CHARLES UNIVERSITY

FACULTY OF SOCIAL SCIENCES

Institute of International Studies

International Masters in Economy, State and Society

Master's Thesis

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The Changing Role of Global Automotive Industry: Analyse the Automotive International Trade of CEE Countries and China

Master's Thesis

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Study programme: International Masters in Economy, State and Society
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Year of the defence: 2024

Declaration

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2. I hereby declare that my thesis has not been used to gain any other academic title.
3. I fully agree to my work being used for study and scientific purposes.
4. During the preparation of this thesis, the author used OECD-ICIO database, BACI database, Stata and Gephi in order to conduct IO analysis and network analysis. After using this tool/service, the author reviewed and edited the content as necessary and takes full responsibility for the content of the publication.

In Prague on 30.7.2024 Yifan Chen

References

Chen, Y.F., 2024. *The changing role of global automotive industry: Analyse the automotive international trade of CEE countries and China.*99p. Master's thesis. Charles University, Faculty of Social Sciences, Institute of International Studies, International Masters in Economy, State and Society. Supervisor prof Vilém Semerák, Ph.D.

Length of the Thesis: 20652

Abstract

The paper examines the role of Central Eastern Europe (CEE) countries and China in the international automotive industry. The research uses the OECD-ICIO database covering 1995-2020, to conduct the Input-Output (IO) analysis and IO network analysis on vehicle sectors. BACI database covering 2017-2022 is used to conduct IO networks in the EV sector. We found that China has become the centre of the global automotive network and CEE has been closer to the network during 1995-2020. The vehicle production in China has been localization, and the whole process from components production to assembly could be completed in China. The vehicle productions of CEE are export-oriented. The pattern of the vehicle industry in CEE countries is “factory economies”, which contribute to the low value-added parts of automotive GVC. The situation of fragmentation of the European automotive value chain is more obvious. Moreover, China and CEE countries are gradually transitioning to EV industries. China has become the second largest country in the network and the CEE countries have become closer to the centre. More China EV companies have invested in and built EV factories in Europe. CEE countries have attracted foreign investment for the EV-related sectors.

Abstrakt

Článek zkoumá roli zemí středovýchodní Evropy (SVE) a Číny v mezinárodním automobilovém průmyslu. Výzkum využívá databázi OECD-ICIO pokrývající období 1995-2020 a provádí analýzu vstupů a výstupů (IO) a analýzu sítě IO v automobilových odvětvích. Databáze BACI pokrývající období 2017-2022 je použita k provedení IO sítí v sektoru elektrických vozidel. Zjistili jsme, že Čína se stala centrem globální automobilové sítě a střední a východní Evropa se v letech 1995-2020 k této síti přiblížila. Výroba vozidel v Číně byla lokalizována a celý proces od výroby komponentů až po montáž mohl být dokončen v Číně. Výroba vozidel ve střední a východní Evropě je orientována na vývoz. Model automobilového průmyslu v zemích

SVE je „tovární ekonomikou“, která přispívá k částem automobilového GVC s nízkou přidanou hodnotou. Situace roztříštěnosti evropského hodnotového řetězce automobilového průmyslu je zřejmější. Kromě toho Čína a země SVE postupně přecházejí na odvětví elektromobilů. Čína se stala druhou největší zemí v síti a země SVE se přiblížily centru. Stále více čínských společností zabývajících se výrobou elektromobilů investuje a staví továrny na výrobu elektromobilů v Evropě. Země SVE přilákaly zahraniční investice do odvětví souvisejících s EV.

Keywords

Automotive industry, EV industry, global value chain, China, CEE countries

Klíčová slova

Automobilový průmysl, průmysl elektrických vozidel, globální hodnotový řetězec, Čína, země střední a východní Evropy

Title

The changing role of global automotive industry: Analyse the automotive international trade of CEE countries and China

Název práce

Měnící se role globálního automobilového průmyslu: Analýza mezinárodního obchodu s automobily v zemích střední a východní Evropy a v Číně

Acknowledgement

Firstly, I would like to express my deepest gratitude to my supervisor prof. Vilém Semerák. Thanks for his invaluable support, thoughtful suggestions and infinite patience. Furthermore, I would like to thank my family and friends for their unconditional support and encouragement during the intense academic years.

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Introduction

The automotive industry is a significant part of modern industry. It creates jobs in a wide range of industries like metal production, electronics, plastics, glass and so on. It also contributes to the development of transportation and manufacturing (Wang, 2015). According to Kierzkowski (2011), large automotive firms shifted the parts and components factors and production to developing countries in order for low costs and markets since the 1980s. The number of vehicle assemblies is increasing rapidly in developing countries located outside the traditional core countries in the automotive industry (Humphrey, et al., 2000). With rapid economic growth, the purchasing power of some large developing countries increased, which led to a high demand for passenger vehicles. Because of the potential market and low costs, foreign automotive transnational corporations (TNCs) provide investment or form joint ventures in these countries (Liu & Yeung, 2008).

Central Eastern Europe (CEE) countries are Hungary, Slovakia, Slovenia, Czech, Lithuania, Estonia, Latvian, Croatia, Poland, Bulgaria, and Romania, which are located near the European core areas of the automotive industries like Germany, the UK and France. CEE countries' low production costs, location advantage and the advantages of regional economic blocs like joining the European Union (EU) make them attractive for the core areas of vehicle production (Pavlínek, 2002).

Since the founding of the People's Republic of China in 1949, the economy of China has been controlled by the Chinese government. During 1949-1976 (the Maoist period), the domestic vehicle industry was dominated and controlled by the government. The government was the main acquirer and distributor of all automobiles. During this period, foreign-oriented activities were through international collaboration agreements and trade. After 1978, the Chinese automotive industry experienced change. The government encouraged international joint ventures to invest and build up production facilities in China in order to supply various types of automobiles to the domestic market. However, to ensure the international technology transfer and the completion of an domestic internationalization process, there were strict conditions to establish a joint venture (Zhou, et al., 2019). In 1994, the China Planning Commission announced the Policy for the Automotive Industry ("1994 Auto Policy"). All foreign companies that want to enter the Chinese market need to register as joint ventures, ensure necessary technology transfer, and commit to applying at least 40% of the inputs from local suppliers. However, these conditions did not deter those multinational companies. In the 1980s, there was a total of 880 million USD FDI in the Chinese automotive sector. There was a 60 billion USD inflow of capital in the next ten decades (Brandt & Rawski, 2008). On 1st January 2022, the Chinese government announced to removal of the ownership limitation on foreign vehicle companies, which allowed foreign investors to establish wholly foreign-owned enterprises (WFOEs) in China (Tim, 2022).

Researchers indicate the global vehicle industry has the phenomenon of geographical fragmentation. The vehicle markets are dominated by a small number of global auto companies from a few core countries. These countries mainly focus on high value-added parts of the automotive value chain, like research & development (R&D), logistics and retail parts and so on.

The production part, which is relatively low value-added, is divided into different parts and carried out by other developing countries (Wang, 2015). However, the expansion of global production networks and consumer demand has led to the high-speed growth of the domestic vehicle industries of these countries. A large number of production firms are taking part. For example, fragmentation has led to an explosive expansion in the trade of parts and components because of the expansion of back-and-forth transactions in vertically fragmented cross-border production processes (Amighini, 2012). The competition for parts and components production is fierce. While the global automobile industry is growing steadily, the emerging market or developing countries are gradually narrowing the gap with traditional auto core countries. Industrial upgrading is necessary for these countries to improve their positions in the automotive global value chain (GVC), which contributes to economic development (Henderson, et al., 2002). There are four types of upgrading: process upgrading, product upgrading, functional upgrading and intersectoral upgrading (Humphrey & Schmitz, 2002). CEE countries and China tend to involve more functional and production upgrading. For example, they plan to move from simple assembly or labour-intensive activities to high-skilled intensive and high value-added activities (Tian, et al., 2019). In addition, the transition to electric vehicles (EV) has been the current trend in the global vehicle industry. China and CEE countries have integrated into the transition to EVs through functional and production upgrading. For example, some of those countries invested and produced new EV-specific products, increased the investment in the improvement of the local capacity of battery production, developed highly automated manufacturing procedures and digital technologies and so on (Szalavetz, 2022). Therefore, the situation of the worldwide vehicle industry situation is quietly changing.

Besides ICE vehicles, the market for electric cars has kept growing in recent years (IEA, 2023). The revolution of the whole EV industry helps to reduce the dependence on oil and the emission of CO_2. China was the largest market of electric cars, accounting for about 60% of global EV sales in 2022, and Europe was the second largest market accounting for about 15%.

It is necessary to discuss whether the role of China and CEE countries in the global automotive industry has changed. The main purpose of this paper is to analyse the trade of automotive industries (including the EV industry) of CEE and China, using input-output analysis combined with network analysis. The vehicle data will be collected using the OECD-ICIO database for 1995-2020, and the BACI database for 2017-2020 will be used for the EV industry analysis.

The paper is organized as follows. Section 2 analyses literature and research papers about the automotive industry trade of CEE and China, input-output (IO) analysis and input-output (IO) network analysis. Section 3 introduces data about the automotive industry collected from OECD-ICIO database for 1995-2020, the data of EV industry collected from BACI database for 2017-2022, as well as the methodology of IO analysis and network analysis. Section 4 analyses the collected data using IO analysis and IO network analysis. Section 5 discusses the empirical results. Section 6 concludes the main findings, and the limitations and future research of the paper. Section 7 provides a summary of the paper.

1. Literature review

1.1 Automotive industry

1.1.1 Automotive industry in China

Before the Communist Party came to power in 1949, there was almost no automotive industry in China. During 1950-1960, China's main alliance was the USSR (Soviet Union) which assisted in the development of the automotive industry (Oliver, et al., 2009). During this period, the quantity and category of domestic vehicle productions were centrally planned which was decided by the government. The government has set production quotas for each category. Priority is given to commercial and industrial vehicles. Most of the vehicles produced were trucks, and passenger cars were produced in very small numbers (China Automotive Industry History Editorial and Review Committee, 1996). Until the early 1970s, the average production of passenger cars per year was less than 1,000 units, which was below 1% of total car production in China (Zheng & Broggi, 2023).

Since reforms began in 1978, there has been a rapid growth of the vehicle industry in China, which grew from a low level of capacity. Since the mid-1980s, China allowed independent Chinese Automobile Manufactures (ICAMs), which are non-state companies with Chinese capital, to appear in the automotive market (Li, 2014). The government tried to launch a strategy named "market for technology" in the early 1980s while supporting domestic companies to join ventures with foreign automotive enterprises that could provide advanced technology. To ensure international technology transfers, there were strict limitations on establishing joint ventures. Firstly, a joint venture can only be founded by a domestic partner and a foreign partner. The foreign partner's shareholding must be less than 50%. Secondly, the foreign partner may not engage in more than two joint ventures in China for the production of the same kind of vehicle. Thirdly, the foreign partner shall guarantee the transfer of technology such as management and organisational methods, to the domestic partner. Fourth, the joint venture should produce vehicles that are compatible with the Chinese market. In addition, priority should be given to the development of local suppliers (Oliver, et al., 2009). There was a gradual growth of vehicle outputs with the influence of the joint ventures. As Table 1 (Zheng & Broggi, 2023) shows, since 1986, the output of passenger cars increased a lot from 4944 units to 30038 units, because of the joint ventures. In the early 2000s, the output of both passenger cars and commercial cars was about two million.

Table 1: China's Automobile Production by Five-Year plans (yearly average)

Five-year Plan	Period	Total (units)	Passenger cars (units)	Commercial vehicles (units)
1st FYP	1953-1957	3,206	-	2,648
2nd FYP	1958-1962	14,301	54	11,351
Restructuration	1963-1965	29,728	81	24,611
3nd FYP	1966-1970	48,322	217	40,056
4nd FYP	1971-1975	116,013	1,136	90,498
5nd FYP	1976-1980	163,530	3,430	122,949
6nd FYP	1981-1985	205,654	4,944	183,344
7nd FYP	1986-1990	416,839	30,038	365,414
8nd FYP	1991-1995	1,027,854	209,854	754,245
9nd FYP	1996-2000	1,608,727	511,340	1,068,944
10nd FYP	2001-2005	4,161,060	2,012,257	2,148,803

(Source: Zheng & Broggi, 2023)

Since 2001 when China joined the World Trade Organization (WTO), China accelerated the process of liberalization in the market. From 2001 till now, the development in automotive manufacturing in domestic companies up to an unprecedented rate. The tariffs on vehicles declined from 200% in the 1980s and 80%-100% in the 1990s (Gao, 2002) to 25% in 2006 and tariffs on spare parts were reduced to about 10% (Gregory, 2006). The liberalisation approach attracted significant investment from foreign assemblers and suppliers. By 2002, many international assemblers and Tier 1 vehicle suppliers had set up major operations in China. The number of China's vehicle components production has increased dramatically since the mid-1990s, especially after 2003. China became a major supplier of components and participated in the international division of production of vehicles. Liu et al (2008) also stated that joining in WTO has an effective influence on the vehicle industry development of China. Within two years of joining in WTO, China became the fourth largest vehicle-producing nation in passenger cars area around the world, only after the United States, Germany and Japan in 2005. Francois and Spinanger (2004) also mentioned that the entry of China into the WTO has a huge influence. One of the reasons is that the domestic automotive industry was restructuring, which focused on reducing costs to the global norms. As a result, domestic manufacturers have become competitive in the vehicle GVC, while the manufacturers have trended to further integrate with the global vehicle industry through exports. Liu et al (2008) also confirmed that the main reason for increasing the competitiveness of the domestic vehicle industry is the development of local industrial clusters that supply parts and components to automobile manufacturers at competitive prices. Li et al (2014) pointed out that, although China has started to export national brand vehicles, the domestic industry is mainly focused on components and assembly. China's strength lies in the high demand for vehicles in the domestic market and its large scale of production. However, the lack of core technology in national vehicle assembly firms has resulted in 90% of the national market share being controlled by multinational companies (MNCs). MNCs still control the key technologies needed to produce engines, key components and so on. (Li & Gao, 2014).

According to the Organisation Internationale des Constructeurs Automobiles (OICA, 2017) passenger vehicle sales from China ranked first in the world in 2017 and it became the fourth-largest country in the global trade of automotive products in 2017, while also the fastest-growing country in the vehicle industry. Besides, China is the third largest importer of vehicle products worldwide, which increased from 0.8% in 2001 to 5.44% in 2017. In 2023, vehicle production in China exceeded 30.16 million units, and sales exceeded about 30.1 million units, which set new records. The export of China’s auto reached 4.91 million, which means that China has been one of the largest automobile exporters in the global vehicle industries (Wang & Tao, 2024).

Li and Gao (2014) stated that though the global automotive market is still highly concentrated, its diversification trend is gradually obvious. Represented by China, those emerging countries are changing the pattern of the global vehicle market, but Germany, the United States, Japan and other countries that have high automotive production and creative capacity still control the global automotive market, and this trade pattern has not changed fundamentally.

1.1.2 Automotive industry in CEE countries

According to Chin, et al (2016), many original equipment manufacturers (OEMs, which means the companies that produce products or components that are sold to other companies to be used in their own products. Countries like Western Europe, Japan and the US sought to tap the CEE market potential, mainly after the collapse of the Soviet Union and the subsequent economic integration of the newly independent countries (Pavlínek, 2015). During the first half of the 1990s, the FDI inflows into the region were primarily motivated by market-entry goals. A large number of small and cheap models were produced in CEE countries (Johann, 2011). In this period, the automotive sectors in Eastern Europe were "the low end of the European car complex". The market demand and development were weak at this stage. With the slow-growth market for cars in CEE, the installed plants ran far below their maximum capacity utilization. The automotive industry was lack of skilled labour, high technology and regulatory certainties (Ruigrok & Van, 1998). Starting from the late 1990s, OEMs re-defined the role of CEE, primarily as hosts to export-oriented assembly and component plants. In 2004 and 2007, eight CEE countries entered the EU, and the automotive industry in these countries became increasingly integrated into world trade and GVC. Formal accession to the EU had implications for the value chain integration framework in these CEE countries in terms of institutions, regulatory mechanisms and policies. Most CEE countries have seen a significant increase in passenger car production after EU accession (Túry, 2014). Adarov (2021) also stated that those CEE countries have successfully integrated into the GVC network after joining the EU.

CEE countries have formed a key centre for European automotive production. Pavlínek et al (2017) described that CEE countries rely more on foreign direct investment and foreign car brands such as Mercedes, Toyota, Volkswagen, Volvo and General Motors have opened plants in these countries. Besides, CEE countries are mainly concentrated in the production part of the automotive value chain, such as vehicle assembly, parts and equipment production. Most of their products are exported. The R&D sector in the CEE countries is still weak and growing (Adarov, 2021).

Lukasz (2017) mentioned that Germany is CEE countries' main trading partner. Germany has been the largest export destination country of automotive goods and services from CEE countries, as well as the largest supplier to those markets. Margherita et al (2022) also found that these CEE countries are in a cluster led by Germany. The Japan and China-led cluster, which contains South Korea, Thailand, India, Indonesia, Malesia and Singapore, imports groups of components from Germany as well as the other countries in the Germany-led cluster.

1.2. Electric vehicles

Electric vehicles (EVs) include full battery electric vehicles (BEVs), range-extended electric vehicles (REEVs), fuel cell electric vehicles (FCEVs) and plug-in hybrid electric vehicles (PHEVs), which are also called hydrogen electric vehicles (H2EVs). As ACEA (2018) defined, BEVs are entirely powered using electric motors, of which the electricity stored in the onboard battery and charged through accessing the grid. A PHEV is a vehicle that has an internal combustion engine and a battery-powered electric motor. The internal combustion engine supports the electric motor when needed, and the battery is charged by connecting to the grid. REEVs are BEVs that run on electric power, but include an auxiliary power unit called a range extender. FCEVs use an electric motor, and the electricity is generated by a fuel cell that can be stored in a small buffer cell. FCEVs require hydrogen (compressed into a tank) as fuel. As the European Commission's report classifies, EVs refer to passenger vehicles like cars, small vehicles like light motorcycles, and goods-carrying vehicles like trucks. The majority of EVs are passenger vehicles (IEA, 2023).

According to IEA (2023), the market for electric cars has kept growing in recent years. Around the new car sales, the share of electric car sales is up from less than 5% in 2020 to about 14% in 2022, when number of electric car sales has over 10 million. China was the largest market of EVs, which accounts for about 60% of global EV sales by 2022. Europe was the second largest market accounting for over 15%, and the United States was the third largest reaching a sales share of 8%. The market of electric cars is expected to enlarge in 2023, which may increase to 14 million in sales and the share of electric cars will be up to 18% of total cars. Stephen (2022) also mentioned that the sales of EVs are expected to exceed of those internal combustion engine (ICE) vehicles by 2030.

Although the EV market has enlarged, it is still a small part of the whole automotive industry. ACEA (2023) reported that electric cars only make up 1.5% of the total European vehicle market. Only four countries' share of BEVs was over 2 % in 2021, which is Denmark (2.4%), Netherlands (2.8%), Iceland (4.6%) and Norway (16.2%). Only five countries' share of plug-in hybrid electric cars is over 2%, which is Denmark (2.8%), Finland (2.8%), Sweden (2.2%), Iceland (6.6%) and Norway (6.3%).

