value added components. In the example in Figure 1.1, Country C's trade deficit with Country B can be recalculated on the basis of the value-added it 'purchases' from Country B by its final demand. Recalculating in this way reduces C's deficit with Country B to $10. This now means that Country C has a deficit of $100 with Country A. As such, Country C's overall trade deficit with the world remains at $110 but its composition changes.

1. See www.oecd.org/sti/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm.

Figure 1.1. Measuring trade in value added

Unpacking trade flows



Source: OECD (2013a).

Once estimates of trade in value added are known, information on how a country participates in a value chain can be estimated. The example above shows that Country B relies heavily on Country A for its exports as the source of most of its inputs. This reveals the GVC and shows that there are two parts from any given country's perspective:

- a 'forward' looking part that shows the extent to which a country's exports form part of a production process in another country, contributing to that other country's exports before the product reaches final demand
- a 'backward' looking part that shows the extent to which imports from other countries are used in the production of a country's exports.

To date, different approaches have been used to characterise the forward and backward participation of a country's in GVCs. The most commonly applied approach is that to calculate an indicator of "vertical specialisation". This indicator was first described by Hummels et al. (2001) and later refined by Koopman et al. (2011). This approach defines value chain participation in terms of the origin of the value added embodied in exports both looking backward and forward from a reference country: backward when it comes to foreign value added embodied in exports; and forward when relates to domestic value added used as inputs to produce exports in the destination country. Such indicators have been calculated by using harmonised systems of ICIO tables (as in Timmer et al. 2012; OECD 2013a; OECD 2013b; and UNCTAD 2013). The OECD-WTO (2013) TiVA database released in 2013 and updated in 2015 is based on this approach and provides, amongst other indicators, a decomposition of gross trade flows into various types of foreign and domestic value added. These indicators, however, have limitations. They represent average results for industries with often very heterogeneous firm structures (or farm types), with some firms solely serving domestic markets and others specialising in exports.

Broadly, the backward participation index is measured as the share of foreign value added that is included in the total export value of a country. In the example on Figure 1.1, for Country B the backward indicator is 0.91 (100/110). The forward GVC participation index is measured as the share of a country's value added arising from its own exports (direct and indirect through the exports of other domestic industries) included in exports of other countries. In the example on Figure 1.1, for Country A the forward indicator is 1 (100/100) as all of its exports are re-exported in the transformed good by Country B. The indexes measure very different forms of engagement. For example, a country that is predominantly assembling products into final goods and subsequently exporting these will have a strong backward participation index but a small forward participation measure. Conversely, a country which predominantly supplies intermediates to an assembler will have a strong forward participation indicator but a small backward participation measure. These participation measures therefore give us a metric of engagement in the form of buying from (backward participation) and selling to (forward participation) GVCs – in other words, the demand and supply sides of the value chain activity. Differences across countries in

forward and backward participation can then be analysed to explore the structural and policy determinants that underpin engagement in GVCs.

1.3. Available data sets that allow for the calculation of GVC participation indicators

Apart from estimates using the GTAP database, there are three major ICIO datasets that have been used in the analysis of trade in value added and GVCs. There are the OECD-WTO (2013) TiVA database, the World Input Output Database (WIOD) project database, and the EORA database.

These three major databases each depict the agriculture and food sectors as distinct but aggregate sectors. Overcoming this aggregation is the focus of this paper.

The differences obtained in terms of GVC participation indicators derived from each of these three databases was assessed in OECD (2015) along with differences in the underlying characteristics of the datasets. Differences in the dataset construction related to the compilation and reconciliation methods and the underlying data which helps to determine coverage. For the WIOD and TiVA databases, the main data source are nation IO tables with the compilation and reconciliation methods differing in their approach to balancing of the individual country IO tables – WIOD relies on balancing national accounts whereas TiVA on balancing trade. In contrast, EORA dataset makes use of data imputations in the absence of individual country IO tables. It uses national IO tables for more countries (74 countries at various intervals in time) and balances these at the same time as extra- or intrapolating values for countries that do not have an IO table through cross-entropy methods. The OECD (2015) states that this means that the data can different to what is actually happening in a country. For example, Lao PDR has poor quality trade statistics and no IO table and the EORA project uses its algorithms for filling in the table values and instead 'generates' this information for this country. The advantage of the EORA database is thus that it has wider country coverage and this is particularly relevant for the analysis of GVC activity in developing and least developed countries. However, given the methods used, there remains some uncertainty over the representativeness of the estimates obtained.

In assessing the outcomes in terms of estimated GVC statistics, the OECD (2015) found estimates form the EORA and TiVA dataset were relatively similar. However, while participation indicators were relatively similar, reported differences in the Leontief matrices suggested that the EORA dataset should only be used at the aggregate level until further robustness measures point otherwise.

Given these results, for the purpose of this paper, comparisons are made between the TiVA database estimates and those generated here as a means to benchmark the results. Given the aggregation of the TiVA database, this means that the estimates generated here are aggregated, however, the method used to compute them remains as set out in this paper.

1.4. Structure of the paper

This report is structured as follows. Details of the methods used to construct the ICIO from the GTAP database and the participation indicators are set out in Section 2. The resulting estimates of trade in value added are explored in Section 3, along with comparisons between value added and gross value trade. Section 4 provides details of the calculated GVC participation indicators, including comparisons with those estimated from the TiVA dataset.

2. Methods for estimating GVCs and participation in agro-food sectors

A significant reason for the lack of analysis on global aspects of GVCs in agro-food sectors is the lack of available data on trade in value added at a disaggregated sector level. This study, through extensions to the use of the GTAP database, fills some of these gaps. Data from the GTAP database is used to construct an ICIO table that forms the basis of building the TiVA-like indicators for 20 agro-food sectors used to better understand agro-food GVCs.[2] The details of the approach adopted are set out in this section.

All OECD countries are included in the study, along with a further 2 high income countries, 13 upper middle income countries, 11 lower middle income countries and 9 low income countries. The list includes all major agricultural producing and trading countries and provides for a good representation across a range of different income categories and geographic locations (Annex A).

2.1. Using GTAP to map industry to industry trade flows and construct an ICIO

The GTAP database contains a rich source of data on agricultural sectors. The model has been used extensively in the literature to analyse the impacts of policies on trade, including a significant body of work that has explored trade in agricultural products.[3] The data that underpins the model contains much of the information that is required to construct the ICIO necessary for the calculation of GVC indicators. However, some modifications are required.

The advantage of making use of the GTAP database for GVC analysis is that it reconciles data from different sources into one consistent database. However, the database itself does not allow for an accounting of how imported intermediate products are used in the exports of countries. Within the GTAP framework, imports of intermediates from all countries are aggregated at the product level at the border into a composite imported good. This composite good is then allocated across sectors and uses based on relative demands and shares. In this way, it is not possible to trace exports of intermediates from one country into the production processes of another, and following from that, into their contributions to the other countries' exports. That is, it is not possible to directly identify the industry to industry trade required for the construction of an ICIO. This issue is overcome by applying the proportionality assumption as discussed below.

2.2. Creating the ICIO from GTAP data

The assumption approach used in this study applies a proportionality assumption to allocate the imports of products from any given country between final demand and intermediates, and then within intermediates, between the intermediate usage by individual production commodities. To apply this method, the proportionality assumption is imposed. That is, if imports from Country X, for example, represent 50% of total imports for a product i in Country Y, then final demand in Country Y of product i will consume 50% of its imports from Country X, with intermediate import demand in Country Y also being made up of 50% from Country X. Further, for each using production industry j in Country Y, of their use of imported product i, 50% will be sourced from Country X.

The key problem with this method is that it ignores differences in the types and quality of imports from different regions. For a given product, some country exports may target final demand, while others may target intermediate demand. For example, imports from the meat sector from one country may exclusively be high quality cuts targeted for final demand, while from another country it may be made up

2. The sector and region listing included in the GTAP model used in this study is given in Annex A. The GTAP agro-food sectors are represented by sectors 1-12 and 19-26. The fisheries sector is also included (sector 14) however it represents a combined sector and also includes hunting. Forestry is also a separate sector (sector 13). In some instances, these sectors are included in the analysis.

3. For a review of recent studies exploring policy impacts on agricultural trade see OECD (2016, forthcoming).

of offal and other lower quality products intended for use in food manufacturing industries. Taking this simplified example, if this dichotomous split existed and there were only two countries which supplied imports, each with a 50% share, then the country with low quality exports would have a greater share in final demand than is actually the case, with the reverse seen for the other country. The size of the error then in exploring GVC participation would vary by the inherent level of specialisation in exports.

One manner to test the effect of possible specialisation in exports is to better define the trade relationships within the GTAP model prior to estimating the ICIO. This can be done via modifying the model theory to change the structure of bilateral trading patterns between countries (Box 2.1). Data derived from the UN's Broad Economic Classification (BEC) of world trade flows is used as the benchmark for changing the trade flows within the database. The cost of this method is that for any significant degree of country disaggregation, the computational time is significant. However, the nature of many agro-food products and the specificity of the BEC classification mean that the errors created in applying the proportionality assumption are likely to be small. For example some products are exclusively intermediates or at least classified as such in the BEC classification scheme. Further, the proportionality assumption is simpler and can be more readily applied to outputs from any GTAP policy simulation, making it is useful for policy analysis. In order to test the differences between the two approaches, GVC participation estimates from 2007 calculated using the two approaches have been compared (Annex B). The results show only relatively minor differences, suggesting that the proportionality assumption is a relevant method to explore GVC participation for the agro-food sectors.

The process applying the proportionality assumption requires identifying the various elements of production; the use of intermediates, labour, land, capital and natural resources differentiated between domestically sourced and imported; and of final demand (households, governments and capital accumulation).

The ICIO used in this study has been constructed broadly following the approach of Peters et al. (2011). The basic structure of the ICIO table is shown in Figure 2.1. In ICIOs, the standard valuation of activity is at basic prices. A basic price is typically defined as one that is net of transport margins and taxes. In terms of the data from GTAP, this means that attention must be given to what variables are used. GTAP offers two valuations of flows: at agent's prices; and at market prices. The market price valuation is net of taxes but includes all domestic transport margins as these are not explicitly modelled in GTAP (rather, they represent an input into the production process of any good). As such, for the construction of the ICIO in this study market prices are used with the caveat that part of the value represented includes domestic transport margins.

