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Dynamic Changes and Effects of Agro-Food GVCS

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DYNAMIC CHANGES AND EFFECTS OF AGRO-FOOD GVCS

Jared Greenville, Kentaro Kawasaki,
and Marie-Agnès Jouanjean

Global value chains (GVCs) in agriculture and food sectors are becoming an important part of the agro-food trading landscape, influencing both the nature of the gains from trade and the impacts of trade policies. This study explores the changes in trade in value added that are occurring within agro-food GVCs and the implications that participation in agro-food GVCs has had on the agro-food sectors. It makes use of a database on trade in value added for 22 agro-food sectors derived from the Global Trade Analysis Project (GTAP) database. The study finds that between 2004 and 2014, agro-food sectors have been increasing their participation in GVCs and that the links created within these production networks have become more "global" in nature. At the same time, agro-food GVCs have become increasingly centred around hubs in the People's Republic of China and Germany where large amounts of value added are funnelled before reaching the end consumer. The study also finds that participation in agro-food GVCs is beneficial for sector development and growth – both in aggregate terms and in terms of domestic value added from exports. Of key importance has been the use of foreign value added and access to a wide diversity of imported inputs. However, policies that restrict trade and limit market openness reduce participation and sector growth and development – including policies that create barriers to trade in agro-food products themselves. In addition, the study finds that the use of services value added in exports is an important factor that contributes to sector growth, which highlights the importance of the broader policy environment to enhance the benefits from agro-food GVCs.

Key words: Agriculture, GTAP, multi-regional output, global value chains, agricultural trade

JEL codes: F14, F60, Q17

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Executive summary

This paper presents findings on the changes in agriculture and food global value chain (GVC) participation between 2004 and 2014 for 22 agro-food sectors. It also explores the effects that GVC participation has had on agro-food sector development and transformation (the dynamic effect). GVC participation is explored by looking at the trade the flows of domestic value added between countries and how they are used in processing and final consumption in the importing country or re-exported before reaching a third (or fourth) country's final demand. This paper takes a country-sector perspective and does not look at the individual relationships between producers and other value chain actors in specific value chains.

Several developments occurred between 2004 and 2014 in international agro-food markets. In particular, this period witnessed a significant shift in trade from and towards developing and emerging countries. Two shocks also hit world markets – the global economic crisis and the food price spikes and rises – which may have disrupted the relationship between GVCs and sector development. However, evidence on agro-food trade growth suggests the economic crisis did not have an immediate impact on trade in aggregate (in contrast to other merchandise trade). Other changes in the international trade landscape have possibly been more important in defining the observed trends.

The results obtained by exploring changes in trade in value added in agro-food markets indicate that GVC participation by agro-food sectors increased between 2004 and 2014. The changes are not uniform, with some countries seeing an increasing intensity in the flow of agro-food products (value) within GVCs. In conjunction, agricultural and food value chains are increasingly centralised around specific hubs, with the ends of the value chains centralised around the People's Republic of China (hereafter "China"), the United States, and Germany. This suggests that the potential ripple effect from supply and demand shocks in these three major hubs could be significant on satellite countries.

Along with increases in GVC participation, there is evidence of changes in the complexity of agro-food GVCs. Changes in the diversity of sourcing from GVCs, both in the number of sources and types of inputs, suggest that sectors are increasingly buying from a wider range of suppliers to support production.

China emerges as a key player, accounting for the largest increase in the use of agro-food value added for exports (backward linkages) and in the supply of agro-food value added for exports (forward linkages). In contrast with the location of global production growth, many developed countries remain significant drivers of agro-food GVCs and have been responsible for significant shares of the growth in trade in agro-food value added – in particular European countries.

There have also been changes in the distribution of the returns from GVC participation. Overall, with rising emerging and developing country participation, the share of total returns accruing to unskilled labour and capital in agro-food sectors have risen, while those of skilled labour and land have fallen (although the total has risen). The shift towards greater emerging and developing country involvement has also seen a reduction in the

aggregate service sector share of agro-food export value given the less service-intensive nature of their production.

This study finds evidence of several important dynamic effects resulting from the impacts of GVC participation on agro-food sectors.

- *GVC participation is a significant driver of sector development*. Using foreign factors in the production of exports (and production more generally) has a positive impact on domestic added value creation and sector growth. The results from the analysis suggest that countries with higher initial backward participation in 2004 experienced stronger aggregate domestic value added growth and stronger growth in domestic value added exports compared with those with lower levels of participation. Similarly, having access to a more diverse set of imported intermediate inputs promoted sector growth and, for agro-food sectors, selling into GVCs has had positive effects on domestic value added creation and exports – be it directly or through other domestic and foreign processing sectors.
- *GVC participation has positive effects on labour and producer returns*. Having access to competitive foreign inputs, and the spillovers from using those inputs, has a positive impact on the share of value added captured by the producing industry itself – a larger share of a larger amount. This means higher returns to farmers and domestic food processors. The strongest effects are seen for capital, land and unskilled labour, but skilled labour also benefits. While it is not possible to tease out further the type of impact on labour – be it more jobs or higher wages – there is a positive impact.
- *Using services along the value chain is an important driver of domestic value added growth*. Increasing service use across the value chain as represented by an increase in the service share of exports – which represents by extension an increase in service use within the domestic production chain – is beneficial for domestic value added growth. This result highlights that the development of GVCs in the agriculture and food sectors is not just about mechanisation and investments to promote efficiency. The "de-commodification" of output means it is not only about what is produced, but also *how* it is produced and *how* it gets delivered to export markets or final consumers. This *how* is the service element of the value chain and increasing shares in export value were found to be beneficial for sector growth. Such a result is important when thinking both in terms of sector development and when considering changes in the share of the agro-food sector in the final value of a product. Adding services value means that the agro-food sector's share in final value will ultimately fall. Thus policies that create the conditions where service value is added can increase producer returns in aggregate, but this may mean that the share of the final dollar captured by producers will actually be less.
- *Protectionist policies harm development and transformation*. For tariffs in particular, increasing levels of protection were found to be harmful for growth in domestic value added. That is, while tariffs are put in place to aid domestic industries, they are more likely to have negative impacts on growth over time. Furthermore, agro-food tariffs see a shift in the share of final value to sectors outside agriculture or food as they lead to a greater share being captured by intermediate inputs – domestic and foreign, likely due to the higher costs of these inputs.

Overview

Several developments occurred between 2004 and 2014 in international agro-food markets that have influenced global agro-food trade. In particular, this period witnessed a significant shift in trade from and towards developing and emerging countries. Two significant shocks hit world markets – the global economic crisis and the food price spikes and rises – which had the potential to disrupt the relationship between global value chains (GVCs) and sector development. However, evidence on agro-food trade growth in suggests the economic crisis did not have an immediate impact on trade in aggregate (in contrast to other merchandise trade) or alter agro-food GVC relationships. Instead, other changes in the international trade landscape have been more important in defining the observed trends.

The integration of world agro-food markets through GVCs has increased

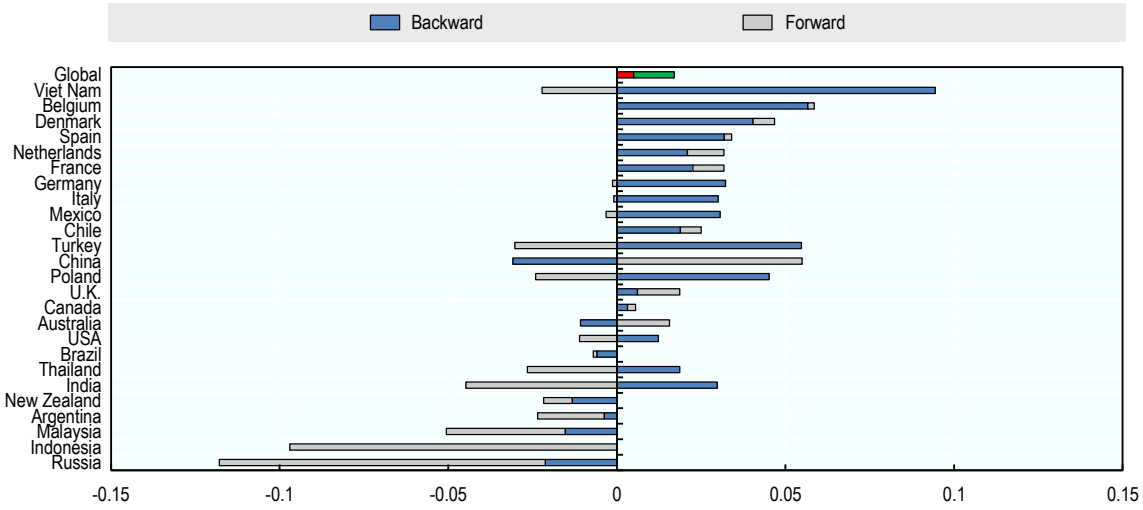
The increase over the period 2004-2014 in agro-food trade was accompanied by increased integration of the world's food system. There are several ways to explore changes in GVC participation, including: the use of foreign value in exports (backward participation); the use of own value added in other country exports (forward participation); the linkages in value added flows between countries; and changes in the location of production of agro-food value added compared with where it is consumed. Across a range of measures, indicators suggest that agro-food GVC participation is increasing, although in many instances this may be to better serve domestic markets through the use of foreign inputs rather than meeting foreign demand. Two of these measures – backward and forward participation – show that agro-food GVC participation has increased globally, with strong increases seen between 2004 and 2011 but small decreases between 2011 and 2014., The overall rise over this period means that agro-food sectors were using more foreign inputs in the production of their exports and a greater share of agro-food exports were being used in the production of other exports.

There was significant diversity across countries and major traders, with changes in GVC participation reflecting changes in both markets and in the location of production. For many major trading countries, much of the increase in GVC participation was driven by rising backward participation (Figure 1). Conversely, for major trading countries that experienced decreases in participation, much of the change resulted from changes in forward participation. However, for these countries the real value of exports and agro-food domestic value added increased suggesting the changes were brought about by changes in the types of GVCs in which they operate – with more value added going straight to foreign final demand or processing for foreign final demand.

Flows of value added between countries also intensified between 2004 and 2014. However, the changes are not uniform. China emerges as a key driver of this growth, playing a major role as a supplier of value added for use in other country exports and as a buyer of value added for its own exports (Figure 2).

Figure 1. Changes in backward and forward participation in agro-food GVCs

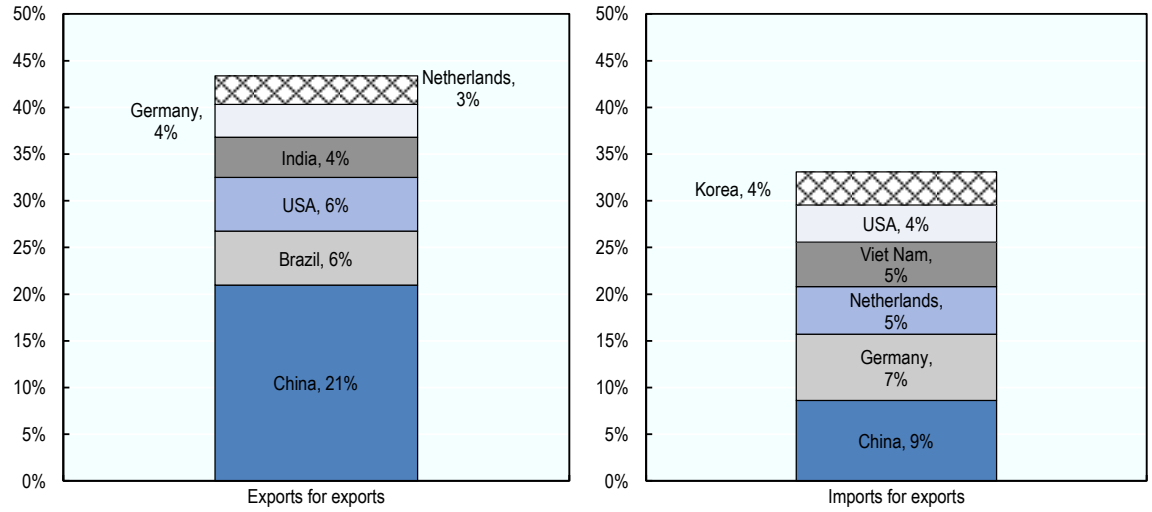
Change in indicator between 2004 and 2014



Note: Global changes represent changes to global trade weighted averages.
Source: Author estimates.

Figure 2. Shares of growth in trade in value added in agro-food GVCs

% share of total global increase of trade in value added in GVCs



Note: Exports for exports represents the value added exported that is used in other countries' exports. Imports for exports represents the value added imported for use in a country's own exports.
Source: Author estimates.

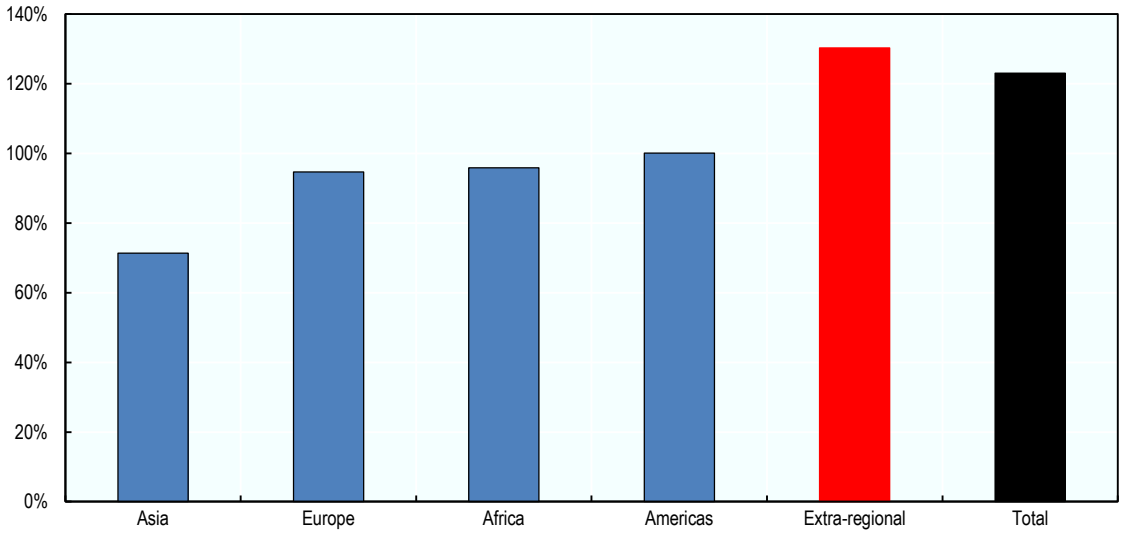
The United States, Germany and the Netherlands are also key traders in agro-food GVCs as both drivers of the increases in the supply of value added and in terms of purchases of value added for exports.

Agro-food GVCs are becoming more global but increasingly centred around individual country hubs

Agro-food GVC linkages through the use of value added in the production of exports are becoming more global. In total, agro-food value added used to produce foreign exports increased by 123% in nominal terms between 2004 and 2014, with the strongest increase seen in extra-regional linkages – those between countries located in different broad geographical regions – which grew at just over 130% (Figure 3). Within regions, intra-Asia linkages had the lowest growth, and intra-Americas experiencing the highest (driven by Central and South America). Key drivers of the growth in the extra-regional linkages were China and Europe, both having global sourcing patterns of value added for use in their agro-food exports. For China, integration in GVCs is occurring alongside further development of its own agro-food sectors which has allowed it to both export more and provide more domestically-produced inputs for the production of exports (resulting in a fall in China's backward participation measure). Nevertheless, in absolute value added terms, and in terms of linkages, its role in agro-food GVCs grew between 2004 and 2014.

Figure 3. Growth in sourcing of value added from agro-food GVCs for use in exports, 2004-14

% change from 2004 to 2014 in nominal trade in value added



Note: Extra-regional trade is defined as those linkages that occur outside countries within each broad region shown.
Source: Author estimates.

Although extra regional linkages have increased, they have done so around a smaller number of key players as agricultural and food value chains become increasingly centralised around specific hubs: China, the United States, and Germany. China, in particular, is both a central seller of intermediates for the production of agro-food products and a buyer of value added for the production of its agro-food exports and to serve its own final demand (largely through the rising volume of value added purchases even if the shares of Chinese exports have fallen). European countries, Germany in particular, are key buyers of value added for use in exports and in final demand – a result which indicates that the food systems of EU members is highly integrated. For the United States, as a buyer, it is

most central for purchases towards its own final demand rather than any other form of engagement.

Other central sellers of value added are some of the world's major agricultural producers and present a more varied picture despite the central role played by China. Despite the greater diversity, however, there has been a consolidation in centrality among several key players.

Diverging trends are observed among some emerging economies. Large exporters of agro-food products in Latin America have maintained their role as central players in agro-food GVCs in various sectors, mainly as sellers of value added (either as intermediates or for final demand). These countries have been joined by several emerging Asian countries who have increased their importance in agro-food GVCs as sellers of intermediates. Few changes seen for other emerging and developing countries.

The changes observed suggest that agro-food GVCs have developed in similar ways to manufacturing sectors. That is, there remains a strong regional dimension despite the growth in extra-regional trade; both ends of the value chains are concentrated around specific hubs and emerging economies have become important players in the middle of the chain as suppliers of agro-food intermediates. The development of hubs in the agro-food GVC system has possible consequences in terms of the resilience of the value chain, with ripple effects possible on satellite countries from both supply and demand shocks in the economies of the three major agro-food GVC hubs. This remains an area for further research.

GVC complexity has increased and changes are observed in the distribution of returns from participation

GVCs have increased in complexity. Looking at the input bundle used in the production of agro-food exports indicates diversification. This means that over time, the source and type of value added used to produce agro-food exports across the world is becoming more varied, suggesting that the number of linkages to a range of other countries and/or sectors is expanding. In other words, agro-food GVCs are becoming more global and varied – supporting the results seen in extra-regional trade in value added.

The returns from GVC participation ultimately flow back to the factors of production used – land, labour and capital. Agro-food GVCs are an important source of employment for many countries and for many sectors. While explored in more detail in Greenville, Kawasaki and Jouanjean (2019a), estimates indicate that agro-food GVCs contribute to around 5% of total employment (in value terms) in ASEAN, 2.3% in Africa, and 2% in the European Union. The shares of the agricultural workforce reliant on agro-food GVCs are significantly higher, up to close to 40% for countries in the European Union (on average) reflecting the heavily integrated European Union food sector.

Between 2004 and 2014, the distribution of returns from agro-food participation changed (Figure 4). Overall, the export value share captured by unskilled labour in agro-food sectors grew over this period – an average increase of 4.5% across the 22 sectors – with the share of capital also increasing (2.0%). These increases represent higher shares of higher total amounts. The increases were offset by falls in the shares captured by land (0.2%) and skilled labour (3.2%). Despite the fall in shares for land and skilled labour, the total aggregate returns to these factors increased. Interestingly, the increase in food prices does not appear to have been capitalised into land values, particularly for staple crops. Instead, land returns increased in sectors where longer term trends of increased demand were

expected, such as the livestock sector. Much of the changes observed in the relative returns to factors of production were due to rising emerging and developing country participation in GVCs as sectors in these countries use higher amounts of labour in the production of their exports. This indicates the possible gains to producers from greater agro-food GVC participation, and the role that removing distortions in agricultural markets could have in improving producers outcomes in emerging and developing countries.

Figure 4. Contributions to the increase in exports value by own sector factors of production between 2004 and 2014

% contribution to changes in the value of exports



Source: Author estimates.

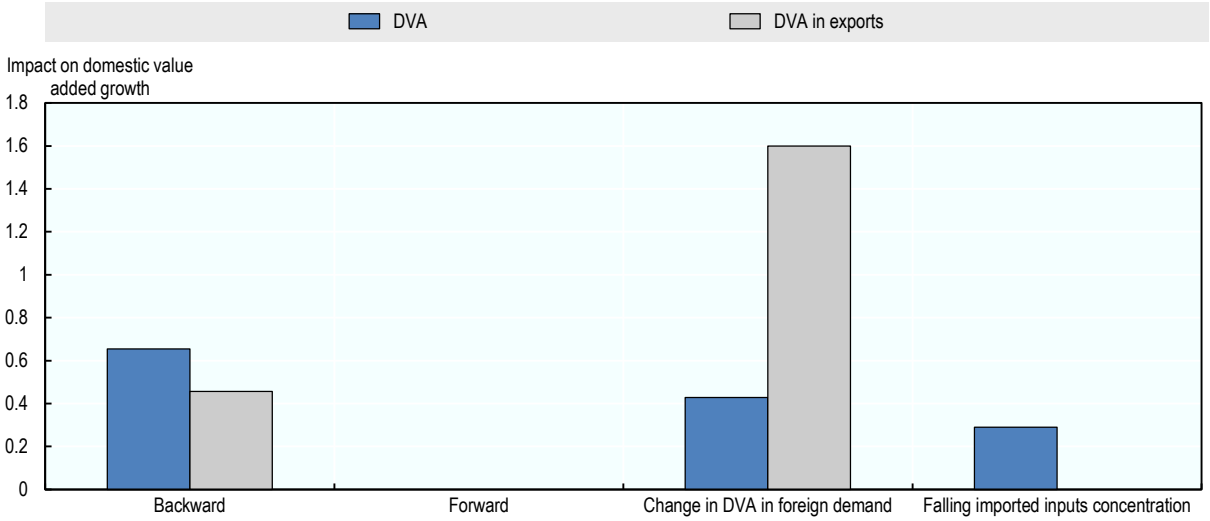
GVC participation is leading to the development of the agro-food sectors

Agro-food GVCs have shaped sector outcomes where participation is seen to be a significant driver of sector development. Using foreign factors in the production of exports (and in production more generally) has a positive impact on domestic added value creation and sector growth. The results from the analysis suggest that countries with higher initial backward participation experienced stronger aggregate domestic value added growth and stronger growth in domestic value added exports compared with those with lower levels of participation (Figure 5). Similarly, having access to a more diverse set of imported intermediate inputs promoted sector growth. Furthermore, for agro-food sectors, selling into GVCs either directly or through other domestic and foreign processing sectors has also had positive effects on domestic value added creation and exports.

Participation influences the returns to various inputs, having a positive effect on labour and producer returns. Having access to competitive foreign inputs and the spillovers from using those inputs has a positive impact on the share of value added captured by the producing industry itself, i.e. a larger share of a larger amount which translates into higher returns to farmers and domestic food processors. The strongest effects are seen for capital, land, and unskilled labour, although skilled labour also benefits. While it is not possible to tease out the type of impact on labour – be it more jobs or higher wages – there is nevertheless a positive impact.

Figure 5. Changes in growth in domestic value added from GVC participation

Estimated coefficients



Note: The result for concentration on imported intermediate inputs depicted has been multiplied by -1 so that it illustrates falls in concentration.
Source: Author estimates.

The analysis suggests that the form of participation can have an impact on the benefits created. In particular, using services along the value chain is seen to be an important driver of domestic value added growth. Increasing service use across the value chain as represented by an increase in the service share of exports – which represents by extension an increase in service use within the domestic production chain – is beneficial for domestic value added growth. This result highlights that the development of GVCs in the agriculture and food sectors is not just about mechanisation and investments to promote efficiency. The "de-commodification" of output means that it is not only about what is produced, but *how* it is produced and *how* it gets delivered to export markets or final consumers wherever they may be. This *how* is the service element of the value chain and increasing service shares in export value were found to be beneficial for sector growth. This result is important when thinking in terms of sector development and when considering changes in the share of the agro-food sector in the final value of a product. Adding services value means that the share of the agro-food sector in the final value will ultimately fall. Thus, policies that create the conditions where service value is added can increase producer returns in aggregate, but this may mean that the share of the final dollar captured by producers will actually be less.

Implications for policy

Policies and policy choices by governments influence the outcomes for producers and sectors from agro-food GVC participation. The positive role played by a more diverse set of inputs into agro-food production indicate that open and non-preferential trade policies that allow for an increase in import diversity are likely to enhance the domestic value added growth of agro-food sectors.

Own sector policies are also important. The analysis finds that protectionist policies harm development and transformation. For tariffs in particular, increasing levels of protection of the agro-food sectors were found to be harmful for growth in domestic value added of those

sectors. That is, although put in place to aid domestic industries, tariffs most likely have negative impacts on growth over time. Furthermore, agro-food tariffs increase the cost of imported agro-food intermediates, leading to a greater share of intermediate – domestic and foreign – costs in final value (due to the higher costs of these intermediates).

The key for policy makers is to create an environment where agro-food sectors can best leverage their comparative advantages and be competitive in agro-food GVCs. This will require open trade policies and a resistance to creating barriers to the import of agro-food products– that is, allowing imports and competition in agro-food products helps to enhance the domestic value added generated by agro-food sectors. The role played by sectors outside agro-food also highlights that policy settings in these areas – both trade and domestic – are important. Services sector inputs, for example, are a key driver of domestic value added growth and can enhance a country's ability to access agro-food GVCs.

Beyond the internal policy settings, changes in participation networks between countries may have consequences for policy makers. The development of GVC hubs around Europe, led by Germany and the Netherlands, China and the United States has implications for the management of risks that may flow through supply chains from demand shocks, whether they stem from macro events or changes to standards, or because of policy changes. Countries globally have a greater collective interest to ensure agricultural markets remain open and free from distortions, and that all players remain part of the global system of trade rules. As some value chains become more integrated globally, the nature of the risks that producers face will change, from responding to domestic consumer demands and domestic shocks to responding to global consumer demand and global shocks. Past evidence suggests that price variability and risks at the global level are often less harmful than those faced domestically, and GVCs may help to manage these shocks better. More work, however, is required to understand these relationships within the emerging GVC context. Nevertheless, the types of risks for producers are different and they require a different approach.

1. Introduction

Global value chains (GVCs) have changed the nature of production and specialisation around the world. Simply defined, GVCs represent all the activities that take place in transforming raw materials into the product delivered at its end use. Transformation activities include the production, marketing and delivery of a product or service to the final consumer. The fact that these activities are increasingly spread over several countries is what makes these value chains "global". The changes in the international production landscape have been most obvious in manufacturing and services, but similar changes have occurred in the agricultural and food sectors (Greenville, Kawasaki and Beaujeu, 2017a).

In the same way that manufacturing production has been unbundled, agriculture and agro-food sector trade has evolved considerably over time. The first unbundling saw a separation in the location of production and consumption, resulting in increased trade in final products. The second unbundling was the fragmentation of production processes across countries, with an increase in trade in intermediates. While some of the drivers in agro-food sectors are similar to those in manufacturing, some characteristics of the agriculture and food sectors have influenced the extent and the manner of these unbundling processes. These characteristics include a sensitive policy and trade environment, and changes in the nature of demand – in diets and consumption patterns, as well as in preferences and sensibilities related to food quality and safety across countries (including use of certain production practices).

For agro-food sectors, the initial unbundling was primarily characterised by commodity trading and supported by the development of standards and grades. These developments allowed the mixing of products from different origins in bulk shipments, facilitating their transport and use for final consumption or in other production activities. The second stage corresponded to a de-commodification process, with increased importance of information about the way food was produced, supported by a range of developments in contracting and marketing arrangements that helped build trust among value chain participants (Rhodes, 1993; Royer, 1995; Drabenstott, 1995; Pasour, 1998; Unneveher, 2000; Kirsten and Sartorius, 2002). This resulted in the integration of various agro-food chains with marketing channels and led to an increase in the importance of services both upstream and downstream in the chain. This second unbundling was further driven by innovations in the agro-food sector and improvements in trade logistics. That said, most agro-food GVCs still do not cross multiple borders. In 2011, for example, exports sold as intermediates exceeded that of exports for final demand for the majority of sectors in value added terms (Greenville, Kawasaki and Beaujeu, 2017a). However, most of the intermediates exported were used in the production of final goods in the importing region destined for the domestic market and were not re-exported.

Moreover, the changing face of international trade in agro-food products is having an impact on the agro-food sectors. For example, studies at the farm or individual value chain level have shown that GVC participation in agro-food activities has several spillovers in terms of productivity improvements, production growth, and livelihood improvement (Dedehouanou, Swinnen and Maertens, 2013; Colen, Maertens and Swinnen, 2012; Maertens and Swinnen, 2009; Jaffee and Masakure, 2005). Similarly, at the aggregate level, there is evidence suggesting that involvement in GVCs is a key driver of economic transformation and growth in non-agricultural sectors (Jouanjean, Gourdon and Korinek, 2017) and for the sector as a whole (Lopez-Gonzalez, 2016; OECD, 2015a), with evidence that jobs associated with GVCs have higher productivity levels (Lopez-Gonzalez, 2016).

These feedback and spillover effects suggest it is not only the developments over time within agro-food GVCs that are important, but the way these developments have in turn shaped agro-food sectors. It is particularly important to understand how policy has interacted with these developments, and which policy measures inhibit or enhance the benefits from GVC participation.

Information is limited on the development in trade within GVCs across agro-food sectors over time and on the impact of GVCs on agro-food sectors and their transformation. This study seeks to understand the changes in agro-food GVC participation over time and how these changes and varying degrees of GVC participation have influenced agro-food sectors across countries. Making use of the approach developed to derive TiVA-like indicators (see OECD's Trade in Value Added database – OECD, 2016a) for 70 regions for the year 2011 using the GTAP database (Greenville Kawasaki and Beaujeu, 2017b), this study explores GVC participation for 141 regions across 22 agro-food sectors in 2004, 2007, 2011 and 2014. Specifically, the following two questions are analysed:

- What were the changes in trade within agro-food GVCs between 2004 and 2014?
- What were the impacts of participation in agro-food GVCs on the country-sectors in question?

Caveats associated with the data used in the analysis – the GTAP database – are necessary. This study makes use of version 10 of the database, which had updates with respect to version 9 based on new input-output data for the 28 European Union member states,

Switzerland, Venezuela, Thailand, Uganda, Philippines, Costa Rica, Tunisia, New Zealand, China, India and the Ukraine.