The market for EVs will be continuously increasing. Yigitcanlar et al (2008) mention that the increasing environmental and energy issues have led the development of sustainable transport to the agenda of cities worldwide. The Paris Agreement has brought climate change issues to the main international policies, leading to massive structural changes in the energy sector (Lindsay, 2023). Climate issues have caused attention to environmentally friendly energy. Vehicle emission is a major source of nitric oxide (NOx) and Particulate Matter 2.5 (PM2.5). As IEA (2021) calculates, general passenger and road vehicles fuelled by oil products may produce six giga-tons of carbon dioxide (CO_2) annually. Therefore, the automotive sector is facing a necessary change in emissions intensity, which stimulates the EV industry improvement. Steinhilber et al (2013) mentioned that EVs have been claimed to provide a way for sustainable transportation because EVs can reduce environmental and energy problems. Liu and Kokko (2013) claimed that developing EVs is a way to shift the dependence on petroleum for the automotive industry and increase the efficiency of energy transfer. Falcao et al (2017) analyse that for EVs, the CO_2 emission is lower than that of ICE vehicle exhaust. Blink (2023) also stated that EVs are one of the most significant shifts to reduce the emission of CO_2 and improve the air quality in cities.

1.2.1 Electric Vehicles in China

In China, EV means new energy vehicle (NEV), which includes PHEV, BEV, REEV and FCEV. China has been one of the largest vehicle production and sale countries worldwide. It plays an important role in employment and government income (Zhang, et al., 2017). China is a competitive manufacturing country, which has the largest automotive sales and consumption market. However, it relies more on low value-added parts of manufacturing and exporting, which still has weaknesses in main technologies and R&D abilities (Lee, et al., 2015). In order to realise the transformation of the automotive industry from investment-driven to innovation-driven, the Chinese government has implemented a range of measures to enhance the improvement of EVs (Chen, et al., 2017). The revolution in the NEV industry provides a survival opportunity for small and medium-sized domestic OEMs that possess innovative technologies but lack sufficient capital and policy support to compete with large OEMs or multinational giants in the classical vehicle market (Li, 2020).

Besides, in China, the demand for oil is mainly from vehicle consumption (Yuan, et al., 2016). Researchers estimate that automotive use accounts for about 60% of total oil consumption (Du & Lin, 2017). Due to insufficient domestic oil reserves, the rapidly growing demand for oil can only rely on imports, and China has become the world's largest oil importer (Lin & Wu, 2021). With the growth of the vehicle industry, China's crude oil consumption will increase rapidly. Without proactive policies and measures to reduce the demand for oil, China's dependence on exporting crude oil will increase to about 80% by 2030, which is a significant risk to Chinese energy security (Chen et al, 2017). Developing NEVs is an efficient way to reduce the dependence on oil for the whole automotive industry (Liu & Kokko, 2013).

Moreover, China's economic growth will continually depend on high energy consumption. The rapid economic growth is the main reason that causes the environmental deterioration. Environmental pollution is as significant problem that China has to solve for sustainable economic growth (Wang, et al., 2017). The main source of air pollution is the exhaust gas emission from vehicles in China's big cities. Chen et al (2017) state that the exhaust gas emission of vehicles accounts for 31.1% of local PM2.5, which is the highest of all pollution sources. In first-tier cities such as Beijing and Shanghai, vehicle emissions account for about 24% of pollution. Studies have shown that the replacement of NEVs can reduce air pollution caused by diesel vehicles (Qu, et al., 2021).

Based on the research from Lin and Wu (2021), the improvement of NEV has an incentive influence on the economy and industry development. The improvement of NEV may decrease the import of crude oil and the cost of vehicle transport. Because coal power plays an important role in the current electricity structure, the substitution of NEV may increase the needs for coal, which may indirectly increase carbon emissions. Nevertheless, as technology develops, electricity is likely to shift to a cleaner mix and CO2 emissions will decrease. The CO_2 emission will be reduced by 2348 million tons from the standard level under the high non-fossil electricity situation,

In addition, people have high intentions to support the improvement of the environment in China (Yuan et al, 2016). To encourage the improvement of the NEV industry, the government has executed a range of measures (Zhang, et al., 2017). Since 2004, the China government has published policies to develop the NEV industry. The earliest policy is “Special Planning for Medium and Long Term Energy Conservation”, in which emphasis was placed on the improvement of hybrid vehicles and research on NEV policies. Subsequently, the government introduced a range of policies to support NEVs. Between 2006 and 2010, China focused on NEV improvement and emphasised the production of NEVs in buses, taxis and other sectors. (NDRC, 2015). Starting in 2009, China raised financial support for NEVs' studying and innovation, and digitized the promotion targets (MF, 2009). Since 2011, China has begun to fully execute a pure electric drive technology transformation strategy (MST, 2011). In addition, China's first-tier cities have adopted measures such as tax reductions, buying incentives and transport privileges (Lin & Wu, 2018). Many local government and local branches of State-owned banks offered investment in the development of NEV companies. Some provinces and main cities even compete with each other to have NEV producers in their areas because they want to attract employment, revenues and gain the attention of the central government (European Commission, 2024).

At the end of 2022, the government stopped the purchase subsidy in order to reduce its intervention in the domestic market. The goal of the subsidy was to support the spread of the use of NEVs. Once the public had accepted and become accustomed to NEVs, the sales and development of NEVs would have continued with the market development.

However, it does not mean that such support completely stopped. Some local governments kept similar subsidies through State funds to support the NEV's production and promotion (European Commission, 2024). The rapid growth of NEVs production has led to overcapacity of both vehicle and battery production. Therefore, the government encourages NEV producers to explore overseas markets and export NEVs. EU is one of the main export destinations of Chinese NEVs.

As European Commission (2024) stated, the measures of the Government not only support the development of the industry, but also be used to control and direct the growth of the industry. The main policy is the Dual-Credit Policy, which rewards the NEV producers that fulfil the production targets and sanctions those that fail to meet the targets by forcing them to purchase performing companies or the "credits" from performing companies in order to offset their "debits". This policy can effectively promote the integration of the NEV market, which ensures the larger companies become larger and the small companies will have fewer resources or even disappear. Besides, through the purchase subsidy and purchase tax exemption, the government suppresses the price and controls the sales of NEVs, especially those NEV types and models that the government tends to favour. The reason is that the subsidy and tax exemption can be allowed to those NEV companies that satisfy the technology requirement of the government. The government also supports some models and technology of NEVs and makes the price much cheaper. In addition, because of the investment provided by the local governments and local branches of state-owned banks to the NEV companies, a share of the equity and debt of NEV producers have become State-owned. The government policies and actions are mainly for Chinese NEV brands and domestic production. Under this situation, the intervention of the government may distort the market of the NEV and battery industries in China.

1.2.2 Electric Vehicles in CEE

The European automotive industry has started to shift from ICE vehicles to EVs, which may cause the reorganisation of the entire European vehicle industry (Pavlínek, 2020). One main reason for the transition is the strict CO_2 emission limitation on new vehicle production issued by the European Commission. The aim is to limit global warming by reducing the release of CO_2. The European Union (EU) plans to adopt the "Fit for 55" package, which will effectively prohibit ICEs in all new vans and cars from 2035 onwards (IEA, 2023). The current vehicle producers are unable to meet the CO_2 emission standard with the existing ICE technologies, so the improvement of EVs becomes one of the most efficient alternative methods (Sigal, 2022). Besides, the development trends of the automotive industries have shifted to EVs in China and the United States, which are the largest and third largest automotive markets worldwide (Yeung, 2019). Because of the growing competitiveness, EVs produced by foreign enterprises in China and the US have started to be imported into Europe (Manthey, 2021). The current market trend generates competitive and regulatory pressure on the European automotive markets. In order not to be eliminated by the new EV market, European automakers need to accept and improve the EV industries (Pavlínek, 2022).

The e-revolution in Europe started in 2020. Since 2020, the registration of NEVs has increased. Registration of EVs increased from 2.3% in 2019 to 12% in the first half of 2022 and PHEV increased from 1.3% to about 9%, while the share of diesel and petrol vehicles decreased a lot (ACEA, 2023). Some CEE countries had a good beginning. Like the battery FDI in Poland and Hungary, and EVs production in Slovenia and Slovakia. The share of EVs in total car exports has increased sharply in 2020 and 2021. The share was about 40% in Germany, Slovenia and Slovakia, and the share of other CEE countries also reached about 30%. The exports of EVs in Slovenia and Austria were mainly in BEVs, which were 68% and 41% respectively. The share in Estonia and Hungary was mainly in PHEV, which was about 52% and 30% separately (Eurostat, 2022).

However, the market scale of EVs in the EU is not large enough. The types of passenger cars in use are still mainly petrol and diesel cars, which account for 52% and 43% respectively. The share of EVs is just 2.3% of the European automotive market (ACEA, 2023). CEE countries are in a disadvantageous situation in EV development. The degree of R&D in EVs of CEE relies on decisions made at the OEM's headquarters, where innovations will be retained, so there is minimizing R&D in CEE countries (Doris, et al., 2021). Pavlínek (2022) also stated that R&D in EVs is mainly developed in the home countries of large global Tier 1 suppliers or assembly firms, most of which are located in core countries like the US, Western Europe (WE), Japan and so on. The abilities of R&D are limited or absent in CEE. There is a low ratio of R&D expenditures to total production and a low ratio of R&D employers to total employers within EV industries in CEE (Pavlínek , 2012). Although the situation has gradually changed some innovation activities have shifted to CEE sectors because of cheaper R&D labour costs in CEE than in WE, the scale of innovation activities will still be larger in the key countries than in the CEE (Isaksen & Trippl, 2017). Therefore, the speed of transition to EV production in CEE is slower than that in Western Europe, especially compared with those developed and core countries of the European vehicle industry in Europe (Randall, 2021).

In addition, incentive policies only executed only in half of the CEE countries. About the Recovery and Resilience Facility (RRF) funds, only a small share of the funds has been used to support the EV infrastructure in CEE. There is 5% of the share in Poland, which is the largest share in CEE, and the shares of other CEE countries are below this level (Delanote , et al., 2022). Moreover, the improvement of the EV industry in CEE is facing some challenges. The structure of EV production is different from the traditional automotive industry, which will cause significant changes in the value chain and the situation of employment. 60% of the content of an EV comes from outside the traditional supply chain, like batteries and electronics. The production of EVs may need more software, rare earths and semiconductors (UBS, 2017). Batteries are an important component of EV, which contributes 40% of the total cost of the EV. The source of the batteries in Europe depends on the export from Asia, especially from China (European Commission, 2024). Recently, Europe has set up the battery supply chain as soon as possible, like the establishment of the Projects of Common European Interest (IPCEIs). IPCEI European Battery Innovation contains six Austrian companies, and three Slovak and Croatian ones (Doris, et al., 2021).

1.3 Methodology of the Analysis

1.3.1 Input-output analysis

Input-output (IO) analysis is an established technique in quantitative economic research. It shows how the outputs of one sector flow into another sector as inputs. The IO model was created by Leontief (1936), which is used to analyse and present the relationships between production and consumption within an economy (Belotti, et al., 2021). It can describe the structure of the economy at the sector level, and the interaction between the economy and environment through flows of resources, energy and emissions (Miller & Blair, 2009). It can track both direct and indirect interdependencies around sectors within the whole economic system, which allows one to understand how sectors connect and interdepend with each other, the relationships among components and parts of a supply chain, as well as how the structure of the economy change (Xu & Liang, 2019).

IO table, as a statistical tool of IO analysis, presents the necessary monetary amount of inputs in each sector to produce the total amount of outputs in a given industry, and how this output is used as intermediate inputs or final consumption for other productions (Belotti, et al., 2021).

Inter-Country Input-Output (ICIO) table combines national IO statistics with trade data. It describes the sale-purchase relationships between and within industries and economies, as well as the use in different final demand components like consumption, government expenditure and investment. It also specifies the country-sector pairs that sell intermediate inputs to a particular industry and the country-sector pairs in which the industry sells its outputs as final products to the final destination market. (OECD, 2022).

Table 2. Inter-Country Input-Output general scheme

		Outputs				Final Demand				Total
		1	2	$\cdots$	G	1	2	$\cdots$	G	Output
Inputs	1	Z_{11}	Z_{12}	$\cdots$	Z_{1G}	Y_{11}	Y_{12}	$\cdots$	Y_{1G}	X_1
	2	Z_{21}		$\cdots$	Z_{2G}	Y_{21}		$\cdots$	Y_{2G}	X_2
	$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
	G	Z_{G1}	Z_{G2}	$\cdots$	Z_{GG}	Y_{G1}	Y_{G2}	$\cdots$	Y_{GG}	X_G
Value Added		VA_1	VA_2	$\cdots$	VA_G					
Total Output		$(X_1)'$	$(X_2)'$	$\cdots$	$(X_G)'$					

(Source: Belotti et al, 2020)

Table 2 shows a generic ICIO model with G counties or regions and N sectors. In this figure, Z_{ij} means the N×N matrix of intermediate inputs produced in country i (rows) and used in country j (columns). Y_{ij} is the N × 1 vector of final goods and services completed in country i and absorbed in country j. X_i is the N × 1 vector of total output produced in country i. VA_i is the 1 × N vector of value-added generated in country i (Belotti, et al., 2021).

IO analysis can be used to analyse the trade of industry. For example, Marin (2011) used IO analysis and found that in the automotive industry, between 1995 and 2008, the proportion of domestic value-added decreased rapidly from 79% to 66% of German vehicles. Timmer et al (2015) found that because of the cheap and relatively skilled labour force, German companies are transferring part of the production processes to Eastern Europe, which is helping to increase the added value of production components for the Eastern European automotive industry.

1.3.2 Network analysis

In recent years, many researchers on industrial economics have applied complex network analysis and have finished a large number of theoretical and empirical research in terms of industrial structure, development, organization and policy making (Xing, 2017).

Network analysis, as a data-driven method, it provides a set of methods and metrics and is used to characterize the structure of large-scale network-like complex systems in order to infer the causal relationship between the structure and functionality of the system (Newman & Girvan, 2002). Network analysis has been used to study many areas and disciplines, like social networks, biological networks and transportation networks (Kossinets & Watts, 2006).

The study of international trade and automotive GVC is addressed through network analysis. Under the network approach, each country-sector is regarded as a node, which connects to other country-sector nodes through links representing intermediate input trade. The global automotive industry can be seen as a network for sectors in all countries intertwined through value-added trade relationships. Network analysis methods have been used to study international trade. For example, in order to describe the dynamics of international trade, Fagiolo et al. (2009) first applied a weighted network approach to describe the distribution of the most important network statistics for the period 1981-2000: node connectivity (provides insights into the robustness and resilience of a network), isomorphism (the structural similarity between two networks), clustering (the tendency of nodes in a network to form clusters or tightly-knit groups) and centrality (the degree to which a person or organization is central to a network). It can used to easily measure the key players in a network, and link weights (numerical values assigned to the links of a network, which provides a detailed and realistic representation of relationships between nodes in a network). Piccardi and Tajoli (2018) focused on network structure to explain specific features of international trade. They used product complexity indices from economic complexity mapping and focus on the characteristics of sub-networks to provide indications for explaining the general characteristics of networks. Some researchers emphasize the need to solve regionalization and the role of the state. They then group auto parts and analyse the regionalization of trade in each group: examining the role of countries within and between each network (Amighini, & Gorgoni, 2013) (Gorgoni, et al., 2018).

1.3.3. IO Network Analysis

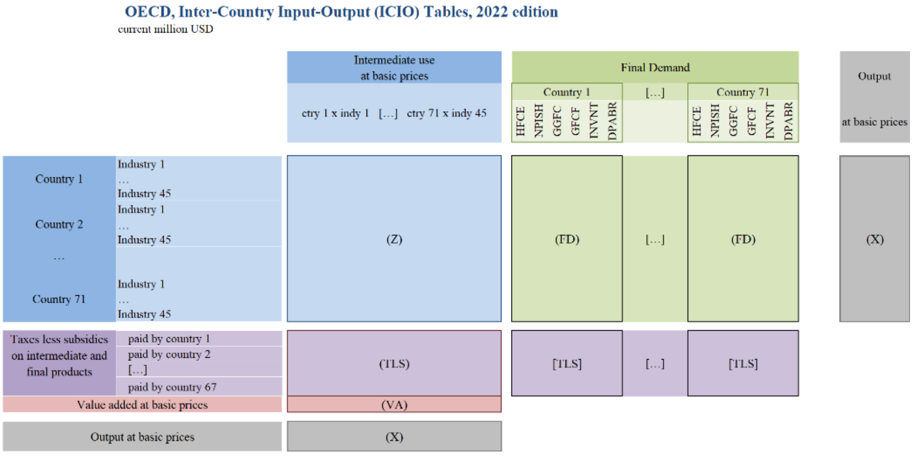
Based on the IO model, the structure of an economy can be treated as a network. In the IO mode, the node represents the sectors and the links connecting nodes indicate the economic transactions between sectors (Xu & Liang, 2019). Researchers have started to use national IO tables combined with network analysis to describe respective economies structure. Fabian et al (2011) applied several measures of centrality to examine the roles of specific sectors in the IO network. The sectors which are closer to the centre than others are more important to the economy. Besides, Fath et al (2013) tried to identify the clusters using an IO network. Clusters are represented by sectors within the IO network, which are interconnected as hubs. The value of goods and services traded is used to measure the strength of the linkages between sectors. Duan (2012) mentioned that the structure of the IO network correlates with the performance of the economy it represents. Xu and Liang (2019) applied the IO network and studied the world economy as a network by measuring the centrality of nodes and links and identifying the clusters. They found that the IO network can provide rich information and a better insight into the economic structure. An economy includes sectors that are interdependent through trade in goods and services. They ranked the top ten communities (which are known as clusters that represent cohesive and tightly-knit structures within the network) based on total output, which includes the Chinese economy, Japanese economy, North American economy, the economic clusters in Europe and the Rest of World (RoW). The sector of electrical and optical has high centrality, which corresponds to the central role of China in the IT sector as s a major producer of IT equipment. Adarov (2021) used the IO network analysis to examine the roles of Central, East and Southeast Europe (CESEE) countries in the GVC. The researcher finds that there is a value-added link formed by Central European countries with Germany's vehicle sector. Besides, as the centrality and the weighted degree measures show, in this cluster, the automotive manufacturing sectors of the Visegrad countries (Czech, Hungary, Poland and Slovakia) are the most interconnected in the CESEE GVC network.

