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Evolving Trends in Global Value Chain Analysis: Country Case Studies of Brunei Darussalam, Malaysia, and Singapore

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Abstract

Over the last two decades, the global economy witnessed an unprecedented rise in global value chain (GVC) activity, a phenomenon that is widely believed to have caused growing fragmentation of cross-border production processes. It has also been recognized that the type and extent of participation in as well as the benefits derived from these global production networks vary across economies, sectors, and temporally. This report utilizes measures of different dimensions of global value chains that were derived from cutting-edge accounting and mathematical frameworks to analyze the changing patterns of trade of Brunei, Malaysia, and Singapore during the period 2000-2018. The multi-regional input-output tables (MRIOTs) compiled by the Asian Development Bank (ADB) were used as the main data source for generating the GVC indicators presented in this paper. The results demonstrate the varying impacts GVCs have had across economies and their domestic sources, which could readily be extended to analyses of trade policies.

Keywords: global value chains, exports decomposition, participation, upstreamness, average production length, revealed comparative advantage, Brunei Darussalam, Malaysia, Singapore

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1. Introduction

In any given economy, there are domestic sectors that purchase output from other sectors to be used as inputs to production within the same, given time period. One simple example is the manufacturing sector purchasing coal and basic metals from the mining sector to produce metal products. Any such sectoral output that is made to meet the demands of other sectors for inputs to be used for same-period production of the latter's output is referred to as "intermediate output" or "intermediates" for short. Obviously, the outputs of domestic sectors are not intended for contemporaneous intersectoral transactions only. Sectors also provide goods and services to meet final demand from households, government, and investors[4].

Fueled by increased international trade and globalization, the demand faced by economic sectors became less restricted to domestic consumers towards the end of the twentieth century and the years that immediately followed. This coincided with falling transactions costs of intersectoral trade in a global scale that pushed firms all over the world to reoptimize their production processes, thereby leading to increased outsourcing and offshoring activities. Consequently, there was an unprecedented rise in the sharing of production activities among different countries, which became commonly known as global value chains (GVCs).

Since the 1990s, economies across Asia have increasingly integrated into these production networks and this paper documents some of the evolving patterns that occurred during this global phenomenon - particularly how the type and extent of the participation, as well as the resulting benefits, varied across economies, across sectors, and over time. To show these differences, we utilized measures of different dimensions of global value chains that were derived from cutting-edge accounting and mathematical frameworks and looked at the specific cases of the interconnected economies of Brunei, Malaysia, and Singapore.

Multi-regional input-output tables (MRIOTs) compiled by the Asian Development Bank (ADB) were used as the primary data source in running calculations of these indicators. The MRIOTs provide a 35-sector breakdown for each economy and for simplicity, the analysis further aggregates our results in broad sector categories[5]. The time period considered covers 2000 and 2007-2018 to compare international trade structures before, during, and after the global financial crisis (GFC).

Results of our calculations are presented and discussed after a brief overview of conceptual frameworks used. These provide a clearer picture of a country's production structure in global trade as well as a comparative framework on how trade measures shift substantially when measured quantitatively in value-added terms rather than in terms of gross exports. The results also demonstrate the varying impacts GVCs have had across economies and their domestic sources, which could readily be extended to analyses of trade policies.

2. Framework

[4] This may very well be other economic sectors. The only difference between output produced for satisfying sectoral demand of intermediates and final products is the timing of the use. For the former, these are used as inputs to production during the same period when they were purchased while the latter's use is stretched out to future time periods. For this reason, this component of final demand is often referred to as "gross fixed capital formation".

[5] Two broad-sector categorizations were used. The first groups the 35 sectors in the MRIOT to 15 broad categories while the second follows a more conventional 5 sector classification (i.e., primary, low-technology manufacturing, medium- to high-technology manufacturing, business services, and other personal and public services).

2.1 Participation and Position in Global Value Chains (GVCs)

In their 2017 paper, Wang, Wei, Yu, and Zhu (WWYZ) presented a framework for the decomposition of final production based on forward and backward linkages. From a forward linkage perspective, the framework is able to trace where and how much an economy-sector's value-added is used in the production of final goods and services by other sectors within and outside the economy in focus. From a backward linkage perspective, on the other hand, an economy-sector's final production is decomposed into value-added contributions by sectors in and outside the same economy. Put simply, the forward linkage perspective shows us where a focal economy-sector's value added goes to while the backward linkage perspective gives us the sources of value of its final goods and services.

Apart from tracing the origin and/or destination of value-added based on the perspective, WWYZ (2017) also quantified value-added related to GVCs by explicitly accounting for geographical flows. For this, three major categories of value-added were characterized by WWYZ (2017): (a) value-added that is domestically produced and consumed, (b) value-added that is embedded in final product exports or imports and (c) value-added that is embodied in intermediate exports or imports. It is then established that only value-added associated with trade in intermediates is related to GVCs.

Now that we have discussed value-added based on perspective and geographical flows, we move on to the GDP and final goods production decomposition framework by WWYZ (2017), for which a simplified framework is shown in **Figure 1**. Breaking down an economy-sector's total value added (or GDP) into different components is the essence of forward-linkage decomposition. To pinpoint production and trade activities that are related to GVCs, GDP can then be decomposed into three parts: (1.a) value-added associated with the production of final products sold in the domestic market (pure domestic), (1.b) value-added associated with the production of final products exported to a direct importing country (traditional trade), and (1.c) value-added associated with the production of intermediate exports (GVC-related value-added).

Figure 1. Decomposition of GDP and Final Goods Production by Country-Sector
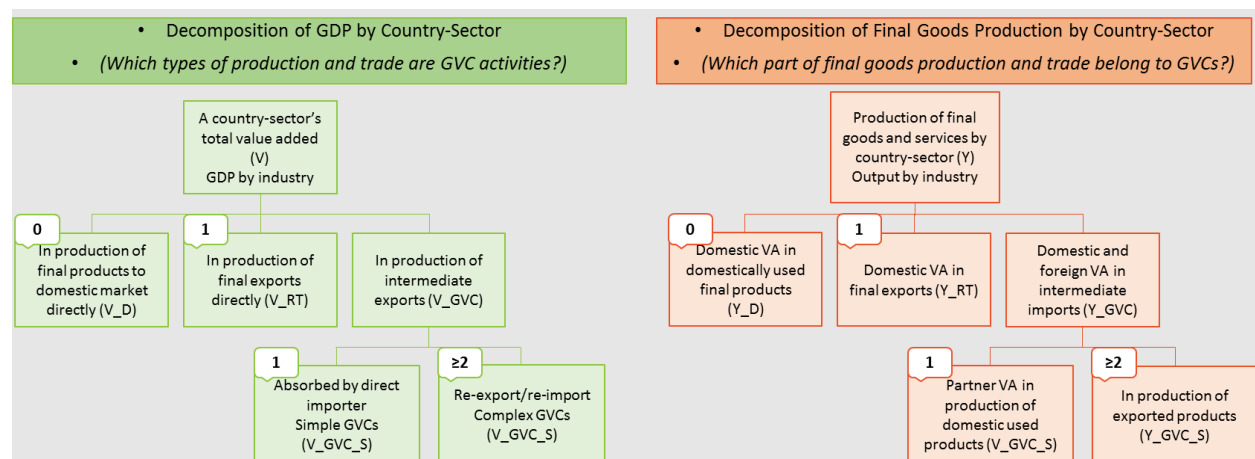
Source: Wang, Wei, Yu, and Zhu (2017)

The key difference between forward- and backward-linkage decomposition is that the latter is concerned with the breakdown of an economy-sector's total value of final goods and services production – not GDP - into several components. Once again, to have an estimate of how much of this value is attributed to GVC-related activities, final production can be broken down into three components: (2.a) domestic value-added embedded in domestically-used final products (pure domestic), (2.b) domestic value added embedded in final exports (traditional trade), and (2.c) domestic and foreign value-added embedded in intermediate imports used to produce final goods and services (GVC-related value-added).

Having established what value-added components of GDP and final goods production are related to GVCs, further distinctions between simple and complex GVC-related activities are made from both perspectives. Starting from a forward perspective, simple GVC-related activities refer to the value-added generated in the production of intermediate exports that are ultimately consumed by the direct importer while complex GVC-related activities pertain to the value-added generated in the production of intermediate exports that undergo further border crossings (i.e. are re-exported or re-imported to the source country) before being ultimately absorbed. From a backward perspective, starting from the condition that intermediate imports[6] are used simple GVC-related activities refer to the creation of value-added embedded in the production of goods and services for domestic consumption while complex GVC-related activities pertain to the creation value-added embedded in the production of exported goods and services.

GVC participation indicators are derived from the decomposition framework discussed above. Participation of an economy-sector in GVCs from the forward perspective is operationally defined as the share of domestic value-added generated through the production of intermediate exports to its total value-added. On the other hand, participation of an economy-sector in GVCs from the backward perspective is derived by getting the share of value-added associated with intermediates trade to its total value of final goods and services.

2.2 Upstreamness and Average Production Length

2.2.1   Upstreamness

Besides knowing the extent of participation of an economy-sector in GVCs, learning its position in global supply chains may also offer valuable insights in analyzing trade patterns. An economy-sector's position in GVCs can be quantified through the upstreamness index as proposed by Fally (2012) and Antràs and Chor (2017), which is simply its average distance from final demand. Mathematically, the upstreamness of sector r in economy i, or U_i^r, is the average distance from final use and is given by[7]:

$$U_i^r = 1 \times \frac{F_i^r}{X_i^r} + 2 \times \frac{\sum_{s=1}^{S} \sum_{j=1}^{J} a_{ij}^{rs} F_j^s}{X_i^r} + 3 \times \frac{\sum_{s=1}^{S} \sum_{j=1}^{J} \sum_{t=1}^{S} \sum_{k=1}^{J} a_{ij}^{rs} a_{jk}^{st} F_k^t}{X_i^r} + \cdots$$

where: F is final demand
             X is gross output
             a_{ij}^{rs} is the dollar amount of sector r's output from economy i needed to produce a dollar's worth of sector s's output in economy j

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[6] Which contain foreign value added and possibly domestic value added
[7] See **Appendix A** for further details

Note that the numerators on the right-hand side of the equation, sans the weights (i.e. the integer multiplicands) are just terms present in an iterated form of X_i^r, which implies that $U_i^r \geq 1$. Given this formulation, an economy-sector is said to be relatively upstream the higher U_i^r is. Intuitively, higher values of U_i^r result from terms with larger weights not being equal to zero, thus providing us information that an economy-sector's output goes through several more stages of production before reaching final use (Miller and Temurshoev, 2017).

An alternative and simpler measure of upstreamness can also be used, which is given by the ratio F_i^r/X_i^r, where F_i^r is the total final use of output from sector r in economy i and X_i^r is the gross output of sector r in economy i. In words, this gives us the share of an economy-sector's gross output that is sold for final consumption. In this case, then, lower F_i^r/X_i^r ratios will be derived if an economy-sector sells a large amount of its output for intermediate use and we consider it relatively upstream.

2.2.2 Average Production Length

Similarly, an economy-sector's position in GVCs can be measured through its average production length (APL). In 2017, Wang et al. introduced a new measure called the GVC position index which gives the relative upstreamness or downstreamness of an economy-sector according to its production length from GVC-related activities. Due to the initial observation that upstreamness and downstreamness[8] do not correspond to each other, this index was developed to address what the authors referred to as an "internal inconsistency" in the way these two measures of sectoral ranking are defined in Antràs et al. (2012).

The production length of an economy-sector is also computed based on forward and backward industrial linkages, which further provides three sub-measures based on pure domestic, traditional trade, and GVC production activities. Pure domestic production is the segment of the production process that is not shared with other countries. Traditional trade production, on the other hand, is the segment characterized by output crossing border once exclusively for final consumption. Lastly, GVC production segments either involve trade of intermediate products supplied to direct importers or production activities that cross borders more than twice for domestic or foreign final consumption.

The average production length of a given sector r in economy i based on forward industrial linkage is defined as the ratio of total gross outputs in all product s of economy j to the value added of given sector r in economy i that induced these gross outputs. Taking all economy-sector pairs (i, r) where the value added originated and all economy-sector pairs (j, s) where the value-added is counted as gross output, the average production length in the economy based on forward industrial linkage is given:

$$PL_v = \frac{\widehat{V}BBY}{\widehat{V}BX}$$

where: $\widehat{V}$ is the diagonalized value-added coefficient vector V
          B is the Leontief inverse matrix
          Y is the final demand vector (F in the previous section)
          X is the output vector

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[8] See Antras and Chor (2017) for the formulation of and intuition behind the downstreamness index.

On the other hand, average production length of a given sector r in economy i based on backward industrial linkage is the ratio of the total value of final goods and services produced in sector s of country j to the the value-added of the given sector r in economy i where these final goods and services originated from. Taking all economy-sector pairs (i, r) where the value added originated and all economy-sector pairs (j, s) whose final goods and services originated from this value-added, the average production length in the economy based on backward industrial linkage is given by:

$$PL_y = \frac{VBB\widehat{Y}}{VB\widehat{Y}}$$

where: V is the value-added coefficient vector
          B is the Leontief inverse matrix
          $\widehat{Y}$ is the diagonalized final demand vector

The production lengths from the three production activities are then computed as follows:

a) Pure Domestic Production

$$PL_D = \frac{\widehat{V}LL\widehat{Y}^D}{\widehat{V}L\widehat{Y}^D}$$

where: $I + A^D + A^D A^D + \cdots = L$
          A^D is the diagonal block of domestic input coefficients
          $\widehat{Y}^D$ is the diagonal matrix of final goods and services production for domestic consumption

b) Traditional Trade Production

$$PL_{RT} = \frac{\widehat{V}LL\widehat{Y}^F}{\widehat{V}L\widehat{Y}^F}$$

where: A^F is the diagonal block of imported input coefficients
          $\widehat{Y}^F$ is the diagonal matrix corresponding to the vector of final product exports
          $Y^F = Y - Y^D$

c) GVC Production

$$PL_{GVC} = \frac{\widehat{V}LLA^F B\widehat{Y}}{\widehat{V}LA^F B\widehat{Y}} + \frac{\widehat{V}LA^F BB\widehat{Y}}{\widehat{V}LA^F B\widehat{Y}}$$

The GVC position index is the ratio of the GVC production length based on forward industrial linkages to the GVC production length based on backward industrial linkage. By comparing all economy-sectors in terms of their GVC position index, sectors with relatively high index values are considered to be more upstream in the economy.

2.3 NRCA

In elementary and even advanced studies of international trade, we often come across the concept of comparative advantage, which has been a long-standing policy concern in the subject matter. Comparative advantage also happens to be a key fundamental theoretical justification for the existence of international trade and the drive for specialization in the global economy. This is mostly due to the potential efficiency gains it offers in the form of reduced opportunity costs to production, better product diversification, and improved consumer welfare owing to increased supply of final goods and services.

