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Trajectory of Southeast Asian Production Fragmentation

David Christian and Lili Yan Ing

Economic Research Institute for ASEAN and East Asia (ERIA)

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Abstract: *This paper examines recent trends in production fragmentation within ASEAN's manufacturing sector in the context of shifting global trade dynamics and rising economic nationalism. Using the OECD's Trade in Value Added (TiVA) database, we construct two key indicators: (i) the input fragmentation ratio (FRI), which measures overall reliance on intermediate inputs, and (ii) the import fragmentation ratio (FRM), which captures the extent of cross-border input sourcing.*

Our analysis reveals that, unlike North America and Europe, ASEAN has not experienced a decline in input fragmentation since the Global Financial Crisis (GFC). However, signs of import defragmentation have emerged since 2010. We also find notable variation in fragmentation patterns across countries and industries. These results highlight the need for further research into the drivers of these trends, including investment and production relocation to ASEAN, market positioning, industry specialisation, and technological factors.

Keywords: production fragmentation, global value chains (GVCs), manufacturing in ASEAN and East Asia, supply chain resilience

JEL classifications: F14, F61, L23, O14

1. Introduction

From the early 1990s until the onset of the global financial crisis (GFC) in 2008, the world witnessed what is often referred to as the golden age of globalisation. This era marked a significant shift in the organisation of production, particularly within the manufacturing sector. One notable aspect of this rapid globalisation was the ability of firms to separate the stages of production for a specific product and carry them out independently in different locations worldwide, termed as the 'second unbundling' by Baldwin (2016). Production fragmentation (hereafter, fragmentation)[1] can be defined as the extent to which production processes are divided into discrete stages that are geographically distributed across a number of firms and/or countries for cost-efficiency purposes. The concept of production fragmentation fundamentally transformed the dynamics of international trade and production. A widely used example of fragmentation is the production of electronic products that extensively incorporate inputs and intermediate goods produced in several countries before being assembled in a specific location. In addition to significant tariff reductions, technological advancements in digital and information and communication technologies significantly reduced management, inventory, and logistics costs across different locations, which contributed to the emergence of regional and global value chains (RVCs and GVCs) from the late 1990s.

Latecomers to the global trade stage, such as China, Hong Kong, Singapore, the Republic of Korea (henceforth, Korea), and Taiwan, had an advantage – tapping into opportunities created by information and communication technology (ICT), as described by Baldwin and Forslid (2014) – and emerged as crucial hubs for global manufacturing production. This transformation in the global economic landscape prompted economists to delve into the study of multinational firms' behaviour in organising production on a global scale. Researchers have explored various aspects, such as firms' decisions on location selection, sourcing strategies for

[1] To preempt misguided interpretations, it is important to carefully delineate the conceptual differences between (i) production fragmentation (covered in this study) and (ii) geoeconomic fragmentation coined by IMF (2023) (not covered in this study). IMF (2023) defined geoeconomic fragmentation as the policy-driven reversal of international integration, influenced by strategic considerations, leading to increased segmentation of trade and investment flows amongst geopolitical blocs. While both concepts could imply geographically dispersed production, the most fundamental difference between production fragmentation and geoeconomic fragmentation is that the former is fueled by the pursuit of cost and economic efficiency in production, while the latter is driven by political and security reasons at the national or supranational level. As such, the trajectory of both types of fragmentation across time could well be driven by different sets of forces and may require distinct explanations. Our study focuses exclusively on production fragmentation, not geoeconomic fragmentation. Table A1 in the Appendix provides a more comprehensive comparison of both concepts of fragmentation.

inputs, and specialisation in different production stages. Key contributions to this field include works by Hummels, Ishii, and Yi (2001), Antràs (2003), Antràs and Helpman (2004), Markusen (2005), Grossman and Rossi-Hansberg (2008), Johnson and Noguera (2012), Antràs and Chor (2013), and Baldwin and Venables (2013).

Globalisation, often characterised by tariff reductions and investment liberalisation, enables the free movement of capital, goods, and services, prompting firms to prioritise cost minimisation. This process has fuelled the rise of GVCs, where production processes are fragmented across various stages and locations worldwide. The expansion of GVCs has led to a significant increase in the fragmentation of production in the manufacturing sector, as companies strategically distribute production across regions to leverage cost advantages such as lower labour costs or specialised resources. As GVCs grow in both reach and complexity, production is increasingly spread across diverse locations, maintaining high levels of fragmentation in manufacturing production (Baldwin, 2016; Gereffi, 2018). This geographical dispersion allows firms to optimise efficiency, though it also introduces challenges in coordination and supply chain management.

Globalisation, while driving economic growth and enhancing global interconnectedness, has also resulted in unintended consequences, with the most significant being the growing inequality observed both within and across nations, affecting both developed and developing economies. These disparities have sparked widespread backlash against globalisation, particularly in recent years. Since the global financial crisis (GFC), the momentum of globalisation has noticeably slowed. As global trade and integration have decelerated, protectionism and industrial policy have made a strong resurgence. Many countries have increasingly turned to these measures to shield domestic industries and safeguard national interests, further challenging the open-market principles that once defined globalisation.

In recent times, particularly since the beginning of the first Trump administration in 2017, geopolitical and geoeconomic tensions between the United States (US) and China have intensified, contributing to the rise of economic nationalism, often driven by national security concerns.

Spurred by the coronavirus disease (COVID-19) pandemic and advancements in digital technologies, there has been increasing momentum to shorten or renationalise supply chains to bolster their resilience during times of crisis. This shift presents a potential challenge to existing global production sharing frameworks, particularly as pressure mounts to relocate certain production activities closer to the largest economies in North America and Europe. As a result, there has been growing evidence of defragmentation – characterised by a decline in the

fragmentation of production networks – taking place across major manufacturing countries and regions, including North America, Europe, and East Asia, particularly China (Baldwin, 2024; Miroudot, 2021; Timmer et al., 2021). Indeed, Ing and Grossman (2023) emphasised how the recent re-emergence of local content requirements (LCRs) around the world since the GFC is often driven by natural security concerns and aspirations to increase domestic value added. This trend highlights the broader tension between the efficiency-driven logic of global production fragmentation and the resilience-focused push for more localised supply chains.

Why is it important to study the patterns of production fragmentation? Because changes in the fragmentation level of production reflect and influence the dynamics of various economic processes, bringing potentially substantial micro and aggregate implications through at least the following three channels. First, fragmentation of production generates efficiency gains from specialisation, competition, knowledge and technology diffusion, productivity growth, and economies of scale. Any reversals in the fragmentation process, especially if accompanied by protectionist policies, may reduce such gains and increase the marginal cost of production. Second, since the degree of fragmentation strongly reflects firms' optimal production decision from the geographical standpoint (i.e. what and how much to produce where?), changes in the fragmentation level also affect relative factor prices, with potential impact on demand for labour at various skill levels, wages, inequality, and ultimately welfare in different countries.[2] Third, cross-border fragmentation of production can have a potentially significant welfare implication from the perspective of supply chain risk management and diversification strategies. Some recent studies have found that having a more diversified set of foreign suppliers would allow countries to become more resilient to domestic or regional shocks compared with a very defragmented scenario where the entire supply chain is purely carried out locally behind the border (Bonadio et al., 2021; OECD, 2021).

Given the relevance of fragmentation and having observed defragmentation in East Asia, particularly in China, this study will examine whether the trend of defragmentation in manufacturing production is also occurring in the Association of Southeast Asian Nations (ASEAN) and whether this defragmentation is cross-border in nature. ASEAN is one of the major manufacturing hubs, after countries such as China, the US, Germany, Japan, and Eastern Europe. With its 670 million population, it is also one of the largest consumer markets when considered as a single entity. ASEAN serves as a major trading partner for some of the

[2] Cross-border fragmentation of production involves international trade in intermediate inputs, which according to Feenstra (1998) tend to drive changes in employment and wages more intensively than trade in final goods.

manufacturing powerhouses in the region, such as China, Japan, and Korea. Similarly, ASEAN uses a significant number of intermediate inputs from top manufacturers in East Asia to fuel its manufacturing production. Therefore, any changes in the organisation of production in ASEAN, as represented by the trend in fragmentation, could have significant consequences and are worth investigating.

The paper has the following structure. Section 2 explains the measures of fragmentation. Section 3 presents the preliminary findings on ratios of fragmentation in ASEAN. Section 4 provides rationales on the recent defragmentation. Section 5 concludes and draws conclusions.