1.4 OECD-ICIO database

There are several databases that can be used for IO analysis and network analysis for the automotive industry like the World Input-Output Database (WIOD), OECD Input-Output database, Eurostat Figaro, EORA, Global Trade Analysis Project (GTAP) and so on. WIOD provides a time series of world input-output tables containing 40 countries during 1995-2011 (Timmer, et al., 2015). Eurostat Figaro represents the EU inter-country supply, use and input-output tables, which use official EU data and data of the main non-EU trading partner. The data covers the time series from 2010-2021 (Robert , et al., 2019). EORA and GTAP can also be used in IO analysis, but these two databases are not free. GTAP (Global Trade Analysis Project) is a paid global network for conducting quantitative analysis of international policy issues. It provides a database containing global economic data for a specific year or a selected period. It can be used to analyse the issues of international trade and economy, but it does not create any input-output matrix for IO analysis. Compared with these databases, the OECD-ICIO database is a free one that contains time-series data of regions (76 countries). The OECD provided the latest version of the ICIO and Trade in Value Added (TiVA) database, which provides indicators for 76 countries over the period 1995-2020 (OECD, 2022).

The database provides an annual table to track the evolution of global production networks since 1995. It provides a globally balanced view of industrial flows between countries for intermediate and final goods and services, which can help to understand the nature and impact of regional and global value chains. The database can be seen as an alternative to traditional bilateral trade statistics, providing a better insight into the complex economic linkages within countries and regions resulting from the increasing prevalence of global value chains (OECD, 2022). It is a key tool for addressing many other policy issues related to the globalization of production, such as employment in global value chains (Horvát & Yamano, 2020), embodied carbon in trade (Yamano & Guilhoto, 2020), and resilience to global and regional shocks.

Table 3. OECD-ICIO Table



(Source: OECD, 2022)

Table 3 shows the ICIO table used in the OECD-ICIO database. In this table, Z zone means the intermediate goods used in the basic price. FD zone means the final demand. X means the output at the basic price. TLS area presents taxes and less subsidies on intermediate and final products. VA area shows the value added in basic prices (OECD, 2022).

2. Data and Methodology

The samples of countries from the OECD-ICIO database used for the analysis include 48 countries in the sector - motor vehicles, trailers and semi-trailers and cover the period of 1995-2020. The countries include CEE countries, China, member countries in the EU, some non-EU countries, member countries in ASEAN (Brunei Darussalam, Cambodia, Indonesia, Lao, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam) and some countries of Latin American and northern American, Asian, which are active or important for the vehicle industry. Appendix 1 lists the selected countries and their ISO3 codes. The data on EV trade flow were collected from BACI, which provides data on bilateral trade flows for countries at the product level (Gaulier & Zignago, 2010). We collected the data of sector EV and covered the period of 2017-2022.

The analysis contains two parts: IO analysis and network analysis. Firstly, we used IO analysis as the approach and used Stata as the tool to conduct the analysis. The 2022 edition of the OECD-ICIO database, the latest version, which covers the data from 1995-2020, was applied in the IO analysis. We followed the method based on Belotti et al (2021) and Wang (2017), of which the degree of participation and value-added of each country's products in global value chains was analysed.

The ratio of global value chain (GVC) participation measures the extent to which a country or an entity participates in GVC (WTO, 2021). As Wang (et al, 2017) found, there are four ways that a firm can participate in international production:

(1) Exporting domestic value-added in intermediate exports used by a direct importing country to produce for domestic consumption.
(2) Exporting domestic value-added in intermediate exports used by a direct importing country to produce products for a third country.
(3) Using other countries' value added to produce its products for export.
(4) Using other countries' value added to produce for domestic use.

GVC participation can be categorised into a "backward" component and a "forward" component. Backward participation means the import content of exports (Belotti, et al., 2021). It is the value added of imported inputs used to produce intermediate or final products or services for export. Forward participation measures the portion of domestic production that is imported into other countries for processing or re-export (Belotti, et al., 2021). It refers to the domestic value added to third economics Therefore, economies can participate in GVC by using imported intermediate products in their exports or exporting intermediate goods and services that other economies use in production. For each country and entity, the variations in GVC participation reflect their relative position and comparative advantage in the global production network.

To apply the IO analysis, we fellow Belotti et al (2021) and use the "icio", a Stata module, to calculate countries' participation in the vehicle sector in GVC and measure the value added of trade. The command allows straight analysis of the ICIO table and measures GVC participation and trade in value-added at the aggregate, bilateral or sectoral levels.

The analysis focused on the GVC participation and value-added of China and CEE countries in the automotive industry and discussed both backwards and forward linkages. We divided the analysis into several steps. Firstly, we compared the ratio of GVC participation of selected countries including CEE countries and China. It can be used to analyse the extent to which CEE and China participate in the GVC of the automotive industry. Secondly, we compared the GVC participation including backward and forward participation, as well as the value-added (domestic value-added and foreign value-added) between China and CEE. Thirdly, we analysed and compared the GVC participation and value-added of CEE and China exports to selected countries in the global automotive industry during 1995-2020.

Secondly, we conducted the IO network analysis in the vehicle industry and EV industry and visualised the international automotive trade network. Stata is used to calculate the indexes needed for the network analysis. Then, to better complete the network figure, we would use Gephi as a tool for the network figure drawing after the calculation of the network indexes.

The analysis of the vehicle industry used the OECD-ICIO database. The automotive trade networks in the years 1995, 2008, 2012 and 2020 were used to compare. In order to focus on the value of intermediate trade and the direction of auto trade between different countries, we constructed the directed and weighted networks. The analysis of the EV industry used the BACI database, covering the period of 2017 to 2022.

To construct the networks, firstly, the IO table, as the form of the adjacency matrix, was imported into Stata. The adjacency matrix is a square matrix containing the relationships between every pair of nodes in the network (Askar et al, 2021). Based on the data, we computed the weighted degree, betweenness centrality and PageRank centrality for each selected country, which can be used to analyse the total value, connectivity and importance of CEE countries and China in the automotive GVC.

The weighted trade network is the weighted version of the network, which considers the total value of trade linkages. Strength centrality (C_S) needs to be examined.

$$C_{S_{out}}^{N} = \frac{\sum_{j \neq i}^{N} w_{ij}}{(N-1)} \qquad C_{S_{in}}^{N} = \frac{\sum_{j \neq i}^{N} w_{ji}}{(N-1)}.$$

In the equation, the centrality is measured by aggregating the weights of the arcs (flows of export or import) connected to the node and normalizing by (N-1). The equation shows the measure of the out-strength and in-strength, which means the weighted out-degree and weighted in-degree. The weighted in-degree and weighted out-degree indicate the total value of incoming and outgoing respectively (Adarov, 2021).

The betweenness centrality of a node presents the number of times that the node connects to two other nodes through the shortest path. If the number of the shortest paths increases, the score of betweenness centrality will be increased. Betweenness centrality provides higher centrality scores to vertices which are on a larger share of the shortest paths connecting other pairs of vertices (Freeman, 1977). The betweenness centrality measure for vertex k can be defined as:

$$\sum_{i \neq j \neq k \neq i} \frac{P_{ij}(k)}{P_{ij}}$$

In this formula, P_{ij} represented the number of the shortest paths from vertex i to vertex j. $P_{ij}(k)$ represents the number of the shortest paths from vertex i to vertex j that contains vertex k.

PageRank centrality shows the probability of a random impulse generated anywhere in a network propagating from one node in the network to another through adjacent linkages, which is a higher probability of selecting the linkages with higher weights, reaching specific nods in a specific time. Therefore, the PageRank centrality presents the eventual significance of a node to a network, considering its linkages and their weights, as well as its adjacent nodes, and the neighbours of the neighbours (Page , et al., 1999). The equation of PageRank is shown below:

$$PR(A) = (1 - d) + d \sum \frac{PR(B)}{N(B)}$$

In the equation, the PageRank score is calculated for node A which is linked to node B. The factor N(B) means all outlinks from node B and d is the damping factor. The value of d generally remains at 0.85 based on the empirical evidence (Fayyaz & Shah , 2021).

3. Analysis

3.1 IO Analysis

3.1.1 Analysis of GVC participation in the automotive industry

There are eleven CEE countries including Hungary (hun), Slovakia (svk), Slovenia (svn), Czech (cze), Lithuania (ltu), Estonia (est), Latvian (lva), Croatia (hrv), Poland (pol), Bulgaria (bgr) and Romania (rou). Based on Figure 1, the CEE countries' share in the global automotive industry was on an increasing trend between 1995-2020. During this period, all CEE countries and China experienced a crisis in 2008, which caused an economic downturn and induced a decline in the production and participation of these countries in automotive GVC between 2008-2009. The crisis seems to have a short-run effect, and the share rebounded in 2011. Compared with the CEE countries and China, the ratio of Slovakia, Hungary, Slovenia and Czech is the highest from 1995-2020, which was always higher than 50%. China's ratio of GVC participation is lower than CEE countries. In Figure 2, the amount of GVC-related trade in Czech, Hungary, Slovakia, and Poland is higher than in other CEE countries. After 2004, when most of the CEE countries joined in EU, the amount of GVC of these four countries in the vehicle industry increased significantly. Although the share of Slovenia in the worldwide vehicle industry was high, the amount related to GVC is quite low which did not exceed 3000 million USD. For China, its amount of GVC-related trade in the automotive sector is at the middle level among CEE countries, though the share in GVC participation is lower than in CEE countries.

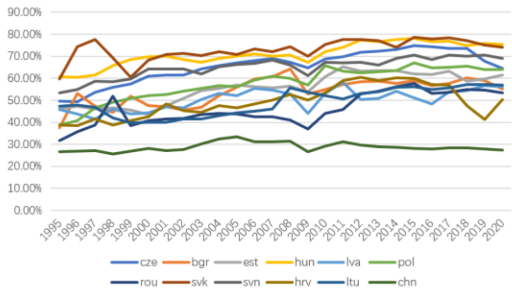


Figure 1. GVC participation in automotive industries in CEE & China

Source: author, based on OECD-ICIO).

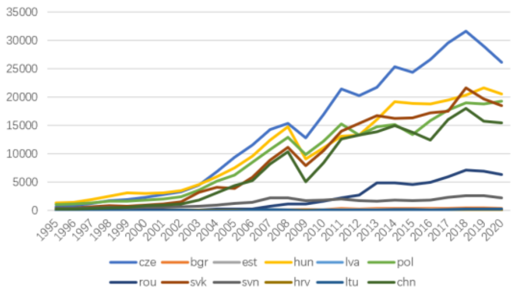


Figure 2. GVC amount in automotive industries in CEE & China (Millions of $)

(Source: author, based on OECD-ICIO).

3.1.2 GVC backward and forward linkages in the automotive industry

To analyse backward and forward participation, firstly we calculated the CEE countries as a group and compared the average ratio of CEE with China. As Figure 3 shows, backward participation is dominant around CEE countries from 1995-2020. For CEE countries, most of their inputs are imported from other countries and they process the inputs and export. As Baldwin and Lopez-Gonzalez indicate (2015), CEE countries are classed as a pattern of "factory economies". In his opinion, in the international production networks, there are "headquarter economies" that arrange the production networks and "factory economies" which provide the labour. CEE countries mainly contribute labour-intensive activities and focus on the production part of the automotive value chain, which uses imported intermediate products in their production for export. The ratio of backward participation of CEE countries shows an increasing trend between 1995-2020.

Then we calculated the backward participation of each country in CEE and compared them with China. As Figure 4 shows, the ratio of Slovakia, Hungary, Slovenia and Czech is higher than other CEE countries. After the effect of the crisis between 2008-2009, the ratio of Estonia and Poland experienced a significant increase which is higher than the level of 2007. The ratio of Estonia is higher than Czech in 2020. The ratio of backward participation of China has been always lower than that of CEE countries. The reason may be that the local supply chain of automotive production is well-developed, so a large share of the value-added of its exports of automotive products originates domestically.

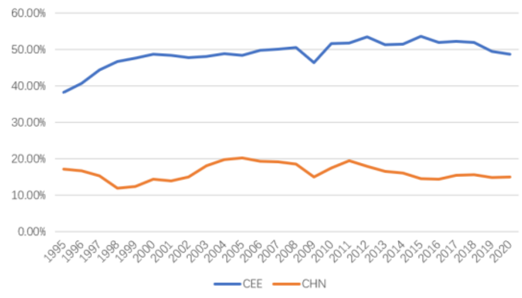


Figure 3. GVC-backward in the motor vehicle industry in CEE& China

(Source: authors, based on OECD ICIO).

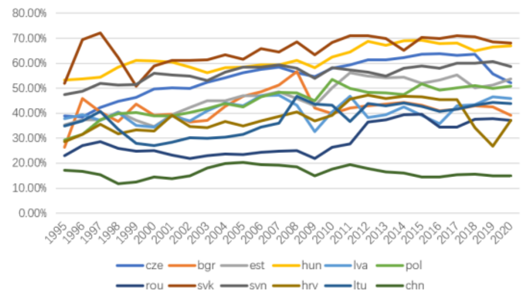


Figure 4. GVC-backward in the motor vehicle industry in CEE& China

(Source: authors, based on OECD ICIO).

For forward participation, the ratio has been lower than backward participation around CEE countries and China during 1995-2020. When we compared the average ratio of CEE countries with China, the ratio of China is higher than CEE countries (Figure 5). The ratio of both of them shows an increasing trend. When we compared the ratio of each CEE country with China, the situation was different. As Figure 6 shows, since 2000, the ratio of Romania is the highest compared with other countries. The ratios of Bulgaria, Poland, Czech, Slovenia and China show an increasing trend. The share of Bulgaria shows a significant increasing trend after the crisis in 2008. The ratio of Estonia and Hungary decreases.

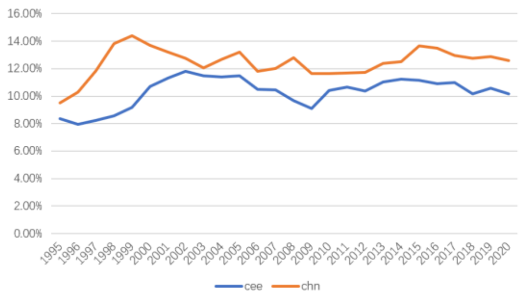


Figure 5. GVC-forward in the motor vehicle industry in CEE& China

(Source: authors, based on OECD ICIO).

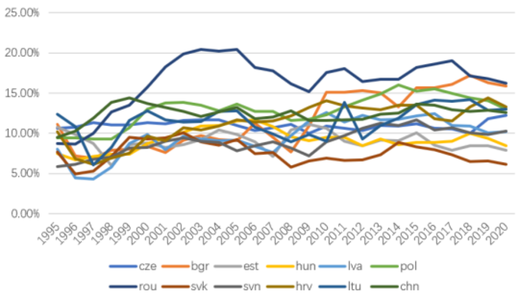


Figure 6. GVC-forward in the motor vehicle industry in CEE& China

(Source: authors, based on OECD ICIO).

3.1.3 Value-added of the global automotive industry from CEE and China

To analyse the exports from CEE and China in the automotive industry, we traced the countries' share of domestic and foreign value added in the final output during 1995-2020. In Figure 7, the domestic value-added of exports in the automotive industry for CEE and China is on a rising trend during 1995-2020. China's proportion of domestic value-added in exports remains higher than CEE over the period. In Figure 8, we compared the individual CEE countries with China. China is higher than all CEE countries. In CEE countries, Romania's domestic value-added in automotive exports was the highest during 1995-2018. Croatia's proportion of domestic value-added becomes the highest in 2019-2020. The share of Slovakia and Hungary is the lowest.

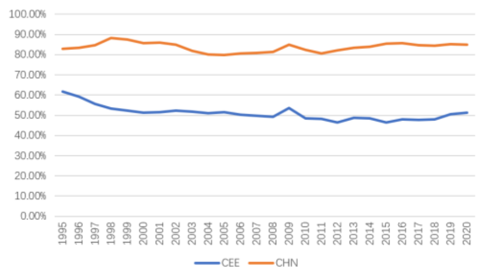


Figure 7. Domestic value-added in the motor vehicle industry in CEE& China

(Source: authors, based on OECD-ICIO).

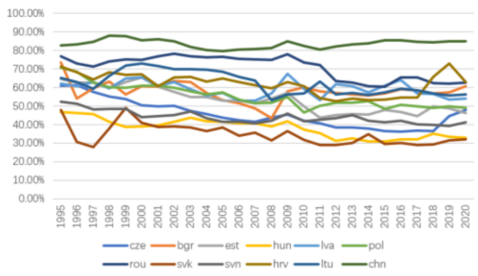


Figure 8. Domestic value-added in the motor vehicle industry in CEE& China

(Source: authors, based on OECD ICIO).

The situation of foreign value-added was opposed. In Figure 9, it shows that China had a low share of foreign value-added for export from China, which is less than 20%. Between 2001-2005, which is the period after China joined the WTO, the foreign value-added increases. The share declines during the crisis and increases again in 2010 and 2012, but it is still below its peak in the mid-2000s. Starting in 2012, the foreign value-added presents a declining trend. For CEE, since 1996, the average share of foreign value-added is higher than 40%, and it shows an increasing trend during the period from 1995-2020. In Figure 10, the foreign value-added of China is the lowest compared with CEE countries. Since 1999, the foreign value-added of Slovakia and Hungary has been the highest. In CEE countries, Czech, Estonia, Latvia, Lithuania, Hungary, Poland, Slovakia and Slovenia joined the EU in 2004. Romania and Bulgaria joined in 2007, and Croatia joined in 2013. Most of these countries got a higher share of foreign value-added after joining the EU, until the crisis happened in 2008, which brought a major decline in the worldwide economy and both domestic and foreign value-added exports declined during that period. For some CEE countries, the foreign value-added rebound after 2009, like Slovakia, Hungary, Poland and Romania. But Bulgaria represents a decreasing trend of foreign value-added after the crisis, and its share of domestic value-added increased at the same time.

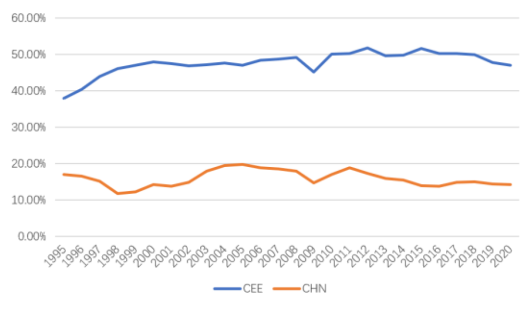


Figure 9. Foreign value-added in the motor vehicle industry in CEE& China

(Source: authors, based on OECD ICIO).

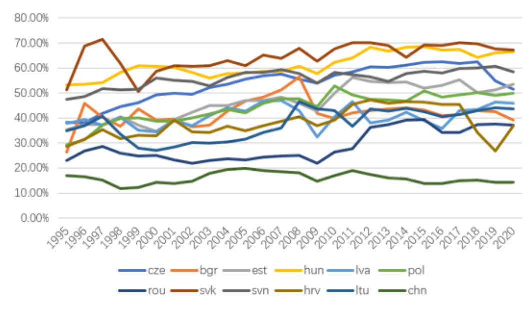


Figure 10. Foreign value-added in the motor vehicle industry in CEE& China

(Source: authors, based on OECD ICIO).