In this paper, we look at metrics that operationalize the concept of comparative advantage and that were derived using the ADB MRIOTs. One such measure is revealed comparative advantage, developed by Balassa in 1965, and is given by:

$$TRCA_i^r = \frac{\left(\dfrac{e_i^{r*}}{\sum_{i=1}^{N} e_i^{r*}} \right)}{\left(\dfrac{\sum_{k=1}^{G} e_i^{k*}}{\sum_{i=1}^{N} \sum_{k=1}^{G} e_i^{k*}} \right)}$$

where: e_i^{r*} is country r's exports of products from sector i
          N is the number of products (or industries in the IO setting)
          G is the number of countries in the world economy

If $TRCA_i^r > 1$, we say that country r has a revealed comparative advantage in sector i. In words, a country is said to have a comparative advantage in a particular sector if the latter's share in total country exports exceeds its share in total world exports (Balassa, 1965).

A major criticism of the TRCA measure is that it only accurately reflects cross-country differences in comparative advantage in a world that exclusively trades final goods and services. Doing so ignores two important facts. First, there may be indirect exports of an economy-sector's value-added through the exports of other sectors that use its output in their production processes. Second, foreign value-added may be present in an economy-sector's exports if it uses imported intermediates as inputs to production. Thus, a conceptually correct measure of comparative advantage should include indirect value-added exports and exclude foreign value-added content.

Building upon this perceived weakness of the TRCA measure especially in analyses of global value chains where trade in intermediates is extensive, Wang, Wei, and Zhu (2018) offered a new measure of comparative advantage given by this equation:

$$NRCA_i^r = \frac{\left(\dfrac{DVA\_F_i^{r*}}{\sum_{i=1}^{N} DVA\_F_i^{r*}} \right)}{\left(\dfrac{\sum_{k=1}^{G} DVA\_F_i^{k*}}{\sum_{i=1}^{N} \sum_{k=1}^{G} DVA\_F_i^{k*}} \right)}$$

The only difference NRCA has with TRCA is its use of DVA_F instead of gross exports. DVA_F refers to domestic value-added that is originated from a country-sector and ultimately embodied in exports regardless of where these exports are finally consumed. Intuitively, it may be interpreted as a measure of a country-sector's significance as a supplier of value-added in exports.

Looking at the results now works this way: if NRCA of an economy-sector is greater than 1, then we say that the country has a revealed comparative advantage in that sector because its share in the domestic value-added of total country exports exceeds the share of that sector (summed across all countries) in the domestic value-added of total world exports.

2.4 WWZ Decomposition

In this section, an accounting framework developed by Wang, Wei, and Zhu (WWZ) in 2018 is used to study international trade structures of Brunei, Malaysia, and Singapore from the perspective of country and economy-sector gross exports. Known as "WWZ decomposition", this approach breaks down gross exports into value-added and double counted terms, each having distinct economic interpretations that can be used to analyze roles, patterns, and dynamic relationships in global production networks.

A key motivation of gross exports decomposition is an awareness about the accounting complexities brought about by cross-country trade in intermediates. To demonstrate, suppose wood is harvested in an economy and some are exported abroad. The direct importer then further processes these before exporting to a separate foreign economy, which uses the processed wood to manufacture wooden chairs. While these transactions will be captured by national accounts of gross exports, the value of processed wood imported by the third economy that will appear in these conventional trade statistics will cover the cost of raw wood purchased from the first economy as well as the value added attributable to manufacturing. Thus, from the perspective of the transaction between the second and third economy, the contribution of the former to the global production network for wooden chairs will be overstated while that of the economy where wood was originally harvested will not be reported at all if everything were evaluated based on gross exports alone.

To complicate matters further, suppose the third economy exports wooden chairs back to the first economy for further furnishing before being sold to the second economy. The value of international wooden chair purchases by the second economy will cover the cost of furnishing, manufacturing, processing, and the initial harvesting of wood. Thus, gross exports figures of wooden chairs from the first to the second economy will double-count the value-added contribution of raw wood products.

In reality, global value chains are even more complex with a large number of economies involved in production processes of varying lengths. As a result, economists and statisticians alike attempted to formulate disaggregated accounting frameworks that neatly encapsulate the sources of value-added and double counting contained in gross exports. Building from the Leontief Insight, value-added exports, and other previous related literature, WWZ decomposed economy-sector exports into value-added from domestic sources (DVA), value-added from foreign sources (FVA), and pure double counted terms (PDC) that become present as a consequence of back-and-forth trade in intermediates.

As shown in WWZ (2018), DVA can be further decomposed into domestic value-added that is absorbed abroad (VAX_G) and domestic value-added that return home after initially being exported (RDV). Since exports that are absorbed abroad may be finally consumed or used as inputs to production, VAX_G has three more components: domestic value-added in final goods and services (DVA_FIN), domestic-value added in intermediates that are absorbed by the direct importer (DVA_INT), and domestic value-added in intermediates that are re-exported by the direct importer to a third country (DVA_INTrex). Similarly, FVA can be further decomposed into foreign value-added contained in final exports (FVA_FIN) as well as intermediate exports (FVA_INT).

Lastly, PDC combines pure double counting coming from both domestic and foreign sources, which are labeled as DDC and FDC, respectively. This information is summarized in **Figure 2**.

Figure 2. The WWZ Decomposition Framework
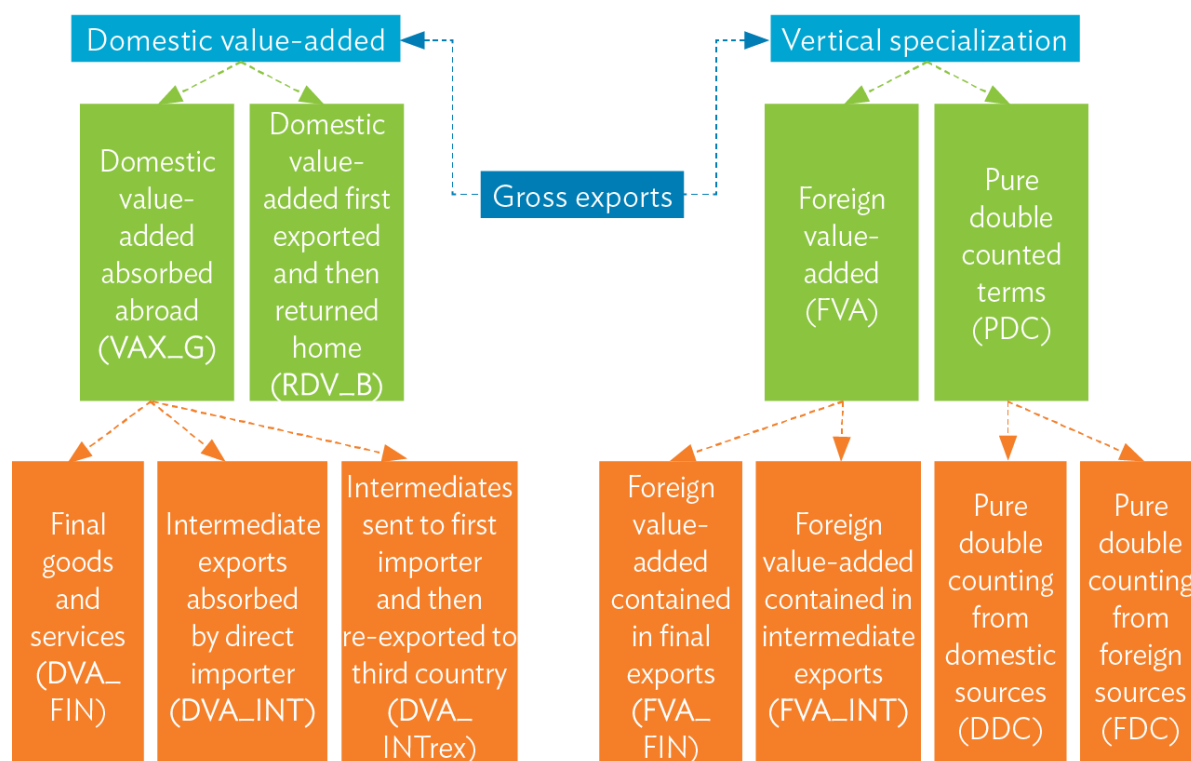
Source: Wang, Wei, and Zhu (2018).

WWZ (2018) went on to decompose DVA_INTrex and RDV into three components each and FVA_FIN, FVA_INT, DDC, and FDC into two components each to arrive at a complete 16-term decomposition of gross exports. Although all 16 terms were included in our calculations, only the initial 8 terms are presented in this paper as these already sufficiently capture trade structures of interest. However, the reader is encouraged to look into the 16-term decomposition of gross exports by WWZ (2018) for a better grasp and appreciation of the conceptual and computational complexity present in this accounting framework.

3. Results

3.1 Participation

Considerable variations in participation and roles in global production networks across the economies of Brunei, Malaysia, and Singapore were noted from 2000 and 2018. Singapore led in terms of both forward and backward participation, revealing its high involvement in international trade. Brunei Darussalam's sectors mostly had high forward participation ratios and relatively low backward participation ratios, suggesting higher supplies of intermediates to – rather than from – other economies. Malaysia, on the other hand, had declining backward and forward participation ratios which implies a decline in the economy's overall trade-related activity.

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In the time period studied, Singapore's forward and backward participation remained relatively steady. In 2000, its forward participation was 45.77% and by 2018, this remained close at 49.5%. Likewise, its backward participation was 46.62% of total final production in 2000 and got to 46.86 % in 2018 (**Figure 3**). These high participation ratios suggest that Singapore used large shares of value added that originated from other economies while at the same time being an important source for others. This may have been strongly influenced by Singapore's pivotal position as a major transit point and oil-refining and trading hub, as well as its well-developed electronics-processing "ecosystem".

Figure 3. GVC Participation Across Manufacturing Hubs, Singapore, 2000-2018 (%)
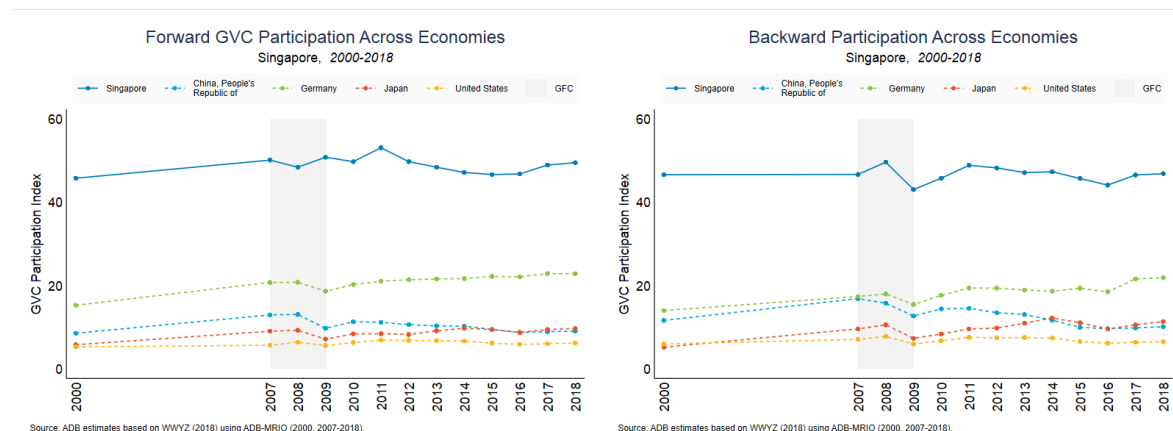
This position is supported by a sector-wise dissection of participation ratios (**Figure 4)**, which shows that Singapore's transport services sector consistently had the highest forward and backward participation ratios in the period considered, ranging between 60-70% and 50-60%, respectively. As for the other sectors, those with the highest forward participation ratios included trade services, financial intermediation, and business services while the heavy manufacturing sector consistently had high backward participation ratios.

Figure 4. Simple and Complex GVC Participation in Singapore, by Sector, 2000-2018 (%)

Forward GVC Participation - Construction
Singapore, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Construction
Singapore, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Education, health, and social work
Singapore, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Education, health, and social work
Singapore, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Financial intermediation
Singapore, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Financial intermediation
Singapore, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Heavy manufacturing
Singapore, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Heavy manufacturing
Singapore, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Hotels and restaurants
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Hotels and restaurants
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Light manufacturing
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Light manufacturing
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Mining and quarrying
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Mining and quarrying
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Other personal services
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Other personal services
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Public administration and defense
Singapore, *2000, 2007-2018*

Backward GVC Participation - Public administration and defense
Singapore, *2000, 2007-2018*

Forward GVC Participation - Real estate, renting, and business activities
Singapore, *2000, 2007-2018*

Backward GVC Participation - Real estate, renting, and business activities
Singapore, *2000, 2007-2018*

Forward GVC Participation - Telecommunications
Singapore, *2000, 2007-2018*

Backward GVC Participation - Telecommunications
Singapore, *2000, 2007-2018*

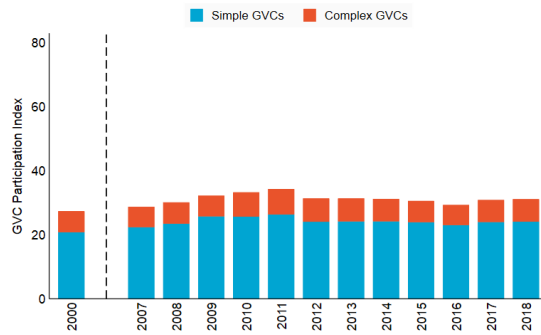**Forward GVC Participation - Trade services**
Singapore, *2000, 2007-2018*

Backward GVC Participation - Trade services
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Transport services
Singapore, *2000, 2007-2018*

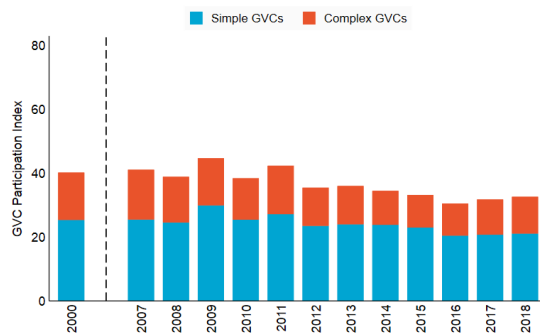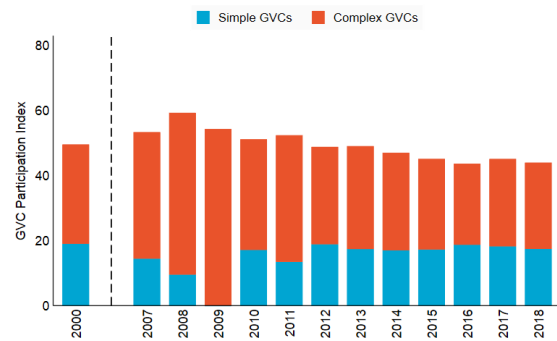**Backward GVC Participation - Transport services**
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

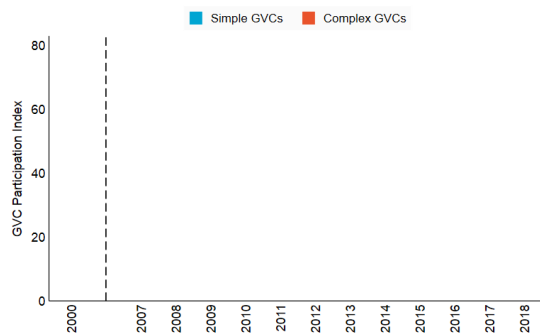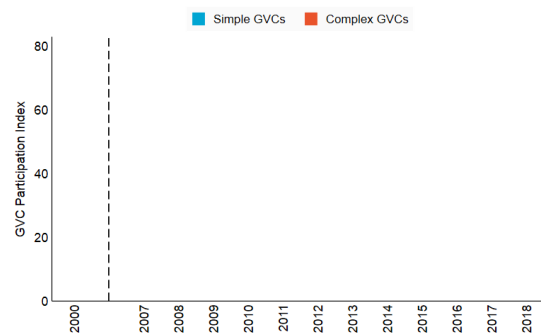**Forward GVC Participation - Utilities**
Singapore, *2000, 2007-2018*

Backward GVC Participation - Utilities
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Except in the heavy and light manufacturing sectors, both forward and backward participation indices of Singapore showed markedly higher proportions of simple GVCs compared to complex GVCs. Simple GVCs capture the use of domestic value-added by the direct importer in its production of final products while complex GVCs account for the intermediates that undergo multiple border crossings before being used as inputs to meet final demand.

