Battery Conflict: A New Frontline in the US-China Trade War

Abstract

The rising concern about the harm of traditional petroleum gas towards the environment and the emerging EVs generate new economic hotspots. The U.S. and EU issued new trade on China battery products. This alters the energy market to a new course. This thesis analyzes the ongoing trade war in the battery field with the Global Simulation Model. Results indicate the success of the U.S. and EU's new policies. It also indicates the robustness of the Chinese battery industry.

Content page

1. Introduction 4
   1.1. Background 4
   1.2. Research Question, Sub-Research Questions, and Objectives 6
   1.3. Research Design and Methodology 6
   1.4. Thesis Structure 7
2. Literature Review 8
   2.1. The long-root history between China and the US 8
   2.2. The Rise of the "New Energy Car" 9
      2.2.1. China 9
      2.2.2. United States 10
      2.2.3. European Union 12
      2.2.4. The World 12
   2.3. The Growth of Lithium-ion Battery Market 12
      2.3.1. General growth 13
      2.3.2. China 14
      2.3.3. United States 16
      2.3.4. European Union 17
   2.4. The New Front Line 18
      2.4.1. China 18
      2.4.2. United States 19
      2.4.3. European Union 20
   2.5. Trade Value of Lithium-ion Batteries 20
      2.5.1. The U.S. Trade Flow 21
      2.5.2. China Trade Flow 22
      2.5.3. South Korea Trade Value 23
      2.5.4. Germany Trade Value 24
      2.5.5. Japan Trade Value 26
      2.5.6. Poland Trade Value 27
      2.5.7. Hungary Trade Value 27
3. Methodology 29
   3.1. Econometric Model Selection 29

3.2. Global Simulation (GSIM) model 30
3.2.1. Elasticities Part 30
3.2.2. Individual Demand and Supply Conditions 30
3.2.3. Global equilibrium conditions 31
3.3. Data Selection 31
3.3.1. Country Selection 31
3.3.2. Scenario development 32
3.3.3. The Data Calculation of Trade Value of Candidate Countries 33
3.3.4. Summary 42
3.3.5. Elasticities 42
3.3.6. Tariffs 43
3.3.7. Non-tariff measures 44
4. Results and Analysis 45
4.1. Scenario 1: US industrial policy on batteries 45
4.1.1. Output Changes 45
4.1.2. Welfare Change 46
4.1.3. Change in Battery Trade 48
4.1.4. Change in prices for batteries 49
4.2. Scenario 2: EU industrial battery policy 49
4.2.1. Output Changes 50
4.2.2. Changes in Welfare 51
4.2.3. Changes in battery trade 52
4.2.4. Change in prices for batteries 53
4.3. Scenario 3: Combined effects of both US and EU policies on batteries 53
4.3.1. Output Changes 54
4.3.2. Welfare Change 54
4.3.3. Change in battery trade 55
4.3.4. Change in prices for batteries 56
5. Conclusions 57
5.1. Key takeaways from the research 57
5.2. Limitations and areas for further research 58
Bibliography 59

1. Introduction

1.1. Background

There is a Chinese saying that thick ice doesn’t form in one day. Tensions between the two world's largest economies have been going on for years. Despite a decade-long honeymoon between 1979 and 1989, and an economic boost beginning in 2000, national security, political system disputes, and narrative conflict have finally come on top of what economists would suggest: fair trade.

This precious market that is vital to both the China and US in terms of their political interest. China, since the beginning of the opening-up period has been utilizing the power of national mobilization, natural endowments, and human resources to create huge economic leaps. Its infrastructure projects and real estate have brought silver and gold to China at their peaks. But now, these ambitious programs have fulfilled their mission and brought both treasure and long-lasting side effects. Searching for a new path, China’s national strength is tested in this new energy field.

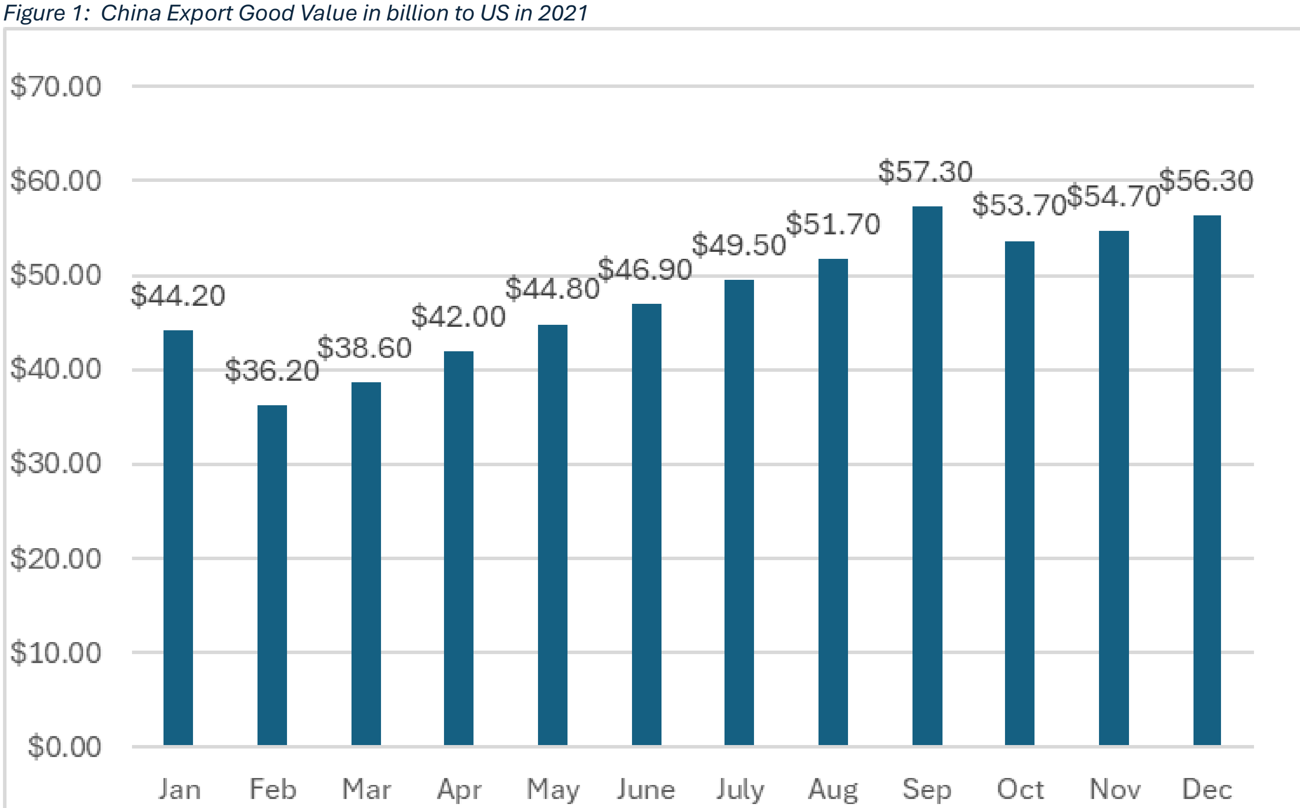
The beginning event of the trade war was marked by the action of the Trump administration by placing 25% duties on products worth $34 billion imported from China. Retaliating, China put the same 25% duties on US products worth $34 billion, targeting various pillar industries in the US. The resulting tariffs are 550 billion US dollars and 185 billion US dollars on US and China goods respectively (Andrew Mullen, 2022).

Beyond the direct cause of the tariff war. The Trade War between China and the US is the result of a series of political distrusts and economic imbalances which rooted in the relation between China and the US many years before it happened.

China's trade surplus with the US was about 400 billion US dollars in 2022, which was 37% higher than the previous year (Jürgen Matthes, 2024)

The China-US phase-one economic and trade agreement coming along with COVID-19 temporarily calmed down the frictions on the economic and trade front. Despite the US increased tariffs on US$200 billion worth of Chinese goods (Andrew Mullen, 2022). The export of China goods to the US in 2021 remained consistent growth within year shown in **Figure 1** (孙承, 2021).

Figure 1: China Export Good Value in billion to US in 2021



Source: Source: Author via General Administration of Customs of the People's Republic of China

The trade data indicates that although the U.S. government continues to pursue the path of "decoupling" from China and promotes international trade toward trustworthy trading partners, the China-US trade volume still reaches its new highs. The newly emerged EVs greatly trigger the demand for EV batteries, specifically the Ion Lithium Battery which is currently the main power source for the EVs due to its high energy density, stability, and heat resistance (POWEROAD, 2023). Affected both by Covid and economic tension, China is experiencing economic difficulties, with low fertility and high unemployment rate among the young generations. China has greatly increased the battery production hoping for utilizing it as a new economic growing point. Confronted by the Biden Administration, the battle around the battery product became the new front line of this ongoing China-US trade war.

As the future will increasingly depend on electric power, China and the US are two of the biggest economic powers in the world. China also has a historical pathway to utilize national strength to focus on economic trigger points to power up its economy. The US, on the other hand, is sensitive of anything that is related to its automobile industry. Cheap and solid Chinese batteries can be seen as a threat to its traditional gas engine. How will the lithium-ion battery industry be affected by the clash of economic and political disputes, will shed light on the energy market. And it also provides hints for Chinese readers who are interested in investing in the Chinese market.

1.2. Research Question, Sub-Research Questions, and Objectives

The demand for lithium-ion batteries in terms of gigawatt-hours globally is estimated to be around 700 gigawatt-hours in 2022, and 4,700 gigawatt-hours in 2030 (Statista Research Department, 2024). The decarbonization effort crucially relies on the development of lithium-ion batteries, thus the demand can surpass 2.4 million metric tons of lithium carbonate by 2030 (Jennifer L, 2024).

The main research question is: What is the impact of US and EU lithium-ion battery industrial policies for the global market dynamics and affect the distribution of global market shares, in particular the position of China?

We define 'economic and trade market dynamics' as changes in welfare and production effects. Trade market dynamics are the effects on exports and imports. To fully answer the research question, we also need to be able to answer the sub-questions. These are defined as follows:

1. What is the nature of the current ongoing trade war regarding lithium-ion batteries in terms of measures taken by parties to the conflict?
2. How do these measures affect the supply chains and costs of production in different parts of the world?
3. Who will benefit and who will lose from the lithium-ion battery trade war between the US and China?
4. What methodology can best be used to answer the research question?

1.3. Research Design and Methodology

In this thesis, we will start by using desk research to look at the context of the conflict, the measures taken by the parties, and what other studies have been done to look at this issue. We then employ the global simulation model (GSIM) partial equilibrium model, using tariff and non-tariff measure (NTM) data applied to the lithium-ion battery, to look at the economic and trade effects of the conflict. GSIM is useful for analyzing global policy changes (Francois & Hall, 2002). GSIM enables us to calculate the Producer Surplus (PS), Consumer Surplus (CS), and tariff revenues based on the inputs of trade flow, tariffs, and NTMs. But most importantly GSIM allows us to look at trade and production effects as well. Data retrieved from various sources will be used as the data for the model.

1.4. Thesis Structure

The structure of the thesis will consist of five chapters. Chapter 1 is the general introduction of the thesis. Chapter 2 will include a literature review of the lithium-ion market. The current state and how the new front line is formed with papers and regulations from multiple sides. It will also cover the back stories about the long-rooted problems between China and US relationships. Chapter 3 will introduce the GSIM model which will be used in this thesis. We explain in detail how the model works, how the targeted countries will be chosen, and what data are needed. In Chapter 4 we will explain the results from the computations and provide a detailed analysis of these outcomes. A sensitivity analysis will also be included in this chapter. Chapter 5 will summarize the key takeaways of the research and also provide insights for the Chinese readers to further help them analyze the economic trajectory of the Chinese economy and present areas for further research.

2. Literature Review

2.1. The long-root history between China and the US

When Kuomintang (KMT) was defeated in mainland China, Chiang Kai-shek (leader of the KMT) with his remaining troops retreated to Taiwan Island were located in the southeast of China, separated by the Taiwan Strait. Mao and his generals' initial plan to liberate Taiwan was planned in 1950 but was postponed due to the lack of preparation in both the Navy and Air Force. 1950, China engaged in the North Korean War, fighting the Army of United Nations Command led by the USA military. The USA sent its fleet to the Taiwan Strait to prevent the PLA from crossing the water. Interrupted by the war, Mao's liberation plan was never executed. After a series of economic difficulties, China's reopening to the world began in the year 1987. In the year 2001, China successfully joined the WTO, with the agreement of terms of non-discrimination, openness, reciprocity, fairness, and transparency (United States Trade Representative, 2023). China's economic growth was about 49% between 2002 and 2006, and 43% between 2007-2011, regardless of the financial crisis that took place in 2008 (Jing Li, Ye Liu, and Yinggang Zhou, 2023). Before the accession of WTO, exports from China to the US were subject to a non-NTR (normal trade relation) tariff, which could result in a 31% tariff. China's exports to the US plumped in the middle of the first 10 years of 2000 (Bilge Erten, Jessica Leight, 2022).

Despite the claim from China that all the terms of the agreement have been kept and fulfilled, the US deemed that China poorly kept those terms in check. Several activities such as technology transfer, indigenous innovation, investment restriction, bad faith trademark registration, online infringement, counterfeit goods, and many other issues are recorded and reported by the US (United States Trade Representative, 2023).

Came to power in 2012, Xing Jinping abolished previous leader Deng's "keep a low profile and concentrate on self-improvement" strategy. With a much stronger attitude in many aspects of technology, economy, and military, China began to stand strong against the US on many of the international issues. China's ambitious The Thousand Talents Plan or Thousand Talents Program (TTP), launched in 2008, introduced 4180 talented people in 2016 (Taiwan Science Park, 2016). The remaining status of the project is unclear due to the increased confidentiality level. The US reckoned it as a major threat to its national intellectual capital (UNITED STATES SENATE, 2019). Constitution of the People's Republic of China in 2018 was seen as a significant change in political power in China and a potential preparation for the war against Taiwan. Therefore, the trade war between China and the US is far more than trade imbalance and protection, but a result of long-rooted political distrust and misalignment.

2.2. The Rise of the "New Energy Car"

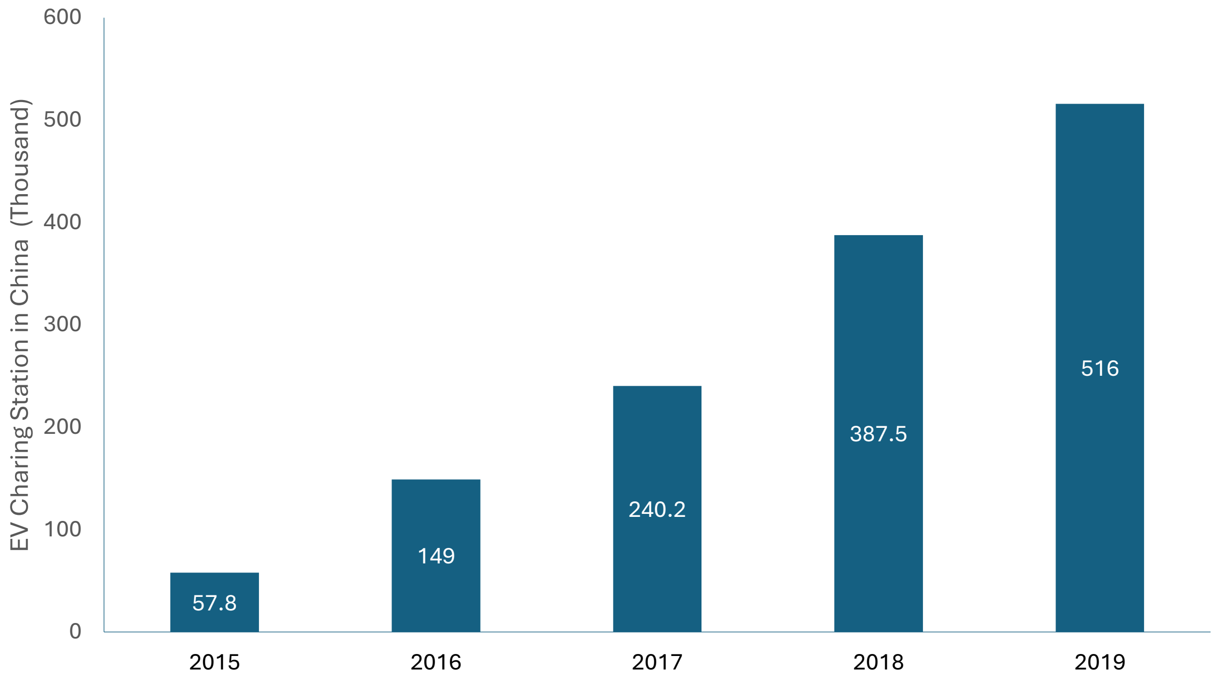
2.2.1. China

The "New Energy Car" is a special term that is commonly used in China. Currently, in 2024, China, the US and Europe are the three largest EV markets in the world (Justyna Matuszak, 2024). Emerged in 2008, the EV in China had sold 2435 units. After a decade of development, the EV market has come to mature, and electric charging stations are widely installed, rising from 57.8 thousand in 2015 to 516 thousand in 2019, almost double of the original year (电动势, 2021).

By the end of 2019, the amount of the EVs on road in China had reached 4.92 million, which took part of half of the global total (ICCT, 2021). China is also the largest EV sales country in the world in 2021 (Zhongshang Industry Research Institute, 2023). The Chinese government also pushed a series of policies to help the growth of EV market, including "Continuing to carry out activities to bring new energy vehicles to the countryside", "Vehicle purchase tax reduction policy extended to the end of 2027", "Targetedly solve problems such as difficulty in finding charging stations" (刘志强, 2023). In year 2023, EV production in China had reached 67.94 million (刘潘, 2024). Accompanied with the EV development, the number of charging stations also increased.