The advantage of using the GTAP database is that it reconciles data from different sources into a single consistent database. The disadvantage is that for several countries the underlying input-output tables are dated and there have been limited updates (Box 1). This means that within the analysis, while trade patterns and size (absolute and relative) of sectors are captured, changes in the production technology (or production function in terms of the ways industries combine inputs to produce outputs) are not captured. There are issues related to differences in the underlying data, including the sectoral coverage within national input-output tables and changes in the sectoral definition within the system of national accounts. As a result, changes over time for some sectors in some countries are driven by changes in macroeconomic conditions and trading patterns rather than changes in the production technologies of individual sectors. That said, over a relatively close span of years, in the absence of a major new disruptive technology, such changes may be small. These shortcomings cannot be overcome and adjustments cannot be made to the data. Given this, these caveats should be borne in mind when viewing the results.

Box 1. Consistency across GTAP databases

The GTAP database provides a consistent representation of the world economy in any given year for which it is constructed. The database is constructed on underlying national input-output tables but incorporates data on trade, macroeconomic variables and taxes and subsidies from a range of different sources (GTAP, 2016a). The database is balanced and compiled to ensure that trade and domestic production data are consistent and that world supply and demand balance.

Despite the primacy of input-output tables in database construction, variations exist in the statistical methods used to compute these, the base years used, and the sectoral detail of the individual tables (GTAP, 2016a). As such, the database is not a repository of input-output tables for any given year. In order to overcome the differences and construct the GTAP database, a number of assumptions and adjustments are made (see GTAP, 2016b for full details of the documentation). These are likely to influence the results of any analysis that seeks to exploit this source of information to derive statistics that use input-out tables as a base – such as constructing the inter-country input-output tables used in the analysis of GVCs.

A further complication is created if comparisons are made across years. Not all of the underlying input output tables are updated regularly and therefore some do not differ across various years in the database. Instead, adjustments are made with respect to changes in macroeconomic and trade variables in order to update the database to more current years (GTAP, 2016a). This means that for some countries the underlying production technology (the way relative proportions and types of value added and intermediate factors are combined in the production of the good or service) does not change based on technical changes in the sectors concerned and that much of the variability over time comes from the adjustment processes that balance the changes in macroeconomic aggregates and trade flows. There is a risk that the adjustments made based on changes in trade and macroeconomic aggregates misrepresent the production technologies of the sectors in the database. That said, even within regularly updated input-output tables, production technology is slow to change and over relatively close time periods, such as 2004 to 2014, in the absence of major new disruptive technologies, changes would be expected to be small.

For this study, little can be done to correct for these issues associated with consistency of the underlying input-output tables and to changes over time. These limitations should be borne in mind in relation to the analysis undertaken.

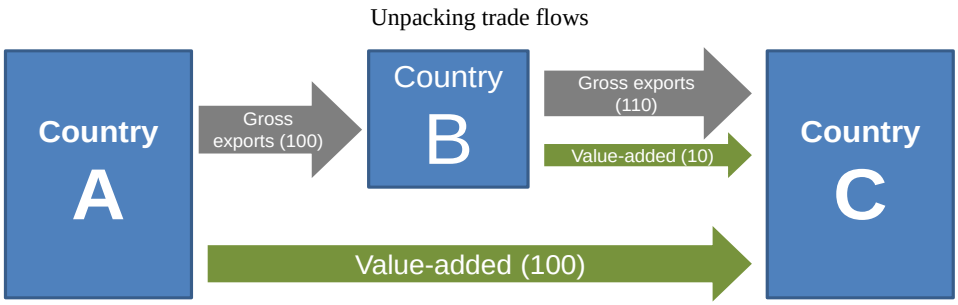
Measuring trade within GVCs and GVC participation

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 local products) 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.

The difference between conventional trade flows and trade in value added is shown in Figure 6. In this simple example, Country A exports USD 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 USD 10 to the goods and so exports USD 110 worth of goods to Country C. Conventional measures of trade show total global exports and imports of USD 210 but only USD 110 of value-added has been generated in their production. Conventional measures also show that Country C has a trade deficit of USD 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.

Figure 6. Measuring trade in value added



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
- 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 in GVCs. The most commonly applied approach is 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 for foreign value added embodied in exports and forward for domestic value added used as inputs to produce exports in the destination country. Such indicators have been calculated by using harmonised systems of inter-country input-output tables (ICIOs) (as in Timmer et al. 2012; OECD 2013a; OECD 2013b; and UNCTAD 2013). The OECD TiVA database released in 2013 and updated in 2016 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 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. The forward GVC participation index is measured as the share of a country's value added arising from its own exports included in exports of other countries.[1] The indexes measure very different forms of engagement. For example, a country that is predominantly processing primary 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 a processor will have a strong forward participation indicator but a small backward participation measure. These participation measures therefore provide 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.

2. GVCs role in agricultural sector development and transformation

The changing face of agro-food trade

Over the period 2004 to 2014 there were significant shifts in global agro-food markets with growth in agro-food trade centred around greater emerging and developing country participation, falling levels of overall support (but differing trends between groups of countries), and falling applied agro-food tariffs (OECD, 2016b). Furthermore, this period encompassed several important global events that most likely had an influence agro-food sectors and GVC development. Of particular importance were the food price spikes of 2007-08, which led to a reversal of the longer run decline in real world food prices (Figure 7), and the global economic crisis (from 2008) which saw falls in aggregate trade around the world. This section details some of these trends to provide context for the development of agro-food GVCs.

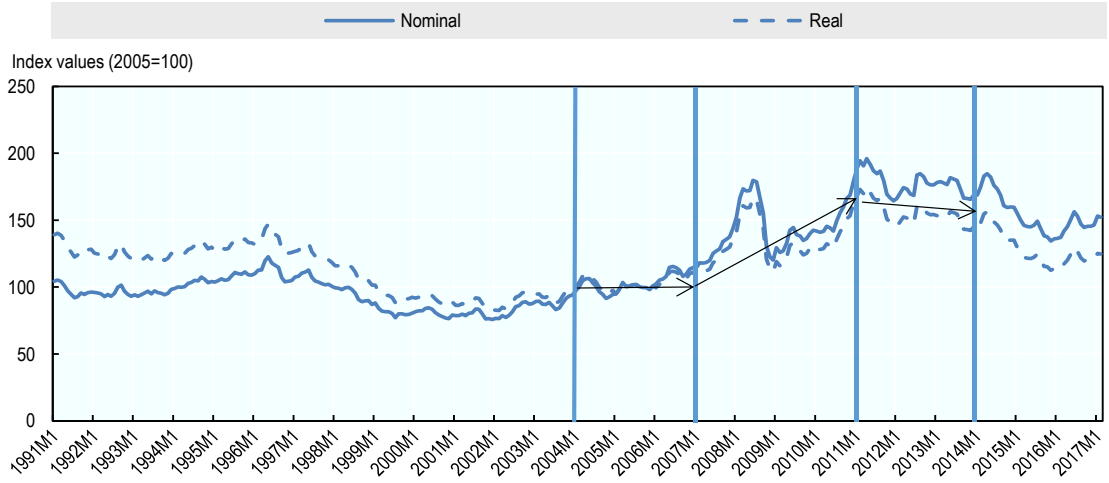
The food price hikes of 2007-08 occurred on the back of several mutually re-enforcing longer term structural changes combined with short-term market shocks that were exacerbated by the policy responses of some governments (OECD, 2016b; OECD, 2008a; Piesse and Thirtle, 2009; Naylor and Falcon, 2010; Headey, 2011). The underlying structural changes in world agricultural demand due to population and income growth, falling stock-to-use ratios in a number of key commodities, and in some cases production

[1] The calculation of value added exported for a sector includes both that embodied in direct exports from the sector itself and that which is embodied in the exports of other domestic industries which have used value added from the sector as an intermediate input. For example, exports from the paddy rice sector that directly feed into a production process in another country, e.g. its processed rice sector, which are then exported to a third country are included. This amount is combined with the value that gets exported by a second country through an indirect domestic link. For paddy rice, exports of value added may come through exports from the domestic processed rice sector. When these exports are used intermediates in the production of a second country's exports, e.g. from its food products sector, the embodied paddy rice value added in those exports is captured by the forward indicator. Both forms of re-exported value added are expressed as a share of the direct gross value of exports from the sector, in this example, the gross exports from the paddy rice sector. In this way, as the indirect linkage is often large, the forward indicator can exceed 1.

being increasingly channelled to biofuels production, placed upward pressure on food prices. In addition, global markets were hit by several short-term shocks, including droughts in key grain-producing regions, other weather events, and exchange rate movements. In this environment, some agents began to build stocks – including some panic buying by private agents – which helped boost already rising prices. In response to rising prices, governments intervened with export restrictions and import measures in several markets, coupled with large purchases for public stocks (rice in particular), which had the effect of exacerbating the spike in prices. Government policies surrounding biofuels mandates and subsidies also contributed. Price rises were greatest in wheat, coarse grains, rice and oilseed crops, all of which experienced strong real price growth between 2005 and 2010.

Figure 7. Food prices, 1991 to 2017

Nominal and real (US GDP deflator)



Source: Author estimates based on IMF (2017) and World Bank (2017).

Following the 2007-08 price spike, prices continued to rise and the long run pattern of declining prices reversed between 2007 and 2011. Since that time, prices have fallen – around 5% in real terms as measured by the food price index between 2011 and 2014. Despite this, in 2014 and subsequently, prices have remained above early 2000s levels. Across the four periods examined in this study, the real price rises that occurred between 2007 and 2011 and the slight fall between 2011 and 2014 may influence the observed changes in GVC participation. Price rises were not uniform and, as such, growth in exports of value added will be biased by the value effect created by the price change unrelated to changes in export volumes or improvements in competitiveness of individual sectors. As such, adjustments were made to the analysis as detailed in Section 4.

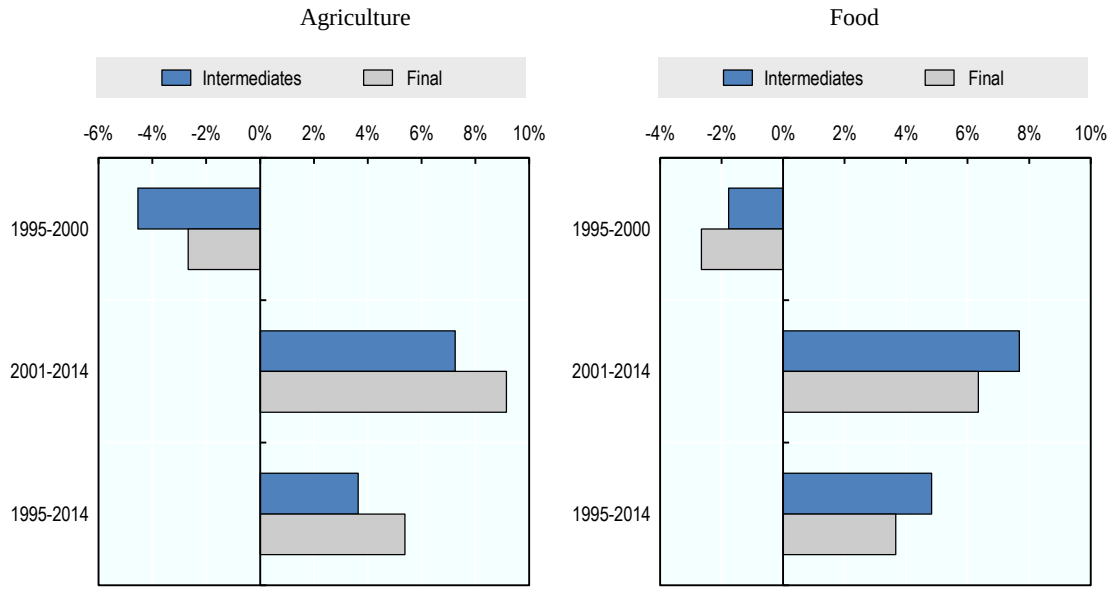
The rise in real prices of agro-food products provides an opportunity to explore whether such an increase in value, driven by demand rather than supply factors (such as changes in competitiveness through productivity or changes in production technology), accrue differently to different factors of production – both across industries and across countries. In other words, it provides an opportunity to explore where the value from the rise in real prices was captured along the value chain by looking at changes in the nominal distribution of value added. The changes in distribution of value added across the value chain and across value added factors are explored in Section 3.

Beyond the price effects, there have been several structural changes in agro-food trade. These relate to the development of agro-food GVCs (explored in more detail here and set out in Greenville, Kawasaki and Beaujeu, 2017a), the rising importance of emerging and developing countries in agro-food trade (OECD, 2016b), and the impact of the global economic crisis.

The development of GVCs in agro-food trade is reflected in rising trade of both intermediate and final goods in the agricultural and food sectors (Figure 8). Between 1995 and 2014, there was strong growth in real trade value overall, but particularly strong growth in intermediates trade (although estimates are influenced by the growth in real prices). Growth in intermediates has been strongest for food products rather than agricultural products. For most agro-food sectors, the majority of domestic value added traded is embodied in intermediate inputs, particularly agriculture sectors (see Greenville, Kawasaki and Beaujeu, 2017a). However, for some food sectors and vegetables, fruits and nuts, exports for final demand account for most of the value added traded.

Figure 8. Final and intermediate agro-food trade

Compound annual growth rates (%) in real values (USD)



Note: Trade values converted to real terms by applying the US GDP deflator from IFS Online. Trade growth estimated on change in exports recorded in the OECD Inter-Country Input-Output Tables.
Source: Author calculations based on OECD (2015b) Inter-Country Input-Output Tables (http://www.oecd.org/sti/ind/input-outputtablesedition2015accesstodata.htm).

Much of the growth in agro-food trade was driven by growth in several emerging and developing regions, a result also seen for aggregate agro-food production (OECD, 2016b). Since 1995, the share of total agro-food exports sourced from high income countries fell from close to 70% to 55% in 2015 (for imports, the share fell from 77% to 62% over the same period). At the same time, the concentration of the top 20 agro-food exporters and importers in total trade also fell by around 5 percentage points, albeit from highly concentrated levels (OECD, 2016b).

Between 2008 and 2010, the world economy was affected by the global economic crisis. During this time there was a sharp drop in merchandise trade[2] which, despite an initial rapid bounce back, has seen sluggish growth which continues to remain below pre-crisis levels. The volume of world trade in goods and services has grown by just over 3% a year since 2012, less than half the average growth rate during the previous three decades (IMF, 2016). The slowdown is broadly based – across most countries – with a key cause being continued weakness in economic activity and investment (therefore in aggregate demand), coupled with the slowing pace of trade liberalisation and a growing level of protectionist measures (IMF, 2016).

However, the effects of the crisis for agro-food trade appear to differ from those seen for overall trade. Looking at different indicators of real values of trade growth – those which are representative of the rising costs of living using the US GDP deflator and that account for the disproportionate rise in food prices using the food price series – indicates that agro-food trade growth continued throughout the crisis (Figure 9). Indeed, the immediate impact of the global economic crisis is only apparent in the series using the US GDP deflator. The unresponsiveness of agro-food trade to the crisis has some theoretical support – food demand is relatively inelastic and even as incomes fall, demand will remain as people need to eat.[3] Despite this, using the food price deflator suggests that there has been a gradual slowing in the growth of agro-food trade but over a longer period, beginning from the mid-2000s. Growth rates were high in the periods closely following the WTO Agreement on Agriculture, but began to slow towards the end of the implementation period in 2000, then subsequently rebounded following China's accession to the WTO – possibly also due to a more rules-based trading environment coming into full effect. However, since the mid-2000s, with inaction at the multilateral level, relatively stable agro-food tariffs, and little change in domestic support in several countries (OECD, 2016b; OECD, 2017; Greenville, 2017), trade growth has slowed, suggesting a strong link to policy.

Effects of trade and GVC participation on economic transformation and sector performance

GVC participation can have flow-on impacts on the industries involved. In particular, several studies have explored the manner in which firms and industries change once they become part of GVCs. This literature has commonly referred to these changes as "upgrading" (OECD, 2015a).[4] While upgrading can be narrowly thought of as moving "up" the value chain, to do so misses several important aspects of the potential benefits that GVCs can bring to industries and countries. These include the effects on growth in total domestic value added and the potential for improvements in employment, productivity, income per worker, and the labour skill mix of particular sectors (Lopez Gonzalez, 2016; OECD, 2015a). OECD (2015a) highlights that in terms of assessing the benefits of GVC

[2] Merchandise trade covers all trade in goods, but not services trade.

[3] Within the mix of traded products there were some changes due to the financial crisis. In particularly, non-staple crops heavily exposed to individual markets such as the United States saw large falls in demand.

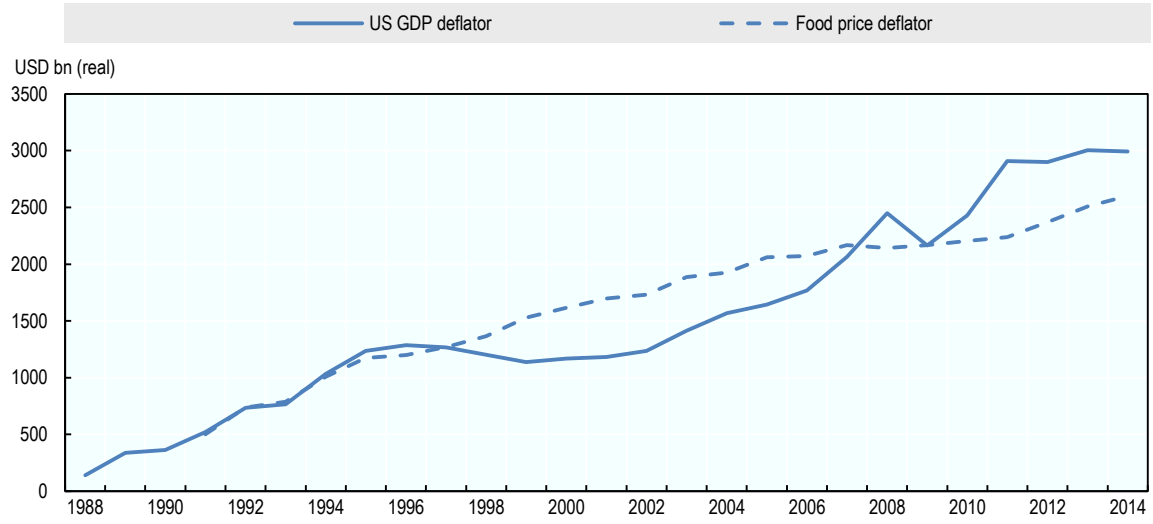
[4] Upgrading can be thought of in economic or in social terms. OECD (2015a) highlights that "economic upgrading is usually defined in terms of efficiency of the production process or characteristics of the product or activities performed, while social upgrading often refers to outcomes related to employment and pay, gender and the environment".

participation, the focus should be on the growth in *absolute* domestic value added created as opposed to just growth in the share of domestic value added in unit value.

From a general perspective, numerous studies have shown that trade is positively related to economic growth (see for example Badinger, 2008; Alesina et al., 2005). That is, countries with greater trade openness, measured by indicators of trade policy openness (such as levels of tariffs and non-tariff barriers among others) or by trade intensity (the ratio of imports plus exports to GDP), exhibit higher rates of economic growth and/or higher rates of technological progress (typically measured by GDP or total factor productivity). There are many channels through which trade might affect economic growth (Meissner, 2014). These include the availability of cheaper inputs, greater competition pressure inducing more efficient business practices (Melitz, 2003), greater availability of foreign technology and spillovers from foreign direct investment, a wider set of stakeholders creating greater pressure for better domestic policies and improved functioning of institutions, and scale economies and traditional comparative advantage-induced static gains from trade. Alcala and Ciccone (2004) provide evidence of the effect of openness on labour productivity, finding that trade helps to improve labour efficiency directly rather than through capital accumulation (capital deepening).

Figure 9. Real agro-food trade growth

USD GDP and food price deflators



Source: Author calculations based on WITS.

The effects of trade at a more disaggregated level are more complex. In terms of employment effects, Shepherd and Stone (2012) show that internationalised firms tend to hire more workers and pay higher wages, suggesting that GVCs can play a positive role in the labour market. In ASEAN, workers specialised in producing intermediates used by other countries in their exports (that is, forward GVC jobs) were found to have, on average, higher productivity than workers producing gross exports (Lopez Gonzalez, 2016). By contrast, recent papers by Autor et al. (2013; 2014; 2016) and Acemoglou et al. (2016) highlight how competitive pressures from China and the role of automation (which is likely to have occurred in anyway) depressed aggregate manufacturing employment in the United States. At the same time, total employment grew with greater services jobs (Wright, 2014), but these were often in different areas and required different skill sets from those jobs that

were lost. At the sectoral level, Yoo et al. (2012) found that trade openness significantly increased productivity growth in Korean agriculture.

The literature suggests that the impact of GVCs on sectoral growth and employment might not be uniform. In some instances, GVC development may hasten structural adjustment within certain sectors compared with past trade-induced adjustments. In other areas, it may provide new opportunities by broadening the range of possible specialisation activities available to any one industry when faced with new competitive pressures. The literature does, however, suggest that more research is needed on the relationship between GVC participation and the performance of the agriculture and food sectors – such as that completed in this paper. Given that gross trade data is increasingly a misleading tool for trade analysis in the presence of GVCs as products cross borders multiple times and can get double counted (Johnson, 2014), the focus of additional analysis should be on the value added traded. Exploring value added trade provides a means to assess the domestic returns from engagement in GVCs and can overcome perceptions that it is always the domestic share in gross value that is important, rather than a more holistic look at the total returns available.

Other studies have pointed to GVCs as playing a role in development and sector transformation. In particular, the greater use of services in the production process has been linked to improvements in sector performance for manufacturing (Hoekman and Shepherd, 2015). Similarly, service sector performance, and in particular transport and storage and within that maritime transport, have been found to influence transformation in sectors important for developing countries, such as automotive, and mining and quarrying (Jouanjean, Gourdon and Korinek, 2017). For agro-food sectors, past results point to the high share of service inputs in export value and the negative impact that service trade restrictions have on domestic value added creation (Greenville, Kawasaki and Beaujeu, 2017a). This may suggest there is a link between service sector performance and agro-food sector development, but more work is required to understand the relationships at play.

3. How has trade within agro-food GVCs changed over time?

This section explores the changes between 2004 and 2014 in agro-food GVCs. It uses a range of metrics to shed light on the various changes that may be important for understanding the impact of GVCs on sector development and transformation. Some of these relate to structural changes in trading patterns, .others relate to the nature and complexity of the GVCs. The various measures and issues explored are as follows.

- Changes in the *flows of agro-food domestic value added used for export* between industries in countries to explore changes in relationships in agro-food GVCs at the country level and depict the changing landscape of agro-food GVC participation.
- Changes in the *importance of individual countries* to agro-food and sector-specific value chains using measures of centrality, either as buyers of value added of a particular product for final consumption or as an input, or as sellers of value added for production of a specific product or for final consumption. This helps to explore the changing importance (or otherwise) of emerging regions in agro-food GVCs.
- Changes in the *backward and forward participation indicators* to explore the changes in the country-sector specific relationships related to the use of foreign value added in their exports or having their exports used for another country's exports. Within this, changes in the selling of value added directly to foreign final

demand or to foreign demand through foreign processing (but no re-export) are also important.

- Changes in the *shares and source of value added within agro-food exports* to explore both the changes associated with rising real prices and changes in the nature and complexity of agro-food GVCs. Specifically, changes in the shares of various factors of production (land, labour, capital and natural resources) show where the changes in real prices accrued and help to point to the changing sources of agro-food trade. Further, exploring changes in the intermediate input bundle used to produce exports – the mix across input types (services, manufacturing, other agro-food) and concentration of imported input use (both in terms of number of sources and types of products) – across the sectors provides insights into the changing complexity of agro-food GVCs.

Due to the large amount of data and possible statistics, much of the summary charts depicted in this section show differences between 2004 and 2014. For more details, see Annex 4 and 5. In Section 4, the influence of the changes depicted in this section on agro-food sector development and transformation with reference to policy factors is explored.

How has the flow of agro-food domestic value added for export between countries changed?

The export and use of value added in further agro-food trade by different countries provides one means to visualise the landscape of agro-food GVCs and how this has changed over time. For a given country, the use and consumption of foreign value added and the use of its value added in other countries' exports indicates its connectedness within global agro-food value chains. For the agro food sector as a whole, these linkages are drawn out in Figure 10. The relative intensity of the shading indicates the change in value terms of value added flows between countries between 2004 and 2014, providing an initial insight into changes in countries' involvement in agro-food GVCs.

Going across the rows to the right in Figure 10 shows the increase in a country's exports of agro food value added that is used in other countries' exports – that is, changes in selling into GVCs. Going down the columns shows the change in the source of foreign value added used in a country's own exports – that is, changes in buying from GVCs.

Figure 10 highlights the dominance of China in the increase in world flows of agro-food value added. On both the exports for use in other country exports (row), and the imports for use it its own exports (column) China is highlighted. The figure also shows the activity that occurs within the European group of countries, and within that, within the European Union.

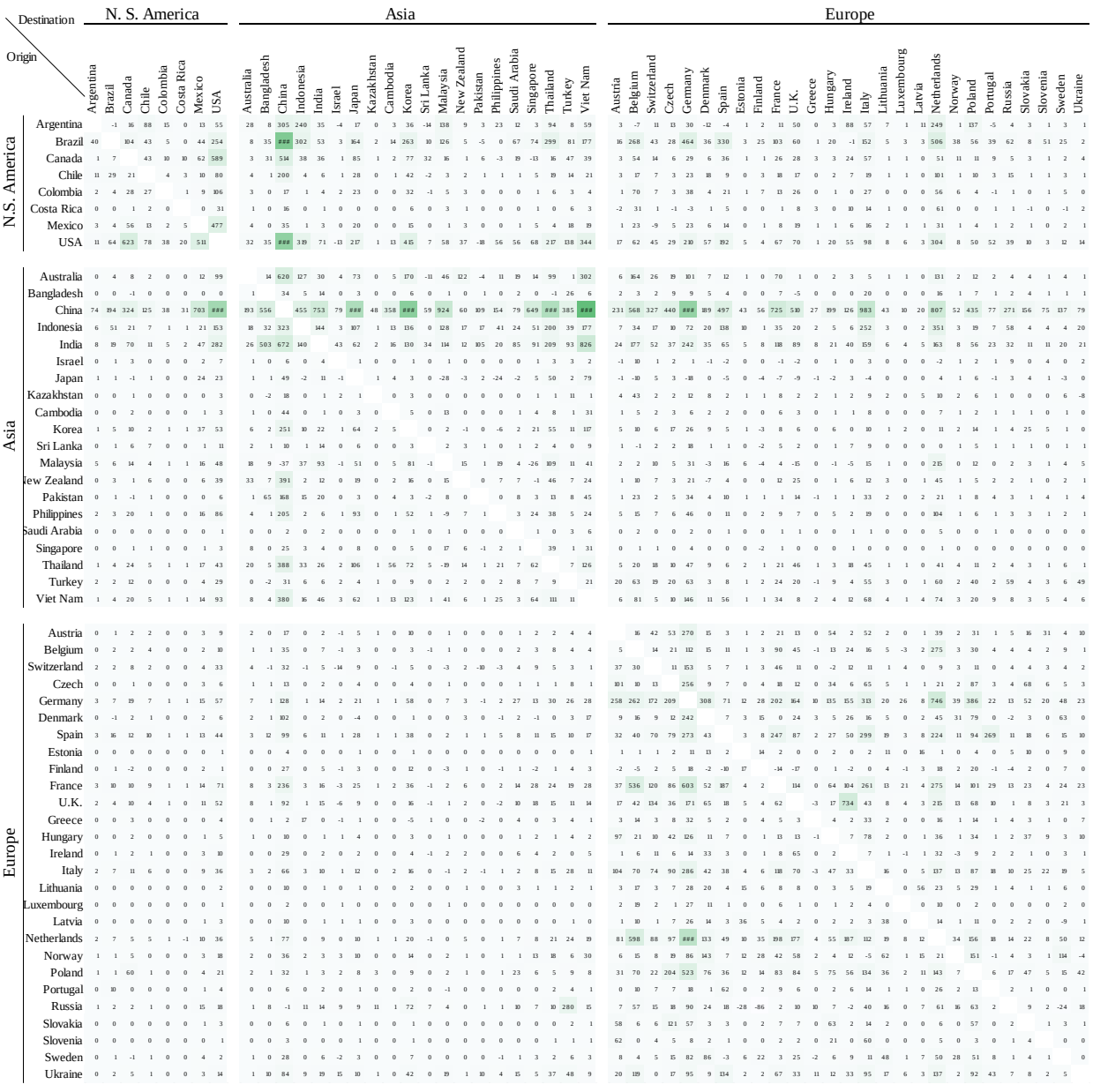
Taking a closer look at the shares of agro-food value added traded within GVCs further highlights the role of China. Figure 11 shows the country shares in the change in value added either exported for use in another country's exports (*exports* in Figure 11) or imported for use it a country's own exports (*imports* in Figure 11). China's share on the export side of the growth in agro-food value added traded in GVCs is close to 21%. That is, agro-food exports from China made up 21% of the total increase in exports of value added used to produce other country's exports. At the same time, to fuel its own exports, China is also a major buyer of foreign value added – accounting for the largest increase in purchases of agro-food value added for use in exports.

Beyond China, Brazil, the United States, India, and Germany represent the other top five sources of the increase in value added used in exports (Figure 11). The share of growth in

agro-food value added sold into GVCs from these four countries, however, is less than that of China. On buying of agro-food value added for use in own agro-food exports, the picture is more spread out. Germany, the Netherlands, Viet Nam, the United States, and Korea are the next five largest buyers for their own exports behind China. In total, these six countries are responsible for 33% of the increase value added purchased within GVCs for export production.