2. Measures of Fragmentation

We employ two measures to observe fragmentation and defragmentation, each corresponding to a distinct type of fragmentation. Both measures are calculated directly from the Organisation for Economic Co-operation and Development (OECD) Trade in Value Added (TiVA) database.[3] The latest edition of the OECD TiVA database is 2023, covering data on 76 economies worldwide (including all 10 ASEAN Member States (AMS)) and 45 economic sectors from 1995 to 2020. The TiVA database is based on the OECD's Inter-Country Input-Output Tables and contains several indicators on value added, production, and flows of goods and services. This database provides deeper insights into global production networks and supply chain activities.

Fragmentation Measure 1: Input Fragmentation Ratio (FRI)

$$Input\ Fragmentation\ Ratio = FRI = \frac{Intermediate\ Input\ Cost}{Gross\ Output} = \frac{PROD - VALU}{PROD} 100$$

The first measure of fragmentation used in our study is what we call **input fragmentation ratio (FRI)**, following the construction of Baldwin (2024). Input fragmentation is measured as a ratio between total intermediate input costs and total output. This ratio can be measured at the country, regional, and sectoral level (including manufacturing). One of the accounting identities employed in the TiVA database construction is that gross output consists of only value added and intermediate input costs. Thus, by definition, the share of output not coming

[3] Several input–output databases are potentially useful for studying the fragmentation of production in the context of our study. These include the World Input-Output Database, the Asian Development Bank Multiregional Input-Output Tables, and the United Nations Conference on Trade and Development-Eora GVC Database, as well as the OECD TiVA. However, to cover the most recent data period while including as many sectors and countries as possible (and all countries in the ASEAN and East Asia region), we employ the OECD TiVA database to construct our fragmentation measures.

from value added must equal total intermediate input costs. By that logic, we construct FRI by having gross output (indicator *PROD* in TiVA) minus total value added (indicator *VALU* in TiVA) as the numerator, and the gross output (*PROD*) as the denominator. We multiply the resulting number by 100, and this ratio should therefore range from 0 to 100.

Intuitively, input fragmentation, represented by FRI, measures how much intermediate inputs need to be sourced from elsewhere for a given production level. The higher the FRI, the higher the share of intermediate input costs in production. A higher FRI value points to higher input fragmentation in production (more fragmented production), where producers must rely more heavily on intermediate inputs from other producers elsewhere, whether domestic or foreign or both. In fact, an FRI of 100 would indicate perfectly fragmented production, where all output is produced by only using intermediate inputs and zero value added. In contrast, a lower FRI value points to lower input fragmentation in production (less fragmented production), in which fewer intermediate inputs are required from elsewhere (and may indicate that more intermediate inputs are self-produced) to produce a given level of output. An FRI of 0 would indicate perfectly defragmented production, where self-sufficient producers use zero intermediate inputs from elsewhere.

Crucially, however, one of the important limitations of the FRI measure is its inability to distinguish between imported intermediate inputs and domestically sourced inputs in production. While it is a good estimate to measure the level of production fragmentation, against domestic value added, we cannot really examine whether this fragmentation has a cross-border nature and its subsequent implications. FRI alone cannot exhibit changes (over time) in the relative importance of *imported* intermediate inputs for domestic manufacturing production, which is also an important feature we seek to uncover in our study. Thus, in this study, we propose a second fragmentation measure that involves information on imported intermediate inputs.[4]

Fragmentation Measure 2: Import Fragmentation Ratio (FRM)

$$Import\ Fragmentation\ Ratio = FRM = \frac{Imported\ Intermediate\ Inputs}{Gross\ Output} = \frac{IMGR\_INT}{PROD}100$$

[4] We acknowledge that we are not the first to have identified the need for an import-based measure to analyse fragmentation of production. For example, Miroudot (2021) examined the fragmentation trend in East Asia using an import intensity index of intermediate products from the World Input-Output Database. Timmer et al. (2021) introduced a novel supply chain fragmentation ratio that sums the volume of imports by all countries participating in a particular supply chain using the same database.

We define **import fragmentation ratio (FRM)** as a ratio between the value of imported intermediate inputs and the gross output. As before, the ratio can be measured at the country, regional, and sectoral level. In the TiVA database, we construct FRM by dividing the gross imports of intermediate inputs (indicator *IMGR_INT* in TiVA) by the total gross output (indicator *PROD* in TiVA) and then normalising it by 100. This ratio should typically range from 0 to 100, similar to the FRI. While we designate this as a measure of *import fragmentation*, it is important to emphasise that what we mean by *import* in this context is *imports of intermediate products* – not all imports.

Intuitively, import fragmentation, represented by FRM, measures how many imported intermediate inputs must be purchased from other countries to achieve a given production or output level. The higher the FRM, the more imported intermediate inputs are required to produce US$1 worth of output. A higher FRM value points to higher import fragmentation in production (i.e. more fragmented production across borders), where producers supply more intermediate inputs from foreign producers relative to the output level. Conversely, a lower FRM value points to lower import fragmentation in production (i.e. less fragmented production across borders), where fewer imports of intermediate inputs are purchased from abroad to produce a given output level. In some cases, this may imply that more intermediate inputs used in the production are produced domestically. An FRM of 0 would indicate completely domestic production, where domestic producers import none of the intermediate inputs they use in production.

We are aware of an argument calling for caution when using gross terms of trade indicators in trying to measure the level of foreign exposure of supply chains. For instance, Baldwin and Freeman (2023) argued that the use of gross data instead of value added-based data may misrepresent the magnitude and geographic location of where the value added takes place, primarily due to the possibility of double-counting occurring in the recording process of gross data (e.g. gross imports). This is especially pertinent in a GVC world, where semi-finished goods may cross borders multiple times at various stages within the production process. On top of that, gross imports may overstate the magnitude of imports as they contain domestic value added embodied in gross imports that the domestic country may have contributed during previous stages of production. Fortunately, the TiVA database contains an indicator representing this, which it calls *IMGR_DVASH* or share of domestic value added in gross imports. However, upon inspecting the TiVA data, we find that the *IMGR_DVASH* value is relatively tiny amongst Southeast Asian countries, ranging from 0 to 1.4% from 1995 to 2020,

with an average of 0.3% during this period. Thus, we consider it unlikely that this will significantly affect our FRM measure.

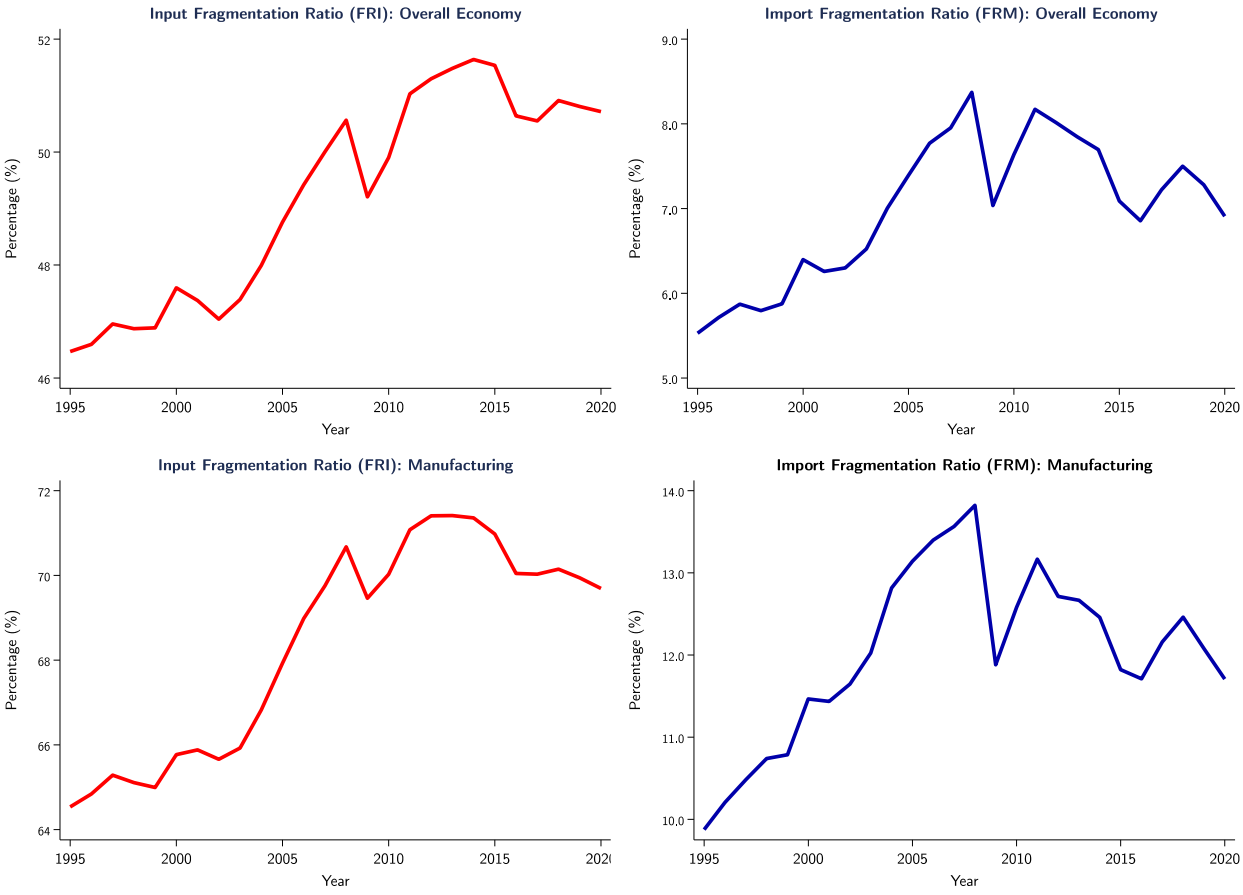
In the subsequent analysis, we will employ both measures of fragmentation (FRI and FRM) to illustrate a more comprehensive picture of the recent trend surrounding the nature of fragmentation in Southeast Asia's manufacturing sector, and whether they show any marked deviations from the trends observed globally and in major manufacturing hubs elsewhere.