Figure 2 shows the change in the number of electric charging stations in China from 2015 to 2018. The Chinese EV industrial scale achieves rapid growth, forming a complete industrial chain with strong competitiveness and the global competitiveness of enterprises has been significantly enhanced. With the overcapacity of domestic production, China has made EVs a new powerhouse for economic development (Frank Chen, 2024).

Figure 2: 2015-2019 Electric Charging Stations in China. Number in Thousand

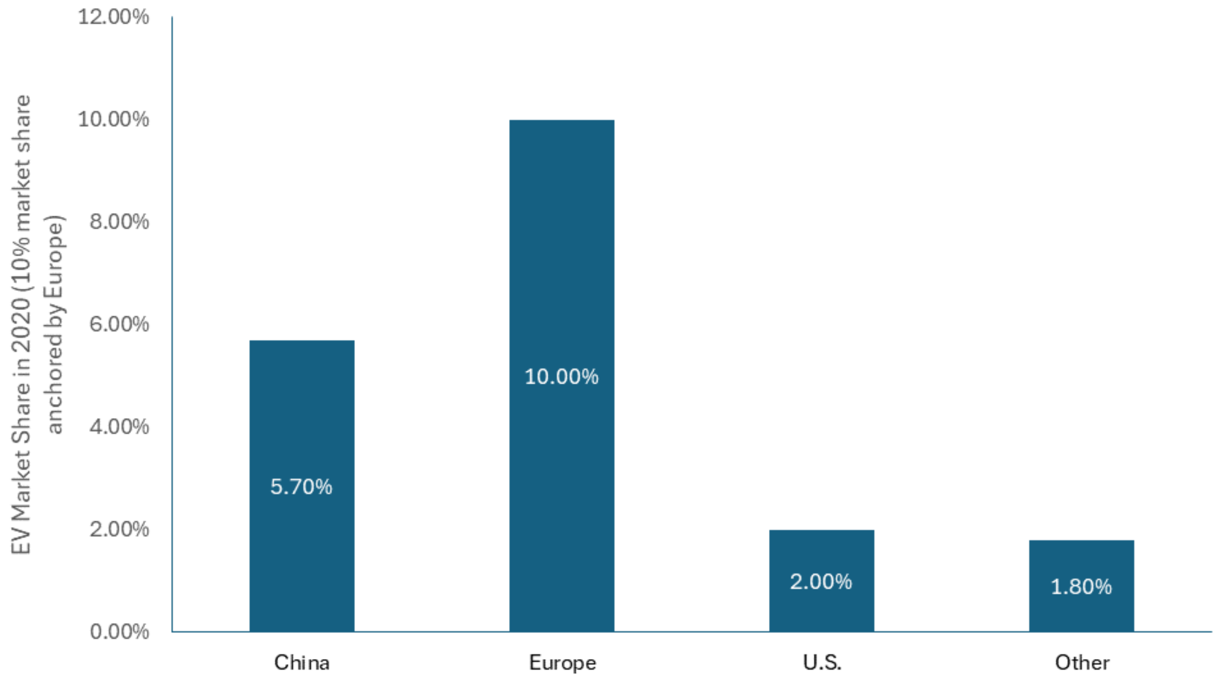


Source: author via Electric Dynamics

2.2.2. United States

Because of the development of EV batteries and mass-scale production, the costs of EVs decreased over the past 10 years. According to a report in 2018, the costs for Lithium-ion batteries would halve in 2030 (European Commission, 2018). The sales of electric vehicles is estimated to take up 29.5% of all new car sales in the US in 2030 (evadoption, 2017). In 2018, 1.8 million EVs were registered in the US. However, the growth of the EV market was slower in the US than in China and Europe, as shown in **Figure 3 (**DREW DESILVER, 2021)**.**

Figure 3: EV Market Share in 2020 (10% market share anchored by Europe)



Source: author via International Energy Agent, PEW RESEARCH CENTER

Affected by traditional gas cars, people in the US are slow reacting to the newly emerged EV technology compared to the Chinese and Europeans. According to a survey published in 2023, half of adult Americans did not plan to buy an EV. Of the 9% of adult Americans who already owned EVs or hybrid-engine cars, 68% of the same group are very or somewhat likely to consider buying them. Saving both money and the environment are the two major motives for the purchasing groups. Interestingly, pro-Democrats, people who live in urban areas, and younger generations are more likely to say that they want to buy EVs (ALISON SPENCER, STEPHANIE ROSS, AND ALEC TYSON, 2023). The number of charging stations in the US has increased from 29,000 in 2020 to over 61,000 in 2024 (SAMUEL BESTVATER AND SONO SHAH, 2024). Biden Administration declared a bold claim that “half of all new cars and trucks sold in 2030 would be zero-emission. Together, we’ve made historic progress. Hundreds of new expanded factories across the country. Hundreds of billions in private investment and thousands of good-paying union jobs. And we’ll meet my goal for 2030 and race forward in the years ahead.” (Coral Davenport, 2024). The supportive policies from the US government will further increase the growth of the EV market in the US. However, EV cars are facing competition from the traditional gas vehicle industry. Given America’s vast territory and lengthy road net, many Americans don’t want to center their lives on finding the charging post. A report revealed that Cobalt, a vital element in the battery is mined in Democratic Republic of Congo. That minefield is under the control of the Chinese authority, where child labor is working in a toxic working environment (JASON ISAAC, 2024). Only 5% percent of lithium-ion batteries worldwide had been recycled in 2022 (CAS Science Team, 2022). “Biden announced that he would quadruple tariffs on Chinese EVs to 100 percent and triple tariffs on Chinese lithium-ion EV batteries to 25 percent.” (Frederik Kelter, 2024).

2.2.3. European Union

The EV market in Europe is steadily expanding. In the year 2024, the market share for plug-in vehicles is 21%. While battery electric vehicles (BEVs) take up 14%. The diesel vehicle registrations declined by 11% yoy, indicating a potential drop-out of the diesel vehicle in the near future (European Commission, 2024). In the EU, about 13.8 million jobs depend on the automobile industry. Among the EU market, Chinese brand EVs have made a significant advance in market share, increasing from 0.5% in 2019 to 8.2% in 2023 (Frederik Kelter, 2024). By the coming year of 2026, the report estimated that there will be 4.4 million EVs sold in E.U. (Martin Armstrong, 2022). VAT for automobile purchases ranges from 17% to 25% in the EU (Maria Chaplia, Anna Arunashvili, Rati Gvasalia). Many European countries provide incentives for the purchase of EVs including tax deductions and bonuses (acea, 2024). The exact policies will not be elaborated.

2.2.4. The World

The global market size of EVs was USD 388.1 billion in 2023 and is projected to reach USD 951.9 billion by 2030 (MarketsandMarkets, 2023). The volume growth was 35% yoy in 2023 and had reached 14.2 million units (autovista, 2024). By the year 2022 fourth quarter, 20% of the automobile market will be EV (DANIEL BLEAKLEY, 2023). The global market for EVs could make up 35% of the new sales according to the annual report of the International Energy Agency (Dan McCarthy, 2023). It is safe to conclude that the EV market will continue to grow in a fast pace before the year 2030. And the market will not cease to expand until 2050. With the consistent growth of the EV market, the demand for EV batteries, especially the Lithium-ion battery will always be stronger.

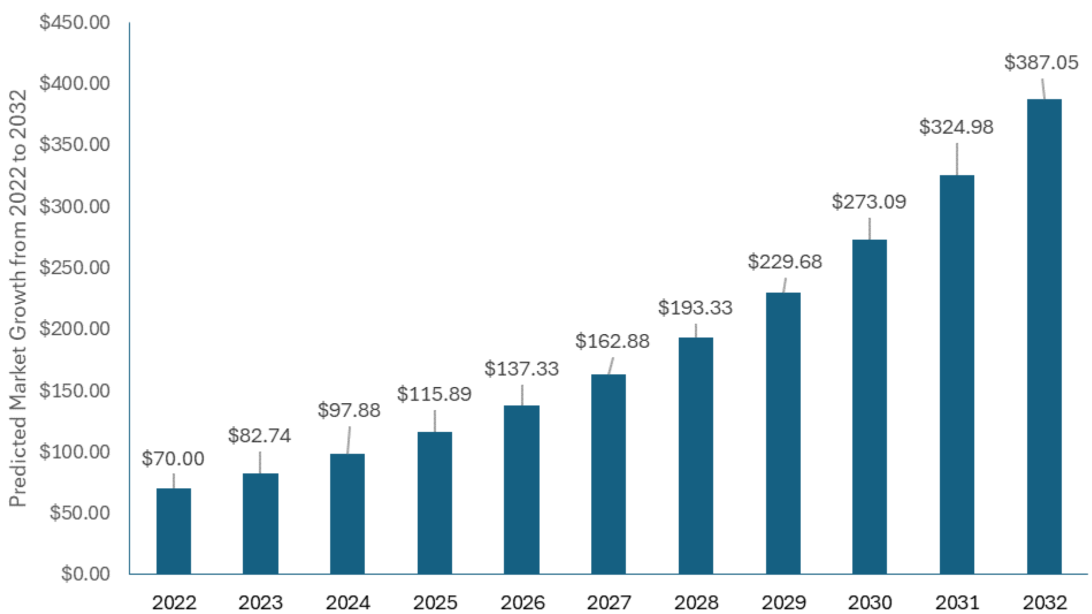
2.3. The Growth of Lithium-ion Battery Market

2.3.1. General growth

The success of the EVs and the development of EV batteries are mutually beneficial to each other. Due to other factors like the trend of decarbonization and mass-scale production of EV batteries, the price for lithium-ion batteries will continue to drop. As it is likely going to be one of the most important markets in the future, and a pillar industry for many countries as well, it is crucial to understand the status of the market.

"According to the International Energy Agency (IEA), up to 40% of the cost of the EV is made up of the battery." (Fransua Vytautas Razvadauskas Bio, 2023). The increased demand for EVs becomes the main driving force for the batteries, especially for the lithium-ion batteries, which are the most commonly used in EVs (Dragonfly Energy, 2022). Between the years 2021 to 2022, the demand for GWh in batteries increased by 65%. In year 2022, 60% of Lithium and 30% of Cobalt were mined for EV batteries (International Energy Agency, 2023). The global market size for Li-ion batteries was valued at USD 59.8 billion in 2022 (market.us, 2023). In year 2023, the value increased to about USD 70 billion (PRECEDENCE RESEARCH, 2023). By 2033, the market size is expected to reach USD 470.5 billion thanks to the demand for automobile and energy storage systems (Dimension Market Research, 2024). **Figure 4** shows another similar report of the world's lithium-ion market growth.

Figure 4: Predicted Market Growth from 2022 to 2032

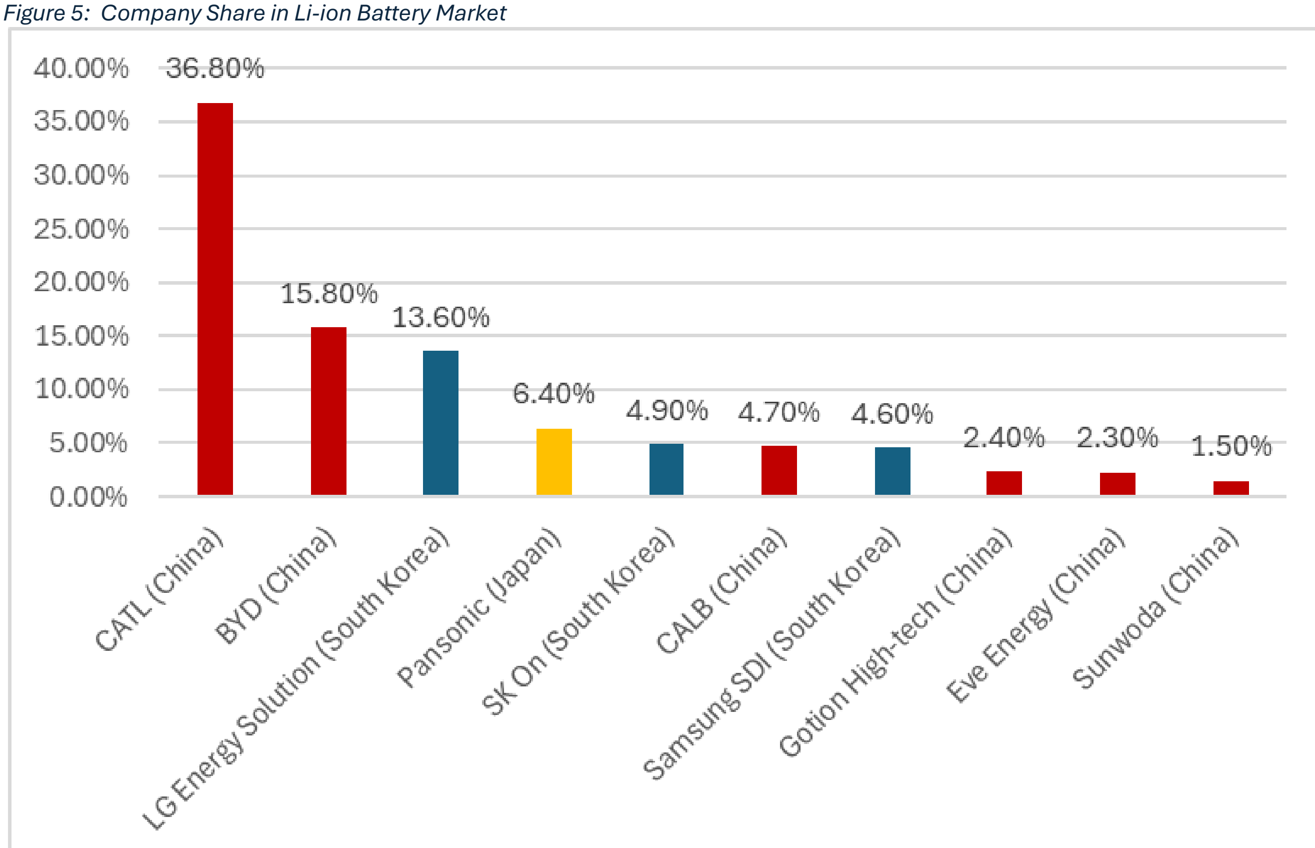


Source: author via precedence research

2.3.2. China

The lithium-ion battery industry in China is seeing rapid growth. Early in 1990-2010, Lithium-Ion battery production was mainly dominated by Japan and Korea in the Asia market. From 2010 to now on, battery production gradually transits from 3C supportive (computer, communication, and consumer) to EV battery power (刘强 and 李若飞, 2020). In the year 2022, the Contemporary Amperex Technology Co. (CATL) which is a Chinese state-owned company, also an enterprise directly under the central government's control, single-handedly contributed 35% (**Figure 5)** of the Li-ion battery market of the world (China Briefing, 2022). Electric vehicles, Lithium-Ion batteries, and solar panels have become the "New Three Commodities" in China, with export value exceeding USD 1 billion (Shenzhen Custom, 2024). The Li-ion battery took part of 43.15% of the "New Three Commodities", reaching the value of USD 4.574 billion (森宁, 2024).

Figure 5: Company Share in Li-ion Battery Market



Source: Author via statista

According to the statistic of the National Bureau of Statistics of China, the Li-ion battery production had reached 232.6 billion units in the year 2022 (观研报告, 2022). However, China's Li-ion battery industry also faces problems in terms of quality control, raw material dependency, and unregulated production due to the repaid growth in recent years of development. (China Briefing, 2022). There are heavy domestic competition in the field of price, delivery time, after-sale service, and many other aspects. In order to solve the issues, the Chinese authorities have published a series of policies to help regulate the battery industry. In one of the guidelines, by 2025, the system cost of the battery should be lowered by 30%. 2030 will be the year that the battery business be fully marketized (National Development and Reform Commission, 2021).

The global value of export of Chinese lithium-ion batteries was USD 65 billion in 2023, rising up to almost 400% prior to the year 2019. The USMCA (United States-Mexico-Canada) and EU are two of the largest importing regions. Nearly half of the Chinese lithium-ion batteries were shipped to those areas (Joseph Webster, 2024). This indicates that despite the decoupling effort, China is still and will probably still be the largest batteries provider for the Western countries.

The US is the largest importing country for Chinese batteries. Coming next are Germany and South Korea, reaching the value of USD 3.934 billion, USD 3.382 billion, and USD 1.175 billion respectively. (Energy Trend, 2024).

Currently, China is facing the outflow of raw materials in order to meet the needs of the Western market. After the passing of the "Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC". The added cost of the post-sale, battery identification, and battery recycling regulation formed a new none-tariff measurement (NTM) for the Chinese battery exporters.

