CHARLES UNIVERSITY

FACULTY OF SOCIAL SCIENCES

Institute of Economic Studies

Potential impacts of increasing Chinese dominance in the electric vehicle industry

Bachelor's thesis

Author: Jakub Čejchan

Study program: Economics and Finance

Supervisor: Ing. Vilém Semerák, M.A., Ph.D.

Year of defense: 2024

Declaration of Authorship

The author hereby declares that he or she compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain any other academic title.

The author grants to Charles University permission to reproduce and to distribute copies of this thesis in whole or in part and agrees with the thesis being used for study and scientific purposes.

Prague, April 29, 2024

Jakub Čejchan

Abstract

This thesis aims to measure the potential impacts of the Chinese electric vehicle expansion on the automotive industry of the European union. Firstly it introduces the industry of electric vehicles, its supply chain and the development on the global scene, specifically in China and Europe. The potential effects are further estimated using the Global extraction method as a modification of the original Hypothetical extraction method in the input-output framework. It simulates the scenario in which automotive industry, represented by the sector *Motor vehicles, trailers and semi-trailers*, of all member countries of the European Union are to be replaced by the Chinese automotive industry. This method was applied on the OECD inter-country input-output tables (ICIO) in combination with FIGARO tables provided by Eurostat. The results are then presented in the total output measures and additional component representing the value spent on employees, estimating the most affected sectors and countries in this area, connected with inter-sector linkages. Such estimations point out the industries and countries that could be endangered, in the case the transition to electric vehicles would result in Chinese dominance throughout the global automotive industry.

Keywords

Electric vehicles, motor vehicles, batteries, automotive industry, input-output analysis, Hypothetical extraction method, Global extraction method, supply chain, inter-industry linkages

Abstrakt

Cílem této práce je měření potenciálních dopadů Čínské expanze v elektromobilovém průmyslu na automobilový sektor Evropské Unie. Nejprve práce nastiňuje úvod do průmyslu elektromobilů, jeho dodavatelský řetěze a situaci v globálním měřítku, především pak v Číně a Evropské Unii. Tyto dopady jsou poté odhadovaní pomocí metody globální extrakce, jež je modifikací původní metody hypotetické extrakce, v rámci input-output analýzi. Práce simuluje hypotetický scénář, ve kterém jsou automobilové průmysly všech členských zemí Evropské Unie nahrazeny průmyslem Čínským. K tomuto výzkumu je využita mezistátní input-output databáze OECD ICIO, následně doplněna o další položky z databáze FIGARO spravovanou Eurostatem. Výsledné dopady tohoto výzkumu jsou následně prezentovány skrz celkový výstup jednotlivých sektorů a ekonomik, společně s položkou prezentující kompenzovanou složkou výdajů za zaměstnance. Odhady získané v této práci vyzdvihnou jednotlivé sektory a země, které by mohli být ohrožené v případě, že by přechod elektromobilů měl za náslědek dominance Číny v celosvětovém automobilovém průmyslu.

Klíčová slova

Elektromobily, motorová vozidla, baterie, automobilový průmysl, input-output analýza, metoda hypotetické extrakce, metoda globální extrakce, dodavatelský řetězec, mezisektorové vazby

Acknowledgments

I would like to express my sincere gratitude to the supervisor of this thesis, Ing. Vilém Semerák, M.A. Ph.D., for his time, guidance and support as well as provision of useful advises and literature, throughout writing this thesis.

Contents

List of Abbreviations

AC	Alternating current
BEV	Battery electric vehicle
CRM	Critical raw material
DRC	Democratic Republic of the Congo
EEA	European Environment Agency
EU	European Union
EV	Electric vehicle
FCEV	Fuel cell electric vehicle
FIGARO	Full international and global accounts for research in input-output analysis
GDP	Gross domestic product
GEM	Global extraction method
GHG	Greenhouse gases
GNI	Gross national income
GNP	Gross national product
HEM	Hypothetical extraction method
HEV	Hybrid electric vehicle
ICE	Internal combustion engine
ICIO	Inter-Country Input-Output Tables
LCA	Life-cycle analysis
LIB	Lithium-ion battery
NEV	New-energy vehicle
OECD	Organisation for Economic Co-operation and Development
PHEV	Plug-in hybrid electric vehicle
US	United States
WIOD	World Input-Output Database

Chapter 1

Introduction

For past decades, automotive industry has become one of the key sectors in the world and its development might be decisive for the future of this planet. Europe, together with the United States, Japan or South Korea, has been indisputably among the biggest producers in the world, and moreover, Europe is the largest private investor in research and development of the industry (European Commission, 2022). The importance of the industry itself is multidimensional. The automotive industry has inter-industry linkages throughout the European economy with close connections to industries such as steel, information and communication technology or mobility services. Furthermore, it employs, either directly or indirectly, nearly 14 million inhabitants in the European Union and represents over 7% of the EU GDP, according to European Commission (2022).

What might become the biggest turning point for the modern automotive industry is the rise of electric vehicles (EVs). The invention of electrically powered vehicles has been the trend of latest years, which is supported by the figure 1.1, where EV car sales as a percentage of total car sales are presented. We can see that EV market share rose twenty fold to total of 14% between years 2015 and 2022. The electric vehicle market is arguably new battlefield to compete in and it can determine the future leader starting new era of automotive industry as a whole. One might expect the great powers of the industry to remain the dominant position, but as it appears, we will and have already seen relatively new player and that is China. China, being the number one dominating both manufacturing and sales of electric vehicles, had a great head-start in the area of electric vehicles supported by substantial amount of subsidies provided by

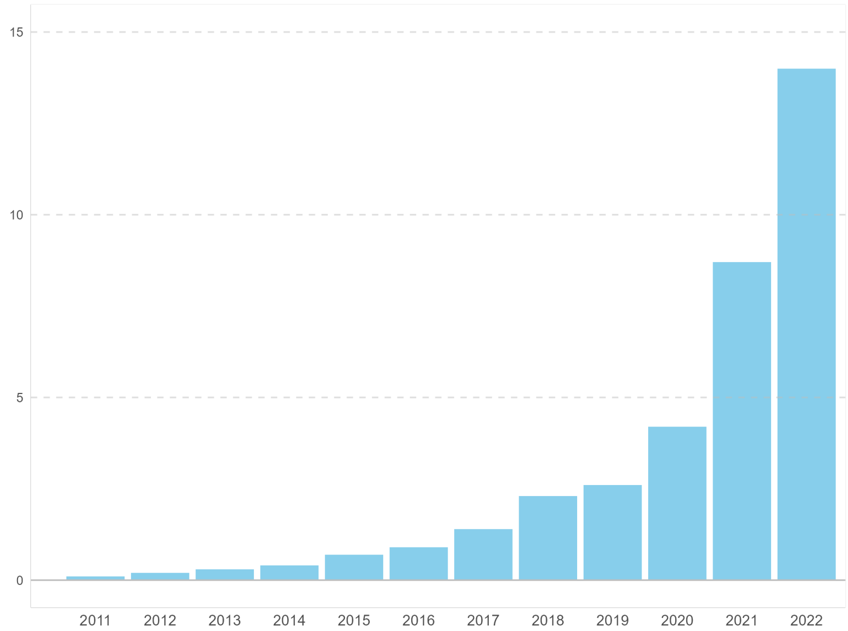

Figure 1.1: EV market share on total cars sold as percentage

Source: IEA

the government. In 2023 China even surpassed Japan and Germany to be the worlds largest exporter of automobiles as it exported 4.91 million vehicles, out of which 1.2 million were new-energy vehicles (Xijia, 2024). This presents a massive challenge to not only the European automotive giants, but even to the entire European economy.

The significance of growing electric vehicle sales together with the ongoing Chinese advancement in the industry leads us to the aim of this thesis, as it will try to measure the potential effects on the automotive industry in the Europe, caused by the Chinese expansion. Formally, the research question is defined as follows:

- *Which European countries would be the most affected by the Chinese expansion in the electric vehicle, respectively automotive industry, in the total output and employment measures?*

To analyse these effects, the thesis will use the input-output framework. As this framework might not be certainly clear to all of the readers, the thesis provide introduction in such framework by following the textbook *Input-Output Analysis - Foundations and Extensions* by Miller & Blair (2009). This textbook explains the functioning, linkages, calculus and application of input-output analysis in great details with multiple examples provided and for this reason it will be used. Input-output framework is used to analyse how the industries in an economy are dependent on each other. This analysis is based on generally observed data for specific region, which could be nation, country or even the whole world. These data are mostly the input-output tables, which, as described in Chapter 4, contain multiple sectors, for instance *Manufacturing*, *Wholesales and Trade* or *Motor vehicle industry*. These tables use fixed relations between the industries that express the inputs and outputs delivered or used, as well as final demands to the costumers, and other components. Using these tables, one can simulate a scenario in which the effects of change in functioning of one sector on other industries can be analysed.

One of the methods used to analyse such change is called the Hypothetical extraction method (HEM) firstly introduced by Paelinck *et al.* (1965). This method takes into account such scenario in which one industry is completely extracted from an economy, as the name suggests. By doing so, it is further possible to quantify the impact of this extraction on other industries. This method, however, has one critical assumption, in which the extracted sector is replaced by "outside the system" foreign imports. This is not suitable for this thesis as the aim is to quantify the effects on the global scene, where we cannot account for "outside the system" subjects. For this reason, the modified version called the Global extraction method (GEM) introduced by Dietzenbacher *et al.* (2019) had to be used. In GEM the assumption is changed in a manner that the extracted industry is replaced by a sector or multiple sectors already included in the system. For the both methods it holds that the total world's GDP remains unchanged, yet in contrary to the HEM, the GEM can calculate the effects in the foreign countries together with the country, in which the sector was extracted.

This thesis then simulates the scenario in which Chinese electric vehicle expansion will lead to such extend that it would replace the whole automotive industry of the European Union, replacing even giant such as Germany. It would not be possible to simulate such scenario without corresponding data. For this reason, the OECD inter-country input-output tables will be used, as they contain sufficient amount of real-world data recorded for 76 different countries further divided into 45 sectors.

The structure of this thesis is following. In the Chapter 2 the introduction of the electric vehicles will be provided. This contains the functioning of EVs, supply chain of the electric batteries as its main value-holding component and brief overlap to the environmental discussion. In the successive Chapter 3, the reader will be introduced to the global situation of the market in China, Europe and America. The literature review will be presented in the Chapter 4. This will be divided into two parts, with the first one summarizing the literature connected to the issues similar to the topic of this thesis and the second one familiarizing reader with the input-output framework and calculus further used in the research. In the Chapter 5 the hypothetical and global extraction methods are introduced alongside the description of the input-output tables used and other alternatives, which could possibly be used for the research. Finally, the Chapter 6 presents the model application and discusses the results estimations obtained, followed by conclusion, contribution and suggestions for the future research summarized in the chapter Chapter 7.

Chapter 2

Electric vehicles and their supply chain

In this chapter we will shortly introduce the functioning of the electric vehicles as well as further examining the supply chain, mostly focused on the electric vehicle batteries. In the end, brief addressing of environmental concerns connected to the EVs will be presented.

2.1 Electric vehicles

An electric vehicle is a vehicle that uses one or more electric motors for propulsion. In contrast with fuel-powered vehicles, purely electric vehicles do not require regular internal combustion engines to operate. The key parts of the electric car are traction battery pack, electric powertrain, electric traction motor, inverter, and charge port (U.S. Department of Energy, 2012).

- The whole high voltage electrical system that powers an electric car is referred to as its powertrain. The inverter, electric traction motor, reduction drive, and traction battery are all standard components of an electric powertrain.

- The primary purpose of the most significant component, traction battery pack, in an electric car is to store energy while the vehicle is being charged. The motor and all other electrical parts of the car are then powered by this energy.

- The electric traction motor uses power gained from the traction battery pack and drives the vehicle's wheels. The most common EV motors need AC power energy.

- Because batteries mostly accept only DC power, this power needs to be changed to AC and that is the function of the inverter. AC/DC inverter changes the battery pack's flow of electrons from DC to AC and transfers it to the electric traction motor. This makes inverters necessary components for EVs.
- Lastly, the charge port enables electric vehicle to be charged from external power source, such as charging station. (U.S. Department of Energy, 2012)

Currently, there are 4 types of electric vehicles. Battery electric vehicles (BEVs), also known as all-electric vehicles, use battery-powered electric drive train that powers them completely, so that BEVs do not require any kind of liquid fuel. The electricity necessary to drive such vehicle is stored in a rechargeable battery pack.

Hybrid electric vehicles (HEVs) combine both conventional internal combustion engine and an electric motor. The engine gets energy from fuel, whereas the motor gets the electricity from battery. The electric motor is used to achieve higher fuel efficiency; however, such vehicle cannot be plugged in for battery charging.

Plug-in Hybrid Electric Vehicles (PHEVs) as well as hybrids have both the engine and the motor. The difference is that the battery pack is rechargeable, making PHEVs more energetically efficient in comparison to HEVs.

Last type is called Fuel Cell Electric Vehicles (FCEVs), also referred to as Zero-emission vehicles, since majority of such vehicles emit only water and heat. These vehicles employ fuel cell technology to generate required electricity using oxygen from the air and compressed hydrogen (Sanguesa *et al.*, 2021).

2.2 Supply chain of electric vehicle batteries

The term supply chain refers to the process through lifetime of a product, from its creation to the delivery to the consumer. The most significant and decisive part of the EV supply chain is the key component of the electric vehicle, the battery, that on average represents around one third of the total value (König *et al.*, 2021). There are different types of batteries used in electric vehicles:

- Because lithium-ion batteries (LIBs) offer the highest energy densities of any battery on the market, almost all electric vehicles now use them in their traction battery packs. The characteristics of lithium-ion-battery are its high energy per unit mass, high power-to-weigh ration, high energy efficiency, long life, good high-temperature performance, and low self-discharge.
- Nickel-metal hydride batteries provide a respectable level of particular energy and power. In contrast to its lead-acid counterpart, they have much longer life cycle and are abuse-tolerant. The main challenges with this type of batteries are high costs and heat generation at high temperatures.
- Lead-acid batteries represent the oldest and cheapest variant out of the three. This type of battery, however, displays low specific energy, poor cold-temperature performance, and short lifecycle. (U.S. Department of energy, 2012)

In order to analyze the supply chain, we need to define the upstream, midstream and downstream industries involved. The upstream part of the supply chain contains mostly mining and extraction of the raw materials for the battery production. These materials include typically lithium, cobalt, manganese, nickel and graphite. The majority of the mining is held in a small number of large businesses in the area of handful of resource-rich nations like Democratic Republic of the Congo, where significant part of the cobalt is located, or Australia with its large lithium concentration. What is important to mention is that more than a half of the cobalt mining companies in the DRC are Chinese-owned (Farchy & Warren, 2018). For the other key materials the situation is similar.