A further difficulty arises in calculating the basic price of imported intermediates and consumption goods. Valued at market prices, imported intermediate inputs (and final goods) include export charges, international transport and importation duties (however defined, including countervailing duties, tariffs, ad-valorem equivalents for quotas and tariff-rate quotas). Collectively termed margins, the inclusion of these requires an adjustment to the market price of imported intermediates.

The adjustment to the value of imported product is done to net out the margin values. The approach used follows the conceptual approach of Peters et al. (2011). The difference between intermediates valued at the market price in the exporting country and the market price of imported intermediates in the importing country accounts for all the margins and allows conversion to basic prices. However, for the GTAP model used here, these values are not given for the disaggregated bilateral and industry specific trade flows, but rather represent the typical GTAP construction for the aggregated bundle of imported intermediates. Therefore, the ratio of the values is used to discount the value of the imported intermediates. This assumes that for any given tradable commodity, the same tariffs and transport costs apply irrespective of the using sector in the importing country (that is, no individual sector has special exemptions for the use of imported intermediates or that where concessions exist, these are shared across all uses). For example, for wheat exports from Country W to Country H which are used in Country H by two sectors – the food processing and livestock sectors as intermediates – the same tariff and transport costs are applied for the products use in each sector. The same logic applies for imports of final goods for

consumption by households and government where the same adjustment process has been applied. It should be noted that specific domestic taxes or subsidies that are differentially applied are captured elsewhere in the ICIO and therefore not affected by this approach.

Transport services also create an additional complication when constructing an ICIO from the GTAP model. With GTAP, transport services are a domestic activity which supplies part of their output to a global pool of transport services that are used to move products on the international market. As such there is a disconnect between the sector output and the various industry users of it as an intermediate product. To overcome this, the value (at basic prices) of transport services supplied by domestic transport industries to the global pool must be included as a separate demand item (depicted as the final column in Figure 2.1).

Box 2.1. An alternative approach to derive an ICIO from GTAP

Work completed by Liapis and Tsigas (2014) has developed an approach to overcome the aggregation issue within the GTAP model. This is completed in several steps. Initially, the model theory is adjusted to remove the aggregation of imports at the border, allowing the sourcing of imports by product for individual industries to be known (the country to country flows are already traced within the model). However, in doing so, an issue arises in determining the shares of each product in the bilateral flows that should be allocated to either intermediate, final household or government demand.

As the database is balanced initially, import use shares can be derived that maintain the current balance and structure of the various economies (the assumption used in this paper). Doing so assumes that each demand source consumes imports from a given country in proportion to their total demand for imports of a given product. This approach is commonly applied in other ICIOs (such as the OECD-WTO TiVA ICIO), and is referred to as the 'proportionality assumption'.

However, there remains an issue as to whether this represents actual trade flows. To obtain a better picture of actual bilateral trade flows by various use categories, trade data is mapped to use categories according to the UN's Broad Economic Classification (BEC) – an approach similar to what is done in the OECD's METRO model database construction. This data is then mapped to the GTAP sectors and regions.

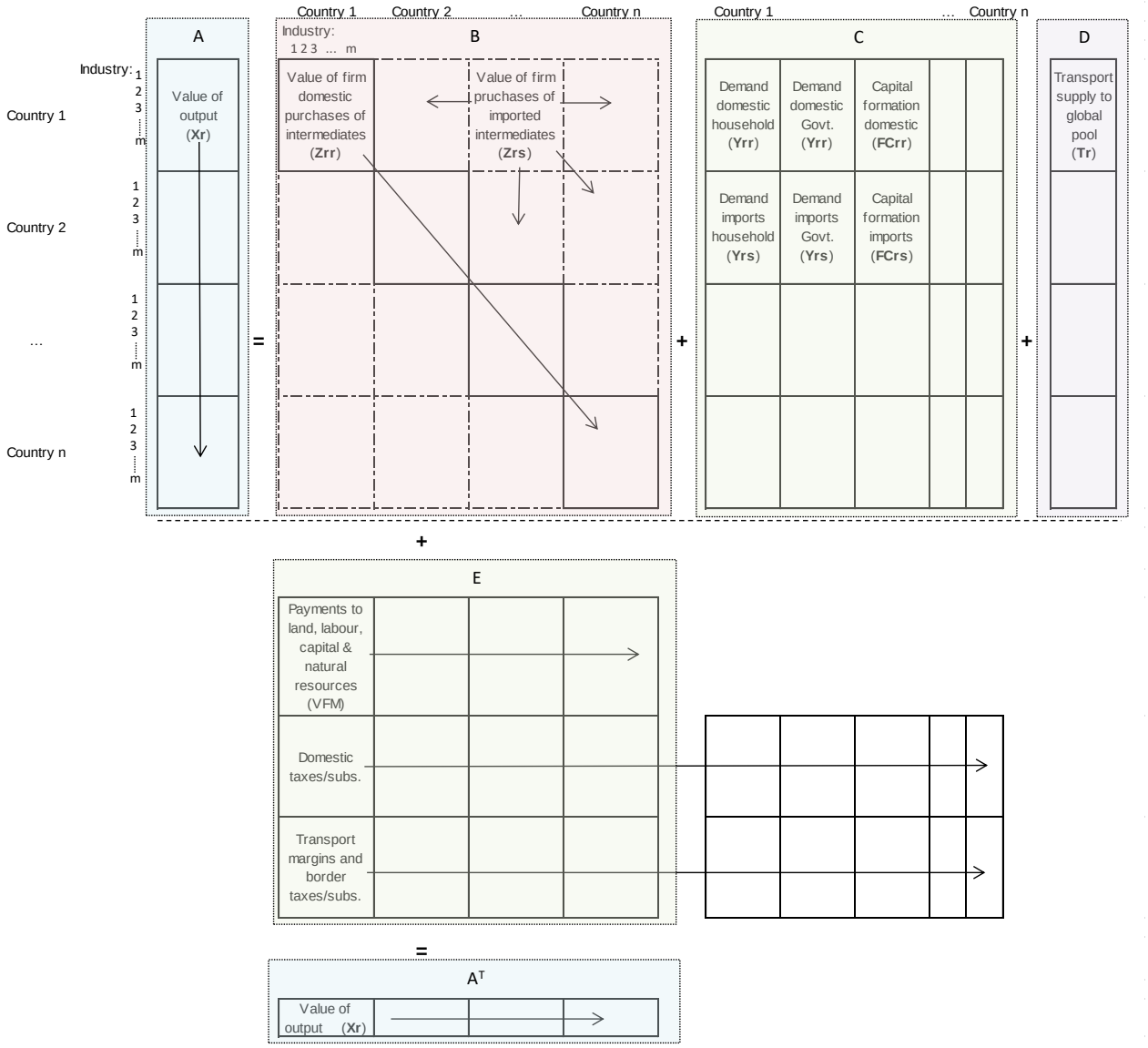
The shares that are calculated using actual trade flows in intermediates and final goods via the BEC mapping differ from those represented within the GTAP database. To overcome this, the model is simulated to target the observed shares. This involves solving the model through various simulations to approximate the observed trade flows. To date, work has been completed to map the GTAP 2007 database to observed 2007 trade flows. The 'closeness' of the revised database to actual trade flows can then be measured as the mean squared difference in error between the observed and within model bilateral trade flows in goods by use categories (Table 2.1). After 16 simulations to iterate the database to better match the observed trade flows, the approach yielded consistent trade flows for most countries, however for some, error remains.

Table 2.1. Differences between observed and model trade flows

	Average	Min	Max	Number of countries exceeding twice the average
Mean squared error initial	203.44	0.024	5780.71	5
Mean squared error final	20.21	0.00	936.08	4
Average improvement from initial to final (%)	91.00	25.00	100.00	n.a

The revised database that contains trade flows that better match observed flows is then used to construct an ICIO table. It should be noted, however, that this process is extremely time consuming due to the significant disaggregation of the model. Results from the comparison between the two approaches for 2007 are set out in Annex B.

Figure 2.1. ICIO broad structure



Notes: Where variables are defined in Table 2.2. On the Figure, the matrix A (which is a vector) represents the value of output, which is equal to the row sum of matrix B + C + D. This sum represents the total sales of each industry. Similarly, the value of output is equal to the column sum of matrix B + E, which represents the total expenditure of each industry (depicted as vector A^T on the figure as it is the transpose of A).
Source: Adapted from Peters et al. (2011).

Table 2.2. GTAP variables used in ICIO

Variable name	GTAP variables used	Computation
Xr	VOM (i,r) = value of output of commodity i in region j at market prices.	VOM(i,r) = sum of domestic purchases by households (VDPM(i,r)), governments (VDGM(I,r)) and firms (summed across production sectors j, VDFM(i,r)) *plus* export sales at domestic market prices (for all destination markets s VXMD(i,r)) *plus* value of transport services provided to the world market pool (VST(i,r)).
Zrr	VDFM(i,j,r) = value of firm domestic purchases of traded commodity i by production activity j in region r. At market prices.	VDFM (i,j,r)is generated by the model and read directly.
Zrs	IFM2adj(i,r,j,s) = value of firm purchases of traded commodity i in region r, by production activity j in region s adjusted to remove transport costs and border taxes.	IFM2(i,r,j,s) * VXMD(i,r,s)/VIMS(i,r,s) where VIMS represents the value of imported i from country r at market prices in the destination market. See below for calculation of IFM2(i,r,j,s). Adjustment represents the removal of transport margins and taxes (discussed below).
Yrr & Yrs	IPM2(i,r,s) and IGM2(i,r,s) = value of purchases of traded commodity i in region r, by final demand (private = P and government = G) in region s adjusted to remove transport costs and border taxes.	IP(G)M2(i,r,s) * VXMD(i,r,s)/VIMS(i,r,s) where VIMS represents the value of imported from country r products at market prices in the destination markets. See below for calculation of IP(G)M2(i,r,s). Adjustment represents the removal of transport margins and taxes (discussed below).
FCrr & FCrs	Represent production activity 58 (j=58) of VDFM(i,j,r) and IFM2adj(i,r,j,s).	As for Zrr and Zrs but for production activity j=58 (capital goods).
VFM	VFM(i,r,j) value of producer expenditure on value added factors at market prices.	VFM (i,j,r)is generated by the model and read directly.
Taxes and subsidy	OSEP, ISEP, FTFB and FDTP. Represent the taxes and subsidies paid to industries, value added factors and final demand.	See below for calculations.
Margins	Represents the transport cost and border taxes/subsidies.	VIMS(i,r,s) – VXMD(i,r,s) allocated across industry and final demand.
Tr	VST(i,r) represents the supply of transport services to the global pool.	VST (i,r)is generated by the model and read directly.