3. Preliminary Findings

This section presents preliminary findings that consist of graphical plotting of the trends in both FRI and FRM, comparing them across major regions in the world, including ASEAN. We pay particular attention to the manufacturing sector and the trajectory of fragmentation levels in the 2010s, in the aftermath of GVC, up until 2020. We first present the global trend and briefly compare the trajectory of fragmentation in some important manufacturing regions worldwide, before zooming in on ASEAN's manufacturing sector. To enhance comprehension, throughout our analyses, plots of input fragmentation (FRI) are red, while those of import fragmentation (FRM) are blue.

Figure 1 exhibits the trajectory of both input and import fragmentation ratios in the world economy, including the manufacturing sector. It shows that globally, the world economy has clearly undergone a pattern of defragmentation since around the early 2010s. The world economy in general has experienced both input and import defragmentation. The same pattern is also reflected in the manufacturing sector, which has seen its fragmentation ratios falling since the early 2010s. Input fragmentation in manufacturing peaked globally in 2013, when 71.4% of outputs consisted of purchases of intermediate inputs. That figure fell to 69.7% in 2020. Import defragmentation, on the other hand, seems to kick off even earlier, with FRM for global manufacturing peaking at 13.8% in 2008, just prior to the GFC and the ensuing so-called great trade collapse. The same FRM figure was 15% lower in 2020, standing at just 11.7%. This indicates that world manufacturing production, overall, relied less on intermediate inputs (including imported intermediate inputs) in 2020 compared with the early 2010s.

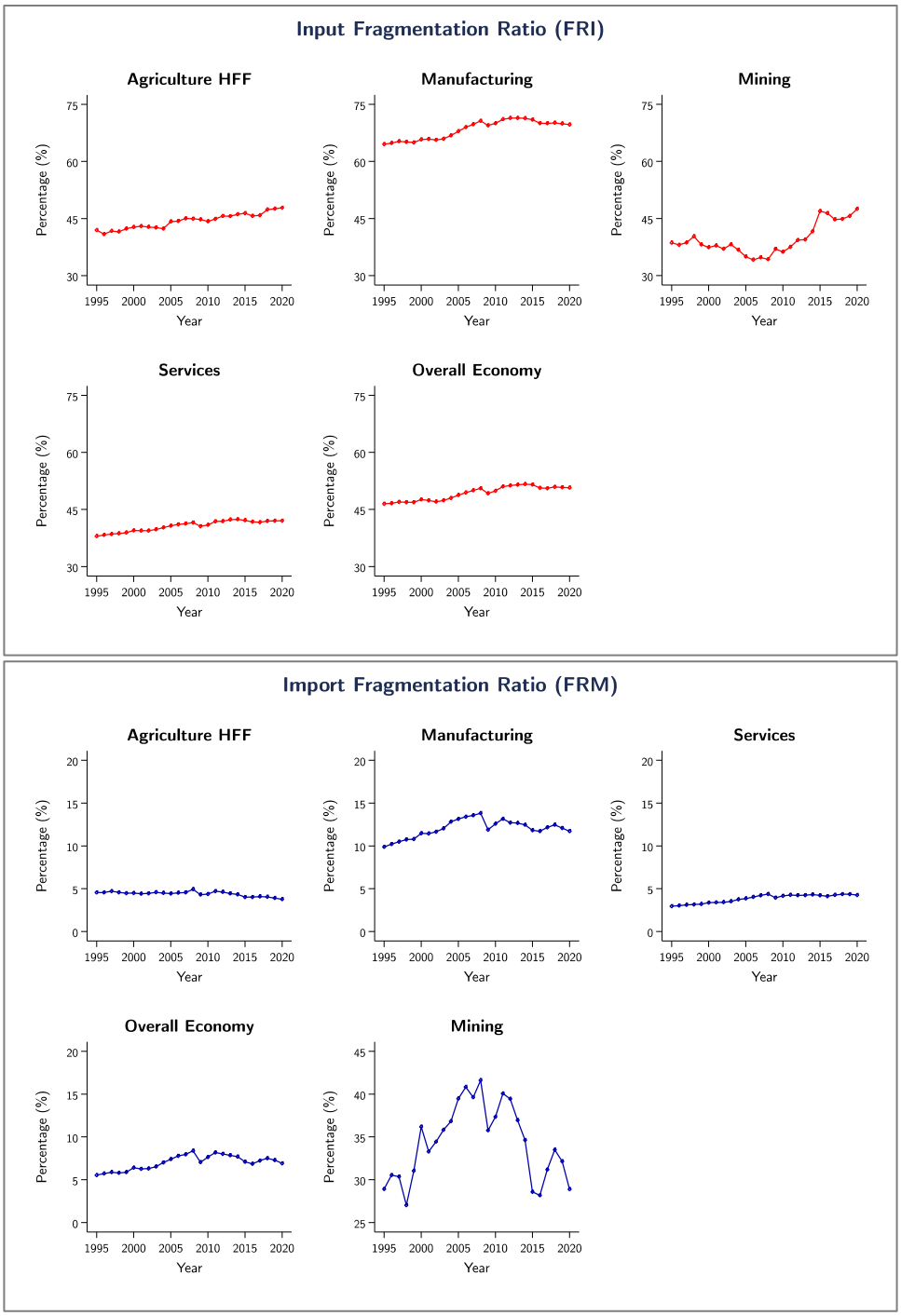
Figure 1: Global Fragmentation Ratios, 1995–2020



FRI = input fragmentation ratio, FRM = import fragmentation ratio, OECD = Organisation for Economic Co-operation and Development, TiVA = Trade in Value Added.
Source: Authors' calculations from OECD (2023), TiVA Database, 2023 edition. https://www.oecd.org/industry/ind/measuring-trade-in-value-added.htm#access (accessed 23 February 2024).

Globally, input fragmentation is rising in agriculture, mining, and services, but declining in manufacturing, as the top panel of Figure 2 shows. However, import fragmentation has a declining trend in all sectors, except services, which is flat in the last 10 years, according to the bottom panel of Figure 2.

Figure 2: Global Fragmentation Ratios by Major Sector, 1995–2020



FRI = input fragmentation ratio; FRM = import fragmentation ratio; HFF = hunting, forestry, fishing; OECD = Organisation for Economic Co-operation and Development; TiVA = Trade in Value Added.
Source: Authors' calculations from OECD (2023), TiVA Database, 2023 edition. https://www.oecd.org/industry/ind/measuring-trade-in-value-added.htm#access (accessed 23 February 2024).

Figure 3 exhibits how the fragmentation level in manufacturing has changed in selected major regions in the world.[5] Interestingly, while the world overall and most major regions have been undergoing clear input defragmentation throughout the 2010s, ASEAN seems not to have done so (see top panel of Figure 3). From 1995 to 2006, ASEAN had become more input-fragmented, just like everywhere else, but since 2007, its level of input fragmentation has consistently stayed between 71% and 72%.