After the material extraction, these materials are sent to processing and refining factories, where they are assembled into battery cells. This phase is referred to as midstream. Processing part cleans the minerals from the excess materials unneeded for the production. During the refining phase, materials undergo processing to make them suitable for inclusion in electric batteries. The midstream portion is dominated by Asia, especially China. According to the IEA (2022), China itself currently hosts 75% of all battery cell manufacturing capacity, and moreover it captures up to 70% of production capacity for cathodes and 85% for anodes, both key for battery assembly. After China, South Korea and Japan are second and third top battery manufacturers respectively.

However, in comparison with China, they are responsible for significantly lower portion.

The downstream portion of the supply chain consist of the assemble of the battery cells into modules which are then placed into battery packs. These batteries together with other components are then sent to automakers who followingly use them into the final EV assembly. Again, global battery manufacturing is dominated by the same Asian countries, accounting for about 70% of the market in 2021, with China being on top of the list one more time. As of companies, Chinese CATL was number one in 2021, with 33 percent market share, followed by Korean's LG (22 percent) and Japanese Panasonic (15 percent) as presented by Carreon (2023).

Additionally, the end-life phase of the battery can be taken into account as part of the chain, as after batteries are no longer able to serve their original purposes, they can be reused or recycled.

Yet all of the phases differ, they have one thing in common. Europe is missing to be significant part of the supply chain.

2.3 Environmental concerns

The most discussed topic connected to the environmental impacts of electric vehicles is that electric vehicles might become beneficial in the area of emission of greenhouse gases (GHGs). In this case, there is a trade-off that has to be evaluated. It can be agreed that electric vehicles do not contribute to greenhouse gas emissions, however, after production EVs, in comparison with ICE vehicles, have higher initial carbon footprint caused by energy-intensive battery manufacturing.

On average, EVs in operation catch up with an ICE vehicle to achieve "carbon parity" after about one year. Nevertheless, this period is clinically dependent on the way the electricity is obtained. This is evaluated in the study of Hawkins *et al.* (2013), with results that EV production is more environmentally intensive, yet with no emissions in use-phase, improvements with regard to global warming or terrestrial acidification could be achieved. Although, the electrification of transportation is counterproductive in regions, where electricity is produced from for instance oil or coal, as the period of catching up extends (Hawkins *et al.*, 2013).

Another, more recent, paper created by Küfeoğlu & Khah Kok Hong (2020), discussed the emissions performance of electric vehicles in the United Kingdom.

The key findings relevant for this section were that transfer to electric vehicles would result in the reduction of the GHG emission level. The pace of the reduction differs between transfer to the BEVs and PHEVs, with BEVs adoption decreasing the emissions occurred more significantly, meaning that hybrid electric cars should not ultimately be the final-end products, rather they should serve as a transition to BEVs (Küfeoğlu & Khah Kok Hong, 2020).

On the other hand, different question arising is the end-life phase of the electric batteries, specifically whether to reuse or to recycle. This area was deeply discussed in the paper by Kotak *et al.* (2021). This study highlighted the need for in-depth analyses for evaluation of the effects, occurring with each possibility considering multiple variables involving market prices, recyclability and economic sustainablity. Kotak *et al.* furthermore mentioned existence of variety of recycling processes in order to maximize material recovery, second-life applications, and detailed cost and life-cycle analysis (LCA) that is essential in assessing the reuse applications. Examples of potential second-life applications include the generation and delivery of electricity, as well as user-level applications such as transportation, energy management or power quality. The conclusion of the paper is that the battery reusing strategy can bring benefits not only in the second life applications, but also in the process of the remanufacturing. Recycling has advantages in an aspect of restoring the crucial rare materials which are supported by both ecological and economical gains. Although Kotak *et al.* argue that combining the two would be the best course of action for creating a sustainable battery end-life process, the LCA study concluded that, based on the current availability of relevant literature, forming a general approach is so far not feasible (Kotak *et al.*, 2021).

Chapter 3

Global situation

3.1 China

On the electric vehicle scene, the undisputed leader is China. Since 2015, China had regularly ranked the top of the EV sales reaching 7.22 million units in 2022, accounting for over 63% of global EV sales according to Zhou *et al.* (2023).

Furthermore, in 2021 China turned for the first time in this century from being net auto importer to being net auto exporter and since middle of 2022, the vehicle imports has been successively outperformed by the exports. Electric vehicles play significant part in this shift. Even though they only represent about one third of the total Chinese automotive exports, the value contributes to more than a half of the total automotive exports (Mazzocco & Gregor, 2023).

The massive expansion of the sector was, however, not out of blue, yet caused by sophisticated strategies of the Chinese policymakers, which are further discussed in the following subsection.

3.1.1 Chinese electric vehicle policies

Chinese government played a key role in the development of the dominant Chinese electric vehicle industry. This development was significantly driven by the governmental subsidies for the technological innovation, energy efficiency and later by both consumer and producer subsidies including for instance a 50% reduction in vehicle purchase tax (Lo *et al.*, 2021).

In 1980's the governmental concerns that Chinese automotive industry is behind and relies mostly on foreign companies led to implementation of localization policies that required foreign auto manufacturers to create joint ventures with local partners, yet the Chinese companies still remained to lag in performance. After realising that the breakthrough is unlikely to happen in the market of regular internal combustion engine vehicles, the governmental point of interest shifted to the electric and other new energy vehicles (The European Commission, 2024). Starting in 2009, the Ministry of Science and Technology introduced series of policies aiming at the development of the national EV industry. These policies were officially projected in the context of *"The 12th Five-Year Plan"*, namely in the document *"New Energy Vehicle Industry Development Plan (2012-2020)"*[1] issued in 2012, consisting of the three-step strategy.[2]

The first phase, which was already underway at the time the document was issued lasting from 2009 to 2012, started with urban pilot programs in major cities, mainly concentrating on BEVs, PHEVs and FCEVs. The majority of the subsidies went towards public transportation; however, they fell short of what the market anticipated. In the national project *"Ten Cities and Thousands of EVs"*, 25 pilot cities, including Beijing and Shanghai, were selected to progressively begin the industrialization and commercialization of EVs countrywide. The first phase set the foundation for the policy framework and technological advancement of the electric vehicle industry, despite achieving only one-third of the original goals (Wu *et al.*, 2021).

The EV market showed a sharp growth in the second phase, starting in 2013, with financial subsidies at both the private and the public level transportation. During the stage, EV adoption occurred at comparable prices to conventional vehicles. In collaboration with the Ministry of Science and Technology, Ministry of Finance and National Development of Reform Commission, issued the central government financial subsidy policies to 88 cities, resulting in an increase of the high-end EV models' technical performance and infrastructure. Yet issues, such as adverse selection or moral hazard emerged, throughout the second phase, forcing the national government to introduce stricter rules to subsidies Wu *et al.* (2021).

From 2016 to 2020, phase three of the electric vehicle industry promotion was launched with its main goal to extend beyond the pilot cities into the entire country. Concurrently, the subsidies were gradually tightened, whereas the technical entry barriers for EV industry enlarged. Initiatives were put in place to support energy-efficiency, technological innovation, and sustainable development. In 2017, commercial vehicle subsidies were reduced by 40-60%

[1] We refer to this plan as *"NEV Plna 2012-2020"* further in the text.
[2] This plan can be attained at: https://www.gov.cn/.

and for passenger vehicles by around 20%. In 2019 the decline in the financial subsidies was about 50%, with cancellation of the supplementary compensation at the same time. Technical indicators sustained to be refined and tightened to encourage up technological upgrade in EV industry (Wu *et al.*, 2021).

The *"New Energy Vehicle Industry Development Plan"* has also set the specific objectives that were to be met. This, besides others, include that by 2015, the production and sales of BEVs and PHEVs should exceed or at least reach 500 000 units; and by 2020 the production should have reached 2 million units and the sum of sales and production 5 million units. The requirement target in 2020 was, however, not met as the production was about 1.3 million units and the sum together was less than 3 million (CAAM, 2020)[3].

The electric vehicle development is further mentioned and supported in the following *"The 13th Five-Year Plan"* and *"The 14th Five-Year Plan"* including actions such as the promotion of the NEV usage, strengthening the efforts in the afterlife of the batteries from NEVs or making breakthrough in key technologies with further acceleration in the area of research and development (R&D). Finally, it introduced the follow-up *"NEV Plan (2021-2035)"*. The objectives are quite similar to the previous plan, including high-quality development of the NEV industry, supply-side structural reform, support of eco-oriented companies, promotion of battery value chain innovations and also set new targets, such as NEVs reaching 20% of the sale volume of new vehicles (International Council on Clean Transportation, 2021).

In addition to the *"NEV Plan (2012-2020)"*, China unveiled its 10-year *"Made in China 2025"* action plan in 2015 as a part of the *"13th Five-Year Plan"*, with the goal of modernizing production networks in key industries by promoting Chinese brands, expanding the service sector, and shifting to higher value-added manufacturing by 2025 (Yeung, 2019).

This action plan consists of three step strategy. In the first step, China should aim to become major manufacturing power in these industries by 2025. Right after the second step would be implemented, reaching intermediate level among world manufacturing powers by 2023 and in the last step, it wants to lead the global manufacturing sector by the year 2049 (The European Commission, 2024).

In accordance with the Ministry of Industry and Information Technology (MIIT), domestic suppliers were expected to secure 80% of the domestic market for electric vehicle batteries and electric motors by 2020, while domestic automakers

[3]CAAM refers to China Association of Automobile Manufacturers.

should have been aiming to rank among the top 10 models by 2020 and should be among the top 10 NEV-makers by 2025 (Yeung, 2019).

3.1.2 Domestic Market

The first leaders in Chinese EV market were surprisingly not companies owned by the state. In 2022 the global largest EV manufacturer was private company BYD, standing for "Build Your Dreams". According to the CPAC[4] statistics presented by Zhang (2024) BYD secured 35% market share on the domestic market with about 2.7 million new energy vehicles (NEV) produced. The second on the list was the United States giant, Tesla, accounting for 7.8% market share with 600 thousand units. Tesla, however, aims to capture substantial market share in China, as it established its "gigafactory" in Shanghai in 2019, as the first factory in China fully owned by a foreign company (Han *et al.*, 2023).

On the third, fourth and fifth place in the CPCA list stand GAC Aion, Geely, and joint venture of largest state owned car manufacturer SAIC Motor Corporation, with General Motors and Wuling, respectively. All of the above mentioned claimed above 6% market share with 450 to 480 thousands NEV sold. The total list is summarized in the Table 3.1.

Table 3.1: NEV retail sales in China (2023)

	Name	Units
1	BYD	2 706 075
2	TESLA	603 664
3	GAC Aion	483 632
4	Geely	469 427
5	SAIC-GM-Wuling	457 848
6	Changan	384 915
7	Li Auto	376 030
8	Great Wall	236 856
9	NIO	160 038
10	Leapmotor	144 155

Source: CPCA.

Widening the list for the whole passenger car retail sales in China in 2023, BYD retained its first position, followed by joint venture of FAW with Volkswagen, Geely, Changan and another Volkswagen joint venture, this time with SAIC. The whole list is summarized in the Table 3.2. As we can see, comparing

[4]CPCA refers to Chinese Passenger Car Association

the 2 tables presented, electric vehicles play a significant role in the Chinese industry as they represent more than 30% of all passenger cars sold.

Table 3.2: Passenger car retail sales in China (2023)

	Name	Units
1	BYD	2 706 075
2	FAW-Volkswagen	1 846 617
3	Geely	1 412 415
4	Changan	1 372 199
5	SAIC-Volkswagen	1 231 433
6	GAC Toyota	901 027
7	SAIC-GM	870 011
8	Chery	811 230
9	FAW Toyota	802 095
10	Great Wall	760 091

Source: CPCA.

According to the government statistics presented by Klein (2023) obtained at Chinese General Administration of Customs, trade balance in finished vehicles of China went from importing 40 billion dollars worth of vehicles in 2021 to an export surplus of over 30 billion in 2023. The change of this magnitude is rather unusual, so one might ask, what stands behind that. In China, there has been a massive production growth, as there was 7 058 000 NEVs produced in 2022, meaning 99% increase compared to previous year (The European Commission, 2024). Years before, there had been a massive demand for vehicles in China, but recently, as Chinese auto-manufacturing grew faster than the demand, the majority of the demand was satisfied, resulting in overcapacity of NEVs. Moreover, government appears to support this overcapacity in order to encourage producers to expand overseas and export NEVs (The European Commission, 2024).

3.2 Europe

The automotive sector in Europe is one of the sectors with the biggest importance. Supporting the previous statement in numbers, according to European Commission (2022), the automotive sector employs nearly 14 million Europeans either directly or indirectly, making it more than 6% of the total EU employment. Moreover, automotive industry contributes to over 7% of the EU GDP (European Commission, 2022). Taking these numbers into account, it shall not surprise us that Chinese lead in the electric vehicle industry could potentially cause disruptions in the whole European economy.

As there is a significant trend in the global EV manufacturing over the last decade, number of electric vehicles manufactured is growing in Europe every year. According to preliminary data provided by EEA (2023), electric car registrations made up to 21% share of total new vehicle registrations in 2022, which in comparison made only less 2% in 2017. However, this number differs significantly across different countries. Scandinavian countries secured massive percentages, with leading Norway approaching nearly 90% and Sweden almost 60%. On the other hand, the NEV registrations in central European countries, such as Czechia, Slovakia or Poland, accounted for only 3-5%.

In production, Europe, as well as other regions, is left behind when compared to China. While with regular internal combustion engines vehicles, Europe has had a long history of success, in terms of electric battery supply chain, no EU companies are among the leading producers, nor leading in the direction of technology development.