Figure 10. Changes in the flow of domestic value added, 2004-14

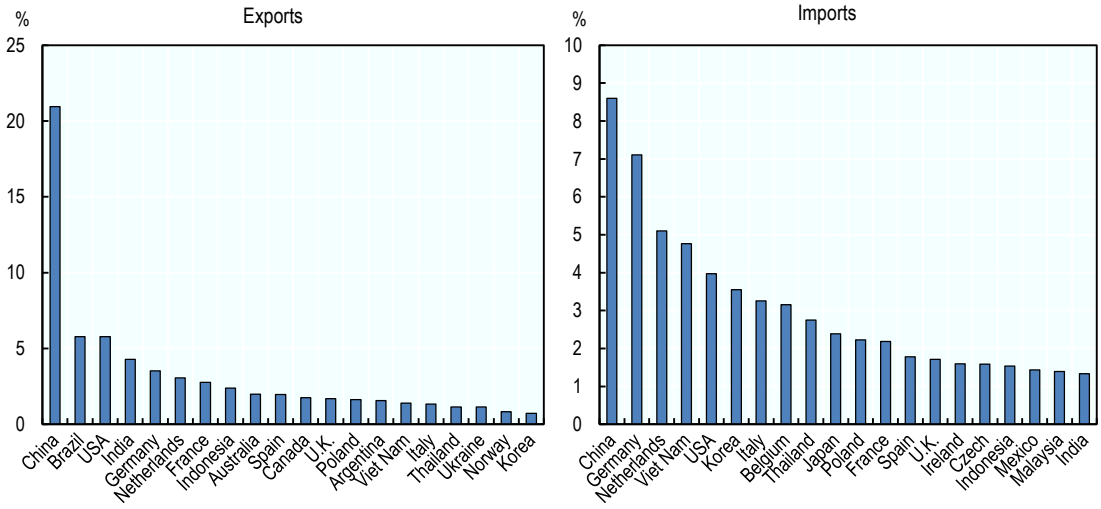
Shading represents relative size measured in USD millions (difference between 2004 and 2014)



Source: Author estimates.

Figure 11. Shares of growth in total agro-food value traded with GVCs from 2004 to 2014

Top 20 sellers of agro-food value added as intermediate for other countries production of exports and top 20 buyers of foreign value added for own production of exports (%)



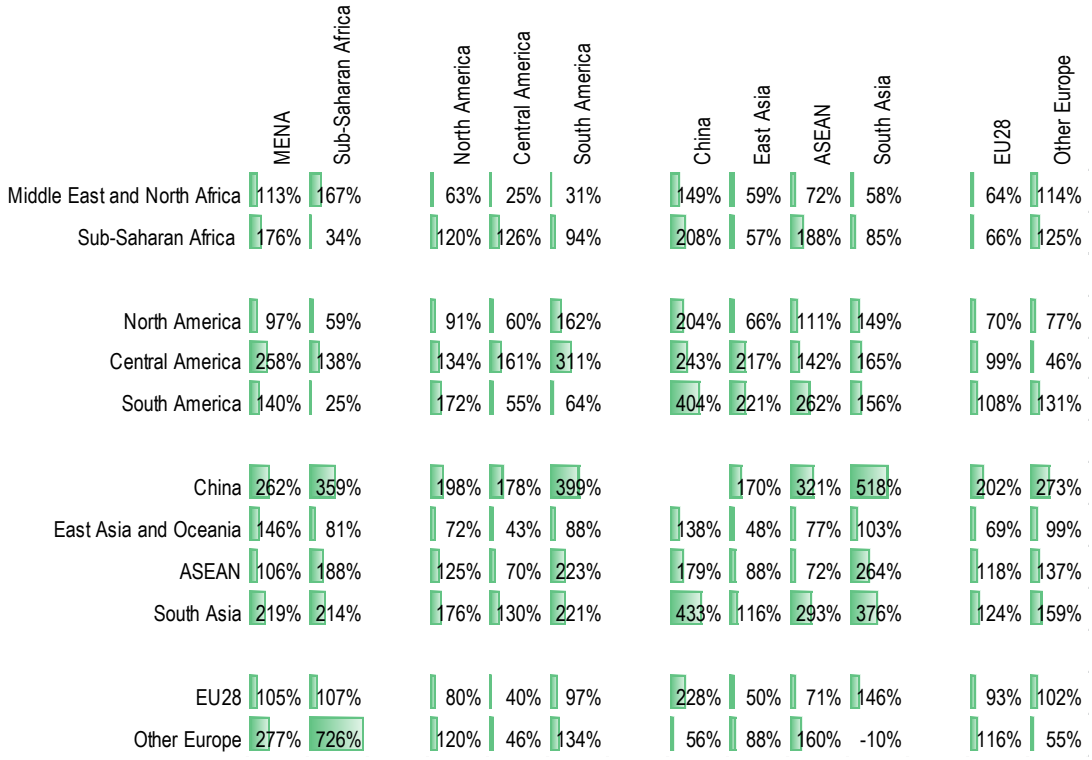
Note: This chart depicts the country shares of the total increase in agro-food value added traded. It depicts the share for a country that is derived from its row sum from Figure 10 (*exports* used in another country's exports) expressed as a share of the total increase in agro-food value added traded, along with the column sum from Figure 10 (*imports* of agro-food value added used in their own exports) expressed as a share of the total increase in agro-food value added traded.
Source: Author calculations.

At the regional level, there have also been changes (Figure 12). Between 2004 and 2014, the nominal value of gross agro-food trade grew worldwide by 133%. By comparison, nominal trade in value added, both in terms of selling into and buying from agro-food GVCs, has been relatively strong for several regions, far outpacing the growth in nominal trade for some other regions. Again, the influence of China has been significant. Regional groupings such as Central and South America and South Asia have also seen significant increases in the use of their value added in other regions' (and China's) exports. For Central America, relative growth in selling into GVCs extends across the world, but for South America much of the growth is oriented towards Asia (China, East Asia, ASEAN and South Asia). South America and South Asia show the greatest changes in terms of buying from GVCs (looking down the column).

The development of GVCs means that gross trade data can at times be misleading with respect to the reliance of individual countries on others as a source of inputs or for products for final demand. Taking China as an example, within the harmonised GTAP database, bilateral export flows of agro-food products between China and the European Union amounted to around USD 8.7 billion in 2014 (Figure 13). However, taking into account that a number of imports from other countries rely on agro-food value added produced in China in their production means that in value added terms, the European Union imported USD 32.6 billion in value added from China – close to four times the value of bilateral flows. However, looking at gross versus value added flows between Australia and China, the gross flows overstate the amount of value added that is exported due to Australia's use of foreign intermediates (many from China) in the production of its exports.

Figure 12. Changes in regional flows of agro-food value added, 2004-14

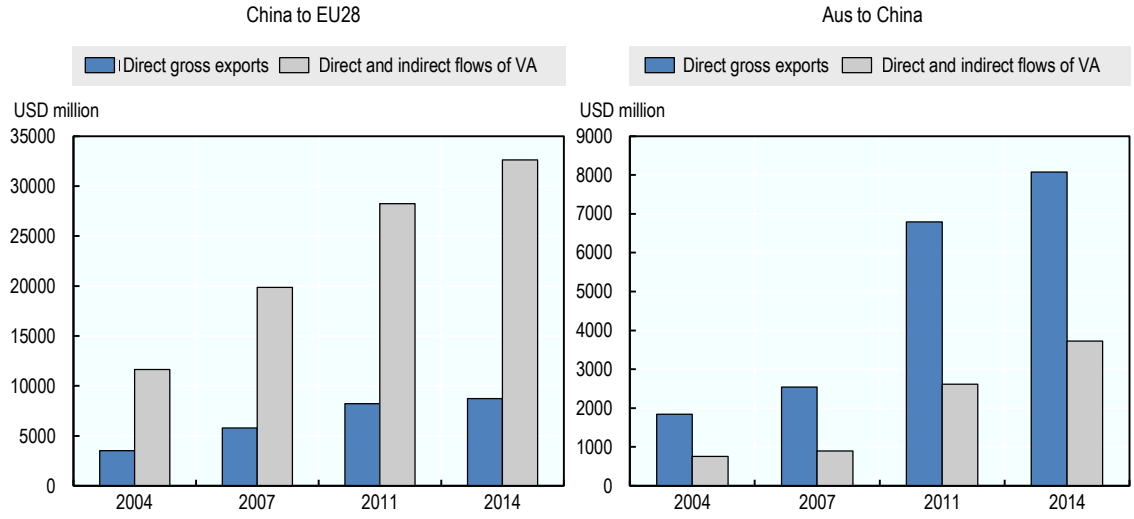
Shading represents relative size (%) measured in USD millions (difference between 2004 and 2014)



Note: The table shows the growth rate between 2004 and 2014 of value-added created in ago-food sectors in Origin country that is included in Destination country's (total) export.
Source: Author estimates.

Figure 13. Flows of gross exports and value added

Direct exports and direct and indirect flows of value added in agro-food products, USD millions



Source: Author estimates.

How has the importance of individual countries in agro-food GVCs changed?

The changes observed in gross agro-food trade flows, along with those seen in trade in value added, suggest that the relationships between countries within agro-food GVCs have also changed over time. Between 2004 and 2014, the greatest growth in agro-food exports has come from several low- and middle-income countries. That said, agro-food trade remains largely concentrated in higher income countries when viewed in absolute value terms.

A more sophisticated way to explore these changing relationships is to examine GVCs through network analysis which can be used to identify the centrality of countries in agro-food value chains – both in aggregate and at the sector level (see Box 2 and Annex 7 for further details). This type of analysis allows GVCs to be depicted in a way that captures both the number of linkages between countries and the volume of trade in value added that is embodied in those links. In this way, how "central" a country is to a GVC for a particular product – as a seller into GVCs or as a buyer from them – can be depicted. The measures depict the relationship within the value chain and depend on the aggregation used – individual sector level versus all agriculture, for example. In this way, a country may be central in a range of metrics due to differing product compositions, or because they may both simultaneously produce and supply a product and purchase it from international markets. Similarly, countries with large processing sectors may be central buyers of intermediates for export and to serve their own final demand.

Centrality of different sectors within GVCs can be depicted in four ways:

- *Buying for export centrality*: This captures the importance of a country as a buyer of value added in intermediates of a particular product for the production of their exports. It captures both the number of interactions and the size of those interactions and thereby captures the GVC dimension of use of imported value addition to produce exports. The buying for export centrality measure accounts for the number of countries from which intermediate products produced by a sector are purchased, weighted by the importance of the relationship in value added. For example, a country will be a central buyer of oilseed value added if it has a relatively large number of suppliers and purchases relatively large volumes as intermediates for the production of their exports. This metric sheds light on how central a given country is to the GVC of a given product.
- *Buying for and selling to final demand centrality*: This captures the importance of countries as sellers or buyers of value added from specific sectors for final demand. The food value chain remains close to final demand with a number of products going straight to final demand or for foreign processing and then to final demand without re-export. Such an indicator provides information about where the value added created by a sector is eventually consumed irrespective of all the places where it was directly or indirectly used as an intermediate for the production of exports.
- *Selling from a sector centrality*: This captures the importance of a country as a seller of intermediates from a specific sector used in a range of other countries' production of their exports.
- *Selling to a sector centrality* captures value added sold as intermediates (from all industries) by a country for the production of a specific export product. Again, the concept is how important or central a seller of value added in intermediates (from

all sectors – from agro-food intermediates, to services and to manufacturing parts) is for the production of exports of a certain sector. For example, this metric captures the importance of a country as a seller of intermediates to other countries producing oilseeds for exports.

Flows of value added between countries are calculated to include both the direct and indirect linkages as per the forward indicator used elsewhere in this paper. In this way, a sector's importance as a seller of intermediates for the production of exports will include cases where it sells directly to foreign processors or where the link occurs through domestic processing first – e.g. paddy rice to processed rice within a country and then the subsequent use of processed rice exports (and their embodied paddy rice value added) as intermediates to produce another country's exports. As a consequence, a country-sector can have a high centrality in the agro-food GVC despite low registered gross exports because of the indirect exports of value addition from that sector and the number of countries that will use that value addition in their intermediates for the production of exports.

The centrality measures, and changes in them, help identify some of the major country-sector nodes for each agro-food sector and can show changes in the importance of individual countries in sector-specific value chains (Table 1). The measures provide insight as to whether agro-food GVCs, like manufacturing, have hubs, producing and buying value added at both ends of the GVCs. Centrality measures have the advantage of accounting for both the number of linkages between countries and their size. The measures presented in this section are largely based on aggregates for agriculture and food in total. Thus, the underlying products which make a country "central" may differ across countries. Due to the volume of sectors and relationships, not all can be depicted. At the individual sector levels, the results are summarised in Table 1 and case studies are presented in Annex 3.

Box 2. Using network analysis to explore GVCs in sectors: Creation of a backward and forward centrality

Network analysis provides a different way to view the organisation of GVCs. Such indicators are built on a mathematical approach based on the computing of the eigenvector of a matrix of trade in value added which depicts the connections between countries (by sector or not) or between sectors. This allows for a more refined analysis of the relative positions and relationships between and within sectors and countries in terms of their relative importance (centrality) in international trade, as well as their sensitivity to shocks. They are also used to infer countries' capacities in economic complexity analysis.

The indicators are compiled using inter-country input-output tables. Different types of centrality can then be calculated according to the "node" of interest in the network. For nodes defined at the country-sector level, a series of indicators are computed looking at the centrality of countries as either sellers or buyers of value added within the network. These indicators can highlight the centrality of a country as a "buyer" from sectors to produce exports (backward centrality) or as a "seller" from the sector to produce exports (forward centrality). Similar indicators are computed to provide information about the centrality of countries as providers of value added in final demand or as buyers of value added from foreign agriculture and food sectors for their own final demand. A last indicator at the country-sector level provides information about the centrality of countries as sellers of intermediates of all sorts – from R&D to machinery – for the production by the agriculture or food sector of interest.

Source: Adapted from Jouanjean, Gourdon and Korinek (2017).

Country centrality within agro-food GVCs

The analysis of the various centrality measures provides further insight into some of the observed developments of agriculture and food GVCs. China's increased presence in agro-food GVCs between 2004 and 2014 is clear (Table 1); it is a central seller of intermediates for the production of agro-food products as well as a central buyer of value added for the

production of its agro-food exports and to serve its own final demand. The importance of European countries is also seen, emphasising the high levels of integration of the European Union food system, with several European countries being central buyers or sellers of agro-food value added traded as intermediate goods for final demand or for the production of exports.

The centrality measures show the diverging trends among emerging economies. Traditional exporters of agro-food products in Latin America have maintained centrality in various sectors as sellers of value added (either as intermediates or for final demand) and have been joined by several other Asian countries which have often increased their importance in agro-food GVCs.

While changes are seen at the country level, the results depict increasing levels of concentration amongst sellers and buyers of value added. On the upstream side, there has been a concentration of suppliers of intermediates to the agriculture and food sectors (including non-agro-food inputs). Similarly, on the downstream side there has been a concentration in buyers of agro-food intermediates for the production of agro-food exports and for final demand. This consolidation has occurred around three key players: the United States, China, and Germany.

The changes suggest that agro-food GVCs have developed in similar ways to manufacturing sectors. That is, there is a strong regional dimension; both ends of the value chains are concentrated around specific hubs and emerging economies have established themselves as important players in the middle of the chain as suppliers of agro-food intermediates – and for larger emerging countries as central for final demand. This has consequences in terms of resilience of the value chain, with ripple effects possible on satellite countries from both supply and demand shocks in the economies of the three major agro-food GVC hubs.

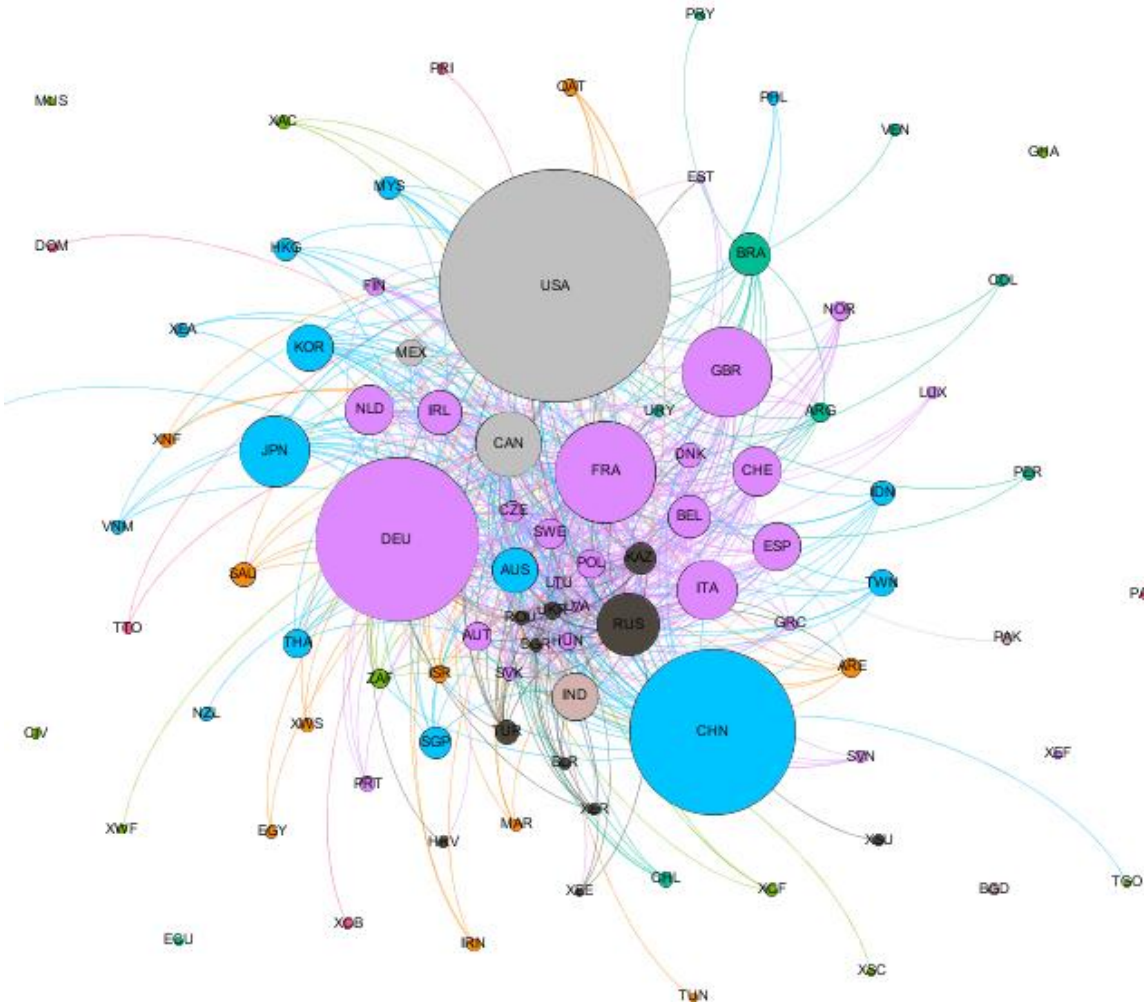
Trade in intermediates within agro-food GVCs

The United States, Germany, and China standout as central sellers of intermediates for the production of exports in the agriculture and food sectors. The United States is the most central country in the greatest number of sectors across the period analysed (e.g. the wheat sector in Figure 14). China's centrality has been increasing and it replaced Germany as the second most central country in a number of sectors over the period. Beyond the top two countries, other central countries which are providers of intermediates for agro-food sectors, including a mix of oil and agricultural producers, are Saudi Arabia, the Russian Federation, Brazil, and India.

This mix of countries in the centrality results of sellers of intermediates highlights two features of agro-food GVCs. The first is the importance of oil as an intermediate in production processes, and which helps to explain the strong correlation between oil and food prices. The second feature highlights that high-income countries lead in the production of inputs for agro-food exports ranging from industrial products to services.

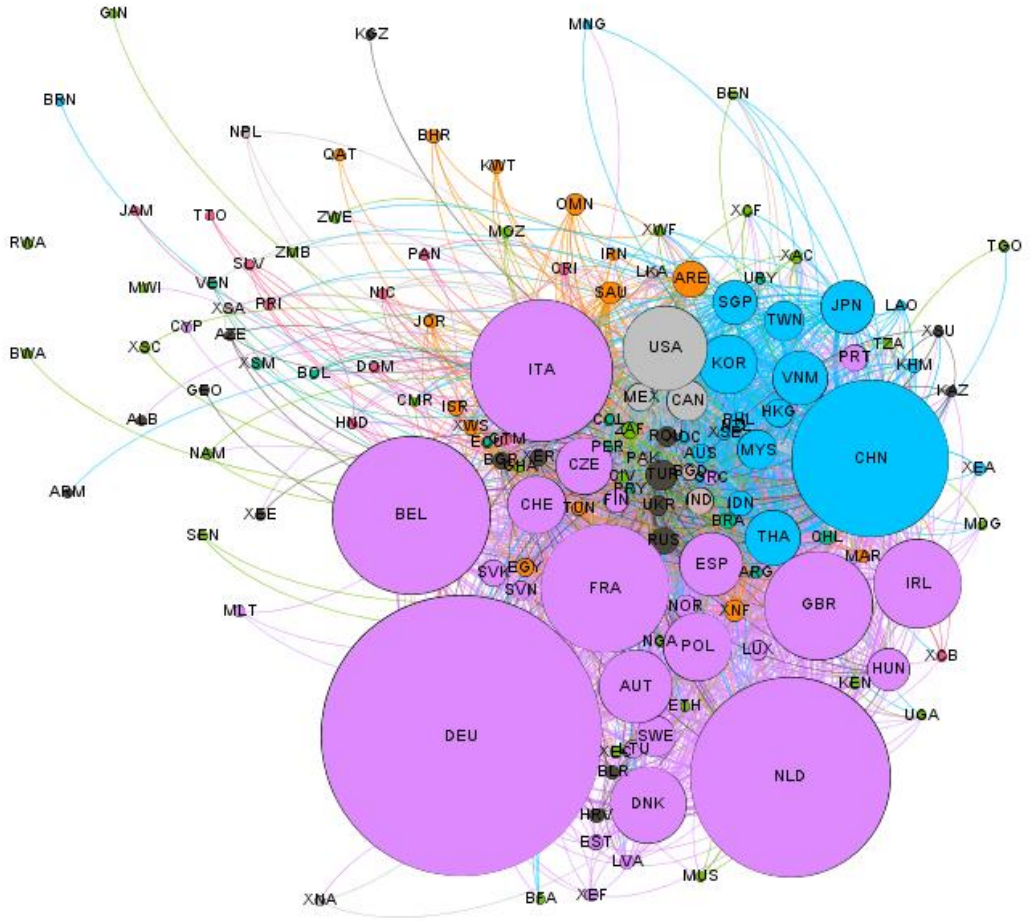
The picture given by the centrality of buyers of agro-food intermediates for the production of exports shows a strong regional clustering in Europe, North America, and Southeast Asia (Figure 15). Several European countries are important in specific value chains (Table 1). This result underscores the integration of the food system within the European Union. Outside of Europe, China has a prominent place as a buyer of agro-food intermediates for the production of exports.

Figure 14. Centrality as a seller of intermediates for the production of wheat exports, 2014



Note: Excludes oil, petroleum and gas sectors. The size of nodes is proportional to their centrality as sellers of intermediates. Edges are value added flows over USD 1 million and colour represents from the node of origin. The curve is clockwise from the exporting node to the importing one. Node colours represent the following regions: Central America and the Caribbean, Central Asia, Europe, Middle East and North Africa, North America, South America, Southeast Asia and Pacific, South Asia, and Sub-Saharan Africa.
Source: Author estimates.

Figure 15. Centrality of countries as buyers of value added from agriculture and food sectors for the production of exports, 2014



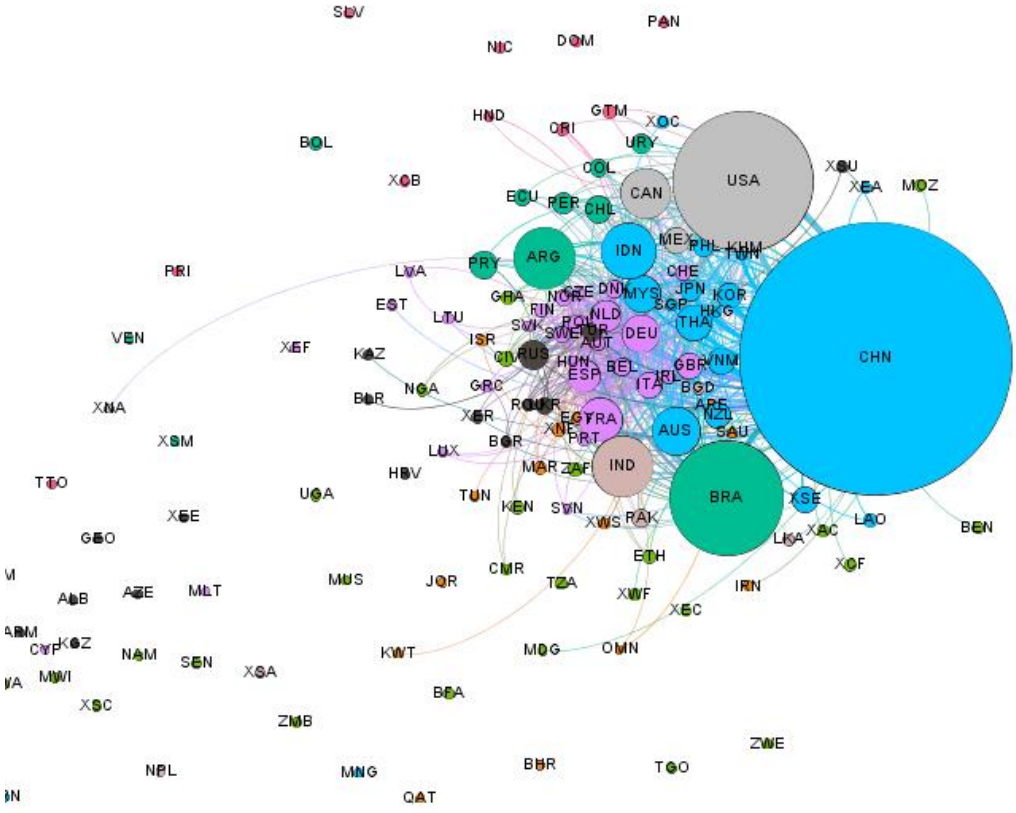
Note: The size of nodes is proportional to their centrality as sellers of intermediates. Edges are value added flows over USD 1 million and colour represents from the node of origin. The curve is clockwise from the exporting node to the importing one. Node colours represent the following regions: Central America and the Caribbean, Central Asia, Europe, Middle East and North Africa, North America, South America, Southeast Asia and Pacific, South Asia, and Sub-Saharan Africa.
Source: Author estimates.

Presenting results at an aggregate level, however, hides important differences across sectors. China is the second most central buyer of value added for the production of exports for agriculture intermediates feeding into manufacturing industries such as textiles – from sectors such as wool, silkworm cocoons, and plant-based fibres. The changes in centrality of buying countries from those sectors reflect the changing competitiveness of manufacturing sectors across the world. It should be noted that a loss of buying centrality does not necessarily mean that a country has reduced its purchases of intermediates; rather, this can be due to other countries increasing their linkages to or purchases of intermediates. For plant-based fibres, Pakistan and Malaysia have lost centrality as buyers of intermediates compared to China, which considerably increased its central position between 2004 and 2014. Across a broader range of sectors, changes over time beyond the top two most central countries suggest a reorganisation of the value chain from buyers in

Europe, the United States, and the Middle East to buyers in South Asia and Southeast Asia. This includes countries such as Viet Nam, Indonesia, India, Bangladesh, and Cambodia.

The landscape of sellers of value added for the production of agro-food exports presents a different picture (Figure 16). China dominated the landscape in 2014 – a position it has built on since 2004. It provided significant amounts of its own domestic value added as inputs into global agro-food exports. Beyond China, a range of emerging economies took a more prominent position in the agro-food GVC, from Latin America to Southeast Asia.

Figure 16. Centrality of countries as sellers of values added from the agriculture and food sectors for the production of exports, 2014



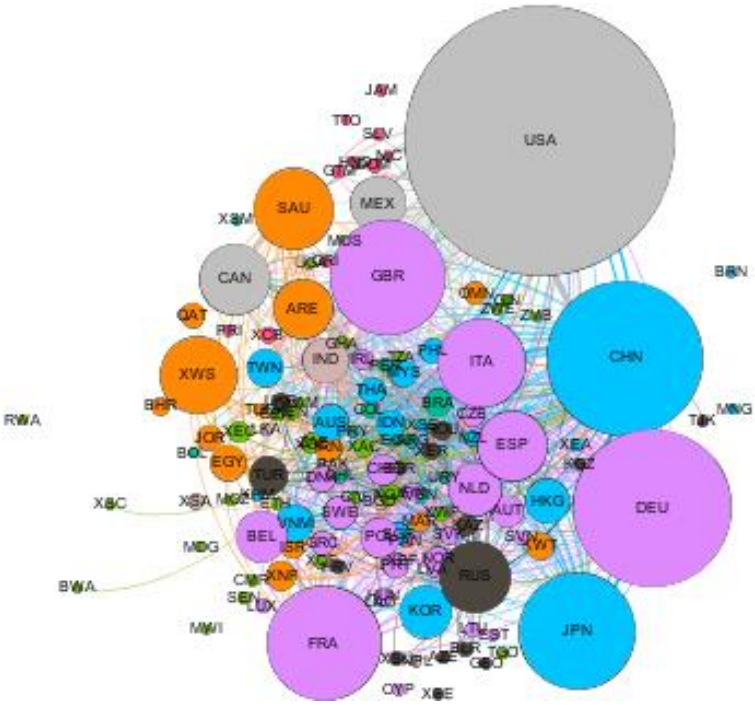
Note: The size of nodes is proportional to their centrality as sellers of intermediates. Edges are value added flows over USD 1 million and colour represents from the node of origin. The curve is clockwise from the exporting node to the importing one. Node colours represent the following regions: Central America and the Caribbean, Central Asia, Europe, Middle East and North Africa, North America, South America, Southeast Asia and Pacific, South Asia, and Sub-Saharan Africa.
Source: Author estimates.

Links to final demand through buying intermediates for domestic processing

The centrality of countries as buyers of intermediates for final demand (thus for domestic processing) differs considerably from that seen as buyers of intermediates for exports (that which is processed domestically and then re-exported) (Figure 17). There is a more compact network of countries and while it is still possible to identify regional clusters, they are less obvious.