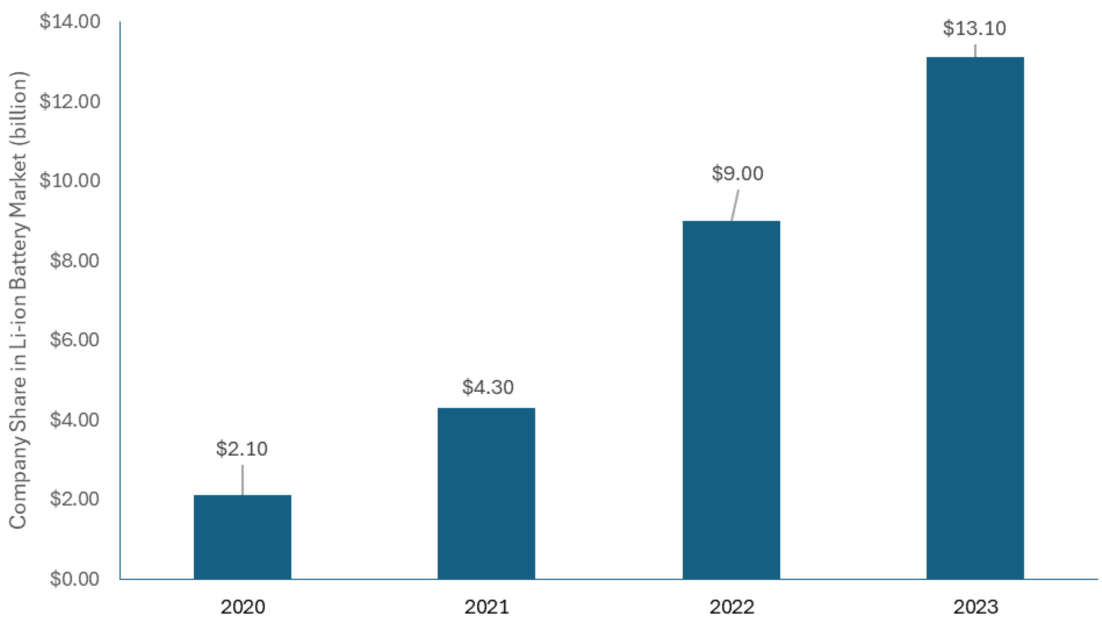
The administration of China issued new guidelines aiming to reduce the scale of domestic battery manufacture, putting effort into mitigating the negative consequences of overproduction (Reuters, 2024).

2.3.3. United States

The United States had developed the power battery for vehicles earlier than China. However, the technological advantage didn't fruit in business advancement. China Li-ion battery production came on top utilizing its industrial scale and superior labor force. The A123 company which was backed by the Obama administration, went bankrupt and was scooped by a Chinese Wanxiang Group Corp that specialized in parts making (Kevin Dolak, 2012). The market for Li-ion batteries was USD 9.98 billion in 2023 (Research and Markets, yahoo!fiance, 2023). While other reports estimated that the market size was USD 33.7 billion (Fact.Mr, 2022) and USD 13.7 billion (Custom Market Insights, 2024). Reports estimated that this value will grow to USD 33.61 billion in 2028 at CAGR (GLOBE NEWSWIRE, 2023). For North America, the market value in 2023 was USD 18.4 billion (GMI, 2024). These reports indicate that the US remain the largest Li-ion battery market in North America in 2023, contributing around or more than half of the market share.

Although slowly expanding compared to China, the imported Li-ion batteries from China took up a major portion of the total import of the Li-ion batteries of the US. The value of the import was at 70% of the total market share (Joseph Webster, 2024). The growth rate was 31.29% compared to the year 2022. **Figure 6** shows the growth pattern of the battery value imported from China in the US.

Figure 6: Company Share in Li-ion Battery Market



Source: Author via statista

The large portion of the import of Chinese batteries has alerted many U.S. politicians, worrying that this will continually worsen the integrity of the US energy independence.

Biden Administration had announced USD 3.5 billion to further strengthen the U.S.A battery production and battery materials development (U.S. Department of Energy, 2023). Also the tax credits for battery production up to USD 45 per kilowatt hour (European Court of Auditors, 2023). Before the year 2035, the Department is trying to achieve 100% zero emission for non-tactical vehicles in order to be in alignment with the Administration guidance in Executive Order 14008 (Installation Energy). The future market size for Li-ion batteries will continue to grow given the policies and demand in EVs.

2.3.4. European Union

The pursuit of the decarbonization of Europe causes high demand in the battery market. The Lithium-ion battery stationary market in the EU was valued at USD 19.7 billion in 2022 (GMI, 2023). The Li-ion battery market sales were valued at USD 11.7 billion by 2023 and will grow to USD 12.6 billion in 2024 (Persistence Market Research, 2023). European countries have launched multiple projects to increase battery production such as Northvolt in Sweden (with 350 million euros provided by European Investment Bank) and Verkor in France. Europe could achieve two-thirds of the Li-ion battery production of self-sufficiency. After around 2026, Europe could be self-sufficient in Li-ion battery production (Transport & Environment, 2024).

The giga factories for battery production in Europe is facing a major obstacle of raw materials reliance. The EU is relying on the international market to import the crucial raw materials for Li-ion batteries.

Table 1 shows the raw materials dependency of Europe.

Table 1: Raw Material Dependency

Raw Material	Cobalt	Lithium	Manganese	Nickle	Natural graphite
Import rate	81%	81%	96%	31%	99%

Source: author via The EU's industrial policy on batteries

Europe, alongside with the U.S, are facing massive pressure from the peer leading cell industry of China. The Chinese battery can be 15% cheaper than the counterpart in the U.S. (BENCHMARK SOURCE, 2023). With Chinese production's advantage in price and quantities, Europe must put more effort into solving its supply chain issue.

2.4. The New Front Line

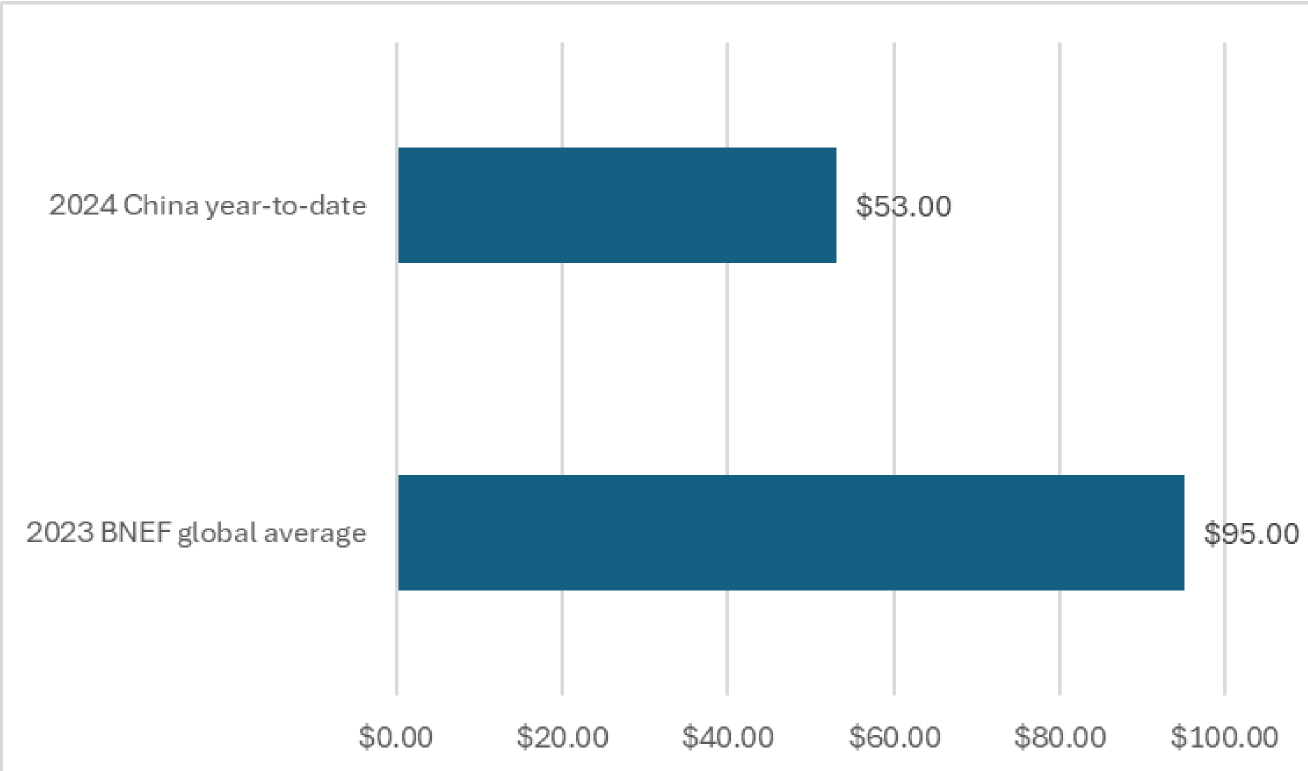
The rise of the EV industry drives high demand for the Li-ion battery market. As China is facing multiple issues in the economy such as declining property investment, debt risk, and poor consumption growth (Jiao Wang, 2024), the Chinese authority is trying to push harder on the high-tech sectors, hoping the export of the "New Three Commodity" can become the new powerhouse for the Chinese economy. Li-ion batteries are a prominent power source for unmanned underwater vessels, unmanned surface vessels, FPV (first-person view) drones, and conventional submarines (Joseph Webster, 2024). An article pointed out that many U.S.A. military pieces of equipment are now powered by Chinese battery cells (THOMAS CORBETT and PETER W. SINGER, 2024). Big or small, batteries are also widely used in many military equipment or pieces. The extraordinary export record achieved by China in these three commodities (EVs, Li-ion batteries, and solar panels) threatens the effort of re-industrialization and has altered the Western countries and regions especially the EU and the US.

2.4.1. China

The Chinese battery research plan was largely funded by the Five-Year Plan's National Key Research and Development Program (NKRDP) and the National Natural Science Foundation. In March 2024, the Qingdao Institute of Bioenergy and Bioprocess Technology announced a new production method claiming that it can enhance the battery charge performance and prolong the battery age (青岛生物能源与过程研究所, 2024). This breakthrough could solidify the already leading position of China in the battery business (THOMAS CORBETT and PETER W. SINGER, 2024). According to SMM, China has obtained an absolute advantage in the upstream position of battery manufacturing (SMM, 2024).

The overproduction of battery cells also pushes Chinese companies to seek overseas opportunities. The low price of Chinese batteries gives it a significant advantage over Western battery products. Given by a report, the price can be as much as 44% lower, as shown in **Figure 7**. The cost difference was valued to be 20% by another report (Transport & Environment, 2024).

Figure 7: Cost of lithium-ion phosphate cell batteries in $/kWh



Source: author via BloombergNEF, ICC Battery

2.4.2. United States

An unclassified report to the prior U.S.A. President Donald Trump stated that up till 2018, the U.S.A. military lacked its domestic battery supply base, and the supply base is diminishing due to the foreign market comparable advantages. One of the non-rechargeable batteries was outsourced to France while many of the rechargeable batteries were coming from Asian areas such as China, South Korea, and Taiwan (Interagency Task Force in Fulfillment of Executive Order 13806, 2018). The reason behind it was partially caused by the lack of demand in EVs because of the US's low charging station number.

In recent years, the United States government started to subsidy the battery industry in order to keep up with the competition of the globe. In year 2022, the Biden Administration passed the Inflation Reduction Act (IRA). The Act requested the battery installed in the purchased EVs must contain a certain percentage of raw material that was either produced within the US or by countries that signed a Free Trade Agreement (FTA) or Critical Mineral Agreement with the US. This percent was 50%-40% in 2023, was expected to reach to 100% to 80% in 2028 (SMM, 2024).

On May 14th, the White House increased the tariff for Chinese EVs and Lithium batteries. The tariffs for EV was significantly high, increased from 1974's 27.5% to 102.5%. The Biden administration announced that it would increase the battery tariff for Chinese lithium-ion battery from 7.5% to 25% (Cameron Murray, 2024). The tariffs for lithium batteries made in China was now on 25% (He Weiwen, 2024). Many would argue that outsourcing battery production would enable the natural endowment to be fully utilized, but the US government thought that this could indeed lower the battery cost and benefit the US customers but it could also damage the US economy in the long run, as losing battery production ability will further lower the U.S industrial level and give away a "know-how" in favor of its opponent countries. Drones and submarines are increasingly important in modern warfare, and the robust production ability of China could provoke uncertainties in Taiwan, threatening Taiwan and the US democratic values (Joseph Webster, 2024).

2.4.3. European Union

The National long-term strategies that cover 26 of the European countries set aim to reduce carbon footprint (European Commission). The decade-long battery productions centralized in Asia had made Europe lag behind the competition. As batteries are a means of clean energy transition and a key element for the automotive sector (EUROPEAN COURT OF AUDITORS, 2023), it increasingly improves the capability of domestic production to meet the goal of self-sufficiency. Given the situation that the battery value chain is not complete, Europe currently faces a dilemma of decarbonization and deindustrialization. It has no choice but to largely rely on imported batteries.

The Chinese battery took up 37% of the European market (Global Times, 2023). Currently, the EU imposed the lowest tariff on China batteries compared to its allies, with only 1.3%. For the US it's 10.9%. The report suggests that the EU tariff should be raised to at least 20% by 2027 to counter Chinese imports (Transport & Environment, 2024).

A state aid subsidy had been issued by the EU to back up the battery factories at around 2023. The aid was at approximately 4 billion euros (Lisa O'Carroll, 2024). Unlike the policy of the U.S., it not only subsidizes its own but also the value chain of battery manufacturing. The coverage is much wider.

2.5. Trade Value of Lithium-ion Batteries

With the country selection complete, we can now proceed to collect the country trade flow data. The commodity will only be one product, the lithium-ion battery cell. According to the European Customs Portal, the HS code for lithium cells and batteries is 850650 (European CustomsPortal, 2024). There are also further sub-categories under this HS code but since the trade values we are going to retrieve are from the UNCOMTRADE, which can only accept HS codes in 6-digit form. Therefore we won't take this further step.

According to the results of UNCOMTRADE, the trade value from China exported to the U.S. was USD 55,870,467, using the HS Code 850650, which was far less than the reports from other sources. We estimated that the value of the U.S. imported Chinese lithium-ion batteries was around 13.1 billion (JOHN MILLER, 2023). There is a huge cape between these two data. Therefore, we must give up using the HS Code in UNCOMTRADE and retrieve data from other statistics websites, even though it has proved to be far more difficult.

The global lithium-ion battery market by import and export size was hard to find. However, according to Joseph Webster, the lithium-ion battery that China exported in 2023 was USD 60 billion. In year 2022, China had taken up around 70% of the U.S.A battery import value in USD (Joseph Webster, 2024). We can use a simple mathematical technique to calculate the other portion of the U.S. imported lithium-ion battery market by dividing the 13.1 billion (imported from China) by 70%.
$US\ TOTAL\ BATTERY\ IMPORT = \text{CHINA BATTERY VALUE} \div \text{CHINA BATTERY PERCENTAGE}$

We get a crude estimated conclusion that the global lithium-ion battery trade market was at around USD 18.714 billion.

2.5.1. The U.S. Trade Flow

In a report of the year 2023, the U.S. imported batteries from South Korea was USD 1.3 billion and from Japan was USD 1.0 billion (Felix Richter, 2023). The value of the battery imported from Hungary was USD 41.9 million (OEC, 2024). And the value imported from Poland was USD 42.5 million (OEC, 2024). It was difficult to check the value of the battery the U.S. imported from Germany but through a reverse search, we acknowledged that Germany exported the battery for USD 1.6 billion (OEC, 2024).

Although the UK and Sweden ranked top 10 battery manufacturers in our ranking list. The battery export and import values for these two countries was very difficult to search for. Therefore we will exclude these two countries in our further research.

The ROW should be the global value minus the sum of the selected countries. The result was USD 1.573 billion. To conclude the result, the trade value of the US to other countries is shown in **Tabel 2** below.

Table 2 The U.S. Import in Billion Dollar

China	South Korea	Japan	Hungary	Poland	Germany
$13.10	$3.54	$2.00	$0.42	$0.43	$1.56

Source: author via oec result

For the export of the U.S.A. batteries, the scale was much smaller than the import given to the US current situation. The total export of the U.S.A. batteries value was USD 821 million in year 2022.

Many of the data weren't shown on the statistics website but we can utilize the graph shown above to calculate the value we needed.

The U.S. export value of batteries to China was USD 0.0917 billion. The export value to Japan was USD 0.186 billion. The export value to Germany was USD 0.142 billion. The export value to Poland was USD $0.064 billion. The export value to South Korea was USD 0.218 billion. Finally, the export value to Hungary was USD 0.00647 billion (OEC, 2024). The total export value from the US to the world was USD 2.12 billion. To sum up, the U.S. battery export value is shown in **Table 3.**

Table 3 U.S. Export Value in Billion Dollar

China	Japan	Germany	Poland	South Korea	Hungary
$0.092	$0.186	$0.142	$0.064	$0.218	$0.006

Source: author via oec results

2.5.2. China Trade Flow

China is the world's largest battery-exporting country. According to the report, China's lithium-ion battery export in USD value was 58.7 billion in 2023. The top export destination countries were the US, Germany, South Korea, the Netherlands, Vietnam, India, South Africa, Japan, Spain, and Belgium. These countries accounted for 76.26% of the total lithium-ion battery export of China billion (China Carbon

Disclosure Platform for Machinery and Electronics, 2023). The export value to Germany was USD 8,08 billion. The export value to South Korea was USD 5.52 billion. The export value to Japan was USD 1.72. The export value to Poland was 1.59 billion (OEC, 2024). The export value from China to Hungary was USD 0.56 billion (OEC, 2024). The export of the electric battery in China was USD 65 billion (Bloomberg News, 2024). Therefore, the ROW value should be the world trade value subtracted from our selected countries' value. The sum-up is shown in **Table 4**.

Table 4: China Export Value in Billion Dollar

Germany	South Korean	Japan	Poland	Hungary	US
$8.08	$5.52	$1.72	$1.59	$0.56	$13.10

Source: author via oec results

The import value of Chinese batteries is smaller than that of exports. In the year 2023, according to Chinese customs, China imported USD 2.551 billion worth of lithium batteries. The top importing country to China was Malaysia, reaching USD 0.523 billion. South Korea and Germany followed second and third, reaching USD 0.32 billion and USD 0.226 billion (麦颖瑶, 2024). The values are rather large than the values we obtained from Western sources. But we proceed not to use it in order to keep the consistency. Even though this data could be more precise.