3.2.1 Chinese position on the EU EV market

Europe has the second-highest demand for electric vehicles, after China itself, therefore it is rational for China to focus its EV exports especially on Europe. Besides the low tariff rates, the reasons behind this are generous purchasing subsidies and aside from China, the most advanced charging infrastructure, with Norway serving as a bridgehead (Gregor & Chimits, 2022). According to statistics published on China Association of Automobile Manufacturers (2021) concerning Chinese automobile exports, in 2021 China's global EV exports more than doubled to approximately 550 thousand units. Around 40% of this was absorbed by Europe, where Chinese made EVs already account for 10% of overall EV sales. The countries that imported the most new energy vehicles from China were Belgium, United Kingdom, Germany and France. Importantly for Europe, Chinese EV exports to the EU have mainly increased not because the cars are better, but because European and American automakers are shifting production of EVs to China, including those for the European market. Foreign carmakers continue to dominate Chinese EV exports, with Tesla accounting for 49 % of 2021 shipments, European joint ventures and Chinese-owned European brands accounting for another 49 %, and "purely" Chinese brands accounting for only 2 % (Gregor & Chimits, 2022).

This production shift could turn the whole SINO-EU[5] automotive trade upside down, giving China comparative advantage, as this trend is about to continue with more and more leading European automotive companies announcing its production shifts to China.

However, Europe is aware of the gap between the European and Chinese level of development in the industry and, as the whole automotive industry is endangered, the Europe has started to react. In the end of the year 2023, European Commission (2023) announced their official investigation into Chinese policies, or subsidies respectively, with the aim to determine illegal subsidisation in the battery electric vehicle value chains. The announcement was made by the president of the European Commission, Ursula von der Leyen, who said in her speech that: *"Global markets are now flooded with cheaper electric cars. And their price is kept artificially low by huge state subsidies"*, after which she continued: *"The electric vehicle sector holds huge potential for Europe's future competitiveness and green industrial leadership. EU car manufacturers and related sectors are already investing and innovating to fully develop this potential. Wherever we find evidence that their efforts are being impeded by market distortions and unfair competition, we will act decisively."*.

3.3 America

Even though this thesis is mainly focused on the relationship between the Chinese and European industries, it is generally convenient to provide a brief insight into the situation in the United States, as it belongs to the greatest and most important economies of the world.

The trend of electric vehicles in the U.S., similarly to China and Europe, is experiencing a rapid growth, yet, in comparison with the two it has been so far relatively stagnant. In 2022, out of 281 million car registration only 1.2%, that is about 3.5 million, were BEVs or PHEVs.[6]

The analysts point multiple reasons behind the slow growth of the industry. There is an insufficient charging infrastructure, lack of affordable options, but mainly missing out in the battery supply chain. According to IEA (2022) the share of global EV battery production capacity was, similarly to Europe, only 7% in the United States. In comparison, China secured massive 76% of

[5]SINO-EU term refers to the bilateral relationship between the EU and the People's republic of China

[6]Statistics provided by U.S. Department of Energy (2022)

the share. Even though, United States claimed the third highest share in the world, they are nowhere near the Chinese production.

If one debates about electric vehicles in America, the electric vehicle giant Tesla should not be forgotten. Tesla under Elon Musk played one of the key factors in the electric vehicle promotion with its courageous and unlikely growth in the automotive industry. What Tesla demonstrated against all the odds was the ability to create an electric vehicle that buyers value and want to buy. Naturally, Tesla has not yet created a car for every social class, but it has brought the possibility of the future with EVs to the public community (Barkenbus, 2020).

Tesla is producing only BEVs and, speaking about volume, it remains at the top of producing companies, competing mostly with BYD, as mentioned in the previous sections. In 2022 tesla manufactured more than 1 300 000 units, making it the second highest EV producer and highest BEV producer.[7]

[7]Statistics provided by Irle (2023) through EV Volumes.

Chapter 4

Literature Review

This section provides the relevant literature review for this thesis. It is divided into two parts, the first covers the studies that are connected to the topic of the electric vehicles in not only the Sino-EU relationship. The second introduces the basics of input-output analysis later used in the research.

4.1 Previous studies connected to the topic

As the electric vehicle revolution is arguably very recent topic, there are not many studies covering the same or similar issues as this paper does. Majority of the studies concerning electric vehicles are related to the efficiency and ecological questions, rather than the actual market insights. For this reason, only a handful of relevant studies fit the literature review for this thesis.

Schmid (2020) discussed the topic of challenges to the European automotive industry in securing critical raw materials for electric mobility. In the study he identified critical raw materials (CRMs), such as cobalt, lithium, graphite, nickel, and manganese, as a subject of high dependence in value creation of EVs. China has become the dominant producer of these materials with strong position in production of most of above mentioned. This market dominance can also be used in politics, as seemed during the trade dispute between China and the US in 2019, where China threatened to restrict exports of such raw materials. Consequently, this dependence adds significant risks to European businesses as the automotive sector grows to be one of the largest consumers of some of the most important raw materials in their transition to an all-electric future. The results of Schmid's study emphasized that, the European automotive industry is significantly behind in the supply chain of the CRMs, and in comparison with China, underestimated the importance of those materials on the future development in the industry. Even though the awareness of the cruciality among the automakers increased, the challenges of implementing specific critical raw material strategy are providing to be difficult. There is a lack of ability or willingness to invest in the rare earth elements supply outside the China as well as avoiding involving in the mining by European companies (Schmid, 2020).

Jetin (2020), on the other hand, dealt with what the global market for electric vehicles now looks like and what will the future bring. In his paper *Who will control the vehicle market?* Jetin discussed the background of revolution of the automotive sector, similarly to what the sections 2 and 3 cover, as well as importance of electric batteries, mostly the LIBs and its dependence on the raw materials. Furthermore, he identified the key aspects mandatory for the successful engagement in the global electric vehicle market. Jetin mentions that only countries that have adopted comprehensive policies to ensure access to critical metals and develop local battery-making have a chance to play a leading role in the electric vehicle market. In conclusion, called *"The one who conquers batteries will conquer the electrification of cars."*[1] Jetin identifies China as the only country ready to face the new age of electric cars, as they secured the dominant position in the mining and processing of critical materials. However, they are lacking in the direction of having global brands that could excess the success abroad. On the other site, Europe and the USA have widely renowned car brands across the world, yet they are lacking in the innovation of batteries and in the area of accessing the critical raw materials. In the end, Jetin argues, that if the trend of Chinese progress in the battery manufacturing will remain, China will be a likely candidate to conquer the electric vehicle industry (Jetin, 2020).

The study by Waas *et al.* (2023) discussed the evolving threats for European automotive industry in the future. Besides other, one of the threats Waas *et al.* identified is that European automakers traditionally benefited from the sales on Chinese market. As the sector is lately endangered, they introduced three possible future scenarios, namely "Gradual decline", "Maintaining pace" and "Securing the lead". For this thesis, the outcomes of the least feasible "Gradual decline" scenario are relevant, as it according to authors simulate the situation in which European forfeit their market share on the global scene especially to

[1] Toyota Executive Vice President Shigeki Terashi, quoted in Tanaka, Kawakami, & Omoto, 2018

China and the United States. The end results of their research were such that European automotive sector would lose 1.5 million jobs, 35% drop in the GDP, 36% decrease in payroll and corporate taxes and further 51% loss in equity value (Waas *et al.*, 2023).

4.2 Input-output framework

In this section, the insights into input-output framework are introduced. For the vast majority of it, the source used was the great textbook by Miller & Blair (2009) that explains the input-output analysis in the great detail, thus if one is interested in better understanding of such framework, please refer to the original book.

4.2.1 Introduction and fundamental understandings

The structure of input-output system contains a set of n linear equations with n unknowns, thus matrix representation is convenient. The input-output model is based on the real observed data for specific area, such as a nation, a region, a state or even the whole world. The area for which input-output tables are created must, however, be able to be separated into different producing sectors. These are usually viewed as industries and can be of different sizes, depending on the construction of such tables. For instance, some frameworks might include transportation as one of the sectors, others could use more specific ones such as motor vehicles or air transport. The crucial data for this framework are flows of the products from one sector to another, referred to as *interindustry* flows or transactions[2] (Miller & Blair, 2009).

For now let us assume that the selected are is a country with n industries and let i and j refer to different sectors. If z_{ij} is a transaction from sector i to sector j, then z_{ij} is associated with the input that sector j needs in order to generate its own product. For example, demand for wheat in the agricultural industry will be related to the amount of bread, produced. Furthermore, industries, in addition to supplying products to other industries, produce good for external consumption. This endogenous consumption is known as *final demand* and consists of subjects such as households, government, or foreign trade. Let x_i

[2]Sometimes we might encounter the term *intersectoral*, which refers to the same thing as terms sector and industry are in the input-output framework often used interchangeably.

denote the total production (output) of sector i and f_i represents total final demand of sector i, then we can write the following equation:

$$x_i = z_{i1} + ... + z_{ij} + ... + z_{in} + f_i = \sum_{j=1}^{n} z_{ij} + f_i \tag{4.1}$$

where z_{ij} terms are *interindustry* sales from sector i to all sectors j, including the sector i itself. The previous equation (4.1) can be rewritten for all n industries, so that we have following system of n linear equations:

$$\begin{aligned} x_1 &= z_{11} + ... + z_{1j} + ... + z_{1n} + f_1 \\ &\vdots \\ x_i &= z_{i1} + ... + z_{ij} + ... + z_{in} + f_i \\ &\vdots \\ x_n &= z_{n1} + ... + z_{nj} + ... + z_{nn} + f_n \end{aligned} \tag{4.2}$$

Furthermore, letting:

$$\mathbf{x} = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}, \quad \mathbf{Z} = \begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{bmatrix}, \quad \text{and} \quad \mathbf{f} = \begin{bmatrix} f_1 \\ \vdots \\ f_n \end{bmatrix} \tag{4.3}$$

where $\mathbf{x}$ represents *total output*, $\mathbf{Z}$ represents *transaction matrix* and $\mathbf{f}$ represents *total final demand* in the system.[3]
Now, setting $\mathbf{i}$ as the representation of column vector of 1's of n-dimension, by setting $\mathbf{Zi}$, we can obtain column vector consisting of summations of the transaction matrix by rows. Thanks to this ability is vector $\mathbf{i}$ usually referred to as *summation vector* (Miller & Blair, 2009).

Similarly, we can use row vector **i'** to obtain row vector with sums of columns as its elements. Using this notation, the data in (4.2) regarding the sales distribution for each sector may be represented in matrix notation as

$$\mathbf{x} = \mathbf{Zi} + \mathbf{f}. \tag{4.4}$$

In table 4.1 the summarized scheme of inderindustry flows of goods in input-

[3]Please note that here, and throughout this paper, the following notation is used: Lower-case bold letters represent vectors ($\mathbf{x}$ or $\mathbf{f}$) and upper-case bold letters represent matrices ($\mathbf{Z}$)

output table is presented. To understand the idea clearly, for instance the first column represents purchases (inputs) of the first industry from all other n industries. Similarly, the elements of the first row represent sales (outputs) from the first industry to all other industries.

Table 4.1: Input-Output Interindustry Flows of Goods

		Buying Sector				
		1	$\cdots$	j	$\cdots$	n
	1	z_{11}	$\cdots$	z_{1j}	$\cdots$	z_{1n}
Selling	$\vdots$	$\vdots$		$\vdots$		$\vdots$
	i	z_{i1}	$\cdots$	z_{ij}	$\cdots$	z_{in}
Sector	$\vdots$	$\vdots$		$\vdots$		$\vdots$
	n	z_{n1}	$\cdots$	z_{nj}	$\cdots$	z_{nn}

Source: Miller & Blair (2009)

4.2.2 Transactions and National accounts

Table of transaction flows 4.1 contributes only one part of the whole economy's income and product accounts. To highlight the additional components of a complete set of accounts, Miller & Blair consider a two-sector economy. In the table 4.2, an expanded flow table for this basic economy is presented. The components of the final demand vector for sectors 1 and 2 corresponds to consumer purchases, purchases for private investments, government purchases and exports. These are further divided in two groups of *domestic final demand*, where $C + I + G$ belongs and *foreign final demand* with the remaining exports E as its part.

The elements of the payments sector are payments for labor services (l_1 and l_2) and for other value-added items (taxes, interest payments for capital, rental, profit and so on). These other value-added components can be denoted as n_1 and n_2. Altogether the total value-added payments for sectors 1 and 2 are defined as $v_1 = l_1 + n_1$ and $v_2 = l_2 + n_2$ respectively.

Moreover, it is assumed that sectors might generally use some imported goods for their production. We will further denote these imports as m_1 and m_2. Miller & Blair added that exports included in final demand are often expressed in the net form. As a result of this, negative numbers might occur.

Table 4.2: Expanded Flow Table for a Two-Sector Economy

		Proces. sectors		Final Demand				Total Output ($\mathbf{x}$)
		1	2					
Processing	1	z_{11}	z_{12}	c_1	i_1	g_1	e_1	x_1
sectors	2	z_{12}	z_{22}	c_2	i_2	g_2	e_2	x_2
Payments	VA ($\mathbf{v'}$)	l_1	l_2	l_C	l_I	l_G	l_E	L
sectors		n_1	n_2	n_C	n_I	n_G	n_E	N
Imports		m_1	m_2	m_C	m_I	m_G	m_E	M
Total Outlays ($\mathbf{x'}$)		x_1	x_2	C	I	G	E	X

Source: Miller & Blair (2009)

The rest of the elements (l_C to l_E) in the final demand column are defined in the same manner, where ,for instance, l_G includes payments for government workers and m_E refers to imported goods that is re-exported afterwards.

Now summing the last column of the table (Total Output) gives us the following equation:

$$X = x_1 + x_2 + L + N + M$$

Similarly summing the last row (Total Outlays) equals the same value namely:

$$X = x_1 + x_2 + C + I + G + E$$

Finally equating the two previous expressions for X and doing some basic mathematical operations, we will get to the following equation:

$$L + M + N = C + I + G + E$$

where the left-hand side refers to the gross national income (GNI) or alternatively total factor payments in the economy, whereas the right-hand side is simply the gross national product (GNP), or the total value spent on consumption, investments, government purchases and value of net exports in the economy (Miller & Blair, 2009).