Combined with domestic value added and foreign value added, it indicates that the pattern of China and CEE countries to take part in the automotive GVC may be different. For China, the share of foreign value-added increases after joining the WTO and reaches a peak in 2005. After 2005, the share shows a declining trend, meanwhile, the share of domestic value-added has an increasing trend. For most of the CEE countries, the share of foreign value indicates an increasing trend overall after joining the EU, but the share of domestic value-added remains stable or in a decreasing trend. It represents that for China's automotive industry, the development of domestic intermediates and components production is significant, which starts to replace the formerly imported components and parts. The domestic production of different components and parts expands in different China provinces. CEE countries still rely on the trade of various intermediates from each other within the European cluster.

3.1.4 Export of CEE and China to selected countries

To discover the role of CEE countries and China in the global automotive industry, we analysed the trade between CEE, China and the selected countries. In Figure 11, we provided the gross export in the automotive sector from CEE countries to selected countries including the rest of the EU (except CEE), DEU (Germany), GBR (British), FRA (France), ITA (Italy), and USA (United States), KOR (Korea), JPN (Japan) and the ASEAN (including Brunei Darussalam, Cambodia, Indonesia, Lao, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam). It indicates that CEE countries intensively trade with the EU, which indicates a regional link within the European automotive value chain. Within the EU, Germany is one of the most important partners, and the CEE exports the highest amount to Germany from 1995-2020, which the trade kept an increasing trend. The exports from CEE to France, Italy, British and the US also show increasing trends during this period. The exports from CEE to Korea, Japan and the ASEAN are low and stable. It indicates the "Europeanness" of the automotive value chain of CEE countries. The trade of CEE countries is more regional and focuses on

Europe. In Figure 12, it shows that China exports the most to the US which increases after the crisis (2009) and continued until 2018. China also keeps exporting frequently with the EU, ASEAN, Japan and Korea. It shows increasing trends between China, the EU and the ASEAN countries. It represents a wider geographic area covered by partners of China. The US is an important partner for China in the automotive industry.

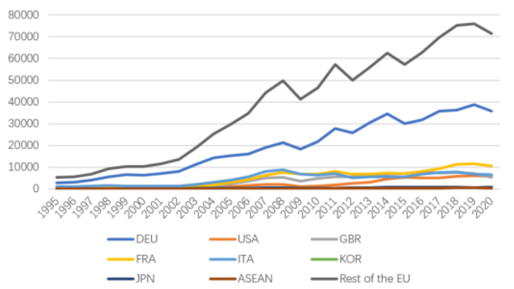


Figure 11. Gross export of CEE to selected countries in the motor vehicle industry (Source: authors, based on OECD ICIO)

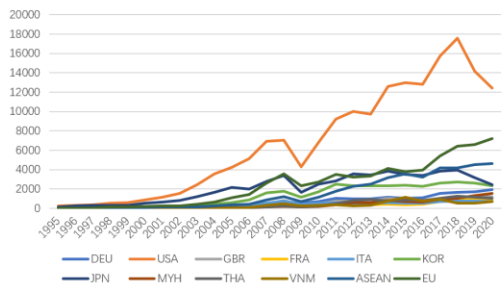


Figure 12. Gross export of China to selected countries in the motor vehicle industry (Source: authors, based on OECD ICIO).

Figure 13 and Figure 14 show the amount and the proportion of backward participation of the exports from CEE countries to selected countries during 1995-2020. Figure 15 and Figure 16 represent the amount and the proportion of forward participation of CEE exports to selected countries. In Figure 13 and Figure 15, considering the amount of GVC participation, it is clear that both backward and forward links of CEE countries are regional with the EU, especially with Germany. Both backward and forward participation towards the EU and Germany have increased over time. However, Figure 14 indicates that around all the exports from CEE to selected countries, the proportions of backward participation in GVC participation are similar, which are between 30%-60%. Although the amount of backward participation exported from CEE to the United States and Japan is not so high, the proportions of those in GVC participation are higher than in other countries. Besides, in Figure 16, we found that though the amount of forward participation in the export from CEE to Korea is very low, the proportion of GVC participation is higher than in other countries. The proportion is also very high between the trade from CEE to Germany. Combined with Figure 14 and Figure 16, the proportions of backward participation are higher than forward participation around all exports of CEE, so the backward structure is dominant, which states that CEE countries specialize in the production export of intermediate products. In Figures 17 and 18, we compared only the backward and forward participation of 1995 and 2020. Figure 17 shows that in 1995, both the proportions of backward and forward participation are not so high, especially when the forward participation towards all the selected countries is lower than 10%. In Figure 18, both backward and forward participation increased in 2020. The highest proportion of forward participation is almost 16%. Although the proportion of backward participation is higher than the proportion of forward participation in both two years, there is an increasing trend in the proportion of forward participation.

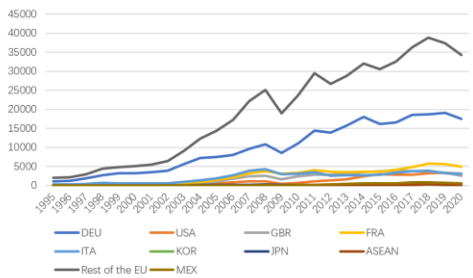


Figure 13. Backward GVC participation of CEE export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

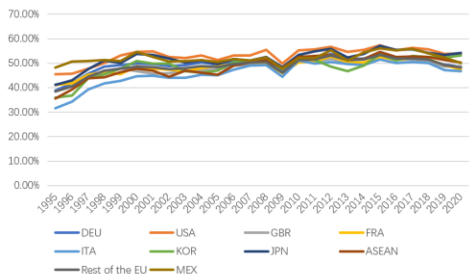


Figure 14. The proportion of backward GVC participation of CEE export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

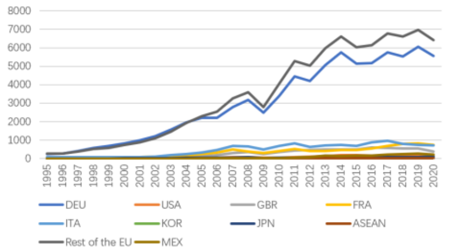


Figure 15. Forward GVC participation of CEE export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

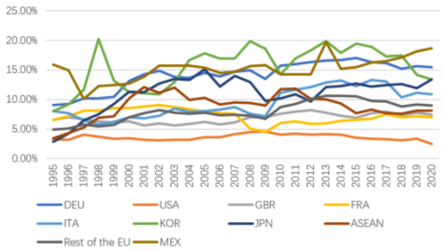


Figure 16. The proportion of forward GVC participation of CEE export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

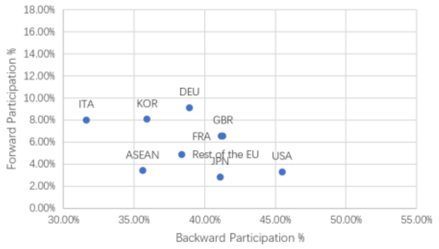


Figure 17. The proportion of GVC participation of CEE export to selected countries in the motor vehicle industry in1995

(Source: authors, based on OECD ICIO).

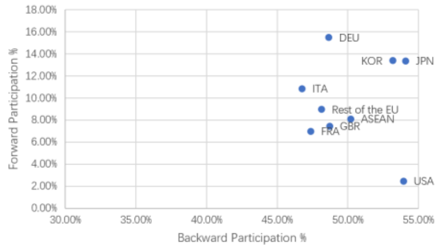


Figure 18. The proportion of GVC participation of CEE export to selected countries in the motor vehicle industry in 2020

(Source: authors, based on OECD ICIO).

Figure 19 and Figure 20 show the amount and the proportion of domestic value-added of the exports from CEE countries to selected countries. Figure 21 states the amount of foreign value added to export from CEE to selected countries. Figure 19 and Figure 21 indicate that the amount of domestic and foreign value added by CEE countries to the EU has been the highest during the period. Within the EU, the value-added of CEE countries mainly export to Germany. Compared with the foreign value-added amount, the amount of domestic value-added is higher and dominates, which represents that the productive capacities gradually transfer to the CEE countries. The interconnectedness of these countries is increasing in the regional automotive GVC. Figure 20 indicates that the proportions of domestic value-added of CEE exporting to other countries are similar to each other, which shows a decreasing trend. So, on the contrary, the proportion of foreign value-added shows an increasing trend (Appendix 2).

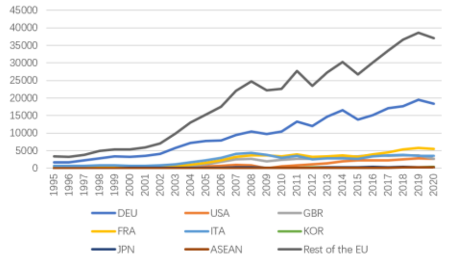


Figure 19. Domestic value-added of CEE export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

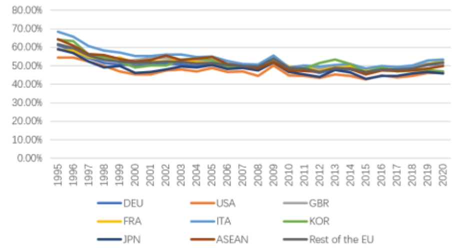


Figure 20. The proportion of domestic value-added of CEE export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

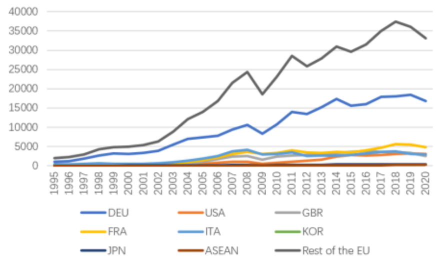


Figure 21. Foreign value-added of CEE export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

Figure 22 and Figure 23 show the amount and the proportion of backward participation of exports from China to selected countries during 1995-2020. Figure 24 and Figure 25 show the amount and the proportion of forward participation in China's exports to selected countries. Figure 22 shows that the backward linkage of China to the US has increased and been higher than China to other countries. It states that China may mainly export intermediate and semi-final products to the US. The integration of these two automotive industries is intense. Figure 23 states that around the export from China to selected countries, the proportions of backward participation of GVC participation are almost the same. Figure 24 and Figure 25 show a different situation. The forward participation of China to the US, Japan and Korea shows a similar trend and is higher than other countries. However, the forward linkages towards these three countries have decreased since 2018. The forward linkage between China and the EU represents an increasing trend. Although the amount of forward participation of China exports to the United States is high, the proportion of that in GVC participation is the lowest. The proportion of forward participation towards Korea has always been higher than others, especially after 2004. The main reason may be that China mainly exports automotive parts and components to Korea, which Korea would use to finally assemble and sell the complete cars locally or export to other countries. In 2022, automotive parts and components were still among the top 10 commodities exported from China to Korea, which worth 2.14 billion USD (GTF, 2023). Compared with Korea, the exporting situation of the US is different. Besides automotive parts and components, China also exports complete cars to the US, including some low-end and middle brands. Table 4 shows that since 2014, the import units of passenger vehicles and light trucks have been increasing, which means that China has been exporting complete cars to the US and the exporting units kept increasing. It may be one of the reasons that the proportion of forward participation of exports from China to the US has been low and shows a decreasing trend. In addition to importing complete vehicles from China directly, the US imports more complete cars from the nearby country Mexico. Table 4 also shows that the US imported a large number of complete cars from Mexico. Figure 24 shows that the proportion of forward participation towards Mexico was high, especially after 2012, and the proportion was the highest in 2020. It indicates that China exported a large number of components and parts including high-valued ones to Mexico. After final assembly, most of the cars would be exported to the US.

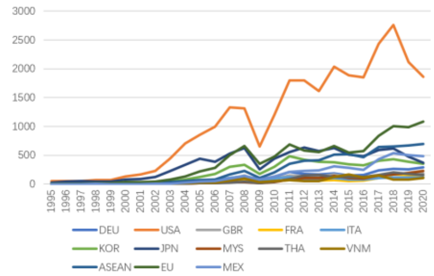


Figure 22. Backward GVC participation of China export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

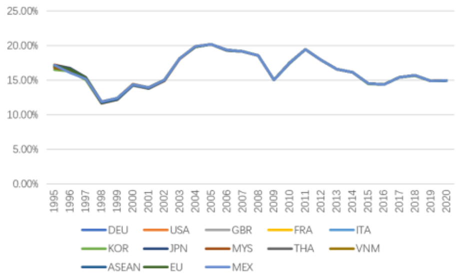


Figure 23. The proportion of backward GVC participation of China export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

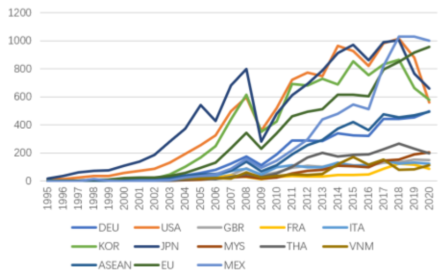


Figure 24. Forward GVC participation of China export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

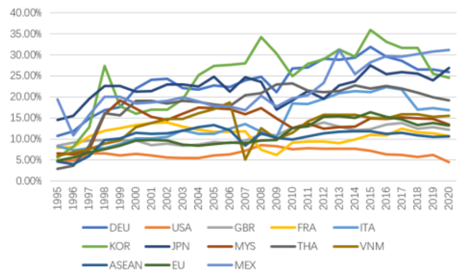


Figure 25. The proportion of forward GVC participation of China export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

Table 4. U.S. Imports of New Passenger Vehicles and Light Trucks (Total Imports Units)

	2014	2015	2016	2017	2018	2019
China	1,067	4,199	45,965	58,414	63,634	68,573
Mexico	1,895,375	2,087,346	2,176,505	2,446,384	2,663,804	2,799,227
Slovakia	26,191	30,681	34,542	42,591	58,397	69,497
Hungary	58,066	75,046	49,840	41,825	31,120	36,910

(Source: United States Department of Commerce, 2019).

Comparing the export proportion of backward and forward participation between CEE and China, the export situation has similarities and differences. Regarding the export proportion of backward participation, both CEE and China show similar proportions to all selected countries (Figure 14 with Figure 23). However, the backward participation of CEE in their exports is higher than those of China as a whole. One of the reasons may be that compared with China, CEE countries have a more limited capacity to produce core components with high value-added, which makes them more dependent on imports for high-value intermediate products used in their exports rather than domestic products. Cieslik et al (2016) stated that the automotive GVC positions of CEE countries were still low and there were high shares of value-added from the EU in CEE countries' exports which shows CEE countries are more dependent on value-added from the EU countries in the automotive industry. Pavlinek (2020) also stated that East European countries may continue to attract low value-added and labour-intensive production of vehicles and generic components. Through dependent supplier linkages, these countries integrate into macro automotive production networks as assembly platforms or components production platforms. The researchers also found that there were increasing value-added flows between CEE countries which indicated the situation of fragmentation of the automotive supply chain around CEE countries (Cieslik, et al., 2016).

Regarding the export proportion of forward participation, both CEE and China show quite different to different countries (Figure 16 with Figure 25). The export proportions of forward participation of both CEE and China are the highest in Korea and the lowest in the US in most years. Regarding the trade between CEE and Korea, many multinational automotive manufacturers of Korea invest and build production factories in CEE. Lee and Ha (2021) stated that in Korea, compared with the domestic finished car market, the domestic auto parts industry was shrinking because of the dependence on imports from the overseas auto industry. Qu et al (2021) also mentioned that because the Korean auto industry has been globalized, those head auto companies set up overseas factories that would export parts and components to the home bases in Korea. It means that the intermediate products produced by overseas factories would re-export to Korea for domestic automotive assembly and production. It may be one of the reasons for the highest export proportion of forward participation of CEE to Korea. Besides, the trade between CEE and the US, though the distance between these two countries is far, the number of complete vehicles exported from some CEE countries to the US has increased. In addition, like the proportion of forward participation of China exporting to Mexico, the proportion of CEE towards Mexico is also very high, which also becomes the highest in 2020. Therefore, like the export situation of China to Mexico, CEE also export vehicle components and parts to Mexico and the final assembly process would be completed in Mexico and re-exports to the US.

Figure 26 and Figure 27 are the amounts and the proportion of domestic value-added exports from China to selected countries during the period. Figure 28 and Appendix 3 show the amount and the proportion of domestic and foreign value-added of China exporting to selected countries. Figure 26 and Figure 28 indicate that the value-added of China to the US is higher than of other countries. The US is the main partner for China in automotive GVC. However, the value added to the US has decreased since 2018. The value added to the EU shows an increasing trend after 2016, indicating that China may gradually trade with the EU more intensively. A possible reason for the change of value added is that the trade war between China and the US started in 2018. The US has implemented a higher tariff to products imported from China, including the import of vehicles and components. Therefore, for China, the number of vehicles and related products exported to the US is decreasing and China started to export more to the EU which implemented lower tariffs on products from China. Figure 27 indicates that the share of domestic value-added of China exporting to other countries are almost the same as each other, as well as the proportions of foreign value-added. The proportions of domestic value-added (>80%) are higher than the share of foreign value-added (10%-20%) of exports from China (Appendix 3), which means the increasing capacity of China to produce components and parts domestically.

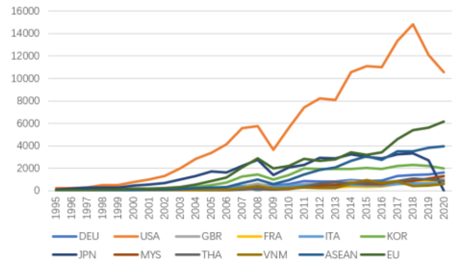


Figure 26. Domestic value-added of China export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

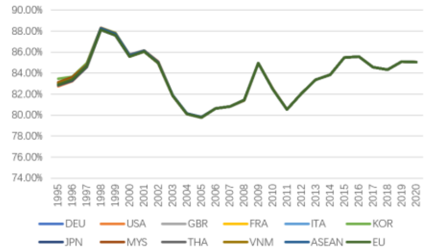


Figure 27. The proportion of domestic value-added of China export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

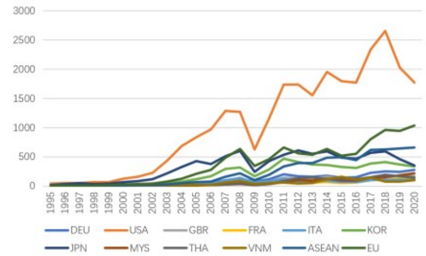


Figure 28. Foreign value-added of China export to selected countries in the motor vehicle industry

(Source: authors, based on OECD ICIO).

3.2 Network analysis

3.2.1 Network Analysis in Vehicles

Figure 30 to Figure 33 shows the vehicle trade around the countries in the network configurations for selected years: 1995, 2008, 2012 and 2020. 1995 and 2020 are the oldest and the newest years in the OECD-ICIO database, which are meaningful to be selected. 2008 is the year of the financial crisis. The global economic contraction caused a decrease in demand and production in the global vehicle market. In 2012, a cooperation named “Cooperation Between China and Central and Eastern European Countries” was established between China and CEE countries in Europe. It was an innovative sub-regional cooperation, which became an important component of the entire cooperation between China and Europe (Liu, 2023). About the network conduction, the size of each node is proportional to the weighted degree, which is the value of vehicle trade flow from IO data. The colour and thickness of the linkages are proportional to the trade weight. The arrows present the direction of the export flow. The network uses a “Fruchterman Reingold” layout algorithm, in which the nodes with higher trade volume and a higher degree of centrality are closer to the centre of the network.