However, the bottom panel of Figure 3 shows that recent trends in import fragmentation are less uniform. For instance, in the past decade, North America and Europe have been gradually importing more intermediate imports relative to their gross manufacturing production, hence becoming more fragmented in a cross-border way. However, elsewhere, East Asia and ASEAN show a trajectory of import defragmentation, and their respective imports of intermediate inputs have marginally fallen. Overall, the world tends towards slight import defragmentation (i.e. declining import fragmentation) within the last 10 years, corresponding to the pattern of China as the largest manufacturer.

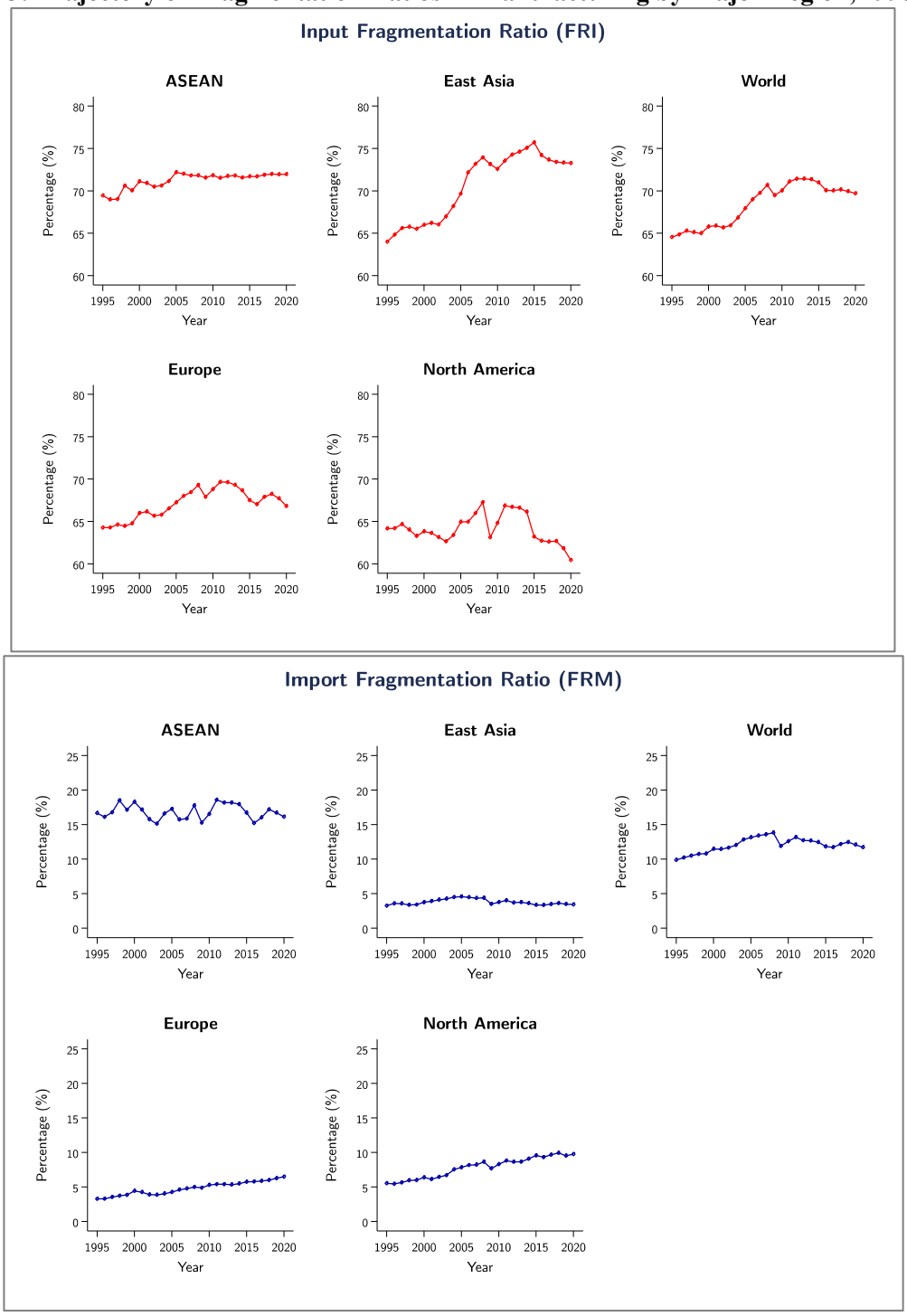
It is important to note that the plots shown in Figure 3 are based on OECD TiVA's pre-calculation for each region as a whole and do not represent the average fragmentation ratios of the countries in each region. The difference between those two approaches is due to treatment of intra-regional trade. The data shown in Figure 3 exclude intra-regional trade, as imports are applied only for the flow of goods from outside each region. For example, suppose a firm located in France imports US$1 million of intermediate products from a supplier located in China. This transaction will show up as part of Europe's imports of intermediate products in the bottom panel of Figure 3. However, if the same French firm instead imports the intermediate products from a firm located in Germany, this transaction is not included in Europe's imports of intermediate products since Germany is also located in Europe.

We compare the trajectory of FRM by major regions by excluding intra-regional trade (just like Figure 3) and including intra-regional trade by applying a weighted average of all the country-specific FRM of all countries in a region, using gross output as the weight. The latter measurement represents the (weighted) average fragmentation ratios of countries belonging to each region, while the former shows the fragmentation ratios of the entire region: two different concepts. However, as Figure A1 in the Appendix shows, both measurements of FRM largely result in a similar trajectory/trend with each other in all major regions, even though the weighted-average-based FRM is always a few percentage points higher owing to the inclusion

[5] The classification of countries in each region is in the Appendix.

of intra-regional trade. Since we are more interested in the trend, and not the absolute level, the use of either FRM measurement is fine, or we will base our analysis on the measurement that excludes intra-regional trade.

Figure 3: Trajectory of Fragmentation Ratios in Manufacturing by Major Region, 1995–2020



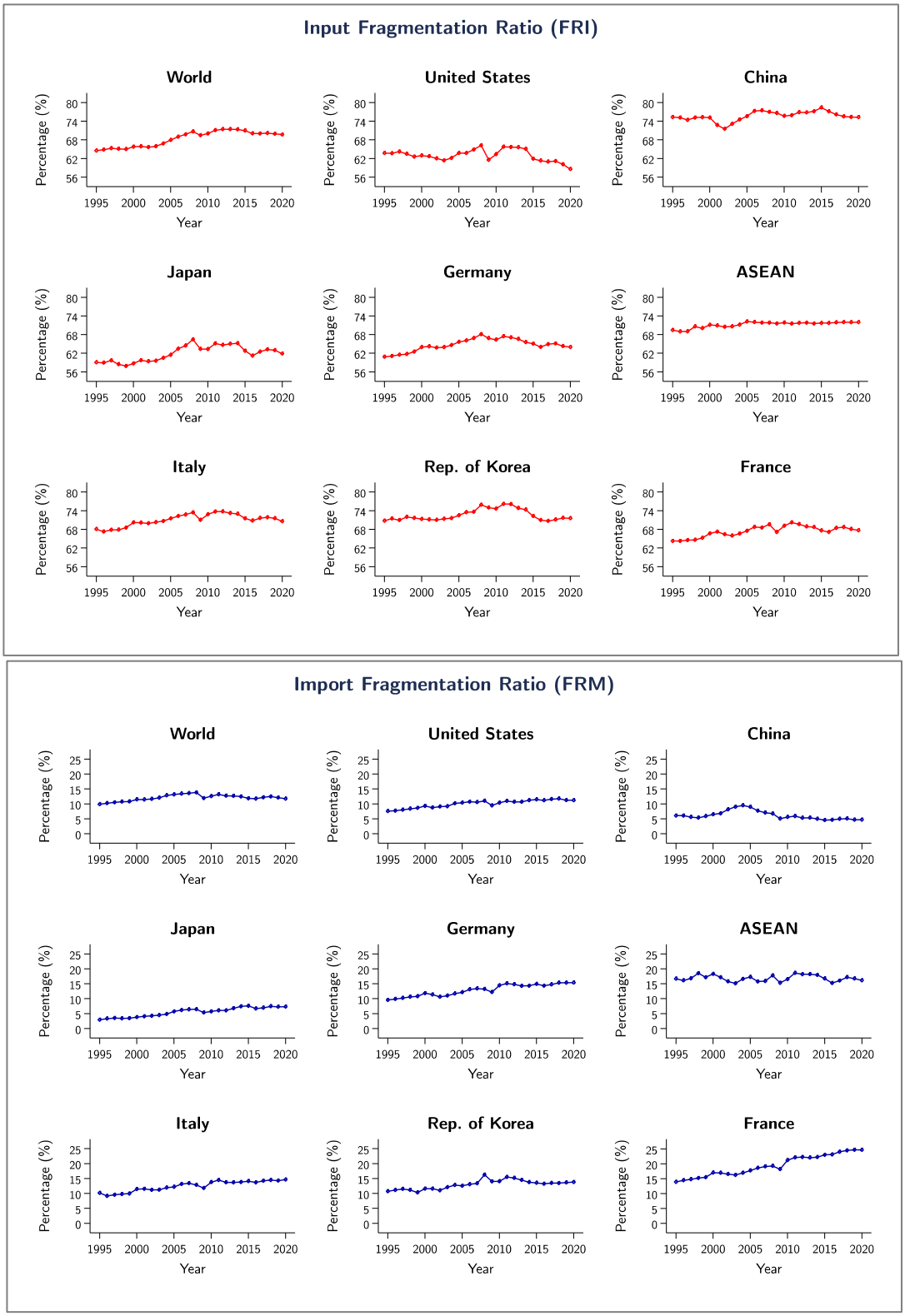
ASEAN = Association of Southeast Asian Nations, FRI = input fragmentation ratio, FRM = import fragmentation ratio, OECD = Organisation for Economic Co-operation and Development, TiVA = Trade in Value Added.
Note: Excluding intra-regional trade, following TiVA's pre-calculation.
Source: Authors' calculations from OECD (2023), TiVA Database, 2023 edition. https://www.oecd.org/industry/ind/measuring-trade-in-value-added.htm#access (accessed 23 February 2024).