4.2.3 Input-Output Model

In this subsection, the input-output model will be introduced. Please note that due to the great detail of the Miller & Blair's paper, only the most essential points will be explained in this work. Please refer to the original work for more detailed information.

In the input-output analysis, the key assumption is the fixed ratios of interindustry flows. Let i and j be different sectors and sector i supply the sector j, which then produces its output x_j. Then we define the following ratio:

$$a_{ij} = \frac{z_{ij}}{x_i} \tag{4.5}$$

where, by Miller & Blair (2009), a_{ij} is called *technical coefficient*, or sometimes input-output coefficient and direct input coefficient. This coefficient is used to save or measure the proportion between sector's output and its inputs. Now using trivial algebra, we can derive that $a_{ij}x_j = z_{ij}$ from the equation 4.5. This relationship can then be substituted into equation 4.2 getting us:

$$\begin{aligned}
&x_1 = a_{11}x_1 + ... + a_{1i}x_i + ... + a_{1n}x_n + f_1\\
&\vdots\\
&x_i = a_{i1}x_1 + ... + a_{ii}x_i + ... + a_{in}x_n + f_i\\
&\vdots\\
&x_n = a_{n1}x_1 + ... + a_{ni}x_i + ... + a_{nn}x_n + f_n
\end{aligned} \tag{4.6}$$

where dependence of inderindustry flows on the total outputs of each sector is more visible. Moreover, putting all x terms to the left and grouping x_1 terms together in the first equation, x_2 terms in the second and further on, we get the following:

$$\begin{aligned}
&(1 - a_{11})x_1 - ... - a_{1i}x_i + ... - a_{1n}x_n = f_1\\
&\vdots\\
&- a_{i1}x_1 - ... - (1 - a_{ii})x_i - ... - a_{in}x_n = f_i\\
&\vdots\\
&- a_{n1}x_1 - ... - a_{ni}x_i - ... - (1 - a_{nn})x_n = f_n
\end{aligned} \tag{4.7}$$

Let $\hat{x} = \begin{bmatrix} x_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & x_n \end{bmatrix}$, then using standard properties of an inverse, we get

$(\hat{\mathbf{x}})(\hat{\mathbf{x}})^{-1} = \mathbf{I}$[4]. In addition, the postmultiplication of a matrix $\mathbf{Z}$ from 4.3 with diagonal matrix $\hat{\mathbf{x}}$ creates a matrix in which each column j of $\mathbf{Z}$ is multiplied by x_j in $\hat{\mathbf{x}}$, therefore getting us matrix representation of technical coefficients:

$$\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1} \tag{4.8}$$

Grouping now 4.3 and 4.8, we can express the matrix expression for 4.6 in the following form:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} \tag{4.9}$$

which further, using identity matrix, can be reconstructed into form corresponding to the 4.7 as:

$$(\mathbf{I} - \mathbf{A})\mathbf{x} = \mathbf{f} \tag{4.10}$$

Finally, if $(\mathbf{I} - \mathbf{A})^{-1}$ exists, meaning it is invertible, which as long as it is singular holds, we can find the unique solution for 4.10 by solving:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{L}\mathbf{f} \tag{4.11}$$

where $(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{L} = [l_{ij}]$ is called *Leontief inverse* or *total requirements matrix* (Miller & Blair, 2009).

To make the dependence of gross output on the final demand values clear, the equation 4.11 can be rewritten back from the matrix notation into:

$$\begin{aligned} x_1 &= l_{11}f_1 + ... + l_{1i}f_i + ... + l_{1n}f_n \\ &\vdots \\ x_i &= l_{i1}f_1 + ... + l_{ii}f_i + ... + l_{in}f_n \\ &\vdots \\ x_n &= l_{n1}f_1 + ... + l_{ni}f_i + ... + l_{nn}f_n \end{aligned} \tag{4.12}$$

4.2.4 Other impacts

To finish this chapter, the alternative interpretation of the results in the input-output analysis is presented.

[4]Please note that here, and throughout this paper, the following notation is used:
A "hat" over a vector denotes a diagonal matrix with the elements of the vector along the main diagonal (Miller & Blair, 2009).
Also, $\mathbf{I}$ matrix refers to identity matrix of corresponding rank - ones on the main diagonal and zeros elsewhere

In some situations one might not ultimately be interested in the dollar value of the sector's output, but in the different type of measure. According to Miller & Blair the gross output can be with initial steps re-interpreted in the form of for instance value added or employment (either in dollar or physical terms). For doing so it is necessary to obtain relevant coefficients that can be further used to estimate the desired results.

To illustrate this Miller & Blair present the example on the calculus of employment through the output changes, as introduced before. Let the economy of our example country consist of only two sectors and the values of employment in those sectors are denoted as:

$$\mathbf{e} = [e_1 \ e_2]$$

Now a vector of *employment coefficients* simply consists of portion of the employment vector $\mathbf{e}$ on the total output in the sectors, mathematically expressed:

$$e_c = [e_1/x_1 \ e_2/x_2] = [e_{c1} \ e_{c2}]$$

Now the term e_{c1} represents the dollar's worth of labor inputs per dollar's worth of output of the sector 1, so for example let e_{c1} be 0.3, then the interpretation would be such that for producing dollar worth of output in sector 1 the sector needs 0.3 dollars worth of labor (Miller & Blair, 2009).

Chapter 5

Methodology and Data

In this chapter are introduced the methodology crucial for the research part of our thesis and relevant databases, in which we further on work.

5.1 Extraction methods

5.1.1 Hypothetical extraction method

Hypothetical extraction method (HEM) is a method that has been used for assessing inter-industry linkages and the importance of industries. This method was developed by Paelinck *et al.* (1965) according to Miller *et al.* (2001). HEM takes into account the hypothetical scenario in which a particular industry is shut down and not in use anymore. To model this, HEM operates in the input-output framework, where the output of entire economy is calculated in order to satisfy the final demands. Then the sector of interest is deleted or nullified and the difference between the original and HEM outputs are measures for linkages of the extracted sector.

HEM was originally developed to serve for national economies. To identify the true effect of the extraction, when performing HEM, it is necessary that other elements stay the same. This implies that, on a national scale, the remaining industries keep their positions and continue to get the inputs they need. Therefore, in the post-extraction scenario, it is often implicitly assumed that new (other) imports fulfill the input requirements that were initially supplied by the extracted industry, as the logic behind this is such that countries are assumed to exhaust their capacities and thus cannot replace the lost inputs (Dietzenbacher & Lahr, 2013; Cai & Leung, 2004).

Assume now an economy with n industries and industry h is hypothetically extracted from such economy. Then we would nullify the input coefficients in hth row and in hth column, as well as hth row in the final demand. Then, instead of $n \times n$ matrix of technical coefficients $\mathbf{A}$, we would have new $(n-1) \times (n-1)$ matrix $\bar{\mathbf{A}}$. Similarly, new final demand vector would be denoted $\bar{\mathbf{f}}$. Using our new variables, we can calculate the total output of the economy using the standard input-output equation 4.11 rewritten as:

$$\bar{\mathbf{x}} = (\bar{\mathbf{I}} - \bar{\mathbf{A}})^{-1}\bar{\mathbf{f}} = \bar{\mathbf{L}}\bar{\mathbf{f}} \tag{5.1}$$

where it holds that:

$$\begin{aligned} \bar{a}_{hj} = \bar{a}_{ih} = 0 \quad \forall i, j, \\ \bar{a}_{ij} = a_{ij} \quad \forall i, j \neq h, \\ \bar{f}_h = 0, \\ \bar{f}_i = f_i \quad \forall i \neq h \end{aligned}$$

Furthermore, let the vector $\mathbf{v}$ contains value added by industries, then v_j is an element of this vector equal to the value added by industry j. Similarly, considering imports, we have vector $\mathbf{m}$ and m_j element equal to imports by industry j. Now, having these variables defined, we can define the total value added formula $VA = \boldsymbol{\pi}'\mathbf{x} = \boldsymbol{\pi}'\mathbf{L}\mathbf{f}$, where $\boldsymbol{\pi}' = \mathbf{v}'\hat{\mathbf{x}}^{-1}$ contains value-added coefficients. In the same fashion, the total imports of intermediate inputs formula is $IMPINT = \boldsymbol{\mu}'\mathbf{x} = \boldsymbol{\mu}'\mathbf{L}\mathbf{f}$, where $\boldsymbol{\mu}' = \mathbf{m}'\hat{\mathbf{x}}^{-1}$ are the import coefficients (Dietzenbacher *et al.*, 2019).

Now satisfiyng the same final demands in this economy, analogously to the 5.1, we can define the total value added and total intermediate imports:

$$\overline{VA} = \boldsymbol{\pi}'\bar{\mathbf{x}} = \boldsymbol{\pi}'\bar{\mathbf{L}}\bar{\mathbf{f}} \tag{5.2}$$

$$\overline{IMPINT} = \bar{\boldsymbol{\mu}}'\bar{\mathbf{x}} = \bar{\boldsymbol{\mu}}'\bar{\mathbf{L}}\bar{\mathbf{f}} \tag{5.3}$$

Now to measure the importance of extracted industry h, the differences between the HEM values and the initial values have to be calculated. After HEM, the total output value decreases under the usual assumptions as industries that are connected to the industry h do not have to produce for industry h's inputs.[1]

The change in total value added is $\Delta VA = \overline{VA}$ - $VA = \boldsymbol{\pi}'(\overline{\mathbf{x}} - \mathbf{x})$. This difference is negative as an extraction of any industry[2] decreases the value

[1]Mathematically expressed $\bar{x}_i < x_i \; \forall i$ and $\bar{x}_k = 0$

[2]Assuming that its value added was positive to any extend, which can be considered reasonable to assume.

added. However, the imports move in the opposite direction than the total output or total value added. This change turns out to be positive, as it was previously assumed, that the extracted industry's outputs (inputs for the other industries) were substituted by foreign imports. Mathematically, the change is given as $\Delta\overline{IMP} = \Delta IMPINT + \Delta IMPFIN = (\overline{IMPINT} - IMPINT) + (\overline{IMPFIN} - IMPFIN) = (\bar{\boldsymbol{\mu}}'\bar{\mathbf{x}} - \boldsymbol{\mu}'\mathbf{x}) + f_h$, where $IMPFIN$ refers to the imports of final goods and f_h is the initial final demand satisfied by the sector h, which is now satisfied by imports (Dietzenbacher *et al.*, 2019).

One interesting phenomenon that can be studied with this method is what happens to gross domestic product (GDP), both at domestic and worlds level. The domestic GDP is given by the total value added in the domestic economy. Thus, using the fact that the ΔVA is negative, we can conclude that the domestic ΔGDP will be negative. On the other hand, the foreign GDP will change positively, as foreign value added increases with the increase of foreign imports. Then the total change of worlds GDP (WGDP) is given by:

$$\Delta WGDP = \Delta VA + \Delta IMP = \boldsymbol{\pi}'(\overline{\mathbf{x}} - \mathbf{x}) + (\bar{\boldsymbol{\mu}}'\bar{\mathbf{x}} - \boldsymbol{\mu}'\mathbf{x}) + f_h.$$

It can be proven that this change is equal to zero and the WGDP remains unchanged under HEM. For the full proof please refer to the original text of Dietzenbacher *et al.* page 5.

5.1.2 Global extraction method

As was already mentioned, HEM was used on the national scale. However, given the increasing availability of the data collected for the whole world as well as input-output tables, Dietzenbacher *et al.* (2019) extended and modified the initial HEM method to the global scale. One might ask, why is the modification needed. The rational answer to this is the always tossed around assumption, that the inputs needed are replaced by "outside the system" foreign imports. This, however, cannot work under the global extraction method (GEM), as in this method, the whole world is involved and thus there is no "outside the system" country that could replace the lost inputs.

Assume now, there are N countries with n industries. Then we have $Nn \times Nn$ matrix of flows $\mathbf{Z}$, $Nn \times N$ matrix of final demands $\mathbf{F}$ and the output vector $\mathbf{x}$ and value added vector $\mathbf{v}$ of size Nn given by:

$$\mathbf{Z} = \begin{bmatrix} \mathbf{Z}^{11} & \cdots & \mathbf{Z}^{1R} & \cdots & \mathbf{Z}^{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ \mathbf{Z}^{R1} & \cdots & \mathbf{Z}^{RR} & \cdots & \mathbf{Z}^{RN} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ \mathbf{Z}^{N1} & \cdots & \mathbf{Z}^{NR} & \cdots & \mathbf{Z}^{NN} \end{bmatrix}; \; \mathbf{F} = \begin{bmatrix} \mathbf{f}^{11} & \cdots & \mathbf{f}^{1R} & \cdots & \mathbf{f}^{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ \mathbf{f}^{R1} & \cdots & \mathbf{f}^{RR} & \cdots & \mathbf{f}^{RN} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ \mathbf{f}^{N1} & \cdots & \mathbf{f}^{NR} & \cdots & \mathbf{f}^{NN} \end{bmatrix}; \; \mathbf{x} = \begin{bmatrix} \mathbf{x}^{1} \\ \vdots \\ \mathbf{x}^{R} \\ \vdots \\ \mathbf{x}^{N} \end{bmatrix}; \; \mathbf{v} = \begin{bmatrix} \mathbf{v}^{1} \\ \vdots \\ \mathbf{v}^{R} \\ \vdots \\ \mathbf{v}^{N} \end{bmatrix} \tag{5.4}$$

Now, as the system gets a little more complex, a reader should be aware that element $\mathbf{Z}^{RS}$ represent $n \times n$ matrix with element z_{ij}^{RS} representing the money value of flows from industry i in country R to industry j in country S. Similarly, $\mathbf{f}^{RS}$ is the n-element vector and f_i^{RS} is element of this vector expressing the deliveries from industry i in country R for final demand in country S. Finally, elements x_k^R and v_k^R represent the output and value added of the industry k in the country R respectively (Dietzenbacher *et al.*, 2019).