From the data website OEC, we know that in the year 2022, China imported USD 3.51 billion in electric batteries. Among them, Japan exported USD 0.57 billion. South Korea exported USD 0.598 billion. Germany exported USD 0.725 billion. The U.S. exported 0.0064 billion (This data was the same in the U.S. export section). Poland exported USD 0.0508 billion. Hungary exported USD 0.00737. The ROW for China would be the total import deducts from the candidate countries' imports, which was USD 1.55243 billion. The result is shown in **Table 5.**

Table 5 China Import Value in Billion Dollar

Japan	South Korea	Germany	United States	Poland	Hungary
$0.57000	$0.59800	$0.72500	$0.00640	$0.05080	$0.00737

Source: author via oec results

2.5.3. South Korea Trade Value

South Korea exported electric batteries in USD 9.71 billion in year 2022 (OEC, 2024). We don't know what exact content does the electric batteries category contain but according to another report in 2023, South Korea exported lithium-ion batteries at USD 7.3 billion (statista). We can say that using 2022's USD 9.71 billion is about 77% accurate.

The main importer of South Korean electric batteries was the U.S., importing USD 3.54 billion in 2022. The second largest exporting market for South Korean batteries was Germany, which was USD 1 billion. South Korea also exported a portion of batteries to China, despite China itself as a super large battery exporter. The value was USD 456 million in 2022. South Korea's exports to Poland were USD 0.376 billion and to Hungary were USD 0.369 billion. South Korea's export to Japan was USD 0.455 billion. ROW value would be the total export value to the world deducting the candidate countries' values. ROW was USD 3.514 billion (OEC). The values are shown in **Table 6**.

Table 6: South Korea Export in Billion Dollar

China	US	Japan	Germany	Poland	Hungary
$5.52	$0.22	$0.06	$0.05	$0.03	$0.01

Source: author via oec results

Unlike China and the U.S., South Korea's electric battery exports and imports is more balanced in terms of value. South Korea imported batteries for USD 6.08 billion in year 2022. China was the biggest exporter of South Korea, taking up around 90% of the battery value. South Korea imported batteries from China were USD 5.52 billion in value. Japan counted for USD 0.0602 billion. The U.S. exported USD 0.218 billion. Germany exported USD 0.054. Poland exported USD 0.0266 billion. Hungary exported USD 0.00867 billion. ROW for South Korea would be the total import value minus the candidate countries, which was USD 0.19253 billion (OEC). The data is shown in **Table 7.**

Table 7: South Korea Export Value in Billion Dollar

US	Germany	China	Poland	Hungary	Japan
$3.54	$1.00	$0.46	$0.38	$0.37	$0.46

Source: author via oec results

2.5.4. Germany Trade Value

Germany exported USD 8.83 billion of electric batteries (OEC). Similarly to South Korea case, we couldn't find the content of the "electric batteries". But a German report said that Germany's lithium-ion battery production was USD 3.22 billion, offset by around USD 5 billion in exports (Zwei, Kontakt Christian Eckert, 2023). From this report, we could know that the OEC data we would use was 68% accurate.

Interestingly, this German report pointed out that Germany exported USD 0.7 billion from China and USD 1.2 billion from the U.S. **Table 8**.

Table 8: Export von Zellen und Batterien aus Deutschland (2023)

		Export (billion Euro)	Change to 2022 (%)
Welt		8.2	2
Europa		5.2	2
	Poland	0.5	33
	France	0.6	9
	UK	0.6	25
Asia		1.2	3
	China	0.7	5
America		1.6	8
	USA	1.2	-3

Source: author via Destatis unz ZVEI, eigene Berechnungen auf Basis der Zahlen Mai 2024

This result is roughly the same to the result for the electric battery data obtained from the OEC website. Therefore, we would still use the data from the OEC.

Germany's total battery export was USD 8.83 billion. Germany's battery export to China was USD 0.725 billion in 2022. Germany's exports to the U.S. were USD 1.56 billion. The export of Germany to Japan was USD 0.0566 billion. The export of Germany to South Korea was USD 0.054 billion. Germany exported USD 0.360 billion to Poland and Germany exported USD 0.251 billion to Hungary (OEC). The data is shown in **Table 9.**

Table 9: Germany Export Value in Billion Dollar

China	U.S.	Japan	South Korea	Poland	Hungary
$0.73	$1.56	$0.06	$0.05	$0.36	$0.25

Source: author via oec results

Germany's total battery import was 42% higher than its import, reaching USD 20.3 billion in the year 2022. The biggest exporter to Germany was China, taking up 39.8% of the total imports. The battery imported from China was USD 8.08 billion. Poland was the second country to the German battery export. Germany imported USD 4.42 billion worth of batteries. Germany imported a USD 2.7 billion battery from Hungary. This value was higher than the U.S., China, or Korea's imports from Hungary, probably due to geographical convenience. Germany imported far more batteries from Korea than Japan. The values were USD 1 billion and USD 0.158 billion respectively. Germany imported USD 0.142 billion worth of batteries from the U.S.. The ROW can be calculated using the same method in other countries' calculations. **Table 10** demonstrates the data below.

Table 10: Germany Import Value in Billion Dollar

China	U.S.	Japan	South Korea	Poland	Hungary
$8.08	$0.14	$0.16	$1.00	$4.42	$2.70

Source: author via oec results

2.5.5. Japan Trade Value

Japan exported USD 5.26 billion of battery in 2022. 10.8% of the value was accounted for the export to China, which was USD 0.57 billion. USD 0.0602 billion of the battery was exported to South Korea. Japan exported USD 2 billion of the batteries to the U.S. Japan exported USD 0.0465 billion to Poland. Japan exported USD 0.158 billion of batteries to Germany. Japan's export to Hungary's battery value was USD 0.0708 billion. The ROW can be calculated by subtracting the total exports of Japan to the world and the candidate countries, which was USD 2.401 billion. The data can be seen in **Table 11** below.

Table 11 Japan Export Value in Billion Dollar

US	China	Germany	South Korea	Hungary	Poland
$2.00000	$0.57000	$0.15800	$0.06020	$0.07080	$0.04650

Source: author via oec results

Japan's import of batteries was about two times lower than its exports. Japan imported USD 2.9 billion worth of batteries. Japan imported USD 1.72 billion worth of batteries from China. Japan imported USD 0.455 billion from South Korea. Japan imported USD 0.0566 billion from Germany. Japan imported USD 0.186 billion from the U.S. Japan imported USD 0.00441 billion from Poland. Japan imported USD 0.000325 billion from Hungary. ROW value can be calculated by subtracting the value of candidate countries from the total import value. ROW was USD $0.477665 billion. The data is displayed in **Table 12** below.

Table 22: Japan Import Value in Billion Dollar

China	South Korea	Germany	US	Poland	Hungary
$1.720000	$0.455000	$0.056600	$0.186000	$0.004410	$0.000325

Source: author via oec results

2.5.6. Poland Trade Value

Poland exported USD 9.55 billion worth of electric batteries in the year 2022. The export value of Poland to Germany was USD 4.42 billion. The export value of Poland to Hungary was USD 0.35 billion. The export value of Poland to China was USD 0.0508 billion. The export value of Poland to Japan was USD 0.00441 billion. The export value of Poland to South Korea was USD 0.0266 billion. The export value of Poland to Hungary was USD 0.35 billion. The export value of Poland to the U.S. was USD 0.425 billion. The ROW can be calculated by subtracting the candidate's value from the total exporting value. The data is shown in **Table 13**.

Table 13: Poland Export Value in Billion Dollar

U.S.	Germany	Hungary	China	Japan	South Korea
$0.425000	$4.420000	$0.350000	$0.050800	$0.004410	$0.026600

Source: author via oec results

Poland's total battery import was at a value of USD 3.4 billion. Poland imported from China at a value of 1.59 billion. Poland imported from Japan at a value of USD 0.00252billion. Poland imported from South Korea at a value of USD 0.376 billion. Poland imported from Germany at a value of 0.36 billion. Poland imported from Hungary at a value of USD 0.026 billion. Poland imported from the U.S. at a value of USD 0.064 billion. The value of ROW can be calculated by subtracting the candidates' countries' value from the total Poland import value, which was USD 0.982 billion. (OEC) The data is displayed in **Table 14**.

Table 14: Poland Import Value in Billion Dollar

China	Japan	South Korea	Germany	Hungary	US
$1.590	$0.003	$0.376	$0.360	$0.026	$0.064

Source: author via oec results

2.5.7. Hungary Trade Value

Hungary exported USD 6.66 billion worth of electric batteries in 2022. Among the exports, Hungary exported USD 2.7 billion to Germany, taking up 40.5 % of the total exports. Hungary exported USD 0.0258 billion to Poland. Hungary exported USD 0.419 billion to the U.S. and exported USD 0.00737 billion to China. Hungary exported USD 0.00876 billion to South Korea and exported USD 0.000325 billion to Japan. The value of ROW can be calculated by subtracting the candidates' countries' value from the total Hungary export value, which was USD 3.498 billion. (OEC) The data is shown in **Table 15**.

Table 15: Hungary Export Value in Billion Dollar

Germany	Poland	US	China	South Korea	Japan
$2.70	$0.03	$0.42	$0.01	$0.01	$0.00

Source: author via oec results

Hungary's battery import was USD 2.18 billion in the year 2022. Hungary imported batteries from China at a value of USD 0.562 billion. Hungary imported batteries from Poland for USD 0.35 billion. Hungary imported batteries from South Korea at a value of USD 0.369 billion. Hungary imported batteries from Germany at a value of USD 0.251 billion. Hungary imported batteries from the U.S. at a value of USD 0.00647 billion. Hungary imported batteries from Japan at a value of USD 0.0708 billion. The value of ROW can be calculated by subtracting the candidates' countries' value from the total Hungary import value, which was USD 2.18 billion (OEC). The data is shown in **Table 16**.

Table 16: Hungary Import Value in Billion Dollar

China	Poland	South Korea	Germany	Japan	US
$0.562	$0.350	$0.369	$0.251	$0.071	$0.006

Source: author via oec results

With all of the imports and exports data at hand, we can now map the trade flow table to better visualize the trade exchange.

3. Methodology

3.1. Econometric Model Selection

The literature review can give us crude and tangled information about this ongoing battery momentum. To be able to better understand and provide useful information for either the involved person or investors, we need to use methods that can quantitively analyze the potential change for the future.

One of the known models is Computable General Equilibrium, it was first invented by Leif Johansen in 1960, and used by the Norwegian government for policy making (Shantayanan Devarajan and Sherman Robinson, 2013). The model is especially useful for computing trade changes due to policy factors. It can provide a framework for policymakers to simulate the income and expenditure flow (Chief Economist Directorate, 2016).

However, the wholeness of the CGE model requires the researchers to input a large number of economic data which have to be up-to-date. This poses a big challenge for the researchers. Even though the CGE may yield a realistic result in theory, the amount of data collected and computed can exceed the capabilities of the author of this thesis. Therefore, choosing an easier and simpler model is needed to conduct the research.

To be able to yield the needed result with limited data accessible, we opted for the partial equilibrium model. The partial equilibrium model is used in the analysis that the market under affection is in a limited scoop. The markets that interact with each other in this model are directly related to rather than considering all the markets in the Computable General Equilibrium Model. The drawbacks of this model are that it is sensitive to a number of behavioral elasticities if the inputs are poorly collected. It also doesn’t react to the feedback of other markets (WITS, The World Bank, 2010). However, because of the Lithium-ion markets are centered in a few regions, the author believed that the partial equilibrium model is enough to provide insightful information.

3.2. Global Simulation (GSIM) model

In this thesis, we use one of the partial equilibrium models developed by Joseph Francois, and H. Keith Hall, named GSIM (Global Simulation Model). GSIM computes the policy trade's impact on the multi-country global market. Based on the input of trade flows, tariffs, and NTMs, the model enables us to calculate the change before and after the policy change. The basic work of the GSIM model can be explained in the following equations:

3.2.1. Elasticities Part

The import demand equation: (1) $M_{(i,v),r} = f(P_{(i,v),r} \ ,P_{(i,v),s\neq r} \ ,y_{(i,v)})$ (Francois and Hall, 2002).

The cross-price elasticities, derived from the first equation:

(2) $N_{(i,v),(r,s)} = \theta_{(i,v),s} E_s + \eta_{(i,v),(r,y)} \left(\eta_{(i,v),(y,s)} - \theta_{(i,v),s}\right)$ (Francois and Hall, 2002).

Own-price demand elasticities, derived from the first equation:

(3) $N_{(i,v)(r,r)} = -\sum_{s\neq r} \theta_{(i,v),s} E_s + \eta_{(i,v),(r,y)} \left(\eta_{(i,v),(y,r)} - \theta_{(i,v),r}\right)$ (Francois and Hall, 2002).

To simplify the equations 2 and 3. The homotheticity preference suggests that income $\eta_{(i,v)(r,y)} = 1$.

Therefore we have equation 4: (4) $\eta_{(i,v)(y,s)} = \theta_{(i,v),s} \left(1 + E_{M,v} \right)$ (Francois and Hall, 2002).

By making substitutions, the following relationships can be made:

(5) $N_{(i,v),(r,s)} = \theta_{(i,v),s} (E_m + E_s)$

(6) $N_{(i,v),(r,r)} = \theta_{(i,v),r} E_m - \sum_{s\neq r} \theta_{(i,v),s} E_s = \theta_{(i,v),r} E_m - (1 - \theta_{(i,v),r}) E_s$ (Francois and Hall, 2002).

3.2.2. Individual Demand and Supply Conditions

Define $P_{i,r}*$ as the export price and $P_{(i,v),r}$ as internal price, the equations below can be made:

(7) $P_{(i,v),r} = (1 + t_{(i,v),r}) P_{i,r}* = T_{(i,v),r} P_{i,r}*$ (Francois and Hall, 2002).

The export supply is being a function of world price P*:

(8) $X_{i,r} = f(P_{i,r}*)$ (Francois and Hall, 2002).

By differentiating equations of 1, 7, and 8 we can get:

(9) $\hat{P}_{(i,v),r} = \hat{P}_{i,r}* + \hat{T}_{(i,v),r}$ (Francois and Hall, 2002).

(10) $\hat{X}_{i,r} = E_{X(i,r)}\hat{P}_{i,r}*$ (Francois and Hall, 2002).

(11) $\hat{M}_{(i,v),r} = N_{(i,v),(r,r)}\hat{P}_{(i,v),r} + \sum_{s\neq r} N_{(i,v),(r,s)}\hat{P}_{(i,v),s}$ (Francois and Hall, 2002).

3.2.3. Global equilibrium conditions

by substituting equations (9), (5), and (6) into (11), and sum over import markets, we can get:

(12)
$$\begin{aligned}\hat{M}_{i,r} &= \sum_v \hat{M}_{(i,v),r} = \sum_v N_{(i,v),(r,r)}\hat{P}_{(i,v),r} + \sum_v\sum_{s\neq r} N_{(i,v),(r,s)}\hat{P}_{(i,v),s} \\ &= \sum_v N_{(i,v),(r,r)}[P_r* + \hat{T}_{(i,v),r}] + \sum_v\sum_{s\neq r} N_{(i,v),(r,s)}[\hat{P}_s* + \hat{T}_{(i,v),s}]\end{aligned}$$
(Francois and Hall, 2002).

After setting the equation (12) equal to equation (10), we can get:

(13)
$$\begin{aligned}\hat{M}_{i,r} = \hat{X}_{i,r} \Rightarrow \quad E_{X(i,r)}\hat{P}_{i,r}* &= \sum_v N_{(i,v),(r,r)}\hat{P}_{(i,v),r} + \sum_v\sum_{s\neq r} N_{(i,v),(r,s)}\hat{P}_{(i,v),s} \\ &= \sum_v N_{(i,v),(r,r)}[P_r* + \hat{T}_{(i,v),r}] + \sum_v\sum_{s\neq r} N_{(i,v),(r,s)}[\hat{P}_s* + \hat{T}_{(i,v),s}]\end{aligned}$$
(Francois and Hall, 2002).

The change in Producer Surplus is represented by the equation below:

(14)
$$\begin{aligned}\Delta PS_{(i,r)} &= R^0{}_{(i,r)} \cdot \hat{P}_{i,r}* + \tfrac{1}{2} \cdot R^0{}_{(i,r)} \cdot \hat{P}_{i,r}* \cdot \hat{X}_{i,r} \\ &= \left(R^0{}_{(i,r)} \cdot \hat{P}_{i,r}*\right)\left(1 + \frac{E_{X,(i,r)} \cdot \hat{P}_{i,r}*}{2}\right)\end{aligned}$$
(Francois and Hall, 2002).

3.3. Data Selection

3.3.1. Country Selection

To be able to access the battery industry change in GSIM, it's important to choose the correct regions or countries. The battery industry is now highly centralized in certain areas. The biggest manufacturing country is China. with its expansion in EVs and huge investment in R&D in the battery field, it covered most of the market in 2021, reaching 79.2%. The US comes second, holding 6.2% of the global market share. Its technological advantages give it a lot of potential. Hungary occupies 4% of the market share. It would soon open its own factory in Europe. Poland owns many of the large lithium-ion battery factories. It is geographically close to Europe where the demand for EVs is rising very quickly. It now owns 3.1% of the battery market. South Korea also has 2.5% of the market share. Its famous brands LGES, SK On, and Samsung SDI were dominant battery supplier to various of automotive makers (USMAN KABIR, 2023).

The other countries following the list are Japan, Germany, Sweden, and the UK. Japan was producing batteries worth approximately 930 billion Japanese yen (Usman Kabir, 2023), which was 9.43 billion euro. Those countries took the battery market as 2.4%, 1.6%, 0.6% and 0.3% respectively. By 2025, Germany's battery production ability is expected to rise substantially (statista, 2021).