Margins and taxes have also been calculated for the final demand matrix. In the GTAP database, final demand (which includes government, households and capital goods – akin to gross fixed capital formation in national accounts) purchases goods and services directly from the international market. That is, private household consumption includes imported products which do not first pass through a margin sector such as retail or wholesale trade first. As such, final demand also pays margins. Taxes on final demand are also included such that the column sum in the extended matrix y above is equal to final demand at agent prices.

Applying the proportionality assumption

The approach used to apply the proportionality assumption takes three steps. It should be noted that calculations are done initially using market prices in the importing country (given by region s in the notation).

First, the share of each source country r in total imports of a given traded commodity i in country s is determined, given by:

SHIM(i,r,s)= VIMS(i,r,s) / sum(over r of VIMS(i,r,s)) [that is, the total imports of i in country s]

Second, once the share of each country r in total imports is know, this share can be applied to the firm purchases in production activity j of traded commodity i so as to obtain the bilateral industry-to-industry trade data by:

*IFM2(i,r,j,s) = VIFM(i,j,s) * SHIM(i,r,s)*

Third, the same approach is applied to obtain the obtain the bilateral industry-to-final demand trade data (both private P and government G) such that:

*IPM2(i,r,s) = VIPM(i,s)*SHIM(i,r,s)*

*IGM2(i,r,s) = VIGM(i,s)*SHIM(i,r,s)*

Correcting for margins

The difference between intermediates values at the market price in the exporting country (therefore net of taxes and denoted by the GTAP variable VXMD) and the market price of imported intermediates in the imported country (VIMS in GTAP that includes export charges, international transport and importation duties[4]) accounts for all the margins and allows conversion to basic prices. However, for the GTAP model used here, VXMD and VIMS are not given for the disaggregated bilateral and industry specific trade flows (i,r,j,s), but rather represent the typical GTAP construction for the aggregated bundle of imported intermediates (i,r,s). Therefore, the ratio of the values is used to discount the value of the imported intermediates such that:

*Intermediates at basic prices = IFM2adj (i,r,j,s)= VXMD(i,r,s)/VIMS(i,r,s) * IFM2(i,r,j,s)*

This assumes that for any given tradable commodity produced by a given sector, the same tariffs and transport costs apply irrespective of the using sector. That is, no individual sector in the importing has special exemptions for its use of imported intermediates (unless these are paid in the form of subsidies or differences to domestic taxes and thus captured elsewhere in the database) or that where concessions exist, these are shared across all uses given the aggregation of the imports into a single bundle. This should be typically reasonable and does not differ from other constructions using GTAP.

The same logic applies for imports of final goods for consumption by households and government. The same adjustment process has been applied.

*Private household purchases at basic prices = IPM2adj (i,r,s)= VXMD(i,r,s)/ VIMS(i,r,s) * IPM2(i,r,s)*

*Government purchases at basic prices = IGM2adj (i,r,s)= VXMD(i,r,s)/ VIMS(i,r,s) * IGM2(i,r,s)*

Calculating the value of taxes and subsidies

To determine the value of taxes the difference between market and agent prices is calculated. Taxes calculated include taxes and subsidies on output (this relates to the variables in GTAP and requires caution in interpretation: if positive it is a subsidy, if negative a tax), taxes and subsidies on intermediates (both imported and domestic) and net factor taxes (land, labour or capital). In the original GTAP data base these are given by OSEP, ISEP and (FTRV-FBEP) respectively (OSEP represents subsidies to output; ISEP represents taxes on intermediates with FTRV represents revenue from factor taxes and FBEP represents subsidies paid to factors). However, as the data is taken from the outputs of a simulation, these are recalculated as the differences between agent and market prices:

4. However defined, including countervailing duties, tariffs among others.

Taxes/subsidies on output (OSEP) = (Value of output at agent price (VOA)-Value of output at market price (VOM))-1*

Taxes/subsidies on intermediates (ISEP) = Value of intermediates purchases at agent prices (VDFA and VIFA) – Value of intermediates purchases at market prices (VDFM and VIFM)

Taxes/subsidies on factors (FTFB) = Value of firms factor purchases at agent's prices (VFA) - Value of firms factor purchases at market prices (VFM)

For taxes placed on final demand (of households and government), the values are computed as the difference between agent and market prices:

Final demand taxes household purchases (FDTP) = Value of private household purchases at agents prices (VDPA+VIPA) – value of private household purchases at market prices (VDPM+VIPM)

Final demand taxes government purchases (FDTP) = Value of private government purchases at agents prices (VDGA+VIGA) – value of government purchases at market prices (VDGM+VIGM)

2.3. Estimating GVC participation and its impacts on domestic economies

The constructed ICIO table allows for trade in intermediate and final products to be traced between countries and industries. This information can then be used to estimate forward and backward participation in the value chain. The methods used to calculate these and other metrics of the effects of GVC participation are briefly described below.

The forward and backward participation indicators and domestic value added

The basic approach to deriving the forward and backward participation indicators is to estimate the foreign and domestic value added shares of each gross trade flow. Backward participation represents the foreign value added share in total exports from a reference country (can be in aggregate or at the industry level) and forward participation represents the share of a reference country's value added exports in the total value of their trading partners' exports, expressed as a share of the industry's direct exports (again, this can be in aggregate or at the industry level).

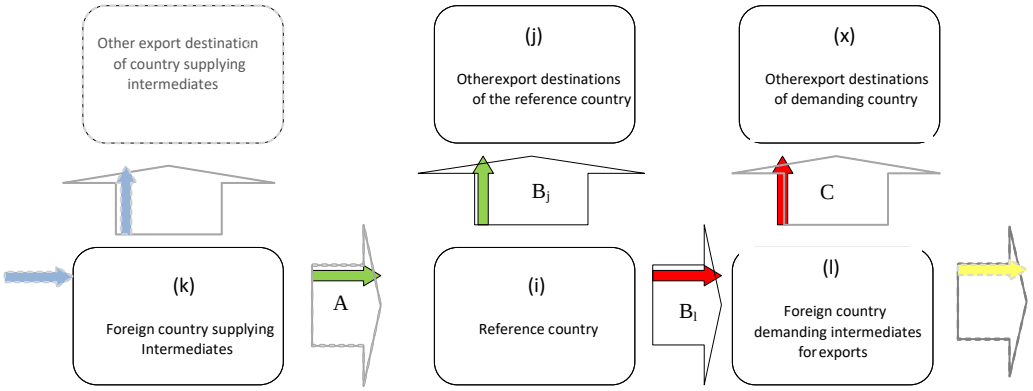
An illustration of the backward and forward linkages between the reference and partner countries is shown in Figure 2.2 (OECD, 2015). Take as example a reference Country (i). This country sources foreign value added from Country (k) to process it in order to export to destinations (j) and (l). In value terms, it buys foreign inputs of value (A), combines them with domestic value added and sells the resulting output to foreign customers via exports of a combined total ($B = B_j + B_l$). The backward indicator for the reference Country (i) is then the amount of foreign value (A) expressed as a percent of export value (B) after accounting for the proportion of A used in the production process. In the case of forward participation the reference Country (i) is the source of value added that its foreign partner (l) uses to produce exports. Country (l) is linked to a third Country (x) (in value terms this link is represented by C) and as such Country (i) is also linked to Country (x) through its sale of intermediate inputs. The forward indicator would be represented by the value added component of Country (i) in exports B_l that, after accounting for amount of B_l that is used to produce Country (l) exports of value C, is expressed as a percent of the value of direct exports B.

At the industry level, for the forward participation indicator, the value added in the exports of partner countries from intermediates sourced from an industry includes the value added that is transferred through indirect linkages. For example, if there were only 2 industries (1 and 2), with industry 1 exporting very little but being a major supplier of intermediates to industry 2 which is a large exporter, industry 1's value added embodied in industry 2's exports that are subsequently used to produce exports in other countries would count towards industry 1's forward indicator. As such, an industry's forward indicator can be very large (well in excess of 1) if it has a low level of direct exports but a high level of indirect exports that are used in the production of other countries' exports. The backward indicator, by contrast, is bound between 0 and 1 in the absence of significant subsidies to domestic value added factors (subsidies can result in

negative value added contributions to exports). For the backward indicator, data on one country is required (including its imports and exports). For the forward indicator, data on at least three countries is required (but generally many more) as it can only be measured when a country's exports forms part of another countries exports.

In the example provided above a number of different trade flows are required to calculate the backward and forward GVC participation indicators. For the reference Country (i), trade flows involve four other countries: the source of intermediates (Country k), the destination of exports (Country j), the destination of intermediates for exports (Country l), and the destination of exports of Country l (Country x). The backward links involve three countries (k, i and j) with the reference Country (i) being at the centre of these links as it is a user of intermediates from k and a supplier of exports to j. The forward links also involve three countries (i, l and x) but the reference Country i is at the "periphery" of this chain being only a supplier of intermediates to l. Along with trade flows, data from input-output tables that details the amount of imported and domestic inputs used in the production of exports is required.

Figure 2.2. Backward and forward participation: Supply and demand of intermediates



Notes: The green arrows denote the foreign value added embodied in imported intermediates used for exports of reference Country (i) the backward linkage. The red arrows denote the value added of the reference Country (i) embodied in its exports of intermediates which are used for exports of Country (l) the forward linkage.
Source: OECD (2015, p. 15).

The construction of the ICIO also allows for a closer examination of domestic value added. Rather than taking the share of value added of a foreign country in a reference country's exports, or that of the reference country in foreign exports, it is worth looking directly at both the domestic value added shares in own exports and total domestic value added generated by exports within a GVC chain. Mathematically, the approach is a simply manipulation of the backward indicator but can be used to shed light on a range of issues surrounding the extent of value adding captured by any given country within a value chain.