Following the matrix representation of technical coefficients defined in Equation 4.8, for the global situation the elements of $\mathbf{A}$ matrix are $\mathbf{A}^{RS} = \mathbf{Z}^{RS}(\hat{\mathbf{x}}^S)^{-1}$. For the final demand in country R it holds that $\mathbf{f}^R = \sum_S \mathbf{f}^{RS}$. Now we can create the same scenario as in the HEM, that is we will extract industry h from the country H. For GEM it holds:

$$\bar{a}_{hj}^{HS} = \bar{a}_{ih}^{TH} = 0 \; \forall i, j; \; \forall S, T; \tag{5.5}$$

$$\bar{f}_h^{HS} = 0 \; \forall S. \tag{5.6}$$

The Equation 5.5 and Equation 5.6 express the situation in which the industry h from the country H does not receive any inputs and does not supply any outputs to other industries as well as that this industry does not satisfy any final demand in any country. Here, however, we have to take care of the output supplied to other industries.

As was already indicated in the beginning of this subsection, the usage of new foreign imports is irrational in this framework. Therefore assume the hypothetical example, inspired by the one demonstrated in the paper of Dietzenbacher *et al.*, where German motor vehicle industry needs electronic parts for the car assembly. Let in our hypothetical example suppose that this industry receives inputs in the following manner: 20% originate in Germany itself, 40% come from China, 20% from the United States and 20% from France. Now assume the first simpler possibility, that the German electronic part manufacturing sector is extracted. In GEM it is then assumed the other countries that take part in delivering to the German motor vehicle industry take over the part which was supplied by the German, that is the 20% previously supplied by Germany electronic parts manufacturing are proportionally divided to Chinese, American and French electronic parts manufacturing. The new situation would be that China deliver now 50%, the United States 25% and France 25% as well. The important rule is that these percentages always add up to 100%.

The GEM operates differently in the second possibility, in which any (for instance Chinese) foreign electric parts manufacturing sector is extracted. In this situation, the percentages are redistributed similarly as in the first example, but with one exemption. Dietzenbacher *et al.* (2019) assume that the Germany imports electronic parts from foreign countries for a particular reason, such as that they already exhaust all of their capacities for electronic parts manufacturing (otherwise they would not need any imports). Thus, the redistribution of the extracted sector from foreign country (China) goes only to the other foreign countries (France and the United States). So the after-GEM scenario would be following: Germany's supply of electronic parts for its motor vehicle industry remains 20% and both France and the United States sell 40%. The same logic holds for the redistribution of the final demands.

In our hypothetical example, Germany represents the country H and the electronic parts manufacturing is the industry h. Mathematically expressed the previous, the assumptions are as follows.

$$\bar{a}_{hj}^{TS} = a_{hj}^{TS} + a_{hj}^{HS} \frac{a_{hj}^{TS}}{\sum_{R \neq H,S} a_{hj}^{RS}} \; \forall j, \; \forall S, \; \forall T \neq H, S; \tag{5.7}$$

$$\bar{f}_{h}^{TS} = f_{h}^{TS} + f_{h}^{HS} \frac{f_{h}^{TS}}{\sum_{R \neq H,S} f_{h}^{RS}} \; \forall S, \; \forall T \neq H, S; \tag{5.8}$$

Any other elements that are uncovered remain the same as the ones in the HEM calculus.

Further on, the calculations in GEM are analogous to the ones made in the standard HEM. To be explicit, the difference $\hat{\mathbf{x}}^T - \mathbf{x}^T$ explains the output effect in the country T, when the industry h-H is extracted. The total value added change in country T is defined $\Delta VA = (\overline{VA}^T - VA^T) = \boldsymbol{\pi}'(\overline{\mathbf{x}}^T - \mathbf{x}^T)$. Again, if we want to investigate GDP, we need to keep in mind that under GEM framework, the WGDP does not change. The proof can be found in the original text of Dietzenbacher *et al.* page 8.

5.2 Input output databases

In this section the description of different input-output databases is provided with emphasis on the ones further used in the research.

The core database used in the thesis is the one provided by OECD (2023) known as inter-country input-output tables (ICIO). According to OECD Directorate for Science & Innovation (2023), the first work on the input-output tables at the OECD started in 1990s, as the need for international technology spillovers measure increased. Ever since the OECD ICIO tables are updated, in recent years annually, with the up to date latest version from the year 2022.

The structure of ICIO tables contains the following key elements:

- a matrix of industry-to-industry flows of intermediate inputs covering both the flows on the national level that is from one industry to other, within one country, and flows on the global level, meaning from industry in one country to industry in other country
- a matrix of deliveries of each industry serving for satisfying the final demands, both in the domestic country as well as in other countries
- additional information about value added of every industry in every country

The tables collected data for 45 different industries from 76 countries + Rest of World (RoW) and China and Mexico split with the aim to account for firm heterogeneity. Both the countries and industries included can be found in Appendix A and Appendix B.

One thing missing in the ICIO tables are the employment components. For this reason, the thesis combines the previously introduced tables with the database provided by EUROSTAT (2023). This database, known as Full international and global accounts for research in input-output Analysis (FIGARO), contains multiple differently structured tables such as inter-country supply, use and input-output tables of the EU and non-EU trading partners. The tables used in the thesis are 2020 EU inter-country input-output tables industry by industry. Structurally they differ only little with the ICIO tables, specifically they cover:

- a matrix of industry-to-industry flows of intermediate inputs covering both the flows on the national level, that is from one industry to other, within one country, and flows on the global level, meaning from industry in one country to industry in other country

- a matrix of different final uses such as final consumption of households, general government, non-profit institutions or changes in inventories
- additional information about value added components and other adjustments

FIGARO tables provide information about 27 EU countries, 18 main non-EU trading partners and again the Rest of the World element. The further division is similarly into specific 64 industries. All relevant countries, industries and other components can be found in Appendices C, D and E. Crucial thing, that these tables contain in comparison with ICIO tables is the part of the Adjustments and Value Added components, that contains component Compensation of employees labeled D1, which is further used in order to calculate employment changes.

One might ask, why the combination of the previous two is used. The reasoning behind this is the asymmetric information about European and non-European countries. This issue would lead to unavailability of measures for linking the effects caused by the extraction later executed in the research. On the other hand, as the secondary interest of the thesis considers the structural changes, specifically employment, on the EU scene, this asymmetry of information shall not affect the desired conclusion.

As the input-output analysis is widely used, there are multiple different databases that could potentially be used for this thesis. Next to OECD ICIO tables, the suitable version of tables could be the project World Input-output tables (WIOD, 2016)). These are constructed in time-series enabling comparability over time and similarly to ICIO tables, they are provided in releases. The biggest drawback of the tables is such that the up-to-date latest release is from the year 2016, containing period 2000 to 2014. In this case, it would be hard to involve the effect of electric vehicles in the automotive industry, as the rise of EVs is a matter of recent years.[3]

The previously mentioned FIGARO tables could be ideal, if we would combine them with the national input-output data provided by Asian Development Bank (ADB). These tables cover sectors in the Asia and the Pacific region with very recent releases containing statistics even for the year 2022. However, the

[3]For detailed overview of the WIOD database refer to Timmer *et al.* (2015)

additional work with merging, combining and comparing ADB tables with the FIGARO would require many times more effort, which is not necessary as the combination of FIGARO tables with ICIO provides all relevant information.[4]

Even though this thesis uses the tables provided by OECD and Eurostat, the previously mentioned tables serve as a good comparison and potential substitutes in case of missing or invalid data occurrence.

[4]ADB input-output tables can be attained at www.adb.org/what-we-do/data/regional-input-output-tables

Chapter 6

Research and results

6.1 Model application

As stated before, this thesis focuses on potential impacts of dominance of China in electric vehicle industry, respectively the whole automotive sector, in Europe. The research question studied is as follows:

- Which European countries would be the most affected by the Chinese expansion in the electric vehicle, respectively automotive industry, in the total output and employment measures?

Input-output tables, as described above, consist of flows matrix that is being referred to as Z, output matrix X, final demand matrix FD and value added matrix VA. To answer the research questions, we implemented hypothetical scenario, in which Chinese electric vehicle expansion leads to such extreme, that it replaces the whole EU automotive industry.

To simulate the situation in which the whole European automotive sector is replaced by Chinese, it is assumed that all European carmakers do not purchase the necessary inputs for production from their previous suppliers. Mathematically this means, that in matrix of technical coefficients A, that was introduced in Chapter 4, we will extract the columns belonging to all 27 *Motor vehicles, trailers and semi-trailers*[1] sectors of the European Union.

After that, it has to be taken care of the outputs of those 27 sectors. We simulate that China replaces the European automotive industry, thus it satisfies all supplies that were previously satisfied by European carmakers. Necessary calculations are similar to the previous step, but applied to rows of the matrix

[1]The sector can be found in the Appendix B and is refereed to as sector C_29 interchangeably.

A and with one exception. The magnitude of outputs in rows representing EU carmakers is now added to the output of Chinese *Motor vehicles, trailers and semi-trailers* sector.

To further follow up with the calculations in the table 6.1, we can see simplified matrix of technical coefficients A. In this matrix we have 3 areas - China (C), European Union (E) and Rest of the World (R) and 2 sectors - Automotive manufacturing (1) and Construction (2).[2] We can see the inputs that would be delivered to the EU automotive sector are annulled. Further the values outputs coming out of the sector EU_1 would be added to the sector China_1, as Chines automotive industry replaces the European. This means that values a_{11}^{EC} to a_{12}^{ER} would be added to values a_{11}^{CC} to a_{12}^{CR}, leaving other values untouched.

Table 6.1: Simplified matrix of technical coefficients

		China		EU		ROW	
		1	2	1	2	1	2
China	1	a_{11}^{CC}	a_{12}^{CC}	0	a_{12}^{CE}	a_{11}^{CR}	a_{12}^{CR}
	2	a_{21}^{CC}	a_{22}^{CC}	0	a_{22}^{CE}	a_{21}^{CR}	a_{22}^{CR}
EU	1	a_{11}^{EC}	a_{12}^{EC}	0	a_{12}^{EE}	a_{11}^{ER}	a_{12}^{ER}
	2	a_{21}^{EC}	a_{22}^{EC}	0	a_{22}^{EE}	a_{21}^{ER}	a_{22}^{ER}
ROW	1	a_{11}^{RC}	a_{12}^{RC}	0	a_{12}^{RE}	a_{11}^{RR}	a_{12}^{RR}
	2	a_{21}^{RC}	a_{22}^{RC}	0	a_{22}^{RE}	a_{21}^{RR}	a_{22}^{RR}

Finally, the same process is applied to the matrix of final demands FD. This simulates the situation where the demands of final consumers that were previously satisfied by EU automotive industry are now transferred to the Chinese one.

Now, as we extracted and transferred all necessary values, we can analyze the effects through calculus of Leontief matrix, as was described again in Chapter 4.

Before getting into the results themselves, one should be aware of the fact that this study is based on, so far, not mentioned assumptions. First of all, we assume that previously introduced replacement is possible, this means that China is able to handle such increase in the automotive sector. In other words, we assume that there is enough production, capital and labour capacity for

[2] The elements in the table 6.1 are interpreted in the following manner: a_{12}^{CE} represents the value in USD coming from sector 1 in China (C) needed for creating USD 1 worth of goods in sector 2 of European Union (E)

satisfying the European demand. Similarly, we assume the production, labour and capital capacity in automotive industries of Europe does not serve other purposes and the replacement takes place in the area of China, meaning we do not create a situation in which for instance China manufactures in the factories previously used by European countries. As the designed scenario is an extreme situation, the assumptions are rather unrealistic, however, since the thesis should serve as a benchmark framework to see the potential impacts of Chinese electric vehicle expansion in automotive industry, it shall cause no shortcomings.

6.1.1 Output changes

In this section the results connected to the output measures are presented, as well as outlining the linkages in between the industries throughout the input-output analysis.

The level at which countries and their sectors were influenced by the replacement of European automotive industries by Chinese can be done in two separate measures, either in the relative way, which represents the percentage change of output, or in the nominal way, which explains the change in the monetary terms.

First of all, we can see the distribution of percentage change in total output in the Europe in the Figure 6.1. In this figure, the red countries represent the highly affected ones. On the other hand, the green colour refers to countries that did not face a shock of big magnitude. As for the grey countries, the data for appropriate output changes were not available or sufficient.

Initially it can be observed that there is evident concentration around the Central Europe, namely Slovakia, Czechia and Hungary. For Slovakia the estimation of the decrease in output is approximately 19.48%, which is arguably significant value. In monetary terms this represents approximately decrease of USD 13.3 billion. For the second most affected, Czechia, the results are quite similar, as the decrease is approximately 14.89%, respectively USD 29 billion.

Besides the Central Europe, there are other noteworthy countries, for instance Romania, Sweden or Spain. These countries were estimated to experience substantial decrease in the relative output as well. Specifically the output was estimated to shrink by 7.73%, 6.98% and 5.81% respectively. In monetary terms this would sum up to USD 14.9 billion for Romania, USD 27.3 billion in the case of Sweden and USD 62.9 billion decrease of Spain economy's total

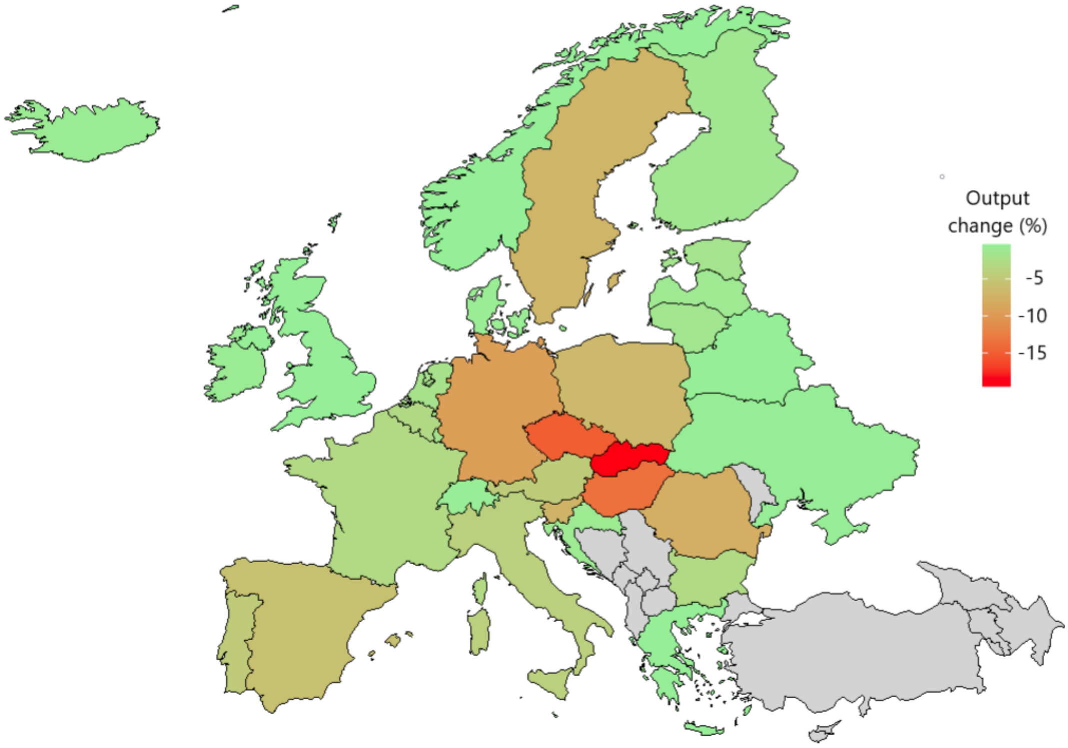

Figure 6.1: Relative output change in Europe

output. What might be of interest to a reader is that even though Romanian total output decreased by nearly 2% more than Spanish, the monetary terms are not following this ranking. That is the main reason why one should be aware of the distinction between the nominal and the relative value, as in the nominal value, the size of the country's economy is significantly reflected.