Despite the more compact network, the United States is seen to be very central as a buyer of intermediates for its own final demand. This contrasts to its more marginal role as a buyer of agro-food intermediates for export production, meaning that most agro-food intermediates are transformed and consumed domestically. The United States is the first or second most central buyer for final demand for 21 of the 22 sectors analysed, and was consistently so over the period analysed. It is important to highlight that both direct trade in value added between countries (bilateral flows) and the indirect trade in value added that goes through third (or more) countries is considered in this analysis. In this way, the links depicted may not always reflect direct trade links.

Figure 17. Centrality of countries as buyers of value added from the agriculture and food sectors for final demand, 2014



Note: The size of nodes is proportional to their centrality as sellers of intermediates. Edges are value added flows over USD 1 million and colour represents from the node of origin. The curve is clockwise from the exporting node to the importing one. Node colours represent the following regions: Central America and the Caribbean, Central Asia, Europe, Middle East and North Africa, North America, South America, Southeast Asia and Pacific, South Asia, and Sub-Saharan Africa.
Source: Author estimates.

The centrality of the three larger countries and region (the United States, China, and the European Union) as buyers for final demand highlights how a shock in domestic demand can have a global effect. That said, as discussed above, any such impact is likely to be tempered by the relatively inelastic nature of food demand (the global economic crisis had a limited impact on overall real agro-food trade flows, notwithstanding a strong impact in several specific sectors GVCs).

Germany was found to be the second most important country as a buyer for final demand – it appears first or second in centrality terms for 15 sectors in 2014. Since 2004, changes within most central buyers of value added for final demand have mostly been

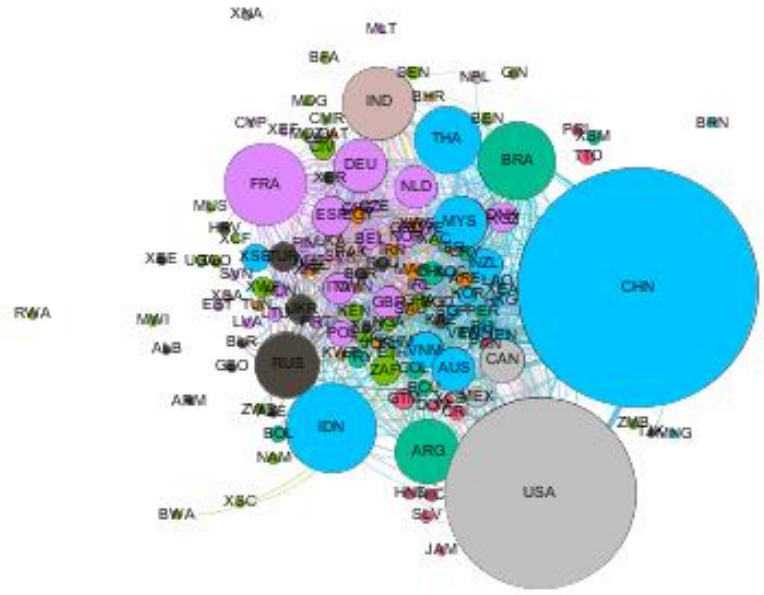
between European countries, with Germany displacing some other European Union members as the most central buyer.

China is increasingly playing an important role as a buyer of intermediates for final demand. It was neither the first nor the second most central country for any sector in 2004, but had become central for three sectors by 2014: plant-based fibres, animal products n.e.c. and forestry. The nature of two of those sectors as intermediate suppliers for the manufacturing industry underscores the important changes in China's production systems, leading to an increased reliance on foreign value added to feed the increased demand for manufacturing goods in the domestic market.

Selling intermediates for foreign final demand

The most central sellers of intermediates for final demand, with a few exceptions, are the same as for sellers of intermediates for exports. Compared with the buyers for final demand, however, there is a wider range of central countries despite the importance of China and the United States – note that the data for European Union members include intra-European Union trade (Figure 18).

Figure 18. Centrality of countries as sellers of value added from the agriculture and food sectors for final demand, 2014



Note: The size of nodes is proportional to their centrality as sellers of intermediates. Edges are value added flows over USD 1 million and colour represents from the node of origin. The curve is clockwise from the exporting node to the importing one. Node colours represent the following regions: Central America and the Caribbean, Central Asia, Europe, Middle East and North Africa, North America, South America, Southeast Asia and Pacific, South Asia, and Sub-Saharan Africa.
Source: Author estimates.

This diversity is driven in part by various natural comparative advantages for different agricultural production activities. Countries with comparative advantages in agriculture due to large amounts of arable land appear as the most important sellers for final demand in crops. These include China, the United States, Brazil, and Argentina. Australia is a central country for livestock related sectors, exporting value added for final demand in

bovine cattle, sheep and goats, horses, wool, silkworm cocoons, and bovine meat products. Raw milk, dairy products and other food products are dominated by European Union countries. Despite greater heterogeneity, it should be noted that China was the first or second most central seller of value added for final demand in 15 of the 22 sectors examined in 2004 and continued to be so in 2014.

Within individual sectors, there is a much wider range of changes that are not depicted here. Case studies demonstrating some of these changes for the oilseeds and bovine meat sectors are found in Annex 3 and summarised in Box 3.

Table 1. Most central countries by sectors within GVC interactions, 2004 and 2014

Top two countries by measure

Sector	Sellers of intermediates from the sector		Sellers of the sector for final demand		Sellers of intermediates to the sector		Buyers of intermediates from the sector		Buyers for final demand from the sector	
	2004	2014	2004	2014	2004	2014	2004	2014	2004	2014
Paddy rice	China	China	China	China	United States	United States	Germany	Belgium	United States	United States
	Thailand[a]	Korea	Thailand	Viet Nam	Germany	China	Belgium	Germany	United Kingdom	Germany
Wheat	China	China	China	China	United States	United States	Belgium	Netherland	United States	United States
	United States	United States	United States	India	Germany	China	Netherland	Germany	Italy	Germany
Cereal grains n.e.c.	China	China	China	China	United States	United States	Germany	Germany	United States	United States
	United States	United States	United States	United States	Germany	China	Netherland	Netherland	Japan	Germany
Vegetables, fruit, nuts	China	China	China	China	United States	United States	Belgium	Germany	Germany	Germany
	Thailand	Thailand	Thailand	Thailand	Germany	China	Netherland	Netherland	United Kingdom	United States
Oil seeds	Brazil	Brazil	Brazil	Brazil	United States	United States	Belgium	Netherland	United States	Germany
	Paraguay	Argentina	Argentina	United States	Germany	China	Germany	Germany	Germany	United States
Sugar cane, sugar beet	Brazil	Brazil	Brazil	Brazil	United States	United States	Belgium	Belgium	United States	United States
	India	China	India	China	Germany	China	Germany	Germany	Italy	Germany
Plant-based fibres	United States	India	China	China	United States	United States	Germany	Belgium	United States	United States
	China	China	United States	India	Germany	China	China	China	Italy	China
Crops n.e.c.	United States	India	United States	India	United States	United States	Netherland	Netherland	United States	United States
	Indonesia	Indonesia	Indonesia	Indonesia	Germany	China	Germany	Germany	Germany	Germany
Bovine cattle, sheep and goats, horses	China	China	China	China	United States	United States	Italy	Netherland	United States	United States
	Australia	Australia	Australia	Australia	Germany	China	Germany	Germany	Italy	Germany

Animal products n.e.c.	China	China	China	China	United States	United States	China	Netherland	United States	United States
	United States	Denmark	United States	Germany	Germany	China	Germany	Germany	Germany	China
Raw milk	Germany	Germany	Germany	Germany	United States	United States	Belgium	Netherland	United States	United States
	France	Netherland	Netherland	Netherland	Germany	China	Germany	Germany	Germany	Germany
Wool, silk-worm cocoons	China	China	China	China	United States	United States	Italy	China	Italy	United States
	Australia	Australia	Australia	Australia	Germany	China	China	Italy	United States	Italy
Forestry	Russia	China	Russia	China	United States	United States	Italy	China	United States	United States
	China	Russia	China	Rest SEA	Germany	China	Germany	Germany	Germany	China
Fishing	China	China	China	China	United States	United States	Belgium	Germany	Spain	United States
	Japan	Norway	Thailand	Norway	Germany	China	Netherland	Netherland	United States	Spain
Bovine meat products	United States	China	United States	China	United States	United States	Italy	Netherland	United States	United States
	Australia	United States	China	Australia	Germany	China	Germany	Germany	France	France
Meat products n.e.c.	United States	China	United States	China	United States	United States	Germany	Germany	United States	United States
	France	United States	France	United States	Germany	China	United Kingdom	China	Germany	Japan
Vegetable oils and fats	Indonesia	Indonesia	Indonesia	Indonesia	United States	United States	Belgium	Netherland	United States	United States
	Brazil	Brazil	Brazil	Brazil	Brazil	Brazil	Germany	Germany	Germany	Germany
Dairy products	Germany	Germany	Germany	Germany	United States	United States	Belgium	Netherland	United States	United States
	France	France	France	France	Germany	Germany	Germany	Germany	Germany	Germany
Processed rice	India	China	India	China	United States	United States	Belgium	Belgium	United Kingdom	United States
	Thailand	India	Thailand	Thailand	Germany	China	Germany	Germany	United States	Germany
Sugar	Brazil	United States	Brazil	United States	United States	United States	Italy	United Kingdom	United States	United States
	United States	Brazil	United States	Brazil	Germany	China	Germany	Germany	Germany	Germany
Food products n.e.c.	United States	China	United States	United States	United States	United States	Netherland	Netherland	United States	United States
	France	United States	France	Germany	Germany	China	Germany	Germany	Japan	Germany
Beverages and tobacco products	China	China	France	China	United States	United States	Italy	China	United States	United States
	Japan	France	United Kingdom	France	Germany	China	Germany	Germany	Japan	Germany

Note: Estimates include indirect value added use in exports. [a] Based off data contained within the GTAP database Korea appears as the second most central country. However, data provided by Korea shows a differentiated food sector using rice versus other products, with processed rice products consumed domestically and not exported. As such, the Korean results are excluded.
Source: Author estimates.

Box 3. Sector findings on centrality

Both the livestock and oilseeds sectors have seen a consolidation and increased centrality of their main actors.

The oilseeds sectors cover two types of products, soybeans and palm oil, used as intermediates for a range of food and non-food industries. The evolution of centrality between 2004 and 2014 shows the increased concentration of the United States and China as sellers of value added at the expense of countries in South America (Brazil, Paraguay, and Bolivia). Malaysia and Indonesia increased their centrality due to exports of palm oil. The most central buyers of oilseeds as intermediates for the production of exports are high income and mostly European Union countries, led by Germany. The United States is the most central country as a buyer from the oilseeds sector for final demand.

For bovine meat, the most central countries in 2004 selling intermediates from the sector for the production of exports were the United States, Australia, Brazil, New Zealand, Canada and China. However, for this sector a stronger regional dimension is observed. In 2014, China took the lead as the most central exporter of intermediates, with centrality also concentrating on the United States and Australia. The same three countries are central as exporters to final demand. However, between 2004 and 2014, the strong centrality of the United States decreased, with China and Australia both becoming the most central sellers for final demand.

In terms of buyers from the bovine meat sector, the most central countries buying for the production of exports are in Europe and Southeast Asia. For final demand, the United States, previously in ninth position became the most important buyer of foreign value added for bovine and meat products mainly through imports of intermediates to serve its domestic market.

The two case studies (see Annex 3) highlight differences in the organisation of agro-food GVCs in different regions. In the United States, there is a significant use of value added for domestic processing for domestic final demand. In contrast, there appears to be in Europe a much more integrated food system with significant linkages in value added used for re-export.

How have backward and forward participation changed?

Participation across sectors

GVC participation can be explored through the extent to which exports of an industry in a given country rely on imports from other countries (backward participation), and the extent to which its exports (both direct and indirect through the exports of other domestic industries) form part of another country's exports (forward participation).[5] For the forward linkages, as both direct and indirect exports of value added are captured, for industries with only small direct exports but relatively large indirect exports, the measured forward participation effect can be large, ranging well above the value of the direct exports (and so well above an indicator value of 1).

The nature of production in agro-food sectors, and for food in particular, suggests that the forward indicator may only be at best a partial indicator of linkages of sectors through their exports to other countries. Given the closeness of the sectors to final demand, there are significant exports that flow either as intermediates to foreign processing and then to final demand, or straight to final demand.

For the group of sectors overall, changes in participation can be viewed in two ways. First, by looking at the changes in the simple averages across sectors (treating each country-

[5] Not all sectors in all countries are directly involved in international trade and so not all have observed levels of gross exports. The reasons for this vary and are related to factors such as the nature of the product and issues of perishability. Of the sectors examined, there are three which have only a small number of observed direct trade interactions: raw milk (the raw unprocessed product) and sugarcane and beet – due to the perishability of the product; and paddy rice (unprocessed rice) – due to the small number of producers involved in the international trade of the raw material. In view of this, for some country-sectors indicators are not calculated.

sector the same) and second, by looking at the trade-weighted averages (so exploring agro-food GVC weighted by a country sector's importance in world agro-food trade). Using these two measures, differences in the development of agro-food GVCs can be observed. For both, over the period between 2004 and 2014, average GVC participation increased – that is, both forward and backward participation rose. However, the trend was not uniform and simple averages were greater than weighted averages (Table 2). For both measures, there was a general rise between 2004 and 2011, and then a fall between 2011 and 2014. This trend was likely driven by a mix of changes in relative prices of agro-food and other products, and the large shift in trade origins that occurred between 2004 and 2011 – that is, the increase in the number of world agro-food exporters predominately from developing regions. These new exporters initially exported more commodities with lower levels of transformation and less imported inputs.

Table 2. Changes in total agro-food backward and forward participation, 2004-14

Simple and weighted average results for aggregate agro-food sector

	Simple		Weighted	
	Backward	Forward	Backward	Forward
2004	0.204	0.352	0.196	0.129
2007	0.201	0.349	0.197	0.131
2011	0.213	0.397	0.204	0.131
2014	0.209	0.364	0.199	0.130
Growth % (2004-14)	2%	3%	2%	1%

Note: Averages represent average across countries. Weighted averages are trade weighted averages.
Source: Author estimates.

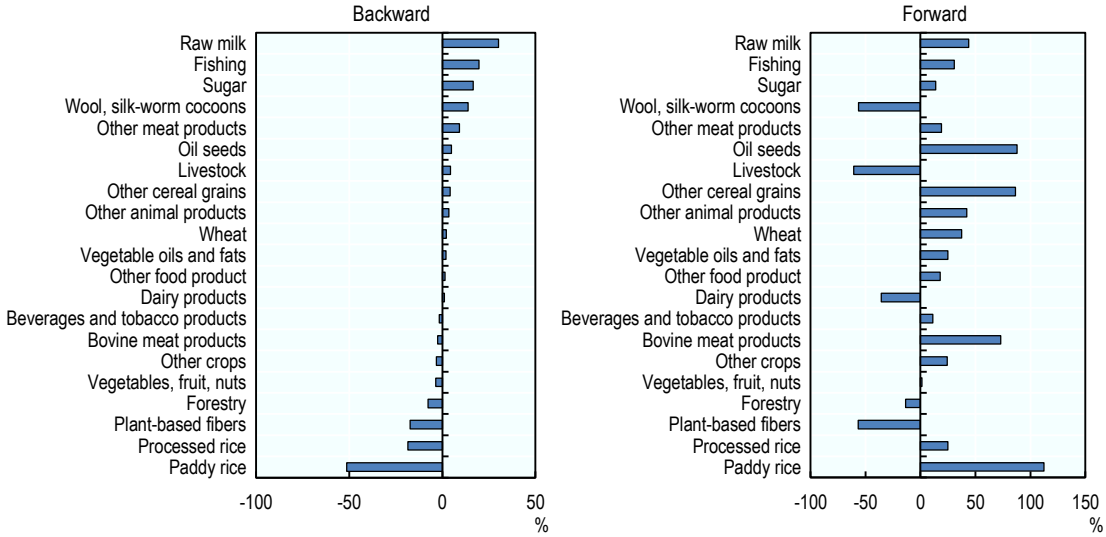
The increase over time is observed across most agro-food sectors (Figure 19). The increase is most consistent in forward participation, with increases in all but five sectors. This trend suggests that increasing shares of intermediate exports from agro-food sectors are used in the production of other countries' exports. This could be indicative of GVCs becoming more "global" over time as it suggests that exported agro-food products are increasingly re-exported. Over half the sectors see increases in average backward participation. However, on a weighted average basis, the number falls with the majority sectors when weighted by trade values experiencing falls in backward participation. This is likely to be driven by two effects: the shift towards emerging and developing countries as export sources and due to rising domestic value added shares as sector transformation takes place (potentially driven by GVC participation and explored in detail in Section 4).

However, it is not only changes in average levels that are of interest. As found in Greenville, Kawasaki and Beaujeu (2017a), there is significant variation in GVC participation across countries for any given agro-food sector. This variation across country-sector participation has persisted over time with most agro-food sectors showing a large diversity in their backward participation across the time periods examined (Annex 4). For most sectors, both the variability in backward and forward participation has increased over time (measured in terms of standard deviation). Two sectors standout as having reduced variation in backward and forward participation: the vegetables, fruits and nuts and the plant-based fibres sectors. For both, participation indicators also fell, potentially indicating changes in the nature of the GVCs in these sectors, and related to servicing final demand more directly (lower forward) and/or transformation of the sectors themselves (lower backward). Allied to this

increase in variation across agro-food sectors participation, the variation in the growth (or falls) of backward and forward participation was also large.

Figure 19. Change in backward and forward participation by sector, 2004-14

% change in simple averages across sectors



Note: Estimates for countries with more than USD 10 million in exports with outliers (estimates greater than 50) excluded.
Source: Author estimates.

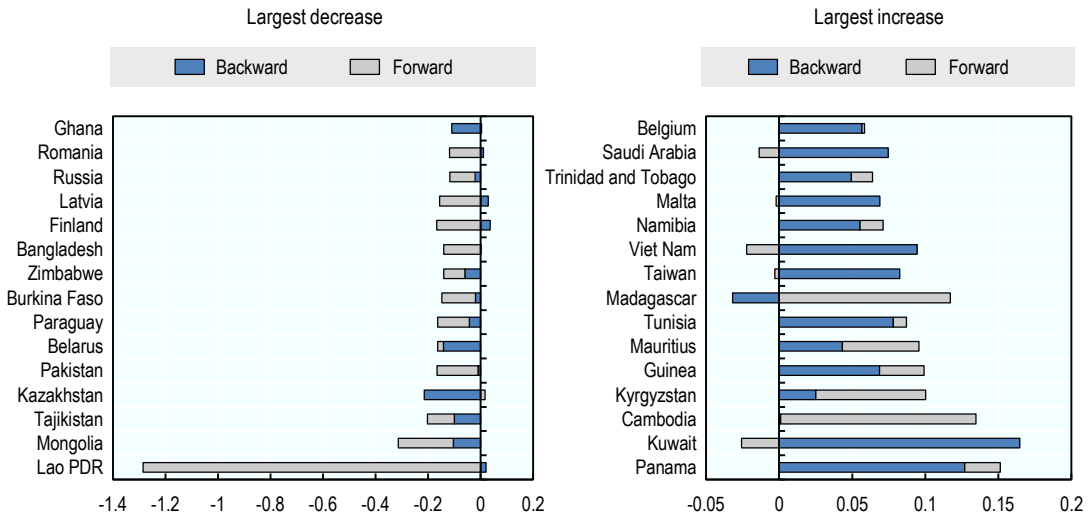
Participation across countries

Across the countries examined the changes in GVC participation reflect both the changes in markets driven by the increased in trade within GVCs, along with changes in the location of production globally (and shifts in comparative advantage). Changes in total participation, proxied by the sum of backward and forward participation, averaged (trade-weighted) across the 22 sectors examined show a large variation across countries.

Changes in forward participation were responsible for the greatest share of the changes seen in the 15 countries with the largest falls in total participation (Figure 20). In contrast, those with the largest increases in total participation were largely driven by increases in backward participation. The fall in total participation was greatest among smaller trading countries, with the exception of the Russian Federation. The same is true in countries which experienced the largest increases, with the exception of Viet Nam and Belgium.

Figure 20. Changes in total participation by country, 2004-14

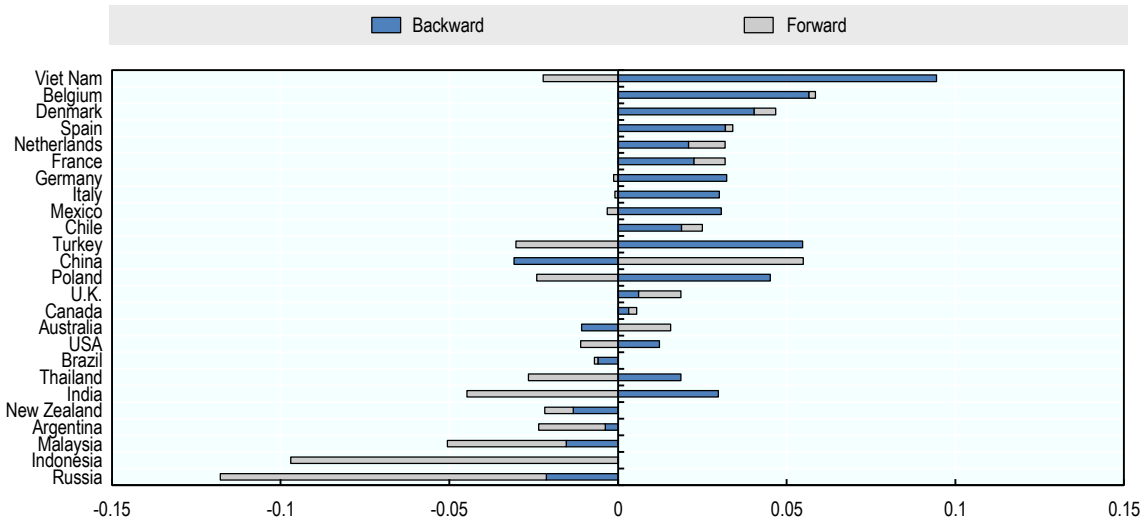
15 largest increases and 15 largest decreases



Note: Trade weighted averages for each country. Estimates for countries with more than USD 10 million in exports with outliers (estimates greater than 50) excluded
Source: Author estimates.

Figure 21. Changes in total participation by major traders, 2004-14

Change in indicator value for the world's top 25 trading countries in domestic value added exported terms



Note: Trade weighted averages for each country. Estimates for countries with more than USD 15 million in exports with outliers (estimates greater than 50) excluded.
Source: Author estimates.

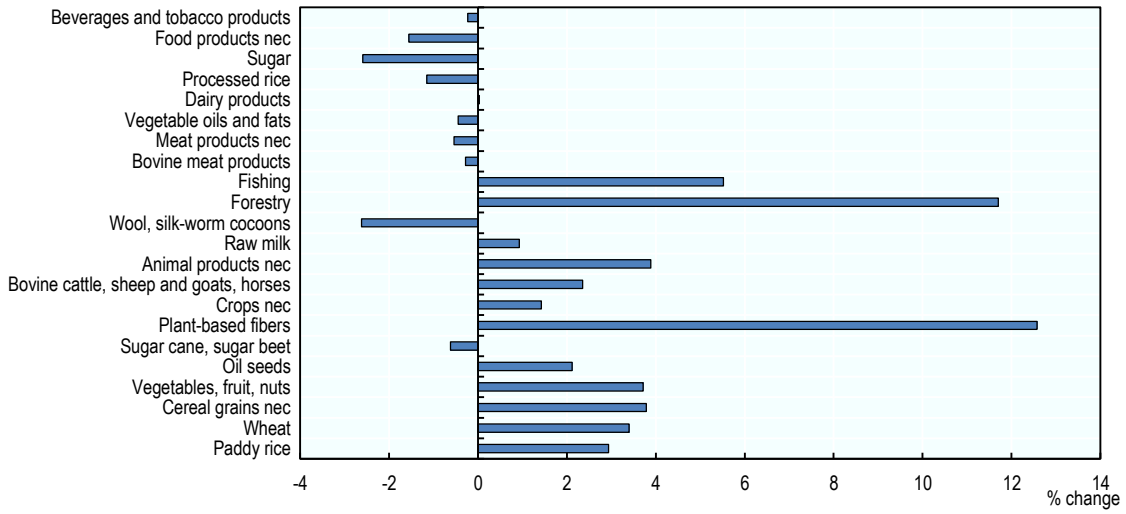
Share of value added in final demand

It is worth contrasting the changes observed in trade within GVCs across different agro-food sectors with the changes in the share of value added that end up meeting final demand in domestic versus foreign markets (Figure 22). For most agro-food products, the majority of production was destined for the domestic market. This has increased over time for most

agro-food sectors (13 out of 22) with the share of domestic value added that ends in domestic final demand increasing over time. This has occurred despite increases in trade in value added overall. However, the increases in shares to domestic final demand occur most often in the agriculture sector. In contrast, most food sectors have experienced an increase in the share of their domestic value added that ends in the final demand of a foreign country. This is the case for all but one sector – dairy, likely due to the strong increase in production in India that is focused on supplying its large domestic market.

Figure 22. Change in share of value added in domestic final demand by sector, 2004-14

% change increase in share of value added in domestic final demand between 2004 and 2014
(equals fall in share in foreign final demand)



Source: Author estimates.

How has the share of value added in production and exports changed?

Changes to international markets, consumer tastes and preferences, and production location, along with policy factors will all influence the relative contribution of different industries to the domestic value added embodied in agro-food exports (and production). Furthermore, changes over time in the real value of agro-food products will have had the potential to change some of these shares, or at least their distribution.

Changes in agro-food and non-agro-food sector contributions to export values

There is a mixed picture when observing the changes in the industry contribution to the value of agro-food exports. Overall, there is a relative shift away from services (domestic and foreign) in terms of their contribution to total export value (Table 13 and Annex 5). However, these changes are complicated by two factors.

- First is the shift in production to developing and emerging regions. These regions typically have a lower service content of production and greater agricultural share (Greenville, Kawasaki and Beaujeu, 2017b). As such, the overall shifts in aggregate trade source will bring down the world average service share depicted over time even though it may be still rising in individual countries.

- Second, agro-food prices increased relative to prices in other sectors of the economy (notwithstanding recent falls). This means that the relative input cost of agro-food inputs (and ultimately some value added factors used agro-food production depending on market structure) will have increased, shifting the relative contribution towards agriculture and food sectors.

The aggregate figures in Table 3 support two hypotheses: the service share is generally falling while the agriculture share is increasing and at the same time, this shift appears to be accompanied by a fall in the "spread" of service sector input shares of exports on a trade weighted basis. The latter is potentially driven by a rising concentration of exports from developing and emerging regions (between 2004 and 2011 the spread conversely fell as expansion occurred). However, this relationship and its influence on sectors and their transformation is unclear from the results, an issue that is explored in Section 4.

Table 3. Changes in the sector shares in exports, 2004-14

Percentage point change in sector value added share in exports, trade weighted

	Domestic					Foreign			
	Own	Agri	Food	Ind	Ser	Agr	Food	Ind	Ser
Paddy rice	-1.0%	0.0%	0.1%	1.5%	1.6%	-0.2%	-0.4%	-0.8%	-0.7%
Wheat	0.9%	0.3%	0.0%	-0.5%	-1.8%	0.0%	0.0%	0.8%	0.3%
Cereal grains	5.2%	0.6%	0.1%	-1.2%	-4.8%	0.1%	-0.1%	0.4%	-0.3%
Vegetables, fruit, nuts	0.5%	-0.1%	0.0%	0.1%	-0.7%	0.3%	0.0%	0.2%	-0.3%
Oil seeds	0.9%	0.1%	0.0%	-0.2%	-0.5%	-0.2%	0.1%	0.1%	-0.2%
Sugar cane, sugar beet	-24.2%	-0.3%	-0.1%	0.7%	12.3%	1.7%	0.4%	5.6%	4.0%
Plant-based fibres	7.3%	1.8%	0.0%	-3.0%	-3.8%	0.1%	0.0%	-1.1%	-1.3%
Other crops	3.5%	-0.2%	0.0%	-0.5%	-1.6%	-0.1%	0.0%	-0.3%	-0.8%
Bovine cattle, sheep and goats, horses	-0.5%	0.6%	0.0%	1.0%	0.3%	0.0%	0.1%	-0.8%	-0.8%
Other animal products	0.6%	-1.1%	-0.3%	-0.2%	-1.2%	0.7%	0.7%	0.4%	0.5%
Raw milk	5.4%	-0.8%	-0.3%	-0.7%	-1.4%	-0.3%	-0.1%	-0.8%	-1.1%
Wool, silk-worm cocoons	17.3%	2.4%	0.4%	-2.4%	-13.4%	1.4%	0.3%	-3.9%	-2.0%
Forestry	2.2%	0.0%	-0.1%	-1.2%	-0.5%	-0.1%	0.0%	0.1%	-0.5%
Fishing	-2.6%	-0.3%	0.8%	0.6%	0.0%	0.0%	0.1%	1.4%	0.0%
Bovine meat products	1.8%	-0.2%	-0.6%	0.1%	0.5%	0.0%	0.0%	-0.5%	-1.1%
Other meat products	0.5%	-0.2%	-0.1%	-0.1%	-0.4%	0.4%	0.3%	-0.1%	-0.3%
Vegetable oils and fats	0.8%	-1.3%	0.0%	-0.3%	-0.5%	0.9%	0.0%	0.3%	0.1%
Dairy products	0.1%	1.2%	-0.2%	0.3%	-0.9%	0.2%	0.1%	-0.2%	-0.8%
Processed rice	3.3%	-1.2%	-0.1%	-0.5%	0.5%	-0.9%	0.0%	-0.3%	-0.7%
Sugar	-2.3%	4.3%	0.0%	-0.5%	-1.4%	0.8%	0.6%	-0.7%	-0.7%
Other food products	-0.7%	0.5%	0.1%	-0.3%	-1.2%	0.9%	0.5%	0.3%	0.0%
Beverages and tobacco products	0.9%	0.3%	-0.1%	0.1%	-1.1%	0.2%	0.2%	0.1%	-0.5%

Note: Own refers to the industry's own contribution of domestic value added to exports.
Source: Author estimates.

