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ARTICLE

# A Study on the Reinforcement of Supply Chains Corresponding to Global Value Chain Reforms in the Automobile Parts and Component Industry

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**Abstract** Global value changes continued to expand until the late 2000s. On the other hand, regional value chains have formed around major regional hubs due to the expansion of domestic demand in emerging economies, such as China, and strengthened trade protectionism since the global financial crisis. Such changes lead to the reorganisation of value chains, focusing on domestic markets (reshoring) or neighbouring countries (nearshoring). In particular, the importance of supply chain risk management has been highlighted following disruptions to the supply network due to the COVID-19 outbreak in December 2019. In this regard, major countries such as the USA and the EU are rapidly shifting to regional value chains for stable and sustainable production, rather than primarily aiming for production efficiency targeted at reducing costs. Industries in particular are more exposed to such supply chain risks under the existing structure and it now has become extremely important for businesses to take reaction to such risks. This is especially important for major industries in a country such as automobile or semiconductor manufacturing industries in South Korea. The aim of this study, therefore, is to establish the basis for the simultaneous growth of ports and linked industries by examining the existing structure of the global value chain for the automotive industry, which has a strong presence in South Korea's domestic economy. In this regard, this research carries out a supply chain analysis focusing on the imports and exports of automotive parts. It also analyses the current structural risks and suggests risk management measures to secure a stable supply chain.

**Keywords** Global value chain, Global supply chain, Automobile parts and component industry, Port-related industry

## 1. Introduction

The accelerated growth of global value chains started in the 2000s as international fragmentation rapidly progressed due to the advancement of globalisation. However, since 2011, their growth has slowed because of developments in the international trade environment, such as strengthened trade protection and the Fourth Industrial Revolution. These developments have resulted in changes in the manufacturing supply chain. Moreover, the demand for reorganising the global value chain system has grown due to worldwide political and human resource issues, such as natural disasters, infectious diseases and labour strikes. This trend follows from the disaster-preparedness movement, arising from the possibility that disasters in a particular region or country could impact others as well. In addition, more and more labour is being replaced by robots and artificial intelligence due to technological development, and developing countries' advantages in areas such as assembly and production are shifting to developed countries. These changes have caused global supply chains to gradually move toward domestic markets (reshoring) or neighbouring countries (nearshoring), which are recognised as countermeasures that can help minimise external risks. The case of the USA automobile industry would be a good example of reshoring which the government motivated the offshored industries to move back to home country in order to protect its jobs and businesses.

A new value chain system is required given the changing trade environment, which is also applicable to South Korea. The international supply chain's unpredictability has led to the distortion of the international division of labour. Furthermore, the outbreak of the COVID-19 pandemic has impacted the global economy, including in Korea, severely disrupting the supply chain across the world's procurement, as well as manufacturing and distribution markets. This situation raised questions about

the structural limitations of the global value chain, once regarded as stable. In addition, the paralysis of the manufacturing sector, which occurred at the same time, served as an opportunity to recognise the flaws of the current global supply system in terms of risk management.

It is expected that society will undergo more diverse changes in trade in the future. Therefore, devising strategies to respond to the changing global value chain is essential for improving competitiveness. Thus, South Korea should design global value chain strategies to improve the risk management of its major industries and explore ways to construct a diversified yet resilient supply network. Therefore, this study examined the existing structure of the global value chain for the automotive industry — a major domestic port-linked industry — and analysed the risks to which the existing structure is exposed, according to internal and external environmental changes. The automotive industry in South Korea is regarded as one of the most prominent industries in the world. They showed a good performance even after the coronavirus pandemic moving up to the fifth-largest car manufacturing country in 2020 whom ranked seventh back in 2018 and 2019. But at the same time, it was one of the most-impacted industries by COVID-19 with unstable supplies of automotive parts. The hit of the major industry in Korea by the external environmental changes showed the risks under the existing supply chain system and this in turn has drawn much attention to propose countermeasures to moderate these current risks.

In particular, China's wiring harness (wire) parts factory was shut down in the first half of 2020 due to the outbreak of Corona 19 for 'wiring harness,' which was largely imported from China. The parts were unavailable due to a lack of imports, resulting in a significant slowdown in automobile production. Additionally, the manufacturing and supply of semiconductors for vehicles are not operating flawlessly, resulting in difficulties with vehicle production in 2021. As a result, if even one of the 20,000 to 30,000 automobile parts required to complete the vehicle is not delivered in time, the vehicle cannot be completed, making it critical to thoroughly supervise the supply chain for the parts and component.

Thus, in contrast to previous qualitative studies, this study aims to provide a method for diagnosing the overseas supply chain of automobile parts required for automotive production and reducing supply chain risk by combining the three analytical approaches. It is envisaged that the proposed three methodology in this study could provide flexible tools to diagnose and implement strategies that would contribute to the resilience of supply chain in other industry.

The remainder of this paper is structured as follows. Section 2 reviews the literature on the global automotive industry supply chain. Section 3 introduces the process of collecting and filtering the data, followed by an outline of the three methodologies employed in this study. The results are presented in Sections 4 to 6, and the final section offers a conclusion and suggests future research.

## 2. Literature review

Varied research has been conducted in the fields of supply chain management (SCM) and the automobile industry. In particular, many published and forthcoming studies respond to the expected reorganisation of the existing value chain and supply chain due to the rapidly changing trade environment. The need for research that responds to this structural transformation of the value chain is highlighted, following suggestions regarding the need for reduced interruptions to the global supply system to avoid excessive dependency on a single country.

Examining previous major studies reveals that research has centred around analysing the green supply chain (GSC) performance in the automobile manufacturing industry. One of the popular research areas was in exploring the criteria which influences the performance of the automobile manufacturing (Lin et al., 2011; Luthra, 2014). In doing so, case studies were often applied. For example, the research by Balon et al. (2016) looked into the case of the automobile industry in India in order to find out the barriers of the GSC. For companies, it has become important to consider GSC management (GSCM) since it can help to achieve sustainable development which in turn helps firms to reduce the environmental impact while improving their operational performance as well. The more recent research (Zhang, 2019) tried to find out the types of business performance that had a positive impact by GSCM. Besides GSCM, sustainability itself has been another popular topic among researchers especially in the fields of Indian automobile industry. Both Gopal and Thakkar (2015) and Luthra et al. (2015) considered the Indian automobile industry in analysing sustainable supply chain.

Researches on SCM in the automobile industry has long been an interesting area. Jeon et al. (2008) tried to identify SCM strategy factors in order to determine the firms' performance. He wanted to see if certain SCM strategy factors influenced the performance of the firms. Analysis on SCM itself was carried out Jeong et al. (2009) which carried out a research on the case of Renault Samsung Motors to look into the transportation network of the parts supply. Nonetheless, the most recent research tends to focus on the management of the supply chain resilience as external shocks, such as trade wars and diseases, cause

significant damages to the main industries of countries. For instance, the outbreak of COVID-19 has shown both the weaknesses and risks of the existing SCM of automobile industries. As a result, there has been a rapid response by the sector to improve its SCM resilience and robustness. Many researchers have started to focus on this topic. The research by Fabbe-Costes and Ziad (2021) was based on a case study of Renault Group. Their main research question relied on whether SC robustness and resilience should be considered together and how these two could be improved within the system. The COVID-19 has drawn much attention on SCM research field since it has greatly impacted the existing SC for most industries especially the automotive manufacturing in the world (Garcevic and Lidberg, 2021). Gonyora et al. (2021) on the other hand looked into the relationship between innovation strategic alignment and sustainable competitive advantage decision-making. This research was based on the automotive SC in South Africa. This research was also carried out in the case of automobile industry since the industry was regarded as the most-impacted sector since the COVID-19.

This study analyses the automotive industry's global chain structure, from which countermeasures to risks that may occur due to external factors (i.e., disasters related to politics or infectious diseases) are derived from a logistics perspective to support the industry's sustainable growth. Specifically, current and future countermeasures are deduced from a logistics system perspective by analysing the current structure and potential for reorganising the global value chain. Methods for the industry's sustainable growth are consequently explored.

## 3. Data and methodology

In this paper, an analysis of the domestic automotive parts supply chain (imports and exports) is presented. The automotive industry is labour-and technology-intensive and has a strong presence within the economy. In this regard, more than 20,000 parts and equipment are used to produce a single car. This industry's supply chain shows signs of reorganisation due to the USA –China trade war and the strengthening of trade protections in each country. Furthermore, the impact of COVID-19 on the global supply chain has also greatly affected the automotive industry, and it is expected that the reorganisation of the global supply chain will further accelerate through trade protectionism, reshoring and regional production. This study analysed major automotive parts and their import and export statuses to determine the damage and risks incurred for the automotive industry's supply chain due to external factors. Accordingly, the import and export status of the automotive parts industry was examined by date (yearly and monthly), import or export, product, customs organisation (e.g., port or airport customs), cost or weight and domestic region (by province (-do) and city).