Figure 4 (top panel) shows that input defragmentation has been nearly unanimous since the 2010s across the top seven manufacturers, which collectively account for 64% of world manufacturing value added from 1995 to 2020. Input defragmentation in China began later than in the other countries, starting around 2015. Notably, ASEAN is the only major market not experiencing input defragmentation. Conversely, the trend is somewhat different regarding import fragmentation. According to this metric, the US, Japan, Germany, Korea, and France have imported more intermediate inputs relative to their production over the last decade, indicating more import fragmentation and a lack of defragmentation. On the other hand, China, Korea, and ASEAN have imported fewer intermediate inputs, signifying less import fragmentation and a trend towards defragmentation. ASEAN falls somewhere in between these extremes, exhibiting a less clear pattern. Compared with its peak in 2011, ASEAN has generally experienced a decline in import fragmentation, indicating reduced reliance on imported intermediate products per US$1 of manufacturing production.

How has ASEAN's manufacturing sector overall fared when it comes to defragmentation? The short answer, according to TiVA data, to the question of whether ASEAN has been defragmenting in the past decade is yes and no. First, ASEAN has not experienced input defragmentation and has shown a clear departure from the trends observed by most global manufacturing leaders in the Western hemisphere. But at the same time, yes, ASEAN has also experienced some import defragmentation since its 2011 peak in FRM at 18.58% (down to 16.13% in 2020), roughly similar to the recent pattern observed in China, the world overall, and to a lesser extent, Korea.

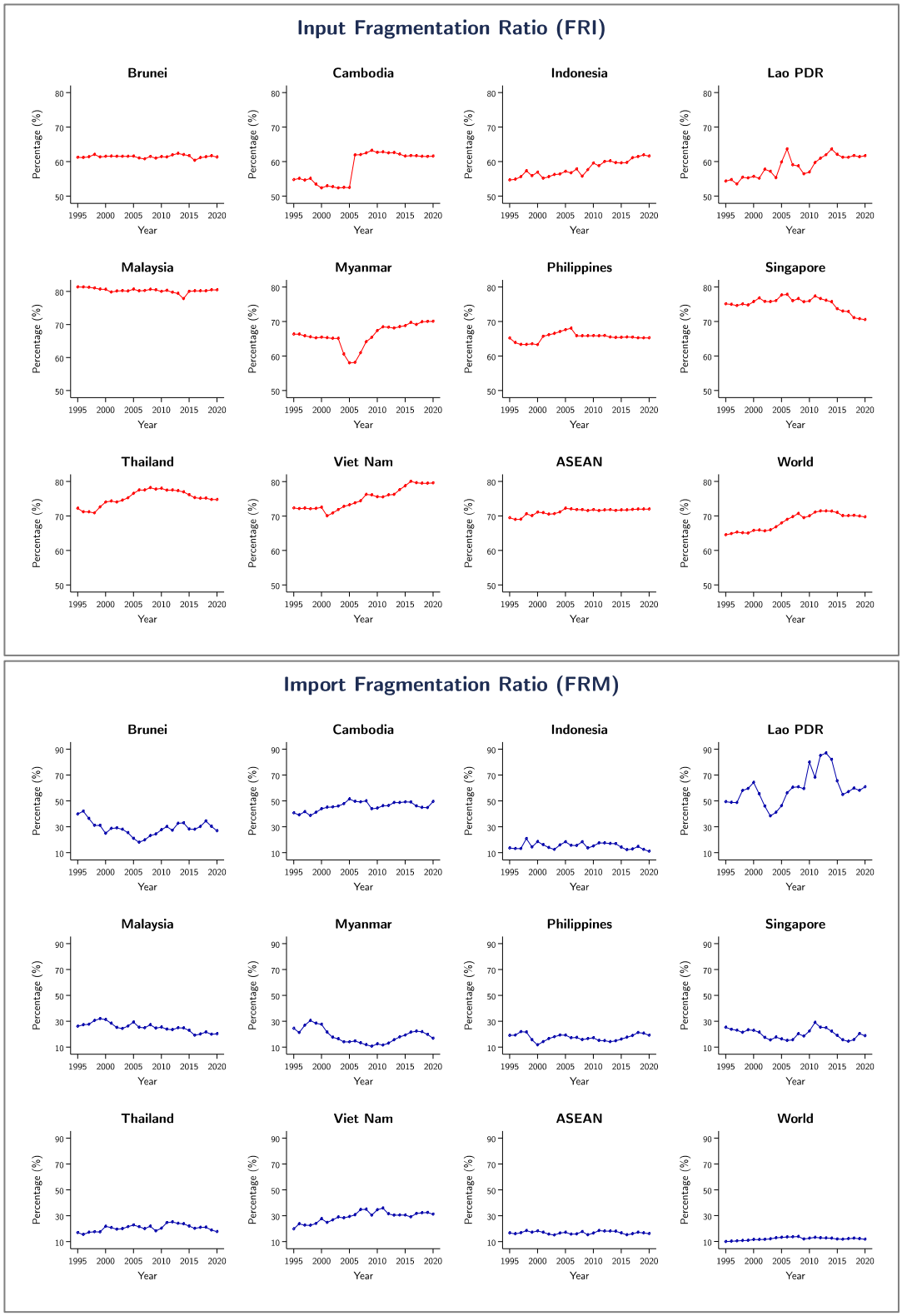
ASEAN consists of 10 countries at different levels of development and stages of advancement in technology and manufacturing capability. Upon closer inspection, the somewhat flat trajectory in ASEAN's fragmentation ratio – at a regional level – is reflected in the wide divergence in patterns amongst individual AMS. Some AMS are defragmenting, while some others are fragmenting. Indeed, data on individual AMS show that to be the case. The diversity of recent production fragmentation trajectories amongst individual AMS is graphically apparent from both panels of Figure 5, corresponding to input and import fragmentation, respectively.

Figure 4: Trajectory of Fragmentation Ratios in Manufacturing Sector in Top Manufacturing Producers Worldwide, 1995–2020



ASEAN = Association of Southeast Asian Nations, FRI = input fragmentation ratio, FRM = import fragmentation ratio, OECD = Organisation for Economic Co-operation and Development, TiVA = Trade in Value Added.
Note: ASEAN data exclude intra-regional trade, following TiVA's pre-calculations.
Source: Authors' calculations from OECD (2023), TiVA Database, 2023 edition. https://www.oecd.org/industry/ind/measuring-trade-in-value-added.htm#access (accessed 23 February 2024).

Figure 5: Trajectory of Fragmentation Ratios in Manufacturing Sector by ASEAN Member States, 1995–2020



Note: ASEAN (as a region) data exclude intra-regional trade, following TiVA's pre-calculations. ASEAN = Association of Southeast Asian Nations, FRI = input fragmentation ratio, FRM = import fragmentation ratio, OECD = Organisation for Economic Co-operation and Development, TiVA = Trade in Value Added.

Source: Authors' calculations from OECD (2023), TiVA Database, 2023 edition. https://www.oecd.org/industry/ind/measuring-trade-in-value-added.htm#access (accessed 23 February 2024).