Further, if mapped to employment data, the ICIO structure allows a closer look at the employment effects of GVC participation. For any given set of industry exports, the production technology of the industry can be used to further break down domestic value added into its components.

Calculating GVC participation indicators

Using the constructed ICIO, backward and forward GVC participation rates are calculated making use of the approach set out below.

Let N and K be the number of countries and sectors respectively (N = 70 and K = 57 in this study). The variable **V** is defined as a $NK \times NK$ diagonal matrix where each diagonal element shows the share of value added in total output − V_{ri}/Y_{ri} where V and Y are value added (the sum of labour wage, capital rental, land rent, and net factor subsidy) and total production value of sector i in country r, respectively. Let **A** be the technological coefficient where each entry represents the necessary amount of intermediate inputs to increase one unit of output.

Then the $NK \times NK$ matrix $\mathbf{V}[\mathbf{I} - \mathbf{A}]^{-1}$, where **I** is an identity matrix, shows the source of value added for one unit of column sector's production. It is important to note that this measure captures all upstream sectors' contributions to value added in a specific sector. For example, in the fruits, nuts and vegetable sector, it includes direct value added in the sector itself as well as indirect value added in inputs from all other sectors (such as seed and fertiliser) used to produce vegetables by the column country.

Using this matrix, it is possible to decompose exports into value added by source. For example, let **E** be a $NK \times NK$ diagonal matrix where each diagonal element shows column sector's export. Then a matrix $\mathbf{V}[\mathbf{I} - \mathbf{A}]^{-1}\ \mathbf{E}$ identifies the source of value added for column sector's export. By summing the non-diagonal elements of this matrix down the country column we get a metric of the foreign value added of exports. Presenting this value as a share of gross exports then gives the measure of *backward participation*. The *forward participation* indicator is calculated from the same baseline matrix but rather than summing down the country column, the sum across the non-diagonal elements of the country rows is taken. Similarly, the value obtained is divided by total gross exports of the row nation to obtain the value added content of gross exports that is used by foreign nations to produce their exports.

Using similar algebra, it is also possible to identify the source of value added for consumption (not export). Let **Y** be a $NK \times N$ matrix where each column entry shows a country's final demand. Then a $NK \times N$ matrix $\mathbf{V}[\mathbf{I} - \mathbf{A}]^{-1}\ \mathbf{Y}$ shows source of value added for a country's total consumption. If interested in a specific product, it is possible replace the matrix **Y** with zero except for that product. For example, let $\mathbf{Y_A}$ be a final demand matrix where non-agricultural/food sectors are replaced as zero. Then $\mathbf{V}[\mathbf{I} - \mathbf{A}]^{-1}\ \mathbf{Y_A}$ shows source of value added for column country's agricultural/food consumption.

To ease understanding, suppose there are two countries (C1 and C2) and two sectors (S1 and S2). In this case, the matrix $\mathbf{V}[\mathbf{I} - \mathbf{A}]^{-1}\ \mathbf{E}$ is given as follow. The table indicates that the total gross export of C1-S1 (sector S1 in country C1) is \$52, and the production of \$52 of exports requires \$10 value added from C1-S1, \$30 value added from C1-S2, and so on. Foreign-sourced value added used to produce C1-S1 exports are \$12 (= 5+7) in total, and thus the sector-level backward participation indicator can be calculated as 0.23 (= 12/52). We can also define country-level backward participation indicator by aggregating all domestic sectors: The backward participation indicator can be calculated as (12+14)/(52+74) for country C1, and (4+6)/(124+146) for country C2. Conversely, \$3 (= 1+2) of value added from C1-S1 is used to produce foreign country's export, and thus forward participation indicator, measured at sector level, is 0.06 (=3/52). Again, country-level forward participation indicator can be obtained by aggregating sectors: (3+7)/(52+74) for country C1, and (11+15)/(124+146) for country C2.

Figure 2.3. The V[I − A]$^{-1}$ E matrix

	C1-S1	C1-S2	C2-S1	C2-S2
C1-S1	10	20	1	2
C1-S2	30	40	3	4
C2-S1	5	6	50	60
C2-S2	7	8	70	80
Row sum	52	74	124	146

Koopman et al. (2011) proposed the *total participation* indicator which is defined as the sum of the backward and forward indicators. Two countries can have identical values of the total participation index in a given sector while having very different degrees of position in GVCs (that is, whether they are more involved upstream or downstream in the value chain). To capture a country's position, Koopman et al. (2011) also proposed the *position index* which is given by log ratio of forward and backward indicators: *ln*(1 + forward indicator) – *ln*(1 + backward indicator). If the sector lies upstream in a supply chain, the first term (numerator) tends to be large. On the other hand, if it lies downstream, then the second term (denominator) tends to be large. For example, in the home electronics sector, if Japan specialises in providing components to assembly firms in China, the index tends to take on a high value for Japan and a low value for China.

For this study, due to a small number of very small non-zero trade flows in the GTAP database, some adjustments are made prior to the calculation of the indicators. These small trade flows appear in the database either as a result of small non-zero values being required for the model to run without error, or small rounding errors in the country-sector aggregation used (70 regions of a possible 140 are included in this study) and are therefore not representative of real trade flows. As such, trade flows of less than 5 are set to zero prior to the calculation of the forward and backward indicators.

3. Estimates of trade in value added

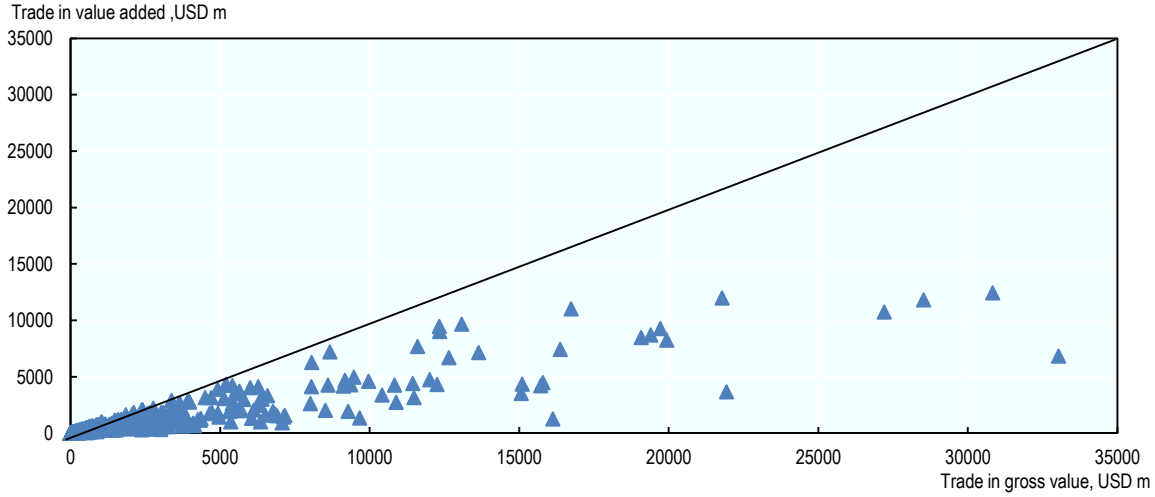
Unpacking agricultural trade and final consumption in value added terms provides a number of insights into the functioning of the agro-food markets and the drivers of competitiveness for individual countries and sectors within GVCs. It can also be used to provide better insights into the benefits created for domestic economies from GVC participation. This section provides details on trade in value added for 2011 for the 20 agro-food sectors and 70 regions examined. The estimates are derived from the ICIO described in Section 2.

3.1. Contrasting trade in value added to gross trade flows in agro-food products

Across a broad range of goods and services, trade in value added statistics have shown that gross trade flows can significantly over-estimate the value of trade flows from individual countries. For example, a commonly cited study about the Apple iPod (Dedrick et al., 2008), found that while the Chinese factory gate price of an assembled iPod was USD 144, Chinese value added only constituted USD 4. For China, the gross value of trade recorded when iPods are exported represents the full factory gate value and not the value added domestically. As different products have differing levels of domestic value added, gross trade values can therefore over-estimate the importance of trade in some products for domestic economic activity relative to others.

Figure 3.1. Agro-food trade in value added versus gross flows

USD million in 2011



Source: Author estimates.

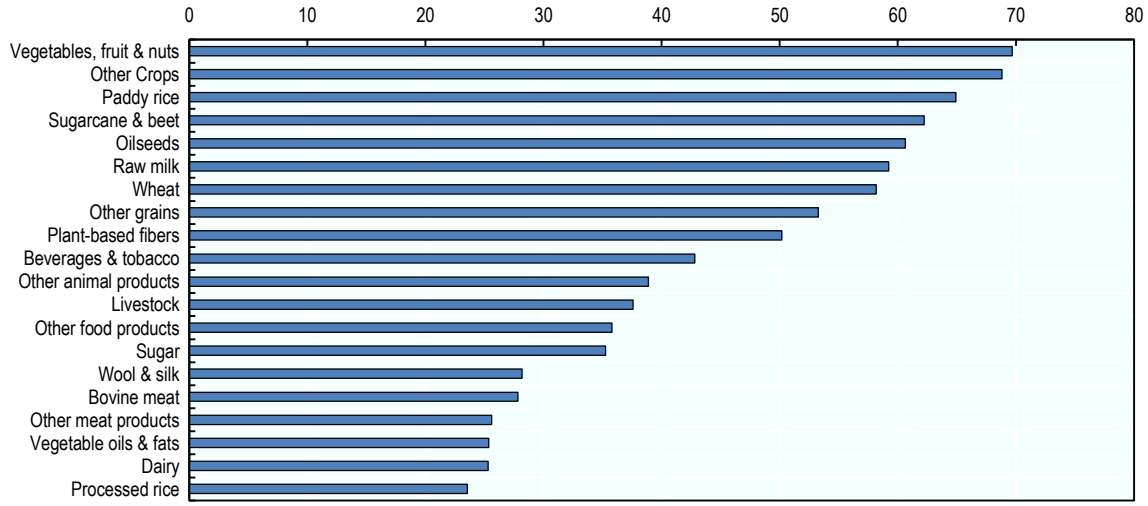
For agro-food products the same patterns appear. Trade measured in gross value terms is significantly greater than trade measured in value added terms (Figure 3.1). This holds for all countries and all products. Trade in value added (from all sources) is generally around half that of trade measured in gross value terms. However, there is considerable variation. For example, for gross export values of around USD 10 000 million, trade in value added terms varies between USD 1 300 million and USD 3 400 million.