Unlike Singapore, trade-related activity as a percentage of value-added and final goods and services production declined for Malaysia (**Figure 5**). In 2000, the economy's forward GVC participation was above all major hubs at 47.18% of total value-added but in 2018, this declined to 30.23%. Backward GVC participation was at 45% of total final production in 2000 and this declined to 30.94% in 2018.

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Figure 5. GVC Participation Across Manufacturing Hubs, Malaysia, 2000-2018 (%)

Forward GVC Participation Across Economies
Malaysia, *2000-2018*

Backward Participation Across Economies
Malaysia, *2000-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
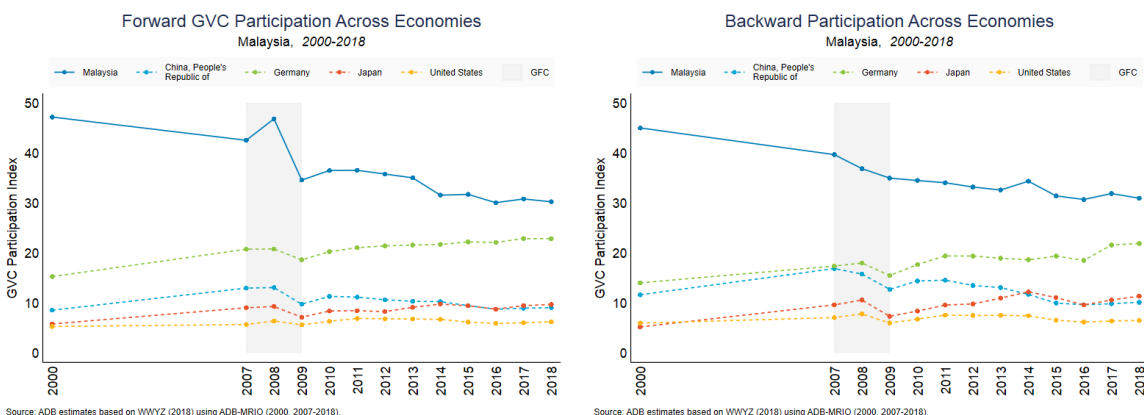
Taking into account Malaysia's position as the seventh largest exporter of electronics during the period studied, these sharp declines in the participation indices may have been caused by a decline in demand for locally-produced electronic products and semiconductors by the United States due to increased competition from Asian peers. In addition, contractions in the manufacturing of electronics, machinery, and equipment as an aftermath of the global financial crisis (GFC) could also have contributed to these declines. Malaysia's heavy manufacturing sector had the highest forward and backward participation ratios, with both indices dominated by simple GVCs (**Figure 6)**. This suggests that the sector's intermediate exports were used as inputs to production of final goods and services by the direct importing economies.

Figure 6. Simple and Complex GVC Participation in Malaysia, by Sector, 2000-2018 (%)

Forward GVC Participation - Agriculture, hunting, forestry, and fishing
Malaysia, *2000, 2007-2018*

Backward GVC Participation - Agriculture, hunting, forestry, and fishing
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Construction
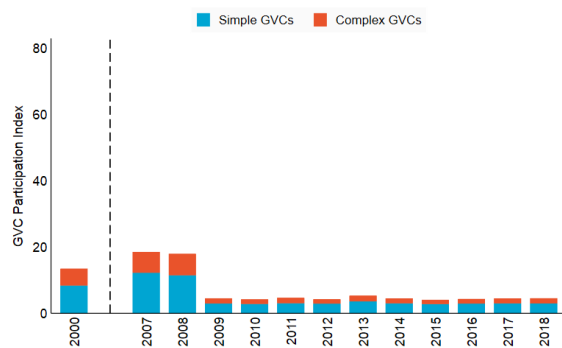### Malaysia, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

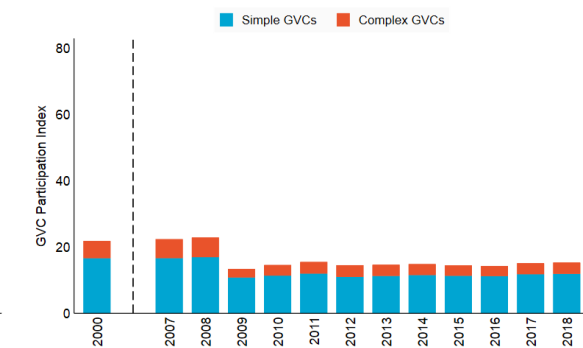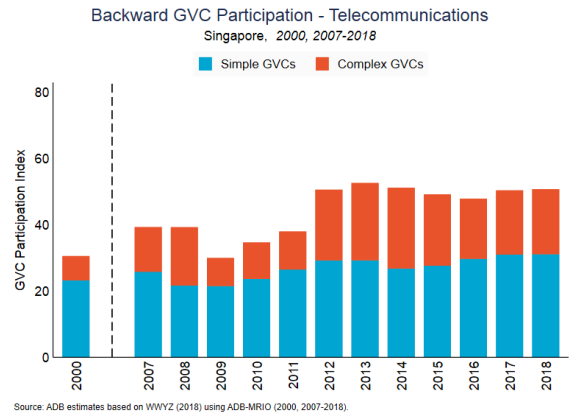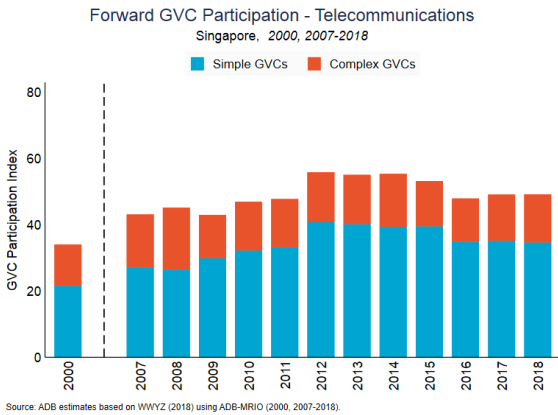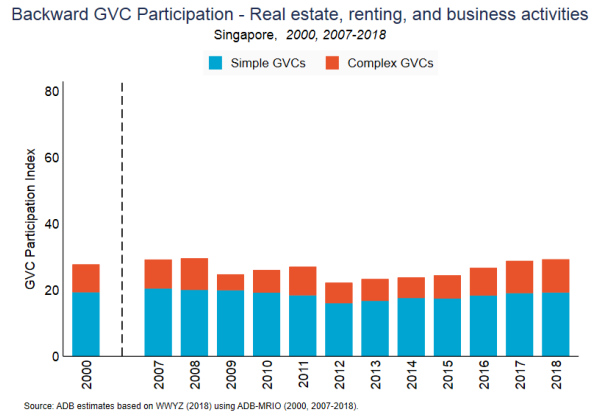## Backward GVC Participation - Construction
Malaysia, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Education, health, and social work
Malaysia, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Education, health, and social work
Malaysia, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Financial intermediation
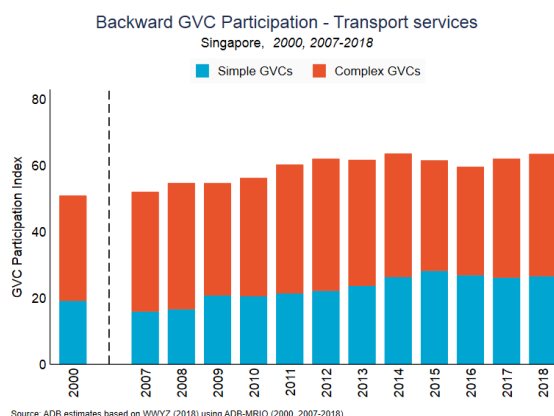### Malaysia, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Financial intermediation
Malaysia, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Heavy manufacturing
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Heavy manufacturing
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Hotels and restaurants
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Hotels and restaurants
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Light manufacturing
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Light manufacturing
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Mining and quarrying
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Mining and quarrying
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Other personal services
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Other personal services
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Public administration and defense
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Public administration and defense
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

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Forward GVC Participation - Real estate, renting, and business activities
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Real estate, renting, and business activities
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Telecommunications
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Telecommunications
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Trade services
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Trade services
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Transport services
Malaysia, 2000, 2007-2018

Backward GVC Participation - Transport services
Malaysia, 2000, 2007-2018

Forward GVC Participation - Utilities
Malaysia, 2000, 2007-2018

Backward GVC Participation - Utilities
Malaysia, 2000, 2007-2018

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

As for Brunei, we see that its two participation indices moved in opposite directions between 2000 and 2018, though it is apparent that the economy participated more in terms of providing value-added. Trade-related activity as a percentage of value-added declined in Brunei while that as a percentage of final goods and services production increased, which consequently led to lower forward participation (from 46.66% to 37.91%) and higher backward participation (from 6% to 19.99%) over time (**Figure 7)**. These results imply that Brunei became more involved in GVCs via importing of value added and involvement in more downstream production activities, thereby making the economy's intermediate supply links with other economies simpler in nature. In support of this claim, Brunei's trade in intermediates was dominated by bilateral transactions from both the backward and forward perspectives as seen in **Figure 8**.

Figure 7. GVC Participation Across Manufacturing Hubs, Brunei, 2000-2018 (%)

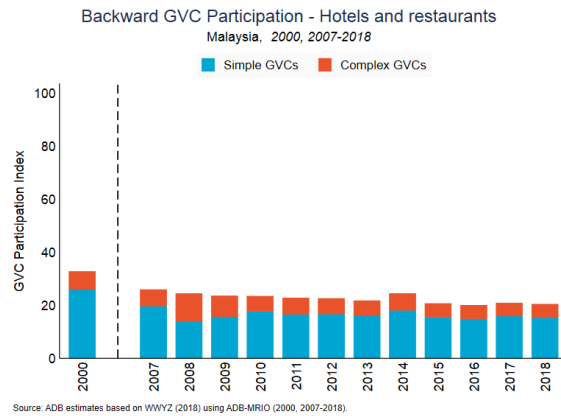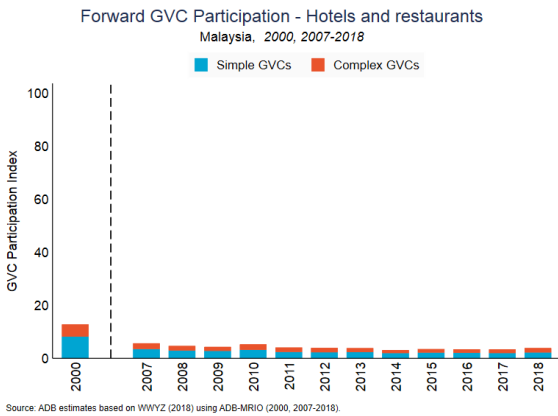Forward GVC Participation Across Economies
Brunei Darussalam, 2000-2018

Backward Participation Across Economies
Brunei Darussalam, 2000-2018

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
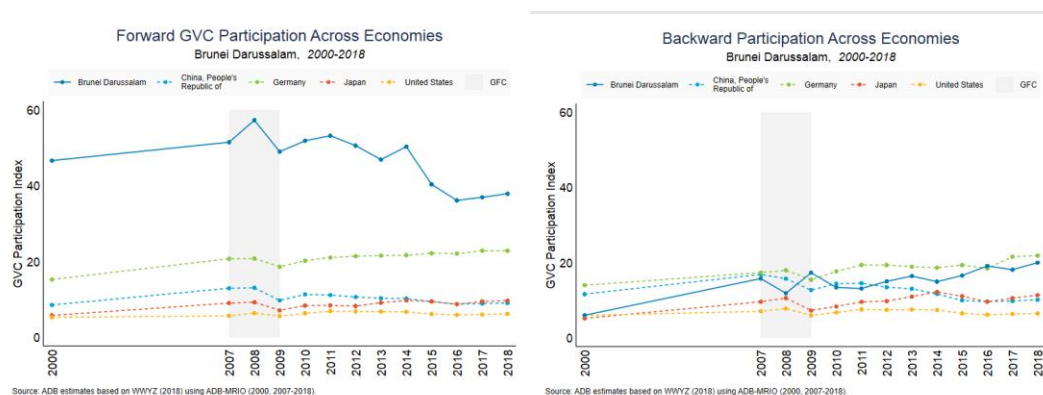
Figure 8. Simple and Complex GVC Participation in Brunei, 2000-2018 (%)

Forward GVC Participation
Brunei Darussalam, *2000, 2007-2018*

Backward GVC Participation
Brunei Darussalam, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
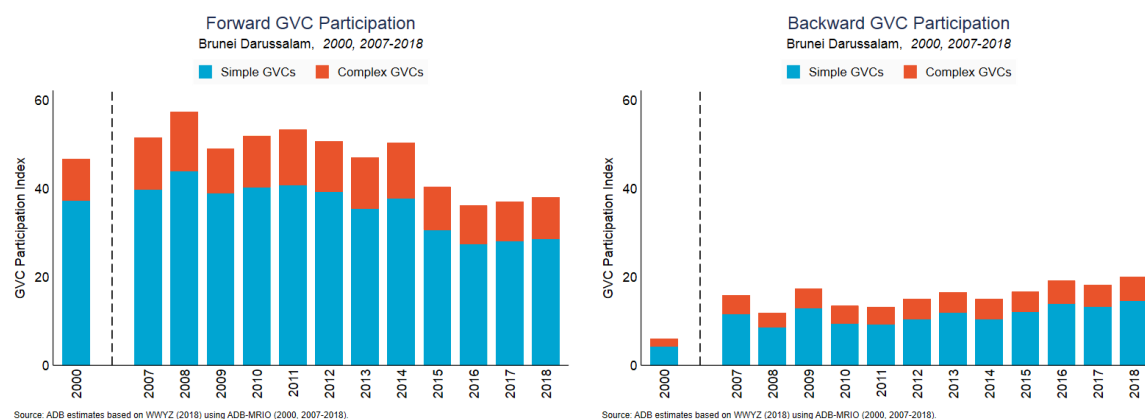
From a sectoral perspective, the heavy manufacturing sector of Brunei consistently had the highest forward participation ratios since 2007, reflecting its orientation towards the oil and gas industry. Brunei's light manufacturing sector also had notably high forward participation ratios, though they have declined since 2000. Similar to the economy as a whole, the trade in intermediates of both the light and heavy manufacturing sectors of the economy was dominated by simple GVCs, regardless of the perspective (**Figure 9**).