However, for ease of analysis, Figure 6 reports the changes in fragmentation ratios, both input and import, since 2010 across each of the 16 countries in East Asia and the Pacific. The leftward bars (<0) indicate a recent defragmenting tendency (i.e. less fragmentation), whereas the rightward bars (>0) indicate a recent fragmenting tendency (i.e. more fragmentation). In Figure 6, some countries have been defragmenting by either input (FRI) or import (FRM). Each AMS falls into one of the four groups. The first country group consists of Malaysia, Indonesia, Viet Nam, the Lao People's Democratic Republic (and ASEAN as a region). Relative to the situation in 2010, this group of countries in 2020 has a smaller value-added share in their respective manufacturing production and shows a greater relative need for intermediate products. However, they also exhibit less reliance on imported intermediate inputs to run manufacturing production in their respective countries. They have become more input-fragmented and less import-fragmented.

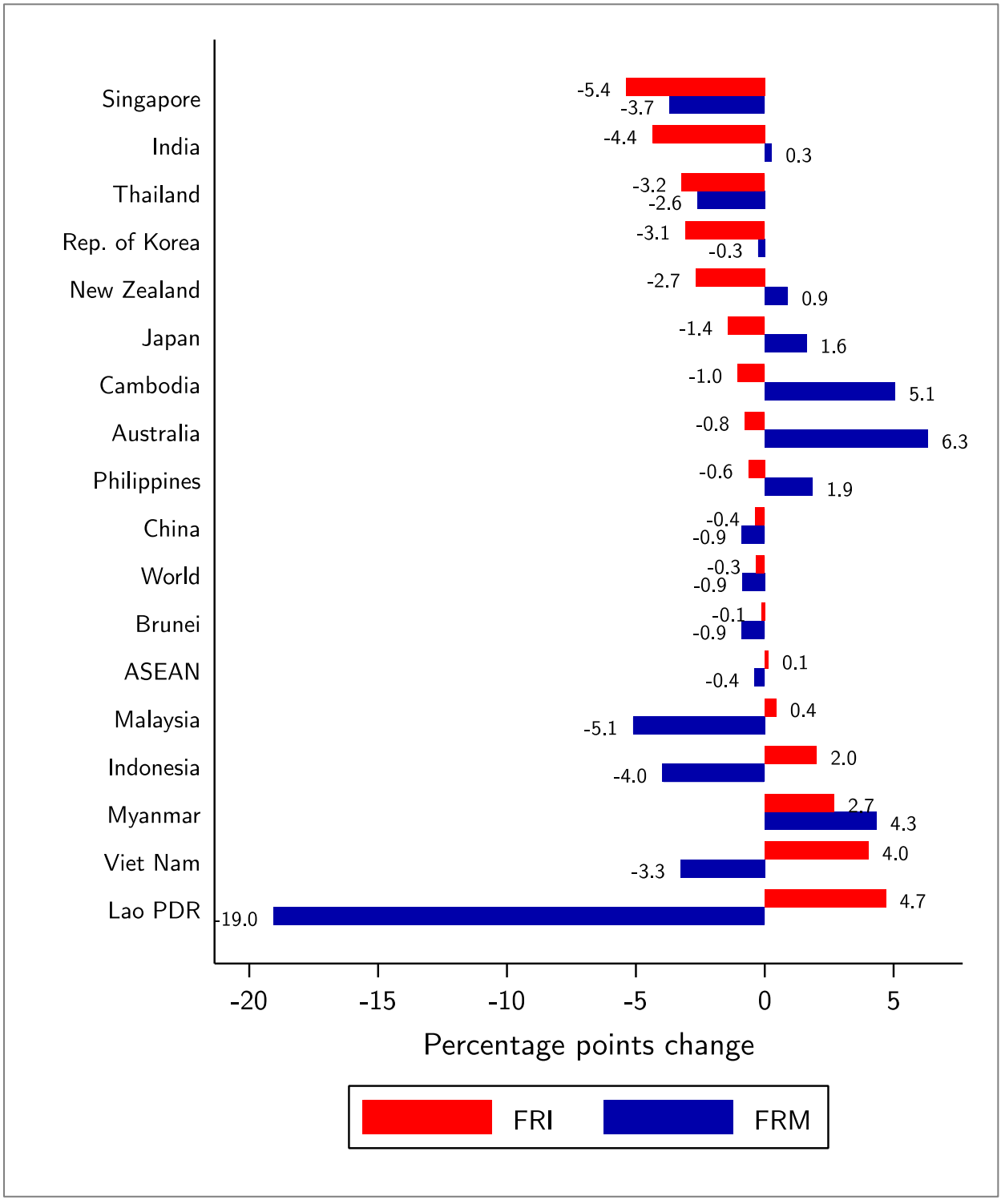
On the other hand, a second group of countries exhibits patterns of input defragmentation alongside import fragmentation. In ASEAN, this includes countries like Cambodia and the Philippines. Relative to 2010, as recently as 2020, this group has a larger share of value added in their manufacturing production and shows a smaller relative need for intermediate inputs overall, but a greater reliance on imported intermediate inputs.

Another group consists of countries that have experienced defragmentation in both inputs and imports, including Singapore, Thailand, and Brunei. Compared with 2010, by 2020, countries in this group have seen an increase in their value-added share in manufacturing production, indicating a reduced need for intermediate inputs and less reliance on imported intermediates. Conversely, Myanmar is the only AMS belonging to the last group, which has experienced both input and import fragmentation. This is characterised by a smaller value-added share in manufacturing production, a higher relative need for intermediate inputs, and consequently, greater reliance on imported intermediates compared with 2010. Table A3 compiles information concerning all four of these country groups.

Further analysis (Figure 7) reveals that the diverse recent trends in fragmentation are also evident across different manufacturing subsectors, not just countries. Some industries have been defragmenting, both in terms of inputs and imports, such as computers and electronics. Others are defragmenting only in terms of inputs but not imports, like electrical equipment and food and beverages. Conversely, some industries are defragmenting only in terms of imports but not inputs, such as auto vehicles, basic metals, coke and refined petroleum, and pharmaceuticals. Finally, a few industries are becoming more fragmented in both inputs and imports, including fabricated metals, non-metallic minerals, rubber and plastics, textiles and

footwear, and wood. Table A4 compiles information concerning recent fragmentation trends of all the industries.

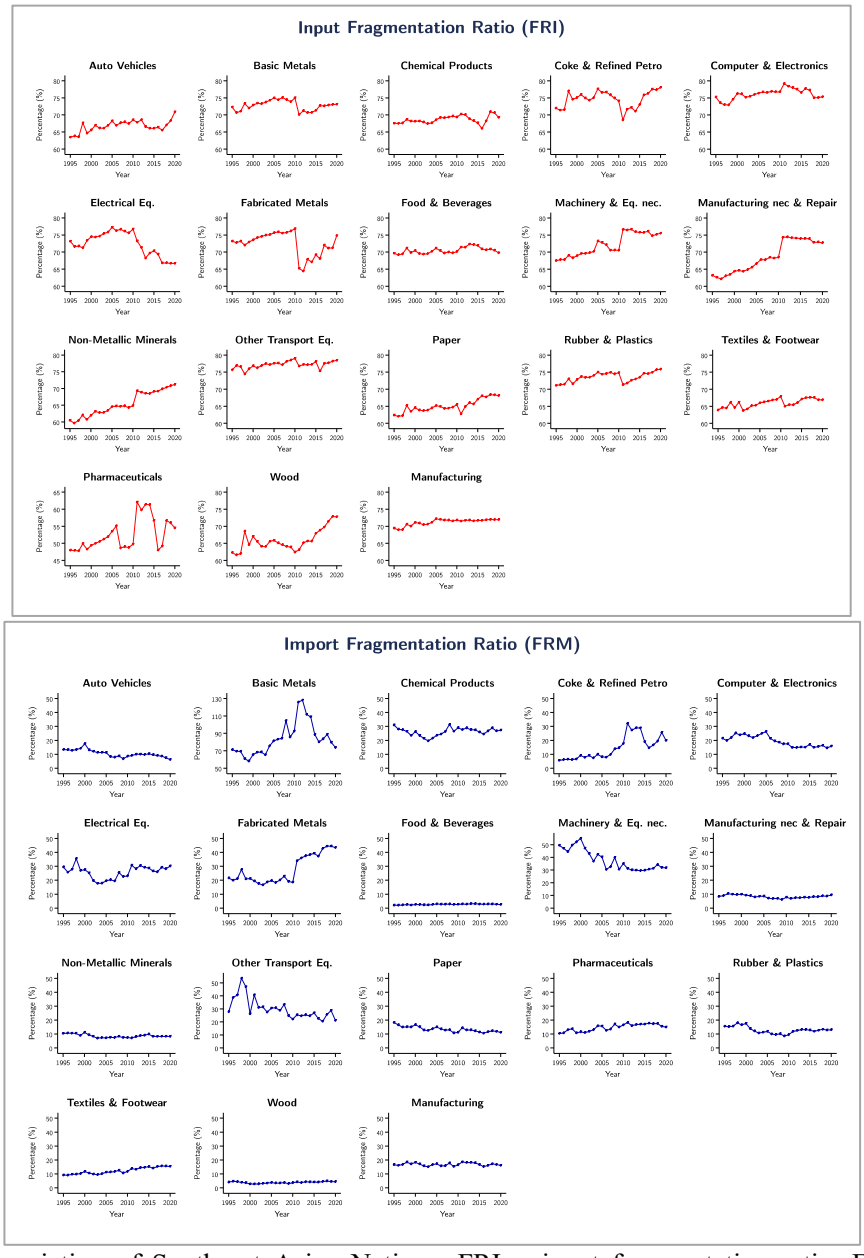
Figure 6: Changes in Fragmentation Ratios by East Asia 16 Countries: 2020 Relative to 2010