First, the data used for this analysis were from the Korea Trade Statistics Promotion Institute, including information on the classification of imports and exports by item, year, HS code, region, country, customs port or airport code, quantity, weight (kg), cost ($), trade classification and trade type by import and export. Information on trade statistics can also be found on the Korea Trade Statistics Promotion Institute website, but since data on the imports and exports of individual items were needed for the analysis, the data were collected from the 'On-demand statistics Application' service on TRASS. Second, the HS code information of the Customs Law Information Portal (Korea Customs Serivce, 2021) was used, including a total of 3,235 sub-categorisations of automotive parts, corresponding details and HS code information. The HS code information for 3,235 automotive parts is provided in seven main categories (power unit, driveline, electronics, body, braking system, steering system and other parts) and 47 sub-categories. However, this data is not provided as a list but is presented as a webpage. Thus, this data were collected by searching for the automotive sub-components and saving the corresponding HS codes in an Excel file.

Since the data collected from the Trade Statistics Service TRASS by period includes all domestic imports and exports (based on HS code), any items corresponding to automotive parts were derived and analysed (see Figure 1). Data on automobile components was extracted for analysis using SQL syntax in an MS-Access query. Then, this study used data (n = 386,772) extracted from 1995 to June 2020 for the analysis, including the HS code for each record, country of import and export, domestic region (place of import and export), import and export airport and port (including customs), import and export weight (kg) and volume ($), as well as the automotive parts classification information. Each record in the data indicates that whenever an automobile component is imported or exported, the corresponding information is recorded. The domestic region considers the administrative district changes depending on the year.

'Tableau' software, which was used in this study, is a data visualisation and analysis tool that allows for visualisation in various forms and has the advantage of constructing visualisation tables quickly and easily. Thus, it is a suitable tool for analysing the current status of automotive part imports and exports and their global supply chain.

A Sankey diagram is a graphical representation of a flow analysis, and, in this study, we use it to analyse imports and exports. The purpose is to identify and characterise the structural aspects of the supply chain in the Korean automotive parts industry

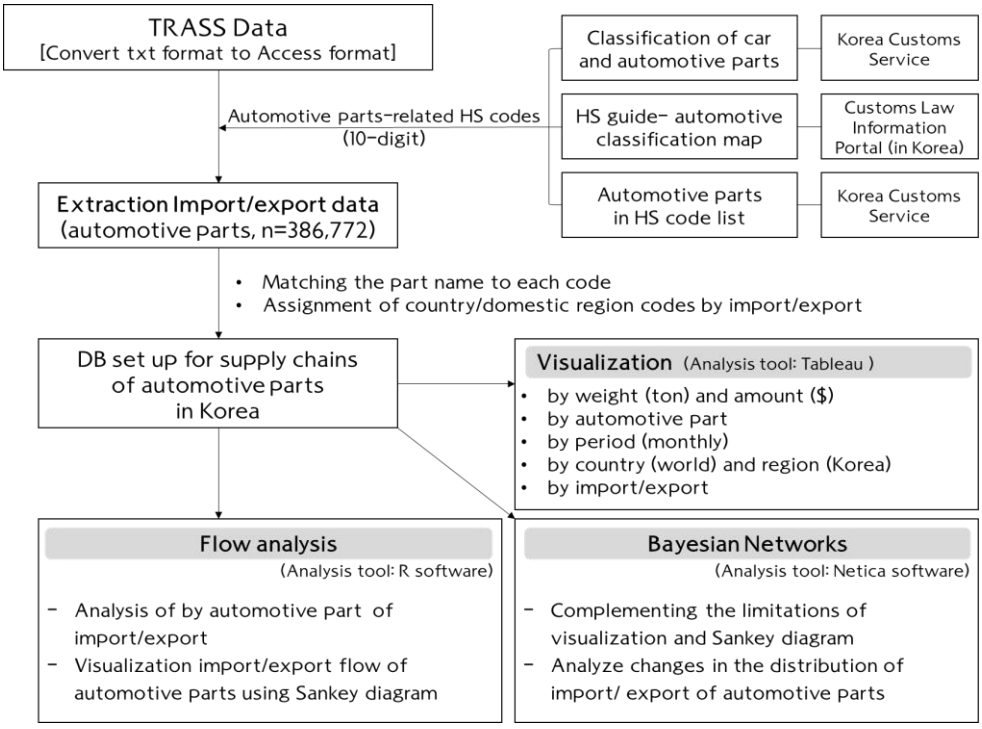



**Figure 1. Process of data pre-processing and analysis.**

using a Sankey diagram-based analytical framework.

Bayesian networks (BNs) have been applied in a wide variety of fields due to their advantage of allowing for the modeling of dependencies between influential factors (Baksh et al., 2018). In this study, a BN was constructed using the Bayes' Theorem as follow:

$$P(Y|X) = \frac{P(X,Y)}{P(X)} \quad (1)$$

This means, “the conditional probability of event Y occurring, given an observable event X is invoked is equal to the joint probability of events X and Y divided by the marginal probability of event X” (Grover, 2016, p.9). The joint probability $P(X,Y)$ can be represented as $P(X|Y)P(Y)$ by the chain rule of probability. By substituting $P(X,Y)$ for $P(X|Y)P(Y)$, $P(Y|X)$ can be represented as follow:

$$P(Y|X) = \frac{P(X|Y)P(Y)}{P(X)} \quad (2)$$

Not only can this formula be used to determine the probability that Y will occur in a given X situation, but it can also be used to determine the probability that X will occur in a given Y situation. In other words, the probability of the opposite situation occurring in a causal relationship can be determined.

Figure 2 depicts the change in the proportion of auto parts imported and exported, by country, before and after the COVID-19 outbreak. This network is composed of nodes and links, in which the links are represented using a Directed Acyclic Graph (DAG). When a condition is specified, the direction of the arrow indicates the change in the distribution of variables within the node receiving the arrow (arrow starting node). As a result, Figure 2 depicts a network model that is complex enough to consider each of the three conditions (import/export, country and before/after the COVID-19 outbreak). For instance, it is assumed that import/export status, country, and post-coronavirus affect the distribution of major auto parts ($P(Parts\_major\_classification)$). These three variables ('Import Export', 'Foreign countries top 20', and 'COVID19 effect') are intended to result in varying distributions of major auto parts depending on the situation (conditional probability).

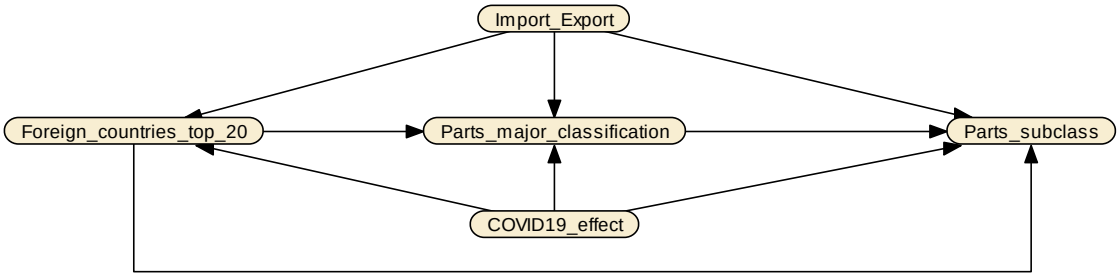



**Figure 2. Bayesian network for imports and exports of automobile parts.**

## 4. Descriptive statistics using visualisation

The current status of automotive parts by year (five-year periods)/imports and exports are shown in Figure 3 (data from 1995 to June 2020). Exports constitute a larger proportion than imports but have been declining since 2015 while imports have been slightly increasing. This trend is seen in both weight and volume ($). The data for 2020 are from January to June, but as can be seen, they are less than half of those for 2019. This is because the outbreak and spread of COVID-19 have had a significant impact on both the imports and exports of automotive parts beginning in January 2020.

Figure 4 below shows that the main target countries for domestic automotive part imports and exports are the USA, China, Japan, Mexico and India. In this regard, the number of exports is relatively higher than that of imports for the USA and China has the largest automotive parts import weights and costs. In addition, imports from Japan and Germany are relatively low in weight but high in volume ($). Data from 1995, 2000, 2010, 2015, 2019, and June 2020 (five-year period) were combined with the data up to June 2020. As a result, the overall status of Korea's auto part import and export destination countries can be determined as shown in Figure 4.

Figure 5 shows the import and export status by country on a map.

These figures show a comparison of automobile part export amounts from January to June 2019 (before the COVID-19 outbreak) and from January to June 2020 (after the COVID-19 outbreak) from/to South Korea. Recently, a comparison of the period from January to June in 2019 and the same period in 2020 was published, and the impact of COVID-19 was barely visible on the map. However, when they are compared for the same month, the difference is quite noticeable.