Changes in the contribution of various agro-food sector value added factors

Between 2004 and 2014, the changes observed in world food prices along with changes in the source of exports are likely to have influenced the relative shares of export value captured by the various value added factors of production used by agro-food sectors. What is observed is that between 2004 and 2014 (and between 2004 and 2011), the relative share

of the growing agro-food trade value captured by unskilled labour[6] increased (Figure 23). In contrast, the share captured by skilled labour fell. The most likely cause of this change was the increased trade from emerging and developing countries, the agro-food sectors of which used unskilled labour more intensively than those in developed regions. This highlights the importance of growing agro-food trade for lower skilled and possibly lower income households, and the ability of trade to directly influence livelihoods in developing countries.

For land, there is a clear difference among sectors. Except for rice where there was virtually no change, the share of export value added captured by land for most staple crops fell. This occurred despite the price rises seen (suggesting these rises were not capitalised in land values). The reason for this may also relate to the shift in location of production and export sources to developing countries, which coupled with land tenure issues, often have lower land values. It is also possibly connected with expectations around the persistence of higher prices for these products. Lower expectations of continued high prices would likely result in the value increase being captured by the other factors of production; this result is supported by the value captured by capital in the sectors in which prices increased most significantly (those of wheat and cereal crops). Conversely, the share of export value captured by land in animal-based production activities and that of sugar and other crops (which include coffee and cocoa, along with cut flowers) increased. For these, it is possible that expectations of more long term price growth (related to shifting diets towards protein and other preference shifts associated with income growth) could be influencing the result.

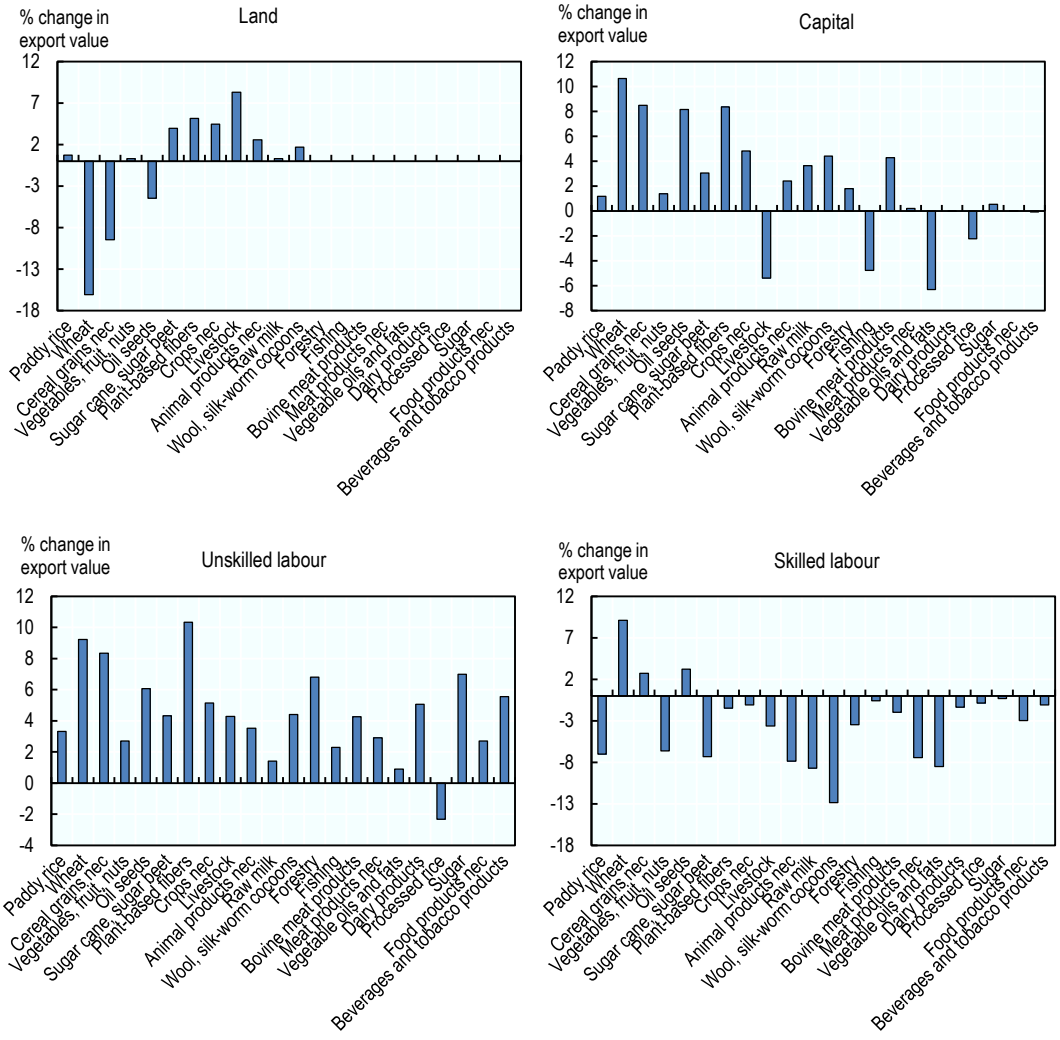
Overall, comparisons between the value added factors of production indicate that over the period, the increases in export value share captured by unskilled labour were highest – an average increase of 4.5% across the 22 sectors – with capital's share also increasing (2.0%). These were offset by falls in the shares captured by land (0.2%) and skilled labour (3.2%).

Along with the average changes, there were changes observed in the distribution of shares. On average across the sectors, the share captured by unskilled labour "shifted to the right", such that, along with the average increasing, the 25th and 75th percentile shares also increased. This indicates that the increases were observed for most countries and sectors involved in agro-food exports (a trend that has continued since 2011). The same was true for the share of capital of export value. For skilled labour and land, the distribution of share in export value became more concentrated around a lower average (a rise in the 25th percentile, on average, and a fall in the 75th percentile). However, overall the changes were relatively small.

[6] Labour categories represent aggregated 2008 International Labour Organisation (ILO) labour categories. Skilled labour categories here include: professionals – ILO categories of Managers and Professionals (major groups 1 and 2); and technical workers – ILO category Technical and Associate Professionals (major group 3). Unskilled labour include: clerks – ILO category Clerical Support Workers (major group 4); service workers – ILO category Services and Sales Workers (major group 5); and agricultural and other low skilled worker – ILO categories Skilled Agricultural, Forestry and Fisheries Workers, Craft and Related Trades Workers, Plant and Machine Operators and Assemblers, and Elementary Occupations (major groups 6-9). See www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_172572.pdf for more details.

Figure 23. Changes in factor shares of export value, 2004-14

% change in share of gross export value



Source: Author estimates.

Changes in the source of the bundle of imported inputs

Participation in agro-food GVCs is likely to be having an impact on the diversity of the bundle of inputs used by sectors. Participation in GVCs can require a different set of inputs as there can be a wider range of requirements placed on production, in particular on greater services inputs.

One way to explore changes in the bundle of inputs is to explore the diversity, or conversely the concentration, in the imported input bundle. There are two aspects to this diversity – one via the type of product and the other via its source.[7] Both of these can be explored by computing the Herfindahl Index (HHI) based on the concentration in the share of imported value added used in a country-sector's exports.[8] This index varies between 0 and 1, with higher values closer to 1 indicating that source of value added used in exports is concentrated from a few countries or input types (in this case sectors).

Exploring changes in the index shows that since 2004, the source (country) bundle of imported inputs used in exports became more diverse for a range of agro-food products – that is, the HHI fell for most products over time (Figure 24). This means that over time, the source of value added used in agro-food exports by sectors across the world became more varied, suggesting that the number of linkages to a range of other countries was expanding. In other words, agro-food GVCs were becoming more global. The diversification of imported input sourcing was greatest in the sugar cane & beet, other animal products, and oilseeds sectors.

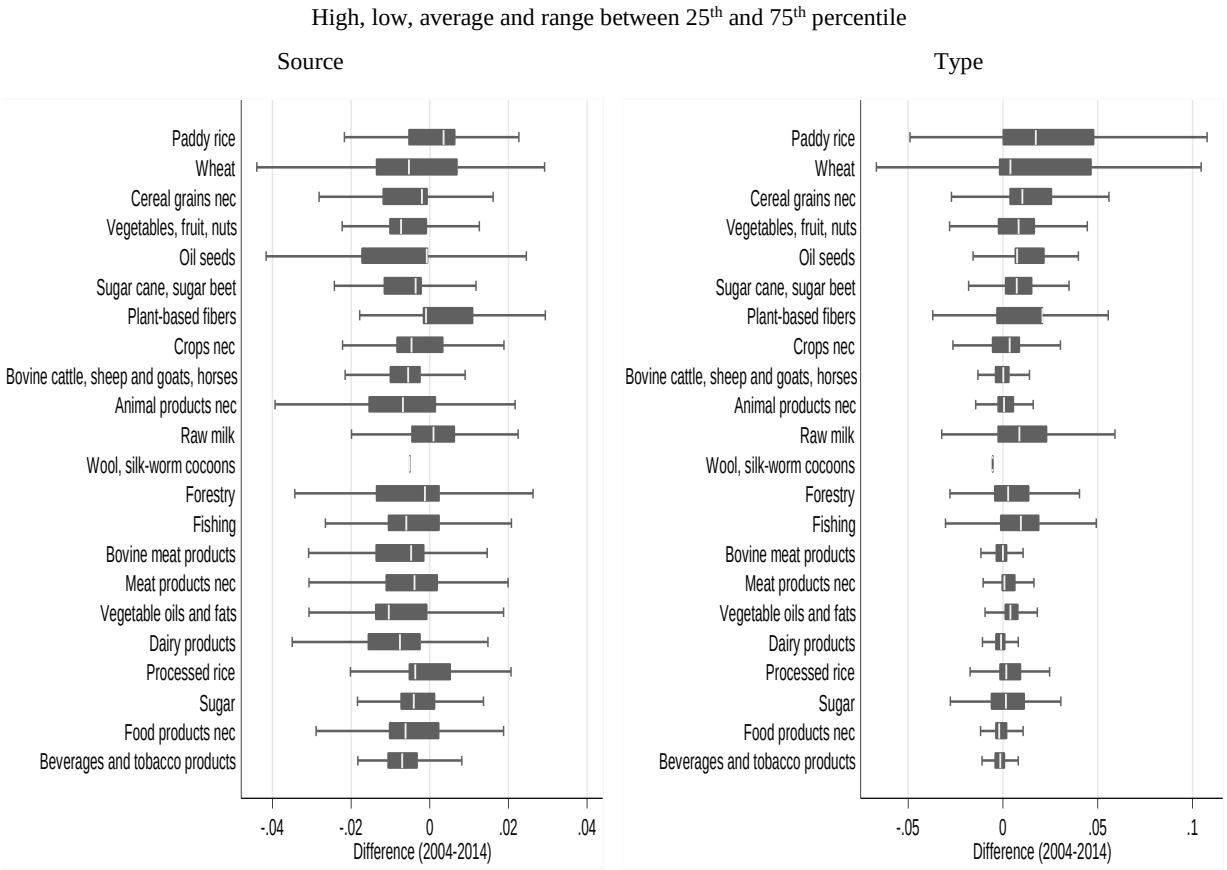
In terms of imported input type, the picture is more varied. The changes were smaller, on average, and there were fewer industries which saw a fall in the concentration of their input bundle. In particular, for agricultural industries, a number of cropping activities saw an increase in the concentration of the input type imported, whereas for food, the reverse was true. Such changes could be a product of specialisation within the industry groupings.

It is possible that levels of concentration in import sourcing and input type, or changes therein, can impact sector performance and transformation. A wider range of sources or input types may suggest greater integration in value chains and could open more opportunities for embodied technical change within the imported inputs to influence the sectors. Alternatively, the changes may be indicative of greater non-discriminatory changes in trade barriers, opening up the number of potential suppliers to an industry and thereby helping its international competitiveness. Such influences are explored in Section 4.

[7] The approach is applied to both type and source. However, a caveat exists in terms of the results seen for type of imported intermediates. Unlike trade data, which has a large number of different types of products, characterised by different HS codes, within the GTAP database used to construct the ICIOs for this study there is an assumption of one sector-one product. This limits an in-depth look at the input bundle.

[8] The Herfindahl Index is calculated as the sum of squared shares of imported value added used in a sector's exports.

Figure 24. Change in the concentration in source and type of imported value added used in exports, 2004-14



Note: Negative values indicate falling concentration. Estimates for countries with more than USD 10 million in exports with outliers (estimates greater than 50) excluded. Trade weighted changes.
Source: Author estimates.

4. How have GVCs changed sectors?

This section explores the ways in which GVC participation has influenced sector transformation. To do so, a regression analysis was undertaken to explore the role of GVC participation and policy influences in influencing domestic value added growth in aggregate and in exports (see Box 4 for the approach and Table 4 for detailed results). Further attention was given to the ways in which GVC participation have influenced the returns to different factors of production. To deal with the real price shifts between periods, country-time fixed effects were used.

For the purpose of this paper, GVC participation was measured in several ways, including:

- Backward participation in the initial period (2004): To capture the use of foreign factors and the original level of integration in GVCs of a country-sector.
- Forward participation in the initial period (2004): To capture the participation in a specific type GVC which continues beyond the trading partners borders.

- Share of domestic value added that ends in foreign final demand (change between periods): To capture participation in ongoing value chains of varying types (selling into GVCs in general).
- The concentration in imported intermediate inputs by a sector: Measured at the source-type level, this was used to explore the concentration of backward connections of an industry (it is, however, likely to be linked to policy settings and overall openness of the sector to international markets).

While GVC participation is believed to be important, so too are policy influences (as shown by Greenville, Kawasaki and Beaujeu, 2017a). Finding a consistent set of policy indicators across a vast array of countries and regions, however, is difficult. Given this, a relatively narrow set of policy indicators were used for this paper. These relate to:

- Tariffs charged (weighted average by import source): Representative of the tariffs applied to imported products of the same sector; that is, the tariffs charged variable on the wheat sector in country A represents country A's wheat tariffs.
- Tariffs faced (weighted average by destination): Representative of the trading environment faced by a country's exports of a certain product as measured by the tariffs they face.
- SPS and TBT charged: Measured as the number of SPS and TBT specific trade concerns raised at the WTO on imports into a specific country.
- SPS and TBT faced: Measured as the number of SPS and TBT specific trade concerns raised at the WTO in markets to which a country exports.

The charged variables are measured in difference terms such that information on changes made by countries on the variables of interest can be explored. The tariff data is obtained from GTAP so includes both tariff and quantitative restrictions (quotas and tariff-rate quotas). For faced variables, as these lie outside the scope of a country's influence, the initial values from 2004 have been used.

The measures of SPS and TBT used in this analysis are limited. Data on specific trade concerns raised at the WTO do not account for much of the friction caused by NTMs, nor do they pick up the complexity of the effects of NTM use. These measures only represent indicative effects and further research is required to explore the impacts of NTMs on agro-food GVCs.

Box 4. Estimating the impact of GVC participation on agro-food sector transformation

To explore the impact of GVC participation a fixed effects panel regression model was used. The model attempts to correct for both the price movements and specific country characteristics that may influence sector development and trade within GVCs. The full details of the model are found in Annex 6.

The model makes use of data on all 22 agro-food sectors across all 141 countries and regions. It includes time-based fixed effects to account for the changes in real prices that occurred over the period and country-year level fixed effects to control for country-specific geographic characteristics and other time based events (such as weather events) than may influence trade and sector growth.

The model is used to explore the impact of GVC participation and policy on total sector domestic value added growth, growth in domestic value added exported, along with shares of domestic value added from intermediates (other sectors), land, labour (skilled and unskilled) and capital. For the regression, export observations with very small trade amounts were dropped.

The main aspects of influences in transformation explored in this section relate to areas identified in past studies as drivers of sector development from GVC participation. Specific aspects identified through the trends observed are also explored. Broadly, these include:

- *Learning through importing – using foreign value added to promote domestic value added*: Past analyses have suggested that use of foreign factors has been an important input into the growth of exports of domestic value added. This growth is driven through changes in the competitiveness of sectors from being able to access foreign factors and the spillovers often created – an extension of the embodied technical change theories applied to foreign direct investment.
- *GVC participation, employment and the factor market in general*: The labour content of agro-food exports has changed over time. This may be a result of shifts in production location but some of the changes may also be related to GVC participation and the impact from obtaining competitively priced intermediate inputs and the technical change that this may embody.
- *The role of services and domestic value added creation*:[9] Services form a significant share of agro-food final and export value. The inclusion of services along the value chain may be indicative of growth opportunities for the sector itself and thus a driver of sector transformation.
- *Policy influences on sector transformation through GVCs*: While GVCs may influence agro-food sector development, policies may help or hinder this. Thus, like for the static case, policies may have a broader impact on sectors.

The main results from the regression analysis are summarised in Table 4. These are separated into the influences on domestic value added creation in aggregate and in exports and the impact on the share of value added in output (and by extension the share of value added in exports). Implications of the results for the various areas of inquiry are discussed below.

[9] For the purpose of this paper, services explored include non-transport services. Notwithstanding their importance for the sector, transport services were excluded from the analysis as the growth in their use should be proportional to rising trade and production levels.

Table 4. Regression results

Significant estimates from regression analysis

Variables	DVA	DVA in exports	Intermediates	Land	Unskilled labour	Skilled labour	Capital
Backward	Positive***	Positive**	Negative***	Positive***	Positive***	Positive***	Positive***
Forward						Positive**	Positive*
Tariffs faced			Negative*			Positive*	Positive***
SPS faced						Negative (weak)	
TBT faced						Negative**	
DVA in foreign demand	Positive***	Positive***			Positive*		Positive (weak)
Change in service share	Positive***			Positive (weak)	Negative**		Positive**
Imported inputs concentration	Negative*		Negative***		Negative***	Negative**	Negative***
Change in tariffs charged	Negative**		Positive***				Negative**
Change in SPS charged							
Change in TBT charged	Negative (weak)			Positive (weak)		Negative***	

Note: Weakly significant represents estimates where p=0.15. *p=0.1, **p=0.05 and ***p=0.01.
Source: Author estimates.

Learning through importing: Using foreign value added to promote domestic value added

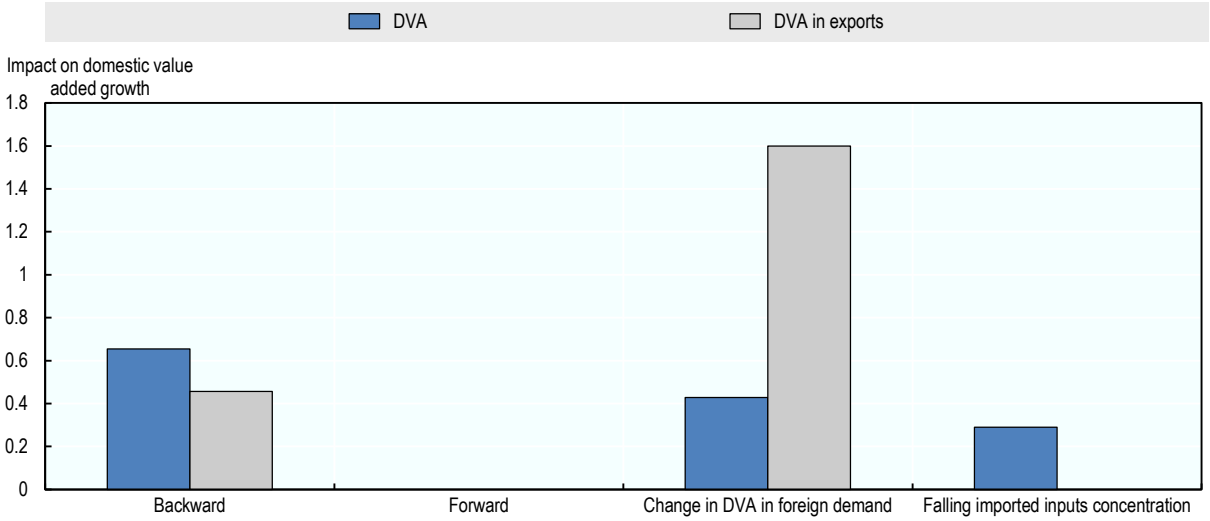
Past backward participation is found to have a significant influence on domestic value added growth on across agro-food sectors (Figure 25). This is true for both overall growth of the sector (its aggregate size) and domestic value added sold in exports. In other words, the use of foreign factors in the production of exports (and by extension the production of domestically sold goods) enhances sector growth. These results are found for all sectors irrespective of the level of processing (Box 5).

The results suggest that once country and sector characteristics are accounted for, participating in GVCs through sourcing foreign inputs helps to grow the sector and its exports. The link is through access to more competitive and potentially better inputs (through embodied technical change) that can help transform production process and transform the sector into a more competitive industry.

It is not only the use of foreign factors that plays a role. Other forms of participation are important, with forward linkages, broadly defined, also having a positive impact. The results suggest that while the type of participation captured by the forward participation indicator (that of exports being re-exported) is not significant, having linkages in any form that extend to foreign markets are. The share of domestic value added that is consumed by final demand has a positive impact on both overall sector growth and growth in exports of domestic value added. That is, an increased share of domestic value added that goes to foreign final demand has a positive impact on growth. This suggests that participation in any form of GVC – be it through domestic processing then export, through exports to foreign processing for demand in that market, or through foreign processing for another foreign market's final demand – has a positive influence on sector growth and transformation.

Figure 25. Changes in growth in domestic value added from GVC participation

Estimated coefficients



Note: The result for concentration on imported intermediate inputs depicted has been multiplied by -1 so that it illustrates falls in concentration.
Source: Author estimates.

Apart from participation indicators based on shares, the analysis suggests that having a wider range of backward linkages – be they a wider range of sources or types of intermediates – helps promote sector growth (depicted in inverse on Figure 25). Measured by the Herfindahl Index (HHI) where an increase represents an increase in concentration, falls over time are positively related sector domestic value added growth. This suggests that it is not only the share foreign value added that counts, but also the range of places (countries or sectors) from which it is sourced.

Box 5. Are the effects of GVC participation different for primary and processed products?

The analysis presented in this paper explores the impacts of agro-food GVC participation on all sectors without differentiation between different sector types. To test whether there are differences between primary and processed products, alternative regressions were explored which differentiated primary agricultural products (GTAP sectors 1 to 14) and processed food products (GTAP sectors 19 to 26). It was not possible to differentiate livestock and crop products as there were too few observations for livestock-related products as many of these are very thinly traded – such as raw milk and live animals.

The results of the alternative specification replicated the main findings (Annex 6). For both primary and processed products, greater GVC participation measured by backward participation has positive impacts on domestic value added growth and value added growth in exports – although for primary agriculture the result for domestic value added in export was not significant. Similarly, the share of value added consumed in foreign final demand (used as a more general measure of forward participation) was also found to have positive impacts, with the positive link between increasing service use and total domestic value added growth also observed.

GVC participation and factor market impacts

GVC participation can influence the use of different factors of production. Employment associated with agro-food GVCs in agro-food sectors is already significant in some regions (Figure 26).[10] It is created through both direct participation in agro-food GVCs from own sector exports, and by supplying to other domestic sectors which in turn export.

Across regions, the employment share associated with agro-food GVCs exhibited conflicting trends between 2004 and 2014. In both Africa and Asia, there was a fall in the share of total employment (in terms of shares of total payments to labour) associated with agro-food GVCs. This is due to structural changes in the agro-food sectors, such as falling labour use within agriculture, and rising incomes and employment outside the sector. In contrast, employment in Europe and the Americas in agro-food sectors associated with GVCs increased – a mix of further integration of the food system in Europe and expanding agriculture-related trade from South America. The effects seen for Europe are likely influenced significantly by EU members and the large amount of intra-European Union trade brought about by their relatively highly integrated food system.

Similar patterns are seen at the sector level, with the exception of Asia where employment shares were steady, suggesting that many changes in total workforce shares were driven by the smaller relative size of the sector rather than less GVC participation. In Africa, both sector and total workforce shares fell, suggesting less relative engagement (a more domestic focus) combined with structural adjustment. For Europe and the Americas, the rising importance of GVCs in agriculture and food were replicated at the sector level.

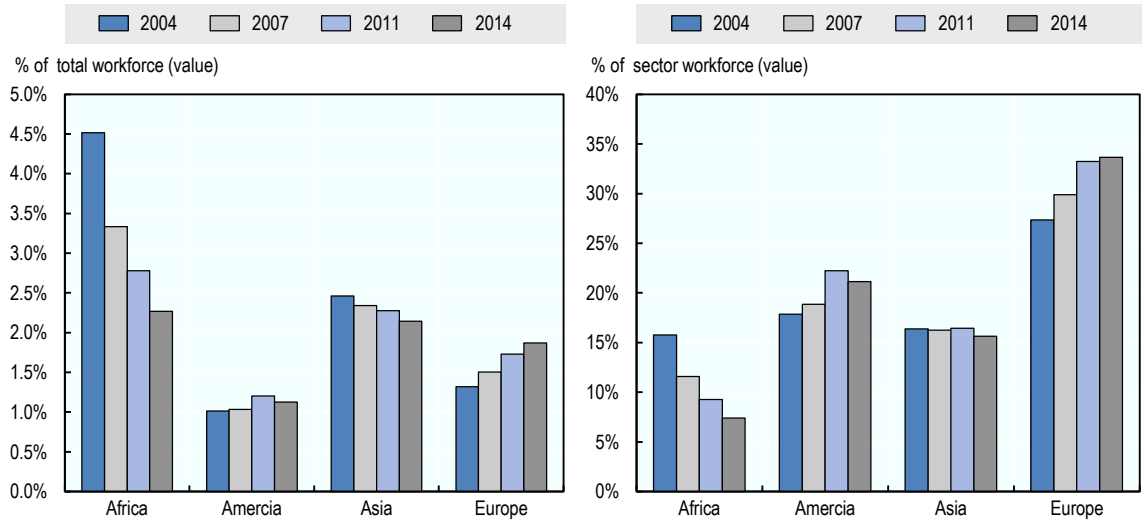
Within individual countries, there is a range of ways in which GVCs may influence employment or the factor market more generally. This may be through employment generated by exports or through competitive effects on the industry itself as it more competitively serves its own domestic market. GVC participation can influence the relative prices of inputs and can induce changes in productivity through the embodied technical change in the imported inputs. The results from the analysis suggest that using foreign factors for the production of exports (and production more generally by extension) creates an increase in the shares of gross value captured by the value added factors. Combined with the effects of *increasing* domestic value added, these changes can mean a growing share of a growing amount going to value added factors employed in the agro-food sector.

What is observed is that backward participation causes a decrease in the share of gross value that is captured by intermediate inputs (Figure 27). In other words, access to competitive intermediate inputs and the technical change brought about by sourcing these from GVCs lowers the cost of intermediates in the production process and causes the share of value captured by intermediates to fall. This necessarily means that the gross value captured by the resources employed in the agro-food sectors has to rise – that is, backward participation leads to a shift in the returns of economic activities to land, labour and capital. These represent returns to agricultural and food producers. It also suggests that higher initial levels of backward participation should lead to lower future backward participation – evidence that supports sector transformation from GVC participation.

[10] The figures presented only examine employment within the 22 agro-food sectors. As such, this analysis excludes indirect employment created in other sectors from agro-food exports.

Figure 26. Shares of total and sector workforce employed in agro-food GVCs

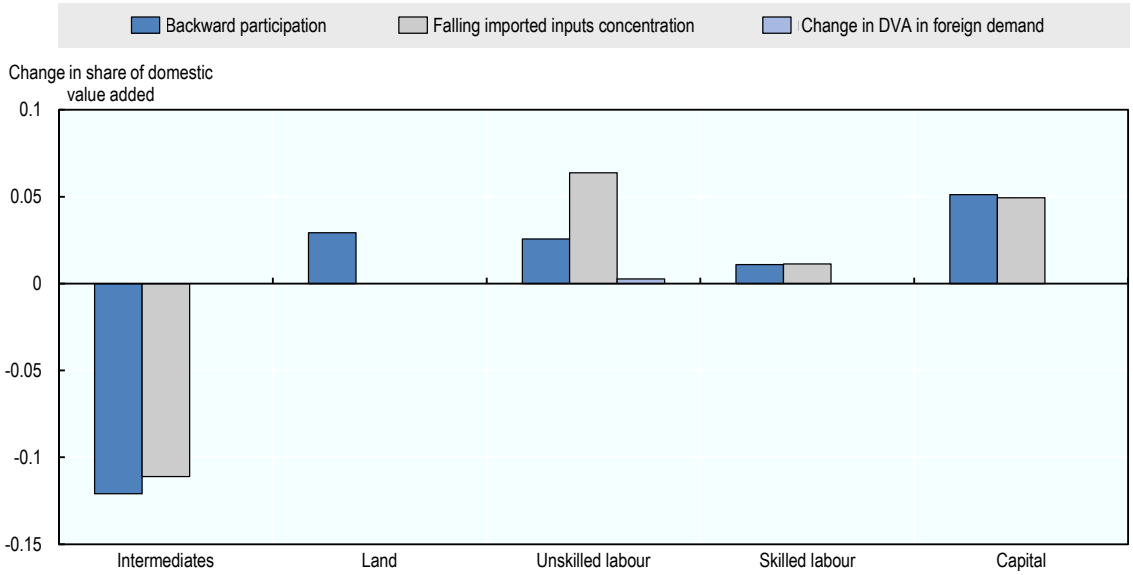
Share of workforce in value terms, average across regions



Note: Total sector value added weighted averages. Both direct GVC participation and indirect (through other domestic sectors) employment included.
Source: Author estimates.

Figure 27. Changes in the share of value added from GVC participation

Estimated coefficients



Note: The result for concentration on imported intermediate inputs depicted has been multiplied by -1 so that it illustrates falls in concentration.
Source: Author estimates.

Across the value added factors, the results indicate that the relative effects are greatest for capital, land and unskilled labour. There are a number of possible reasons for these shifts. Involvement in GVCs may increase the use of fixed capital in farms due to greater access to new capital through the linkages created and/or as a tool for driving productivity gains

as a result of the initially higher returns and subsequent investment. However, in either case, it suggests a transformation in the production processes that is facilitated through the use of foreign factors. The returns to land and unskilled labour are the next largest increases (and statistically similar). These represent returns to farm households and farm workers directly. The increase in the share captured by unskilled labour (a bigger share of a larger amount) may be created through either wage increases or increases in employment (it is not possible to differentiate in this analysis). As land in most countries is fully utilised, the higher returns to land should represent higher returns to farming households, albeit a return that is tied up in a fixed asset.