In the Figure 6.2 we can see the total output change expressed in USD million. Please note that in this measure we disregard the change in output of *Motor vehicles, trailers and semi-trailers* sector, as this would not serve the purposes of the research question with potential biases in the size of each country's automotive industry. In this matter we can notice huge variability as the Germany loses by far the biggest amount of output with massive USD 235.9 billion loss. Nearly half of this loss comes from 5 sectors, namely in descending order: *Wholesale and retail trade; repair of motor vehicles*, *Professional, scientific and technical activities*, *Fabricated metal products*, *Machinery and equipment* and *Basic metals*. This shall be no surprise, as the automotive industry of Germany is undoubtedly the biggest on the European scene.

Besides Germany, France and Italy complete the top three in the nominal

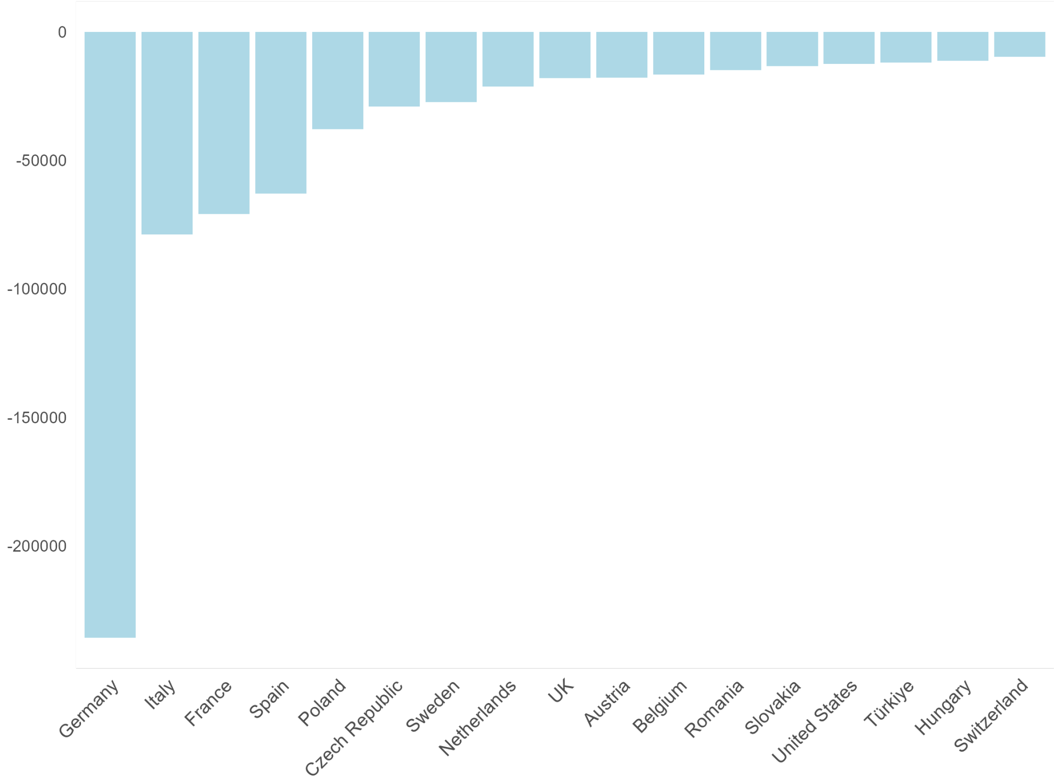

Figure 6.2: Nominal output change (Millions USD)

output change. From a big part this is caused by the monetary drop in the sector *Wholesale and retail trade; repair of motor vehicles*. This, however, represents only a 2-3% drop in the total output of this sector for both countries. Reasoning for that is such there is lack of division throughout this sector, as it accounts total wholesale and retail trade including all products like clothing, construction materials, food and so on, thus the sector itself is of massive magnitude and the nominal drop do not reflect significantly in it.

To further examine where does the decrease in the relative value come from, in the Table 6.2 we can see the top 10 most affected EU sectors, after the extraction of European automotive industries and subsequent Chinese replacement was executed. The ranking of affectedness was again measured through the relative output change ($Ychange$) presented in the percentages.

Table 6.2: Mostly affected European sectors by the extraction of automobile industry.

	Sector	Output change (%)
1	SVK_25	-26.62
2	CZE_22	-26.05
3	SVK_22	-22.10
4	CZE_24	-21.52
5	ESP_25	-20.85
6	SVK_24	-18.77
7	ROU_24	-18.22
8	ROU_22	-18.09
9	CZE_25	-17.85
10	HUN_25	-16.04

An initial observation that may capture our attention is that the top of the table is occupied with Czechia and Slovakia, which intuitively corresponds to the results shown before. Other than that, one might notice that only 3 industries occur throughout the table. Specifically these are *Fabricated metal products* sector (C_25), *Basic metals* sector (C_24) and *Rubber and plastics products* (C_22). The reasoning behind it is that out of the 10 industries mentioned in the Table 6.2, for 6 of them it holds the supply to its country's automotive industry (C_29) represents the main partner on the input-supply side. For instance, the Slovak *Fabricated metal products* sector (SVK_25) delivers to the SVK_29 industry approximately USD 1190 million worth of inputs, which makes up to nearly 17% of all deliveries. Moreover, of total deliveries of this industry to other sectors, more than 20% is covered by the *Motor vehicles, trailers and semi-trailers* industries throughout the European Union. Similarly, for Czechia it holds that nearly 17% of input deliveries of the CZK_22 industry captures its CZK_29 industry and the whole automotive sector of the European Union represents approximately 22% of the total deliveries.[3]

On the contrary, the change is not only result of the supply side, but rather a combination of both supply and demand, respectively input and output, effects. Using the Miller & Blair (2009) explanation of technical coefficients described in Chapter 4, we can interpret the results as follows. For Spanish *Fabricated metal products* sector the technical coefficient $a_{ESP29,ESP25}$ equals approximately 0.083 meaning that for 1 dollar worth of output, the ESP_25

[3]As one might argue, that our estimations are rather significant, we have tried to verify our statistics of Czech and Slovak industries with the Czech and Slovak Statistical Office. The relevant data for the sectors can be found in Appendix F

industry uses 0.083 dollars worth of inputs from the sector ESP_29, which is, excluding the sector itself, the highest out of all industries. Similarly, Romanian *Basic metals* sector uses nearly 0.072 dollars worth of inputs from the Romanian automotive industry.

As we have already discussed, the Global extraction method is unique in a way, that we can measure the redistribution effects and thus it would be appropriate to mention, which countries would benefit from the extraction presented in our scenario. The obvious answer is China, as it would replace the whole automotive sector, but besides China, there are other interesting findings. In the Table 6.3, we can see the top 5 countries, whose output would increase the most, excluding China itself.

Table 6.3: Most gaining countries.

Country	Output change (%)
CHL	0.87
TWN	0.44
AUS	0.44
LAO	0.43
BRN	0.35

We can see that some of the mentioned countries are expected, including Australia or Taiwan as generally known partners of Chinese automotive industry. What could be rather surprising is for instance Chile, being the first on the list. Chile has been sufficiently linked to the Chinese *Basic metals* sector (CHN_24) as this sector receives the most intermediate inputs from Chile, excluding the Chilean sectors. This is supported by the fact that out of all Chilean exports, 38% is delivered to China, with more than 60% being copper ore or refined copper (MIT Media Lab, 2020).

Moving onto Australia and Laos, the situation is similar, as they both export great magnitudes of iron and copper to China respectively, creating significant linkages to the same sector CHN_24.

In the case of Taiwan and Brunei, the linkages are different. Taiwan, being significant player in the electronic component manufacturing is linked to the Chinese *Computer, electronic and optical equipment* industry, as it is, after the same Taiwanese sector, the second most receiving one to which Taiwanese economy deliver intermediate inputs. Out of all exports from Taiwan to China, electrical machinery and electronic components represent approximately 65%. On the other hand, Brunei is dependent on the exports of crude oil and natural gas, thus it is connected to the China mainly through the *Chemical and chemical products* and *Coke and refined petroleum products* sectors (CHN_20 and CHN_19 respectively). China represents significant partner for Brunei as well, as it received 17.2% of all exports coming from Brunei in 2020. The absolute majority of all exports to China consist of the organic chemicals, mostly being cyclic hydrocarbons, and also petroleum gas (MIT Media Lab, 2020).

6.1.2 Employment changes

This section provides further results regarding the employment change calculated through employment coefficient and previously calculated output.

As introduced in the chapter 4, using the calculus of Leontief inverse matrix we can further analyse the effects on the employment. In order to do so, we need to calculate employment coefficients that are further multiplied by the output change calculated previously. For this purpose the model uses additional component of the FIGARO tables *Compensation of employees* labelled as D_1. These results, however, are presented only in nominal or monetary terms, as presenting them through relative change would bring no additional value based on the principles of the calculus itself. Put differently, the results for the relative output change and potential relative employment change would not particularly differ as they are both based the calculus of the output change.

In the Figure 6.3 we can see the countries that experienced the biggest loss in the employment, or compensation of employees respectively.

These results are similar to the results shown in Figure 6.2, yet they differ in some aspects. What remains, is Germany being massive outlier topping the list, again, with USD 134 billion loss in the compensation of employees component. The second place is held by France and the top three is closed by Spain, moving Italy to the fourth position.

Even though we cannot compare countries by relative change of employment now, we can proportionally compare the nominal change in output and nominal change in employment. For the benchmark we can for example pick Germany and Czechia. According to Figure 6.2, the total output of Czechia dropped by approximately 0.085% of the drop of the Germany's output. In the case of employment, the compensation of employees item for the Czech Republic dropped by approximately 0.123% of the Germany's drop in the D_1. This indicates that the differences in the employment changes are not that drastic in comparison with the total output changes.

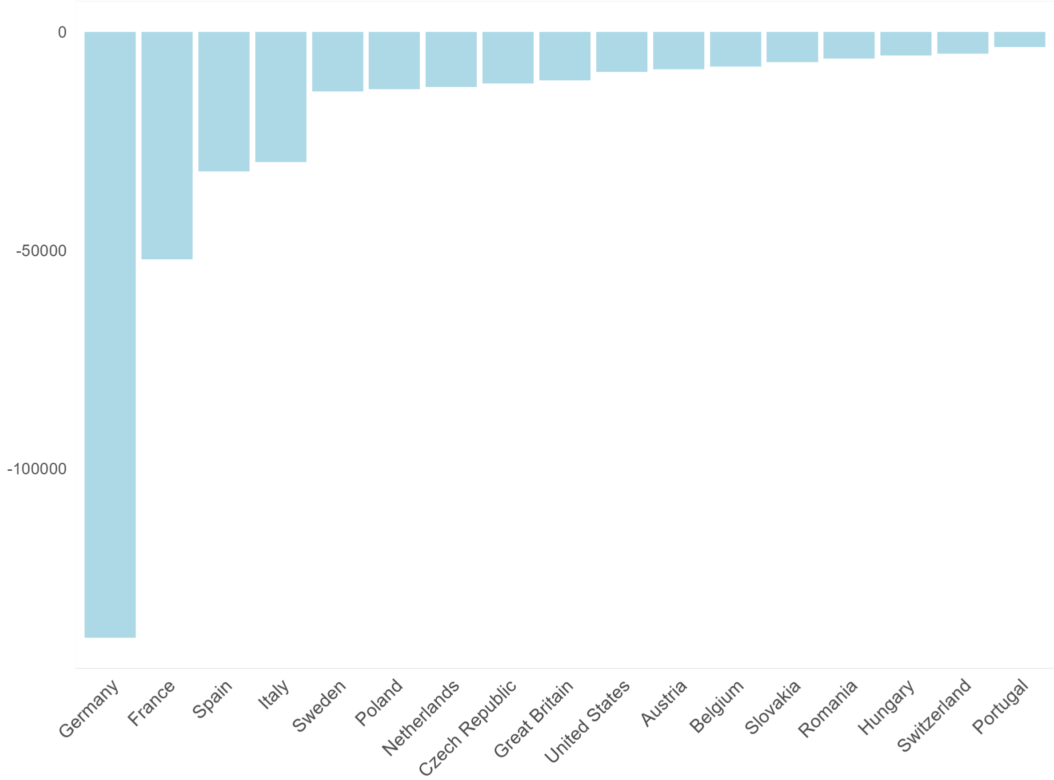

Figure 6.3: Nominal change in compensation of employees item (Millions USD)

To sum up the answer to the research question *"Which European countries would be the most affected by the Chinese expansion in the electric vehicle, respectively automotive industry?"*, we saw multiple results out of which some might be intuitive and others rather unexpected. As of percentage drop in output, the countries of Central Europe would lose the most, especially Slovakia, Czechia and Hungary. This is caused mostly by the fact that these countries rely heavily on the automotive industry and the multiplicative effect of the method in which the extraction of the automotive industries leads to loses in the intermediate delivery of inputs, meaning that the industries producing basic metals, plastics and other necessary parts for the automobile assembly would simply lose the main partner. From another angle, the Germany would be the most affected in the monetary terms. This is rather intuitive as the automotive industry of Germany is sizeable like no other in Europe.