ASEAN = Association of Southeast Asian Nations, FRI = input fragmentation ratio, FRM = import fragmentation ratio, OECD = Organisation for Economic Co-operation and Development, TiVA = Trade in Value Added.

Notes:
1. Positive numbers indicate more fragmented production, while negative numbers point to more defragmented production.
2. The East Asia 16 countries consist of the 10 ASEAN Member States plus Australia, China, India, Japan, New Zealand, and the Republic of Korea.
Source: Authors' calculations from OECD (2023), TiVA Database, 2023 edition. https://www.oecd.org/industry/ind/measuring-trade-in-value-added.htm#access (accessed 23 February 2024).

Figure 7: Fragmentation Ratios in ASEAN Manufacturing by Subsector, 1995–2020



ASEAN = Association of Southeast Asian Nations, FRI = input fragmentation ratio, FRM = import fragmentation ratio, OECD = Organisation for Economic Co-operation and Development, TiVA = Trade in Value Added, Eq. = equipment, nec = not elsewhere classified.
Note: Data used in this figure exclude intra-ASEAN trade.
Source: Authors' calculations from OECD (2023), TiVA Database, 2023 edition. https://www.oecd.org/industry/ind/measuring-trade-in-value-added.htm#access (accessed 23 February 2024).

4. Key Factors of Defragmentation

This section presents preliminary discussions on potential key factors that may partly explain the trends of the recent defragmentation and rationales on why ASEAN does not experience defragmentation. We also include factors that could influence the trajectory of either input or import fragmentation, particularly in the ASEAN context. Our findings in the previous section could be attributed to a combination of the following factors, classified into three categories: market, relocation, and technology.

i. Investment and Production Relocation to ASEAN

One of the key factors that is especially relevant in the context of East Asia and the Pacific, including ASEAN, is the relocation of manufacturing activities away from top East Asia hubs like China, Korea, and Japan, to some AMS. This trend has been quite common in ASEAN over the past decade, as labour costs in East Asia continue to rise relative to some AMS. However, since 2016, relocation to ASEAN has intensified due to the rising China–US trade tensions, involving the two largest economies in the world. Some manufacturing firms have chosen to relocate their production facilities to ASEAN, partly to secure market access to either China or the US and the recipient country, while benefiting from greater access to lower-cost labour. Precise data on manufacturing relocation are hard to come by, but we can look for signs of it through detailed analysis of investment/foreign direct investment data and trade data (including intermediates). In fact, this is the channel we plan to explore more precisely in the following stage of our study.

The impacts of relocation on input and/or import fragmentation largely depend on several factors. These include where the relocating firms or industries stand on the technological ladder, whether they operate upstream or downstream, what aspects of production are being relocated, the sourcing strategies employed, and the readiness of the destination relocation country. Additionally, factors such as the availability of local suppliers before the relocation and the country's stage of technology play crucial roles. However, in the longer run, relocation is likely to result in reduced imports of intermediate inputs in the recipient country. This occurs as the relocating company establishes its production facilities and strengthens connections with local suppliers, thereby saving on transportation costs associated with imports.

ii. Market Shares and Industry Specialisation

Following the 2009 GFC, there has been a growing trend worldwide for industries to pursue greater vertical integration, driven by efficiency, security, or both. Vertical integration efforts may extend across borders, such as when a parent technology company in China acquires a supplier in Viet Nam and integrates it into its foreign subsidiary. From Viet Nam's perspective in this scenario, such integration should theoretically reduce input (and potentially import) fragmentation of production, as intermediate inputs previously sourced from domestic or foreign suppliers can now be produced in-house within the same firm or network of firms.

Examining the behaviour of multinational firms operating in and around Asia, particularly in Southeast Asia, is also crucial to understanding whether there has been a shift in strategies in response to current global events or macro-level developments in the 2010s. Given that most international trade and investment occurs through multinational firms, understanding their behaviour is essential. However, as highlighted by Ramondo, Rappoport, and Ruhl (2016), identifying multinational behaviour using aggregate data sets (like the OECD TiVA in our case) can be challenging.

In addition, it is important to consider the evolving nature of certain industries, which may influence firms' spending structures in production. The manufacturing industry typically encompasses various stages, including design, research and development (R&D), innovation, marketing, distribution, and advertising, alongside physical transformation activities like assembly or manufacturing inputs (Fort, 2023). Many of these activities fall under the broad category of value-added activities. Therefore, it is necessary to explore whether recent market or technology trends in some industries require a shift in emphasis towards value-added activities or stages. To be specific, in certain industries, increased spending on digital marketing and advertising may be necessary to sell an additional unit of a product, reflecting a strategic move by firms to maintain competitiveness or gain market traction. In such cases, the relative use of intermediate inputs may appear to decrease when there is a relative increase in value-added stages of production.

iii. Technology

The latest changes in production strategy have largely been driven by advancements in technology. Decades ago, the rapid growth of ICT and the development of computer-aided design/computer-aided manufacturing (CAD/CAM) systems facilitated increased fragmentation of production and separation of production stages. However, recent technological advancements focusing on 3D printing, automation, industrial robotics, and

artificial intelligence (AI) could theoretically enable more stages of production to be conducted in-house, even in the Western hemisphere. Are these technologies discouraging production fragmentation? If true, this could lead to input defragmentation, which would then have a secondary effect on international trade in intermediate inputs in both developed and developing countries.

One possible explanation as to why ASEAN does not experience as much defragmentation as other regions is that ASEAN for the most part is lagging global manufacturing leaders in adopting automation, robotics, and AI technologies, which could partly explain why ASEAN has yet to show signs of input defragmentation. China's significant input defragmentation since 2015 appears to coincide with its increased adoption of industrial robots in production around the same time, as it has been the largest adopter of industrial robots since the mid-2010s. It is worth exploring whether the rise in innovation and adoption of industrial robots, automation, digital transformation, and AI have substantially altered how firms organise production and select their production locations.

5. Conclusion and Policy Recommendations

Our study has examined the recent trend in production fragmentation in the manufacturing sector of ASEAN using data from the OECD TiVA database, covering the period from 1995 to 2020. We have employed two measures of fragmentation: FRI, which measures the share of intermediate inputs in gross manufacturing output, and FRM, which measures the share of imported intermediate inputs relative to gross manufacturing output.

Our preliminary findings indicate that since the GFC and the significant rise in anti-globalisation sentiment largely driven by rising inequality across and within countries, ASEAN has not experienced any episodes of input defragmentation, unlike the trends observed globally and in many major manufacturing hubs, including North America and Europe. However, since 2010, ASEAN overall has shown a pattern of import defragmentation, following the trends observed in China and Korea, but opposite to those in North America and Europe. Upon closer analysis, individual AMS show diverse recent trajectories of input and import fragmentation. The diversity in fragmentation trends is also apparent across manufacturing subsectors/industries in ASEAN.

A combination of key factors, including investment and production relocation to ASEAN, market shares and industry specialisation, and technology may partly explain our findings to varying degrees. Much remains to be explored in the next stage of the study to produce a

coherent analysis and explanation of what led to ASEAN not experiencing input defragmentation but showing signs of import defragmentation throughout the last decade. Nonetheless, given ASEAN's crucial role in the manufacturing production network in the Asian region and globally, these findings warrant further and deeper investigation.