Across agro-food products, there is considerable variation in the difference between trade in value added and gross values (expressed as the share of value added in gross flows in Figure 3.2). As expected, for less processed products, gross trade flows better approximate the trade in value added – for example, much of the gross value in vegetable, fruits and nuts trade is trade in value added (a share closer to 100%). On the other hand, for products which involve a greater level of processing, such as processed rice and dairy, trade in value added is only a small proportion of the gross trade value observed.

Despite the differences between trade in value added and gross trade flow value for individual countries, overall, looking at trade in value added does not change the relative importance of individual countries in total trade. Countries who dominate trade in gross value terms also dominate trade in value added terms. Of 70 countries and regions examined, there is virtually perfect correlation (a value of 0.98) between rankings based on trade in value added and those of trade in gross flow terms. This means that in contrast to other products, the gross flow trading patterns better represent the areas where the gains from trade accrue.

Figure 3.2. Agro-food trade in value added is less than gross trade value

Value added share of gross flows by sector (%), 2011



Source: Author estimates.

3.2. Unpacking the source of value added

Value added flows not only between countries but also across sectors. The decomposition of value added allows a better understanding of the make-up of the value of output from the agro-food sector. This section explores the broad characteristics of the sector linkages that exist between agro-food sectors and those between agro-food sectors and the rest of the economy.

In exports

For any given $1 of exported value from agro-food sectors, there are embodied a range of inputs from not only the exporting sector but also other sectors. These inputs, both material and services, can be traced back to the value added factors of production that underpin their production. As such, through the ICIO framework, the contribution from a range of sectors, both domestic and foreign, to the exports from agro-food sectors can be explored (Figure 3.3).

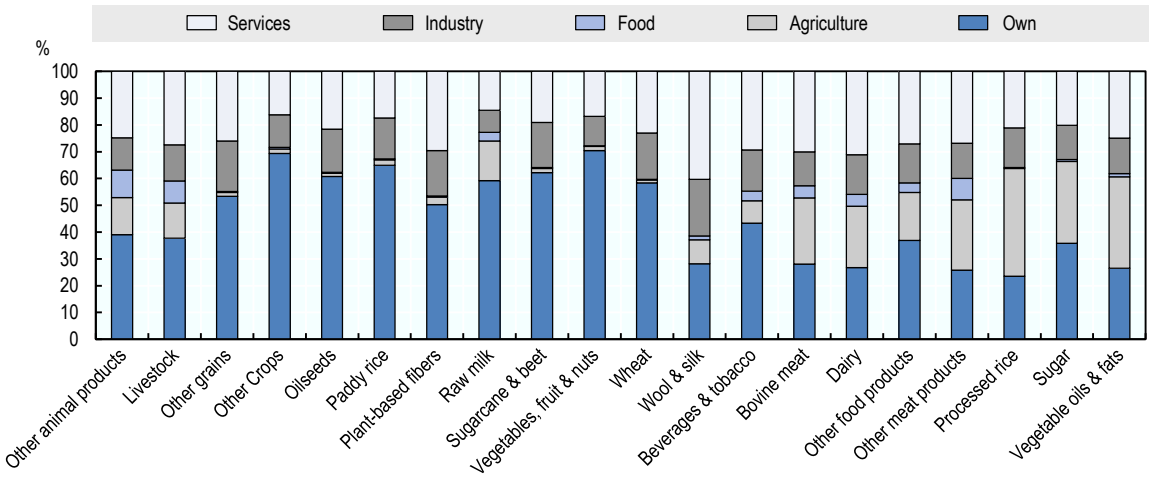
For agriculture, due to the primary nature of its production, the majority of value added is generated in the industry itself – that is, from the land, labour and capital employed.[5] For food products, on the other hand, the value added that is embodied in any export is derived more from other industries (Figure 3.3). Indeed, globally, much of the value added embodied in exports from the food sector is derived from primary agriculture. For the livestock sector, given the share of feed inputs, a much greater share of value added is contributed from other agricultural activities than that seen for other primary production activities. The services sector also plays a role for all agro-food exports. The service share varies by product, but is generally higher for the food sector.

The shares of value added by source for agro-food exports point to the importance of productivity in the agricultural sector as a means to enhance value added. The high share of value added derived within the industry, and the importance of agricultural output as a source of value added in the food sector highlight this point. Further, this high share points to the importance of competitively priced agricultural inputs for the international competiveness of the sector. This applies to both domestically produced sources and to imported intermediate agricultural products.

5. Value added in the ICIO also includes taxes (positive value added) and subsidies (negative).

Figure 3.3 Source of value added in agro-food exports

% Share of world total value added in agro-food exports, 2011



Source: Author estimates.

In final consumption

By the time agro-food products reach final demand they have used a number of further inputs from a wide range of different sectors along their path from an intermediate product to a final good. For example, production of a specific food product first requires labour, land, and capital in primary agriculture as well as various intermediate inputs such as seed, fertilisers, and pesticides. In going to the final point of sale, the product may be processed and various services are likely to be employed in the process of delivering the product to consumers (such as wholesale and retail trade and transport). All these other inputs also require labour, land and capital along with other intermediate inputs. This process continues across the economy. The ICIO provides a means to trace back through value added factors and intermediate input use to split the final value observed at end use for agro-food products between returns to labour, capital and other value added inputs across the sectors examined. This breakdown is shown in Figure 3.4 for all agro-food products in aggregate.

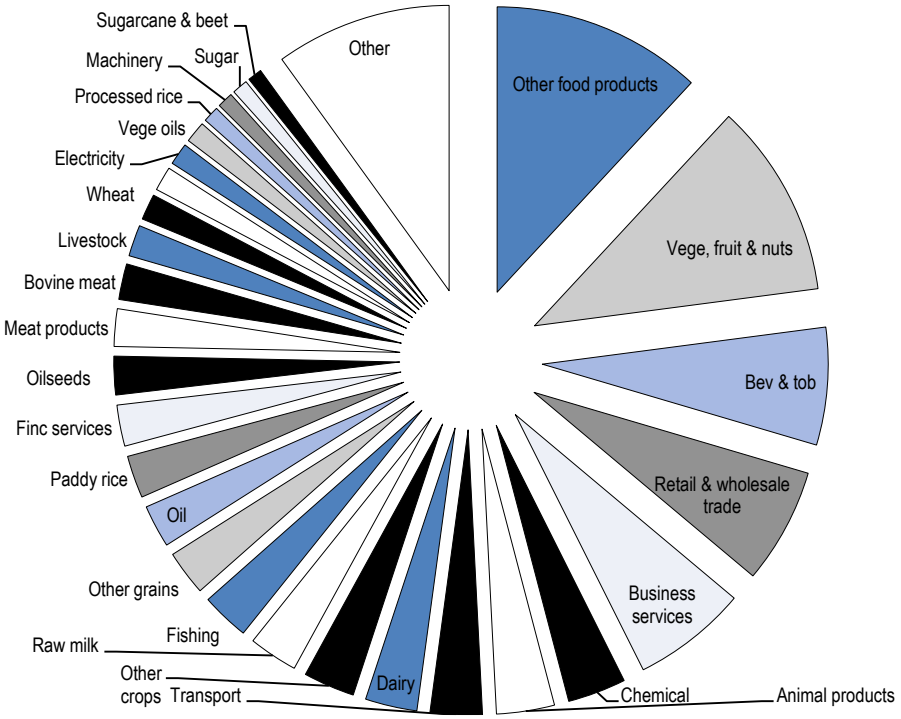
For every $1 of aggregate agro-food products consumed, varying proportions of the value of the product will accrue to different sectors in the economy. The amounts will vary by relative demand (for example, sectors with relatively higher volume and value of sales will potentially see higher shares) but also with the various production technologies used across industries and the accompanying market structures.

Worldwide a significant number of industries contribute to the value of the final agro-food product. Key sectors include other food products (food processing activities); vegetables, fruits and nuts; beverages and tobacco along with service sectors such as retail and wholesale trade; and business services. However, when viewed by broad sector category, it is agriculture that contributes (and captures) the greatest share of total value added in the final value of agro-food products consumed. Importantly, services account for around 25% of the total value added in final agro-food consumption (in aggregate terms) – more than that contributed by industrial inputs (such as machinery, fertilisers, petrol fuel, amongst others).

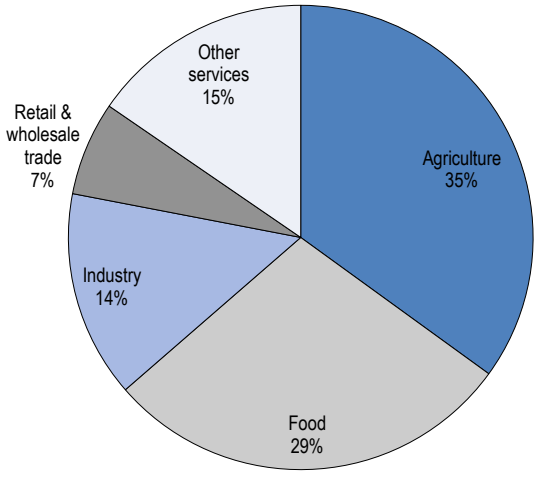
Overall, agriculture still captures the greatest share of final value of agro-food products – at 35% (or 35 cents in every dollar). This is followed by the food sector which captures 29%. The relative share captured by the final margin services provided by retail and wholesale trade accounts for around 7%. Breakdowns in value added can also be obtained by various groupings, such as between high and middle to low income countries (Figure 3.5). Such breakdowns reveal significant differences in the industry share of final value and as such the nature of the value chains within the country groupings.