Chapter 7

Conclusion

The electric vehicle industry is a constantly growing phenomenon of the latest years, and the race for leading this industry might become decisive for the future of the world. So far, the indisputable leader in this area is China and for this reason the aim of this thesis was to introduce, point out and estimate the potential effects of the Chinese electric vehicle expansion on the Europe through the input-output analysis.

In the Chapter 2 and Chapter 3, the introduction of electric vehicle industry and its development in China, European Union and America were presented. The research was conducted by using the Hypothetical extraction method (HEM), respectively its adjusted version known as the Global extraction method (GEM). In order to understand this method properly, the basics of input-output framework had to be introduced in the Chapter 4.

The hypothetical extraction method was aimed to work with input-output tables created for economy of one nation, country or region. The principles work in a way that in this economy one or more industries are extracted and the effects on the remaining industries are further measured. This original method was, however, not suitable for this thesis as it works with an crucial assumption, in which the extracted industry is replaced by other country outside of the framework. Because of that, the global extraction method was used, as it accounts for multiple countries, for which the relevant input-output tables are created, and the extracted industry is redistributed into already existing countries, as introduced by Dietzenbacher *et al.* (2019). Both of these methods, together with the data used to conduct this research, were introduced in the Chapter 5.

To answer the research question, the following scenario was presented. The Chinese electric vehicle industry expands to such extend that the automotive industry of China completely replaces the automotive industry of European Union. This was executed by applying the extraction method on the *Motor vehicles, trailers and semi-trailers* sectors in all of the member countries in the European Union and further by redistributing the necessary elements of such sectors to the Chinese one. This itself simulates the replacement properly. The details of applying this scenario, together with estimated effects, were introduced the Chapter 6.

The research indicated that the countries of the Central Europe would experience the biggest percentage drop in total output, mainly Slovakia, Czechia and Hungary. The drops for the previously mentioned countries were 19.45%, 14.89% and 13.44% respectively. In the nominal interpretation, Germany was estimated to face substantially the biggest decrease in total output with approximately USD 235 billion. The other countries that experienced a significant drop in nominal value of total output were Italy, France and Spain. However, one should be aware of the fact that in the nominal interpretation, one of the key aspects is the size of country's economy itself.
Furthermore, it was discovered that in the ten most affected sectors only 3 of them occurred, namely *Fabricated metal products*, *Basic metals* and *Rubber and plastics products*.
Additionally, the *Compensation of employees* item was used to estimate the employment effects through further created employment coefficients. In this aspect, similar results to the total output were estimated. The biggest decline was estimated for Germany with total USD 134 billion loss. It was, however, found out that the variability of this effect was not that significant as it was in the case of total output.

One should be aware of the fact, that the results presented consider only the multiplicative effect of the first type. This type of effect sum direct and indirect effect on the sectors[1]. There is, however, possible to show also the so called induced effect through multipliers of type two. In reality this would mean, that

[1]According to the Scottish Chief Economist Directorate published at: https://www.gov.scot/publications/about-supply-use-input-output-tables/pages/user-guide-multipliers/

once the income of employees in automotive sector of for instance Germany would decrease, they would tend to be more aware of their spendings leading to change of preferences such that they would prefer buying cheaper products from for instance China. In summary it is generally expected, that the effects calculated through the multipliers of type one tend to be underestimated. On the other hand, the type two multiplicative effects are usually overestimated. All together they can present the lower and higher bound of the estimated effect respectively (Miller & Blair, 2009).

Furthermore, there are also parts of the automotive sector that might and probably would prevail even if the sector was to be replaced. These include the smaller companies manufacturing luxurious or custom cars, that are not expected to be replaced by any third party. Such companies would on the other hand decrease the results gained in the industry, yet it is assumed that these companies do not represent significant part of industry, thus it is not accounted for them.

The information this thesis provide might become useful for anyone interested in the topic of electric vehicles and the situation on the global scene. It could also bring the insights of what stands behind the Chinese lead in this area closer to the reader. Furthermore, it can uplift the importance and the multiplicative effect of the automotive industry in the economy of European Union, as well as it can help in analysis of potentially endangered countries and sectors while evaluating electric vehicle industry. Even though the method applied is of an extreme nature, since the extraction of all auto-industries in the European Union is nearly unimaginable, it might prove useful to quickly detect the industry linkages and also introduce the worst possible results. Finally the research provided in the thesis can inspire and encourage others to further develop more advanced analysis of impacts of electric vehicle industry on the futurity of our planet. The methods used are flexible over the upcoming years, thus it would be interesting to repeat the same or similar research on the data after for instance 10 years advancement. Also, once there is enough sufficient data recorded for the electric vehicle industry itself[2] it would be interesting to observe the potential differences between the results of this thesis and the ones hypothetically obtained in the future.

[2] To this date, in the publicly available input-output tables, there is not sufficient division for the electric vehicle industry alone.

Bibliography

Barkenbus, J. N. (2020): "Prospects for electric vehicles." *Sustainability* **12(14)**: p. 5813.

CAAM (2020): "Sales of New Energy Vehicles." URL: http://en.caam.org.cn/Index/show/catid/34/id/140.html.

Cai, J. & P. Leung (2004): "Linkage measures: a revisit and a suggested alternative." *Technology Analysis & Strategic Management* **16(1)**: pp. 63–83.

Carreon, A. R. (2023): "The EV Battery Supply Chain explained." URL: https://rmi.org/the-ev-battery-supply-chain-explained/.

China Association of Automobile Manufacturers (2021): "Automotive statistics." URL: http://en.caam.org.cn/.

Dietzenbacher, E., B. van Burken, & Y. Kondo (2019): "Hypothetical extractions from a global perspective." *Economic Systems Research* **31(4)**: pp. 505–519.

Dietzenbacher, E. & M. L. Lahr (2013): "Expanding extractions." *Economic Systems Research* **25(3)**: pp. 341–360.

EEA (2023): "New registrations of electric vehicles in Europe." URL: https://www.eea.europa.eu/en/analysis/indicators/new-registrations-of-electric-vehicles.

European Commission (2022): "Automotive Industry." URL: https://single-market-economy.ec.europa.eu/sectors/automotive-industry.

European Commission (2023): "Commission launches investigation on subsidised electric cars from china." URL: https://ec.europa.eu/commission/presscorner/home/en.

EUROSTAT (2023): "The Full international and global accounts for research in input-output analysis (FIGARO)." URL: https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/information-data.

Farchy, J. & H. Warren (2018): "China has a secret weapon in the race to dominate electric cars." *Bloomberg* URL: https://www.bloomberg.com/opinion/articles/2019-04-14/china-s-secret-weapon-in-the-electric-car-race.

Gregor & Chimits (2022): "Made in China electric vehicles could turn Sino-EU trade on its head." *Merics* URL: https://merics.org/en/comment/made-china-electric-vehicles-could-turn-sino-eu-trade-its-head.

Han, X., W. Liu, & T. Jiang (2023): "Practising future-making: Anticipation and translocal politics of Tesla's Gigafactory in Shanghai as assemblage." *Transactions of the Institute of British Geographers* .

Hawkins, T. R., B. Singh, G. Majeau-Bettez, & A. H. StrĂ¸mman (2013): "Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles." *Journal of Industrial Ecology* **17(1)**: pp. 53–64. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1530-9290.2012.00532.x.

IEA (2022): "Global supply chains of EV Batteries - analysis." URL: https://www.iea.org/reports/global-supply-chains-of-ev-batteries.

International Council on Clean Transportation (2021): "China's New Energy Vehicle Industrial Development Plan for 2021 to 2035." URL: https://theicct.org/wp-content/uploads/2021/12/China-new-vehicle-industrial-dev-plan-jun2021.pdf.

Irle, R. (2023): "Global EV Sales for 2022." URL: https://ev-volumes.com/news/ev/global-ev-sales-for-2022/.

Jetin, B. (2020): "Who will control the electric vehicle market?" *International Journal of Automotive Technology and Management* **20(2)**: pp. 156–177.

Klein, M. C. (2023): "How China's Booming Car Exports Might Force European Rebalancing, Plus How Protection Can Work (or Not)."

König, A., L. Nicoletti, D. Schröder, S. Wolff, A. Waclaw, & M. Lienkamp (2021): "An Overview of Parameter and Cost for Battery Electric Vehicles." *World Electric Vehicle Journal* **12(1)**.

Kotak, Y., C. Marchante Fernández, L. Canals Casals, B. S. Kotak, D. Koch, C. Geisbauer, L. Trilla, A. Gómez-Núñez, & H.-G. Schweiger (2021): "End of electric vehicle batteries: Reuse vs. recycle." *Energies* **14(8)**: p. 2217.

Küfeoğlu, S. & D. Khah Kok Hong (2020): "Emissions performance of electric vehicles: A case study from the United Kingdom." *Applied Energy* **260**: pp. 114–241. URL: https://www.sciencedirect.com/science/article/pii/S0306261919319282.

Lo, K. L., Y. Fan, C. Zhang, & J. J. Mi (2021): "Emission reduction effect and mechanism of auto-purchase tax preference." *Journal of Advanced Transportation* **2021**: pp. 1–12.

Mazzocco & Gregor (2023): "Electric shock: Interpreting China's Electric Vehicle Export Boom." *Center for strategic and international studies* URL: https://www.csis.org/analysis/electric-shock-interpreting-chinas-electric-vehicle-export-boom.

Miller, R. E. & P. D. Blair (2009): *Input-Output Analysis: Foundations and Extensions*. Cambridge University Press, 2 edition.

Miller, R. E., M. L. Lahr *et al.* (2001): "A taxonomy of extractions." *Contributions to Economic Analysis* **249**: pp. 407–441.

MIT Media Lab (2020): "The Observatory of Economic Complexity." URL: https://oec.world/en.

OECD (2023): "OECD Inter-Country Input-Output Database." URL: http://oe.cd/icio.

Paelinck, J., J. De Caevel, & J. Degueldre (1965): "Analyse quantitative de certaines phénomenes du développment régional polarisé: Essai de simulation statique d'itérarires de propogation." *Bibliothèque de l'Institut de Science économique* **7**: pp. 341–387.

SANGUESA, J. A., V. TORRES-SANZ, P. GARRIDO, F. J. MARTINEZ, & J. M. MARQUEZ-BARJA (2021): "A review on electric vehicles: Technologies and challenges." *Smart Cities* **4(1)**: pp. 372–404. URL: https://www.mdpi.com/2624-6511/4/1/22.

SCHMID, M. (2020): "Challenges to the european automotive industry in securing critical raw materials for electric mobility: the case of rare earths." *Mineralogical Magazine* **84(1)**: pp. 5–17.

OECD DIRECTORATE FOR SCIENCE, T. & INNOVATION (2023): "Overview of development and applications." URL: https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm.

STATISTICAL OFFICE OF THE CZECH REPUBLIC (2024): "National accounts." URL: https://www.czso.cz/.

STATISTICAL OFFICE OF THE SLOVAK REPUBLIC (2024): "National accounts." URL: https://slovak.statistics.sk/.

THE EUROPEAN COMMISSION (2024): "Significant distortions in the economy of the People's Republic of China for the purposes of trade defence investigations." URL: https://policy.trade.ec.europa.eu/news/commission-updates-report-state-induced-distortions-chinas-economy-2024-04-10-en.

TIMMER, M. P., E. DIETZENBACHER, B. LOS, R. STEHRER, & G. J. DE VRIES (2015): "An illustrated user guide to the world input–output database: the case of global automotive production." *Review of International Economics* **23(3)**: pp. 575–605.

U.S. DEPARTMENT OF ENERGY (2012): "Alternative fuels data center: Batteries for electric vehicles." URL: https://afdc.energy.gov/vehicles/electric-batteries.html.

U.S. DEPARTMENT OF ENERGY (2012): "Alternative fuels data center: How do all-electric cars work?" URL: https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work.

U.S. DEPARTMENT OF ENERGY (2022): "Vehicle registration counts by state." URL: https://afdc.energy.gov/vehicle-registration.

WAAS, A., P. SADEK, B. HOFMANN, & J. GRUENER (2023): "European auto industry is at a crossroads." URL:

https://www.bcg.com/publications/2023/european-auto-industry-is-under-pressure.

WIOD (2016): "World Input-Output Database." URL: http://oe.cd/icio.

Wu, A. Y., W. A. Ng, Z. Yu, J. Haung, M. Ke, & Z. Y. Dong (2021): "A review of evolutionary policy incentives for sustainable development of electric vehicles in china: Strategic implications." *Energy Policy* **148**: pp. 111–983.

Xijia, Q. (2024): "China surpasses Japan to be worldâ€™s largest auto exporter in 2023, showcasing economic momentum." URL: https://www.globaltimes.cn/page/202401/1306439.shtml.

Yeung, G. (2019): "Made in China 2025: the development of a new energy vehicle industry in China." *Area Development and Policy* **4(1)**: pp. 39–59.

Zhang, P. (2024): "Automakers' NEV market share in China in 2023." URL: https://cnevpost.com/2024/01/10/automakers-nev-market-share-in-china-in-2023.

Zhou, T., J. Gosens, & F. Jotzo (2023): "China's EV plans - Domestic market and policy developments & Australia-China links in decarbonisation." *Policy brief - EV* URL: https://iceds.anu.edu.au/.