Figure 9. Simple and Complex GVC Participation in Brunei, by Sector, 2000-2018 (%)

Forward GVC Participation - Agriculture, hunting, forestry, and fishing
Brunei Darussalam, *2000, 2007-2018*

Backward GVC Participation - Agriculture, hunting, forestry, and fishing
Brunei Darussalam, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Construction
Brunei Darussalam, *2000, 2007-2018*

Backward GVC Participation - Construction
Brunei Darussalam, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Education, health, and social work
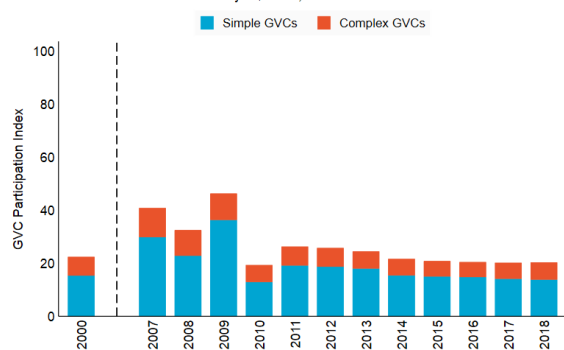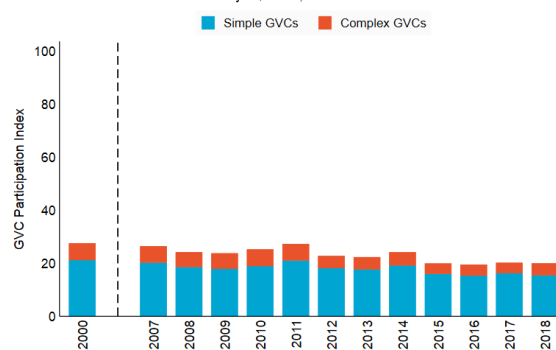Brunei Darussalam, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Education, health, and social work
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Financial intermediation
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Financial intermediation
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Heavy manufacturing
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Heavy manufacturing
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Hotels and restaurants
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Hotels and restaurants
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs   Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

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Forward GVC Participation - Light manufacturing
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Light manufacturing
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Mining and quarrying
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Mining and quarrying
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Other personal services
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Other personal services
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Public administration and defense
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Public administration and defense
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Real estate, renting, and business activities
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Real estate, renting, and business activities
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Telecommunications
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Telecommunications
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Trade services
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Trade services
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Forward GVC Participation - Transport services
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Backward GVC Participation - Transport services
Brunei Darussalam, *2000, 2007-2018*

Simple GVCs ■ Complex GVCs

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

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Forward GVC Participation - Utilities
Brunei Darussalam, *2000, 2007-2018*

Backward GVC Participation - Utilities
Brunei Darussalam, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

3.2 Upstreamness and Average Production Length

The observed trends in participation for the economies of Brunei, Malaysia, and Singapore appeared to be related to their respective patterns in upstreamness. This is particularly evident for Brunei where decreasing upstreamness indices and forward-linkage-based production lengths were accompanied by decreasing forward participation and an increasing backward participation. This makes intuitive sense as a high upstreamness index (or forward linkage production length) would mean that an economy-sector's output is relatively far from final use. Thus, its output is passed on to several more sectors for further use and/or processing, which expands its value-added contributions and thereby positively influencing participation from a forward perspective. Since this type of output functions as in intermediate input in early stages of production, it will carry less value-added from other economy-sectors that are part of the same production chain, thus negatively affecting backward participation assuming similar production structures.

Brunei's decreasing upstreamness indices showed a trend that was contrary to that of the world average as well as some key manufacturing hubs (**Figure 10**). For the period studied, Brunei registered a slight decrease in its upstreamness index while most economies (e.g., People's Republic of China and Viet Nam) had rising upstreamness indices and declining total final use to gross output ratios. As GVCs were becoming more complex, with several economies strengthening their links to global intermediate supply chains, Brunei showed an increasing concentration on exports of final goods and services, thereby weakening its forward intermediate supply links with other countries over the period considered, albeit marginally.

Figure 10. Upstreamness Across Economies, Brunei, 2000-2018

Upstreamness Across Economies
Brunei Darussalam, *2000-2018*

Source: ADB estimates based on Antràs and Chor (2018) and Miller and Temurshoev (2017) using ADB MRIO (2000, 2007-2018).
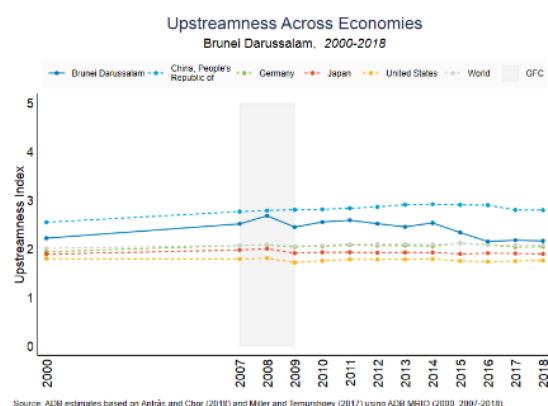
Looking at production length suggests the same narrative. Between the period 2009 to 2018, forward-linkage-based production lengths decreased while backward-linkage-based production lengths increased, with such movements appearing to be mirrored by trends in their GVC-related components. Between 2007 and 2018, the economy's backward-linkage-based production length declined by 8.39% and 36.41% for production related to domestic trade and traditional trade, respectively. On the other hand, that related to GVCs increased by 22.92% (**Figure 11**).

Figure 11. Average Production Length, Brunei, 2000-2018
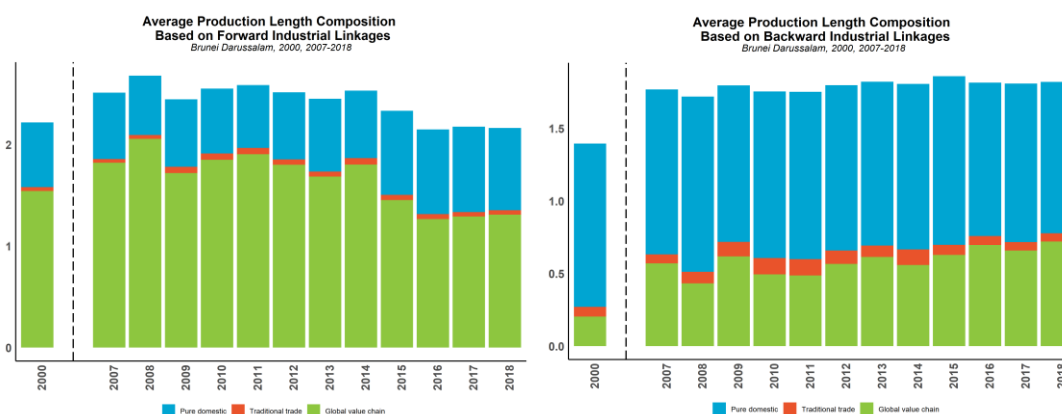
Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018)

Compared to Brunei, Malaysia and Singapore were among the economies that had relatively stable average upstreamness indices[9] from 2000 to 2017, implying little movement in GVC positions (**Figures 12 & 13**). Decomposing production activities, however, offer some insight on pattern shifts that occurred over time.

Figure 12. Upstreamness Across Economies, Malaysia, 2000-2018
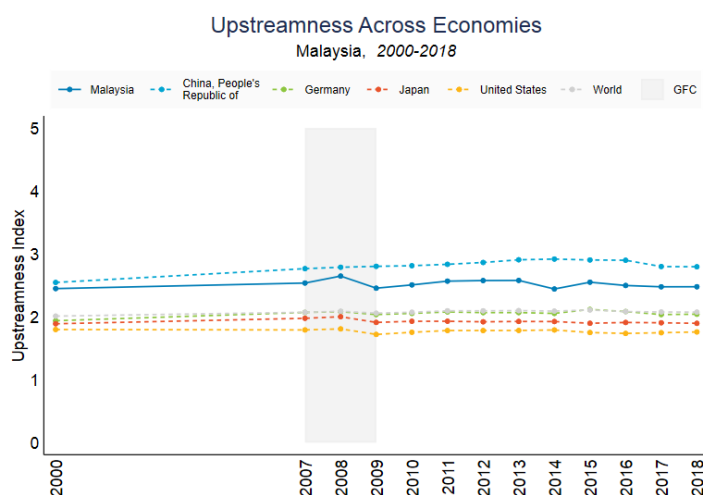
Source: ADB estimates based on Antràs and Chor (2018) and Miller and Temurshoev (2017) using ADB MRIO (2000, 2007-2018).

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[9] Weighted by gross output and production staging from final demand plus one

Figure 13. Upstreamness Across Economies, Singapore, 2000-2018
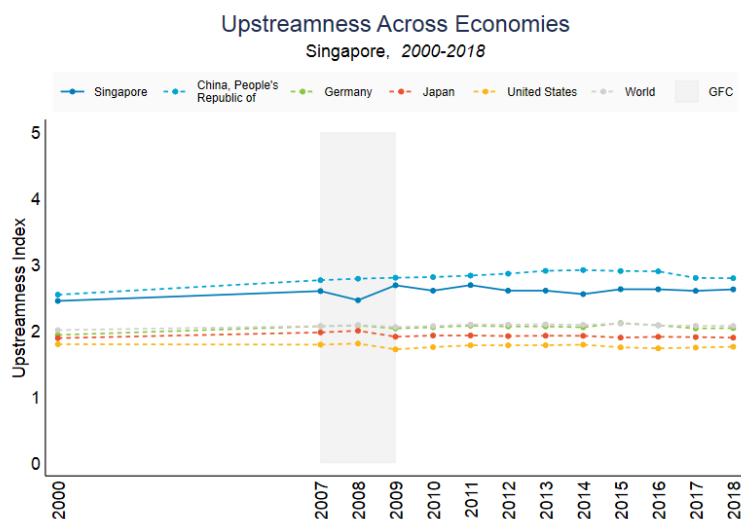
Upstreamness Across Economies
Singapore, *2000-2018*

Between 2007 and 2018, Malaysia's forward-linkage-based production length increased by 38.87 percent for domestic production, while it decreased by 1.31 percent and 20.89 percent for production related to traditional trade and GVC, respectively. From a backward perspective, the economy's production length increased by 22.99 percent for domestic production, while it fell by 3.89% for production related to traditional trade and 16.95% for production related to GVCs (**Figure 14**).

Figure 14. Average Production Length, Malaysia, 2000-2018

Average Production Length Composition
Based on Forward Industrial Linkages
Malaysia, 2000, 2007-2018

Average Production Length Composition
Based on Backward Industrial Linkages
Malaysia, 2000, 2007-2018
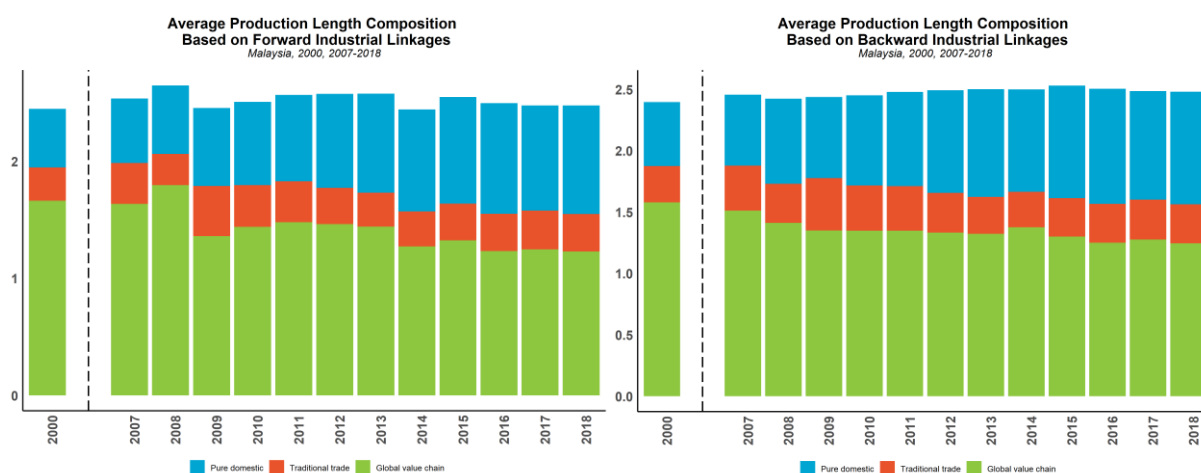
Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018)

As for Singapore, forward-linkage-based production length increased by 1.15 percent for domestic production, while it fell by 7.79 percent for production related to traditional trade as well as by 3.06 percent for the component related to GVCs. On the other hand, backward-linkage-

based production length declined by 1.46 percent for domestic production and 7.93 percent for production related to traditional trade. An increase of around 3.95 percent is also computed for GVC-related production from the backward perspective (**Figure 15**).