Figure 6 below compares automotive part imports by country and month for specific comparisons between the top-five import/

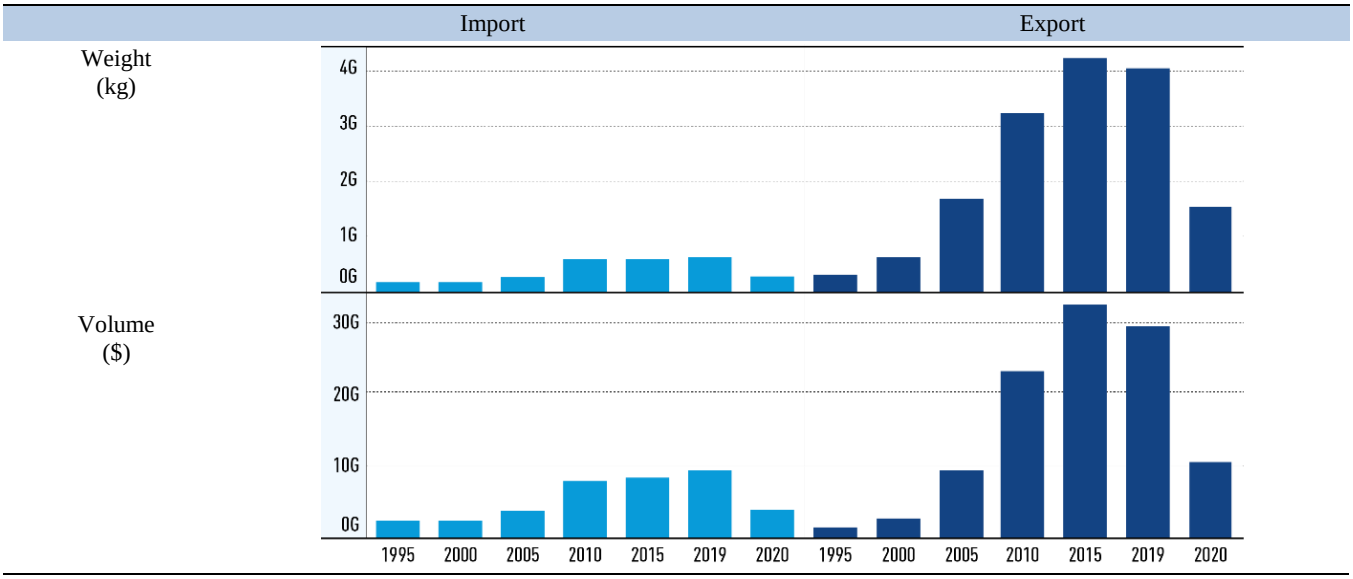



**Figure 3. Import and export trends of automotive parts in five-year periods (1995–June 2020).**
Note: 'G' on the y-axis represents 1 billion.

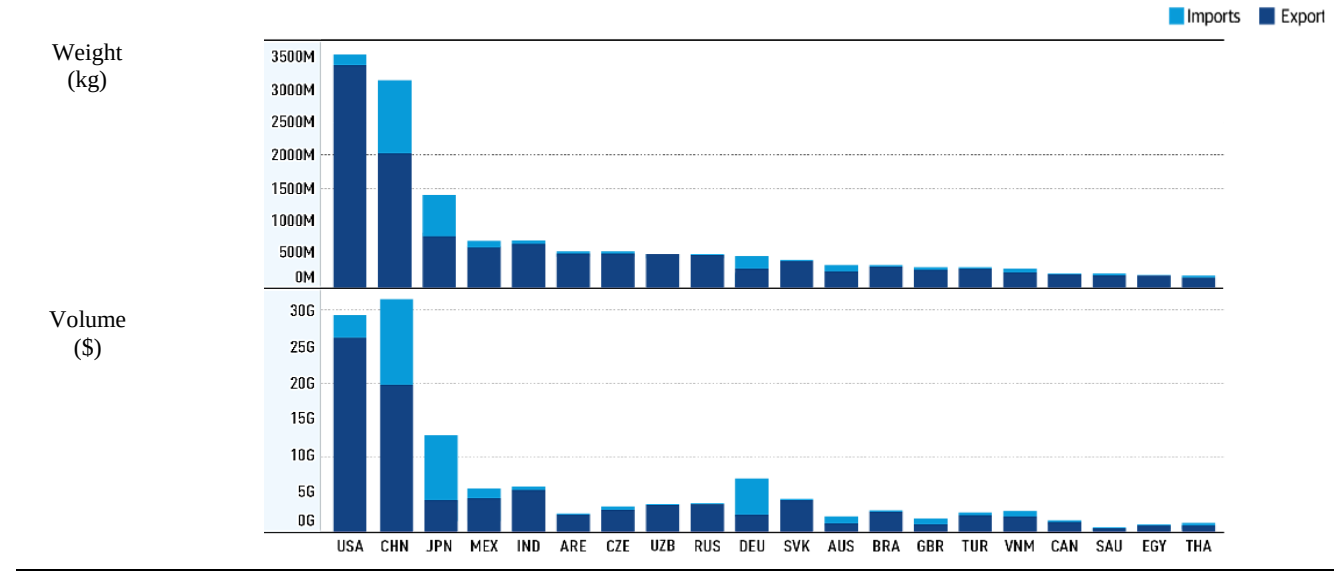
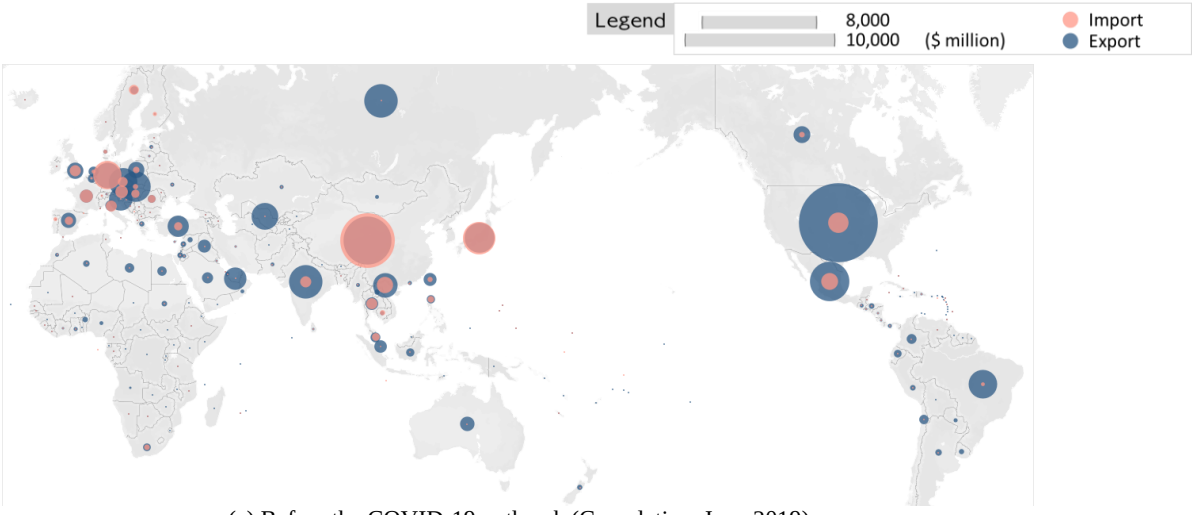
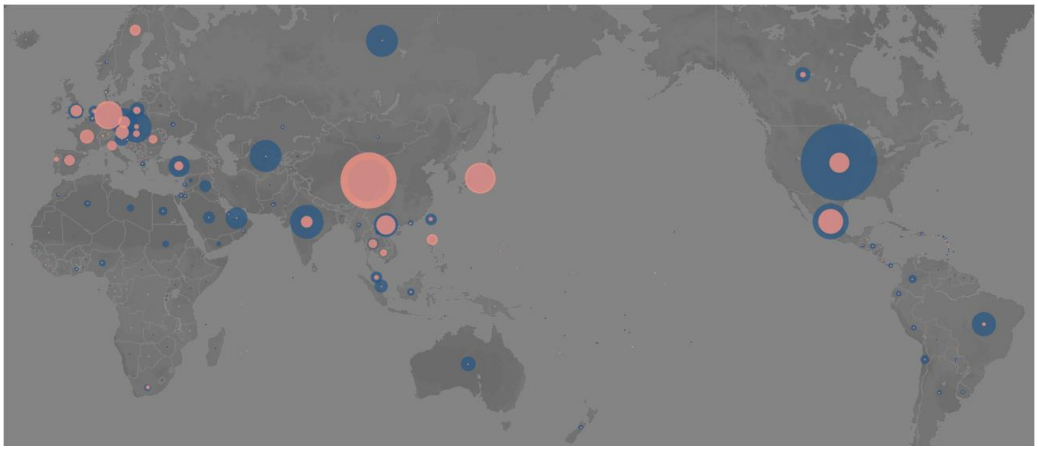



**Figure 4. Status of import and export partner countries for automotive parts.**
Note: 'G' in the y-axis represents 1 billion. Data was extracted in five-year periods (1995–1999), and from January to June 2020.