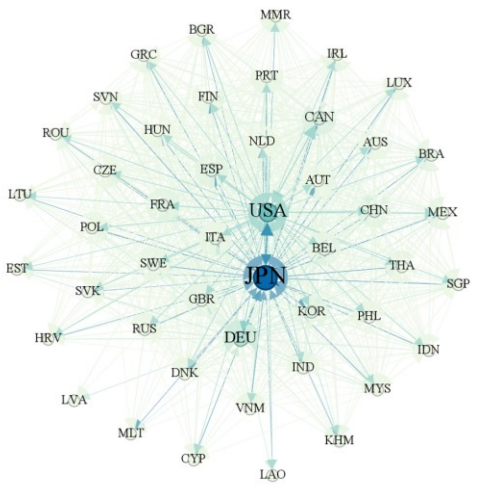


Figure 29. Vehicle network in 1995

(Source: authors, based on OECD ICIO).

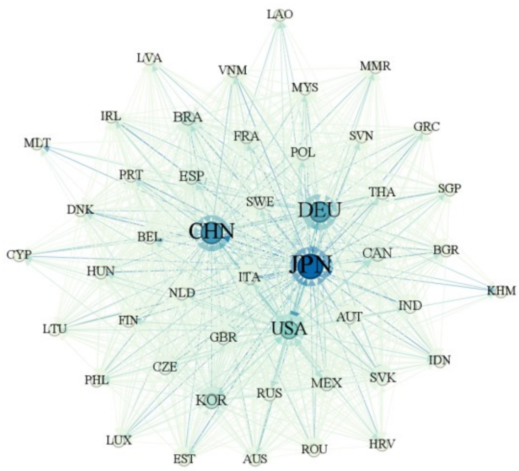


Figure 30. Vehicle network in 2008

(Source: authors, based on OECD ICIO).

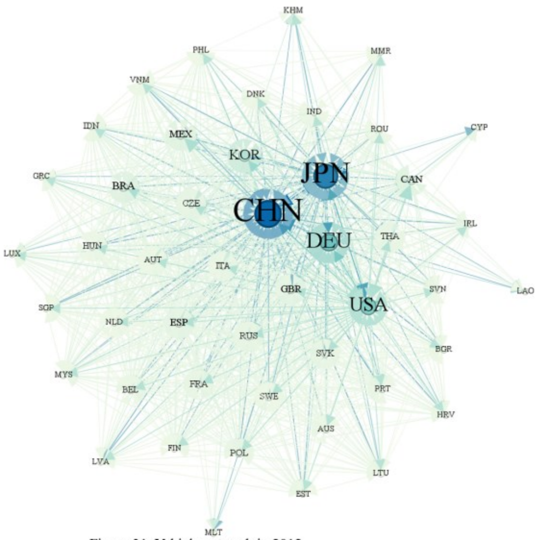


Figure 31. Vehicle network in 2012

(Source: authors, based on OECD ICIO).

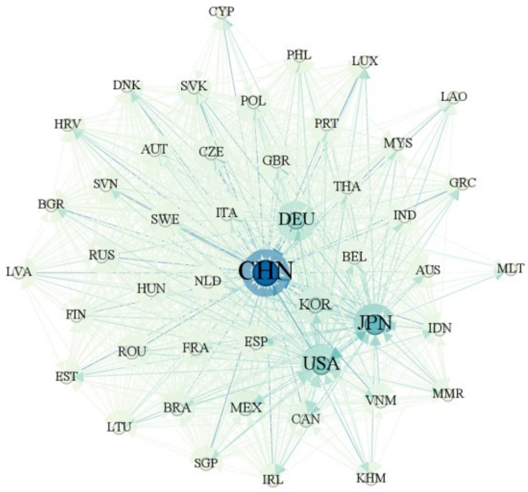


Figure 32. Vehicle network in 2020

(Source: authors, based on OECD ICIO).

Figure 29 shows the network analysis result of global vehicle trade in 1995. It presents that in 1995, the centre of the worldwide vehicle trade network was Japan, which had the largest export value of vehicles to other countries and the imported value of vehicles was also the largest. For Japan, the arrow pointing towards the US was the deepest, which shows that the vehicle export value from Japan to the US was the highest. The main export target country for the US was also Japan. In addition to this, Japan also mainly exported vehicles to Germany, Korea, China, Vietnam and so on. The second and third largest vehicle trade nodes in the network were the US and Germany, which were the subcentres of the network. During this period, China and CEE countries were all small nodes in the vehicle network which means that vehicle industries of these countries were in the initial development stage. The import demand of vehicles was not so high and the capacities of producing and exporting vehicles were still weak. The location of nodes in China was closer to the centre than that of CEE countries, which indicates that the development of China might be better than CEE countries. For China, it mainly imported vehicle products from the US and Japan. CEE countries mainly imported vehicle products from Germany.

Figure 30 states the vehicle trade network in 2008. During this period, the centre of the vehicle network was still Japan. However, the subcentres of the networks have changed. The second and the third largest nodes of the vehicle network were Germany and China. The trade value of the US was lower than that in China, which made the node of the US the fourth largest one. The positions of CEE countries were also changed. Poland and Slovenia became much closer to the centre of the network, which means that the development of vehicle production and the import demands were higher in these two countries than in other CEE countries.

Figure 31 presents the vehicle trade network in 2012. During this period, the centre of the trade network changed, which became China. Japan was the second largest node in the network. The US and Germany also played significant roles in the network. Korea also has a large amount of trade value in the network. The node size of Korea was also larger than in the last period, which shows that the vehicle trade value of Korea was much higher than before. For CEE countries, Czechia was closer to the centre of the network. However, Slovenia was further away from the centre than that in 2008.

Figure 32 states the vehicle trade network in 2020. The centre of the network was still China. The nodes of Japan, Germany, the US and Korea were still larger than other countries, which are important in the vehicle GVC. For CEE countries, the number of countries that were closer to the centre of the networks increased. Hungary, Czechia, Poland and Slovakia were close to the centre, which presents the export values and imported demand for vehicle products were higher, and the development of the vehicle industries was significant. It shows a regional specialization in CEE countries, because the developments of vehicle industries were in all CEE countries, not just one or two countries. The development of one CEE country would lead to the development of other countries. Different countries have different specialised levels of different parts of the vehicle production process.

Although the figures provide a clear view of the vehicle trade network that is convenient to read and understand, the network figures cannot provide detailed information about the nodes and linkages. Table 5 and Table 6 show the top 20 countries of key centrality metrics in 1995 and 2020, including weighted degree, weighted in-degree, weighted out-degree, PageRank centrality and betweenness centrality. The completed tables of selected countries are shown in the Appendix 4 and 5.

As the "Weighted Degree" column of Table 5 shows, in 1995, Japan, the US and Germany were the top 3 countries, which had the highest total value of GVC in the global vehicle industry. There were about 309 billion USD of Japan, 169.7 billion USD of the US and 75 billion USD of Germany. Both the weighted in-degree and weighted out-degree of these three countries were the highest, which shows that the vehicle trade value including the import and export of these countries were the largest. For China, though it was not the centre country of the vehicle network, the total value of China was ranked seventh in the list, which was 22 billion USD. For CEE countries, their total value of GVC was in the middle and lower level of the list. Among the CEE countries, the total value of Hungary, Poland and Czechia was the highest, which means that these three countries were more involved in the global vehicle trade. Nevertheless, the total values of vehicle GVC of Latvia and Lithuania were at the lowest level, even though the value of Latvia was only 0.1 million USD. It means that the development of the vehicle industry in these two countries was very low, with a low level of vehicle production capacity. The demand for vehicles was also low in the domestic vehicle market. Besides, as the "PageRank Centrality" and "Betweenness Centrality" columns in Table 5, the connectivity of the global vehicle industry of Germany and Japan was the highest. These two countries not only had close trade relations in vehicles with other developed countries but also maintained good vehicle trade relations with developing countries. They were the hub of the global vehicle trade. The betweenness centrality of

China and Czechia was close, which ranked twelfth and fourteenth on the list. It shows that these two countries acted as connectors in the Asian and European vehicle trade networks, which were the important vehicle trade transit points of the vehicle GVC.

As can be seen in Table 6, the situation of the vehicle network changed in 2020. In the "Weighted Degree" column, the highest total value of vehicle GVC has changed from Japan to China. The weighted degree of China was 597 billion USD. It indicates that China has become the new main centre of the vehicle trade network, which plays a key role in the global vehicle industry. Besides China, Japan, Germany and the US still ranked at the top of the list. For CEE countries, some countries had moved to a higher rank on the list than before. Czechia and Slovakia ranked tenth and eleventh on the list, which had the highest total value of vehicle GVC among CEE countries, and the values were 31.3 billion USD and 25.5 billion USD respectively. Czechia and Slovakia played important roles in the CEE vehicle industries, which were the main exporters and importers of vehicle products among CEE countries. Latvia was still with the lowest total value of vehicle GVC in CEE countries. Although some other CEE countries still kept a similar rank on the list as before, the total value of these countries also increased a lot. It means that there was a significant development of the production capacity of the vehicle industry in CEE countries. The market demand for vehicles also increased a lot for CEE countries. In the "Weighted Out-degree" column, the value of Czechia ranked seventh on the list, which was valued at 17.4 billion USD. It shows a significant increase in production capacity in the vehicle industry in Czechia. The export value of Czechia was higher than other European countries, except Germany, which indicates that Czechia was the main exporter country of vehicle products in Europe. About the "PageRank Centrality" and "Betweenness Centrality", there were significant changes. Hungary significantly intensified its connectivity in the vehicle GVC, which ranked the first in betweenness centrality and it was higher than that of other European countries. It means that Hungary has become the main trade hub of the European vehicle network, which attracted a large amount of international investment. In addition, the connectivity of Thailand (THA) also remarkably increased. The PageRank centrality and betweenness centrality of Thailand ranked in the top 3 of the lists.

Table 5. Vehicle linkages of Top 20 selected countries in 1995, million USD

Weighted Degree		Weighted In-degree		Weighted Out-degree		PageRank Centrality		Betweenness Centrality	
JPN	308869.37	JPN	152328.8	JPN	156540.56	DEU	0.028452	DEU	0.056231
USA	169720.47	USA	87400.327	USA	82320.147	JPN	0.027598	JPN	0.0342
DEU	75053.912	DEU	33813.061	DEU	41240.851	NLD	0.025035	SWE	0.031988
CAN	34396.62	CAN	19004.6	CAN	15392.02	GBR	0.024774	RUS	0.02531
FRA	23366.35	ESP	11582.74	FRA	12241.26	SWE	0.024592	GBR	0.024316
ESP	22913.85	CHN	11212.1	ESP	11331.11	FRA	0.022648	USA	0.018617
CHN	22239.73	FRA	11125.09	CHN	11027.63	ITA	0.022436	FRA	0.016193
KOR	21099.829	KOR	10112.09	KOR	10987.74	USA	0.022436	NLD	0.015611
BEL	15515.52	BEL	8719.5801	BEL	6795.9401	RUS	0.022369	ITA	0.014175
GBR	13171.84	GBR	6413.8199	GBR	6758.0199	PHL	0.022142	ESP	0.011338
MEX	11842.32	MEX	6113.8601	ITA	6010.6101	CHN	0.021957	IND	0.01071
BRA	11318.8	BRA	5860.1199	MEX	5728.4601	CAN	0.021144	CHN	0.010696
ITA	11250.7	ITA	5240.0901	BRA	5458.6799	AUT	0.021063	BEL	0.009029
SWE	9550.04	SWE	4491.49	SWE	5058.55	ESP	0.020967	CZE	0.008696
THA	4824.8601	THA	2731.2301	THA	2093.63	PRT	0.020913	AUT	0.008465
PRT	4110.7199	PRT	2372.0599	PRT	1738.66	BEL	0.020381	HUN	0.008115
AUS	2966.1201	AUS	1859.31	AUT	1331.7	IND	0.019915	KOR	0.007659
AUT	2635.2	AUT	1303.5	IND	1132.9199	HUN	0.0198	THA	0.007364
IND	2213.6199	RUS	1252.72	AUS	1106.81	SGP	0.019474	CAN	0.007334
RUS	2200.1999	IND	1080.6999	RUS	947.47997	VNM	0.019189	PHL	0.006936

(Source: authors, based on OECD ICIO).

Table 6. Vehicle linkages of Top 20 selected countries in 2020, million USD

Weighted Degree		**Weighted In-degree**		**Weighted Out-degree**		**PageRank Centrality**		**Betweenness Centrality**	
CHN	597313.5675	CHN	303571.3536	CHN	293742.2139	JPN	0.025306	HUN	0.027056
JPN	350191.5213	JPN	166732.8456	JPN	183458.6757	THA	0.025218	JPN	0.026577
USA	269617.7729	USA	148395.1924	USA	121222.5806	HUN	0.024563	THA	0.01703
DEU	213646.9487	DEU	100105.6496	DEU	113541.299	NLD	0.024406	DEU	0.0162
KOR	112403.5938	KOR	51486.80186	KOR	60916.79197	USA	0.023955	KOR	0.015374
MEX	51386.09058	MEX	22356.48978	MEX	29029.6008	DEU	0.023546	GBR	0.014516
CAN	36495.62021	CAN	22218.33985	CZE	17427.46972	KOR	0.023472	ITA	0.012788
BRA	32343.21029	BRA	16740.31014	BRA	15602.90016	CAN	0.023407	USA	0.010588
ESP	31860.08978	ESP	16349.66981	ESP	15510.41997	CHN	0.023065	NLD	0.010418
CZE	31372.29939	SVK	14632.96984	CAN	14277.28036	RUS	0.022973	CHN	0.010187
SVK	25552.57971	CZE	13944.82967	SVK	10919.60987	GBR	0.022632	ESP	0.010116
GBR	23443.6997	RUS	13846.66019	GBR	10904.4599	ITA	0.022623	SWE	0.009556
RUS	20201.18038	GBR	12539.2398	POL	10691.71008	SWE	0.022614	CZE	0.008451
POL	19353.41013	THA	8726.350055	THA	10486.95012	CZE	0.022604	SVK	0.007241
THA	19213.30018	POL	8661.700053	FRA	10318.21995	AUT	0.022594	AUT	0.006599
FRA	18349.63988	FRA	8031.419926	ITA	8909.620127	POL	0.022594	POL	0.006599
ITA	15366.93016	HUN	6780.670062	HUN	8376.440045	FRA	0.022572	CAN	0.006504
HUN	15157.11011	ITA	6457.310029	RUS	6354.520192	BRA	0.022483	RUS	0.005448
SWE	12422.32998	SWE	6178.640007	SWE	6243.689976	ESP	0.022152	FRA	0.005283
ROU	10720.1302	VNM	5098.680094	ROU	5790.840111	BEL	0.022122	IND	0.004731

(Source: authors, based on OECD ICIO).

3.2.2 Network analysis in EV

Figures 33- 38 show the EV trade around the countries in the network configurations for 2017-2022. The size of each node is proportional to the weighted degree, which is the value of export flow. The colour and thickness of the linkages are proportional to their weight. The arrows present the direction of the export flow. The network uses a "Fruchterman Reingold" layout algorithm, in which the nodes with higher trade volume and a higher degree of centrality are closer to the centre of the network.

The figure highlights a network of EV export volume with the change of the core of the network from 2017-2022. During 2017-2019, the network cantered in the US, which was the global hub of the trade network in EV. In 2020-2022, the centre changed to be Germany (DEU). In 2017, the US, as the key player in the network, the thickness of its linkage towards China (CHN) was the most significant which means that the EV export amount from the US to China is the largest. The US also exported large volumes of EVs to Norway (NOR), Japan (JPN) and Canada (CAN). Besides, Germany, the Netherlands, Norway and China also played significant roles in the EV network. For CEE countries, Slovakia (SVK), Poland (POL) and Croatia (HRV) were closer to the centrality, which had larger EV trade volumes than other CEE countries. In 2018, the US was still the centre of the network. Germany was much closer to the centre than it was in 2017, which shows that it plays a more important role in the global EV industry. Besides those main nodes of countries shown in 2018, there were several newly large nodes: the UK (GBR), France (FRA) and Korea (KOR). For CEE countries, Poland and Bulgaria were closer to the centre, especially Poland, which indicates that the demand for EVs and the production of EVs were higher than before in these countries. In 2019, Belgium became a new main node, which was one of the countries that the US had a large number of EVs trade with. It indicates that more European countries have improved the production of EVs and the market demands for EVs have also increased. In 2020, the centre of EV trade network changed to Germany, and the US became the second largest one. The EV industry had a significant development in Germany, which enhanced the production of EV and the customers' demand for EVs also increased. With the development of Germany, the CEE countries that were highly linked with and depended on Germany also had an increasing trade volume of EVs. The CEE countries were all closer to the centre of the network. In both 2021 and 2022, Germany was still the hub network, and its EV trade value with the US and China was increasing. The position of China in the trade network was more significant than before and the trade value of EVs with other countries was increasing. The CEE countries, especially Slovakia and Hungary, gradually became more important for the trade network, which had a larger trade volume with other countries. It states that the CEE countries focused more on the EV industry and participated more in the production of EVs and the trade of EVs is more frequent.

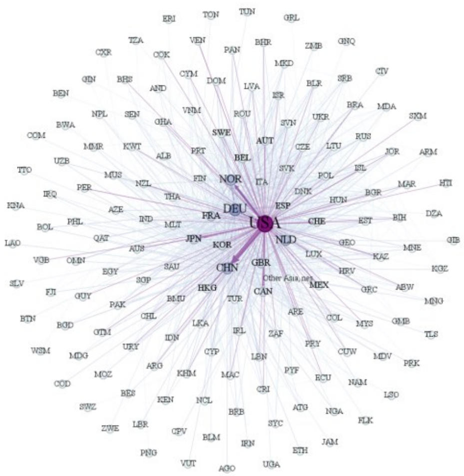


Figure 33. EV network in 2017

(Source: authors, based on BACI).

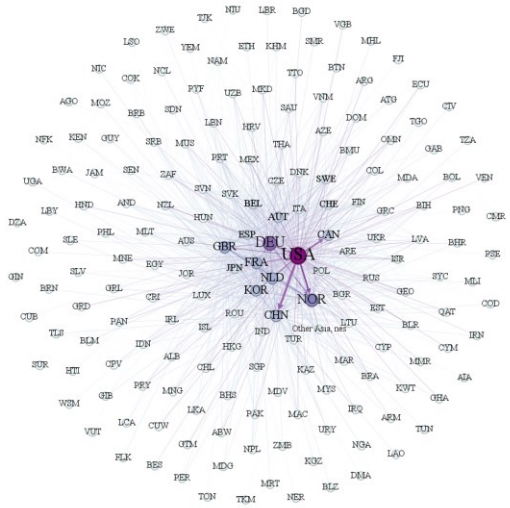


Figure 34. EV network in 2018

(Source: authors, based on BACI).