While forward participation was not found to have significant impacts on the use of differing value added factors, a small and positive effect on unskilled labour was found for the share of domestic value added used in foreign final demand. This appears to re-enforce the result from backward participation on the returns to unskilled workers in the agriculture and food sectors.

For changes in the concentration of imported intermediate inputs, the effects are similar (Figure 27). Decreasing concentration in the imported input bundle also decreases the share of value captured by intermediates, causing a substitution in value towards the other factors of production. The strongest impacts are seen for unskilled labour. This may be related to the changes in the production systems caused by production transformation that calls on a wider range of inputs and therefore a more diverse imported intermediate input bundle. This more diverse input bundle provides greater opportunities for technical change from the use of foreign inputs. Alternatively, having access to a wider range of foreign inputs (either sources or types) may offer greater opportunities for participation in GVCs and thereby induce a change in production that ultimately creates the impacts on value added factors. Thus, while the direction of causation is unclear, it nevertheless represents higher domestic returns captured by the sector itself.

The role of services and domestic value added creation

The role of services in agro-food sector development was explored through the impact that a change in the service share in exports (and production) has on sector growth and growth in domestic value added exports. The results suggest that increasing "servicification" of production has a positive impact on domestic value added creation in agro-food sectors. In other words, participation in value chains, be they domestic or global, that involve greater service use across the value chain increases the returns to agricultural and food producers.

Such a result is important when thinking both in terms of sector development and when considering changes in *shares* of final value. Services already form a significant part of final value for many agro-food products. This result suggests that their use across the value chain is important for adding value at the producer level. However, in adding this value to producers, it necessarily means that the *share* of the final value of agro-food products captured by producers will *fall*. That is, it cannot be said that adding value for primary producers – i.e. income – will mean that these producers capture a greater share of the final dollar. Indeed, successfully growing producer incomes in total may mean that the share of the final dollar captured by producers will actually be less.

Policy influences on sector transformation through GVCs

The impact of interventionist policy on sector development was found to be largely negative. Both increases in tariffs charged on agro-food imports and increases in the number of TBT complaints were found to have negative impacts on domestic value added

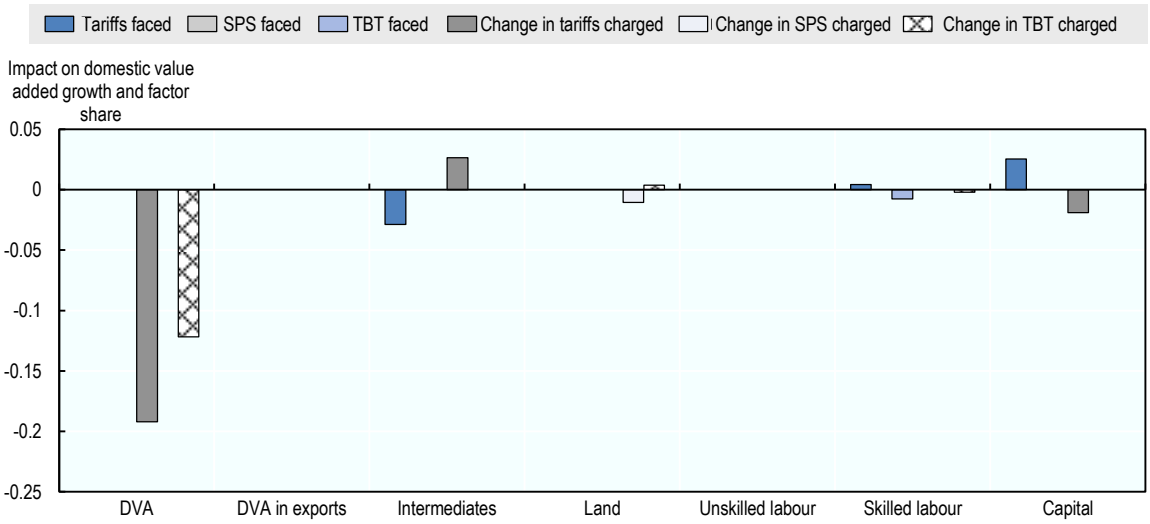
growth (Figure 28). For tariffs, it suggests that policies seeking to protect domestic industries through higher tariffs have a long-term negative impact on sector growth – showing the cost drag on the industry of such policies. Furthermore, the impact of increasing tariffs on the share of returns to factors of production indicates that tariffs increases share of value that goes to intermediates. This occurs as producers do not have access (or have reduced access) to competitively priced inputs including those with the potential to induce sector transformation as tariffs limit producers access to GVCs. Ultimately, this means that the returns to the producing sector itself are lower as it has negative impacts on the value added factors of production – mostly capital in this case.

In terms of non-tariff measures applied by a country, the impacts were once again mixed. Noting the limitations in the measures used in this study, the findings are in line with earlier findings where both positive and negative effects of NTMs have been found (Greenville, Kawasaki and Beaujeu, 2017a). While there was little impact found in the case of domestic value added exports, both SPS and TBT measures had mixed effects on the shares of value added factors in gross production value. Increasing SPS frictions saw a fall in the share of the returns to land but no significant effects elsewhere. TBT frictions on the other hand, had a positive impact on land and negative on skilled labour. Further work is needed to better measure and explore the impacts of NTMs on GVC participation. Work recently completed by Cadot, Gourdon and van Tongeren (2018) should aid in this, and provide a means to better explore NTMs in future work.

On the outward policy side, facing higher external tariffs caused a decrease in the share of value captured by intermediates with movements towards capital and skilled labour. The reasons for this are less clear. It may be due to the influence that tariffs have on the profitability of accessing markets with higher tariffs – that to do so, only the most efficient producers can profitably do so. This creates a bias towards capital and skilled labour use.

Figure 28. Impacts of policies on value added and factor shares

Scaled (by 1 000) estimated coefficients



Source: Author estimates.

5. Policy implications

GVC participation in most agro-food sectors increased between 2004 and 2014. There was an increasing intensity around the world in the flow of agro-food value added within global value chains. There were also shifts in the centrality of different countries within each agro-food sector explored. Overall, it appears that GVC participation in most agro-food sectors increased over the 2004 to 2014 period. Furthermore, there is evidence suggesting there were changes in the complexity of GVCs (when looking at the diversity of sourcing from GVCs), along with changes in their location (greater involvement of developing countries).

From a regional perspective, China emerges as a key player in trade in value added within agro-food GVCs. It accounted for the largest increases in the use of agro-food value added for exports and in the supply of agro-food value added for exports. In contrast with changes in global production that have seen an increased role of developing countries in total global agricultural output, many developed countries remain significant drivers of agro-food GVCs. Over the period, centrality estimates suggest that China, the United States and Germany were the three major hubs in agro-food GVCs.

The shifts in the nature of GVCs have led to changes in the distribution of the benefits that stem from participation. Overall, the shares of the returns accruing to unskilled labour and capital rose, while those for skilled labour and land fell. The shift towards greater developing country involvement saw a decrease in the aggregate service sector share of agro-food export value.

The analysis presented sheds light on some of the impacts of GVC participation on agro-food sector development and transformation. The study highlights:

- *GVC participation is a significant driver of sector development*. Using foreign factors in the production of agro-food exports (and production more generally) has a positive impact on sector growth. Countries with higher backward participation experienced stronger aggregate domestic value added growth and growth in domestic value added exports compared with those with lower levels of participation. Furthermore, for agro-food sectors, selling into GVCs has positive effects on domestic value added creation and exports. While selling into GVCs that continue across borders was not separately significant (forward participation indicator), selling into foreign markets for whatever purpose was.
- *GVC participation has positive effects on labour and producer returns*. Having access to competitive foreign inputs from GVCs and the technical change this embodied leads to a greater share of a larger amount of value added being captured by the producing industry. This means higher returns to farmers and domestic food processors. The strongest effects are seen for capital, land and unskilled labour, but skilled labour also benefits. While it is not possible to tease out the type of impact on labour – be it more jobs or higher wages – the results show a positive impact on total labour returns.
- *Using services along the value chain is an important driver of domestic value added growth*. Increasing service use across the value chain as represented by an increase in the service share of exports, and by extension within the domestic production chain, is beneficial for domestic value added growth. This result helps to highlight that agriculture and food sector development today is not just about mechanisation and investment to promote efficiency. The "de-commodification" of output means that it is not only about what is produced, but also *how* it is produced and *how* it

gets delivered to export markets or consumers. This *how* is the service element of the value chain, with increases in services shares of export value being shown to be beneficial for total domestic value added growth. This result is important when thinking in terms of sector development and when considering changes in shares of final value. Adding service value to producers means that the share of the final value of agro-food products captured by producers will fall. That is, growing the incomes of primary producers may mean that their share of the final dollar falls.

- *Protectionist policies harm development and transformation*. For tariffs in particular, increasing levels of protection were found to be harmful domestic value added growth. While such measures are often put in place to aid domestic industries, they are most likely to have negative impacts on growth over time. Furthermore, increasing tariffs sees a shift in the share of the gross value production from the agriculture or food sector to other sectors through an increase in the share of gross value added captured by intermediates, both domestic and foreign.

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Annex 1.

GTAP Sector list

Table 5. GTAP sector list

Number	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	Veg & Fruit: vegetables, fruit vegetables, fruit and nuts, potatoes, cassava, truffles
5	osd	Oil Seeds: oil seeds and oleaginous fruit; soy beans, copra
6	c_b	Cane & Beet: sugar cane and sugar beet
7	pfb	Plant 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	Cattle: 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, whether or not refined or coloured
11	rmk	Raw milk
12	wol	Wool: 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	Cattle 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: 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.
22	mil	Milk: dairy products
23	pcr	Processed Rice: rice, semi- or wholly milled
24	sgr	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

Number	Code	Description
		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, food products n.e.c.
26	b_t	Beverages and Tobacco products
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: 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 (see next)
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 organizations n.e.c., extra-territorial organizations and bodies
57	dwe	Dwellings: ownership of dwellings (imputed rents of houses occupied by owners)

Annex 2.

GTAP region list

Table 6. GTAP regions

No.	Region	No.	Region	No.	Region
1	Australia	48	Rest of Central America	95	Armenia
2	New Zealand	49	Dominican Republic	96	Azerbaijan
3	Rest of Oceania	50	Jamaica	97	Georgia
4	China	51	Puerto Rico	98	Bahrain
5	Hong Kong	52	Trinidad and Tobago	99	Iran Islamic Republic of
6	Japan	53	Caribbean	100	Israel
7	Korea Republic of	54	Austria	101	Jordan
8	Mongolia	55	Belgium	102	Kuwait
9	Taiwan	56	Cyprus[1,2]	103	Oman
10	Rest of East Asia	57	Czech Republic	104	Qatar
11	Brunei Darussalam	58	Denmark	105	Saudi Arabia
12	Cambodia	59	Estonia	106	Turkey
13	Indonesia	60	Finland	107	United Arab Emirates
14	Lao PDR	61	France	108	Rest of Western Asia
15	Malaysia	62	Germany	109	Egypt
16	Philippines	63	Greece	110	Morocco
17	Singapore	64	Hungary	111	Tunisia
18	Thailand	65	Ireland	112	Rest of North Africa
19	Viet Nam	66	Italy	113	Benin
20	Rest of Southeast Asia	67	Latvia	114	Burkina Faso
21	Bangladesh	68	Lithuania	115	Cameroon
22	India	69	Luxembourg	116	Cote d'Ivoire
23	Nepal	70	Malta	117	Ghana
24	Pakistan	71	Netherlands	118	Guinea
25	Sri Lanka	72	Poland	119	Nigeria
26	Rest of South Asia	73	Portugal	120	Senegal
27	Canada	74	Slovakia	121	Togo
28	United States	75	Slovenia	122	Rest of Western Africa
29	Mexico	76	Spain	123	Central Africa
30	Rest of North America	77	Sweden	124	South Central Africa
31	Argentina	78	United Kingdom	125	Ethiopia
32	Bolivia	79	Switzerland	126	Kenya
33	Brazil	80	Norway	127	Madagascar
34	Chile	81	Rest of EFTA	128	Malawi
35	Colombia	82	Albania	129	Mauritius
36	Ecuador	83	Bulgaria	130	Mozambique
37	Paraguay	84	Belarus	131	Rwanda
38	Peru	85	Croatia	132	Tanzania United Republic of
39	Uruguay	86	Romania	133	Uganda
40	Venezuela	87	Russian Federation	134	Zambia
41	Rest of South America	88	Ukraine	135	Zimbabwe

No.	Region	No.	Region	No.	Region
42	Costa Rica	89	Rest of Eastern Europe	136	Rest of Eastern Africa
43	Guatemala	90	Rest of Europe	137	Botswana
44	Honduras	91	Kazakhstan	138	Namibia
45	Nicaragua	92	Kyrgyzstan	139	South Africa
46	Panama	93	Tajikistan	140	Rest of South African Customs Union
47	El Salvador	94	Rest of Former Soviet Union	141	Rest of the World

Notes:
1. Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue."
2. Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Annex 3.

Centrality to agro-food trade case studies

GVCs in oilseeds

The oilseed sector supplies a mix of products used as intermediates in a range of agro-food and manufacturing value chains. As such, it provides a useful case study to examine the various flows of agro-food value added and countries' importance in these value chains. Changes in centrality are first explored through the centrality of countries as sellers or buyers of value added in oilseed for the production of exports by examining countries' participation in a "multiple countries" global production chain. The second part then explores the centrality of different countries as buyers of value added for their final demand. This value added can be bought either directly from the sector itself or sourced indirectly through other processing industries. In the oilseeds sector, for example, this indirect link could be through oilseed feed for livestock production, which goes into meat production which is consumed by final demand in that country.

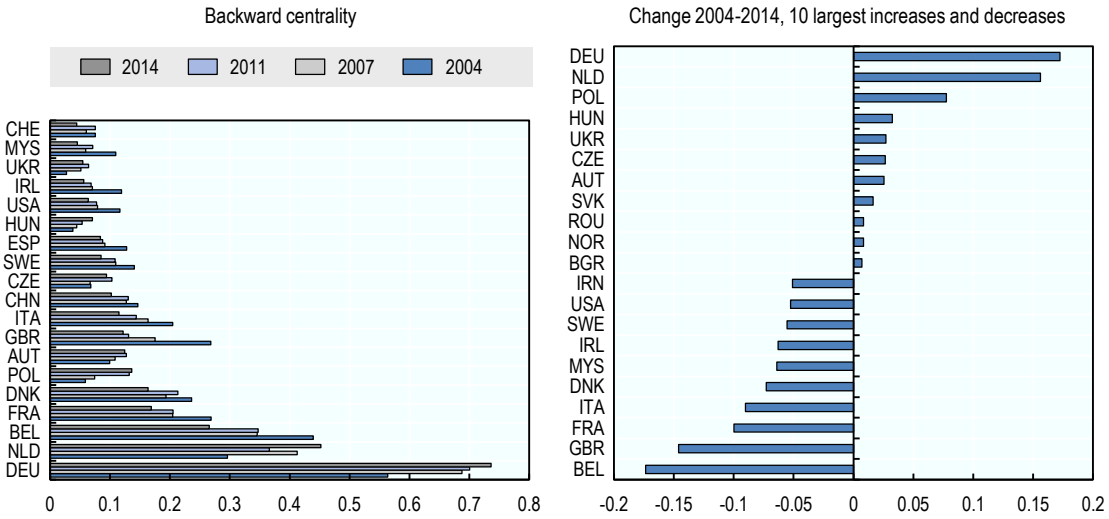
The most central countries buying oilseeds value added the production of exports are countries from the European Union (Figure 29 and 31). Germany is the most central country followed by eight other members of the European Union, including relatively small countries in population terms: the Netherlands, Belgium, and Denmark. The first non-European country in the ranking for 2014 is China (10th position) and then the United States (15th position). This dominance of European Union members increased between 2004 and 2014, and was accompanied by a rise in centrality of other European Union members – Poland, Hungary and the Czech Republic. Beyond European countries, there was a growth in the centrality of India to the oilseeds value chain since 2004 as it has become an increasingly large trader of world agro-food value added and a particularly large buyer of palm oil.

The picture is very different when looking at sellers of value added for the production of exports (Figure 30 and 32). Many emerging economies from Latin America, Asia, in addition to the United States and Canada, are the most central countries. This first observation highlights a clear geographic separation between producers and consumers of oilseeds as intermediates for the GVC, with on the one side producers in North and South America and Asia, and on the other with buyers in Europe. Most of all it highlights the strong integration of the European Union food and manufacturing sector.

Some other countries have decreased their relative centrality. This can be due to a number of factors, including a decrease in activity in sectors using oilseeds as intermediates or a substitution from imported value added to domestically produced supply. For example, Malaysia's centrality as a buyer of oilseeds value added has fallen, likely on the back of increasing production of palm fruit domestically, confirmed by its increased position as a seller (and similarly in the case of soybeans in the United States).

Figure 29. Buying of oilseeds value added for export centrality, 2004-14

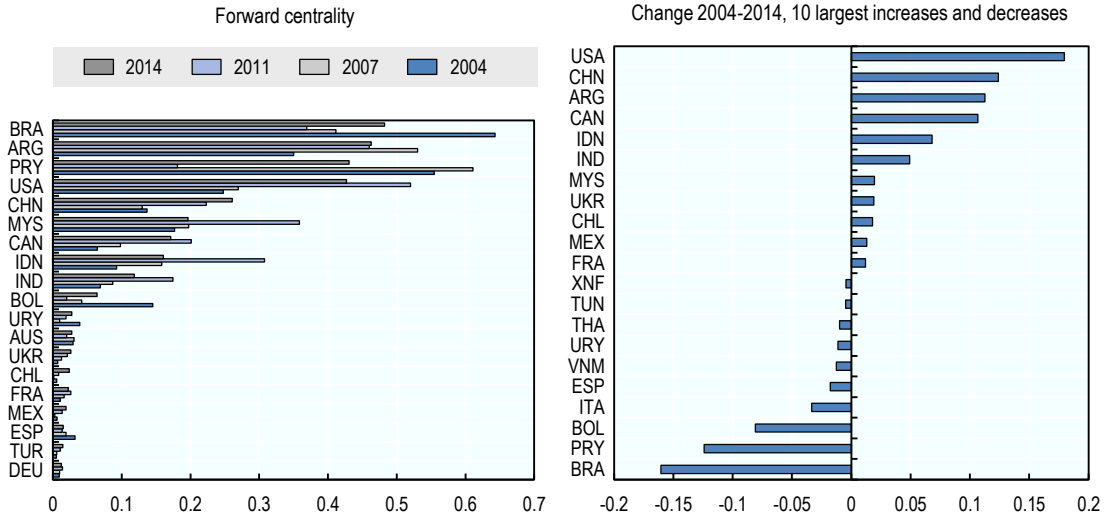
Levels and changes between 2004 and 2014



Note: Figure depicts the buying for export centrality which captures the importance of a country as a buyer of value added in intermediates of a particular product for the production of their exports and the changes that have occurred between 2004 and 2014 for the 20 countries with the largest changes (10 largest increases and 10 largest decreases).
Source: Author estimates.

Figure 30. Selling for oilseeds exports centrality, 2004-14

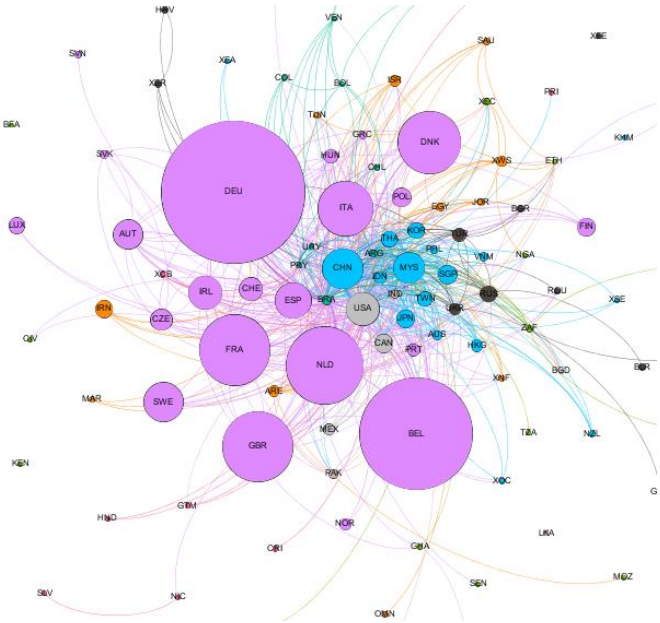
Levels and changes between 2004 and 2014



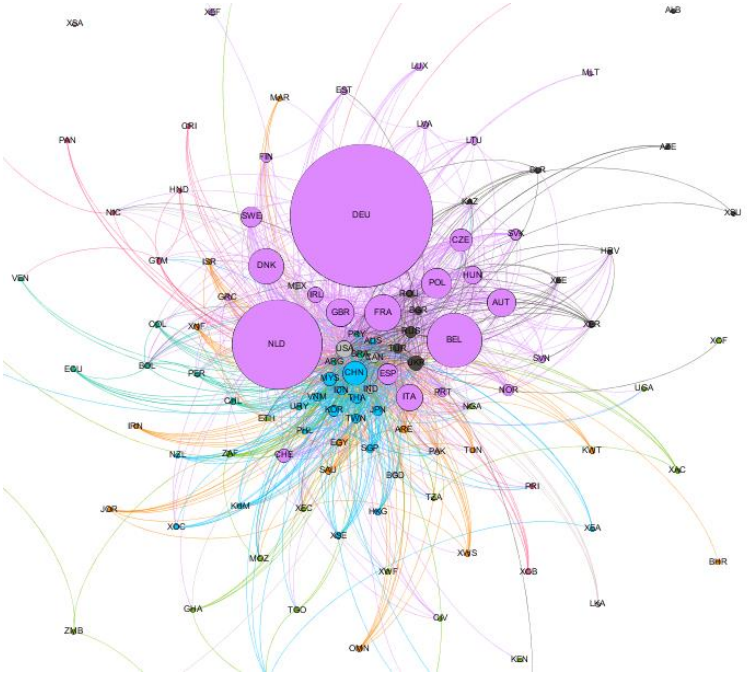
Note: Figure depicts the selling for export centrality that captures value added sold (from all industries) by a country for the production of a specific export product and the changes that have occurred between 2004 and 2014 for the 20 countries with the largest changes (10 largest increases and 10 largest decreases).
Source: Author estimates.

Figure 31. Buying of oilseeds value added for export centrality, 2004 and 2014

2014



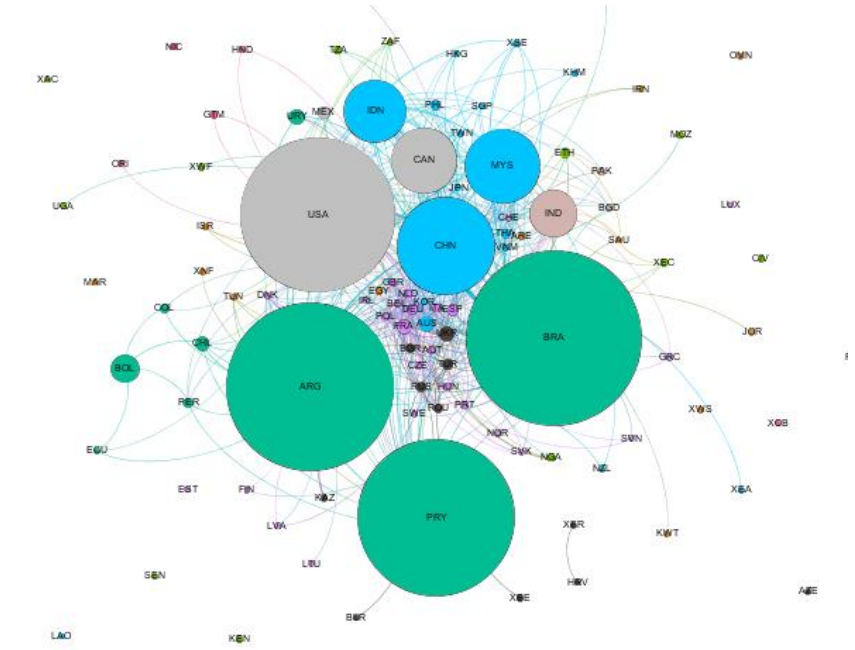
2004



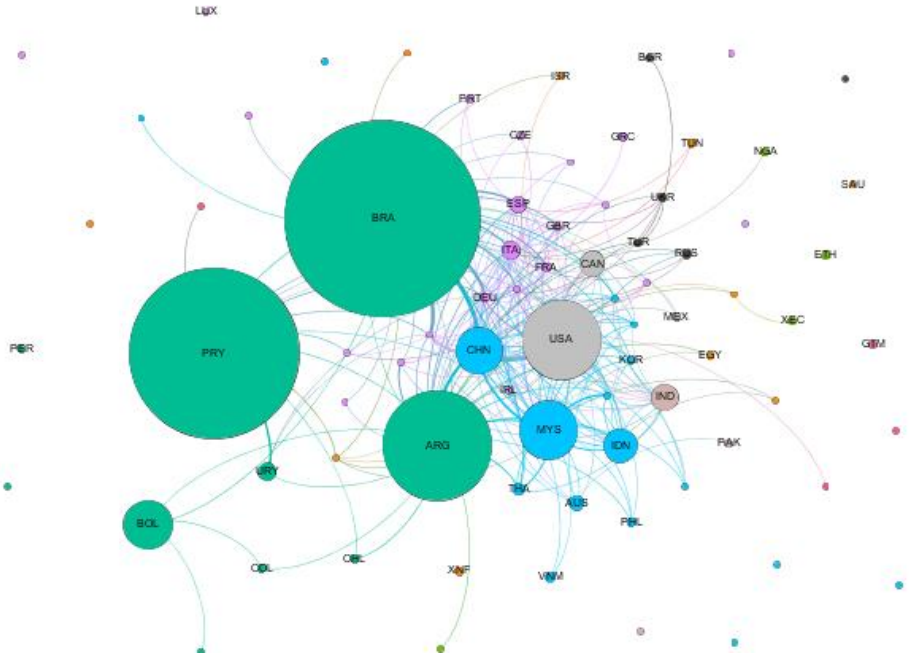
Note: The size of nodes is proportional to their centrality as sellers of intermediates. Edges are value added flows over USD 1 million and colour represents from the node of origin. The curve is clockwise from the exporting node to the importing one. Node colours represent the following regions: Central America and the Caribbean, Central Asia, Europe, Middle East and North Africa, North America, South America, Southeast Asia and Pacific, South Asia, and Sub-Saharan Africa.
Source: Author estimates.

Figure 32. Selling of oilseeds value added for export centrality, 2004 and 2014

2014



2004

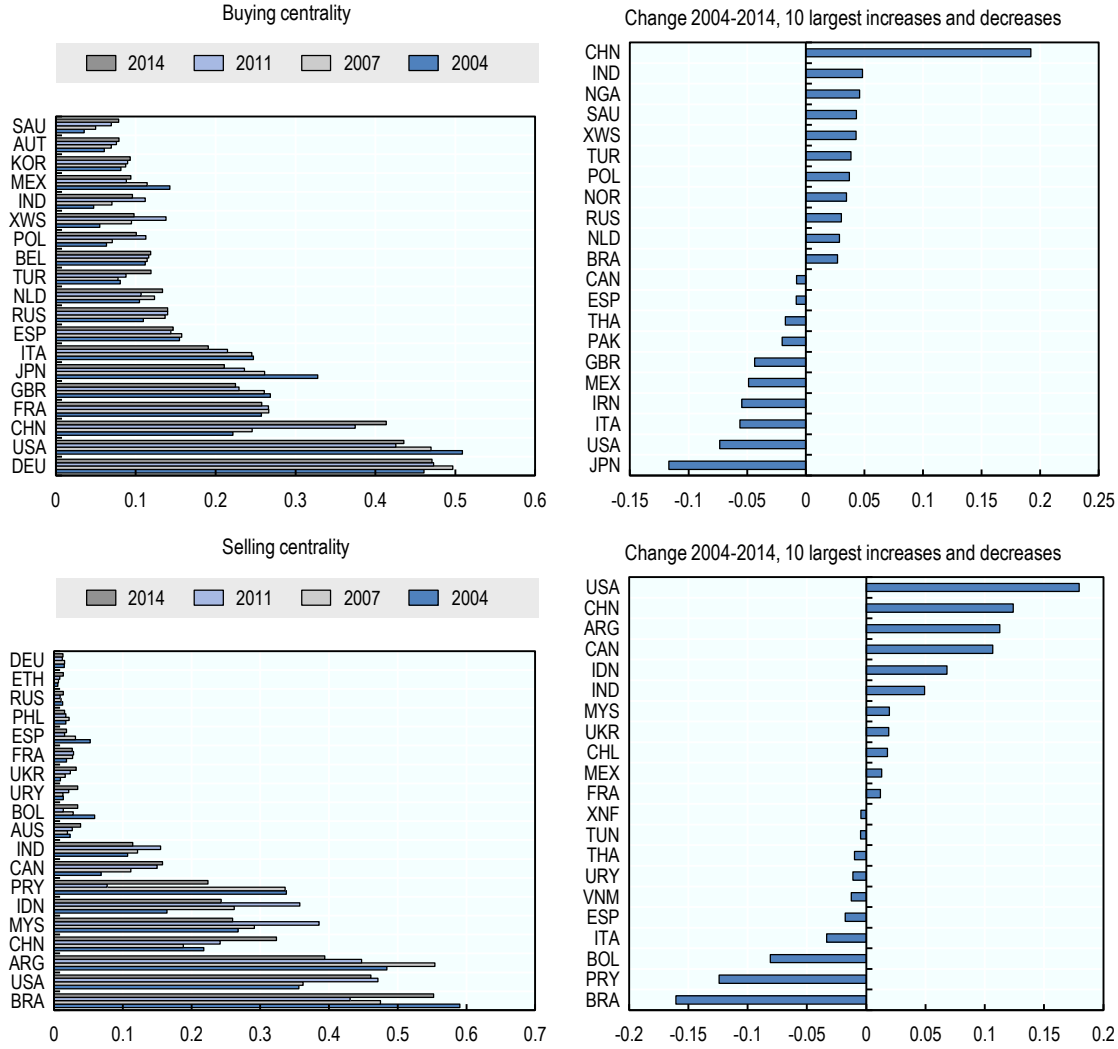


Note: The size of nodes is proportional to their centrality as sellers of intermediates. Edges are value added flows over USD 1 million and colour represents from the node of origin. The curve is clockwise from the exporting node to the importing one. Node colours represent the following regions: Central America and the Caribbean, Central Asia, Europe, Middle East and North Africa, North America, South America, Southeast Asia and Pacific, South Asia, and Sub-Saharan Africa.
Source: Author estimates.