(a) Before the COVID-19 outbreak (Cumulative, June 2019)



(b) After the COVID-19 outbreak (Cumulative, June 2020)

**Figure 5. Status of import and export partner countries for automotive parts.**

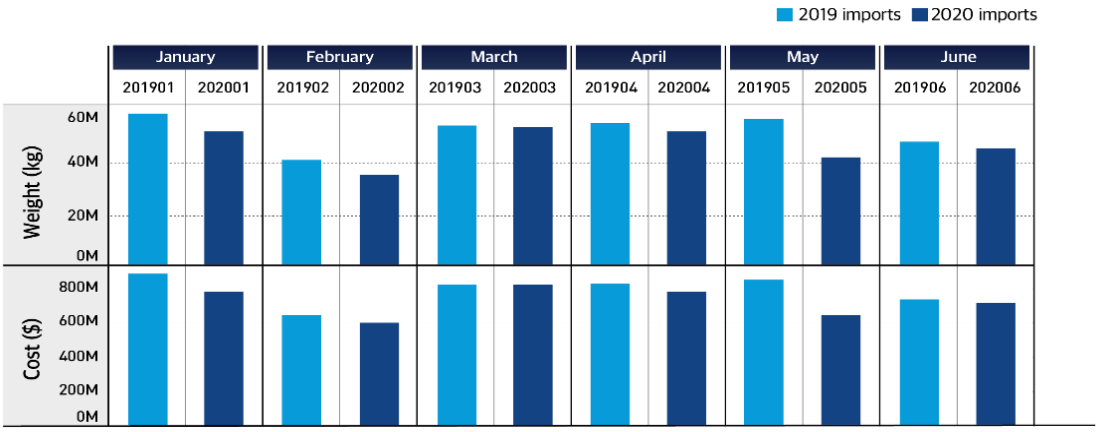



**Figure 6. Comparison of automotive part imports by month (comparison of 2019 and the first half of 2020: top-five import countries).**

export countries. In this regard, monthly volumes and costs of automotive parts imported from overseas decreased the most in May, due to the COVID-19 outbreak in 2020, compared to the same period in the previous year. Imports of automotive parts from China decreased the most in February, reflecting a decline due to China's annual 'Spring Festival' in February. Nevertheless, the import decline in February was the largest compared to the same month of the previous year. On the other hand, imports from China increased in March and April 2020 compared to the previous year, which appears to be a temporary increase due to stock exhaustion from the import decrease in February and the securing of safety stock. Thus, it seems that the demand for parts from China decreased in May and June due to the overall decrease in manufacturing and demand for automotive parts resulting from the continuation of the COVID-19 pandemic and secured stock.

On the other hand, export volumes and the volume of imported automotive parts officially started to decrease in April 2020, recording the largest decline in May 2020 compared to the same month of the previous year (Figure 7), indicating that COVID-19 had a sizable impact on the Korean auto parts industry. However, these numbers have increased since June 2020, apparently due to the restart of manufacturing by companies whose production lines had previously ceased due to the COVID-19 pandemic.

This study examined the trends in the decline of automotive part imports since the onset of the COVID-19 pandemic, based on the analysis performed above (Figure 8). The import costs of automotive parts from China declined year-on-year in January and February due to the impact of the COVID-19 pandemic; however, they increased again in March and April 2020 compared to the previous year. This appears to reflect a temporary increase arising from an increase in imports and securing safety stock in March and April in response to the stock exhaustion from the decreased imports in January and February. However, the decrease in demand for automotive parts from China in May and June appears to have resulted from reduced demand for automotive parts overall, given the decreased automobile demand and manufacturing during COVID-19. Thus, the COVID-19 pandemic has increased the necessity and importance of supply chain risk management. In this regard, it is necessary to secure

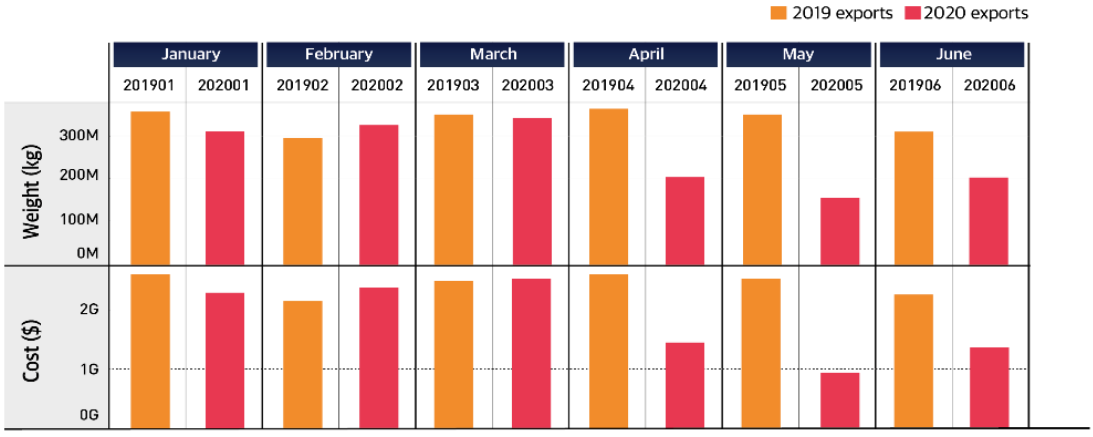



**Figure 7. Comparison of automotive part exports by month (comparison of 2019 with the first half of 2020).**


**Figure 8. Import status (based on cost, 2019 – June 2020, based on the top-two import countries).**

a stable supply chain for the future by examining the efficiency and resilience of global supply chains.

The main findings from the analysis can be summarised as follows.

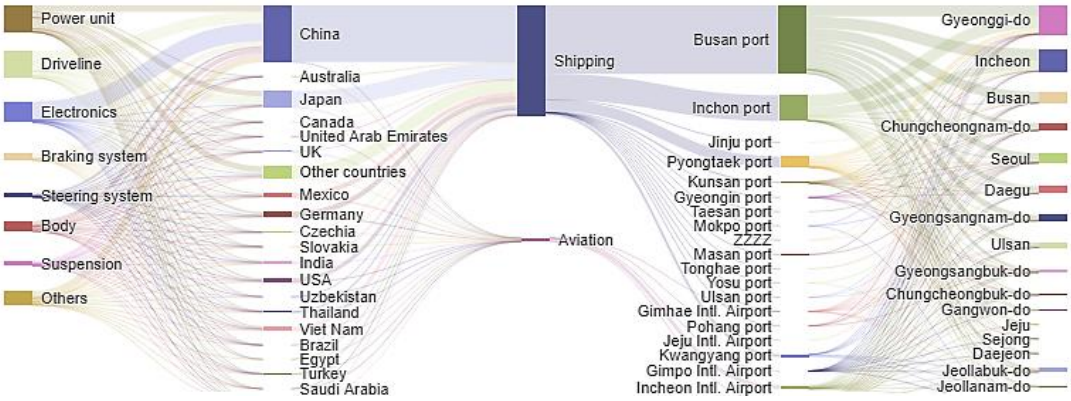
First of all, in general, the exports of automotive parts are greater than imports both in volume and weight. But the exports have been showing a decline since 2015 while the imports are showing a slight increase. Second of all, the main exporting countries of automotive parts are the USA, China, Japan, Mexico and India. South Korea exports large volumes to the USA while imports the largest from China. This shows that South Korea heavily relies on China for automotive parts. Last of all, this paper tried to find out whether the imports and exports have been affected by COVID-19. The results show that the imports of automotive parts in May 2020 were significantly decreased when compared to the same period in 2019. Exports are turned to be the same which showed a significant decrease. This is assumed to have been caused as a result of coronavirus pandemic. From the results of the analysis, it was clear to see that the pandemic (external shocks) has caused impact on the volumes of exports and imports of automotive parts in South Korea which in turn affected the whole supply chains of the industry.

## 5. Flow analysis by automobile parts and import/export region

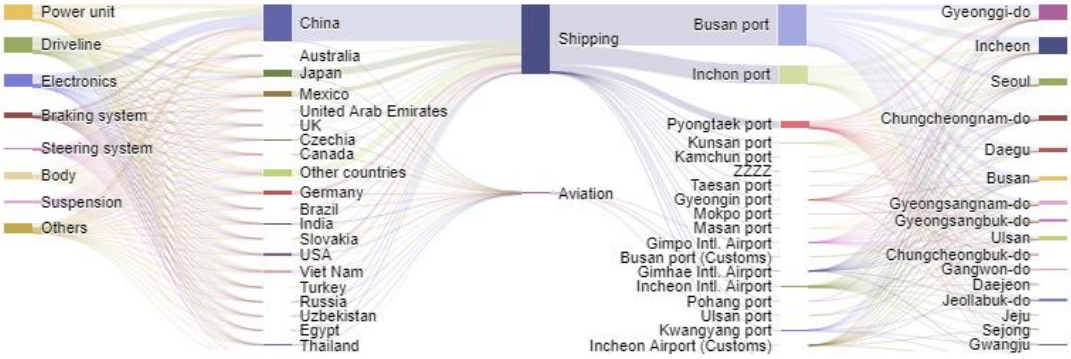
Automobile components were classified into eight major categories in this study (power unit, driveline, electronics, braking system, steering system, body, suspension, and other parts), and the imports and exports of each component were examined. The Sankey diagram can be used to intuitively confirm the import flow of automobile parts by displaying the import destination country, mode of transport, import seaport or airport and domestic import region for each part. The import volumes for 2019 and 2020 were compared in order to establish a baseline for comparisons of the time before and after the global COVID-19 outbreak. Figure 9 depicts the import link between nodes, and the relative flow volume (tons) is directly proportional to the thickness of the link.

Automobile parts are primarily imported via shipping. Also, automobile parts are not high-value-added items with low weight, such as semiconductors, but rather relatively heavy products with a low value, necessitating the use of sea transport. In Korea, the majority of automobile parts are imported through Busan Port, as well as the Incheon and Pyeongtaek ports. However, because Figure 9 cannot confirm the import regions of Korea, the Figure 10 illustrates the import destinations of auto parts imported from abroad to Korea at the city level.