Figure 3.4. Agriculture and food sectors dominate share of value added final demand value

Share of world total value added in agro-food final consumption, 2011



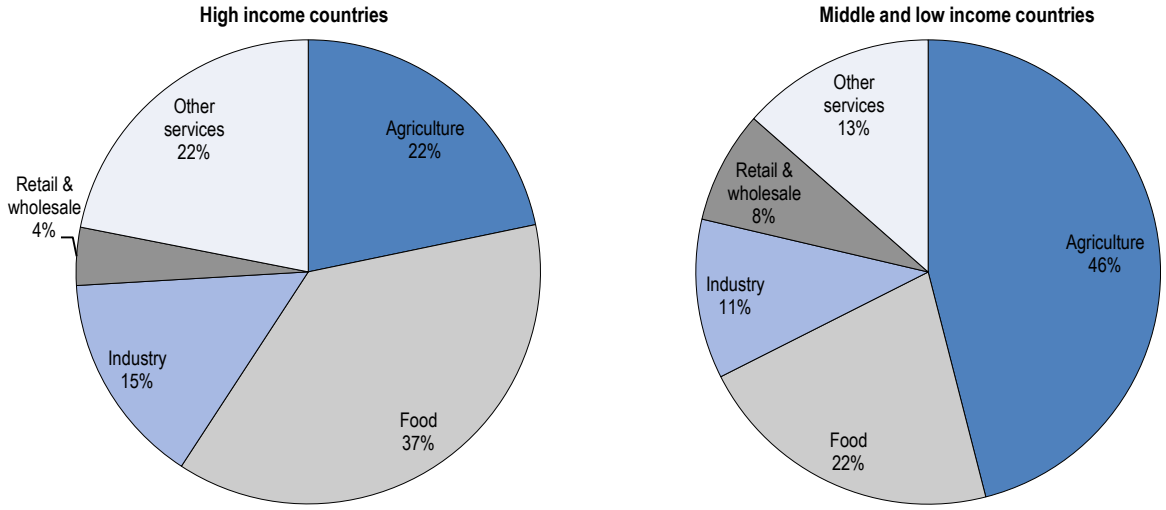
By broad sector



Notes: The figure shows each sector's contribution to value added in final demand of agro-food products. The contribution is measured as share so that sum of all 57 sectors is equal to 1. The sectors with small shares have been aggregated. Final consumption does not include demand for intermediate products. Agro-food total value includes final fisheries and forestry goods.
Source: Author estimates.

Figure 3.5. Differences in share of final value of agro-food products in high and middle to low income countries

Average share of total value added in agro-food final consumption, 2011



Notes: The figure shows each sector's contribution to value added in final demand of agro-food products. The contribution is measured as share so that sum of all 57 sectors is equal to 1. The sectors with small shares have been aggregated. Final consumption does not include demand for intermediate products. Agro-food total value includes final fisheries and forestry goods. Country classification based on World Bank High Income Country classification.
Source: Author estimates.

4. Estimates of GVC participation across agro-food sectors

In this section estimates of the forward and backward indicators of GVC participation in 2011 are presented for 20 agro-food sectors. Further, differences between the estimates derived in this study to those from the TiVA database for the aggregate agriculture and food sectors are presented.

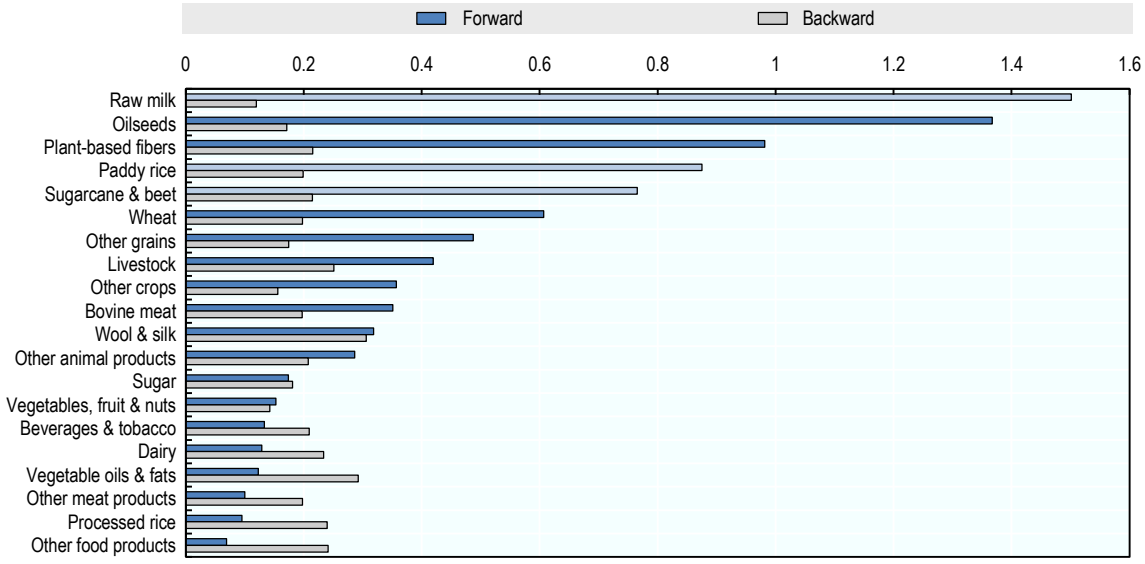
4.1. Forwards and backwards participation estimates

In general, the results indicate that agricultural sectors participate in value chains as the supplier of raw materials and food sectors in terms of sourcing these inputs from around the globe (as found in other studies). However, within each sector there is significant variation, with plant-based fibres, wool (and silk) along with some animal products countering the general statements in terms of backward participation. Across the sectors, the raw milk sector has the highest rates of forward participation (on average) with wool and silk having the highest rates of backward participation (on average) (Figure 4.1). However, it should be noted that there are only very few countries involved in the export of raw milk – this is also true for paddy rice and sugarcane & beet (all with lighter shading on Figure 4.1).

The backward and forward indicators shown in Figure 4.1 depict the simple averages across industries. However, as trade is not uniform across countries, it is also useful to look at the weighted average results that take into account relative trade volumes - representing the participation of a 'typical' traded commodity (Figure 4.2). In general, the results are similar to the simple averages; however, the weighted averages are lower, suggesting a greater volume of trade is associated with lower GVC participation than indicated from the simple averages. The differences are greatest for oilseeds, plant-based fibres and wheat. For these, while some sectors in some countries with small export volumes are associated with either high backward and/or forward participation, the bulk of trade occurs in simpler GVCs.

Figure 4.1. Average forward and backward participation

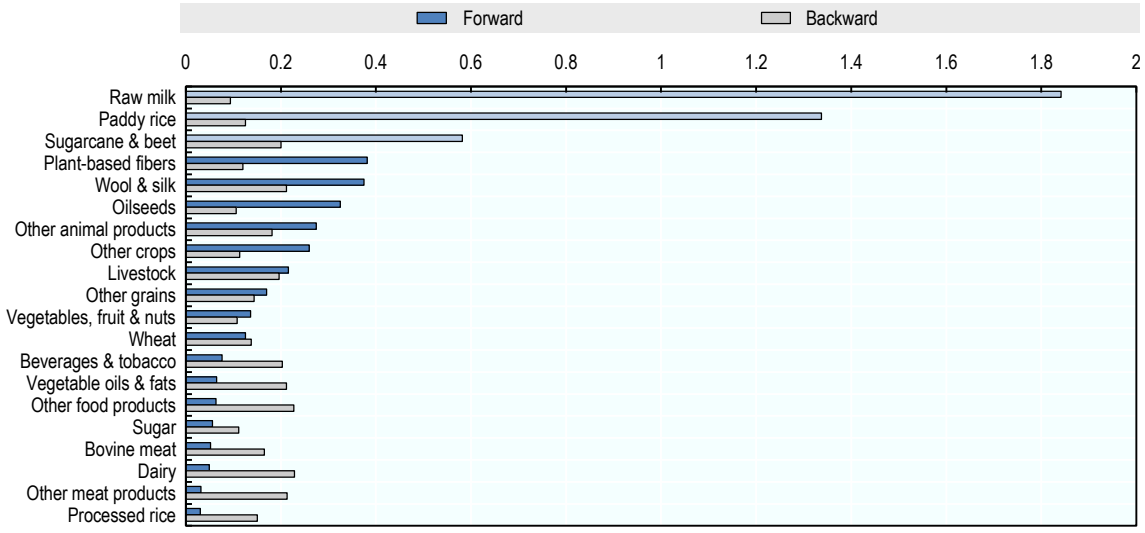
Average by sector, 2011



Notes: Sectors with lighter shading represent those with limited trade observations. As such, while for those sectors where trade exists, forward participation is high, it is not representative of most sectors worldwide.
Source: Author estimates.

Figure 4.2. Trade weighted average forward and backward participation

Weighted average by sector, 2011

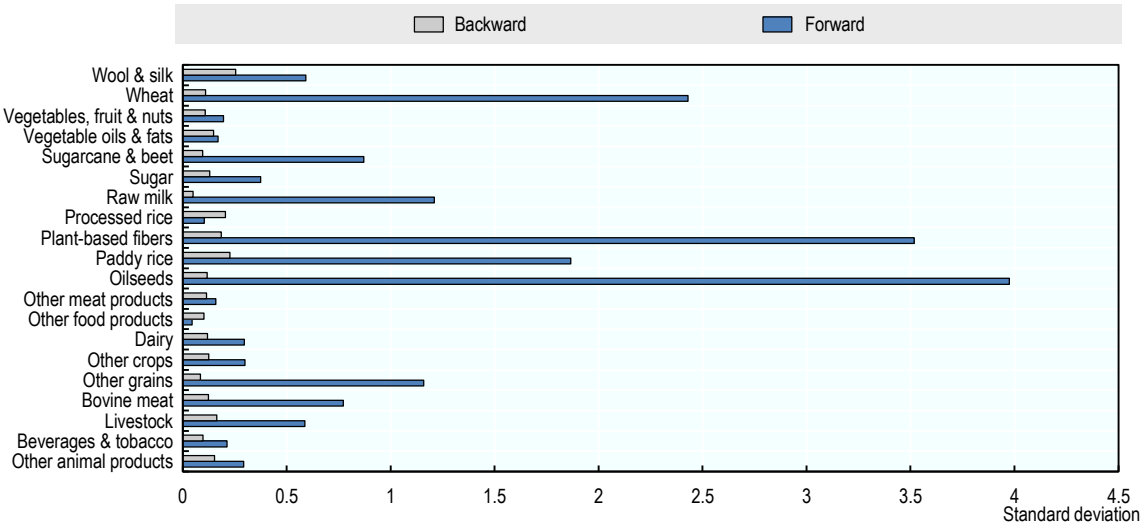


Notes: Sectors with lighter shading represent those with limited trade observations. As such, while for those sectors where trade exists, forward participation is high, it is not representative of most sectors worldwide.
Source: Author estimates.