Figure 15. Average Production Length, Singapore, 2000-2018
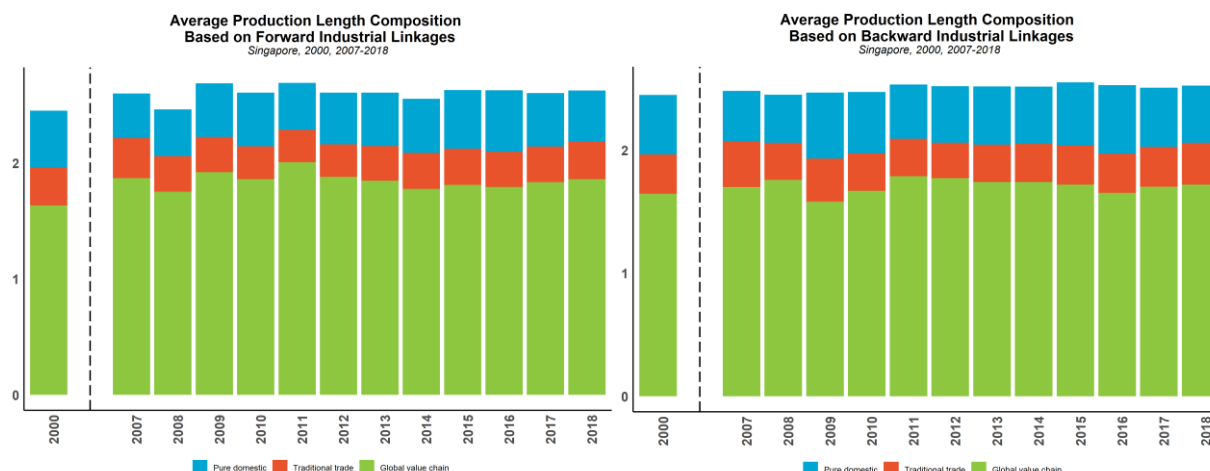
Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018)

Trends in the aggregate economy's upstreamness indices can be traced back to sectoral changes. In Brunei, all sectors except for construction, heavy manufacturing, education, health and social work, public administration and defense, as well as other personal services saw a decrease in their production lengths based on forward industrial linkages. Sectors that exhibited large movements towards downstream activities included coke, refined petroleum, and nuclear fuel; basic metals and fabricated metals; air transport; and leather and footwear. In line with the concept but in contrast with observed trends in Brunei, economic sectors in Malaysia and Singapore displayed few significant movements in their respective production chain positions (**Figure 16**).

Figure 16. Upstreamness in Brunei, Malaysia, and Singapore, 2000 & 2018

Upstreamness
Malaysia, 2000

Sector	Upstreamness
Financial Intermediation	3.7
Mining and Quarrying	3.5
Chemicals and Chemical Products	3.4
Basic Metals and Fabricated Metal	3.1
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	3.1
Renting of Machinery & Equipment and Other Business Activities	3.1
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	3.1
Electricity, Gas and Water Supply	3.0
Rubber and Plastics	2.9
Agriculture, Hunting, Forestry and Fishing	2.9
Machinery, N.E.C.	2.8
Pulp, Paper, Paper, Printing and Publishing	2.8
Wood and Products of Wood and Cork	2.8
Other Non-Metallic Mineral	2.8
Coke, Refined Petroleum and Nuclear Fuel	2.7
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	2.7
Inland Transport	2.6
Air Transport	2.6
Water Transport	2.5
Electrical and Optical Equipment	2.5
Food, Beverages and Tobacco	2.5
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	2.3
Manufacturing, N.E.C.; Recycling	2.1
Hotels and Restaurants	1.8
Transport Equipment	1.8
Leather, Leather and Footwear	1.7
Textiles and Textile Products	1.7
Real Estate Activities	1.7
Private Households with Employed Persons	1.4
Other Community, Social and Personal Services	1.4
Construction	1.2
Public Administration and Defence; Compulsory Social Security	1.1
Health and Social Work	1.1
Education	1.0

Mean Upstreamness, *2000*: 2.4   Median Upstreamness, *2000*: 2.6
Source: ADB estimates based on Antràs et al. (2012) using ADB-MRIO (2000, 2007-2018).

Upstreamness
Malaysia, 2018

Sector	Upstreamness
Mining and Quarrying	3.9
Rubber and Plastics	3.8
Financial Intermediation	3.3
Pulp, Paper, Paper, Printing and Publishing	3.3
Real Estate Activities	3.2
Renting of Machinery & Equipment and Other Business Activities	3.2
Chemicals and Chemical Products	3.2
Agriculture, Hunting, Forestry and Fishing	3.1
Wood and Products of Wood and Cork	3.0
Inland Transport	3.0
Electrical and Optical Equipment	2.9
Air Transport	2.9
Other Non-Metallic Mineral	2.9
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	2.9
Coke, Refined Petroleum and Nuclear Fuel	2.9
Electricity, Gas and Water Supply	2.8
Leather, Leather and Footwear	2.7
Water Transport	2.7
Basic Metals and Fabricated Metal	2.7
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	2.6
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	2.5
Manufacturing, N.E.C.; Recycling	2.5
Post and Telecommunications	2.3
Machinery, N.E.C.	2.3
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	2.3
Food, Beverages and Tobacco	2.1
Textiles and Textile Products	2.1
Transport Equipment	1.8
Other Community, Social and Personal Services	1.8
Construction	1.6
Hotels and Restaurants	1.6
Health and Social Work	1.3
Education	1.1
Public Administration and Defence; Compulsory Social Security	1.0

Mean Upstreamness, *2018*: 2.6   Median Upstreamness, *2018*: 2.7
Source: ADB estimates based on Antràs et al. (2012) using ADB-MRIO (2000, 2007-2018).

Upstreamness
Singapore, 2000

Sector	Upstreamness
Water Transport	3.9
Chemicals and Chemical Products	3.1
Financial Intermediation	3.1
Wood and Products of Wood and Cork	3.1
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	3.0
Other Non-Metallic Mineral	3.0
Electricity, Gas and Water Supply	3.0
Renting of Machinery & Equipment and Other Business Activities	3.0
Basic Metals and Fabricated Metal	3.0
Post and Telecommunications	2.8
Pulp, Paper, Paper, Printing and Publishing	2.8
Rubber and Plastics	2.8
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	2.7
Coke, Refined Petroleum and Nuclear Fuel	2.4
Electrical and Optical Equipment	2.4
Transport Equipment	2.3
Manufacturing, N.E.C.; Recycling	2.2
Other Community, Social and Personal Services	2.2
Air Transport	2.1
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	2.1
Construction	2.1
Machinery, N.E.C.	2.1
Agriculture, Hunting, Forestry and Fishing	2.0
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	1.9
Real Estate Activities	1.9
Inland Transport	1.9
Food, Beverages and Tobacco	1.8
Hotels and Restaurants	1.8
Health and Social Work	1.7
Textiles and Textile Products	1.6
Leather, Leather and Footwear	1.6
Private Households with Employed Persons	1.4
Public Administration and Defence; Compulsory Social Security	1.3
Education	1.1

Mean Upstreamness, *2000*: 2.3   Median Upstreamness, *2000*: 2.2
Source: ADB estimates based on Antràs et al. (2012) using ADB-MRIO (2000, 2007-2018).

Upstreamness
Singapore, 2018

Sector	Upstreamness
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	3.5
Water Transport	3.5
Other Non-Metallic Mineral	3.5
Rubber and Plastics	3.4
Basic Metals and Fabricated Metal	3.4
Wood and Products of Wood and Cork	3.3
Chemicals and Chemical Products	3.2
Renting of Machinery & Equipment and Other Business Activities	3.1
Pulp, Paper, Paper, Printing and Publishing	3.0
Electricity, Gas and Water Supply	3.0
Post and Telecommunications	3.0
Coke, Refined Petroleum and Nuclear Fuel	3.0
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	2.8
Electrical and Optical Equipment	2.8
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	2.8
Financial Intermediation	2.7
Agriculture, Hunting, Forestry and Fishing	2.6
Machinery, N.E.C.	2.4
Inland Transport	2.4
Air Transport	2.3
Food, Beverages and Tobacco	2.2
Transport Equipment	2.0
Manufacturing, N.E.C.; Recycling	2.0
Construction	1.8
Textiles and Textile Products	1.7
Hotels and Restaurants	1.7
Real Estate Activities	1.7
Health and Social Work	1.5
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	1.4
Other Community, Social and Personal Services	1.3
Education	1.3
Private Households with Employed Persons	1.2
Public Administration and Defence; Compulsory Social Security	1.2

Mean Upstreamness, *2018*: 2.4   Median Upstreamness, *2018*: 2.6
Source: ADB estimates based on Antràs et al. (2012) using ADB-MRIO (2000, 2007-2018).

3.3 NRCA

From 2000 to 2018, only one broad sector – the primary sector - in Brunei had a comparative advantage based on NRCA. Given that production in this sector is dominated by oil and natural gas production and the observed fall in oil prices in the period, it perhaps comes as no surprise that its NRCA index fell over time (**Figure 17**). To address losses related to oil price changes, the economy recently announced that one of its main economic objectives was diversification, which may have proven to be successful given the gradual rise in the NRCA indices for the medium- to high-technology manufacturing sector, albeit it being dominated by a natural resource-dependent industry (i.e., petroleum refining). Certain services industries that were prioritized by the government of Brunei also had notable increases in competitiveness during the period considered. Examples of which were industries that covered hotels and restaurants, repair of motor vehicles and transport/travel services, telecommunications, and financial intermediation (**Figure 18**).

Figure 17. New Revealed Comparative Advantage by Broad Aggregate Sector, Brunei, 2000-2018

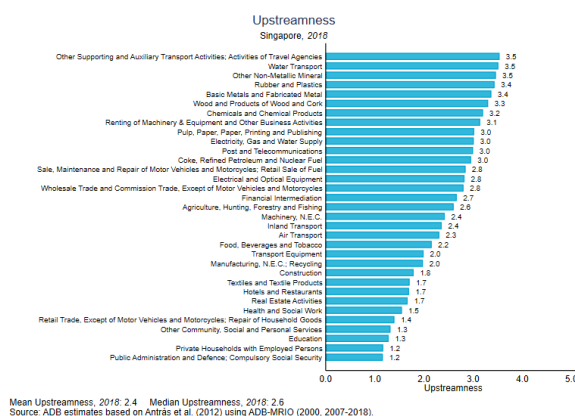Revealed Comparative Advantage by Sector
Brunei Darussalam, *2000, 2007-2018*

Source: ADB estimates based on WWZ (2018) using ADB-MRIO (2000, 2007-2018).

Figure 18. Sectoral NRCA Ranking, Brunei, 2000, 2007, and 2018
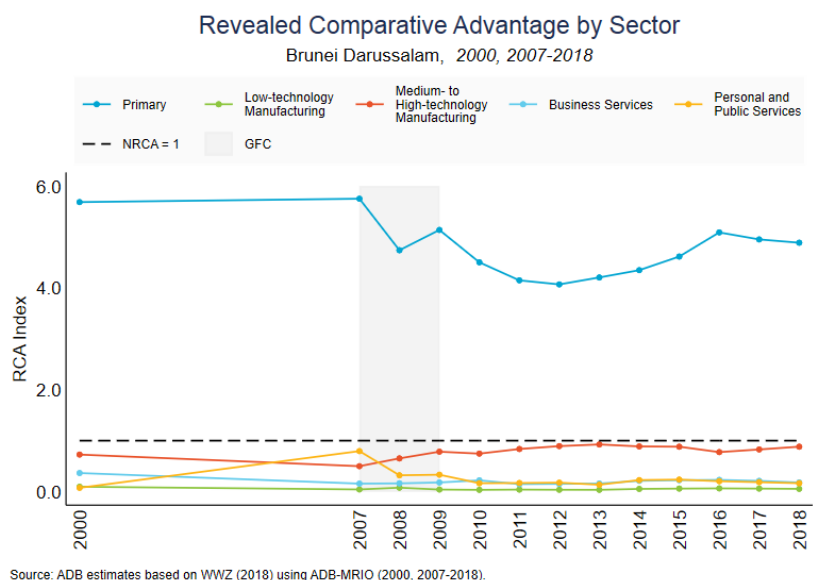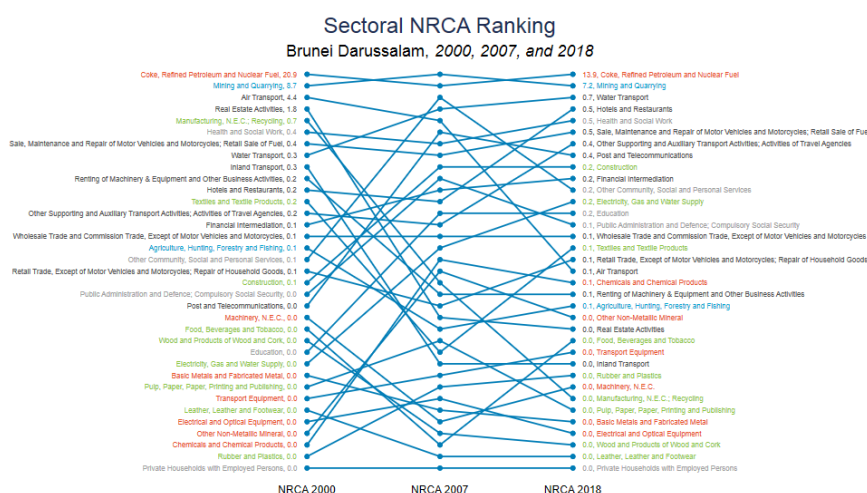

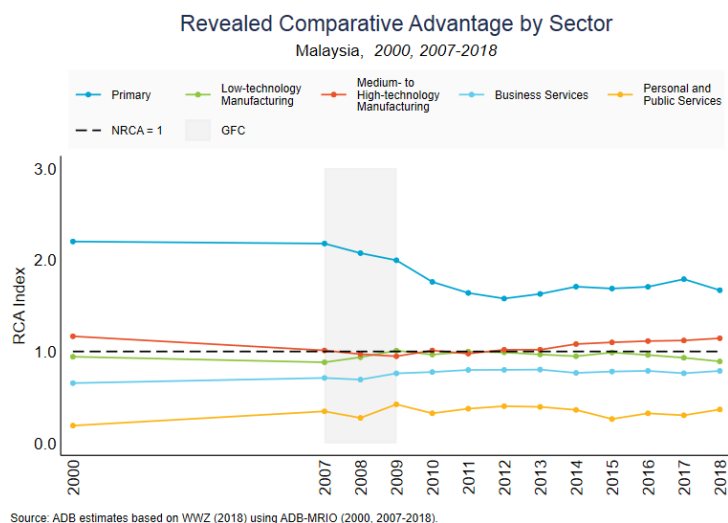Sectoral NRCA Ranking
Brunei Darussalam, *2000, 2007, and 2018*