As shown in Figure 10, Busan, Ulsan, Gwangju, Daegu, Pyeongtaek, Hwaseong, and Incheon all have a high import demand for automobile components. Additionally, imports often go to Seoul and metropolitan area as a result of the demand for maintenance and replacement of imported automobiles. When comparing auto part imports in 2020 to 2019, there does not appear to be a significant difference at first glance, but it is clear that imports in Busan and some other cities in the metropolitan

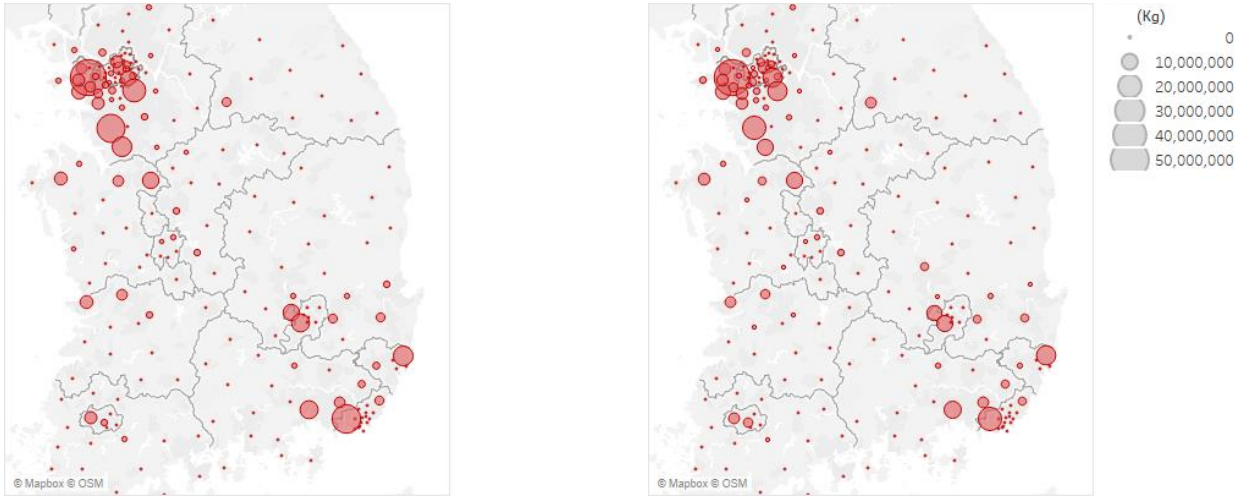



(a) Imports of 2019 (Jan.–June)




(b) Imports of 2020 (Jan.–June)

**Figure 9. Sankey diagram for automobile part imports before and after the COVID-19 outbreak.**
Note: 'ZZZZ' stands for an unknown port.

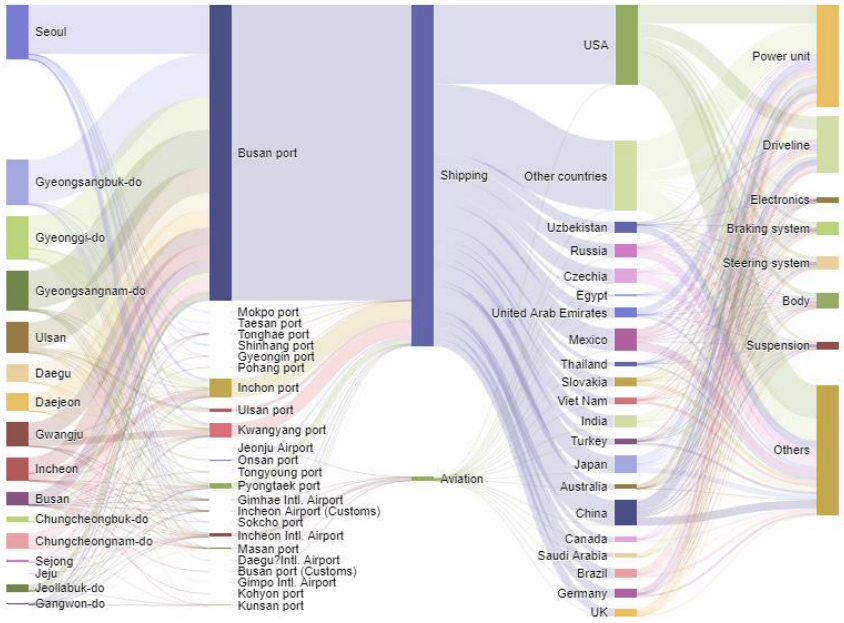



(a) 2019 (Jan.–June) (b) 2020 (Jan.–June)

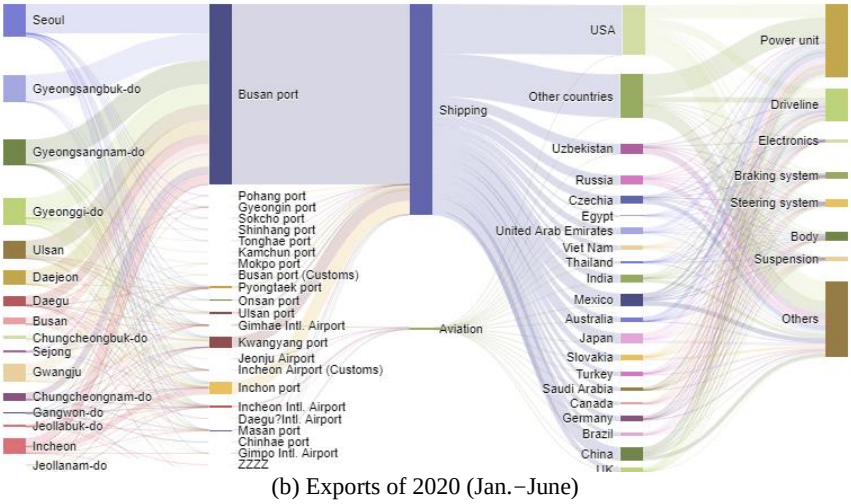
**Figure 10. Import regions for automobile parts in South Korea**
Note: The size of the circle represents the weight of imported automotive parts.

area have decreased. The difference in imports following the outbreak of COVID-19 is illustrated in greater detail in Figure 11. Also, as previously stated, automotive part exports exceed the imports, as shown in Figure 11.

As with imports, automobile components are exported to Busan, Ulsan, Gwangju, Daegu, Pyeongtaek, Hwaseong, and Incheon, all of which are hubs for Korean automobile manufacturing. This is because each automobile manufacturer is




Exports of 2019 (Jan.−June)




(b) Exports of 2020 (Jan.−June)

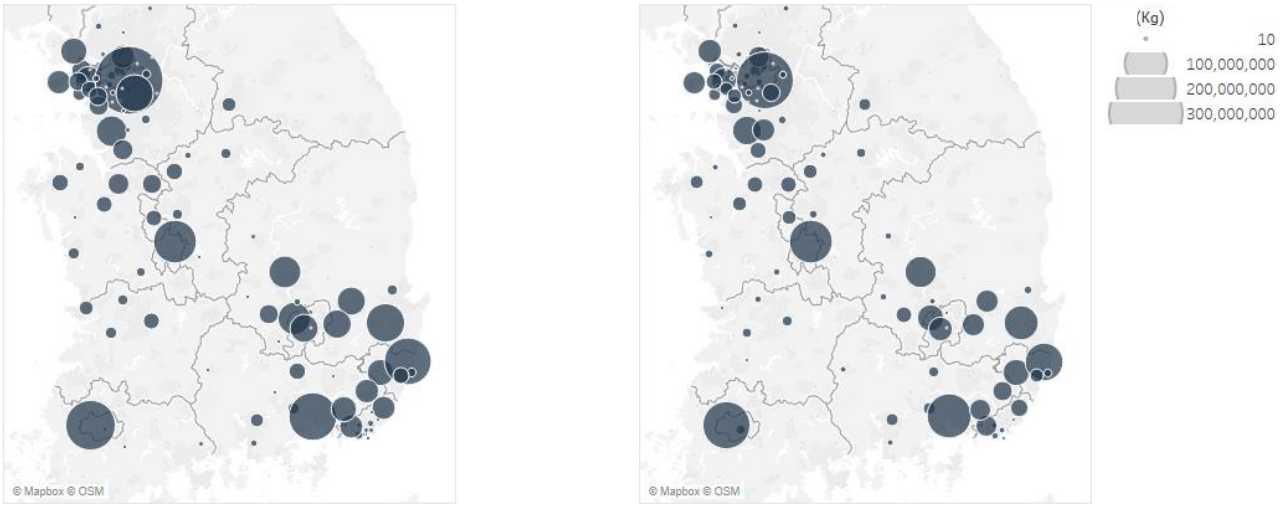
**Figure 11. Sankey diagram for automobile part imports before and after the COVID-19 outbreak.**
Note: 1) 'ZZZZ' stands for an unknown port.
2) Although exports account for a significantly larger share of total imports/exports than imports, the export diagram has been condensed in size.

responsible for exporting the components to be assembled into complete vehicles at overseas manufacturing facilities (Figure 12). Unlike imports, many automobile components are exported from Daejeon and Gumi.