According to reports in recent years, the top ten lithium-ion battery manufacturers in countries are given in **Table 17** below:

Table 17 Top-19 lithium-ion battery manufacturers

Country	China	U.S.	Hungary	Poland	South Korea	Japan	Germany	Sweden	UK
Market Share	79.20%	6.20%	4.00%	3.10%	2.50%	2.40%	1.60%	0.60%	0.30%

Source: author via Mapped: EV Battery Manufacturing Capacity, by Region

Therefore, we will pick those countries as our candidates. To further divide the main manufacturing countries in the EU and other European countries, we also exclude the non-major battery manufacture countries as the rest of the EU (REU). Finally, the rest of the countries are the Rest of the World (ROW).

3.3.2. Scenario development

Scenario 1 – US tariffs and subsidies on lithium-ion batteries

The first scenario we are going to simulate is the U.S. imposing tariffs and subsidies (through the Inflation Reduction Act) for the battery market. As discussed in the literature review section, we simulate that the U.S government will adopt higher tariffs on imported Chinese batteries, from 7.5% to 25% and also subsidies U.S. produced batteries. Batteries tariffs for non-EVs will be adopted in 2026, also reaching

25% (Cameron Murray, 2024). Scenario 1 will center on the US battery tariff policy, investigating its consequences.

Scenario 2 – EU battery regulation and subsidies on lithium-ion batteries

The second scenario will focus on how the EU's newly passed battery regulation and subsidies affect the distribution of the market share of the lithium-ion battery. In this scenario, We simulate a 5% subsidy, no changes in tariffs, but an open policy that allows third-country producers to also benefit from the EU subsidy if they produce batteries for the EU market.

Scenario 3 – Combined US and EU subsidy policies

In the third scenario, we will see how the combined U.S. tariff policy and EU NTM policy will affect the global battery trade market: the combination of two active industrial policies, both in the EU and in the US, where the US industrial policy is larger in subsidy support but more discriminatory and the EU one that is smaller, but more open to third countries

3.3.3. The Data Calculation of Trade Value of Candidate Countries

The Trade Value of the Rest of the European Union

In the previous Chapter, we talked about the trading values including imports and exports of the countries we selected. It is important to also calculate the trade value of the rest of the world and the trade values of the rest of the European Union. To get the trade value for the ROW, first, we need to get the trade value of the rest of the EU.

For it is crucial to isolate the rest of the European countries from the rest of the world group. Otherwise, the NTMs of the non-focusing EU countries will be blended into the ROW, causing inaccuracy. Therefore, we need also to find out the trade values of the Rest of the European Union Countries (REU). The EU currently consists of 27 countries, including Austria, Belgium, Bulgaria, Croatia, the Republic of Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden (GOV.UK). Through the OEC website, we managed to find out all the trading flows of the member countries. Adding those trade values together, we get the EU trade value of electric batteries for the year 2022. Then we can deduct the trade values of Germany, Hungary, and Poland to get the trade value of the REU.

According to the report, The total EU export value of electric batteries to the world was USD 36.2 billion. EU trade value to China was USD 0.888 billion. The trade value to South Korea was USD 0.127 billion. The trade value to Japan was USD 0.092 billion. The trade value to the U.S. was USD 2.8 billion. Now we already know the Trade values of Germany, Poland, and Hungary, we can then know that Germany, Hungary, and Poland's total trade value to China was USD 0.783 billion. Germany, Hungary, and Poland's total trade value to South Korea was USD 0.0894 billion. Germany, Hungary, and Poland's total trade value to Japan was USD 0.0613 billion. We now get REU to China was USD 0.783 billion. REU to South Korea was 0.0894 billion. REU to the U.S. was USD 2.8 billion. REU to the World was 24.6 billion. Within the European Union, the EU's trade with Germany was USD 9.92 billion. After excluding the trade of Germany, Poland, and Hungary, the REU trade to Germany was USD 2.8 billion. The REU to Poland was USD 1.21 billion. The REU to Hungary was USD 0.968 billion. We also need to find out the export value for China to REU, the U.S. to REU, South Korea to REU, Japan to REU, and REU to ROW. To simplify this, we can check the imports from China, the U.S., and Japan to REU. We here assume that the export value of one country equals the import value of the receiver country. Even this is not always the case due to the classification concepts and detail, time of recording, valuation, coverage, and processing errors (International Monetary Fund). The imports of China to REU were USD 21.1 billion. South Korea to REU was USD 2.57 billion. Japan to REU was USD 0.742 billion. From the U.S. to REU was USD 0.658 billion. In this case, we can assume that China exported USD 21.1 billion to REU, South Korea exported USD 2.57 billion to REU, Japan exported USD 0.742 billion to REU and the U.S. exported USD 0.658 billion to REU. We can also retrieve the data directly from oec, knowing that the value of all 27 countries that imported electric batteries from Germany was USD 4.19 billion. Since Germany couldn’t import from itself, we can regard this value as Germany's export value to the REU. This applies to Poland and Hungary, where the exporting value to REU was USD 5.98 billion and USD 7.31 billion respectively. he REU imported at a value of USD 54.2 billion worth of electric batteries from the World. We deducted the trade value between REU to China, the U.S., Japan, South Korea, Poland, Germany, and Hungary, we got the export of the ROW to REU was USD 17. 032 billion. Data is shown in **Table 18.**

Table 18: REU Export Value in Billion Dollar

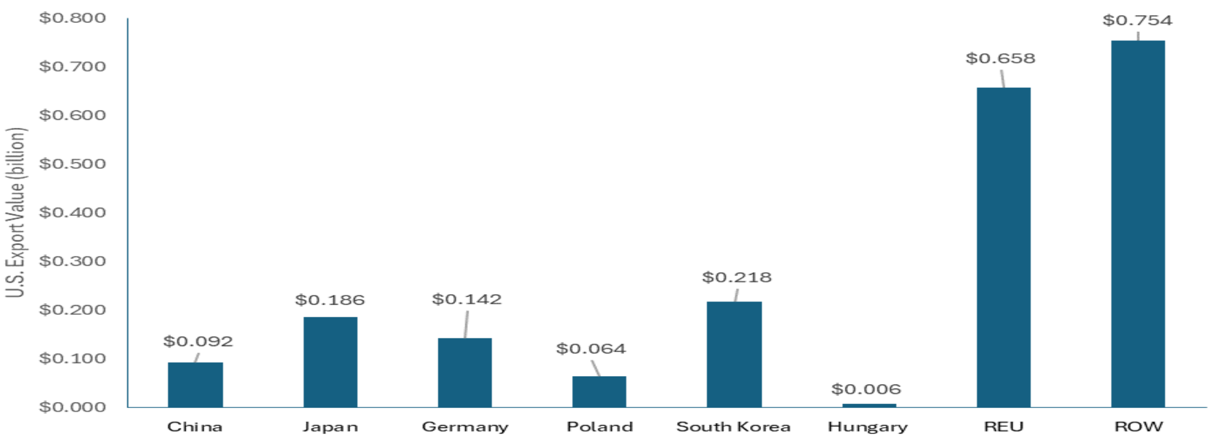
Exports to countries	Value (bn USD)
REU – China	0.11
REU - South Korea	0.04
REU – Japan	0.03
REU – US	0.40
REU – Germany	2.80
REU – Poland	0.85
REU – Hungary	0.37
REU – ROW	11.60

Source: author's calculation based on oec results

The Trade Value of the U.S.

The U.S. battery export value to the world was USD 2.12 billion dollars in 2022. The U.S. battery export to the REU was USD 0.0658 billion dollars. Therefore, we know that the U.S. battery export to the ROW was the U.S. to world export value deducts the U.S. trade value to the sum of China, Japan, Germany, Poland, South Korea, Hungary, and REU. Which is USD 0.754 billion dollars. The results can be illustrated in **Figure 8.**

Figure 8: U.S. Export Value in Billion Dollar

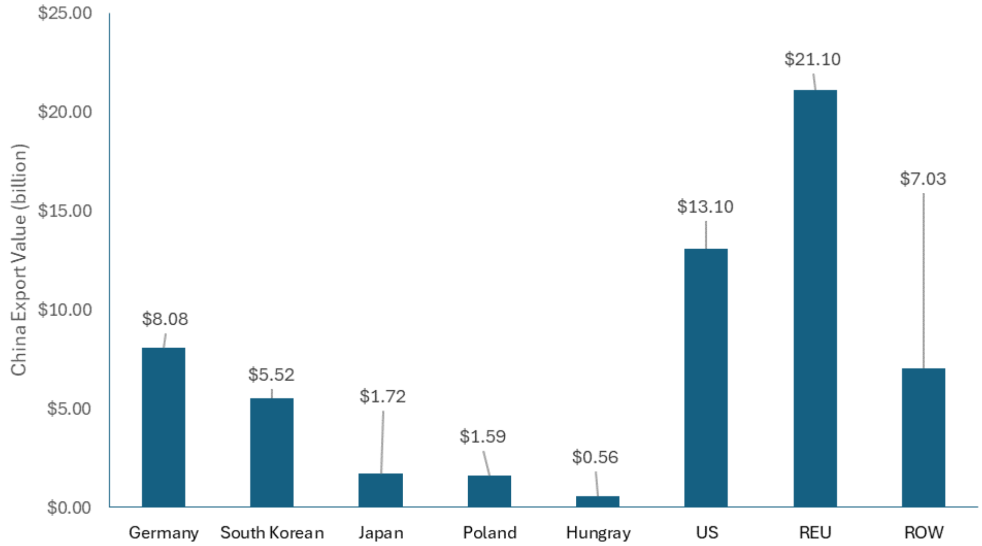


Source: author's calculations based on oec results

The Trade Value of China

The China battery export value to the world was USD 58.7 billion dollars. China's export to the REU was USD 21.1 billion dollars. Therefore we know that China's export to ROW was the value of China's export to the world deducting the value of the sum of China's export to the rest of the selected countries and REU. Which is USD 7.03 billion dollars. The results are illustrated in **Figure 9.**

Figure 9: China Export Value in Billion Dollar

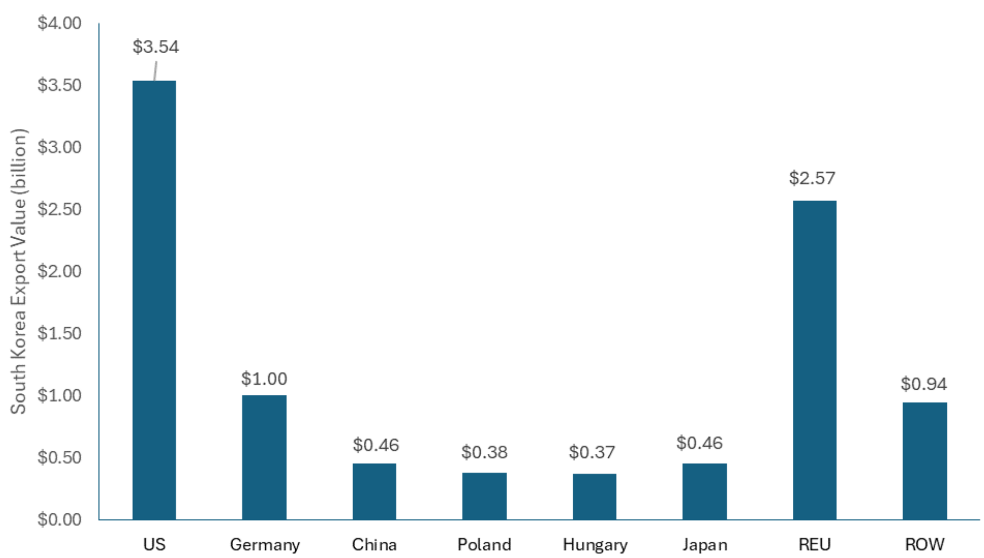


Source: author's calculations based on oec results

The Trade Value of South Korea

The trade value of South Korea to the world was USD 9.71 billion dollars in 2022. The export value of South Korea to REU was 2.57 billion dollars. Therefore we can know that the trade value of South Korea to the ROW was the trade value of South Korea to the world deducts the sum of the trade value of South Korea to the rest of the candidate countries. Which was USD 0.94 billion dollars. The results are illustrated in **Figure 10.**

Figure 10: South Korea Export Value in Billion Dollar

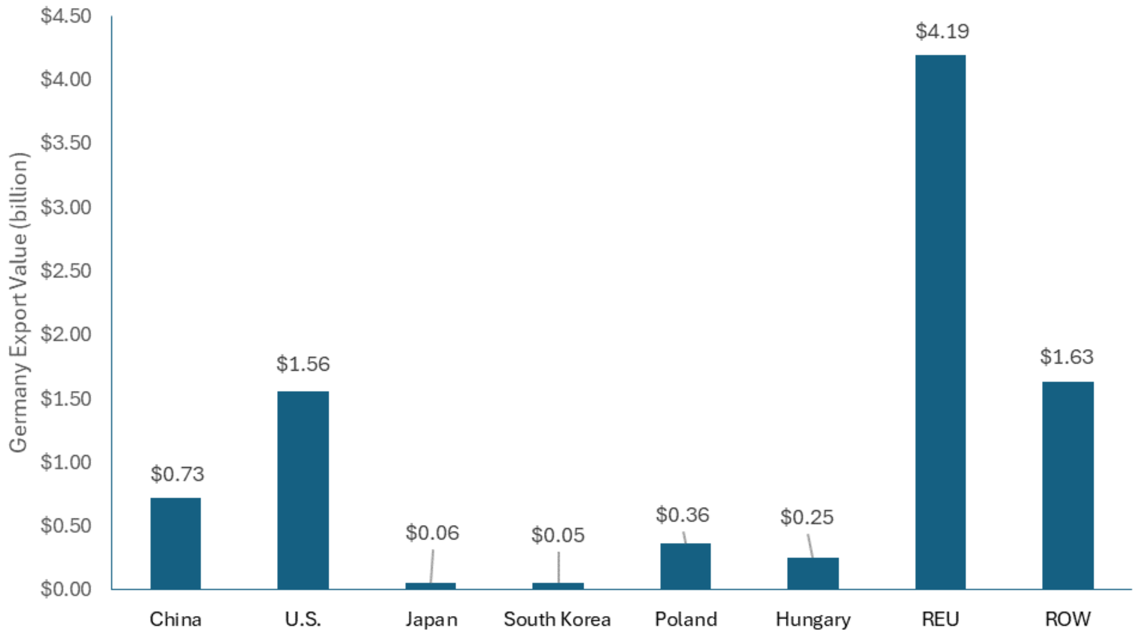


Source: author's calculations based on oec results

The Trade Value of Germany

The trade value of Germany's electric batteries to the world was USD 8.83 billion dollars. Therefore we know that the trade value of Germany to REU was the trade value to the world deducts the trade value to the rest of the candidate countries, which was USD 4.19 billion dollars. The results are illustrated in **Figure 11.**

Figure 11: Germany Export Value in Billion Dollar

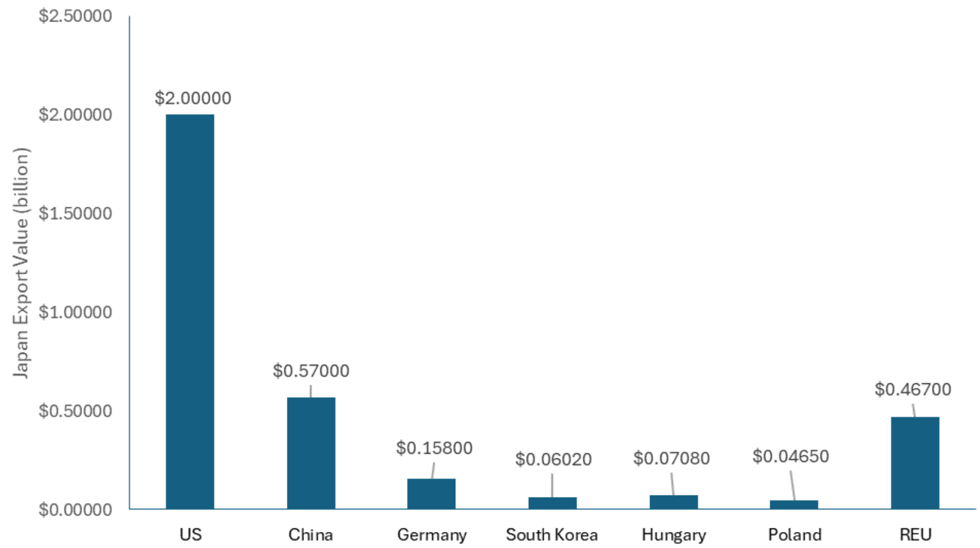


Source: author's calculations via oec results

The Trade Value of Japan

The export value of Japan to the world was USD 5.26 billion dollars in 2022. Therefore we know that the export value of Japan to the REU was equivalent to the total export value of Japan deducts the total export value of Japan to the rest of the candidate countries, which was USD 1.887 billion dollars. The results are shown in **Figure 12.**