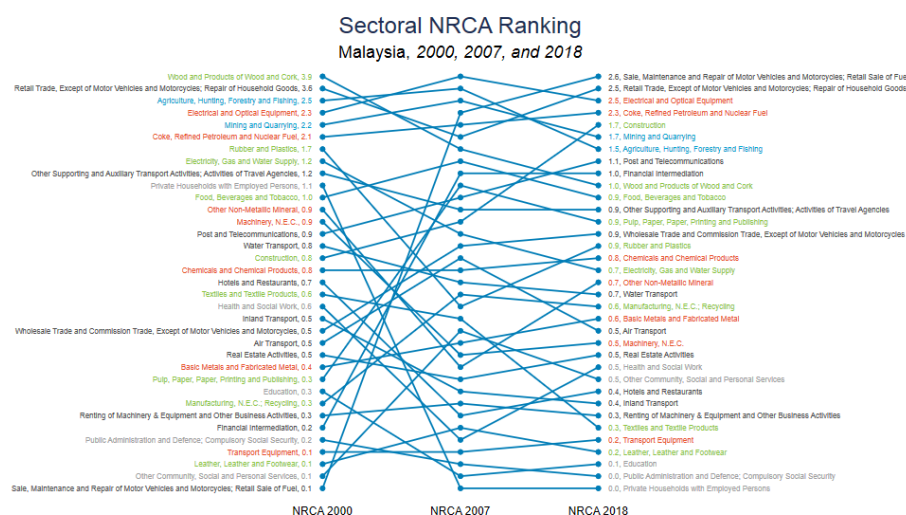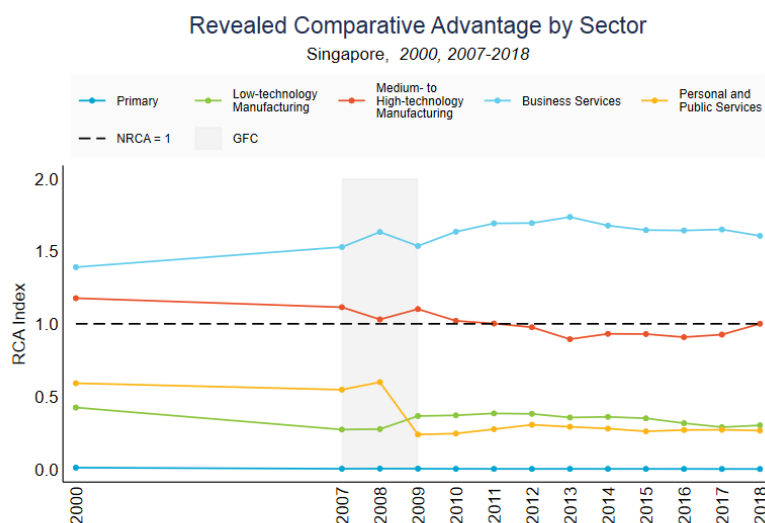Source: ADB estimates based on WWZ (2018) using ADB-MRIO (2000, 2007-2018)

The Malaysian economy, on the other hand, had a comparative advantage both in the primary and medium- to high-technology aggregate sectors. However, since the GFC, the government facilitated the movement towards more services-oriented policies that could have resulted in the slow decline of their NRCA indices a few years after the crisis (**Figure 19**). Fortunately, the competitiveness of these industries started recovering gradually since 2013. Looking at more disaggregated sectors reveal that there had been a shift in the economy's comparative advantage from manufacturing to business services, with several retail industries sitting atop the NRCA rankings in 2018 (**Figure 20**).

Figure 19. New Revealed Comparative Advantage by Broad Aggregate Sector, Malaysia, 2000-2018

Source: ADB estimates based on WWZ (2018) using ADB-MRIO (2000, 2007-2018).

Figure 20. Sectoral NRCA Ranking, Malaysia, 2000, 2007, and 2018

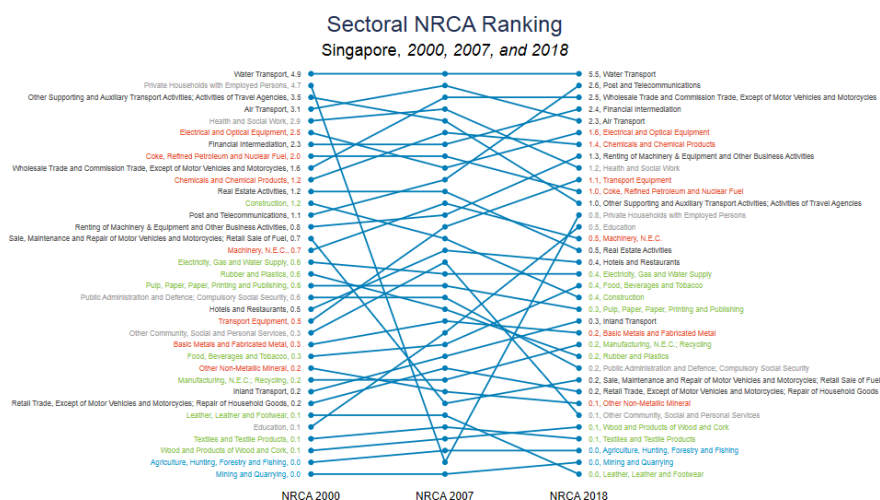Source: ADB estimates based on WWZ (2018) using ADB-MRIO (2000, 2007-2018)

Singapore had a comparative advantage in the business services and medium- to high-technology manufacturing sectors for most of the periods considered (**Figure 21**). In fact, the former consistently had a NRCA index above 1 and even exhibited some growth. Looking at a more disaggregated level displays the relative consistency in terms of international trade competitiveness of the economy's industries (**Figure 22**).

Figure 21. New Revealed Comparative Advantage by Broad Aggregate Sector, Singapore, 2000-2018

Source: ADB estimates based on WWZ (2018) using ADB-MRIO (2000, 2007-2018).

**Figure 22. Sectoral NRCA Ranking, Singapore, 2000, 2007, and 2018**

Source: ADB estimates based on WWZ (2018) using ADB-MRIO (2000, 2007-2018)
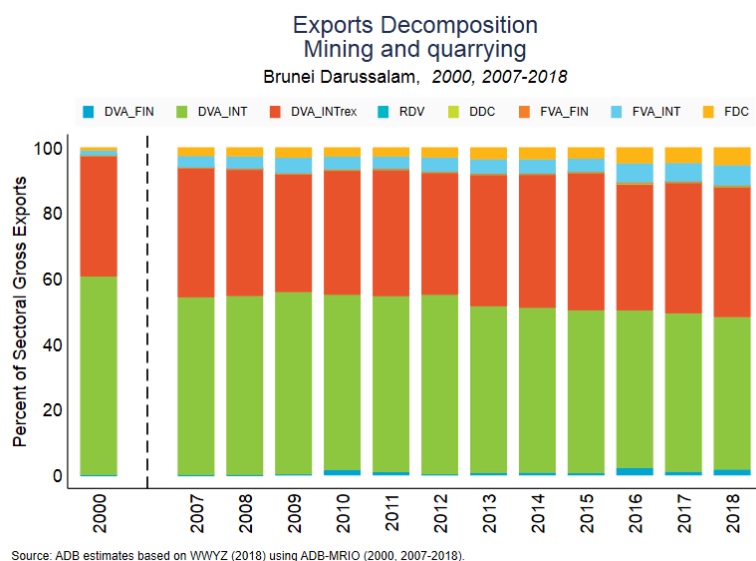
3.4 WWZ Decomposition

Decomposing Brunei's gross exports shows that most of the value-added contributions came from domestic sources but that there was a gradual decline in the dominance of DVA over time, accompanied by an increasing share of FVA to total gross exports (**Figure 23**). While the shares of PDC stayed low, it had an upward time trend, indicating that the economy slowly increased the intensity of its cross-border production sharing activities throughout the years considered.

Figure 23. Gross Exports Decomposition, Brunei, 2000-2018

Exports Decomposition
Brunei Darussalam, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
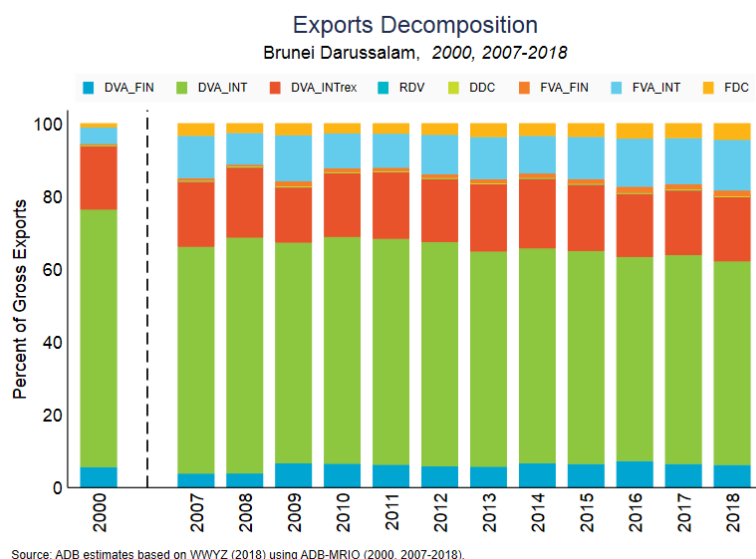
We also see in **Figure 24** that value-added in Brunei's gross exports came mostly from intermediates. DVA_INT and FVA_INT followed the same pattern as DVA and FVA, while DVA_INTrex had shares that stayed within a narrow range of values (15-20%), suggesting a relatively steady degree of involvement in global production chains. Lastly, since the combined shares of DVA_FIN and DVA_INT were considerably higher compared to DVA_INTrex, it is reasonable to posit that Brunei's trade activity during these years was more bilateral than multilateral.

Figure 24. Gross Exports Decomposition, Mining and Quarrying, Brunei, 2000-2018

Exports Decomposition
Mining and quarrying
Brunei Darussalam, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Two potential culprits behind the steady fall in domestic backward linkages of gross exports are the persistent yet lessening dependence of the economy on the primary sector - particularly oil and gas and directly related industries - as well as its pursuit for diversification. For the former, three scenarios could result in lower shares of DVA and DVA_INT as well as higher concentrations of FVA and FVA_INT. First, oil and gas are used as intermediates across various sectors, which means that if there so happens to be a lessened domestic reliance on these products and given relatively fixed technology over adjacent years, they have to be sourced elsewhere (i.e. abroad) to keep production steady.

Second, assuming the volume of domestic oil and gas production is unchanged, firms comprising these industries could have resorted to more cost-effective inputs to production supplied by other foreign economies. Third, keeping the same assumption on constant volume, the shares of DVA and DVA_INT could have gone down as a result of plunging oil prices even without altering the distribution of use between domestic and foreign inputs[10]. As seen in **Figure 24**, the patterns observed in the trade structure of Brunei as a whole were actually reflected in the mining and quarrying sector, with FVA slowly infiltrating gross exports.

To compensate for economic losses brought about by oil price changes, sourcing income from other sectors could also have taken place in Brunei, which brings us to the case of diversification. The primary sector is associated with higher levels of DVA as its products usually appear in earlier stages of value chains. Thus, a gradual move away from oil and gas to goods and services that appear in later stages of production could have resulted in decreasing levels of DVA and DVA_INT over time, especially if higher volumes of foreign intermediates are used relative to the primary sector.

As seen in **Figure 25**, for the light manufacturing sector, DVA considerably went down over the years – from almost 90% in 2000 to around 50% in 2018. FVA, on the other hand, increased and had some of its highest shares starting 2016. PDC also went up to as high as 10% in 2018, suggesting that the sector became more involved in complex GVC activities. The value-added contributions to gross exports of final goods outweighed that of intermediates, although this became less obvious over time, driven mostly by the continued increase of FVA_INT's shares.

**Figure 25. Gross Exports Decomposition, Light Manufacturing, Brunei, 2000-2018**

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

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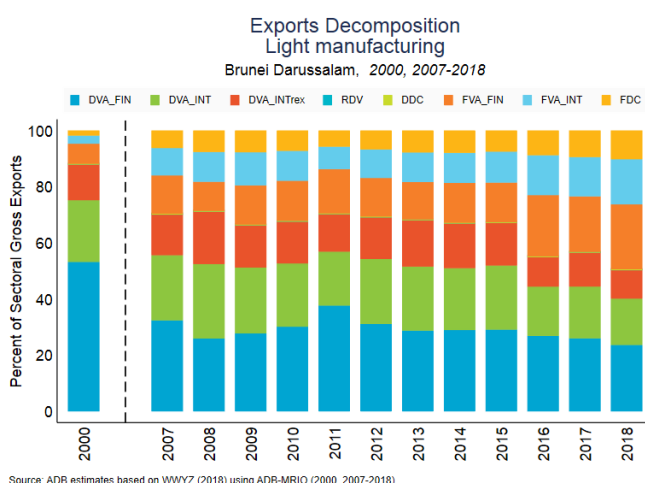
[10] See Appendix B for a simple mathematical demonstration

Since industries that fall under the light manufacturing sector have relatively short production lengths, it is no surprise that we see more DVA_FIN and FVA_FIN in gross exports compared to the economy as a whole. Note that a higher share of DVA_FIN could mean that an economy processes raw materials of its own while a higher FVA_FIN could mean that an economy processes raw materials from abroad. However, production lengths within this sector are not limited to two stages (i.e., extraction then processing) so it is still possible for processed raw materials to be used as intermediates elsewhere. Looking at the evolution of the structure of gross exports tells a story of a sector that gradually diverted its attention to the export of intermediates, which increasingly used foreign products.

With regard to heavy manufacturing, the low concentration of DVA_FIN coupled with the high shares of DVA_INT and DVA_INTrex indicates that the sector supplied intermediates that mostly used locally-sourced inputs (**Figure 26**). This is understandable since the sector contains industries that directly manufacture raw materials from the mining and quarrying sector which are used mostly for industrial purposes. Unlike heavy manufacturing, the construction sector had more value-added contributions from final exports than intermediates, which is expected as its output included residential, commercial, and industrial structures. FVA and FVA_FIN slowly took over some of the shares of DVA and DVA_FIN, which suggests that more foreign-sourced inputs were used over time.