## 6. Bayesian network (BN) analysis

China's imports are illustrated in Figure 13. They can be represented mathematically as P [Parts major classification | Import Export = Import, Foreign countries top 20 = China]. At the moment, the distribution of eight types of auto parts from China in Korea can be tracked. Additionally, as indicated by the 'COVID-19 effect' node, the percentage of imports from China has decreased since the outbreak of COVID-19. In other words, the number of imports was lower in 2020 than it was in 2019. Figure 14 illustrates the impact of COVID-19 item by item.

The largest difference in auto part imports from China before and after the COVID-19 outbreak was observed for wires and cables. In the case of automobile manufacturing, if even a single critical component is not delivered on time, automobile




(a) 2019 (b) 2020

**Figure 12. Export regions for automobile parts in South Korea.**

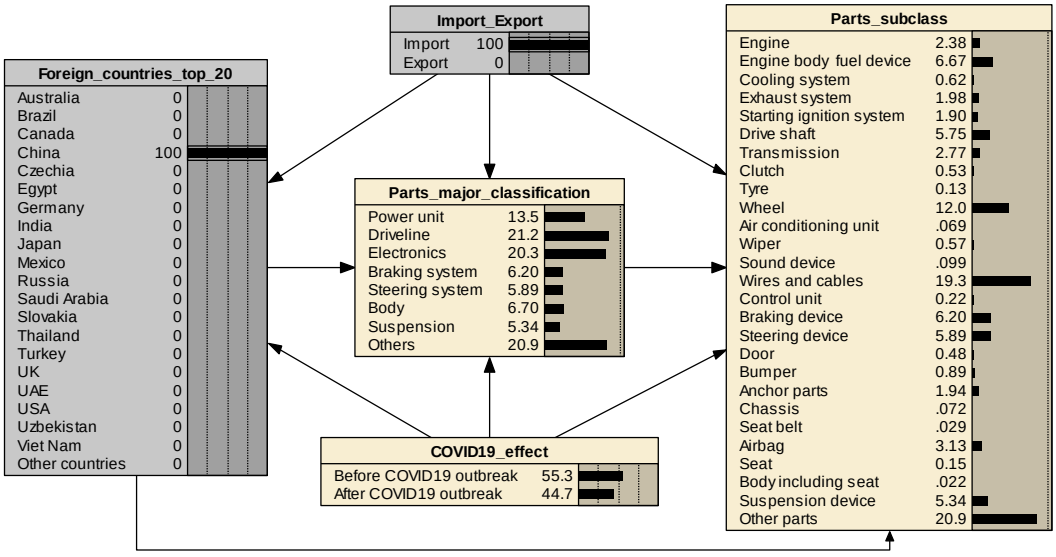


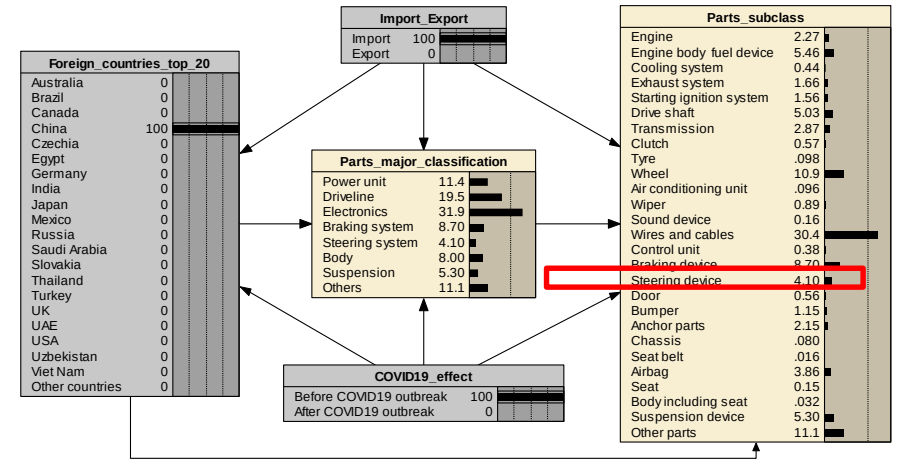

**Figure 13. Bayesian network for automobile part imports from China.**

production will be halted. Indeed, there is a case where production had to be halted because a part could not be included in the domestic car manufacturing process due to the Chinese factory that manufactured the 'wiring harness' ceasing operations due to COVID-19. In Figure 14, we can see the supply disruption due to the lack of 'wiring harness' components, which are highly reliant on imports from China. It is necessary to reduce the proportion of cooling system imports from China and manage supply chain risks through diversification of importing countries to avoid a repetition of this kind of situation, resulting in the disruption of the domestic automobile production.

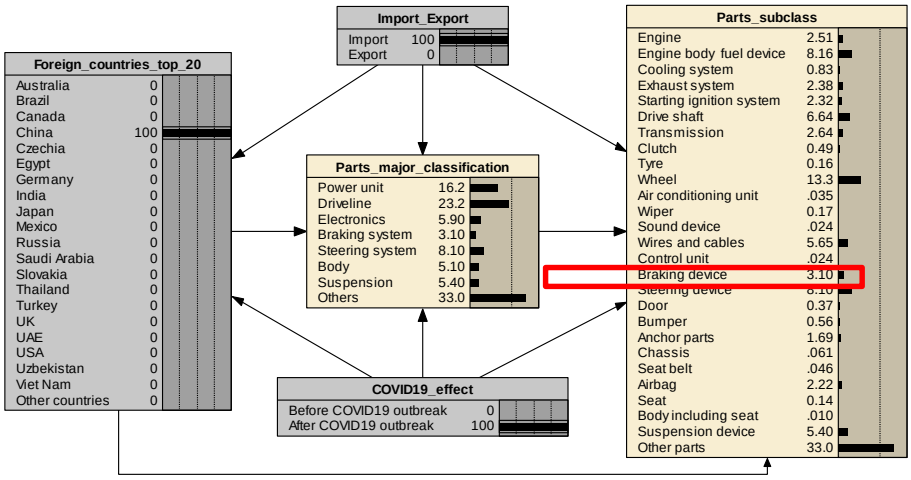
As a result of the Bayesian inverse probability, we can determine which products pose a high supply chain risk. Calculating the inverse probability of imports of the wires and cables discussed previously reveals that imports from China exceed 90%, as shown in Figure 15. Additionally, it can be seen that the proportion has changed significantly since the outbreak of COVID-19.

As illustrated in Figure 16, the proportion of tires imported from Japan is high, and their proportion has decreased significantly since the COVID-19 outbreak. However, because tires are manufactured domestically, they can be viewed as stable supply chain components.

As illustrated in Figure 17, the proportion of imported wheels and air conditioning units is not evenly distributed across countries, and the proportion of imports from China is particularly high. As with wires and cables, this is a product that requires




(a) Before the COVID-19 outbreak




(b) After the COVID-19 outbreak

**Figure 14. Automotive parts by import volume (weight, kg) from China before/after the COVID-19 outbreak.**

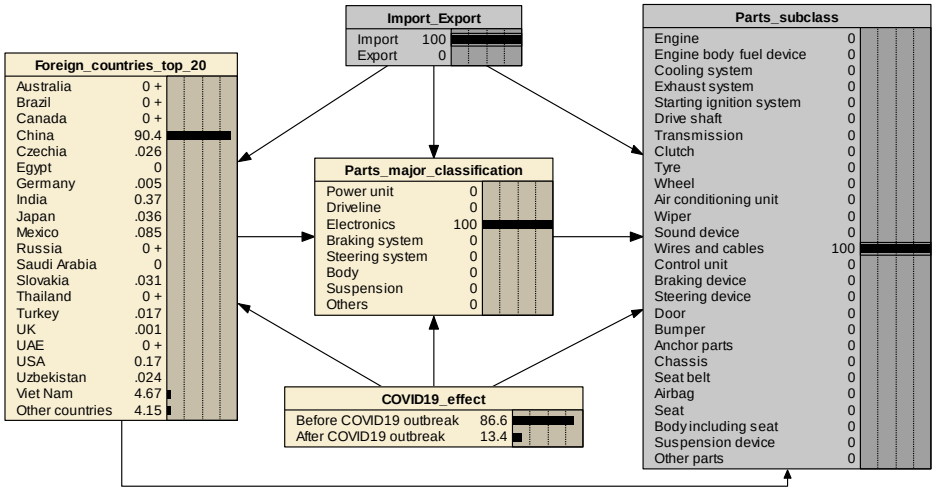



**Figure 15. Inverse probability when 'wires and cables' are selected as the import item.**

monitoring and securing of the part supply chain from China, as well as diversifying the overall part supply chain.