Appendix A

OECD ICIO included countries

	Code	Country		Code	Country
1	ARG	Argentina	42	KAZ	Kazakhstan
2	AUS	Australia	43	KHM	Cambodia
3	AUT	Austria	44	KOR	Korea
4	BEL	Belgium	45	LAO	Lao (People's Dem. Rep.)
5	BGD	Bangladesh	46	LVA	Latvia
6	BGR	Bulgaria	47	MAR	Morocco
7	BLR	Belarus	48	MEX	Mexico
8	BRA	Brazil	49	MLT	Malta
9	BRN	Brunei	50	MMR	Myanmar
10	CAN	Canada	51	MYS	Malaysia
11	CHE	Switzerland	52	NGA	Nigeria
12	CHL	Chile	53	NLD	Netherlands
13	CHN	China	54	NOR	Norway
14	CIV	CĂ´te d'Ivoire	55	NZL	New Zealand
15	CMR	Cameroon	56	PAK	Pakistan
16	COL	Colombia	57	PER	Peru
17	CRI	Costa Rica	58	PHL	Philippines
18	CYP	Cyprus	59	POL	Poland
19	CZE	Czechia	60	PRT	Portugal
20	DEU	Germany	61	ROU	Romania
21	DNK	Denmark	62	RUS	Russian Federation
22	EGY	Egypt	63	SAU	Saudi Arabia
23	ESP	Spain	64	SEN	Senegal
24	EST	Estonia	65	SGP	Singapore

Continued on next page

	Code	Country		Code	Country
25	FIN	Finland	66	SVK	Slovakia
26	FRA	France	67	SVN	Slovenia
27	GBR	United Kingdom	68	SWE	Sweden
28	GRC	Greece	69	THA	Thailand
29	HKG	Hong Kong	70	TUN	Tunisia
30	HRV	Croatia	71	TUR	TĂĽrkiye
31	HUN	Hungary	72	TWN	Chinese Taipei
32	IDN	Indonesia	73	UKR	Ukraine
33	IND	India	74	USA	United States
34	IRL	Ireland	75	VNM	Viet Nam
35	ISL	Iceland	76	ZAF	South Africa
36	ISR	Israel	77	ROW	Rest of the World
37	ITA	Italy	78	MX1	Mexico Non-global
38	JOR	Jordan	79	MX2	Mexico Global
39	JPN	Japan	80	CN1	China Non-Processing
40	KAZ	Kazakhstan	81	CN2	China Processing
41	KHM	Cambodia			

Appendix B

OECD ICIO included industries

Old code	New code	Industry	ISIC Rev.4
D01T02	A01_02	Agriculture, hunting, forestry	01, 02
D03	A03	Fishing and aquaculture	03
D05T06	B05_06	Mining and quarrying, energy producing products	05, 06
D07T08	B07_08	Mining and quarrying, non-energy producing products	07, 08
D09	B09	Mining support service activities	09
D10T12	C10T12	Food products, beverages and tobacco	10, 11, 12
D13T15	C13T15	Textiles, textile products, leather and footwear	13, 14, 15
D16	C16	Wood and products of wood and cork	16
D17T18	C17_18	Paper products and printing	17, 18
D19	C19	Coke and refined petroleum products	19
D20	C20	Chemical and chemical products	20
D21	C21	Pharmaceuticals, medicinal chemical and botanical products	21
D22	C22	Rubber and plastics products	22
D23	C23	Other non-metallic mineral products	23
D24	C24	Basic metals	24
D25	C25	Fabricated metal products	25
D26	C26	Computer, electronic and optical equipment	26
D27	C27	Electrical equipment	27
D28	C28	Machinery and equipment, nec	28
D29	**C29**	**Motor vehicles, trailers and semi-trailers**	**29**
D30	C30	Other transport equipment	30

Continued on next page

Old code	New code	Industry	ISIC Rev.4
D31T33	C31T33	Manufacturing nec; repair and installation of machinery and equipment	31, 32, 33
D35	D	Electricity, gas, steam and air conditioning supply	35
D36T39	E	Water supply; sewerage, waste management and remediation activities	36, 37, 38, 39
D41T43	F	Construction	41, 42, 43
D45T47	G	Wholesale and retail trade; repair of motor vehicles	45, 46, 47
D49	H49	Land transport and transport via pipelines	49
D50	H50	Water transport	50
D51	H51	Air transport	51
D52	H52	Warehousing and support activities for transportation	52
D53	H53	Postal and courier activities	53
D55T56	I	Accommodation and food service activities	55, 56
D58T60	J58T60	Publishing, audiovisual and broadcasting activities	58, 59, 60
D61	J61	Telecommunications	61
D62T63	J62_63	IT and other information services	62, 63
D64T66	K	Financial and insurance activities	64, 65, 66
D68	L	Real estate activities	68
D69T75	M	Professional, scientific and technical activities	69 to 75
D77T82	N	Administrative and support services	77 to 82
D84	O	Public administration and defence; compulsory social security	84
D85	P	Education	85
D86T88	Q	Human health and social work activities	86, 87, 88
D90T93	R	Arts, entertainment and recreation	90, 91, 92, 93
D94T96	S	Other service activities	94, 95, 96
D97T98	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	97, 98

Appendix C

FIGARO included industries

	Code	Country		Code	Country
1	AR	Argentina	24	IN	India
2	AT	Austria	25	IT	Italy
3	AU	Australia	26	JP	Japan
4	BE	Belgium	27	KR	South Korea
5	BG	Bulgaria	28	LT	Lithuania
6	BR	Brazil	29	LU	Luxembourg
7	CA	Canada	30	LV	Latvia
8	CH	Switzerland	31	MT	Malta
9	CN	China	32	MX	Mexico
10	CY	Cyprus	33	NL	Netherlands
11	CZ	Czech Republic	34	NO	Norway
12	DE	Germany	35	PL	Poland
13	DK	Denmark	36	PT	Portugal
14	EE	Estonia	37	RO	Romania
15	EL	Greece	38	RU	Russia
16	ES	Spain	39	SA	Saudi Arabia
17	FI	Finland	40	SE	Sweden
18	FIGW1	Rest of the world	41	SI	Slovenia
19	FR	France	42	SK	Slovakia
20	HR	Croatia	43	TR	Turkey
21	HU	Hungary	44	UK	United Kingdom
22	ID	Indonesia	45	US	United States
23	IE	Ireland	46	ZA	South Africa

Appendix D

FIGARO included industries

Code	Label
A01	Crop and animal production, hunting and related service activities
A02	Forestry and logging
A03	Fishing and aquaculture
B	Mining and quarrying
C10T12	Manufacture of food products; beverages and tobacco products
C13T15	Manufacture of textiles, wearing apparel, leather and related products
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C19	Manufacture of coke and refined petroleum products
C20	Manufacture of chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacture of rubber and plastic products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment n.e.c.
C29	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacture of other transport equipment
C31_32	Manufacture of furniture; other manufacturing
C33	Repair and installation of machinery and equipment
D35	Electricity, gas, steam and air conditioning supply

Continued on next page

Code	Label
E36	Water collection, treatment and supply
E37T39	Sewerage, waste management, remediation activities
F	Construction
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
G46	Wholesale trade, except of motor vehicles and motorcycles
G47	Retail trade, except of motor vehicles and motorcycles
H49	Land transport and transport via pipelines
H50	Water transport
H51	Air transport
H52	Warehousing and support activities for transportation
H53	Postal and courier activities
I	Accommodation and food service activities
J58	Publishing activities
J59_60	Motion picture, video, television programme production; programming and broadcasting activities
J61	Telecommunications
J62_63	Computer programming, consultancy, and information service activities
K64	Financial service activities, except insurance and pension funding
K65	Insurance, reinsurance and pension funding, except compulsory social security
K66	Activities auxiliary to financial services and insurance activities
L	Real estate activities
M69_70	Legal and accounting activities; activities of head offices; management consultancy activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research
M74_75	Other professional, scientific and technical activities; veterinary activities
N77	Rental and leasing activities
N78	Employment activities
N79	Travel agency, tour operator and other reservation service and related activities
N80T82	Security and investigation, service and landscape, office administrative and support activities
O84	Public administration and defence; compulsory social security
P85	Education
Q86	Human health activities
Q87_88	Residential care activities and social work activities without accommodation

Continued on next page

Code	Label
R90T92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities
R93	Sports activities and amusement and recreation activities
S94	Activities of membership organisations
S95	Repair of computers and personal and household goods
S96	Other personal service activities
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	Activities of extraterritorial organisations and bodies

Appendix E

FIGARO adjustments and additional components

Code	Label
D21X31	Taxes less subsidies on products
OP_NRES	Purchases of non-residents in the domestic territory
OP_RES	Direct purchase abroad by residents
D1	**Compensation of employees**
D29X39	Other net taxes on production
B2A3G	Gross operating surplus

Appendix F

Czech and Slovak national accounts

In the following tables, the statistics obtained from Statistical office of the Czech Republic (2024) and Statistical office of the Slovak Republic (2024) are presented. Such statistics refer to the input-output tables comparable to the ones in our thesis, summarized for selected sectors in the year 2020. It shall serve to support the results obtained in the research. One should be aware of the fact, that the tables for the Czech republic are in the industry-to-industry type of interpretation, however, the Slovak tables refer to product-to-product, as the appropriate industry-to-industry is not available to this date. Yet, for supporting the sector linkages, this shall cause no issues.

In the table Table F.1, we can see the flows of intermediate inputs in between the selected sectors, namely *Agriculture*, *Food products*, *Chemicals and chemical products*, *Rubber and plastics*, *Basic metals*, *Fabricated metals* and *Motor vehicles, trailers and semi-trailers*, together with the final *Total intermediate flows* and *Total use* values. As our research suggested, we can see significant amounts flowing in between industries CZK_22, CZK_24, CZK_25 and CZK_29, as for instance approximately one third of intermediate inputs coming out from the Czehc *Rubber and plastic products* sector end up in the *Motor vehicle, trailers and semi-trailers* sector.

		01 Agr.	10 Food pr.	20 Chem.	22 Rubb. Pl.	24 Bas. met.	25 Fab. met.	29 Mot. Veh.	Int.	Total
01	**Agric.**	28 680	93 911	690	1 329	178	982	735	182 927	297 171
10	**Food**	28 064	39 085	4 150	3 375	232	636	1 736	122 600	463 394
20	**Chemical**	16 397	3 195	60 091	55 561	9 131	5 292	13 214	281 545	506 168
22	**Rubber**	995	3 186	2 416	45 800	954	8 743	88 272	251 470	441 296
24	**Bas. met.**	557	230	616	1 968	49 451	66 948	37 523	261 102	385 319
25	**Fab. m.**	511	1 320	2 499	4 354	8 580	69 327	75 008	302 077	538 937
29	**Mot. Veh.**	1 918	1 198	339	5 497	1 253	2 873	461 290	594 334	1 710 332
	Int.	142 336	216 256	170 683	183 747	142 388	238 619	969 153		
	Total	297 171	463 394	506 168	441 296	385 319	538 937	1 710332		

Table F.1: Intermediate flows in the Czech Republic (Million CZK)

On the other hand, in the Table F.2, we can see the technical coefficients for the selected industries. These are interpreted such, that for instance for creating 1 CZK worth of goods in the *Food products* sector, it needs 0.207 CZK worth of inputs coming out from *Agriculture*.

		01 Agr.	10 Food pr.	20 Chem.	22 Rubb. Pl.	24 Bas. met.	25 Fab. met.	29 Mot. Veh.
01	**Agric.**	0.0965	0.2027	0.0014	0.0030	0.0005	0.0018	0.0004
10	**Food**	0.0944	0.0843	0.0082	0.0076	0.0006	0.0012	0.0010
20	**Chemical**	0.0552	0.0069	0.1187	0.1259	0.0237	0.0098	0.0077
22	**Rubber**	0.0033	0.0069	0.0048	0.1038	0.0025	0.0162	0.0516
24	**Bas. met.**	0.0019	0.0005	0.0012	0.0045	0.1283	0.1242	0.0219
25	**Fab. m.**	0.0017	0.0028	0.0049	0.0099	0.0223	0.1286	0.0439
29	**Mot. Veh.**	0.0065	0.0026	0.0007	0.0125	0.0033	0.0053	0.2697

Table F.2: Technical coefficients for selected Czech sectors

Similarly, for Slovakia, we obtained the same tables, yet in the product-to-product interpretation. Firstly, it can be observed, that the sector *Food products* is not present in the case of Slovakia. This was caused by the fact, that the Slovakia Statistical Office states this sector in aggregation with multiple others, thus it is not possible to separate it from the rest. Second, the Slovak tables use Euro as its unit.

In the table Table F.3, we can see the intermediate flows in the Slovak Republic. Comparably to the Czech Republic, the linkages across the sectors SVK_22, SVK_24, SVK_25 and SVK_29, are visible.

		01 Agr.	**20 Chem.**	**22 Rubb. Pl.**	**24 Bas. met.**	**25 Fab. met.**	**29 Mot. Veh.**	**Int.**	**Total**
01	**Agric.**	290.6	66.2	63.8	0.5	4.1	5.3	1 453.4	3 747.6
20	**Chemical**	309.1	458.5	624.0	34.4	75.3	362.8	2 975.2	6 094.8
22	**Rubber**	15.2	52.2	566.3	8.9	82.1	1 319.4	3 427.6	6 813.4
24	**Bas. met.**	4.3	13.5	69.9	957.2	586.2	341.1	3 647.9	6 772.6
25	**Fab. m.**	9.6	17.8	93.3	354.2	1 045.7	1 264.2	4 862.0	8 985.5
29	**Mot. Veh.**	24.8	5.6	141.5	20.4	90.1	14 017.1	15 754.1	43 021.6
	Int.	1 672.1	1 621.2	2 604.6	2 901.3	3 650.9	23 734.4		
	Total	3 747.6	6 094.8	6 813.4	6 772.6	8 985.5	43 021.6		

Table F.3: Intermediate flows in the Slovakia (Million EUR)

Analogously, in the Table F.4 we can see the table of technical coefficients for the selected sectors. The interpretation is yet again similar, as for example the *Motor vehicles, trailers and semi-trailers* sector needs 0.031 Eur worth of inputs coming from *Rubber and plastic products* for creating 1 Eur worth of output.

		01 Agr.	**20 Chem.**	**22 Rubb. Pl.**	**24 Bas. met.**	**25 Fab. met.**	**29 Mot. Veh.**
01	**Agric.**	0.078	0.011	0.009	0.000	0.000	0.000
20	**Chemical**	0.082	0.075	0.092	0.005	0.008	0.008
22	**Rubber**	0.004	0.009	0.083	0.001	0.009	0.031
24	**Bas. met.**	0.001	0.002	0.010	0.141	0.065	0.008
25	**Fab. m.**	0.003	0.003	0.014	0.052	0.116	0.029
29	**Mot. Veh.**	0.007	0.001	0.021	0.003	0.010	0.326

Table F.4: Technical coefficients for selected Slovak sectors