Figure 12: Japan Export Value in Billion Dollar

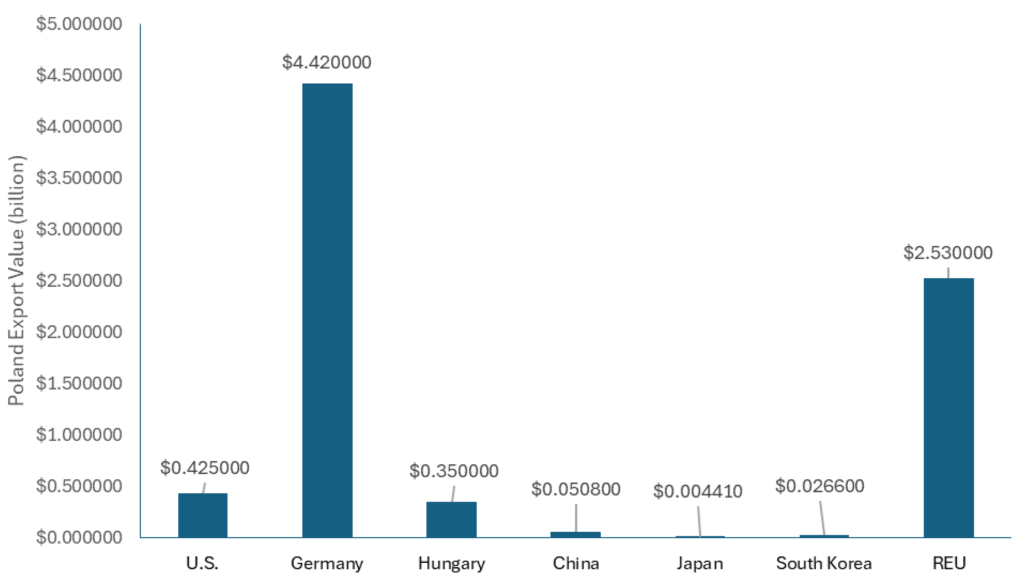


Source: author's calculations based on oec results

The Trade Value of Poland

The export value of Poland to the world was USD 9.55 billion dollars. Therefore we know that the trade value to the ROW was equal to the total Poland export value to the world deducting the total value of Poland to the candidate countries, which was USD 1.74 billion dollars. The results were illustrated in **Figure 13.**

Figure 13: Poland Export Value in Billion Dollars

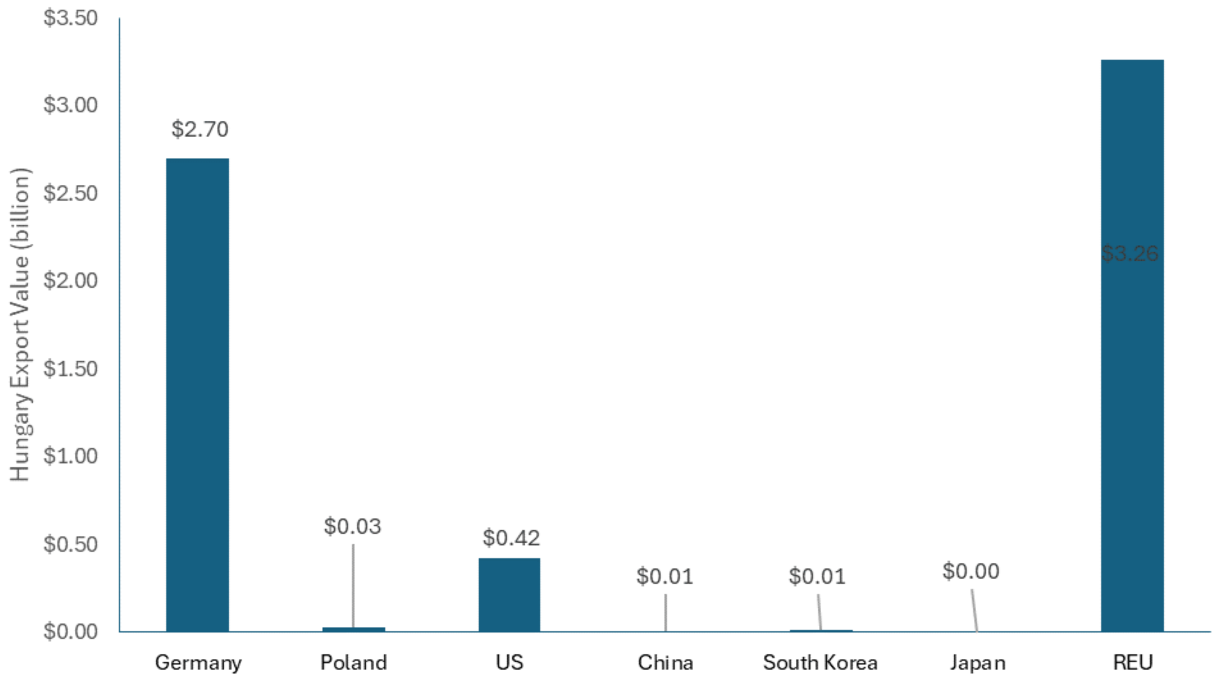


Source: author's calculations based on oec results

The Trade Value of Hungary

The export value of Hungary to the world was USD 6.66 billion dollars. Therefore we know that the export value of Hungary to ROW was the total export value of Hungary to the world deducting the total export value of Hungary to the rest of the candidate countries, which was USD 0.24 billion dollars. The results are illustrated in **Figure 14.**

Figure 14: Hungary Export Value in Billion Dollar



Source: author's calculations based on oec results

The Import Value of Candidate Countries from ROW

Finally, we also need to know how much billion dollars each candidate country imports from the ROW. We don't have any database for this data because our ROW is customized. But with all the other data at hand, we can calculate the data ourselves.

The trade value should be the total EU trade value to the candidate country minus the export value of Germany, Hungary, and Poland. From the website, we know that the EU to China was USD 0.89 billion dollars. EU to the U.S. was USD 2.8 billion dollars. EU to Japan was USD 0.09 billion dollars. EU to South Korea was 0.13 billion dollars. The data is shown in **Table 19.**

Table 19: EU Export Value in Billion Dollar

EU - China	EU - South Korea	EU - Japan	EU - US	EU - World
$0.89	$0.13	$0.09	$2.80	$36.20

Source: author via oec

Then we can retrieve the trade data of Germany, Hungary, and Poland and sum the trade flow to the candidate countries. We use the first letter of each three countries to represent the name. The trade flows are as follows in **Table 19.**

Table 20: Germany, Hungary, and Poland Trade Flow to Countries.

G, P, H - China	G, P, H - South Korea	G, P, H - Japan	G, P, H - U.S.	G, P, H - World
$0.78	$0.09	$0.06	$2.40	$24.60

Source: author's calculations based on oec results.

Then we can get the REU trade value to the candidate countries. The results are shown in the **table 21** below.

Table 21: REU's Export to Candidate Countries

REU - China	REU - South Korea	REU - Japan	REU - US	REU - Germany	REU - Poland	REU - Hungary	REU - ROW
$0.105	$0.0376	$0.0307	$0.4	$2.8	$0.845	$0.366	$11.6

Source: author's calculations based on oec results

Finally, we can get the ROW trade value to ROW by deducting the ROW trade value to candidate countries from World to World, which was USD 105.9 billion dollars in the year 2022.

The Domestic Value of Production

We also need to know the domestic trade values for the usage of subsidies as NTMs. Unfortunately, the domestic production and trade values weren't keen to be documented by the governments nor reported in research papers. But we can still obtain these values by calculating the shares of each country's battery production capability and then multiplying the average battery price. Then we can further balance the value by including and excluding the imported values and exported values. Then we can get the domestic trade values for each country.

According to Statista, the world's battery production capacity was 1.57 terawatt-hours in 2022 (Statista Research Department, 2024). 1 terawatt equals 1e+9 kilowatt. So the battery production capacity was 1,570,000,000 kilowatt in 2022. The average lithium-ion battery price worldwide was about 160 U.S. dollars per kilowatt hour in the year 2022 (Statista Research Department, 2023). We can first know the world's total battery value by multiplying 1,570,000,000 * 160 = 251,200,000,000 USD dollars, which was USD 251.2 billion dollars. Now we can list every country's raw battery production in **Table 22**.

Table 22: Country Raw Battery Value in 2022

Country	Market Share	Production value (bn USD)
China	79%	198.95
The U.S.	6%	15.57
Hungary	4%	10.05
Poland	3%	7.79
South Korea	3%	6.28
Japan	2%	6.03
Germany	2%	4.02

Source: author calculation based on data of 2022

Then we calculate by adding the imported values and deducting the exported values in total. Since we already have REU and ROW, we can sum up all the exporting values to get the total exported value. And we can use the same method to get the total imported value. The results are shown in **Table 23**.

Table 24: Domestic Trade Value

Country	Market Share	Values in bn USD	Total Import Value, USD	Total Export Value, USD	Domestic Trade Value, USD
China	79%	198.95	3.45	58.70	143.70
The U.S.	6%	15.57	23.20	2.06	36.72
Hungary	4%	10.05	1.77	6.66	23.69
Poland	3%	7.79	3.71	12.31	2.29
South Korea	3%	6.28	6.07	12.31	0.05
Japan	2%	6.03	3.41	3.75	5.69
Germany	2%	4.02	20.30	13.53	10.79

Source: author calculation based on data of 2022

We therefore are able to get all the domestic values of our selected countries. For REU, it is difficult to calculate countries one by one but according to another report, the EU's battery production accounted for 1% of the world's production. We thus know that the EU domestic battery value was USD 25.12 billion.

3.3.4. Summary

After finding all the trade data we need, we can fill them into the table for better visualization in **Table 22**.

Table 22: World Trade Flow For Li-ion Batteries (USD)

	China	US	Germany	Korea	Japan	Poland	Hungary	REU
China	143.698	13.10	8.08	5.52	1.72	1.59	0.562	21.1
US	0.092	36.73	0.142	0.218	0.186	0.00647	0.00647	0.658
Germany	0.725	1.56	10.7932	0.054	0.566	0.36	0.251	4.19
Korea	0.456	3.54	1	0.047	0.455	0.376	0.369	2.57
Japan	0.570	2.00	0.158	0.0602	5.6914	0.00252	0.0000039	0.742
Poland	0.051	0.42	4.42	0.0266	0.00441	2.28777	0.0072	2.53
Hungary	0.007	0.42	2.7	0.008	0.00032	0.0258	23.68	3.26
REU	0.105	0.40	2.8	0.0376	0.0307	1.21	0.366	25.12

Source: author via oec

3.3.5. Elasticities

To run the GISM model, we need to know the supply elasticities, substitution elasticities, and composite demand elasticities. Composite demand happens when a single product has multiple uses (Indeed Editorial Team, 2022). The increased demand for the number of products can cause a shortage of other products. (tutor2u, 2020).

The price elasticity of demand is how much the quantity supplied responds to a change in price (Mankiw, 2002). The elasticity of the battery can't be accessed due to very little research being conducted on it. But we can calculate it by using the function of price elasticity = $\frac{(Q_2-Q_1)/[(Q_2+Q_1)/2]}{(P_2-P1)/[(P2+P1)/2]}$, Q_1, Q_2 are quantity and P_1, P_2 are prices.

According to the report that the lithium-ion battery's demand increased a 40% of year 2023 (iea, 2024). Price in 2023 was USD 139 per kilowatt-hour. The price in 2022 was USD 161 per kilowatt-hour (statista, 2023). The price change percentage was 16%. If using the function we can know that the elasticity of demand was 2.5.

Composite demand for lithium-ion batteries hasn't been documented. We assume that the lithium-ion batteries here were all used by EV cars. Each manufacturer of one EV use uses one battery. Therefore we assume that the composite demand is 1.

We don't know the substitution elasticity of battery but according to Ahmad and Riker, the substitution elasticity of motor vehicle parts was 4.01 in 2017 (Ahmad and Riker, 2020). We will use this as a rough reference.

3.3.6. Tariffs

We need tariff data for the GISM to work. The major tariff affection we want to investigate in this paper is how protectionism from the US government will shift the lithium battery market. As we discussed in the previous chapter, the US government will likely improve the tariff on lithium batteries for EVs and other battery parts going up from 7.5% to 25% (Marcus Williams, 2024). Thus we would assume that the tariff factor we would put into the model was 1.25. To complete the tariffs for other countries, we retrieve the tariff data from WITS Database. The tariffs are shown in **Table 23** below.

Table 23: Tariffs of lithium batteries for selected countries

	China	U.S.	Germany	Poland	Hungary	Japan	South Korea	REU	ROW
China	0%	8%	3%	3%	3%	0%	8%	3%	10%
The U.S.	10%	0%	3%	3%	3%	0%	8%	3%	10%
Germany	10%	3%	0%	0%	3%	0%	8%	3%	10%
Poland	10%	3%	3%	3%	3%	0%	8%	3%	10%
Hungary	10%	3%	3%	3%	0%	0%	8%	3%	10%
Japan	10%	3%	3%	3%	3%	0%	8%	3%	10%
South Korea	10%	3%	3%	3%	3%	0%	0%	3%	10%
REU	10%	3%	3%	3%	3%	0%	8%	0%	10%
ROW	10%	10%	10%	10%	10%	10%	10%	10%	10%

Source: author via WITS Database

3.3.7. Non-tariff measures

"NTMs are defined as policy measures, other than ordinary customs tariffs, which can potentially have an economic effect on international trade in goods, changing quantities traded, or prices or both (UNCTAD)." Non-tariff measurement (NTM) is an essential part of the GSIM model. NTM increases the cost of importing. The additional barriers implied for the exporters such as identification and information processing can cause difficulties (Julien Gourdon, Susan Stone, Frank van Tongeren, 2020). The NTW we are going to discuss in this paper is how the new EU battery regulation will put pressure of the exporting countries that are outside of the EU. These countries will be China, the US, South Korea and Japan. Germany, Hungary, and Poland are not affected by this policy because those countries are part of the EU membership.

Another form of NTM will be the NTM applied by the U.S. As mentioned earlier, the U.S. will try to re-industrialize to face competition overseas and domestic unsettlement. The U.S. has granted a subsidy tax credit of 35 USD per kilowatt (kWh) for domestically produced batteries (Ahmed Mehdi & Tom Moerenhout, 2023). Using the average battery price in the year 2022, which was 160 USD/kWh, this was a subsidy of 21.87%.

The equation of subsidy in GISM export subsidy = 1/(1+sx). Therefore, the subsidy of the U.S. was 0.8205.

For the NTMs of the EU, according to a recently published report, the EU had launched a series of state aid investments in the factories where the lithium batteries for EV cars were made. The aid reached in 4 billion euros in total, which is about USD 4.42 billion (Lisa O'Carroll, 2024). The converted subsidy percent for EU policy was 5%.

4. Results and Analysis

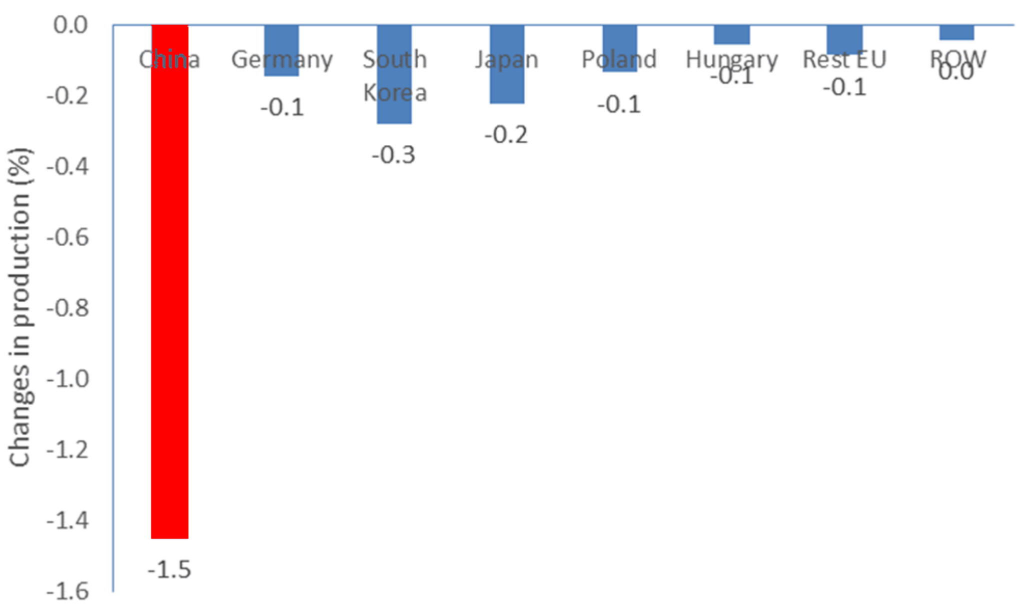
The results yielded by the GISM model will mainly consists of two parts: trade values and welfare effects. This will include a percentage a change in output, a change in consumer surplus, and then the net welfare effects.

4.1. Scenario 1: US industrial policy on batteries

In the first scenario, we isolate the situation that only the US would increase the tariff against China's lithium-ion battery products. This will help us understand what the US government will do to China's battery industry as well as its battery industry without the combined efforts of Europe.