Along with differences across the sectors, there is also considerable variation within sectors across countries (Figure 4.3). What is noticeable is that the variation in forward participation is considerably greater than that of backward participation, showing a high degree of variation in the connectedness to international markets through exports. These issues are explored in detail in the accompanying paper in this series (Greenville et al., 2017 forthcoming).

Figure 4.3. Variation in GVC participation

Standard deviation by sector, 2011



Notes: Sectors with lighter shading represent those with limited trade observations. As such, while for those sectors where trade exists, forward participation is high, it is not representative of most sectors worldwide.
Source: Author estimates.

4.2. Comparisons with TiVA database derived estimates

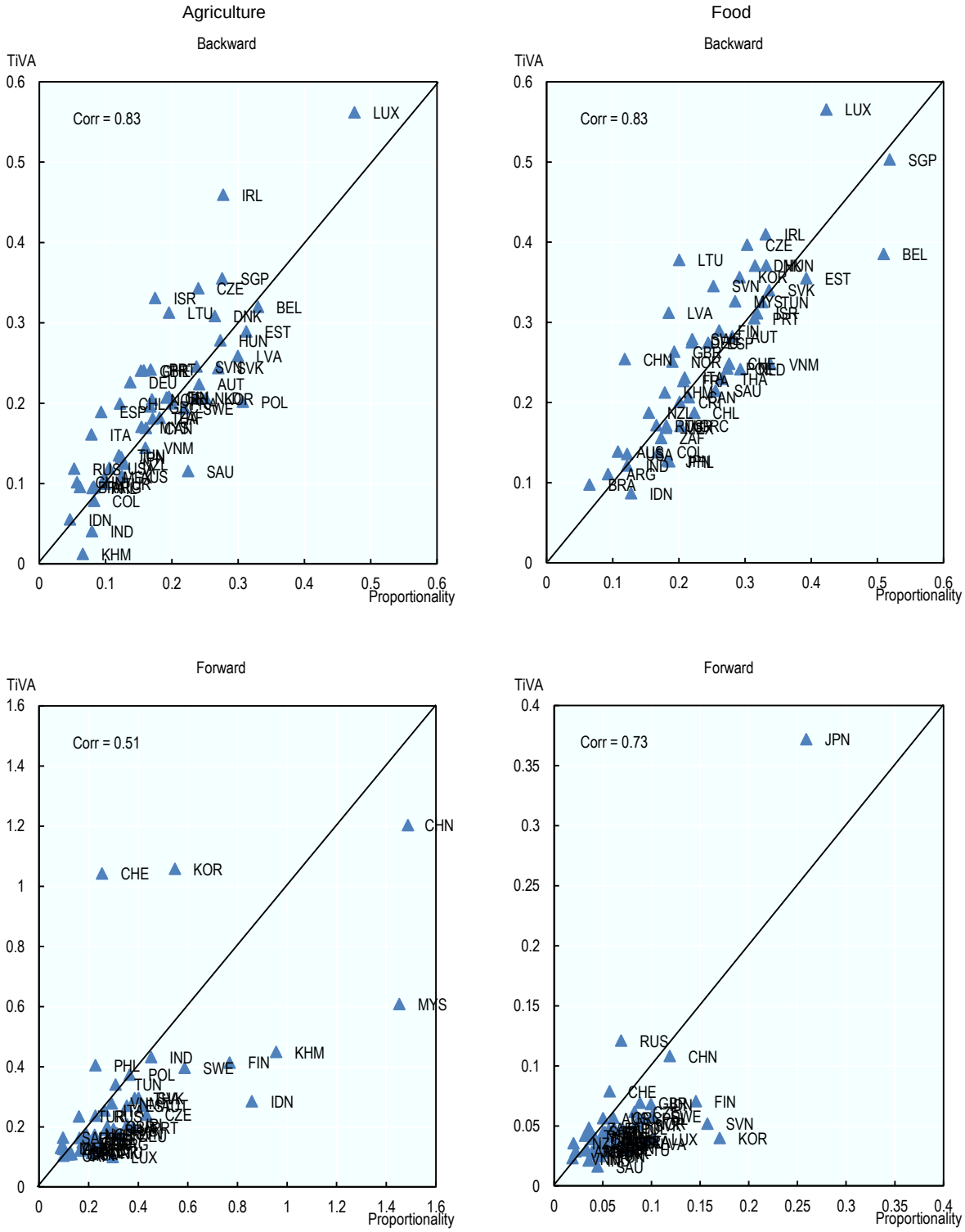
As the TiVA database only contains information at the aggregate level for agriculture and food sectors, the comparisons presented here are also at the aggregate level. For the proportionality assumption, this has been done by aggregating the GTAP sectors to match those broader categories presented in the TiVA database.

The comparisons show a strong similarity between the two measures (Figure 4.4). In particular, the results from the backward participation by both the agriculture and food sectors and the forward for the food sector are very similar for each country examined. Differences are greater when looking at the agriculture sectors forward participation. Overall, the estimates from the GTAP database generate lower backward participation but higher forward participation for both the agriculture and food sectors in aggregate. On average, the differences across countries were greater for agriculture than seen for food sectors. The largest differences are observed for forward indicators for Japan's food sector, and Korea's and Chile's agriculture sector.

The main reason underpinning the differences observed is likely to be due to the differences in the underlying input-output tables. GTAP contains a range of disaggregated input-output tables and invariably there are likely to be differences in these structures which, although aggregated, change the nature of the relationships. Further, in compiling the GTAP database adjustments are made to trade flows to correct for differences between reporter exporter and importer flows. The corrections differ to the adjustments made within the TiVA database and as such will also likely introduce some divergence in the results (trade flows are used as the denominator in the calculation of the forward and backward indicators).

Figure 4.4. Comparisons between backward and forward indicators

Proportionality assumption versus TiVA 2011



Source: Author estimates.

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Annex A.

GTAP Sectors and regions in the study

Table A.1. GTAP sectors in the model

No.	Code	Description
1	pdr	**Paddy Rice**: rice, husked and unhusked
2	wht	**Wheat**: wheat and meslin
3	gro	**Other Grains**: maize (corn), barley, rye, oats, other cereals
4	v_f	**Vegetables, fruit & nuts**: vegetables, fruit, fruit and nuts, potatoes, cassava, truffles,
5	osd	**Oilseeds**: oil seeds and oleaginous fruit; soy beans, copra
6	c_b	**Sugarcane & beet**: sugar cane and sugar beet
7	pfb	**Plant-based Fibres**: cotton, flax, hemp, sisal and other raw vegetable materials used in textiles
8	ocr	**Other Crops**: live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds, beverage and spice crops, unmanufactured tobacco, cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets, plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes, sugar beet seed and seeds of forage plants, other raw vegetable materials
9	ctl	**Livestock**: cattle, sheep, goats, horses, asses, mules, and hinnies; and semen thereof
10	oap	**Other animal products**: swine, poultry and other live animals; eggs, in shell (fresh or cooked), natural honey, snails (fresh or preserved) except sea snails; frogs' legs, edible products of animal origin n.e.c., hides, skins and furskins, raw , insect waxes and spermaceti
11	rmk	**Raw milk**
12	wol	**Wool & silk**: wool, silk, and other raw animal materials used in textile
13	frs	**Forestry**: forestry, logging and related service activities
14	fsh	**Fishing**: hunting, trapping and game propagation including related service activities, fishing, fish farms; service activities incidental to fishing
15	coa	**Coal**: mining and agglomeration of hard coal, lignite and peat
16	oil	**Oil**: extraction of crude petroleum and natural gas (part), service activities incidental to oil and gas extraction excluding surveying (part)
17	gas	**Gas**: extraction of crude petroleum and natural gas (part), service activities incidental to oil and gas extraction excluding surveying (part)
18	omn	**Other Mining**: mining of metal ores, uranium, gems. other mining and quarrying
19	cmt	**Bovine meat**: fresh or chilled meat and edible offal of cattle, sheep, goats, horses, asses, mules, and hinnies. raw fats or grease from any animal or bird.
20	omt	**Other meat**: pig meat and offal. preserves and preparations of meat, meat offal or blood, flours, meals and pellets of meat or inedible meat offal; greaves
21	vol	**Vegetable oils & fats**: crude and refined oils of soya-bean, maize (corn),olive, sesame, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and canola, mustard, coconut palm, palm kernel, castor, tung jojoba, babassu and linseed, perhaps partly or wholly hydrogenated,inter-esterified, re-esterified or elaidinised. Also margarine and similar preparations, animal or vegetable waxes, fats and oils and their fractions, cotton linters, oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; degras and other residues resulting from the treatment of fatty substances or animal or vegetable waxes.