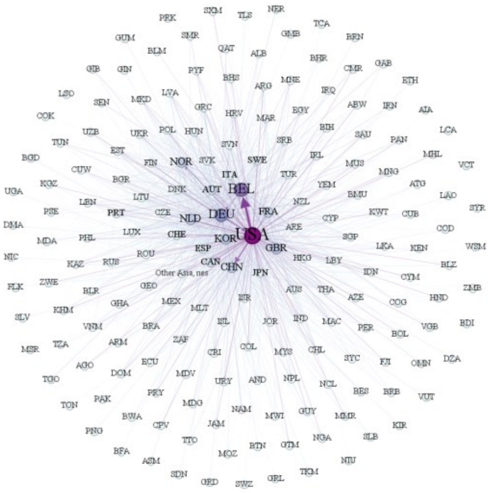


Figure 35. EV network in 2019

(Source: authors, based on BACI).

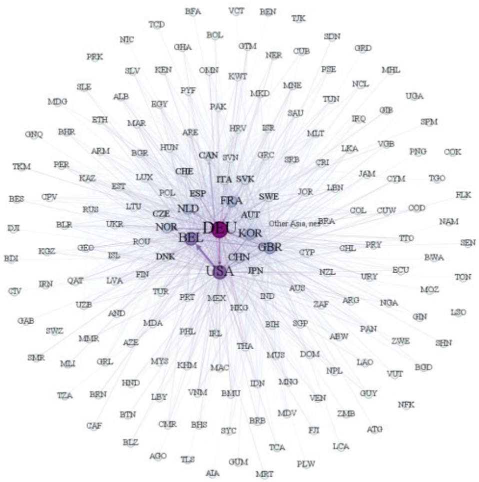


Figure 36. EV network in 2020

(Source: authors, based on BACI).

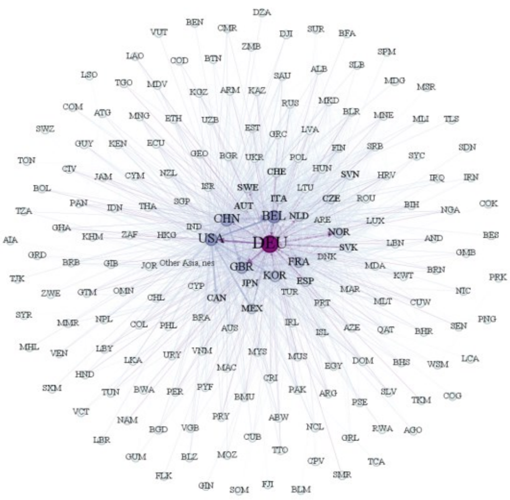


Figure 37. EV network in 2021

(Source: authors, based on BACI).

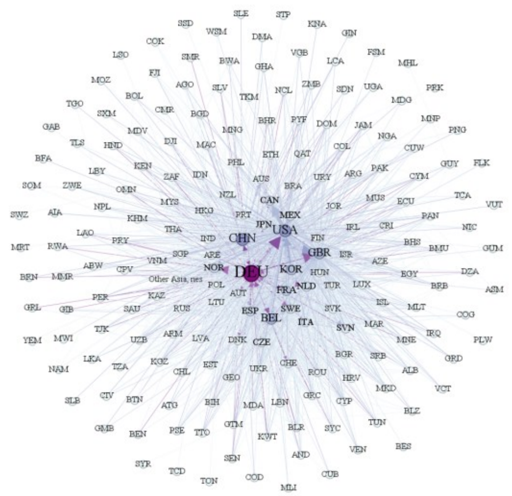


Figure 38. EV network in 2022

(Source: authors, based on BACI).

4. Discussion

4.1 Automotive industry in CEE countries and China based on ICIO analysis

According to the ICIO analysis, the figures show the change of vehicle trade from 1995-2020 in CEE countries and China. The analysis can be divided into several parts. Firstly, GVC participation in vehicle industries is analysed. The total GVC participation of CEE countries has been higher than China during the period from 1995-2020. One of the main reasons is that most of the products in CEE countries are export-oriented. For example, OEC (2022) states that over 90% of the assembled vehicles from CEE countries are exported. Compared with CEE countries, the domestic demand for vehicles and related components in China is higher. The production in the vehicle industry primarily serves the needs of the domestic market. In 2023, China’s automotive production was 30.16 million and sales were 30.1 million, of which vehicle export was 4.91 million, accounting for 16.3% of production (Jiang, 2024).

Secondly, GVC participation can be divided into backward participation and forward participation. The analysis shows that the backward participation of CEE countries has been higher than that of China during the whole period. Table 7 lists the indexes of foreign control in the European vehicle industry calculated by Pavlínek (2023). The indexes are the average values of the share of foreign controlled companies of five indicators in the motor vehicles, trailers and semi-trailers industries: value-added of factor cost, value of production, gross investment in tangible products, number of employers and turnover or gross written premiums. As Table 7 shows, there are eight CEE countries with foreign control of the vehicle industry higher than 80% in 2019, which states that there is a high degree of foreign control and ownership around the CEE vehicle industry through FDI (Pavlínek, 2023). In order to develop the domestic automotive industry, the governments of many CEE countries provide FDI-friendly national policies, tax benefits and large incentive investments from the governments (Pavlínek, 2016). With high foreign control over CEE countries, the future developments of CEE's automotive industries are mainly decided and controlled by those foreign-owned companies. About CEE countries, their locations are close to the core area of the European automotive industry. Therefore, the transportation costs of vehicle products from CEE countries to core areas are low. With the support of the transportation advantage, the modern transport infrastructure of these countries can be developed, like the modern high-speed railways. CEE countries as the EU members, are offered the advantages of tariff-free and some preferential trading arrangements. Besides, the labour costs of CEE countries are obviously lower than those in the core areas of the vehicle industry (Pavlínek, 2022). Therefore, CEE countries are suitable for developing labour-intensive activities of the production parts of the European automotive value chain, which the products can be exported and used in the European macro automotive industry network. The pattern of vehicle industries in CEE countries can be regarded as "factory economies", which mainly contribute to labour-intensive activities and focus on the low value-added production part of the vehicle value chain. As the high value-added parts of the automotive value chain like R&D and strategic decision making are controlled by the core areas and foreign-owned companies, CEE countries can mainly develop the low value-added parts of the automotive value chain, like the production of vehicle components and parts, car assembly and so on, which leads to the truncated and weekly development of the CEE countries' domestic vehicle industries (Pavlínek, 2017). As a result, CEE countries' domestic automotive companies can only enter into the European macro-regional automotive GVC as subordinate positions like the suppliers of simple vehicle components and parts and niche products (Pavlínek, 2018).

As Pavlínek (2018) defined, the automotive industries of CEE countries can be regarded as the integrated peripheries of the automotive industry in Europe, which are areas with relatively low cost, close to a core and large market and integrated into a macro regional production network based on that core market through FDI (foreign direct investment). As the integrated peripheries, the function of production, organization and strategy of a specific industry are controlled by foreign ownership.

Table 7: The index of foreign control in the European automotive industry, 2019

Country	**Index**
Slovakia	97.9
Hungary	96.3
Romania	94.2
Czechia	93.4
Bulgaria	92
Poland	89.7
Lithuania	83.6
Slovenia	83.3
Estonia	57.2
Croatia	54.4

(Source: Pavlínek, 2023).

The third part of the ICIO analysis is the analysis of the domestic and foreign value-added in the automotive industry in CEE countries and China. As the figures present, the proportion of domestic value-added in China is higher than that of CEE countries in the automotive industry from 1995 -2020. On the contrary, the proportion of foreign value-added of China is lower than that of CEE countries. About the CEE countries situation, it indicates that most of the products exported from CEE countries are processed from the products imported from other countries. CEE countries mainly export components and parts and assembled vehicles to European countries. There is a regional specialization based on the spatial division of labour led by the strategy of complementary specialization among CEE countries and the core regions in Europe. The core regions are responsible for the high value-added parts of the vehicle value chain like R&D, vehicle design, strategic decisions and so on. CEE countries as the periphery areas of the vehicle value chain, are responsible for the low value-added parts of the vehicle value chain, which will finally be used to assemble and produce a finished vehicle, like the production of engines, components parts and so on. Different CEE countries have different degrees of specialization in producing different products and components, which presents a situation of regional fragmentation of the vehicle value chain within the CEE countries. For example, in 2019, Poland exported the largest number of engine parts. Hungary was the largest producer and exporter of engines of vehicles. Romania mostly exported transmissions of vehicles (OEC, 2022). Therefore, CEE countries rely on the trade of different intermediates of vehicles from each other within the European cluster. The share of foreign value-added in the automotive industry of CEE countries shows an increasing trend during 1995-2020, which states that the value-added flows around CEE countries are increasing and the situation of fragmentation of the automotive value chain is more obvious.

In order to limit global warming, the European Commission plans to limit the emission of CO_2 on newly produced automobiles and expects to ban ICEs in all new vehicles in

2035 (European Council , 2022). To achieve the goals of the European Commission, the European vehicle industries have started to transition from vehicle production with ICEs to EV production. The restructuring of ICE production in Europe will be realized by closing ICE factories or transiting the factories to produce EVs and related components like electric engines, batteries and so on. The remaining ICE production will move to suitable integrated peripheries which can produce at a lower cost (Sigal, 2022).

The production of ICEs and ICE vehicles may keep longer in CEE countries than in core areas of the European vehicle industry. There are several possible reasons. Firstly, in order to gain more space to produce EVs, some countries in the core regions plan to move the production of ICE vehicles to the integrated peripheries like CEE countries, which have lower labour costs and mature production systems. For example, Volkswagen is moving the production of the VW Passat from Germany to Slovakia (VW , 2021). Secondly, there are advantages of low labour costs, production costs and transportation costs of ICE production in CEE countries than in the core regions. Besides, ICEs and ICE vehicle productions are the main parts of CEE vehicle industries, which provide large profits and jobs for the CEE countries. It is not an easy thing for CEE countries to abandon the ICE industry. CEE countries may keep producing ICE and ICE vehicles for the non-EU markets. For example, Škoda Auto plans to produce ICE vehicles and export to less developed regions like Southeast Asia, Africa, India and South America (Škoda Auto, 2021). Moreover, the production cost of EVs is higher than that of ICE vehicles currently, so the price of EVs is also higher. The subsidies offered by the governments for purchasing EVs are limited in CEE countries. Therefore, the customers’ demands for EVs are lower in CEE vehicle markets.

As Pavlínek (2023) estimated, the production of ICEs and ICE vehicles will remain for at least another 20 years. However, for the development of CEE countries' vehicle industries, it is a risky strategy to depend on the production of ICE vehicles. With the rapid development of EV production technologies, the continued specialization in ICE technologies may become obsolete at a rapid speed. The delay in transiting to EV production of CEE vehicle industries may make the industries not keep up with the development of EVs in the European vehicle markets, which leaves the CEE vehicle industries at a long-term disadvantage.

The situation of China is different from that of CEE countries. On the one hand, as a large manufacturing country, China has established a relatively complete range of industrial categories. According to the report, there are more than 100,000 vehicle components and parts companies in China, which almost realize the full coverage of 1,500 kinds of automotive components. On the other hand, in order to reduce production and transportation costs and avoid tariffs, the top 50 Tier 1 and Tier 2 components suppliers in the world have built factories in China for large-scale localization development. The top 10 Tier 1 foreign companies have built up more than 400 production factories and R&D institutions in China (Sun, 2020). Therefore, the automotive industry chain of China has a low level of dependence on imports from other countries. Because of the integrity of the automotive industry chain in China, a great number of automotive companies including joint ventures have realized a production localization rate of almost 100%, which means that the whole process of producing a car from the raw materials to all needed components producing and to the final process of car assembly can be completed in China. For example, the localization rate of Beijing Mercedes-Benz was below 60%, and it increased to 80% in 2015 and now is close to 100% (Sun, 2020). There is no need to import a large number of intermediate vehicle products from other countries and the whole process of production vehicles can be finished domestically with nearly 100% of localization. Therefore, the forward participation and domestic value-added of China in the vehicle industry are always higher than in CEE countries.

Although the overall scale of automotive vehicle companies is large in China, which can realize the full coverage of automotive components, the number of low-end productions is high and the competitiveness is still weak. The export business of most of the domestic component manufacturers is to offer component products to the international Tier 1 manufacturers as the role of Tier 2 suppliers (Sun, 2020). The R&D of the components and parts with high technology are carried on in the overseas parent companies and produced in China of those foreign-owned companies or joint ventures.

The regional specialization of the European automotive industry is within the Europe cluster. For CEE countries, different countries have different degrees of specialization in different parts of vehicle production. Compared with CEE countries, regional specialization can be realized in China. There are several vehicles industrial based in different geographical clusters within China, and different clusters may specialize in different parts of vehicle production. For example, there is a cluster of automotive components manufacturers that specialise in vehicle spare parts in PRD (the Pearl River Delta) and YRD (Yangtze Delta) of China (Liu, et al., 2008). According to Table 8 which presents the automotive production in China in 2022, it states that Guangdong, Shanghai, Chongqing and Jilin are the top 4 provinces of vehicle production in China which are located in the coastal, southwest and northeast China. It can also prove that the industrial bases are located in different areas in China. It also indicates that the developments of automotive production are unbalanced in different regions of China (Lai, 2024).

Table 8: Automobile production in China in 2022, by region (in 1,000 units)

Region	Production (in 1,000 units)
Guangdong	4,153.70
Shanghai	3,024.50
Jilin	2,155.80
Chongqing	2,037.70
Hubei	1,852.50
Guangxi	1,770
Anhui	1,746.90
Shaanxi	1,337.90
Zhejiang	1,248.50
Shandong	1,019.20
Jiangsu	943.60
Hebei	905.50
Beijing	871.10
Liaoning	766
Sichuan	724.80
Tianjin	603.20
Henan	553.10
Jiangxi	414.10
Fujian	338.90
Hunan	263.50
Shanxi	165
Heilongjiang	82.60
Inner Mongolia	54.10
Guizhou	46
Yunnan	22.30
Hainan	22
Xinjiang	13.80

(Source: Lai, 2024).

As the results of ICIO analysis, the gross export value of vehicles from China to the US and the domestic and foreign value-added of China export to the US are all the highest. It indicates that the US is the main trade partner of China in the automotive industry. Since the trade war started between the US and China in 2018, there have been higher tariffs targeting the automotive industry from both two sides, which was more than 25%. With the effects of tariffs, the gross export value of vehicles and the value-added of China exports to the US have decreased from 2018. As the IHS Markit (2020) reported, the trade of vehicles and components between the US and China decreased by 27% of the total trade in the first six months of 2019 compared with 2018. With the implementation of tariffs in the vehicle industry, the trend of trade of vehicles and components in China and the US has started to change. The US imports of vehicles and components from China have decreased, in the same period, its imports from Latin America, especially Mexico have increased. For example, Within the first six months of 2019, compared to the first six months of 2018, there was a decrease of 12% in the imports of vehicles and components from China, at the same time, there was an increase of 16% in the imports from Mexico, which states a significant shift in the trade flow of the US (IHS Markit, 2020). Some Mexican suppliers also exported components from China and exported to the US. For China, in order to make up for the reduction in exports caused by the US tariffs, China started to focus more on its second-largest automotive export target region – the EU. The export value of vehicles to the EU increased by about 13% from 2018 to 2020 (OECD, 2022).

4.2 Automotive industry in CEE countries and China based on network analysis

According to the network analysis, Figures 33 – 38 show the position changes of selected countries in global vehicle networks in selected years: 1995, 2008, 2012 and 2020. In 1995, Japan, the US and Germany were the core countries in the vehicle networks, which accounted for a large amount of trade value including export and import in the global automotive industry. The automotive manufacturers of these countries played significant roles in the global vehicle market. During this period, the developments of vehicle production in China and CEE countries were in the initial stage. The automotive industry of China was dominated by state-owned enterprises. Foreign automotive manufacturers started to get into the Chinese vehicle industry by joint ventures with Chinese state-owned companies. For CEE countries, foreign automotive manufacturers also started to enter CEE vehicle industries by building foreign-owned factories or joint ventures with domestic companies. For example, the crucial moment of the beginning of the development of the automotive industry in Slovakia could be traced while the Volkswagen AG started to invest and operate the factories in Bratislava (Folfas, et al., 2022). The production capacity and demand for vehicles were weak in China and CEE countries, and these countries had low levels of integration into the automotive GVC. Therefore, the positions of China and CEE countries were not close to the centre of the vehicle network. In 2008, the automotive industries of China and CEE countries had been gradually developing. They had gradually participated into the vehicle GVC after the entry of WTO or the EU. In 2012, with the rapid growth of the automotive industry, China became the centre of the vehicle network. China's share of global vehicle production has been 22.88%, which was the highest in the global vehicle industry. It was the first time that the export volume of vehicles was over one million (Lai, 2024). Among CEE countries, Czechia was the closest to the centre of the network, which had the highest trade value of vehicle products among the CEE countries. The report of Folfas et al (2022) also shows that vehicle production in Czechia has accounted for a higher share in the EU since 2010.

In 2020, the centre of the network was still China. The share of global vehicle production for China was 32.5%, which was the highest compared with other countries (Lai, 2024). China has been one of the largest vehicle production and trade countries. The nodes of CEE countries kept closer to the centre. Czechia and Slovakia were the main vehicle trade countries, which the values of weighted degree were the highest within the CEE countries. Czechia has become the third largest vehicle producer in the EU in 2020, which exceeded the production of France (ACEA, 2021). Czechia was also a main vehicle products exporter country. In 2020, there were 90.6% of final vehicle products and 76.1% of automotive suppliers' production exported. The EU was the main destination for Czechia, especially Germany (Sdružení automobilového průmyslu, 2022). The production of passenger vehicles accounted for about 48% of the industrial production in Slovakia, which shows the importance and rapid development of the vehicle industry in the Slovakia economy (SARIO, 2022). For most of the CEE countries like Czechia, Slovakia, Hungary and so on, the automotive industry was the main supported industry, with significant contributions to the national economies. For example, the automotive industry plays a key role in the economy of Hungary by the integration into GVC, export, employment and added value. The automotive industry accounted for 5% of Hungary's GDP in 2020 (ITM, 2021).

4.3 EV industry in China

As the limitation of CO_2 emissions announced by the European Commission, the China government also released emissions standards and goals. In 2019, the China government started to implement the "China 6th level New Energy Vehicle Standard", which are mandatory environmental regulations to control vehicle pollutant emissions. The government expected that by 2035, the annual sale proportion of energy-saving vehicles and NEVs can reach 50% separately. Besides, the government announced to achieve carbon neutrality before 2060 (China -SAE, 2021).