4.1.1. Output Changes

Figure 15: Percentage Change in OUTPUT



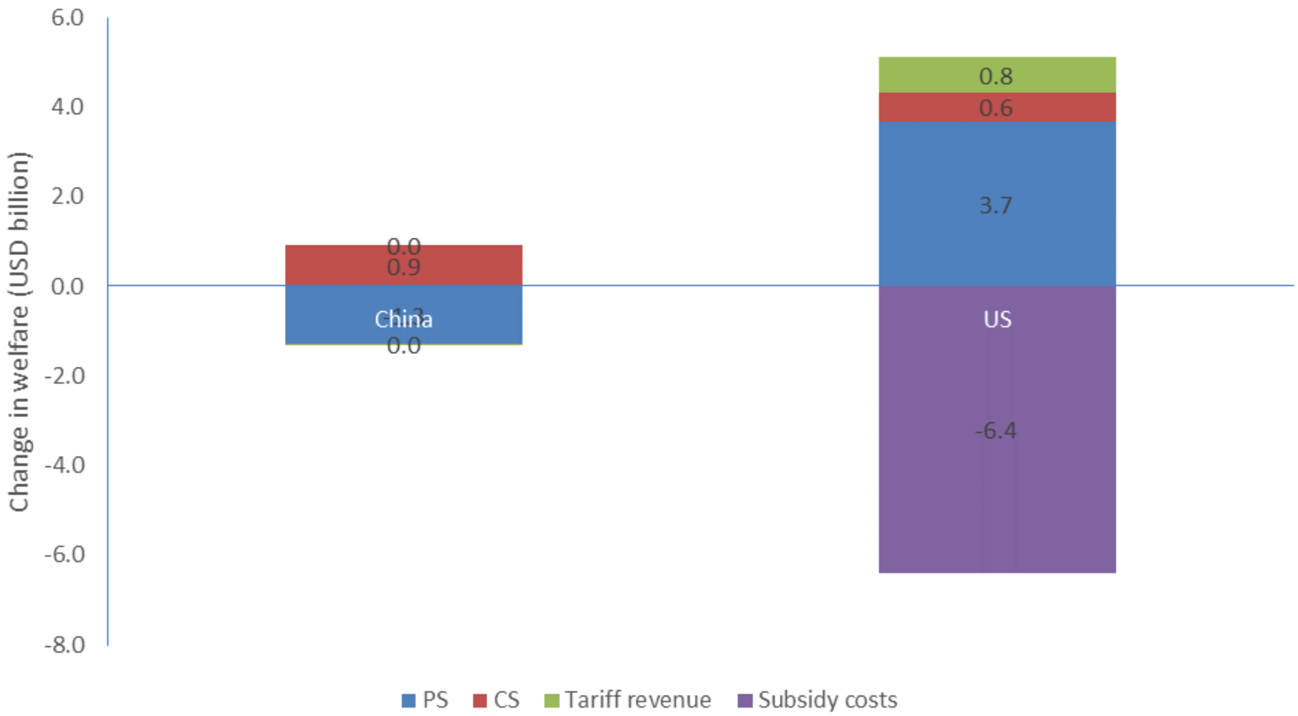
Source: author via GISM results

Figure 15 shows the percentage change in OUTPUT. Interestingly, the OUTPUT result indicates that the US successfully achieved its attempt. While China's lithium-ion production decreased by around 1.5%, the US gained at about 20.53%. It also improves its allied countries' production output. Every other country except the U.S. all lost certain amount percent of production output. But these losses weren't as significant as China was. Germany, Poland, Hungary, Japan, South Korea, and the rest of the EU countries all suffered output losses ranging from 0.1 to 0.3. The rest of the countries didn't affect too much.

4.1.2. Welfare Change

Figure 16 shows the welfare change and its consisted sub-elements.

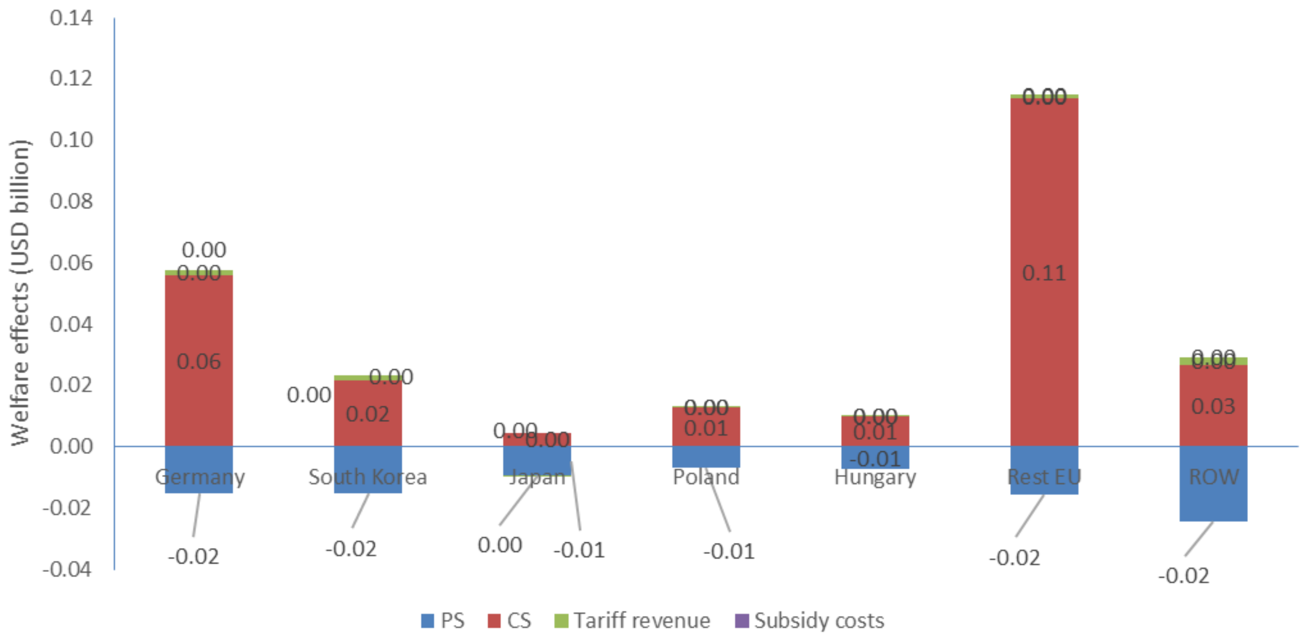
Figure 16: Change in Welfare



Source: author via GISM results

With additional high tariffs against Chinese batteries, the U.S. successfully caused damage to China's industry. China's producer surplus lost USD 1.3 billion. However, as the fewer exports, the consumer surplus gained USD 0.9 billion. China in the end would lose USD 0.4 billion. The U.S.'s producer surplus had a USD 3.7 billion increase, boosting its domestic production capabilities. The consumer surplus and tariff revenue also increased by USD 0.6 billion and USD 0.8 billion, respectively. However, this victory was built on the cost of its subsidy cost, which was USD 6.4 billion. Summing up all the cost, the U.S. lost USD 1.3 billion. This was USD 0.9 billion more losses than China, which lost USD 0.4 billion.

Figure 17: Other Countries Change in Welfare

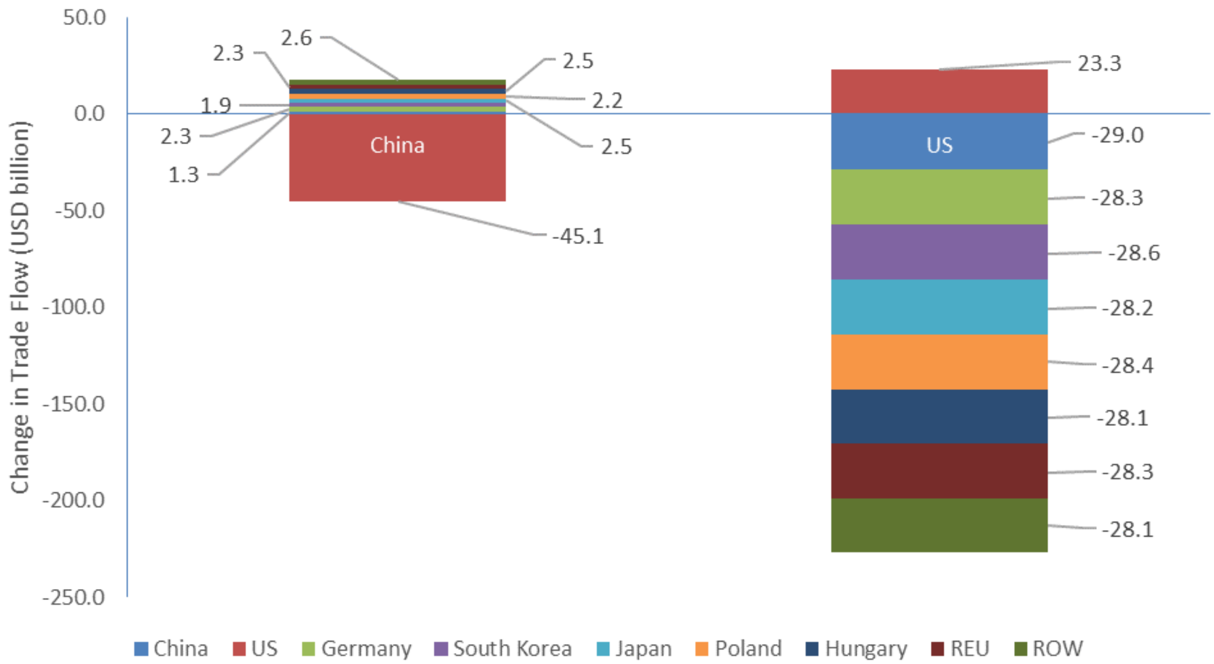


Source: author via GISM results

The welfare change for other countries in this scenario is almost minimal. Most of the countries received consumer surplus outweighed the losses of producer surplus except Japan. Germany had USD 0.06 billion increase in consumer surplus and USD 0.02 billion decrease in producer surplus. Poland and Hungary had both USD 0.01 billion increase and decrease in producer and consumer surplus. Janpan had USD 0.01 billion decrease in producer surplus. And South Korea had both 0.02 increase and decrease in producer and consumer surplus. The REU had USD 0.11 billion increase in consumer surplus and USD 0.02 billion decrease in producer surplus. In general, in scenario 1, the big changes took place between China and the U.S.

4.1.3. Change in Battery Trade

Figure 18: Change in Trade Flow

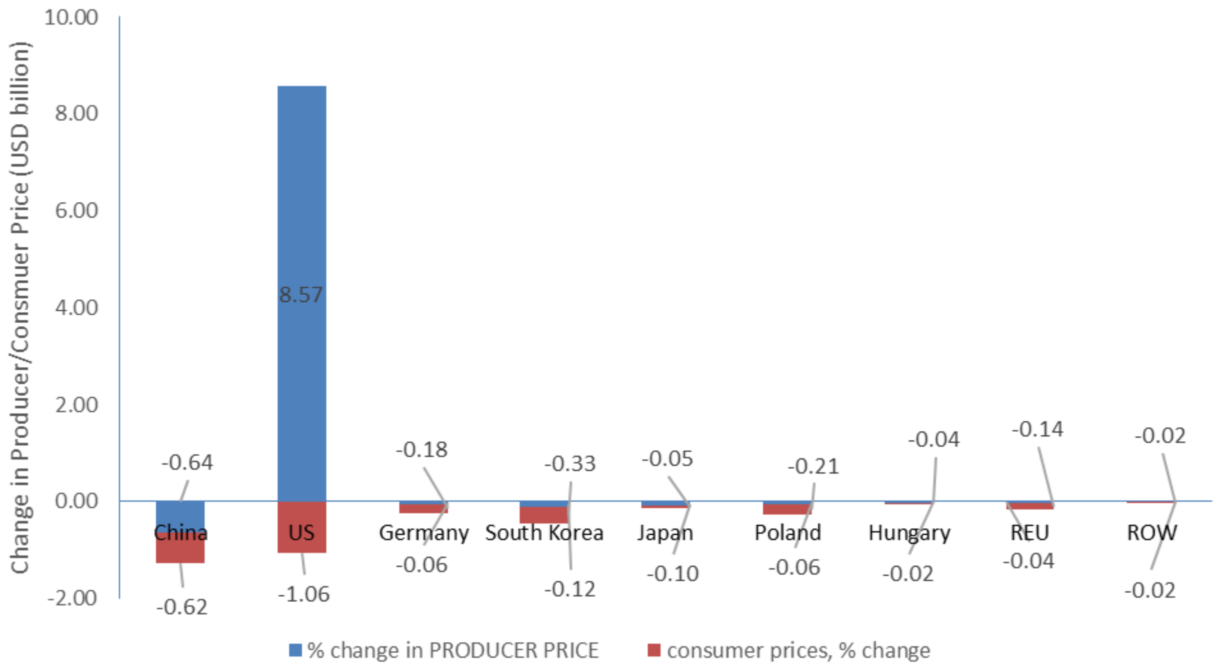


Source: author via GISM results

In this scenario we mainly examined the battery trade flow of China and the U.S. because the rest of the countries had small changes according to the model. In **Figure 18** we can see that in this scenario China lost as big as twice the portion of trade flow to the U.S. This indicates the possible success of the U.S. tariff policy. China still could have increased its exports to other countries. The U.S. had a decline of trade flow with all countries except its domestic trade. This shows by increasing the tariff, the U.S. may help its battery industry to grow.

4.1.4. Change in prices for batteries

Figure19: Change in Producer/Consumer Price



Source: author via GISM results

In **Figure 19** shows that in terms of the commodity price, the U.S. battery producers had a significant price rise at the price. The consumer's price went down a bit. China's producer price and consumer price both went down.

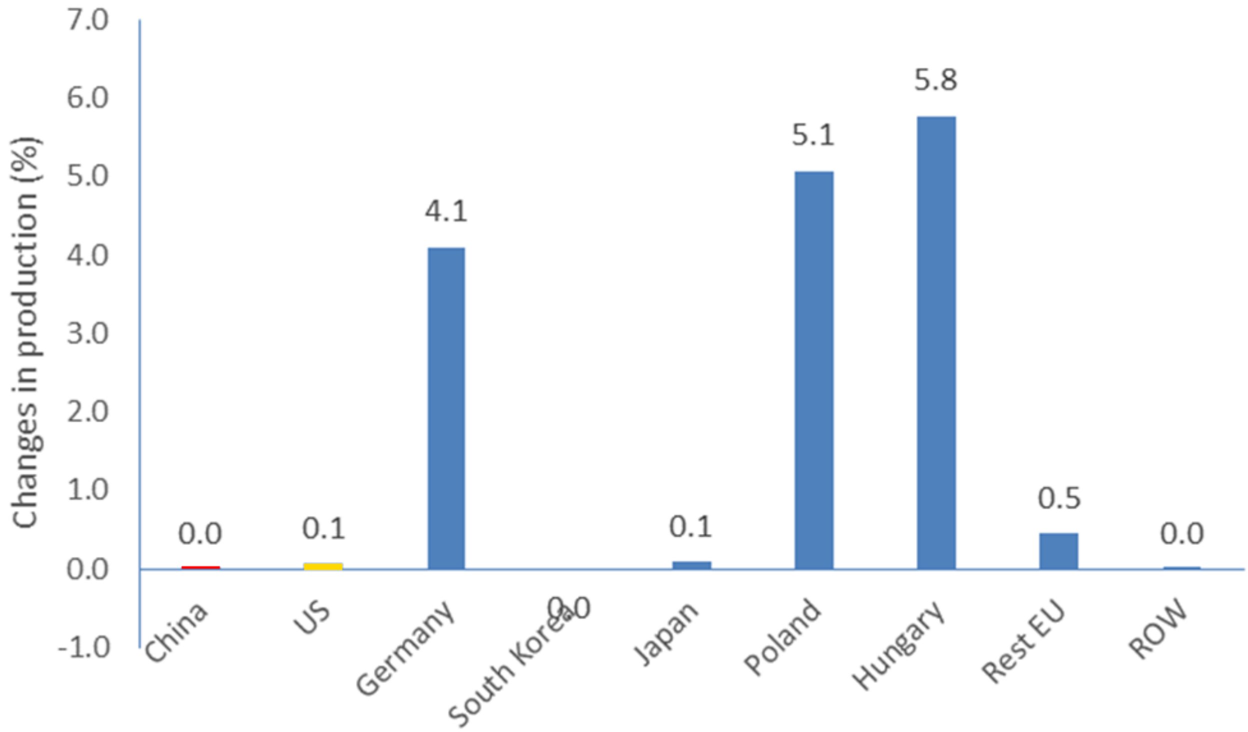
4.2. Scenario 2: EU industrial battery policy

In the second scenario, we will discuss what will happen if the EU solely changes the NTMs whilst other countries have no actions. In this case, the EU applied a 5% subsidy to its domestic battery product and relevant value chain.

Unlike the subsidies adopted by the U.S., the EU's subsidies are also open to third-country producers as long as the batteries are destined for the EU market. This means that NTMs also go down a bit for non-EU, third-country, producers of batteries, making the EU's industrial policy more open and less discriminatory than the US one.

4.2.1. Output Changes

Figure 20: Change in Production Output

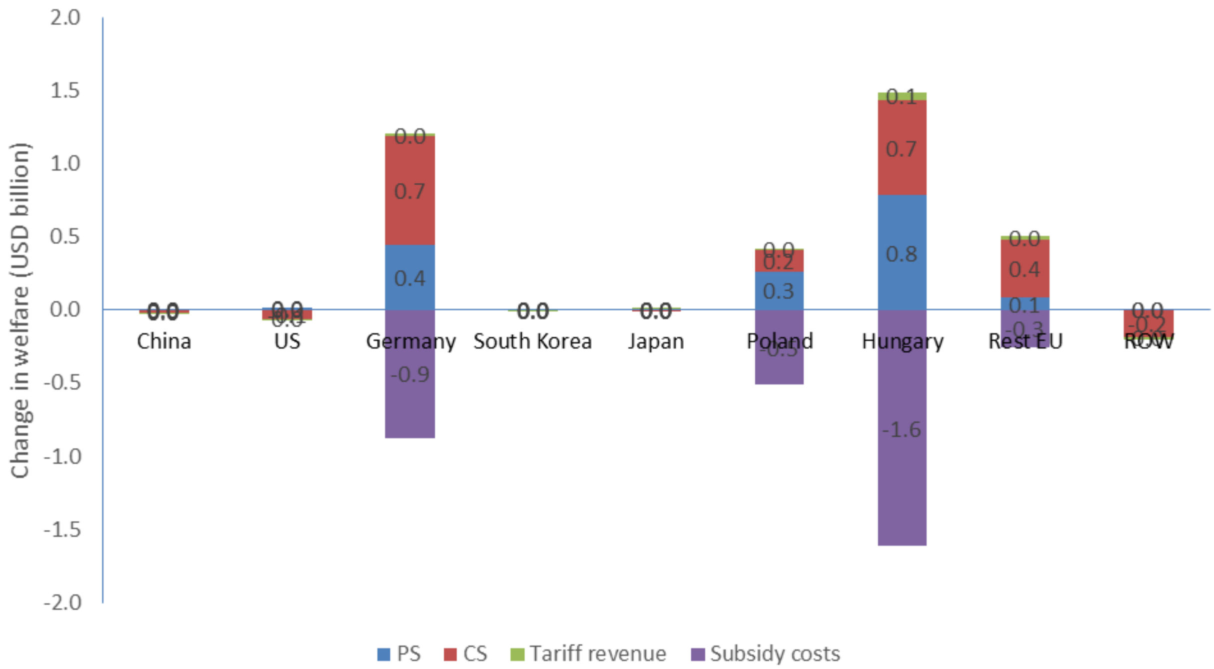


Source: author via GISM results

Figure 20 shows when only the EU lowered the NTM by subsiding the industry, the output for the main battery exporters in Europe went up significantly. Germany's output went up 4.1 percent. Poland's went up 5.1 percent. Hungary's output went up 5.8 percent. The REU's output went up a little, which was 0.5 percent. The rest of the countries or regions weren't affected by this policy. The EU successfully boosted its industry without causing collaborative damage. This is a clearly different with a "US-first policy".