**Figure 26. Gross Exports Decomposition, Heavy Manufacturing, Brunei, 2000-2018**
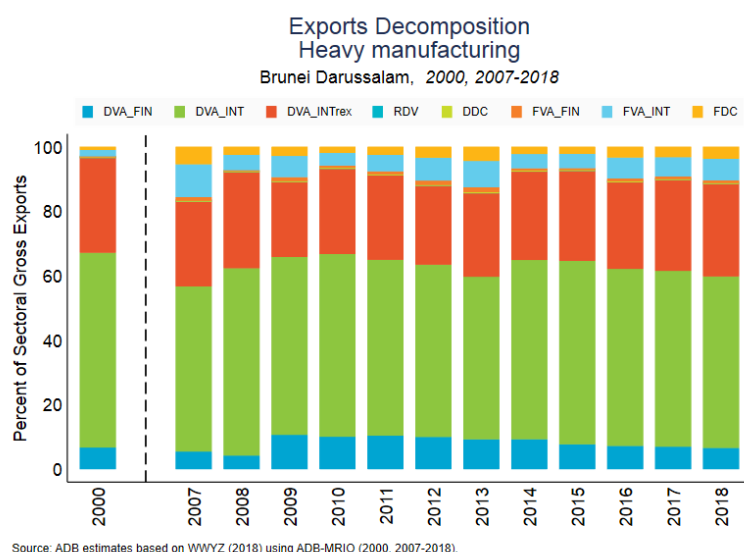
Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

The gross exports of Brunei's business services sectors were also dominated by domestic sources of value-added as seen in **Figure 27**. However, similar to the primary and manufacturing sectors, FVA increased over time, with some shares more than quintupling (though this is a function of small initial shares). Trade came mostly in the form of intermediates as foreign companies used domestic services for their own business or industrial purposes – the obvious exception being hotels and restaurants. **Figure 27** also shows that sectors that fall under personal and public services also had dominant yet decreasing shares of DVA but, in contrast to the business services sectors, their gross exports derived more value from final services than

intermediates – except for a few years after the GFC when there was a spike in the share of intermediate exports.

Figure 27. Gross Exports Decomposition, Services Sectors, Brunei, 2000-2018

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
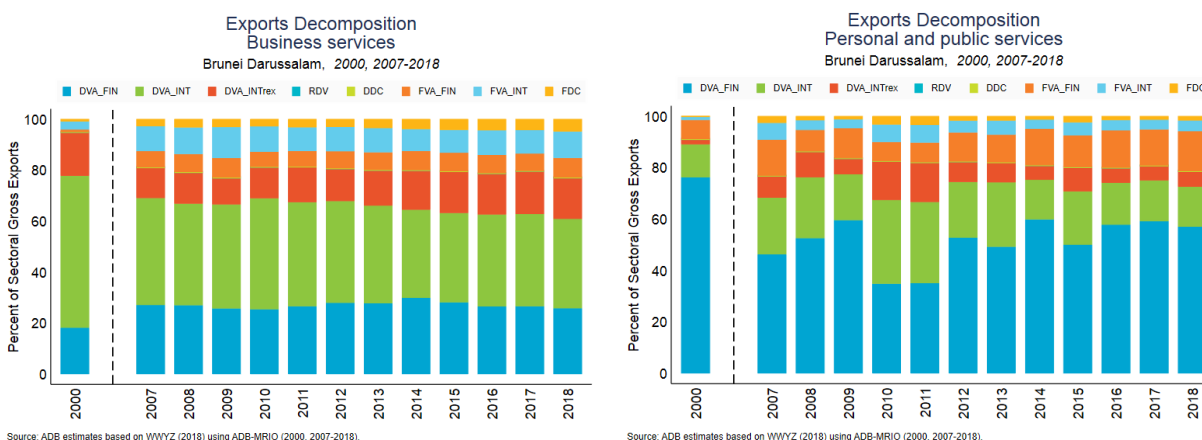
Overall, though Brunei's reliance on domestic sources of value-added remained persistent, the results suggest that the economy gradually welcomed more foreign sources over time as a response to lower oil prices and its diversification objectives. Throughout the years considered, we saw lesser shares of DVA regardless of composition – i.e., whether they were mostly comprised of intermediates or final goods and services. This increased openness coincided with increasing involvement in multilateral production sharing activities, as evidenced by gradual increases in double counted terms.

It is clear that domestic sources of value-added became more central to Malaysia's gross exports from 2000 to 2018 (**Figure 28**). As a result, FVA in gross exports exhibited a downward trend, whether it be in the form of intermediates or final goods and services. Trade in intermediates contributed the most in terms of value-added and while the combined share of DVA_FIN and DVA_INT remained high, DVA_INtrex had an increasing share indicating more multilateral trade relations.

Figure 28. Gross Exports Decomposition, Malaysia, 2000-2018

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
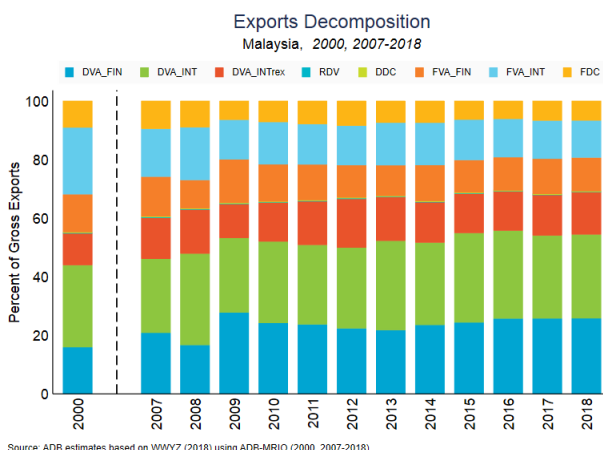
It is important to look at the performance of Malaysia's heavy manufacturing sector from the perspective of gross exports as it contains the electronics industry, which is widely recognized as one of the economy's top sources of income. We see from **Figure 29** that in earlier years, foreign sources of value-added had majority of the shares of the sector's gross exports before eventually being overtaken by domestic sources – with shares of DVA going beyond 50% since 2015. It might also be worth noting that PDC had its highest share of around 21% during the GFC.

Figure 29. Gross Exports Decomposition, Heavy Manufacturing, Malaysia, 2000-2018

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
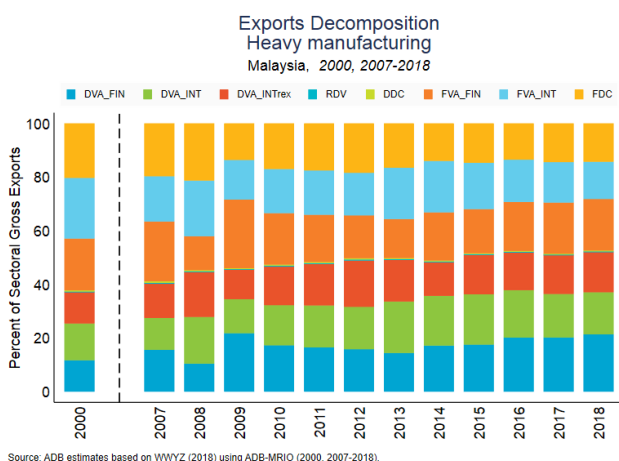
Throughout the years studied, the composition of the heavy manufacturing sector's gross exports between final and intermediate exports remained relatively even. The gradual rise in exports of final products and fall intermediate exports absorbed by the direct importer has been offset by an increase in DVA_INTrex. Thus, even if final exports increased at a bilateral level, more trade in intermediates occurred at multilateral level, which ultimately kept the shares between final and intermediate exports even.

Since there is no clear dominant source of value-added in the gross exports of the sector, it could be said that Malaysia was involved in different levels of the global production chain for heavy manufacturing. If we're looking at the electronics industry, for example, the results suggest that domestic industries produced electrical components and assembled electrical equipment at the same time, which would explain why the value-added composition of gross exports was more or less even for intermediates and final products. On the other hand, the rise in the share of DVA_INTrex, coupled with relatively high shares of double counted terms, could mean that electrical components manufactured by Malaysia found their way to longer and more complex production processes or that they began holding more value over time. The obvious presence of foreign value-added is also partly explained by the numerous layers of production involved in heavy manufacturing. Lastly, by looking at **Figures 28 and 29**, we can see that the structure and observed patterns of value-added in the heavy manufacturing sector of Malaysia looked quite similar to the economy as a whole, suggesting a dominance on overall country exports by the sector.

The construction sector is also recognized to play a substantial role in the Malaysian economy. From **Figure 30**, we see that the sector's gross exports also derived most of its value from domestic sources and this became more pronounced over time with the share of DVA reaching

almost 70% in 2018. Interestingly, most of the value-added contributions came from intermediates, which suggest that there were more purchases of construction services than physical structures by other economies. In fact, DVA_FIN had its lowest shares in more recent years, contrasted by peaks in shares of DVA_INT as well as DVA_INTrex. The composition of foreign sources of value-added, on the other hand, were more or less even in the years studied.

Figure 30. Gross Exports Decomposition, Construction, Malaysia, 2000-2018

Exports Decomposition
Construction
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
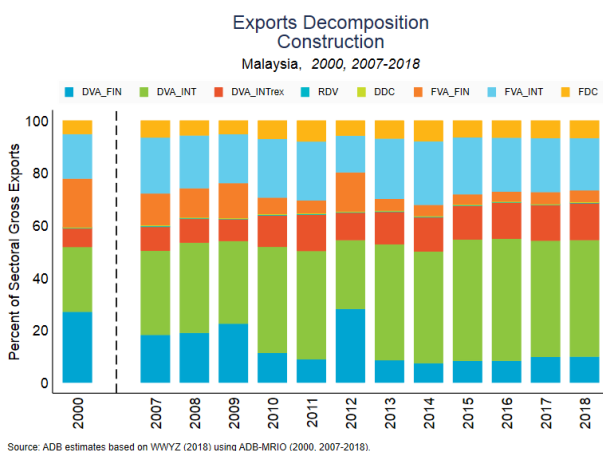
Gross exports of Malaysia's agriculture, hunting, forestry, and fishing sectors benefited more from domestic sources of value-added compared with the entire economy and even the manufacturing sectors (**Figure 31**), which is expected given its wealth of natural resources. When looking at patterns or trends, there are noticeable structural shifts that occurred over time. In the early 2000s, trade came mostly in the form of intermediates until the share of DVA_FIN started to increase to as much as 30-40% from 2009-2015. From 2016, however, DVA_FIN decreased considerably before once again increasing in 2017, then falling to its lowest recorded share of around 4% in 2018. The same patterns can be seen when looking at FVA_FIN and FVA_INT. Lastly, a rise in the shares of DVA_INTrex occurred over time which signifies stronger forward linkages with global value chains.

Figure 31. Gross Exports Decomposition, Agriculture, Hunting, Forestry, and Fishing, Malaysia, 2000-2018

Exports Decomposition
Agriculture, hunting, forestry, and fishing
Malaysia, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
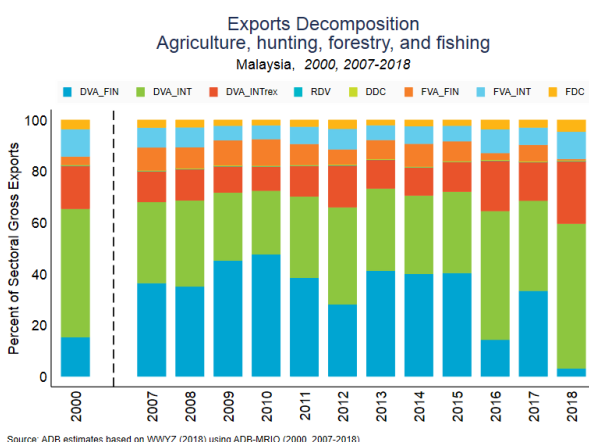
With regard to Malaysia's services sectors, the same trend of increasing dependence on domestic sources of value-added were observed throughout the years. With the exception of the hotels and restaurants sector, most foreign purchases of business services were done for industrial – rather than personal – purposes, evidenced by the higher concentration of value-added from intermediates. For most of these sectors, DVA_INTrex increased especially for more recent years, implying that even business services sectors were part of complex global production processes. As for the personal and public services sector, foreign purchases seemed to be less motivated by industrial purposes as trade in intermediates outweighed trade in final services. The results of decomposition of gross exports from the services sectors are presented in **Figure 32**.

Figure 32. Gross Exports Decomposition, Services Sectors, Malaysia, 2000-2018

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
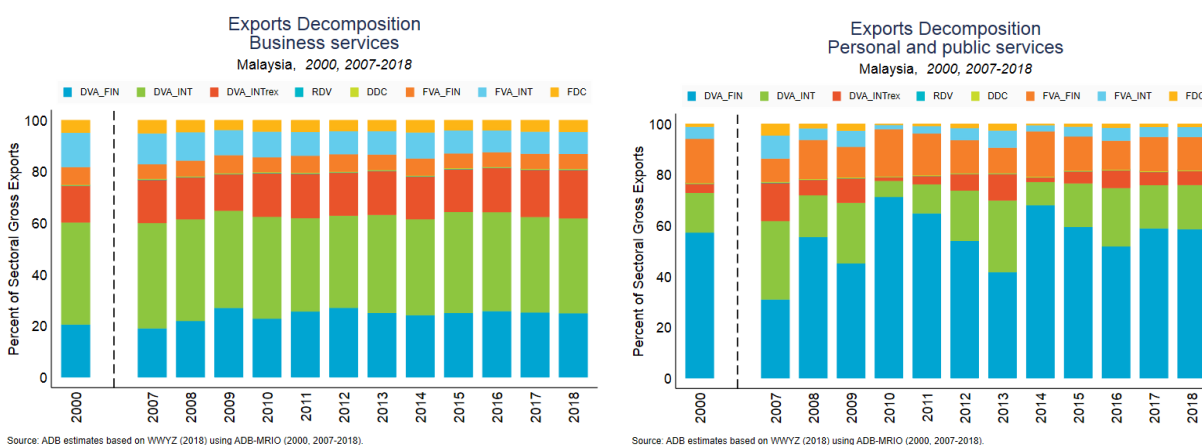
Overall, decomposing Malaysia's gross exports reveal that value-added contributions mostly came from domestic sources. This pattern became increasingly apparent over time and was shared among the primary, manufacturing, and services sectors. The structure and pattern of the overall economy's exports were very similar to those observed for the heavy manufacturing sector, which contains a key source of domestic income in the electronics industry. However, the breakdown in shares between intermediate and final exports of this sector were more even compared to the whole economy, the argument being that heavy manufacturing is characterized by multiple layers of production that operate in a global scale. Lastly, we see that Malaysia gradually increased its involvement in multilateral trade with the shares of DVA_INTrex having gone up over the years studied.

Applying WWZ decomposition in analyzing Singapore's gross exports reveal a steady structure at the 3-term level, i.e. DVA, FVA, and PDC (**Figure 33**). Shares of DVA in gross exports were highest among the three – ranging about 50-57% across the years, followed by FVA, and PDC. Going deeper into the trade structure also shows a relatively steady distribution of shares but with increased volatility, albeit within a narrow range of values. Intermediate exports contributed more in terms of value-added compared to final exports but no clear trends are seen in their components aside from the presence of extreme values during the GFC. DVA_INT had its lowest share during the crisis while FVA_FIN had its highest during this period, which could mean that Singapore sourced more foreign intermediates during the GFC, which led to higher foreign content of final exports, assuming that these used the former as inputs to production.