With the development of technology, the rising cost of fuel vehicles and the consumers' increasing intention to environmental protection, the demand for EVs has increased. Therefore, the production and sale of EVs show a rapid growth trend. As Figure 38 shows, the role of China is gradually significant in the EV industry, which has become a key node of the trade network in 2022. In 2023, the production of BEV has reached 6.7 million USD, a 22.6% increase from the prior year (Liu, 2024). The export of BEV was 1.2 million, which was valued at about 35.8 billion USD that increase of 68.95% compared with a year earlier. The main export destinations were Belgium, the UK and Spain. The export value of PEV has reached 5.99 billion USD, a year-on-year increase of 105.2%. The main export countries of China were Brazil, Belgium and the UK (Mai, 2024). It indicates that the main overseas market for China's EVs is Europe. Belgium is located in the centre of Europe with convenient transportation. It is one of the most important gateways for EVs from China exporting to the Europe market. Chinese automakers can export EVs to the entire European market through Belgium, which effectively reduces transportation and time costs. The situation of EV import in China is different. The import value of BEV was 2.22 billion USD in 2023, a year-on-year increase of 54.11%. The main import countries of China were Germany, the US and Japan. The import value of PEV was 5.88 billion USD, which decreased by 5.25% compared with the previous year. The main import countries of China were Japan, the US and Slovakia (Mai, 2024). As the important countries in the global vehicle industry, Germany and Japan have advanced automobile manufacturing technology and a mature value chain. The EVs produced from these two countries have high quality and performance. The automobile brands of these countries enjoy high reputations and brand loyalty, which are attractive in the Chinese market. EV's import and export trade surplus in China expanded in 2023. The trade surplus of EVs was 33.69 billion USD in 2023, an increase of 17.23 billion USD from 2022. From the overall trend, the scale of EV import and export is large and maintains a rapid growth trend in China. From the perspective of export, the number of EV exports keeps increasing, which shows the increasing competitive advantage of China's EV in the global vehicle market and there is still huge space to improve in the future. From the import perspective, though the import volume shows an increasing trend, the growth rate is slower than the export.

However, China's EV industry development still faces several challenges. Firstly, China's EV industry is still in the initial stage of development, many EV companies have not formed economies of scale yet. In 2023, the top three China's EV export brands were Tesla, BYD and MG. Tesla's Shanghai factory, as a foreign-owned company, exported 344,000 EVs which accounted for a quarter of China's EV export (1.2 million) in 2023, most of which were exported to European countries. China's domestic brands only exported 123,000 EVs to Europe (Zhang, 2024). It shows that China's domestic brands do not have a high market penetration rate and market acceptance now.

Besides, the development of the EV market faces the challenge of industry profit pressure. Compared with traditional fuel vehicles, EVs have not formed cost competitiveness and substitution advantages. The cost of pure electric passenger vehicles was still about 20%-30% higher than that of fuel vehicles of the same level. It is estimated that the purchase cost of EVs will still be higher than that of fuel vehicles in 2025 (Xu, 2023).

In addition, the imbalance and insufficiency of development exist in the EV industry. China's EV market penetration rate is over 25%, but the industry still has problems with uneven development of regional and segmented markets. For example, the sales of EVs in East China were about 41% of the national sales, while that in Northeast and Northwest China was lower than 5% (Xu, 2023).

Moreover, the industry faces the challenge of foreign countries' subsidy policies to their own EV industries and the tariff policies towards EVs imported from China. For China, the domestic development of the EV industry is supported by various industrial policies and subsidy policies issued by the Chinese government. The tax exemption policy for EV purchases is an efficient policy that has been implemented since 2014, which positively promotes EV consumption and the development of the industry (Xu, 2023). Because the EV industry has been developing steadily, the government has cancelled most of the subsidy policies. However, to promote the EV industry's rapid development, many foreign countries have started to issue various subsidy policies, so there is a possibility that the development of their EV industries will catch up with China.

Besides, the tariff policies of some countries have changed. In May, the US announced to increase in the tariff on EV imported from China from 25% to 100%; tariff on lithium-ion EV battery from 7.5% to 25% and tariff on solar cell from 25% to 50%. The EU also increased the tariffs on China's EVs. In the previous years, the tariff was 10 % which was low. Since July 4th, the EU has imposed temporary tariffs on EVs made in China. The new tariffs on EVs range from 17.4% to 37.6%, which is the extra tariff of the 10% duty that was already imposed for EVs imported from China. The extra tariff is calculated based on the estimate of how much support from the government each company receives. There were three Chinese EV brands (BYD, SAIC and Geely) that have been set extra duties by the European Commission. BYD faces an additional tariff of 17.4%. SAIC has been set the highest extra tariff (37.6%). Geely will face an extra tariff of 19.9% (Silva, 2024). The tariff policy may increase the price of China's EVs in the European market, which will decrease the customers' demand for China's EVs. However, customers' demand for EVs provides opportunities for any EV producers that can produce and sell EVs at competitive prices. If other European EV companies can sell products at low prices, the customers may not choose China's products. Therefore, the fear of China crowding out European vehicle makers may be exaggerated.

To enhance the competitive advantages of China's EVs in the European market and avoid the possible extra tariffs, some Chinese companies have invested and built manufacturing factories in some European countries, especially in some CEE countries. In 2023, China's EV battery and component manufacturing companies announced the investment that more than 10 billion EUR from companies like Contemporary Amperex Technology (CATL), Huyao Cobalt, Gotion High-Tech to CEE countries (Oxford Analytica, 2023a). In 2022, CATL (EV manufacturer) invested 7.3 billion EUR in a battery manufacturing facility in Hungary. In 2023, Huyao Cobalt announced to building of its first European factory in northern Hungary, which invested 1.3 billion

EUR and will provide 900 extra jobs (Oxford Analytica, 2023b). In 2024, Gotion High-Tech will cooperate with Slovak battery company InoBat, which will invest 1.2 billion EUR to build an EV battery plant in Slovakia (Oxford Analytica, 2024). In order to build a home-grown battery industry, and build up their own competitive advantage in battery manufacturing in the EV industry, some CEE countries' governments provide subsidies and intensive policies for foreign investment. These countries become ideal places for China to expand overseas markets.

4.4 EV industry in CEE countries

As Figures 33-38 presented, CEE countries were gradually closer to the centre of the trade network from 2017-2022. In 2022, the export value of EVs from CEE was 7.2 million USD, which was an increase of 15% from 2021. The import value of EVs was 3.5 million USD, a year-on-year increase of 96.5%. It indicates that CEE countries pay more attention to the development of the EV industry. Customers' demands for EVs are higher than before. In CEE's vehicle industry, the transition from fuel vehicles to EVs will be gradual, which needs the participants of the whole value chain to adjust. Szabo (2023) estimated that as ICE vehicles are phased out and EVs are phased in, the parallel production will continue over the next decade.

The figures also show that core countries in Europe (Germany, the UK, France and so on) are around the network centre, which states the improvement of EV production and the demand for EVs. As the integrated peripheries that are not the centre of EV innovation, vehicle companies in CEE start to respond and diversify production including a range of products beyond EVs like batteries, components and charging infrastructures. They attempt to get into the sectors that are closely linked to the vehicle industry with harness synergies (Szabo, 2023). With the support of the governments, many countries choose to develop the battery industries and attract foreign investors to invest. For example, Hungary provided state aid (209 million EUR) to SK On for the battery factory construction in Iváncsa and EUR108 million supported to Samsung SDI for the expansion of the battery factory in Göd. Poland offered 95 million EUR aid to LG Energy Solution to expand the battery factory in Wroclaw (Pavlínek, 2023).

Attracting FDI to battery manufacturing is also an efficient strategy to attract EV assembly, which promotes the future development of the EV industry in CEE and provides jobs. CEE countries have geographical advantages, which are close to the vehicles' core region. As the EU member countries, CEE countries do not need to pay for the tariff. The battery is heavy, and accounts for about one-third of the weight of a total EV (Delanote , et al., 2022). Because of the geographic proximity of CEE countries, the cost of transporting finished batteries to assembly factories can be lower. Besides, lithium deposits are an important raw material for EV battery production. There are two large deposits have been discovered in EE, one is in Czechia and the other one is in Serbia. Therefore, the Czechia government has planned to launch lithium mining to support the role in the supply chain.

However, the transition to EV in CEE still meets several problems. Firstly, the R&D capabilities of EVs in CEE countries are very limited. Most of the CEE countries specialize in the low value-added sectors in the vehicle industry. For example, EV battery assembly jobs are not high value-added jobs in the EV value chain (Szalavetz, 2022). There are low R&D expenditures as a share of total output and a low share of R&D sector employees in total employment (Pavlínek, 2023). There are low shares of high value-added activities like R&D functions, strategic planning and so on in foreign-owned companies or factories. The high value-added activities are concentrated in the home countries of those foreign investors (Pavlínek, 2017). There is a significant effect on CEE countries' EV development caused by the high levels of foreign control and ownership. It means that the development of EVs in CEE countries, including the transition process from ICE vehicles to EVs will be controlled and decided by those large foreign-owned companies by their decisions of allocation on production and investment, which will be at the expense of the demands of local companies and other domestic needs (Pavlínek, 2016).

Secondly, battery production is an energy-intensive industry. The future development of the battery industry in CEE may be negatively affected by a possible increase in energy prices and a high dependence on Russian natural gas if cheap alternative energy sources cannot be found in CEE (Pavlínek, 2023).

In addition, compared with the core countries in the European vehicle industry, CEE countries' process of transition to EV production is slower. In order to reduce the cost of production, most of the CEE planets apply the strategy of mixed production, which means that the assembly of EVs use the same factory as ICE vehicles. This strategy will make it difficult for EV production to become economies of scale in CEE countries. There is no competitive advantage of the mixed strategy compared with those dedicated EV factories that each assembly line is fully dedicated to one platform (Gibbs, 2019).

Besides, the transition to EV production will disrupt employment patterns, which will be uneven across different sectors. The two most important sectors in traditional ICE vehicle production which employ the largest number of workers are the manufacture of vehicles and engines and the production of parts and components. For example, the component suppliers of the ICE powertrain like parts for engines, fuel and so on will be the most affected because these products will become useless in the BEV (Schwabe, 2020). The drivetrain of a BEV is easier than that of an ICE vehicle, which only needs half of its bearings (Davies, et al., 2015). Therefore, the production of EVs is less labour-intensive than the production of ICE, leading to a significant job loss. The new sectors related to EV production like battery production, sensors and so on will provide new jobs. However, new sectors like the production of batteries are highly automated, and do not need so much labour (Schade, et al., 2022). The battery assembly of BEVs is also less labour-intensive than ICE vehicle assembly because there are fewer mechanical parts needed for BEVs. For example, Volkswagen's BEV factory in Zwickau integrated some processes applied in ICE vehicle production like stamping work for the hood, door and so on, which finally resulted in fewer jobs in the sector (Gibbs, 2019). The effect on employment patterns will also be geographically uneven throughout CEE countries because different CEE countries may specialize in different parts and sectors of the production of vehicles. For example, Poland is the largest engine production country, with the engine export value in 2020 was EUR 2.8 billion (OEC, 2022). Czechia, Hungary and Poland are the largest exporting countries of engine components. The decreased need for ICE components will negatively affect these countries. As CLEPA (2021) estimated, about 50% jobs of powertrains will be lost in Poland, Czechia and Romania between 2030-2040. Most of the local vehicle suppliers are Tier-three suppliers (Pavlínek, 2018). As foreign control and ownership are high degree over the vehicle industry in CEE, Local companies in the industry are in weak positions, which cannot affect the changes in the transition from ICE vehicles to EVs.

Moreover, though CEE countries are willing to provide large investments to intensive companies in the EV production parts like large suppliers, battery manufacturers and assembly firms, some of those countries' support for other parts like EV sales and purchases are limited. As Table 8 shows, Hungary and Croatia provide generous EV purchase intensive for customers. Slovenia, Poland, Lithuania, Estonia and Czechia provide little purchase intensives. Bulgaria, Latvia and Slovakia do not provide any intensives for customers' purchase and EV's related infrastructure. Regarding the tax benefit, Bulgaria, Hungary, Latvia, Lithuania and Romania provide tax exemptions for EVs (ACEA, 2024). In some situations, the governments of some CEE countries are unsupportive of EC regulations and the transition to EV. For example, the EU plans to prohibit ICEs in all vehicles in 2035 (European Council , 2022). For most of the CEE countries, the ICE vehicle industry is one of the most important industries. The ban on ICE sales may be unacceptable. Therefore, the governments in CEE countries may just play the roles of facilitators in the vehicles' transition to EV production. The future of EV industry development will mainly rely on strategies and investment from multinational enterprises (Horner, 2017).

Table 8: Tax benefits and incentives: electric cars

	Tax Benefits			Incentives	
	Acquisition	**Ownership**	**Company cars**	**Purchase**	**Infrastructure**
Bulgaria		Tax exemption for EVs.			
Croatia	No excise tax for EVs.	No special environmental tax for EVs.	×	Incentive policy (once a year, limited funds): • 9,000 EUR for BEVs . •5,000 EUR for PHEVs. •The deadline for purchase is 31 December 2024. • The vehicle must be kept for at least two years and cost less than 50,000 EUR.	×
Czechia	BEVs and FCEVs with emissions≤ 50g CO2/km are exempt from registration fees (with a special number plate).	(1) BEVs, PHEVs, and FCEVs are exempt from road tax. Road toll: • BEVs exempt • PHEVs emissions no more than 50g CO2/km pay 25%. (2) Reduced depreciation period for EV charging stations from 10 to 5 years (wall boxes and standalone charging stations). (3) Accelerated depreciation for BEVs and FCEVs.	Tax reduction from 0.25–1% for BEVs, and 0.5% for PHEVs (Also applied for private purposes).	(1) Provide incentives for state and local government agencies to purchase low-emission and zero-emission vehicles. (2) Provide guaranteed discounted loans for BEVs, FCEVs and charging stations for business persons, with a budget of 1.95 billion CZK.	The Ministry of Transport supports the development of charging and hydrogen refuelling infrastructure for BEVs and FCEVs with a total of 6 billion CZK.
Estonia	×	×	×	New BEV and FCEV (purchase and lease): • 5,000 EUR per vehicle for individuals. • 4,000 EUR per vehicle for legal persons.	×
Hungary	Tax exemption for BEVs and PHEVs.	Tax exemption for BEVs and PHEVs.	Tax exemption for BEVs and PHEVs.	From June 15, 2020, the purchase incentive for EVs: • 7,350 EUR for a total price of up to 32,000 EUR. • 1,500 EUR for a total price between 32,000 EUR and 44,000 EUR.	×
Lithuania	Purchase BEV: • No registration tax. • VAT reduction up to 50,000 EUR (including VAT)	Tax exemption for BEVs until the end of 2024.	Purchase incentive (bonus) for vehicles less than six months: • BEV: 5,000 EUR • Additional 1,000 EUR for scrapping a used diesel or petrol car, owned for at least 12 months with a valid MOT. (The maximum subsidy is 400,000 EUR per company).	Individual purchase incentives (bonuses): • 2,500 EUR for a used BEV first registered after 2 April 2016 or model year 2016 or newer. • 5,000 EUR for a new BEV within 6 months from the first registration. • 2,000 EUR for a new PHEV. • An additional 1,000 EUR for scrapping a used diesel or petrol car used at least 12 months with a valid MOT (The maximum purchase price of an eligible car is 45,000 EUR).	(1) Subsidy for private charging infrastructure: • Up to 1,500 EUR for a wallbox or charging cable. • Up to 3,000 EUR for a shared system in a multi-party building. (2) Subsidy for public charging infrastructure: Up to 10,000 EUR.
Latvia	No registration tax for BEVs (only the first time registration).	Tax exemption for vehicles emissions ≤ 50g CO2/km.	Minimum price for BEV (EUR 10).	×	×
Poland	(1) Tax exemption for BEVs and FCEVs. (2) Tax exemption for PHEVs up to 2,000cc until the end of 2029.	Depreciation: • Up to 225,000 PLN for BEVs and FCEVs. • Up to 150,000 PLN for vehicles with CO2 emissions of 0-50 g/km. • Up to 100,000 PLN for vehicles with CO2 emissions > 50 g/km.	×	Purchase incentives for individuals and legal persons (purchase, lease): from 18,750 PLN to 27,000 PLN for BEVs and FCEVs, with a maximum price of 225,000 PLN.	×
Romania	×	Tax exemption for BEVs.	(1) Vehicle Renewal Scheme (RABLA): • At least one vehicle older than 8 years must be scrapped. • HEV (less than 150 g CO2/km) can receive up to3,300 EUR. (2) RABLA PLUS cars: • PHEV (less than 80 g CO2/km) can receive bonus 2,500 EUR. • BEV can receive bonus 5,000 EUR. • No mandatory scrapping of vehicles is required.	×	×
Slovakia	Registration fee for • BEV: Maximum charging fee of EUR33. • PHEV: 50% reduction.	(1) Road tax: • Tax exemption for BEVs · 50% for PHEVs. (2) Accelerated depreciation for PHEVs and BEVs from four years to two years.	×	×	×
Slovenia	The lowest additional tax rate for BEVs (0.5%).	×	×	Incentive policy: up to 4,500 EUR for BEVs.	

Source: Organized by author from information available in ACEA (2024).

Conclusion

In this paper, we explore the changing role of CEE countries and China in the global automotive industry during 1995-2020, through the ICIO analysis and network analysis. The OECD-ICIO database containing the trade flow between countries over the period 1995-2020 was used for the analysis. Firstly, applying the ICIO analysis, we compared the GVC participation and value-added in the vehicle industry between CEE countries and China as well as discussed the GVC participation and value-added of the exports from CEE countries and China to selected countries during the period. The results show that the GVC participation of CEE countries has been higher than that of China during the period. The GVC backward participation and foreign value-added of CEE countries have been higher than that of China over the period. However, the GVC forward participation and domestic value-added of CEE countries have been lower than that of China. Based on the results, it can be found that, firstly, CEE countries are export-oriented and a large number of the products are exported to other countries. The main export destination of CEE countries is the European countries, especially Germany. Compared with CEE countries, the production in China's vehicle industry primarily serves the domestic market, which has a high demand. Besides, the pattern of vehicle industries in CEE countries can be regarded as "factory economies", which mainly contribute to labour-intensive activities and low value-added parts of the automotive value chain. The low labour cost and transportation costs make CEE countries suitable for developing labour-intensive and production activities. Because of the high foreign control of CEE countries, the developments of CEE automotive industries are mainly decided by foreign-owner enterprises. These companies keep the high value-added parts of the automotive value chain in the headquarters and core areas of Europe and move the low value-added parts to countries like CEE. Therefore, CEE countries mainly enter the European macro-regional automotive GVCs as subordinate positions.

In addition, there is a phenomenon of complementary specialization among CEE countries and the core regions in Europe. CEE countries rely on the trade of automotive intermediates from each other or other countries in the European cluster. The situation of fragmentation of the European automotive value chain is more and more obvious. Moreover, in China, automotive factories can realize the full coverage of automotive components. The whole process of vehicle production from components to assembly has been completed in China, which has realized a production localization rate of almost 100%. Within China, there is a phenomenon of regional specialization that different regions in China specialize in different parts of the vehicle value chain, and the developments of the automotive industry are unbalanced in different regions. In addition, the main export destination of China is the US. Hence, since the trade war started between the US and China in 2018, the export value of vehicles between these two countries has decreased. China started to shift the destination to the EU.