On the other hand, the steering system was the only component that increased in price following the COVID-19 outbreak,

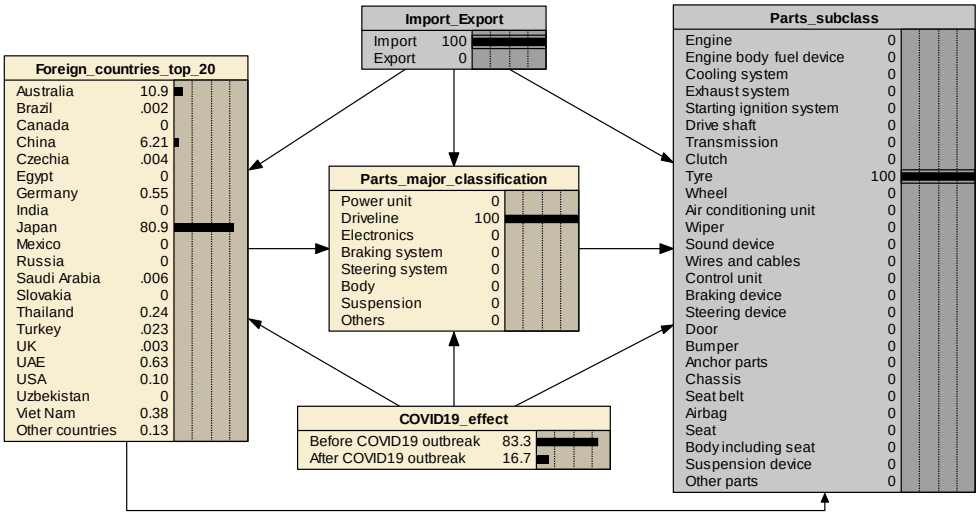
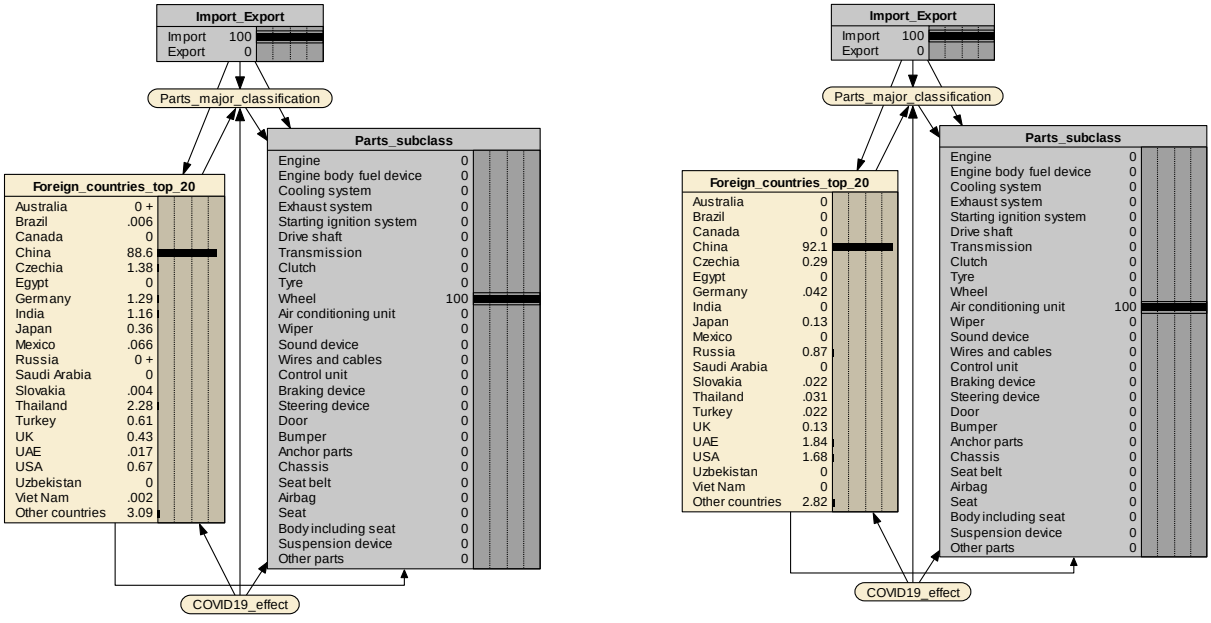



**Figure 16. Inverse probability when 'tire' is selected as the import item.**




(a) Wheel (b) Air conditioning unit

**Figure 17. Inverse probability when the respective import item is selected.**

as shown in Figure 18. For instance, Taelim Industrial is a company that supplies conventional automobile steering systems. Taelim Industrial's competitiveness increased significantly after it invested in a smart factory to offset the decline in sales caused by changing times and prepare for the future.

Additionally, as the automobile industry's paradigm shifts toward the production of carbon-neutral automobiles, such as electric vehicles, the components used in internal combustion engines are expected to decrease in the future. Thus, existing component manufacturers must actively respond to changes by investing in smart processes, as well as in component development.

While the majority of automobile parts are imported via Busan Port, some are imported via Incheon Port and Pyeongtaek Port (Figure 19). By examining each item, it becomes clear that the proportion of electronics products imported into Incheon and Pyeongtaek Ports was greater than that being imported through Busan Port, and that the proportion of braking and steering system imports through Incheon and Pyeongtaek Ports was also greater than that of Busan Port. This could be viewed as a benefit as a port adjacent to China. There was no difference in exports between parts, and the busiest port overall was Busan

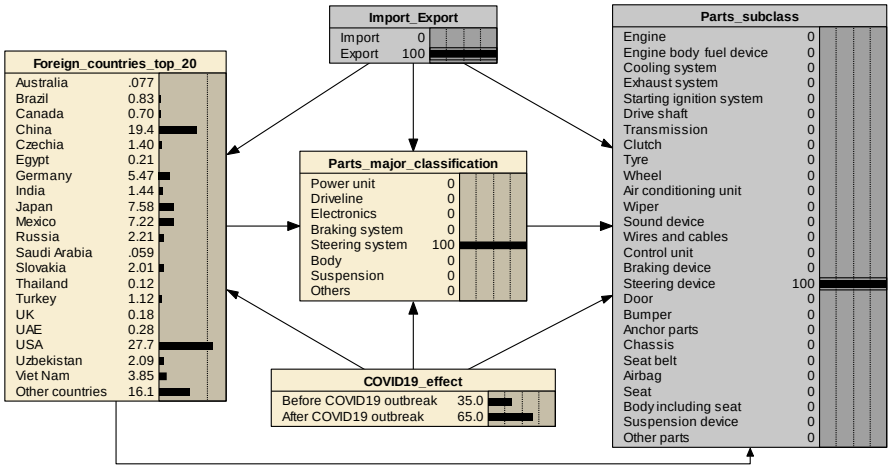
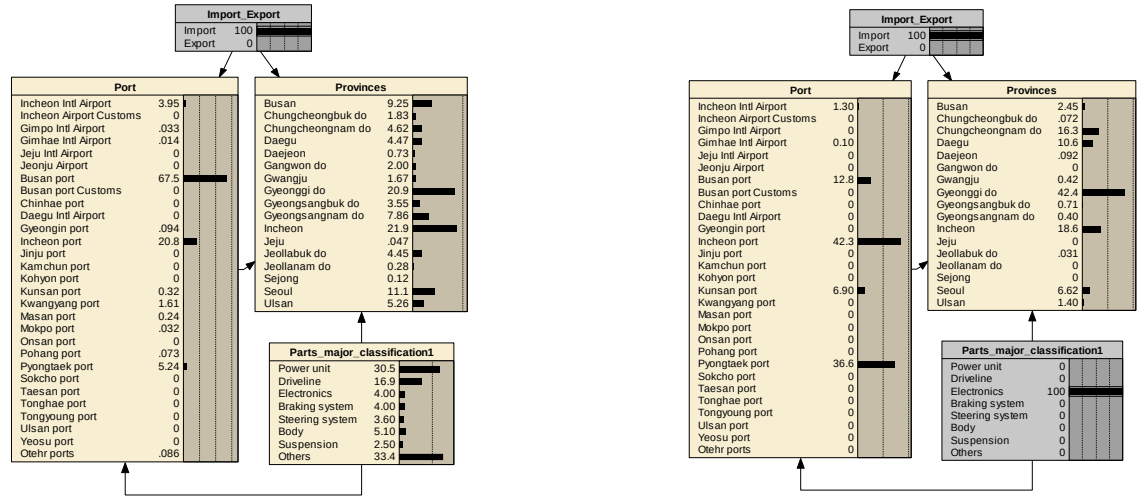


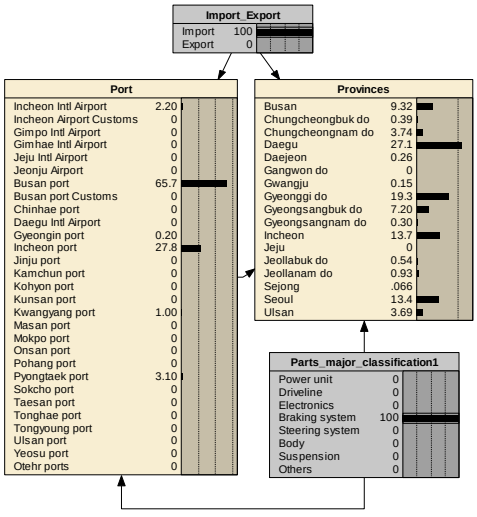

**Figure 18. Inverse probability when the 'steering device' is selected as the import item.**



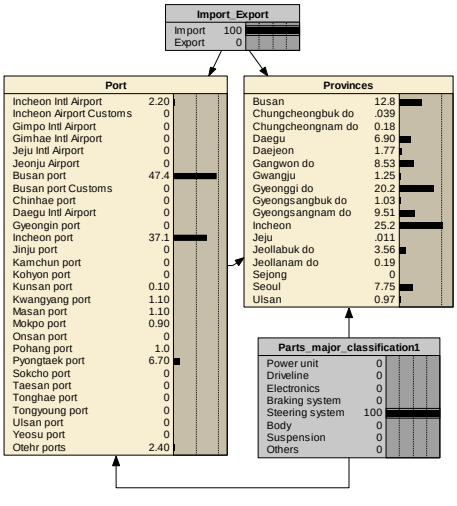

(a) Import




(b) Import of electronics




(c) Imports of braking systems




(b) Imports of steering systems

**Figure 19. Bayesian network between 'Port' and 'Province' by import/export and automobile parts.**

Port, as illustrated in Figure 20.