Table A.1. GTAP sectors in the model (*continued*)

No.	Code	Description
22	mil	**Dairy**: dairy products
23	pcr	**Processed Rice**: rice, semi- or wholly milled
24	sgr	**Sugar:** processed sugar
25	ofd	**Other Food**: prepared and preserved fish or vegetables, fruit juices and vegetable juices, prepared and preserved fruit and nuts, all cereal flours, groats, meal and pellets of wheat, cereal groats, meal and pellets n.e.c., other cereal grain products (including corn flakes), other vegetable flours and meals, mixes and doughs for the preparation of bakers' wares, starches and starch products; sugars and sugar syrups n.e.c., preparations used in animal feeding, bakery products, cocoa, chocolate and sugar confectionery, macaroni, noodles, couscous and similar farinaceous products
26	b_t	**Beverages & Tobacco**
27	tex	**Textiles**: textiles and man-made fibres
28	wap	**Wearing Apparel**: Clothing, dressing and dyeing of fur
29	lea	**Leather**: tanning and dressing of leather; luggage, handbags, saddlery, harness and footwear
30	lum	**Lumber**: wood and products of wood and cork, except furniture; articles of straw and plaiting materials
31	ppp	**Paper & Paper Products**: includes publishing, printing and reproduction of recorded media
32	p_c	**Petroleum & Coke**: coke oven products, refined petroleum products, processing of nuclear fuel
33	crp	**Chemical Rubber Products**: basic chemicals, other chemical products, rubber and plastics products
34	nmm	**Non-Metallic Minerals**: cement, plaster, lime, gravel, concrete
35	i_s	**Iron & Steel**: basic production and casting
36	nfm	**Non-Ferrous Metals**: production and casting of copper, aluminium, zinc, lead, gold, and silver
37	fmp	**Fabricated Metal Products**: Sheet metal products, but not machinery and equipment
38	mvh	**Motor vehicles and parts**: cars, lorries, trailers and semi-trailers
39	otn	**Other Transport Equipment**: Manufacture of other transport equipment
40	ele	**Electronic Equipment**: office, accounting and computing machinery, radio, television and communication equipment and apparatus
41	ome	**Other Machinery & Equipment**: electrical machinery and apparatus n.e.c., medical, precision and optical instruments, watches and clocks
42	omf	**Other Manufacturing**: includes recycling
43	ely	**Electricity**: production, collection and distribution
44	gdt	**Gas Distribution**: distribution of gaseous fuels through mains; steam and hot water supply
45	wtr	**Water**: collection, purification and distribution
46	cns	**Construction**: building houses factories offices and roads
47	trd	**Trade**: all retail sales; wholesale trade and commission trade; hotels and restaurants; repairs of motor vehicles and personal and household goods; retail sale of automotive fuel
48	otp	**Other Transport**: road, rail ; pipelines, auxiliary transport activities; travel agencies
49	wtp	**Water transport**
50	atp	**Air transport**
51	cmn	**Communications**: post and telecommunications
52	ofi	**Other Financial Intermediation**: includes auxiliary activities but not insurance and pension funding
53	isr	**Insurance**: includes pension funding, except compulsory social security
54	obs	**Other Business Services**: real estate, renting and business activities
55	ros	**Recreation & Other Services**: recreational, cultural and sporting activities, other service activities; private households with employed persons (servants)
56	osg	**Other Services (Government)**: public administration and defense; compulsory social security, education, health and social work, sewage and refuse disposal, sanitation and similar activities, activities of membership organisations n.e.c., extra-territorial organisations and bodies
57	dwe	**Dwellings**: ownership of dwellings (imputed rents of houses occupied by owners)

Table A.2. GTAP regions in the study

No.	Code	Description	No.	Code	Description
1	AUS	Australia	43	SVK	Slovakia
2	NZL	New Zealand	44	SVN	Slovenia
3	CHN	China	45	ESP	Spain
4	JPN	Japan	46	SWE	Sweden
5	KOR	Korea	47	GBR	United Kingdom
6	KHM	Cambodia	48	CHE	Switzerland
7	IDN	Indonesia	49	NOR	Norway
8	MYS	Malaysia	50	RUS	Russian Federation
9	PHL	Philippines	51	UKR	Ukraine
10	SGP	Singapore	52	KAZ	Kazakhstan
11	THA	Thailand	53	ISR	Israel
12	VNM	Viet Nam	54	SAU	Saudi Arabia
13	BGD	Bangladesh	55	TUR	Turkey
14	IND	India	56	EGY	Egypt
15	PAK	Pakistan	57	MAR	Morocco
16	LKA	Sri Lanka	58	TUN	Tunisia
17	CAN	Canada	59	CMR	Cameroon
18	USA	United States of America	60	CIV	Cote d'Ivoire
19	MEX	Mexico	61	GHA	Ghana
20	ARG	Argentina	62	NGA	Nigeria
21	BRA	Brazil	63	ETH	Ethiopia
22	CHL	Chile	64	KEN	Kenya
23	COL	Colombia	65	MDG	Madagascar
24	CRI	Costa Rica	66	MWI	Malawi
25	AUT	Austria	67	MUS	Mauritius
26	BEL	Belgium	68	MOZ	Mozambique
27	CZE	Czech Republic	69	ZAF	South Africa
28	DNK	Denmark	70	ROW	Rest of the World
29	EST	Estonia			
30	FIN	Finland			
31	FRA	France			
32	DEU	Germany			
33	GRC	Greece			
34	HUN	Hungary			
35	IRL	Ireland			
36	ITA	Italy			
37	LVA	Latvia			
38	LTU	Lithuania			
39	LUX	Luxembourg			
40	NLD	Netherlands			
41	POL	Poland			
42	PRT	Portugal			

Annex B.

Differences between the calculated GVC indicators

The differences in the forward and backward indicators based on the proportionality assumption (as used in this study) and those based on the alternative method (Section 2) are explored in this annex. On the whole, the results indicate strong consistency between the two approaches.

Proportionality versus alternative methods

In this study, the estimates of GVC participation have been derived from an ICIO that has been constructed under the "proportionality assumption". The approach maintains the current trade structure within the database and makes use of the industry use shares of imported products in order to allocate the bilateral trade flows to specific industries and demand sources.

An alternative approach has been developed by Liapis and Tsigas (2014) which instead adjusts the GTAP model theory to allow for the sourcing of imports by product for individual industries to be known. That is, sector to sector bilateral trade flows are explicitly modelled. Under this approach, the bilateral sector to sector trade flows can then be adjusted, through various simulations, to better match the observed intermediate and final goods trade flows as represented in the UN's Broad Economic Classification (BEC) use categories. The BEC data is available at a detailed HS6 (six-digit classification of the Harmonized System) level. For food products, BEC allocates products into four categories: "Food and beverages, Primary, Mainly for industry Intermediate goods"; "Food and beverages, Primary, Mainly for household consumption Consumption goods"; "Food and beverages, Processed, Mainly for industry Intermediate goods"; and "Food and beverages, Processed, Mainly for household consumption Consumption goods". The key difference between the proportionality assumption and the alternative approach is that under the alternative approach the trade in intermediates derived based on observed bilateral trading patterns between countries.

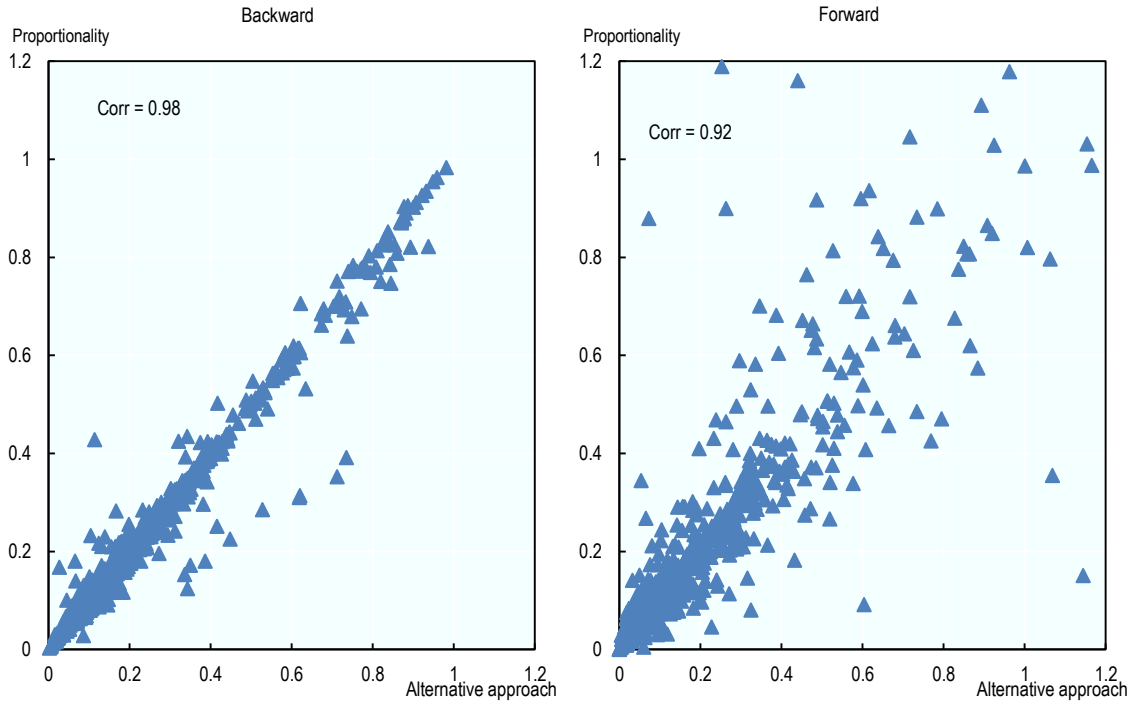
After a series of targeting simulation, an ICIO can be constructed with the revised GTAP database using the same method as described in the technical appendix. These simulations assure that the sectoral bilateral trade flows do not change and that the supply and use balance for each sector in each country. To date, work has been completed in applying this approach to the 2007 database. Making use of the revised database for 2007, estimates of forward and backward participation for agro-food sectors have been calculated. The differences between these estimates and those from applying the proportionality assumption are shown in Figure B.1.

What is observed is that the estimates for backward participation for each agro-food sector and region in the model remain virtually unchanged. Both approaches therefore yield consistent estimates of the backward linkages within agro-food GVCs.

The results for forward estimates are more varied; however, overall the estimates are highly correlated. The proportionality assumption appears to more often overestimate the forward linkages when compared with the alternative approach. On average, the size of the error is small suggesting that the proportionality assumption provides a good proxy of results from a more accurate mapping of trade by use category. The likely explanation of this relates to the fairly broad classification of intermediate and final goods with the BEC system, with many agricultural goods being classed entirely as intermediate products. The differences are biased by large forward estimates for a small number of sectors under the proportionality assumption.

Figure B.1. Correlation between backward and forward estimates

Proportionality versus alternative approaches, 2007 estimates



Source: OECD estimates. The data is at country-sector level, where only agricultural and food sectors are used.