Figure 33. Gross Exports Decomposition, Singapore, 2000-2018

Exports Decomposition
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
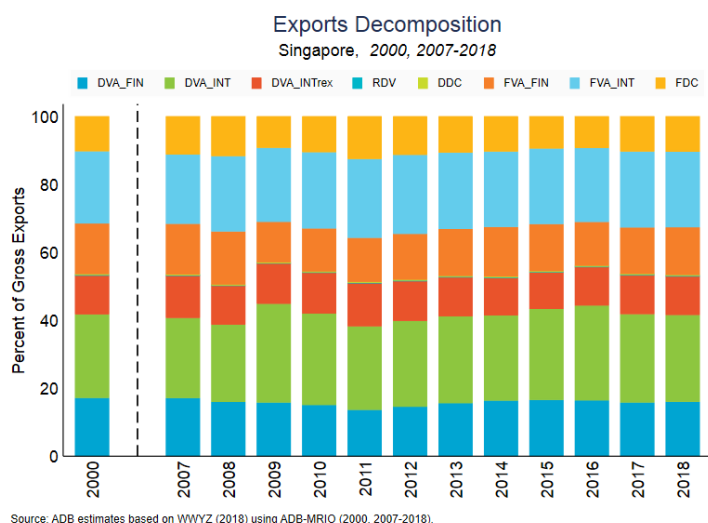
Singapore is known for manufacturing electronic, chemical, and biomedical products, while also being recognized as a hub for oil trading and export refinement, thus making it crucial to look at the economy's trade performance when it comes to heavy manufacturing (**Figure 34**). Based on our results, one of the first things to note is that the sector had unusually high shares of PDC, which implies that it was intensively involved in cross border production sharing activities. We also see that the value-added shares of intermediate and final exports were relatively even throughout the years.

Figure 34. Gross Exports Decomposition, Heavy Manufacturing, Singapore, 2000-2018

Exports Decomposition
Heavy manufacturing
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
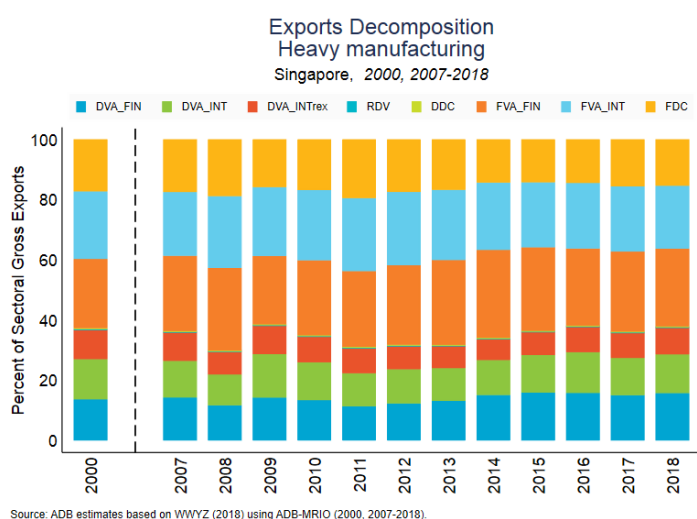
Next, even if heavy manufacturing contains some of Singapore's key industries, we still observe that the sector was more reliant on foreign inputs. There are three possible reasons for this. First (and most obvious) is the dearth of natural resources that characterizes the economy. Thus, unlike Brunei and Malaysia which source raw materials domestically, Singapore has to import

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these and, given that they appear in various production processes as well as their high industrial linkages, it is reasonable to expect high content of foreign value-added in exports. Second, it is important to note that Singapore is also characterized by its free-market policies and openness to trade, which paved the way for a sizeable number of foreign products to enter the economy. Lastly, the sector is associated with various layers of production and use of intermediates, both of which are not limited to a domestic context.
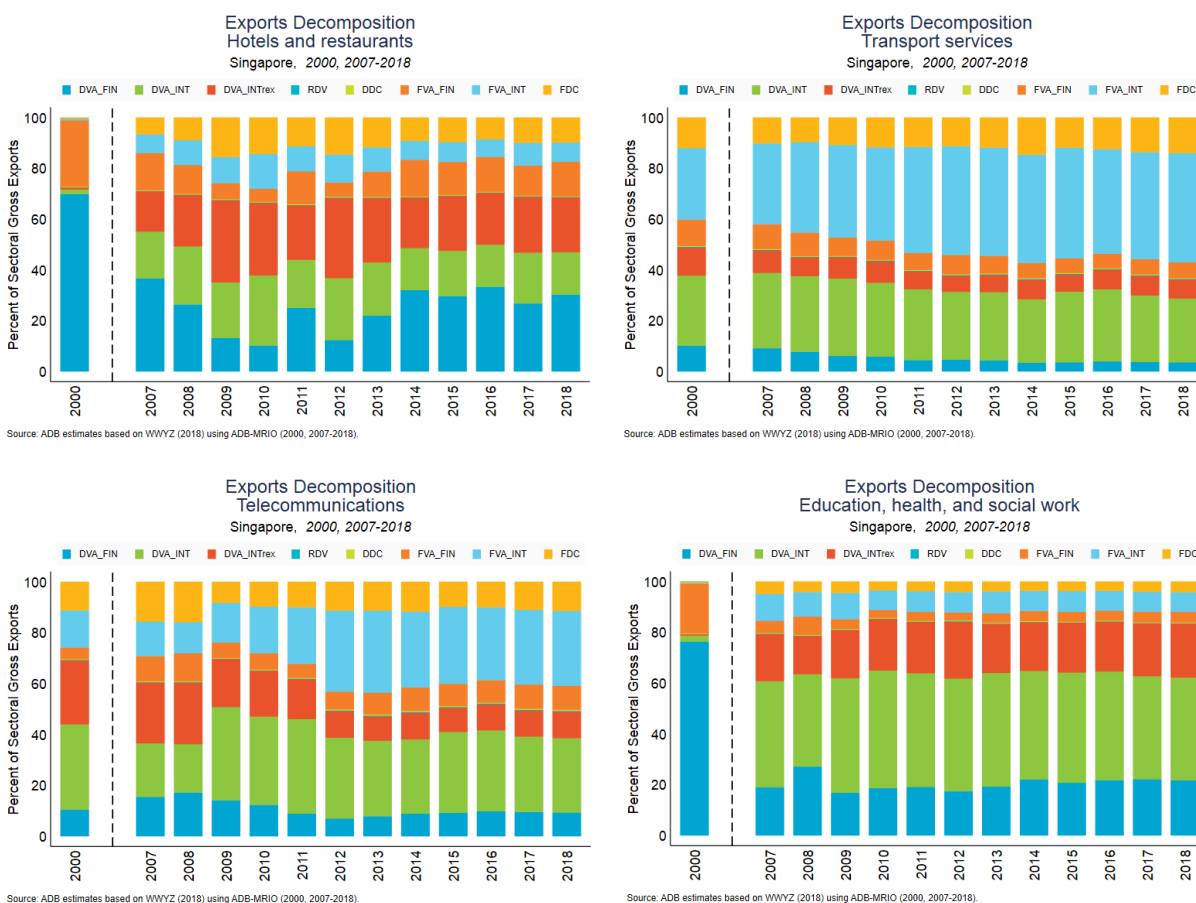
Singapore is also known for its high-quality services sectors, making it worthwhile to dissect the structure of gross exports of sectors that offer financial intermediation, tourism-related services, telecommunications, as well as education and health. Being a global financial center, it is no surprise that the financial intermediation sector's gross exports mostly derived value from domestic sources (up to as high as 80% in 2000). However, recent data showed that more foreign content was present during latter years (values above 23% in the late 2010s). The sector mostly catered to industries, evidenced by higher shares of intermediates as seen in **Figure 35**. Lastly, the results suggest that the sector was impacted by the GFC given the trends exhibited in the components of DVA and FVA. DVA_FIN was higher during the GFC years and has since stabilized at around 13 to 17% starting 2010. DVA_INT fell from around 45% in 2000 to about 37% during the financial crisis and went back to its initial levels in 2009 at around 38-42%, albeit with noticeable fluctuations. DVA_INTrex was highest in 2000 (18%) and since then stayed within 13-15%. FVA_FIN peaked during the GFC (8%) before falling in 2009 and gradually increasing to 7% in 2017 and 2018. FVA_INT had an initial value of 11%, peaked at almost 17% in 2011, and gradually declined and stabilized at around 16-17% in most recent years.

Figure 34. Gross Exports Decomposition, Financial Intermediation, Singapore, 2000-2018

Exports Decomposition
Financial intermediation
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).
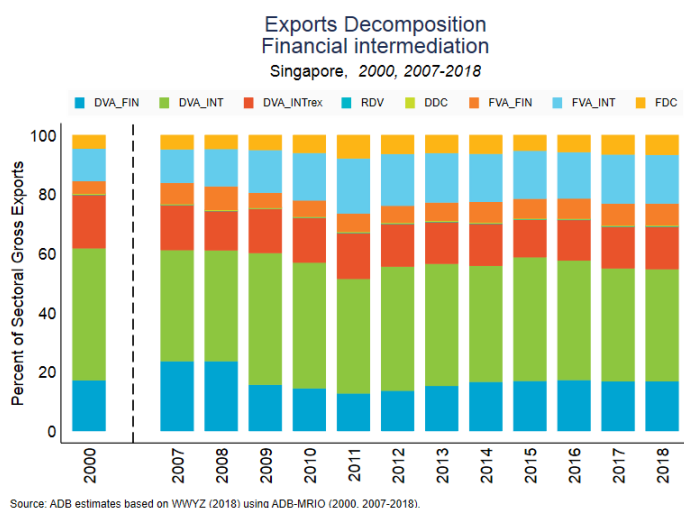
Gross exports of the hotels and restaurants as well as the transport services sectors also derived most of their value from domestic sources. There were more exports in intermediates than final services for the hotels and restaurants sector, which means that the sector served more clients for personal, rather than business or industrial, purposes, while the opposite can be said for the transport services sector. Both telecommunications and education, health, and social work sectors benefited mostly from backward domestic linkages when it came to services to foreigners, with a higher concentration of intermediates compared to final services, especially in most recent years (**Figure 35**).

Figure 35. Gross Exports Decomposition, Other Services Sectors, Singapore, 2000-2018

Exports Decomposition
Hotels and restaurants
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Exports Decomposition
Transport services
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Exports Decomposition
Telecommunications
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Exports Decomposition
Education, health, and social work
Singapore, *2000, 2007-2018*

Source: ADB estimates based on WWYZ (2018) using ADB-MRIO (2000, 2007-2018).

Overall, even though majority of Singapore's gross exports' value-added came from domestic sources for all years considered, its shares of DVA were lowest among the three countries studied. As pointed out above, this may have resulted from the economy's weak reliance on the domestic primary sector as well as its policies that advocate free trade and openness.

4. Conclusion

This paper looked into different aspects of global value chains through the application of cutting-edge methods on multi-regional input-output tables, with particular focus on the interconnected economies of Brunei, Malaysia, and Singapore. These economies exhibited inter-sectoral shifts in the composition of exports as well as intra-sectoral changes in GVC participation. In terms of the latter, Singapore led the three countries both in terms of forward and backward participation, driven mostly by its services sectors. Malaysia appeared to be less involved in trade as both of its backward and forward participation ratios fell over time, although its heavy manufacturing sector remained active in international trade. Results for Brunei, on the other hand, imply weakened intermediate supply links with its trends in backward and forward participation ratios having gone in opposite directions over time. Results for analyses of upstreamness supported the these observed patterns.

With regard to NRCA, Singapore's business services sectors remained competitive in the context of international trade across the years studied. Malaysia saw its NRCA indices for both the primary and medium- to high-technology sectors decline a few years after the GFC before gradually recovering. Being an oil-rich country, Brunei had a comparative advantage in the primary sector that exhibited a downward trend – due in part to the fall in global oil prices as well as policies supporting economic diversification.

Decomposing the countries' gross exports into value-added terms revealed that all of them benefitted mostly from domestic backward linkages but with varying levels. Brunei had the most dominant shares of DVA due to the persistent reliance on oil and natural gas production but this declined over time with an increased trade openness and involvement in multilateral production sharing activities. Malaysia's domestic sources of value-added in exports became increasingly apparent over time, albeit the heavy manufacturing sector – a key source of domestic income – having remained open to use of foreign intermediates. Lastly, Singapore had the lowest concentration of DVA in gross exports, which can be attributed to its dearth of natural resources and policies supporting both free trade and openness.

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Appendix A

Given that $\sum_{s=1}^{S}\sum_{j=1}^{J} a_{ij}^{rs} < 1$ for all $j - s$ pairs, Antràs and Chor (2018) show that the numerator of U_i^r is just the $((i-1) \times S + r)$-th element of the $J \times S$ by 1 column vector $[I - \mathbf{A}]^{-2}\mathbf{F}$, where $\mathbf{A}$ is a $J \times S$ by $J \times S$ matrix whose $((i-1) \times S + r, (j-1) \times S + s)$-th element is a_{ij}^{rs}, while $\mathbf{F}$ is a column vector whose $((i-1) \times S + r)$-th row is F_i^r. Furthermore, given that the $J \times S$ by 1 gross output column vector satisfies, $\mathbf{X} = [I - \mathbf{A}]^{-1}\mathbf{F}$, the numerator of U_i^r is also equal to the $((i-1) \times S + r)$-th element of the $J \times S$ by 1 matrix $[I - \mathbf{A}]^{-1}\mathbf{X}$.

Appendix B

To demonstrate, let's say that oil is indexed by 1 and that it only uses its own output as well as some foreign product (indexed by 2) as inputs. Thus, the share of DVA is given by:

$$DVA_{share} = \frac{DVA(p_1, v_d)}{DVA(p_1, v_d) + FVA(p_2, v_f) + PDC}$$

$$\frac{\partial DVA_{share}}{\partial p_1} = \frac{DVA_{p_1}[DVA(p_1, v_d) + FVA(p_2, v_f) + PDC] - DVA(p_1, v_d)DVA_{p_1}}{[DVA(p_1, v_d) + FVA(p_2, v_f) + PDC]^2}$$

Which will be less than zero if $DVA_{p_1}[DVA(p_1, v_d) + FVA(p_2, v_f) + PDC] - DVA(p_1, v_d)DVA_{p_1}$ is less than zero. Since $FVA(p_2, v_f)$ and PDC are nonzero the share of DVA goes down if $DVA_{p_1} < 0$, i.e., if DVA is a decreasing function of the price of oil. This simple demonstration assumes that volumes are unchanged and that the price of oil is exogenous to both domestic oil production, v_d, foreign production of inputs, v_f, and price of foreign inputs, p_2.