To clearly discuss the position changes of China and CEE countries in vehicle GVC, the network analysis was applied to directly visualize the changes during 1995-2020. The network figures show that from 1995 to 2020, China played a more and more important role in the automotive GVC, which became the centre of the vehicle network in 2012 and kept the centre position still 2020. The total value of China in automotive GVC kept larger which shows the development of the vehicles' production and demands. For CEE countries, the positions in the network kept closer to the centre of the network, indicating the improvement of production in the vehicle industries and the much more important roles of CEE for the automotive GVC than before. The automotive industry has become the support industry for the CEE countries.

With the development of technology and the demand for the markets, the transition to EV production has become a current trend in the automotive industry. The network analysis of EVs shows the rapid growth of EV production and trade in China. The position of China has become closer and closer to the centre of the network during 2017-2022. The key EV overseas market for China is Europe. In order to avoid increasing tariffs from the EU and expand the European EV market, more China EV enterprises started to invest and build production factories in Europe, especially the CEE countries. For CEE countries, the positions in the network have been gradually closer to the centre during the period. Some CEE countries started to attract foreign investment for the development of EV related sectors, like battery production, EV assembly and so on. The transit from ICE production to EV production is a gradual and slow process in CEE countries, which still meet various challenges. The cost of EV production is higher than that of ICE and the market demand for EVs is still weak. Many CEE countries' governments' subsidies for EV development are limited. The production of EVs is less labour-intensive, leading to a significant job loss. Compared with EV production, the production of ICE and ICE vehicles are the main parts of CEE vehicle industries, which have more competitive advantages, like mature production systems, lower costs, large job needs and profits. Therefore, it is not easy for CEE countries to quickly abandon the ICE industry and transit to EV industry.

The limitations of the analysis are related to the analysis content. The dataset we used only contain the data of vehicle, which do not include the data about automotive components and parts. Components production and exports are also a main part of vehicle industries in China and CEE countries. For further research, we can analyse the components and parts sector using ICIO analysis and network analysis, which can help to discuss more about the positions of China and CEE countries in automotive GVC. Besides, as the discussion of the development of the EV industry, government subsidies and support policies are necessary for the EV industry. Therefore, it is necessary to analyse and discuss the effect of government on EV industry improvement and what kinds of policies are effective and necessary.

Summary

China has become the centre of the global automotive network. The whole process of vehicle production can be completed in China. CEE countries have become closer to the centre during this period. The vehicle productions of CEE countries contribute to the low value-added of automotive GVC, which are export-oriented. The main destinations are European countries, especially Germany. Besides, China and CEE countries have gradually transitioned to EV industries. The positions in the EV network are gradually getting closer to the centre. China has invested more in Europe and started to build EV factories in Europe. CEE countries focus on the development of EV-related sectors like battery manufacturing.

Souhrn

Čína se stala centrem globální automobilové sítě. Celý proces výroby vozidel může být dokončen v Číně. Země střední a východní Evropy se v tomto období přiblížily centru. Výroba vozidel v zemích SVE přispívá k nízké přidané hodnotě automobilových GVC, které jsou orientovány na vývoz. Hlavními destinacemi jsou evropské země, zejména Německo. Kromě toho Čína a země SVE postupně přešly na odvětví výroby elektrických vozidel. Pozice v síti EV se postupně přibližují centru. Čína v Evropě více investovala a začala v Evropě stavět továrny na elektromobily. Země střední a východní Evropy se zaměřují na rozvoj odvětví souvisejících s EV, jako je výroba baterií.

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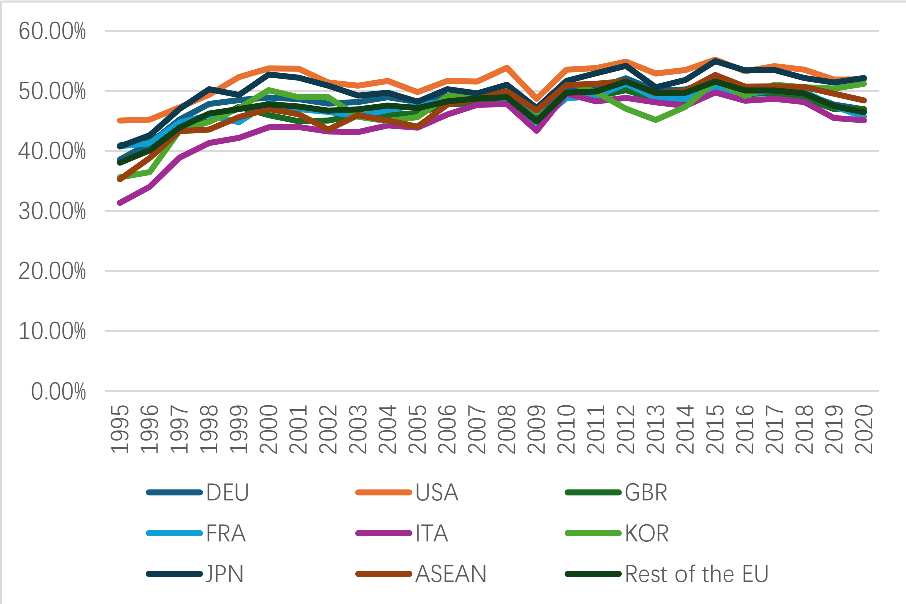
List of Appendixes

Appendix no. 1: Sample of Countries (table)

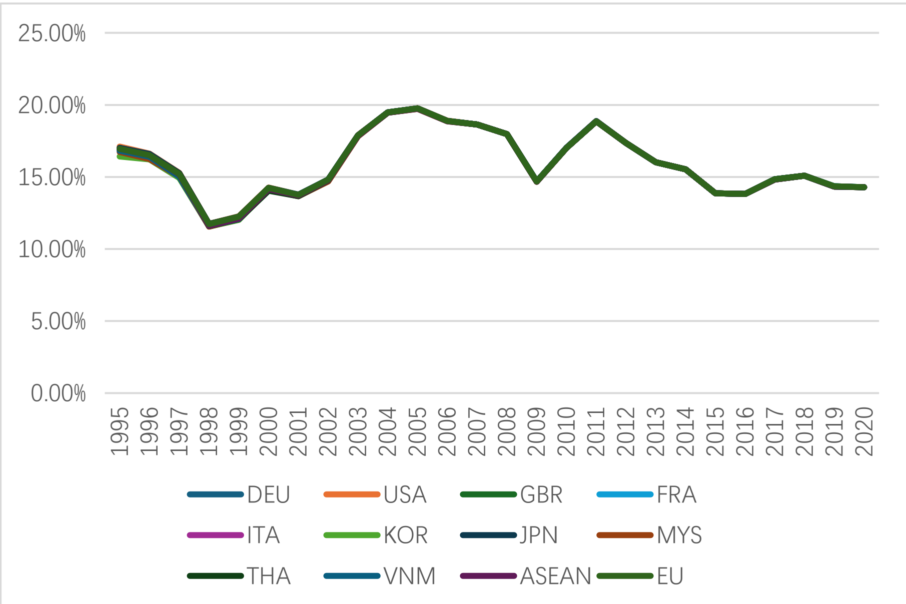
ISO3	Country name
AUS	Australia
AUT	Austria
BEL	Belgium
BGR	Bulgaria
BRA	Brazil
BRN	Brunei Darussalam
CAN	Canada
CHN	China (People's Republic of)
CYP	Cyprus
CZE	Czechia
DEU	Germany
DNK	Denmark
ESP	Spain
EST	Estonia
FIN	Finland
FRA	France
GBR	United Kingdom
GRC	Greece
HRV	Croatia
HUN	Hungary
IDN	Indonesia
IND	India
IRL	Ireland
ITA	Italy
JPN	Japan
KHM	Cambodia
KOR	Korea
LAO	Lao (People's Democratic Republic)
LTU	Lithuania
LUX	Luxembourg
LVA	Latvia
MEX	Mexico
MLT	Malta
MMR	Myanmar
MYS	Malaysia
NLD	Netherlands
PHL	Philippines
POL	Poland
PRT	Portugal
ROU	Romania
RUS	Russian Federation
SGP	Singapore
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
THA	Thailand
USA	United States
VNM	Viet Nam

Appendix no. 2 The proportion of foreign value-added of CEE export to selected countries in the motor vehicle industry (figure)



(Source: authors, based on OECD ICIO).

Appendix no. 3 The proportion of foreign value-added of China export to selected countries in the motor vehicle industry (figure)



(Source: authors, based on OECD ICIO).

Appendix no. 4: Vehicle linkages of selected countries in 1995 (table)

Weighted Degree		Weighted In-degree		Weighted Out-degree		PageRank Centrality		Betweenness Centrality	
JPN	308869.37	JPN	152328.8	JPN	156540.56	DEU	0.028452	DEU	0.056231
USA	169720.47	USA	87400.327	USA	82320.147	JPN	0.027598	JPN	0.0342
DEU	75053.912	DEU	33813.061	DEU	41240.851	NLD	0.025035	SWE	0.031988
CAN	34396.62	CAN	19004.6	CAN	15392.02	GBR	0.024774	RUS	0.02531
FRA	23366.35	ESP	11582.74	FRA	12241.26	SWE	0.024592	GBR	0.024316
ESP	22913.85	CHN	11212.1	ESP	11331.11	FRA	0.022648	USA	0.018617
CHN	22239.73	FRA	11125.09	CHN	11027.63	ITA	0.022436	FRA	0.016193
KOR	21099.829	KOR	10112.09	KOR	10987.74	USA	0.022436	NLD	0.015611
BEL	15515.52	BEL	8719.5801	BEL	6795.9401	RUS	0.022369	ITA	0.014175
GBR	13171.84	GBR	6413.8199	GBR	6758.0199	PHL	0.022142	ESP	0.011338
MEX	11842.32	MEX	6113.8601	ITA	6010.6101	CHN	0.021957	IND	0.01071
BRA	11318.8	BRA	5860.1199	MEX	5728.4601	CAN	0.021144	CHN	0.010696
ITA	11250.7	ITA	5240.0901	BRA	5458.6799	AUT	0.021063	BEL	0.009029
SWE	9550.04	SWE	4491.49	SWE	5058.55	ESP	0.020967	CZE	0.008696
THA	4824.8601	THA	2731.2301	THA	2093.63	PRT	0.020913	AUT	0.008465
PRT	4110.7199	PRT	2372.0599	PRT	1738.66	BEL	0.020381	HUN	0.008115
AUS	2966.1201	AUS	1859.31	AUT	1331.7	IND	0.019915	KOR	0.007659
AUT	2635.2	AUT	1303.5	IND	1132.9199	HUN	0.0198	THA	0.007364
IND	2213.6199	RUS	1252.72	AUS	1106.81	SGP	0.019474	CAN	0.007334
RUS	2200.1999	IND	1080.6999	RUS	947.47997	VNM	0.019189	PHL	0.006936
HUN	1733.85	HUN	905.13	HUN	828.72	AUS	0.019003	PRT	0.005261
POL	1503.17	NLD	753.88	POL	822.38003	THA	0.018871	POL	0.005206
PHL	1284.62	POL	680.79001	PHL	632.03	KOR	0.018222	FIN	0.004652
CZE	1134.67	PHL	652.58999	CZE	569.17	CZE	0.018106	SGP	0.003518
IDN	1056.21	MYS	574.75001	IDN	503.83	MEX	0.017463	SVN	0.00311
NLD	1024.62	CZE	565.5	MYS	425.09001	POL	0.017329	AUS	0.002731
MYS	999.84001	SVN	563.73001	SVN	382.94001	FIN	0.016602	BRA	0.002582
SVN	946.67002	IDN	552.37999	NLD	270.74	BRA	0.016503	MEX	0.001999
SVK	506.40999	SVK	301.69999	SVK	204.70999	SVN	0.01635	DNK	0.001537
VNM	413.62999	VNM	248.86999	VNM	164.75999	MMR	0.016305	MYS	0.000814
FIN	316.63	FIN	184.55	FIN	132.08	BGR	0.015797	SVK	0.000693
DNK	124.92	SGP	91.63	ROU	52.790001	LUX	0.015797	BGR	0.000632
ROU	97.100002	DNK	77.959999	DNK	46.96	GRC	0.015661	GRC	0.000593
SGP	96.349999	ROU	44.310001	IRL	19.39	DNK	0.015364	ROU	0.000324
IRL	55.36	GRC	36.919999	MMR	16.22	MYS	0.015211	VNM	0.000295
GRC	44.069999	IRL	35.97	GRC	7.15	SVK	0.014618	IDN	0.000251
MMR	41.280001	MMR	25.06	SGP	4.72	IDN	0.014287	IRL	0.000236
BGR	8.66	BGR	5.54	BGR	3.12	ROU	0.013889	LUX	0.000082
LUX	6.45	LUX	4.96	LUX	1.49	IRL	0.013093	MMR	0.000082
HRV	5	HRV	3.81	HRV	1.19	HRV	0.011842	LTU	0.000019
EST	3.61	CYP	2.92	EST	1.01	LTU	0.010443	HRV	0.000018
CYP	3.07	EST	2.6	LTU	0.97	KHM	0.00999	KHM	0.000018
LTU	1.77	LTU	0.8	CYP	0.15	EST	0.009558	CYP	0
KHM	0.71	KHM	0.57	KHM	0.14	CYP	0.009185	EST	0
MLT	0.37	MLT	0.34	LVA	0.06	MLT	0.007717	MLT	0
LVA	0.1	LAO	0.04	MLT	0.03	LAO	0.004695	LAO	0
LAO	0.05	LVA	0.04	LAO	0.01	LVA	0.004679	LVA	0

(Source: authors, based on OECD ICIO).

Appendix no. 5: Vehicle linkages of selected countries in 2020 (table)

Weighted Degree		**Weighted In-degree**		**Weighted Out-degree**		**PageRank Centrality**		**Betweenness Centrality**	
CHN	597313.5675	CHN	303571.3536	CHN	293742.2139	JPN	0.025306	HUN	0.027056
JPN	350191.5213	JPN	166732.8456	JPN	183458.6757	THA	0.025218	JPN	0.026577
USA	269617.7729	USA	148395.1924	USA	121222.5806	HUN	0.024563	THA	0.01703
DEU	213646.9487	DEU	100105.6496	DEU	113541.299	NLD	0.024406	DEU	0.0162
KOR	112403.5938	KOR	51486.80186	KOR	60916.79197	USA	0.023955	KOR	0.015374
MEX	51386.09058	MEX	22356.48978	MEX	29029.6008	DEU	0.023546	GBR	0.014516
CAN	36495.62021	CAN	22218.33985	CZE	17427.46972	KOR	0.023472	ITA	0.012788
BRA	32343.21029	BRA	16740.31014	BRA	15602.90016	CAN	0.023407	USA	0.010588
ESP	31860.08978	ESP	16349.66981	ESP	15510.41997	CHN	0.023065	NLD	0.010418
CZE	31372.29939	SVK	14632.96984	CAN	14277.28036	RUS	0.022973	CHN	0.010187
SVK	25552.57971	CZE	13944.82967	SVK	10919.60987	GBR	0.022632	ESP	0.010116
GBR	23443.6997	RUS	13846.66019	GBR	10904.4599	ITA	0.022623	SWE	0.009556
RUS	20201.18038	GBR	12539.2398	POL	10691.71008	SWE	0.022614	CZE	0.008451
POL	19353.41013	THA	8726.350055	THA	10486.95012	CZE	0.022604	SVK	0.007241
THA	19213.30018	POL	8661.700053	FRA	10318.21995	AUT	0.022594	AUT	0.006599
FRA	18349.63988	FRA	8031.419926	ITA	8909.620127	POL	0.022594	POL	0.006599
ITA	15366.93016	HUN	6780.670062	HUN	8376.440045	FRA	0.022572	CAN	0.006504
HUN	15157.11011	ITA	6457.310029	RUS	6354.520192	BRA	0.022483	RUS	0.005448
SWE	12422.32998	SWE	6178.640007	SWE	6243.689976	ESP	0.022152	FRA	0.005283
ROU	10720.1302	VNM	5098.680094	ROU	5790.840111	BEL	0.022122	IND	0.004731
VNM	10316.3402	ROU	4929.290084	VNM	5217.660107	SVK	0.022019	VNM	0.004633
AUT	8940.319909	BEL	4520.639952	AUT	4733.799948	ROU	0.021509	ROU	0.004559
IDN	8075.699792	MYS	4348.409984	IDN	4231.949889	MEX	0.021307	PRT	0.004461
MYS	8061.329974	AUT	4206.519961	IND	3908.119997	PRT	0.020805	BEL	0.004379
BEL	7727.629941	NLD	4142.609927	MYS	3712.919991	SGP	0.020662	MEX	0.003598
NLD	7278.349849	IDN	3843.749903	BEL	3206.989989	AUS	0.020584	IDN	0.003064
PRT	6533.480108	PRT	3613.130078	NLD	3135.739921	VNM	0.020365	BRA	0.002967
IND	6101.739997	IND	2193.62	PRT	2920.35003	MYS	0.020219	SVN	0.001754
SVN	1828.349989	SVN	796.160002	SVN	1032.189987	IND	0.020131	FIN	0.001744
AUS	1054.470021	AUS	788.690016	AUS	265.780005	IDN	0.020023	AUS	0.001672
MMR	441.450006	MMR	242.600003	FIN	241.890003	FIN	0.019024	LTU	0.001166
FIN	410.860007	FIN	168.970004	PHL	235.539996	SVN	0.019017	BGR	0.001004
BGR	348.059999	BGR	159.819999	MMR	198.850003	BGR	0.017582	SGP	0.000999
PHL	263.849997	EST	121.610002	BGR	188.24	LTU	0.017566	MYS	0.000805
LTU	209.469997	LTU	105.839998	LTU	103.629999	MMR	0.017333	EST	0.000687
EST	190.620003	SGP	87.49	EST	69.010001	EST	0.017223	DNK	0.000133
SGP	131.76	DNK	46.140002	SGP	44.27	PHL	0.016325	PHL	0.000098
DNK	73.730002	HRV	34.03	IRL	32.26	DNK	0.016247	LVA	0.00005
HRV	43.26	PHL	28.31	DNK	27.59	HRV	0.014008	IRL	0.000033
IRL	35.42	LUX	20.92	LUX	13.08	GRC	0.013185	HRV	0.000015
LUX	34	KHM	4.51	LVA	9.86	LUX	0.013185	MMR	0
LVA	12.49	GRC	4.12	HRV	9.23	IRL	0.012217	GRC	0
KHM	8.86	IRL	3.16	KHM	4.35	LVA	0.009967	LUX	0
GRC	5.13	LVA	2.63	GRC	1.01	KHM	0.009645	KHM	0
LAO	2.04	LAO	1.78	CYP	0.4	LAO	0.00824	CYP	0
CYP	0.66	CYP	0.26	LAO	0.26	CYP	0.007155	LAO	0
MLT	0.17	MLT	0.15	MLT	0.02	MLT	0.005813	MLT	0

(Source: authors, based on OECD ICIO).