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Appendix

Table A1: Summary of Differences Between Production Fragmentation and Geoeconomic Fragmentation

	Production Fragmentation	Geoeconomic Fragmentation
Definition	The extent to which production processes are divided into discrete stages that are geographically distributed across a number of firms and/or countries	Policy-driven reversal of international integration, influenced by strategic considerations. (IMF, 2023)
Coverage	Mostly about production: number and distribution of firms and countries involved in the production processes of particular goods or services, and investment and trade patterns surrounding those dynamics	Many dimensions, including through trade, capital flows, foreign direct investment, the movement of workers, technological diffusion, provision of global public goods, and international payments
Drivers	Technological advancements (especially ICT), second unbundling, reduced coordination cost	Rising geopolitical tensions, national security concerns, protectionism and nationalism, pressures to have domestic supply chains
Context	Efficiency gains from specialisation in the context of global value chains. Production takes place where it makes the most economic sense.	Protectionism; economic nationalism; and selective, strategic partnership between countries. Production takes place where it makes the most geopolitical sense, typically involving blocs.
Purpose	Pursuit of cost-efficiency in production processes, ultimately economic motivation	Ensuring national security by reducing supply chain exposure from rivals or unfriendly nations
Examples	(i) A European firm offshores specific production stages to Asian countries with lower labour cost. (ii) A US firm outsources production of some inputs to other US firms instead of manufacturing them in-house.	(i) US imposing technological ban on a Chinese electronic firm, preventing them from accessing US tech supply chains. (ii) Friendshoring policy by relocating supply chain facilities towards more friendly nations away from unfriendly or rival ones.

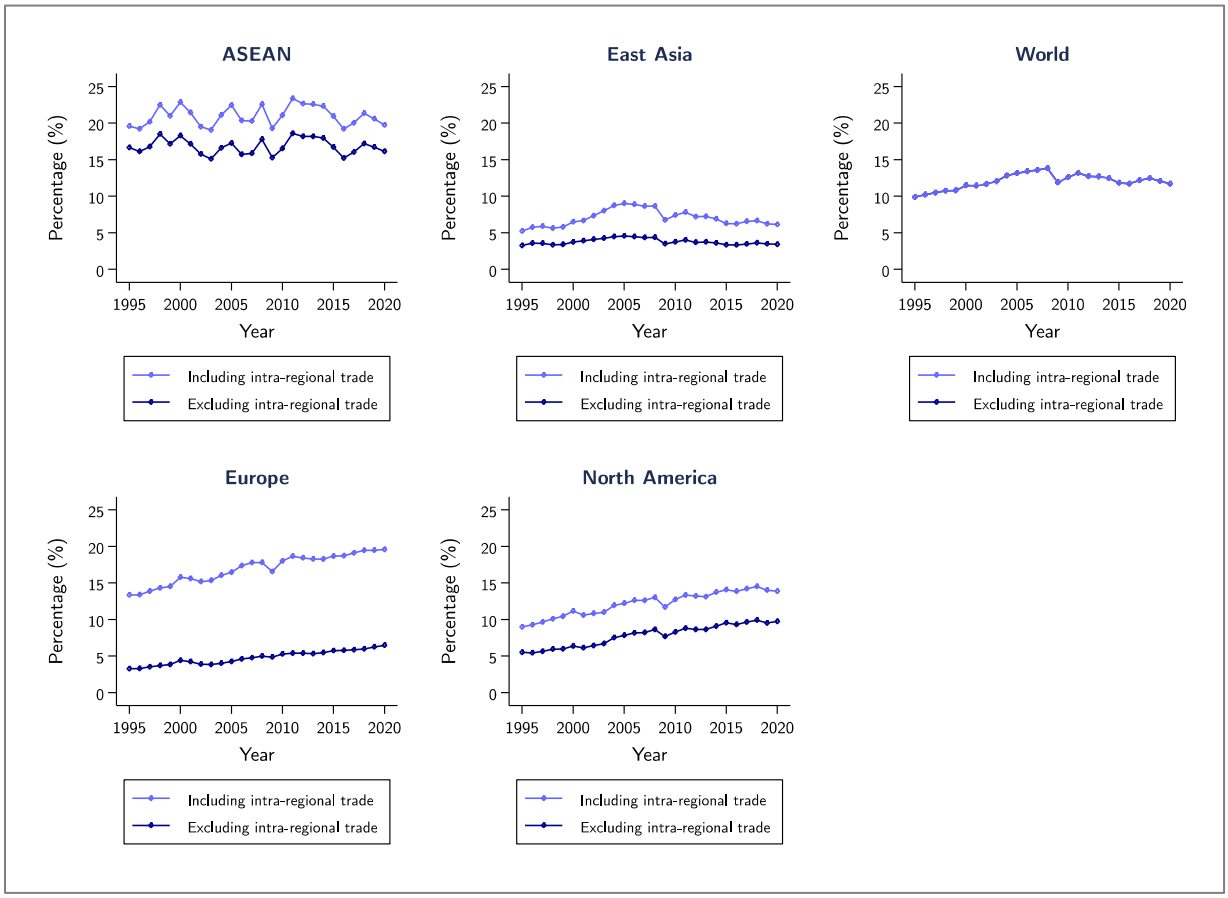
ICT = information and communication technology, US = United States.
Source: Authors' compilation.

Table A2: Country Classification by Region

Region	Country
ASEAN	Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam
East Asia	China, Japan, Republic of Korea, Hong Kong, Taiwan
Europe	Austria, Belgium, Czechia, Denmark, Estonia, Finland, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Bulgaria, Cyprus, Croatia, Malta, Romania
North America	Canada, Mexico, United States

ASEAN = Association of Southeast Asian Nations.
Source: Based on OECD (2023).

Figure A1: Comparison of Trajectory of Import Fragmentation Ratio (FRM) in Major Regions Under Two Treatments of Intra-Regional Trade, 1995–2020



ASEAN = Association of Southeast Asian Nations, FRM = import fragmentation ratio, OECD = Organisation for Economic Co-operation and Development, TiVA = Trade in Value Added.
Source: Authors' calculations from OECD (2023), TiVA Database, 2023 edition. https://www.oecd.org/industry/ind/measuring-trade-in-value-added.htm#access (accessed 23 February 2024).

Table A3: Recent Trends in Fragmentation in the Manufacturing Sector of Selected Countries

		Import fragmentation	
		Less import fragmentation (= defragmenting = share of imported IP falls = less reliance on/relative need for imported IP)	**More import fragmentation** (= not defragmenting = share of imported IP rises = more reliance on/relative need for imported IP)
Input fragmentation	**Less input fragmentation** (= defragmenting = VA share in production rises = less reliance on/relative need for IP in production)	Singapore, Thailand, Brunei, World, EA16, China, Rep. of Korea	Cambodia, Philippines, US, Europe, Japan
	More input fragmentation (= not defragmenting = VA share in production falls = more reliance on/ relative need for IP in production)	Malaysia, Indonesia, Viet Nam, Lao PDR, ASEAN	Myanmar

ASEAN = Association of Southeast Asian Nations, IP = intermediate products, US = United States, VA = value added.
Note: EA16 refers to the East Asia 16 (10 ASEAN Member States plus Australia, China, India, Japan, New Zealand, and the Republic of Korea).
Source: Authors.

Table A4: Recent Trends in Fragmentation in Manufacturing Subsectors of ASEAN

		Import fragmentation		
		Clearly less import fragmentation (= defragmenting = share of imported IP falls = less reliance on/relative need for imported IP)	**Stagnant** (stagnant/no clear trend either way; share of imported IP largely remains; not defragmenting)	**Clearly more import fragmentation** (not defragmenting; share of imported IP rises; more reliance on/relative need for imported IP)
Input fragmentation	**Clearly less input fragmentation** (= defragmenting = VA share in production rises = less reliance on/relative need of IP in production)	Computer and electronics	Food and beverages	Electrical equipment
	Stagnant (= stagnant/no clear trend either way = not defragmenting)	**Manufacturing Total**	Chemical; machinery and equipment	
	More input fragmentation (= not defragmenting = VA share in production falls = more reliance on/ relative need of IP in production)	Auto vehicles, basic metals, coke and refined petroleum, pharmaceuticals	Other transport equipment, paper	Fabricated metals, non-metallic minerals, rubber and plastic, textile and footwear, wood

ASEAN = Association of Southeast Asian Nations, IP = intermediate products, Mfg. = manufacturing, VA = value added.
Source: Authors.

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