A different landscape is seen in the centrality of countries as buyers and sellers of oilseeds for final demand (Figure 33). Whilst the most important buyer remains Germany, the second and third buyers of oilseed as intermediates for final demand are the United States and China. They are followed by very mixed group of countries, high income, emerging economies, but also countries with large populations such as Nigeria (which ranked 24th in 2014). The evolution of centrality between 2004 and 2014 shows an increased concentration on the United States and China as sellers of value added for final demand, at the expense of other countries in South America (Brazil, Paraguay and Bolivia). Malaysia and Indonesia also increased their centrality due to exports of palm oil. Finally the centralities of countries as buyers of oilseed for final demand highlight a concentration towards the largest economies and those with large populations.

Figure 33. Buying and selling for final demand centrality in oilseeds, 2004-14

Levels and changes between 2004 and 2014



Note: Figure depicts the buying for final demand centrality: top 20 most central countries shown.
Source: Author estimates.

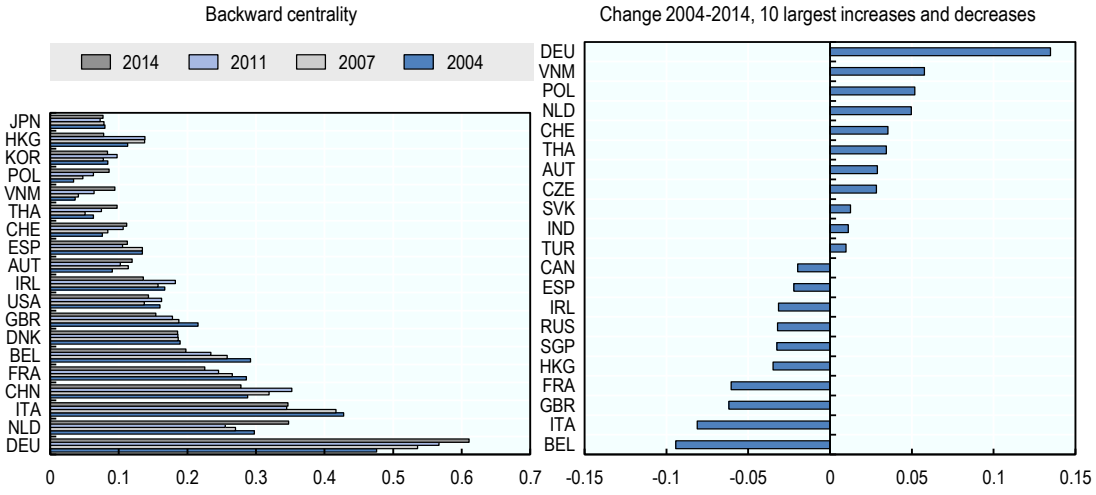
GVCs in bovine meat

For bovine meat, the most central countries involved and the changes observed are more varied. In terms of the centrality of buyers of value added from the bovine meat sector as intermediates for the production of exports, the importance of EU countries is observed, but China is also central (Figure 34). A range of Southeast Asian countries also appears as relatively central for the use of foreign bovine meat products as an intermediate for the production of its exports (in particular, for the production from "other food products" industry). Trade in value added for the production of exports was highly regionally clustered in 2004 (Figure 34 and 35). Despite a clear increase in the amount of flows of value added and a slight increase in integration between regions, trade between countries of the same region continues to prevail in 2014. Thus, the regionally-based meat markets continue to exist. The reasons for this centre on traditional market access arrangements (cemented by regional and preferential agreements), preferences, and importantly differing food safety and SPS requirements which differ considerably between European and other markets.

Between 2004 and 2014 Germany was the country that increased the most its centrality, with Viet Nam, Poland and the Netherlands also showing significant changes. Across all countries with significant changes, the evolution of centrality between 2004 and 2014 reveals an increased presence of some emerging and developing countries in importing bovine meat with a view to export: Turkey, China, Chile, Viet Nam, Indonesia – all of which have increased their centrality as buyers from the bovine meat sector as intermediates. It also shows the dynamic of the integration of the European Union food system with increased centrality in a range of countries entering the European Union during the period analysed.

Figure 34. Buying of bovine meat value added for export centrality, 2004-14

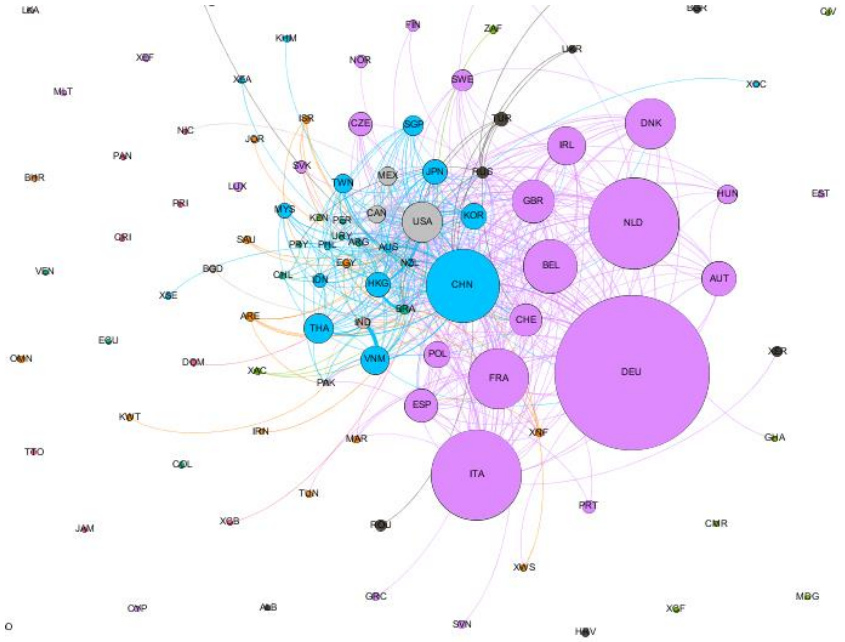
Levels and changes between 2004 and 2014



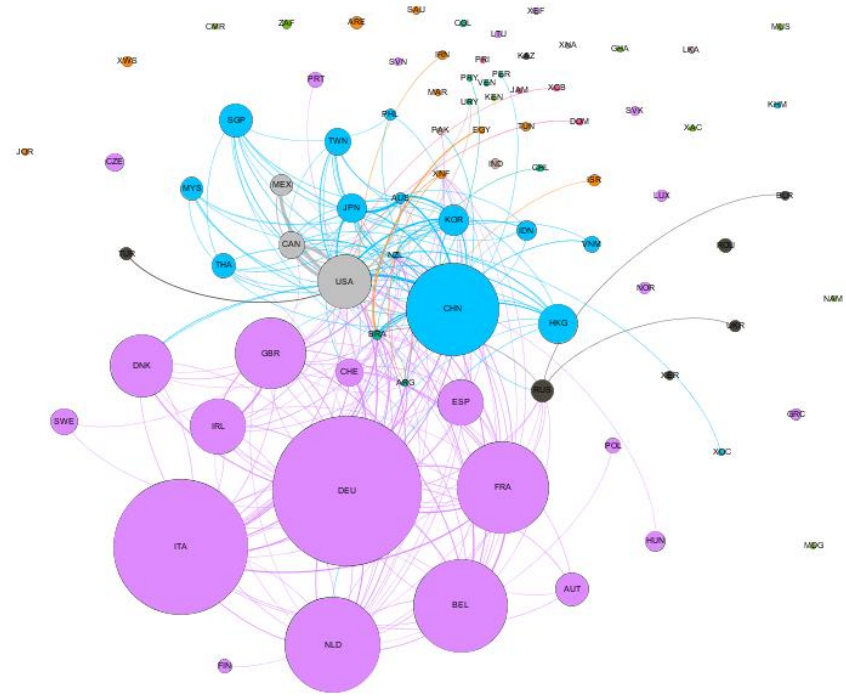
Note: Figure depicts the buying for export centrality which captures the importance of a country as a buyer of value added in intermediates of a particular product for the production of their exports and the changes that have occurred between 2004 and 2014 for the 20 countries with the largest changes (10 largest increases and 10 largest decreases).
Source: Author estimates.

Figure 35. Buying of bovine meat value added for export centrality, 2004 and 2014

2014



2004

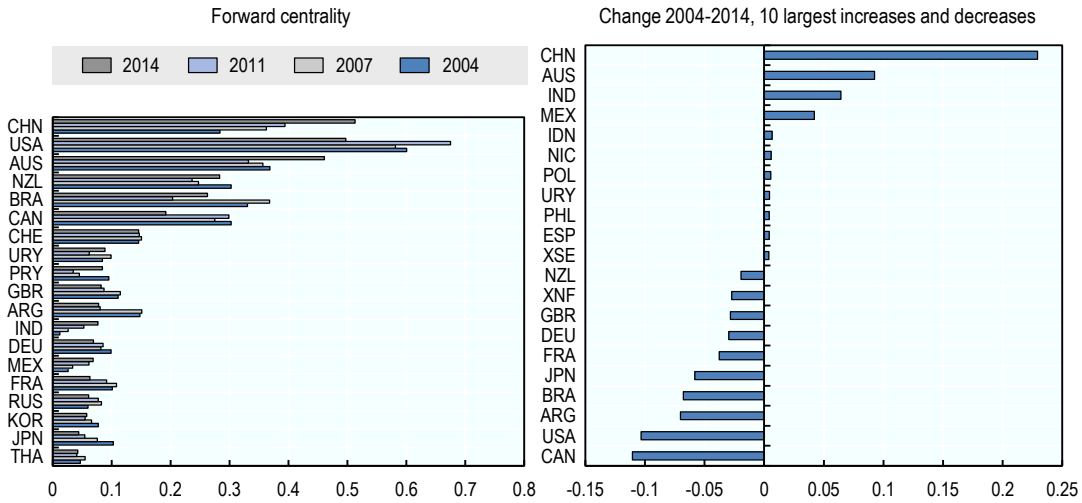


Note: The size of nodes is proportional to their centrality as sellers of intermediates. Edges are value added flows over USD 1 million and colour represents from the node of origin. The curve is clockwise from the exporting node to the importing one. Node colours represent the following regions: Central America and the Caribbean, Central Asia, Europe, Middle East and North Africa, North America, South America, Southeast Asia and Pacific, South Asia, and Sub-Saharan Africa.
Source: Author estimates.

The centrality of sellers of value added once again shows a polarization between buyers and sellers, with the importance of large exporters as sellers of value added for the production of exports – particularly China, the United States and Australia (Figure 36 and 37). In 2004 the most central countries selling products from the sector as intermediates for the production of exports were the United States, Australia, Brazil, New Zealand, Canada and China. In 2014, China took the lead as the most central exporter of intermediates, with centrality also concentrating on the United States and Australia. The increase in centrality of North American suppliers was mostly at the expense of South American suppliers of Paraguay, Argentina, Brazil, and Bolivia, all of which are losing in centrality.

Figure 36. Selling for bovine meat exports centrality, 2004-14

Levels and changes between 2004 and 2014

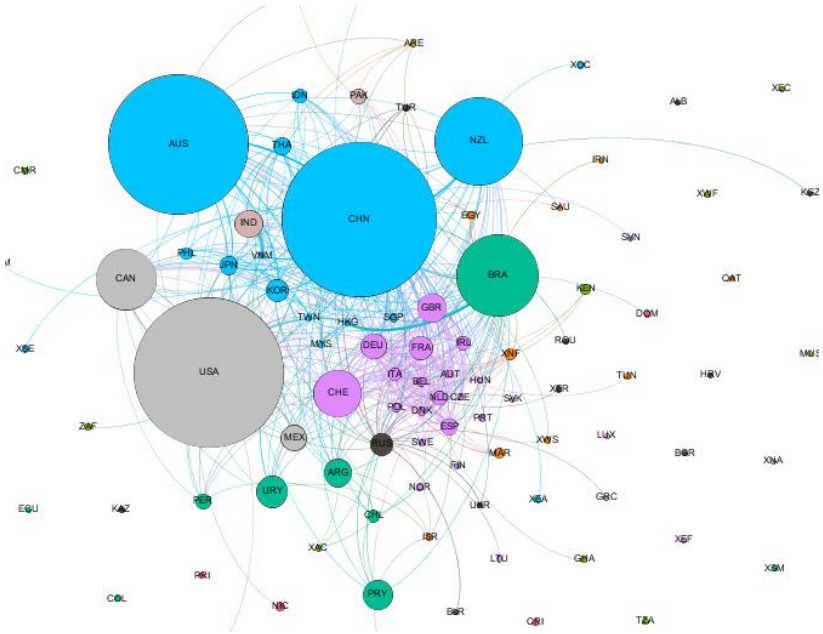


Note: Figure depicts the selling for export centrality that captures value added sold (from all industries) by a country for the production of a specific export product and the changes that have occurred between 2004 and 2014 for the 20 countries with the largest changes (10 largest increases and 10 largest decreases).
Source: Author estimates.

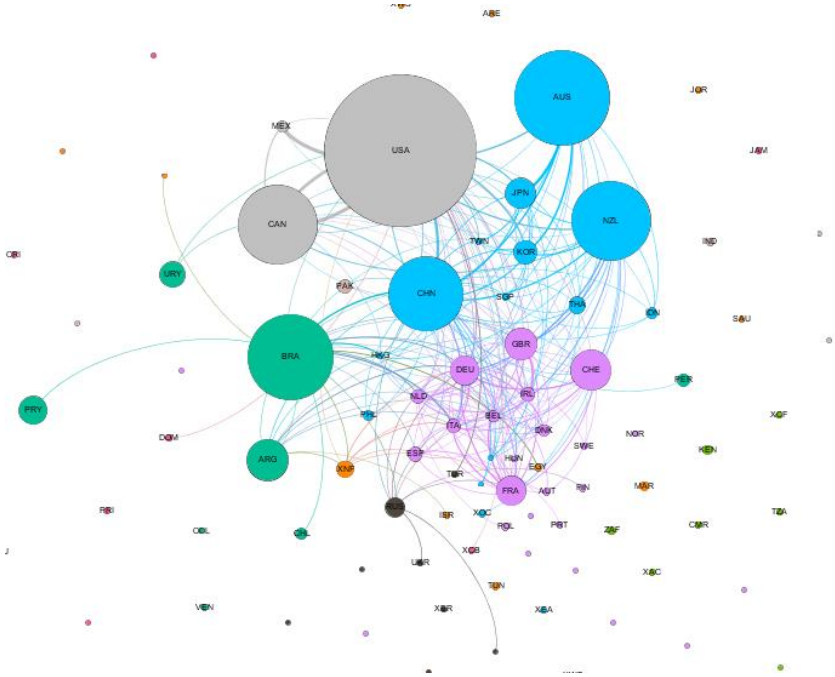
For the bovine meat sector, there were some changes in the most central countries as buyers for final demand (Figure 38). The United States, previously the 9th most central country, became the most important buyer of foreign value added from the bovine and meat products. It was followed by France and Germany. China reached 7th position over the period and strongly increased its centrality along with Germany. In terms of selling bovine meat for final demand, the United States, Australia, Brazil, New Zealand, Canada, and China were all important in 2004. In 2014, China took the lead as the most central seller. The sector seemed to concentrate on three countries: China, the United States, and Australia. Overall, whilst changes highlight a reorganisation of the chain with the increased importance of China, the Asia Pacific region – through Australia, New Zealand, Brazil, and the United States – shows a clear dynamic of integration of the bovine meat value chain.

Figure 37. Selling of bovine meat value added for export centrality, 2004 and 2014

2014



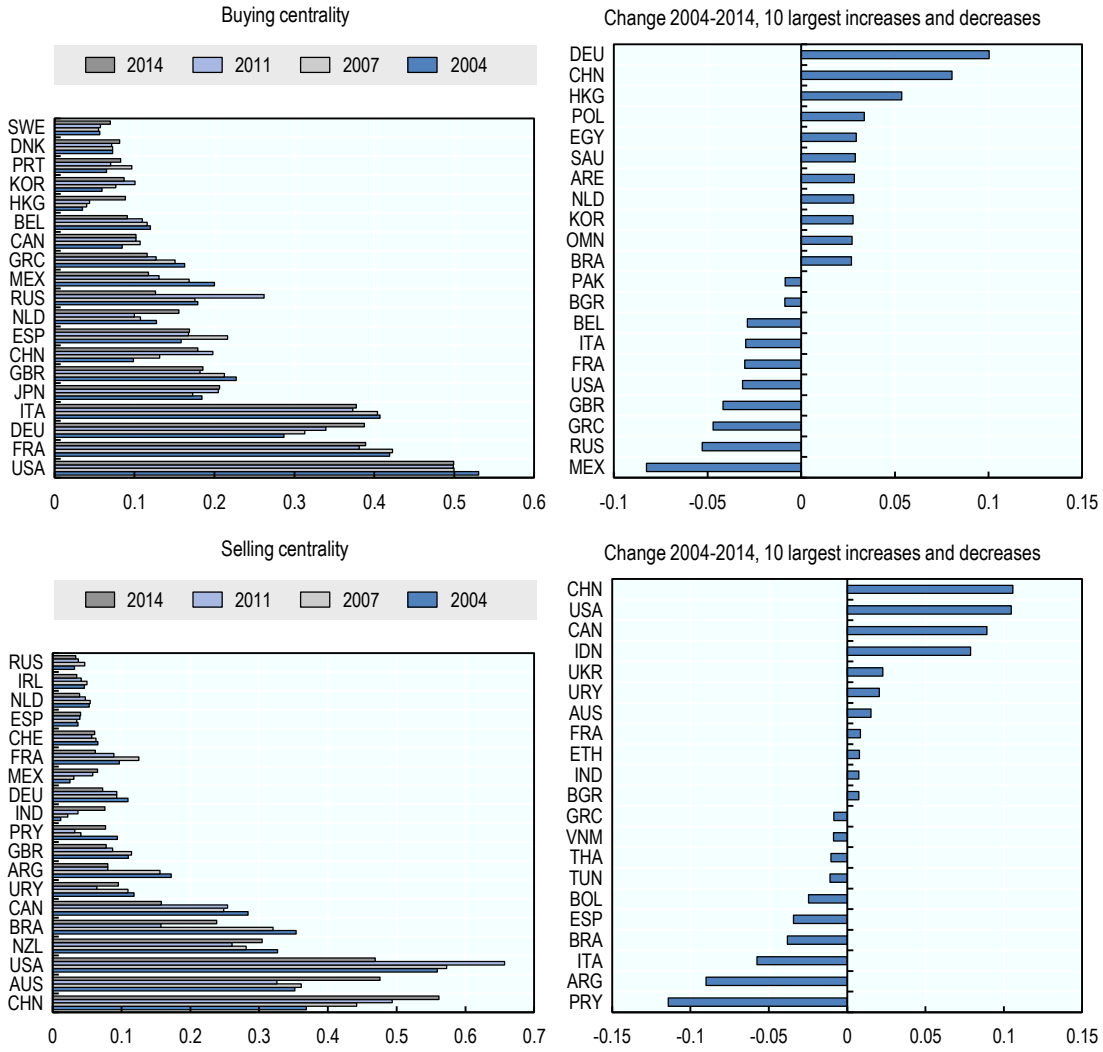
2004



Note: The size of nodes is proportional to their centrality as sellers of intermediates. Edges are value added flows over USD 1 million and colour represents from the node of origin. The curve is clockwise from the exporting node to the importing one. Node colours represent the following regions: Central America and the Caribbean, Central Asia, Europe, Middle East and North Africa, North America, South America, Southeast Asia and Pacific, South Asia, and Sub-Saharan Africa.
Source: Author estimates.

Figure 38. Buying and selling for final demand centrality in bovine meat, 2004-14

Levels and changes between 2004 and 2014



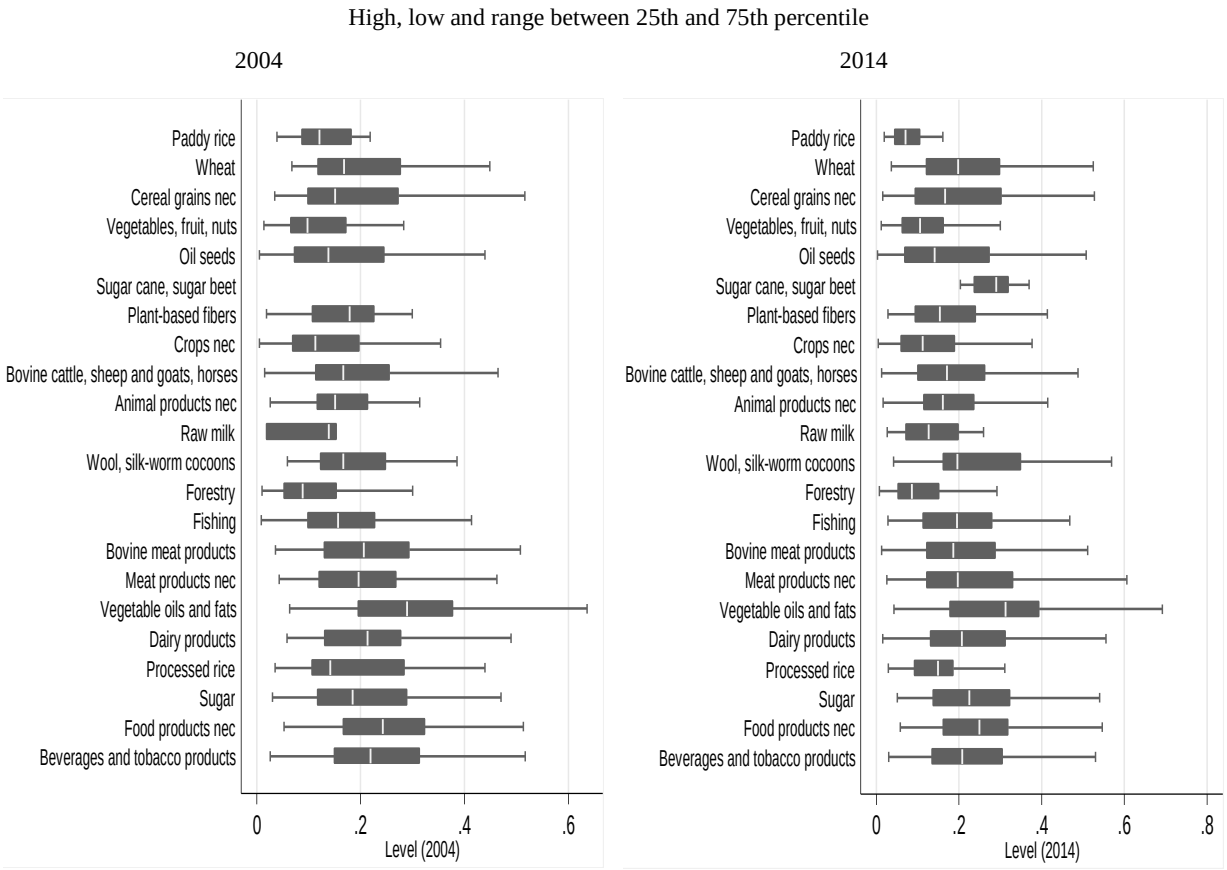
Note: Figure depicts the buying for final demand centrality: top 20 most central countries shown.
Source: Author estimates.

Annex 4.

Distributional changes in backward and forward participation

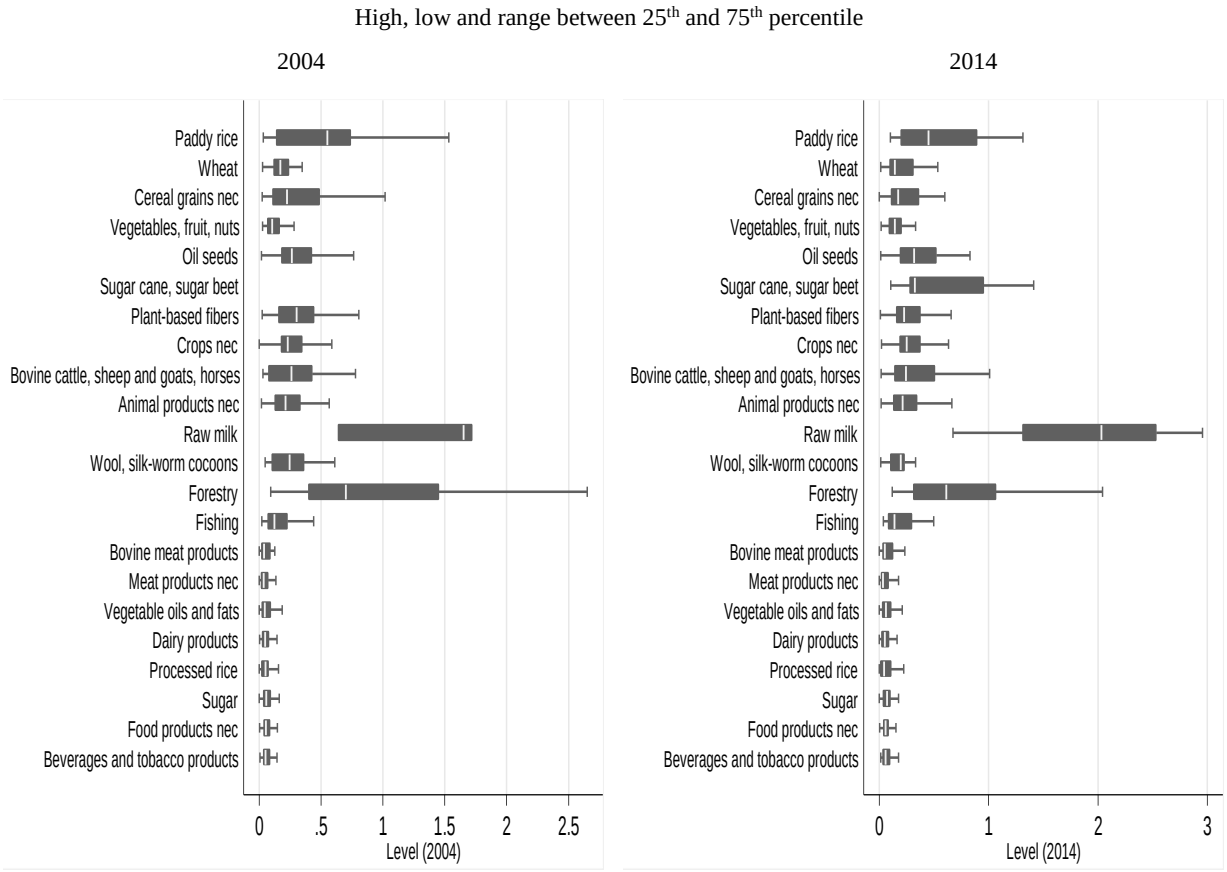
This annex provides details on the distribution of backward and forward participation in agro-food sectors between 2004 and 2014.

Figure 39. Distribution of backward participation by sector, 2004 and 2014



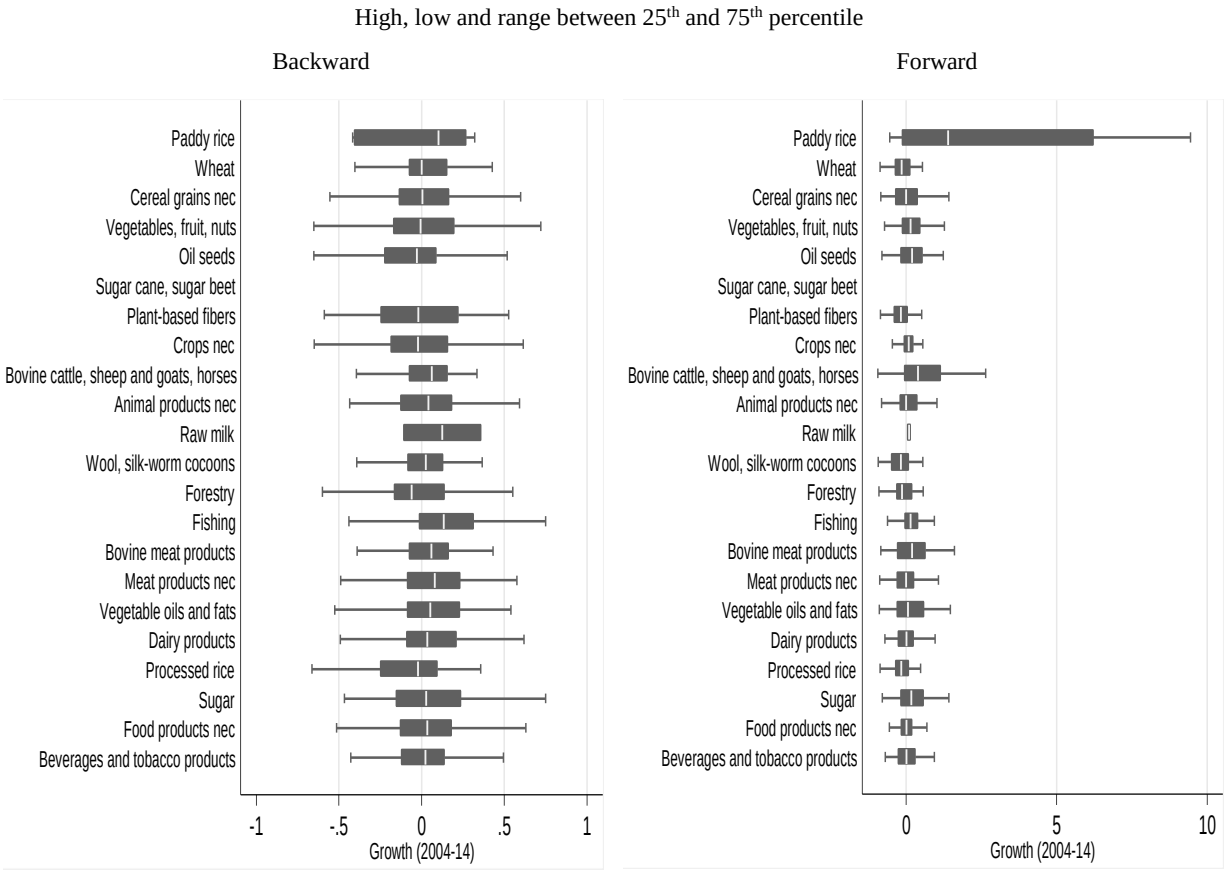
Note: Estimates for countries with more than USD 10 million in exports with outliers (estimates greater than 50) excluded.
Source: Author estimates.