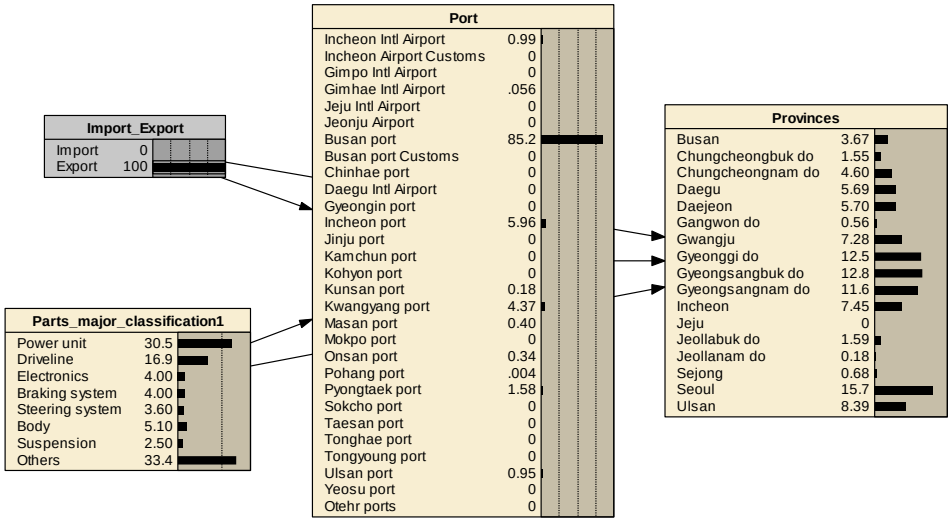



**Figure 20. Bayesian Network between 'Port' and 'Province' of automobile part exports.**

## 7. Summary and discussion

Not only completed automobiles but also automobile parts were exported in large quantities as the automobile industry developed. Since 1995, the USA, China, Japan, Mexico and India have been major export and import destinations for automobile parts by volume. However, COVID-19 had a sizable impact on Korea's automobile parts industry.

The majority of automobile parts are imported via shipping. The demand for automobile part imports was high in regions with automobile manufacturing plants (Busan, Ulsan, Gwangju, Daegu, Pyeongtaek, Hwaseong, and Incheon), and automobile parts imported from other regions were used in the maintenance and replacement of imported automobiles, among other things. Exports are similar to imports in that the export region of automobile parts is primarily the region where Korean automobile manufacturing plants are located. Supply disruption involving the lack of 'wiring harness' components, for which Korea is highly reliant on imports from China, can be seen in the BN. It is necessary to reduce the proportion of cooling device imports from China and manage supply chain risks through diversification of importing countries in order to avoid a repetition of such a situation that resulted in a major disruption of the domestic automobile production.

As a result of Bayesian inverse probability, this study determines which products pose a high supply chain risk. Even if Japan's share of imports, such as tires, is greater than the average for all countries, a stable supply chain can be ensured if domestic production is feasible. However, it is clear that the proportion of imported wheels and air conditioning units is not evenly distributed across countries, with a disproportionately high proportion of imports from China. As with wires and cables, special attention should be paid to inspecting and securing the supply chain for Chinese components. Additionally, as the automobile industry's paradigm shifts toward the production of carbon-neutral automobiles, such as electric vehicles, the need for components used in internal combustion engines is expected to decrease in the future.

As a result, existing component manufacturers must actively respond to changes by investing in smart processes as well as component development. While the majority of auto parts are imported through Busan Port, some are imported via the Incheon and Pyeongtaek Ports.

Global supply chain changes are also having an effect on the Korean automobile industry. In particular, as a result of COVID-19's "unpredictable" situation, the supply chain formula that had been considered the traditional answer is changing. This study used a visualization technique that enables intuitive analysis of auto part import/export data following the Corona 19 outbreak, diagnosed the global supply chain for parts used in automobile production in Korea, and examined parts with potential supply chain risks. This requires reducing the risk of supply chain disruption by diversifying the supply chain, which is currently concentrated in a few countries, and enabling low-cost domestic production of core components through automation and smart processes. Due to the expected reduction in the number of components used in internal combustion engines in the future, existing component manufacturers must actively respond to changes through investment in smart processes and component development.

This study suggests the need to reorganise the automotive parts industry's existing global value chain structure. An analysis

of the main parts needed to build automobiles confirmed that the import dependence on certain countries and associated risks are high. Accordingly, a global value chain reorganisation plan for the automotive industry is presented by suggesting a risk management strategy for risks inherent in the current global value chain structure. This study proposes 'reshoring' to diversify the supply chain, as well as 'diversification of the production base to other Southern countries' as risk management strategies.

As mentioned above, the study's first suggestion is a reshoring strategy. Reshoring emerged in the government policy discourse at the outset of the collapse of the existing global value chain. The current government has also mentioned the need for reshoring as a job creation measure. Accordingly, it appears necessary to implement a reshoring strategy that relocates the automotive part production bases in China and Japan to South Korea. The reconstruction from labour-intensive to capital-intensive production manufacturing systems has become possible due to the development of technologies based on the Fourth Industrial Revolution, such as artificial intelligence and smart factories, making it relatively easier for companies that had relocated overseas to reduce their labour costs, enabling them to return to their home countries.

Next, the study proposes a diversification strategy for the production bases, moving them to 'new Southern countries'. This strategy involves diversifying the production capacity currently concentrated in China and Japan to new Southern countries, such as Vietnam, Thailand and Indonesia. In other words, it is expected that the 'Southeast Asia + 1' strategy can be implemented, which can expand the production base from China and Japan to other Southeast Asian countries. The Association of Southeast Asian Nations (ASEAN) market currently draws attention as the second global production base to replace China as China's advantages as a production hub are becoming less apparent due to the intensification of non-tariff barriers and increasing manufacturing costs. Furthermore, the strategic and economic value of the ASEAN region as a production base is increasing because of its rapid growth, young and abundant labour force, low wages and the promotion of strategies to foster manufacturing at the national level. It is expected that South Korea will be able to reduce existing value chain risks and contribute to the realisation of the New Southern Policy (NSP), which is being actively promoted by the current government that selects Southeast Asian countries for the diversification of automotive part production bases.

## 8. Conclusion

This study examined the existing structure of the global value chain for automobiles, selected as a major port-linked domestic industry, and analysed the risks affecting the current structure according to internal and external environmental changes. Furthermore, the study derived the main automotive parts through a paradigm analysis of the automotive industry. From this perspective, the automotive industry was categorised into eight broad areas, and the import status of sub-components focused on the three areas with the highest import and export prices and weight (i.e., power units, drivelines, and electronics).

First, the proportion of imported power units, excluding engines, was higher for certain countries (mainly China, Germany and Japan). This result includes imports of cooling systems, exhaust systems and starting and ignition systems. In particular, most power units, except for engines, are currently being imported from China. The 'de-China' phenomenon, arising as a movement toward the reorganisation of global supply chains due to China's supply chain risks emerging from the recent COVID-19 pandemic, accordingly calls for the necessity of supply chain risk management for relevant parts. Similarly, a large proportion of imports of many driveline parts, excluding clutches, come from certain countries (i.e., drive shafts come from China, transmissions and tires come from Japan). In particular, imports of drive shafts and wheels come more frequently from China than other countries, highlighting the need to consider domestic manufacturing volumes and review supply chain risks. Among electronic parts, the disruption to the import of wires and cables from China due to the COVID-19 pandemic affected automotive manufacturing in South Korea, indicating that a very high proportion of imports came from China. Similarly, a highly concentrated number of supplies for air conditioning units also come from China, which is another area that requires diversified supply chains in the future.

Despite the care with which this research was conducted, research cannot be without limitations. To begin, no consideration was given to the localisation ratio of each part. As a result, accurate dependence should be calculated in future studies, where both the localisation and overseas import ratios are taken into account. Second, because KD (knock-down) was not captured in the data, imports and exports of KD were excluded. Finally, while this study did not consider the location of overseas automobile manufacturing bases, it is significant because it depicts the overall flow of SCM in the automobile parts industry and suggests implications.

Policies aiming to minimise the spread of COVID-19 worldwide are now also applied to commerce, trade and global supply chains. Therefore, the necessity and importance of supply chain risk management have only increased with the spread of COVID-19, and South Korea should, consequently, secure a stable supply chain by considering the efficiency and resilience of

global supply chains in the future.

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