Figure 40. Distribution of forward participation by sector, 2004 and 2014



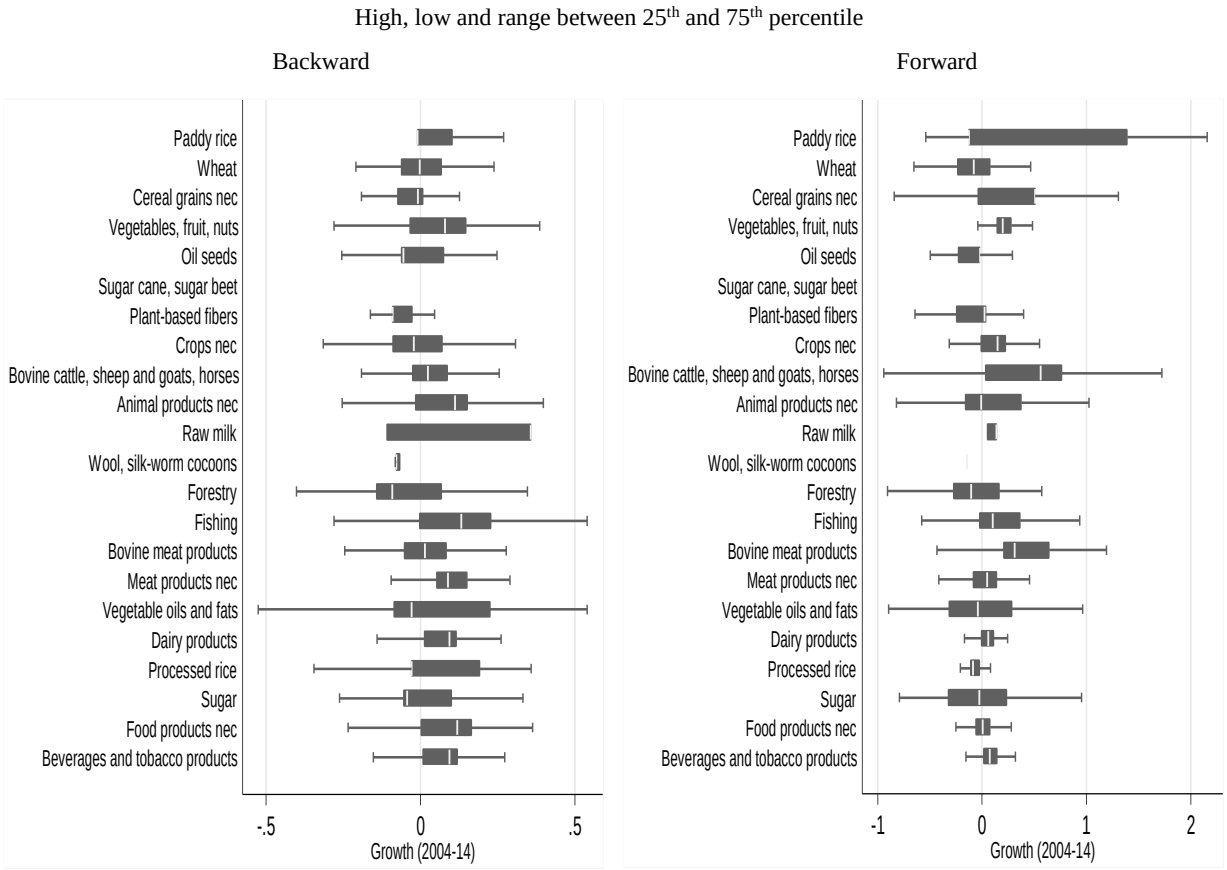
Note: Estimates for countries with more than USD 10 million in exports with outliers (estimates greater than 50) excluded.
Source: Author estimates.

Figure 41. Distribution of change in backward and forward participation by sector, 2004-14



Note: Estimates for countries with more than USD 10 million in exports with outliers (estimates greater than 50) excluded.
Source: Author estimates.

Figure 42. Distribution of change in backward and forward participation by sector, weighted estimates 2004-14



Note: Estimates for countries with more than USD 10 million in exports with outliers (estimates greater than 50) excluded.
Source: Author estimates.

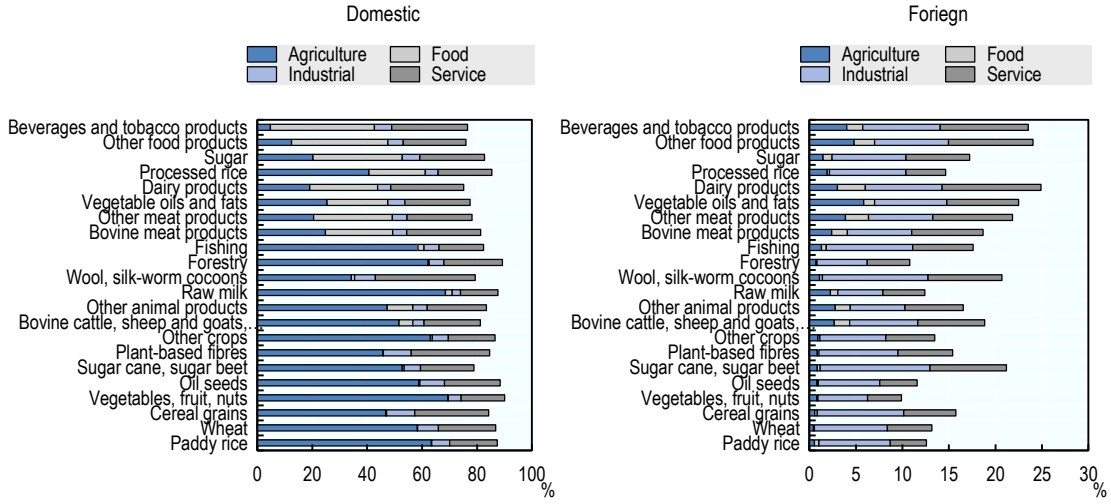
Annex 5.

Value added composition of exports

This annex provides information on the composition of domestic and foreign value added in agro-food gross exports over time. A recurring feature observed is that in terms of shares, agricultural exports have a higher domestic value added share than those from the food sector, indicating caution over using shares as a performance indicator (as highlighted in Greenville and Beaujeu, 2017).

Figure 43. Domestic and foreign shares of gross export value by sector, 2004

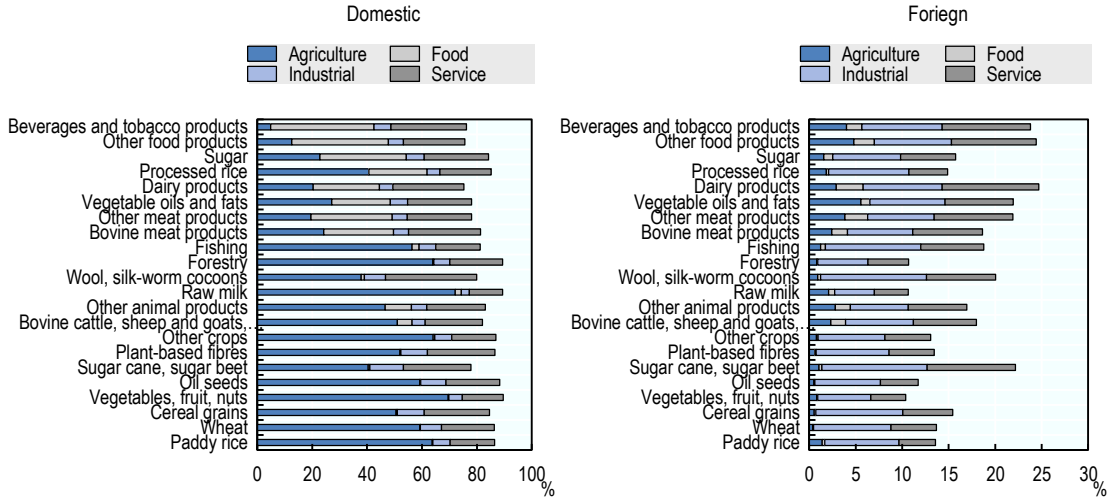
Shares by broad industry grouping (%)



Note: Trade weighted averages.
Source: Author estimates.

Figure 44. Domestic and foreign shares of gross export value by sector, 2007

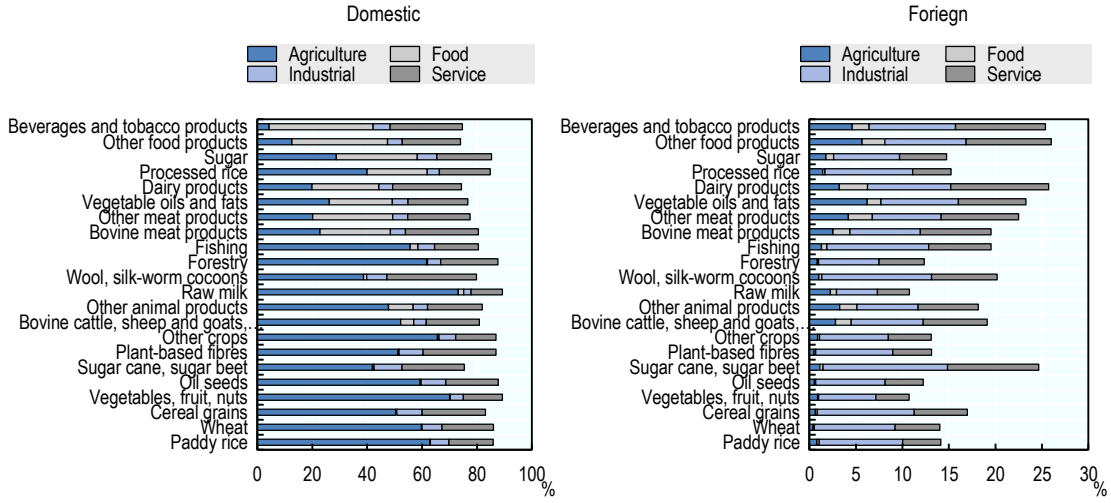
Shares by broad industry grouping (%)



Note: Trade weighted averages.
Source: Author estimates.

Figure 45. Domestic and foreign shares of gross export value by sector, 2011

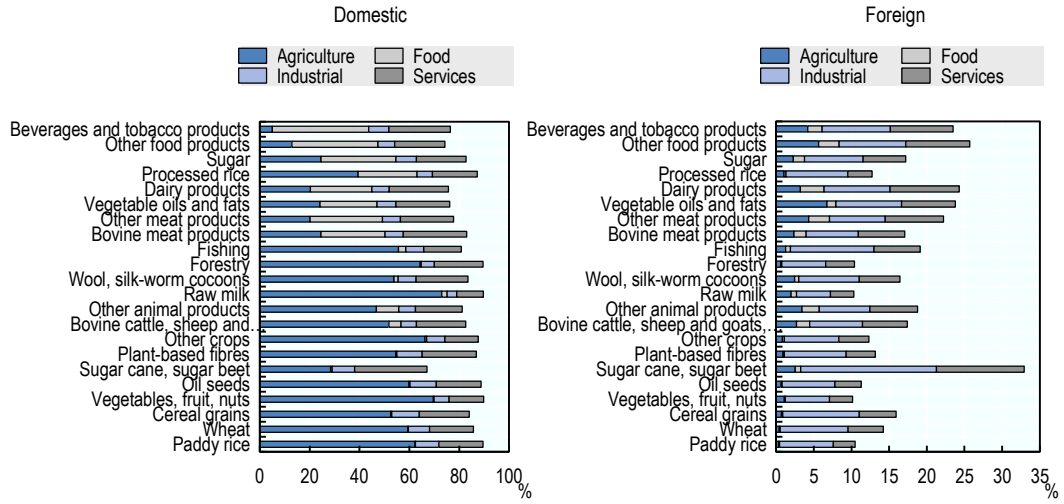
Shares by broad industry grouping (%)



Note: Trade weighted averages.
Source: Author estimates.

Figure 46. Domestic and foreign shares of gross export value by sector, 2014

Shares by broad industry grouping (%)



Note: Trade weighted averages.
Source: Author estimates.

Annex 6.

Model specification and detailed results

The model

The regression analysis used in this study is based on the estimation of the following equation:

$$\Delta y_{cst} = \boldsymbol{\alpha}\mathbf{X}_{cs,t-1} + \boldsymbol{\beta}\Delta\mathbf{Z}_{cst} + \theta_{cs} + \eta_{ct} + u_{cst} \quad \text{(A1)}$$

where the indices c, s, and t represent country, sector, and year and α and β are parameters to be estimated. The symbol Δ denotes the difference (per year) from the previous period (for example, $\Delta y_{cst} \equiv y_{cst} - y_{cs,t-1}$). The dependent variable y is either sector's total value-added (DVA), value-added embedded in sector's export (DVA in exports), or the input/factor shares (intermediate, land, skilled labour, unskilled labour, and capital) of gross production value. **X** and **Z** are vectors of regressors. Some regressors (**X**) are measured as initial value at period t-1 to avoid endogeneity concern caused by reverse causality, while others (**Z**) are measured as difference when reverse causality is less likely to be the case. The model includes two fixed effects: θ controls for country-sector specific unobservable factors (e.g. product characteristics) and η for country-year specific unobservables (e.g. weather, macroeconomic shocks, and food prices).

Parameters are estimated by the fixed effect estimator using panel dataset for 2004, 2007, 2011, and 2014. The dataset covers 22 agro-food sectors (GTAP sector 1 through 14 and 19 through 26) for 141 countries and regions. To avoid unrealistic changes in dependent variables, observations with small value added (less than USD 10 million) are dropped from the regressions (when dependent variable is DVA in exports, observations with DVA in exports less than USD 10 million are dropped).

The following tables show summary statistics (measured as level, not in differences) and full regression results. As DVA and DVA in exports are transformed in logarithm, the difference from the previous period approximates growth rate. Therefore, the estimated results indicate, for example, a 0.1 unit increase in backward indicator in 2004 increased (per year) growth rate in DVA by 6.5%.

Table 7. Summary statistics

Variable name	Mean	Std. Dev.	Min	Max	Description
Dependent variables					
DVA	5.630	1.776	2.303	12.173	Value-added (log of USD million)
DVA in exports	3.116	2.283	0	9.428	Value-added embedded in export (log of USD million)
Intermediate share	0.554	0.233	0.002	0.994	The share of intermediate in total gross input
Land share	0.073	0.106	0.000	0.951	The share of value added by land in total gross input
Unskilled labour share	0.159	0.144	0.000	0.693	The share of value added by unskilled labour in total gross input
Skilled labour share	0.037	0.048	0.000	0.608	The share of value added by skilled labour in total gross input
Capital share	0.161	0.117	0.001	0.838	The share of value added by capital in total gross input
Regressors					
Backward	0.188	0.126	0.001	0.813	Backward indicator
Forward	0.740	2.375	0.000	29.778	Forward indicator
Tariffs faced	6.685	13.491	0.000	250.0	Average tariff faced (weighted by export value. %)
SPS faced	1.856	7.302	0.000	128.0	# of SPS faced
TBT faced	0.847	6.135	0.000	192.0	# of TBT faced
Tariffs charged	9.838	23.723	0.000	485.9	Average tariff charged (weighted by import value. %)
SPS charged	1.327	8.310	0.000	225.0	# of SPS charged
TBT charged	0.605	7.315	0.000	360.0	# of TBT charged
DVA in foreign demand	0.297	0.259	0.001	1.000	This represents the destination of the value added generated in the sector - that is the domestic or foreign markets. It shows the share which is ultimately consumed by foreign consumers.
Service share	0.102	0.068	0.000	0.414	This represents the source of value added in the output of the sector that ultimately originated from service sectors (GTAP sector 51-57)
Imported inputs concentration	0.016	0.015	0.003	0.236	Herfindahl index, measured as the sum of squared share of imported value added used for the output (calculated at source country * source sector level), where a higher value indicates higher concentration.

Source: Author estimates.

Table 8. Full regression results

Variables	DVA	DVA in exports	Intermediate share	Land share	Unskilled labour share	Skilled labour share	Capital share
Backward	0.655	0.457	-0.1210	0.0293	0.0257	0.0110	0.0512
	[7.57]***	[2.22]**	[-8.46]***	[2.93]***	[4.16]***	[4.33]***	[6.31]***
Forward	-1.20.E-03	2.05.E-02	-1.27.E-04	-1.30.E-04	7.21.E-05	3.17.E-05	1.59.E-04
	[-1.40]	[1.14]	[-1.02]	[-1.18]	[1.30]	[2.14]**	[1.86]*
Tariffs faced	1.13.E-04	-9.05.E-05	-2.88.E-05	-7.38.E-06	5.58.E-06	4.20.E-06	2.55.E-05
	[0.65]	[-0.26]	[-1.73]*	[-0.56]	[0.85]	[1.88]*	[2.77]***
SPS faced	-2.73.E-04	-2.87.E-04	3.26.E-05	-8.79.E-06	5.35.E-07	-1.24.E-05	-1.13.E-05
	[-0.77]	[-0.36]	[1.22]	[-0.77]	[0.06]	[-1.47]	[-0.85]
TBT faced	2.41.E-04	1.73.E-04	1.57.E-05	-1.25.E-06	-4.19.E-06	-7.59.E-06	-1.76.E-06
	[1.14]	[0.51]	[1.50]	[-0.25]	[-1.22]	[-2.18]**	[-0.29]
DVA in foreign demand (difference)	0.429	1.600	-0.0026	-0.0022	0.0026	-0.0002	0.0024
	[10.24]***	[18.71]***	[-0.74]	[-0.57]	[1.92]*	[-0.38]	[1.48]
Service share	2.910	-0.184	-0.1100	0.1120	-0.0871	-0.0082	0.0931
	[3.63]***	[-0.15]	[-1.19]	[1.55]	[-2.38]**	[-0.51]	[2.47]**
Imported inputs concentration (difference)	-0.290	-0.264	0.1110	0.0155	-0.0637	-0.0113	-0.0494
	[-1.91]*	[-0.57]	[4.05]***	[0.94]	[-4.79]***	[-2.49]**	[-4.21]***
Tariffs charged(difference)	-1.92.E-04	-5.28.E-05	2.64.E-05	-8.26.E-06	2.32.E-06	-1.82.E-06	-1.89.E-05
	[-2.08]**	[-0.26]	[2.77]***	[-1.34]	[0.75]	[-1.25]	[-2.53]**
SPS charged (difference)	-1.17.E-05	4.02.E-04	8.21.E-06	-1.05.E-05	3.92.E-06	7.35.E-07	-1.91.E-06
	[-0.14]	[0.84]	[1.06]	[-1.42]	[0.87]	[0.55]	[-0.39]
TBT charged (difference)	-1.22.E-04	-3.11.E-05	3.15.E-06	3.66.E-06	-2.64.E-06	-2.16.E-06	-2.30.E-06
	[-1.63]	[-0.16]	[0.47]	[1.49]	[-1.13]	[-2.77]***	[-0.63]
Observations	5099	3204	5099	5099	5099	5099	5099
R-squared	0.538	0.578	0.323	0.209	0.499	0.385	0.157

Note: t-statistics in brackets. *** p<0.01, ** p<0.05, * p<0.1
Source: Author estimates.

Table 9. Regression results by primary and processed products

	DVA			DVA in exports		
	All sectors	Primary	Processing	All sectors	Primary	Processing
Backward	0.655	0.72	0.63	0.457	-0.06	0.95
	[7.57]***	[3.99]***	[6.91]***	[2.22]**	[-.11]	[4.73]***
Forward	0.00	0.00	-0.01	0.02	0.02	0.36
	[-1.40]	[-1.36]	[-2.61]***	[1.14]	[1.18]	[3.36]***
Tariffs faced	0.00	0.00	0.00	0.00	0.00	0.00
	[0.65]	[-0.66]	[0.93]	[-0.26]	[-0.31]	[-0.63]
SPS faced	0.00	0.00	0.00	0.00	0.00	0.00
	[-0.77]	[-0.24]	[-1.26]	[-0.36]	[0.85]	[-0.95]
TBT faced	0.00	0.00	0.00	0.00	0.00	0.00
	[1.14]	[1.19]	[-0.36]	[0.51]	[0.88]	[-0.81]
DVA in foreign demand	0.43	0.40	0.54	1.60	1.46	1.89
	[10.24]***	[6.85]***	[26.31]***	[18.71]***	[13.11]***	[24.09]***
Change in service share	2.91	3.12	1.65	-0.18	-0.08	-0.72
	[3.63]***	[2.28]**	[5.35]***	[-0.15]	[-0.03]	[1.13]
Imported inputs concentration	-0.29	-0.67	-0.18	-0.26	-1.61	0.41
	[-1.91]*	[-2.30]**	[-1.65]*	[-0.57]	[-1.62]	[0.75]
Change in tariffs charged	0.00	0.00	0.00	0.00	0.00	0.00
	[-2.08]**	[-2.47]**	[-3.00]***	[-0.26]	[0.20]	[-0.77]
Change in SPS charged	0.00	0.00	0.00	0.00	0.00	0.00
	[-0.14]	[0.66]	[-1.66]*	[0.84]	[1.46]	[0.11]
Change in TBT charged	0.000	0.00	0.00	0.000	0.00	0.00
	[-1.63]	[-0.31]	[-1.97]**	[-0.16]	[-1.64]	[1.58]

Note: t-statistics in brackets. *** p<0.01, ** p<0.05, * p<0.1. Primary sectors corresponds to GTAP sectors 1 to 14, while processed sectors to GTAP sectors 19 to 26.
Source: Author estimates.

Annex 7.

Calculating centrality estimates

Network Analysis is a methodology particularly suited for GVC analysis. It provides greater insight into the relative position of various sectors and countries in GVCs – measured as their degree of centrality – both as a seller and a buyer of value added. It identifies the relative importance of a sector over others in the global economy, for example as a seller of intermediates, and provides an indicator of the relative importance of two different countries exporting products from the same sector. The measures used, termed centrality indicators, are estimated by calculating the eigenvectors.

All the centrality indicators presented in this report use the same calculation, but vary in the perspective of calculation with respect to different "nodes". Using the ICIO, nodes can be countries or sectors, as both can be defined as entities consuming value added or producing value added. Nodes can be defined at different levels of aggregation according to the type of perspective and granularity required, at the country, sector, and country-sector levels. The choice depends on whether the interest is to look at a specific sector or country as a driver of flows of value added in the global economy, or as a sector or a country as a key element of a specific global value chain (sector). Following this choice, the type of flows of value added of interest between the selected nodes needs to be defined. It is possible to both look at the centrality of a node as a buyer or a seller of value added to the rest of the nodes.[11] There is therefore a multitude of centrality figures according to the types of node and the type of flows (and economic dependence) analysed. For the analysis in this paper, only the centrality of particular country-sectors is analysed.

In the present analysis conducted, the objective is to highlight the different types of participation in global value chain, looking at countries as providers of value added in the agro-food value chain. This has been done in terms of selling to and buying or products in the form of intermediates or as final goods, and whether these are then used to produce exports or and what eventually ends up in domestic consumers in final demand. That is, the original source of value added in the food that is consumed and clothing worn – plus a range of other product. For example, focusing on the value added produced in the paddy rice sector ending in final demand, it is possible to get an idea of the importance of the paddy rice value added produced in Thailand for consumers all around the world. This can then be compared to paddy rice value added from other countries. The pathways by which value added in any one country can end in another's' final demand can vary. It can be in the form of directly exported paddy rice, say from Thailand or exported indirectly by a third or fourth country which has been using it as an input. In the latter, for example, it could be paddy rice value added from Thailand used to produce a processed rice in Lao PDR, then exported to France where it is transformed into pudding and finally exported and consumed in Germany. In other words, there is value added from the Thai paddy sector in the pudding consumed in Germany. These linkages are compared to others from all producing and

[11] The calculation can include, or not, own use by the node. For example, a country producing an intermediate good that it then consumed for its own production. In this paper, the focus is on international dependencies; therefore own consumption of locally produced intermediates is not taken into account.

exporting countries. In the example, it is possible therefore to compare the dependence of consumers in a country for the value added from the paddy rice sector in Thailand, versus value added from the paddy rice sector in India. The information can then shed light on possible effects of production shocks on consumers – for example, how a drop in production in Thailand versus India might affect German consumers.

In the example below, the centrality measure allows to provide nuance to the analysis of GVC participation in the following way:

- Focusing on the centrality of sellers of sector (*i*) the results would show that country *U* would be more central as it exports intermediates (*i*) to both *A* and *B*, whereas *V* and *W* are only exporting (i) to B. A shock to U would affect both A and B in the short run and it would particularly affect A, which only depends on U.
    - From the perspective of seller *V*, Country *B* is the only one that matters, the same for *W*, but for *U*, both *A* and *B* matter.
- Focusing on the centrality of buyers of sector (*i*), Country *B* is more central as a buyer as it imports (*i*) from the three exporters, and *A* only imports (*i*) from U.

More formally, splitting the types of measures into two groups – as buyers of value added and sellers of value added – the calculations can be described. The first set of indicators aims at capturing the centrality of a sector as a buyer of value added by looking at how many supplying sectors are selling to that sector for the production of exports. The importance of this connection is weighted by the share of the value added provided by the supplying sector over the sum of all the supplying sector's exports in value added. In other words, it is weighted by the importance of the sector of interest as a buyer of value added by supplying sector.

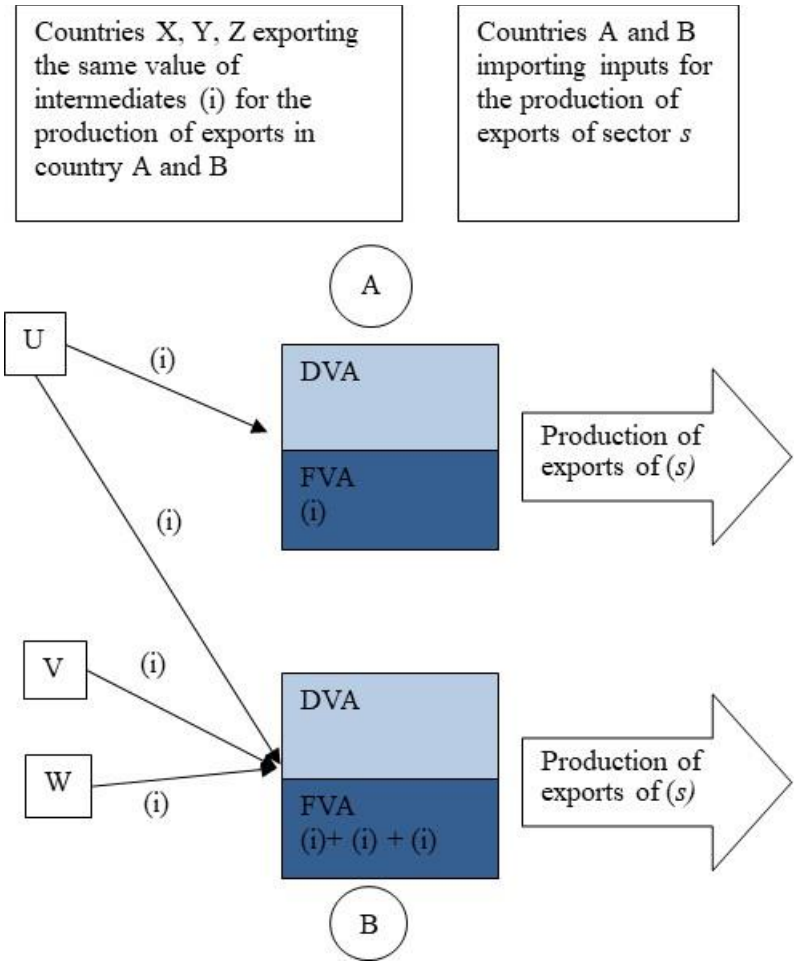
The second gives information about the importance of a sector of interest as a seller of value added to other sectors (countries) for the production of exports. This time it focuses on the amount of time a sector is pointing to other sectors, weighted by the share of the value added sold by the sector compared to the total amount of value added used by the sector it supplies for the production of its exports.

The use of shares as weight has important features. The first is that, while the importance of value added exchanged in size still matters, it does not uniquely define the centrality of a sector (or a country). Using raw flows would indeed result in a focus on large trading sectors or economies. While it is undeniable that those are an important feature of the network, small sectors or economies might still be very well connected to international trade networks.

The second feature relates to interpretation. The use of the eigenvector centrality presents results slightly different from the backward and forward indicators also presented in this study. Computing an eigenvector of a network provides insights into resilience to shocks. In network analysis, the centrality of a node is based on a random walk model. A random walk starts at a node i, randomly chooses a neighbour j of i, moves to j and repeats the process from there. Each step, assuming that each node has more than one neighbour, increases the choices of random walks. After a few steps, various paths might have been taken, each of them leading to a node with a probability determined by the characteristics of the network. In more tangible terms, consider a dollar is injected in a network from a node i. After n steps, it is possible to get a probability distribution of where the dollar might be. This corresponds to a vector v (n) of which each coordinate is associated with a node,

a sector or a country according to the network we choose to analyse, and represents the probability that the dollar arrived at that node.

Figure 47. Exploring centrality linkages



The eigenvector can be thought of as such a vector, computed by taking the limit of the random walk to infinity. As such it provides a tool for shock propagation as a long term phenomenon, explaining differences with traditional TiVA indicators. As presented by Shepherd and Archanskaia (2014), it is therefore possible to show that the eigenvector represents the economic value of an extra dollar of value added traded at a random point in the network analysed and allowed to flow through all possible nodes. This feature of the eigenvector can be used to analyse the resilience of the value chains.