4.2.2. Changes in Welfare

Figure 21: Change in Welfare

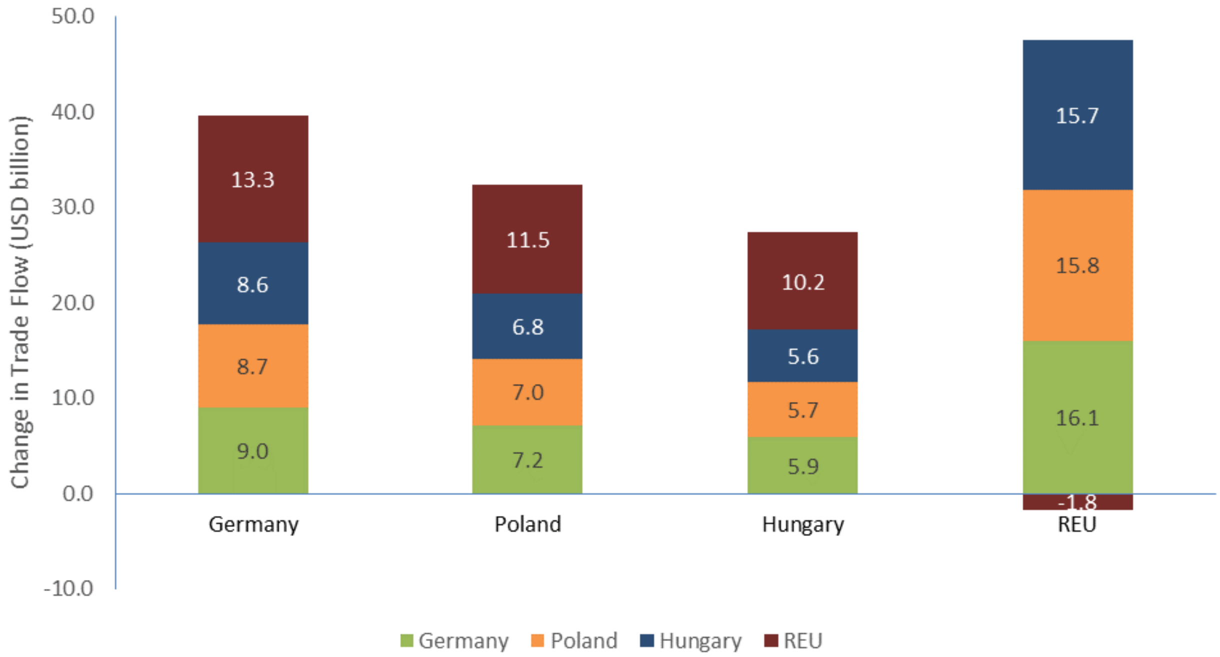


Source: author via GISM results

Figure 21 shows the change in welfare in the scenario 2. The EU in this case also successfully boosted its industry while causing the minimum negative effect on the other countries. Germany, Poland, and Hungary, as the three of the most significant batter exporters in the EU, had gained USD 0.4 billion, USD 0.1 billion, and USD 0.7 billion. The additional producer surplus is helpful for these three countries' battery industries. The total welfare which consisted of both producer surplus, consumer surplus, tariff revenue, and subsidy cost also showed that the NTMs issued by the EU had less to none side effects. Germany gained USD 0.2 billion. Poland didn't receive gain or loss. Hungary lost USD 0.2 billion. The REU also benefited from the subsidies. Although the subsidy cost was high but the increased consumer surplus covered the expense.

4.2.3. Changes in battery trade

Figure 22: Change in Battery Trade



Source: author via GISM results

Figure 22 shows that the major change in trade flow took place between EU countries. Germany to REU went up USD 13.3 billion. Germany to Hungary went up USD 8.6 billion. Germany to Poland went up USD 8.7 billion. The domestic trade flow of Germany went up to USD 9.0 billion.

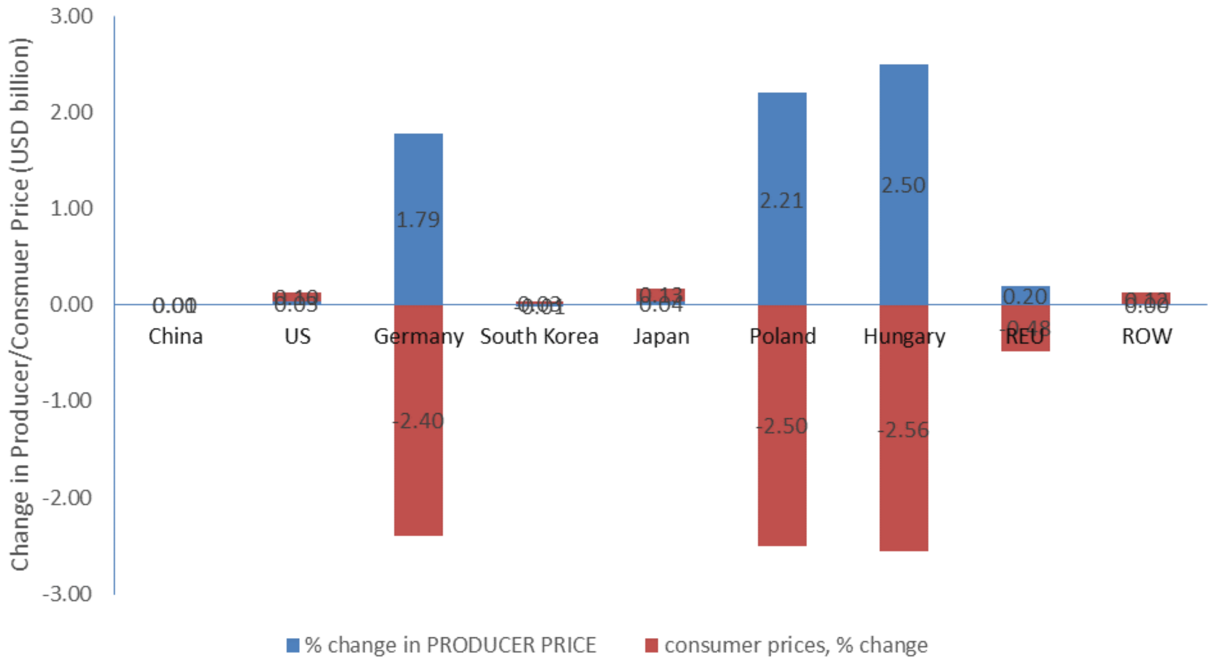
Poland to REU went up USD 11.5 billion. Poland to Hungary went up USD 6.8 billion. Poland to Germany went up USD 7.2 billion. The Poland domestic trade flow went up USD 7.0 billion.

The trade flow between Hungary and the REU went up USD 10.2 billion. Hungary to Poland went up USD 5.7 billion. Hungary to Germany went up USD 5.9 billion. The domestic trade flow of Hungary went up USD 5.6 billion.

The REU also increased its trade flow to these three countries to various degrees. However, the domestic trade flow decreased by USD 1.8 billion.

4.2.4. Change in prices for batteries

Figure 23: Change in Producer/Consumer Pirce



Source: author via GISM results

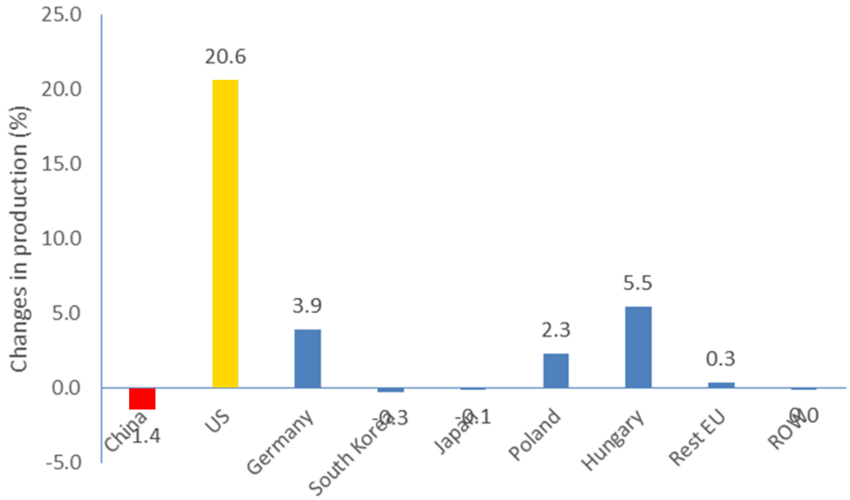
Figure 23 shows that when EU subsidized the battery market, it would increase the producer's price and also lowered the consumer price. The rest of the countries weren't largely affected by this policy.

4.3. Scenario 3: Combined effects of both US and EU policies on batteries

Scenario 1 depicts how the US industrial policy (consisting of tariffs on China and a domestic subsidy) will work against the China battery market. Scenario 2 depicts the EU's battery industrial policy. In Scenario 3, we will discuss how will the US industrial policy combined with the EU industrial policy affect the global battery manufacturing distribution. In this scenario, not only will the tariff be set to 1.25 from the US against China, and will the US give a 10% domestic subsidy. But also the EU Member States will get a 5% subsidy and so do (in part) all non-EU member countries.

4.3.1. Output Changes

Figure 24: Percentage Change in OUTPUT

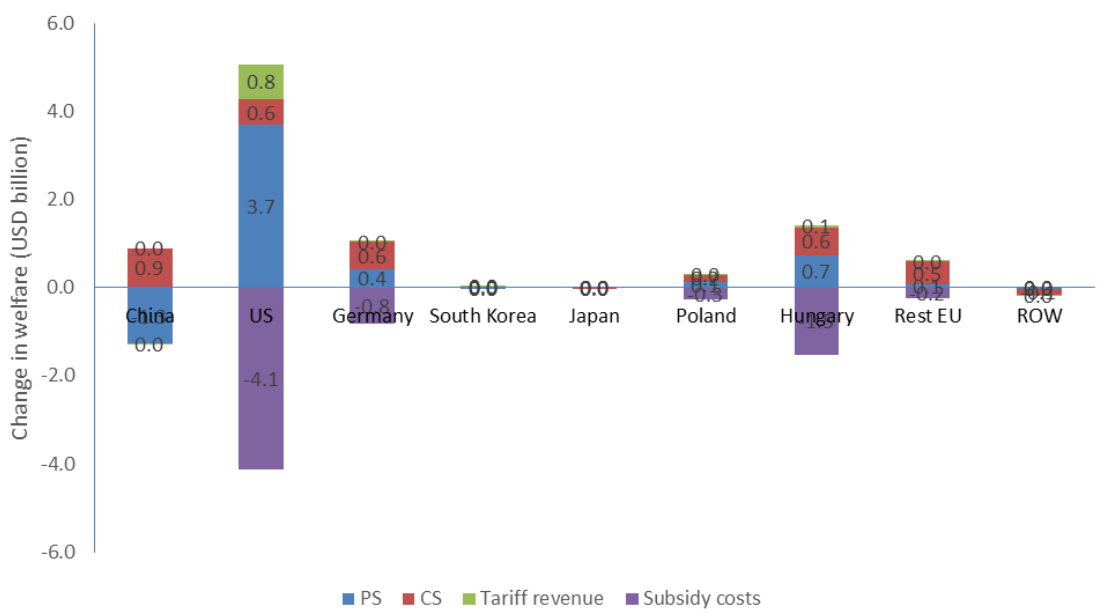


Source: author via GISM model

In this scenario, the output changes are clear: the U.S. was leading ahead with a 20.6% increase. Followed by European countries like Germany, Poland, Hungary, and the Rest of the EU, which gained 3.9%, 2.3%, 5.5%, and 0.3% increase respectively. China would likely to lose 1.4% of its production output, becoming the biggest victim. With the new European NTMs, South Korea and Japan also received minor losses.

4.3.2. Welfare Change

Figure 25: Change in Welfares

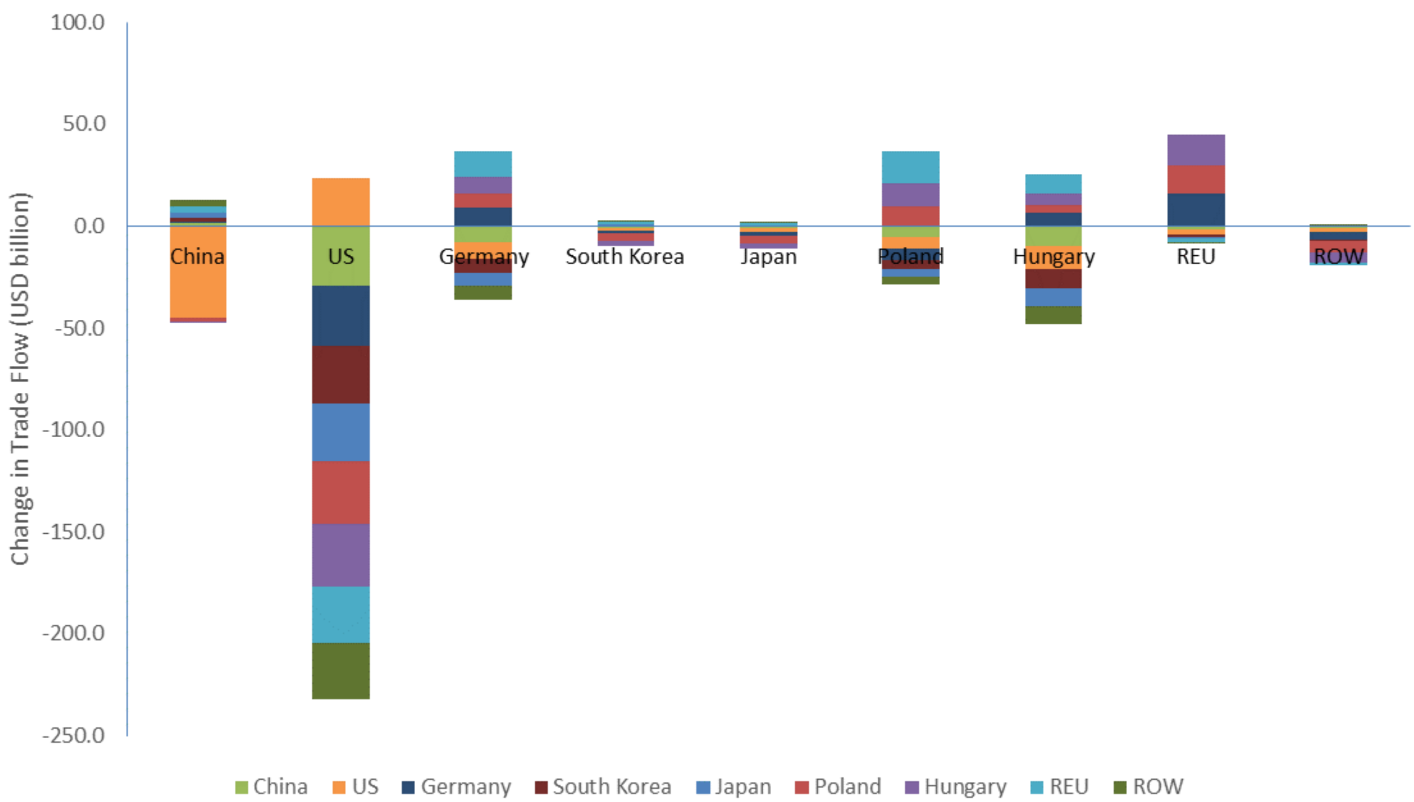


Source: author via GISM results

Figure 25 illustrates the final result of our GISM. The U.S. had won by gaining the most welfare. Despite the high amount of subsidies that the U.S. had to put in, the U.S. gained USD 0.9 billion in welfare. Its producer surplus gained USD 3.7 billion and its consumer surplus gained USD 0.6 billion. China lost USD 0.4 billion in welfare. The consumer surplus was USD 0.9 billion but China lost USD 1.3 billion in its prouder surplus. Other countries fluctuated and remained largely balanced, including the ROW.

4.3.3. Change in battery trade

Figure 26: Change in Trade Flow



Source: author via GISM results

Figure 26 shows the trade flow from China to the U.S. largely decreased, indicating that the effectiveness of the U.S. policy. The trade flow from the U.S. to other countries or regions declined. The only increase for the U.S. was the domestic trade flow. South Korea and Japan were facing a similar situation. They both had an increased in domestic trade and trade with REU and ROW. European countries have increased the trade flow within the Europe region. The trade flow between European countries towards other countries including ROW decreased. The increase and decrease are basically balanced.

4.3.4. Change in prices for batteries

Figure 27: Change in Producer/Consumer Price

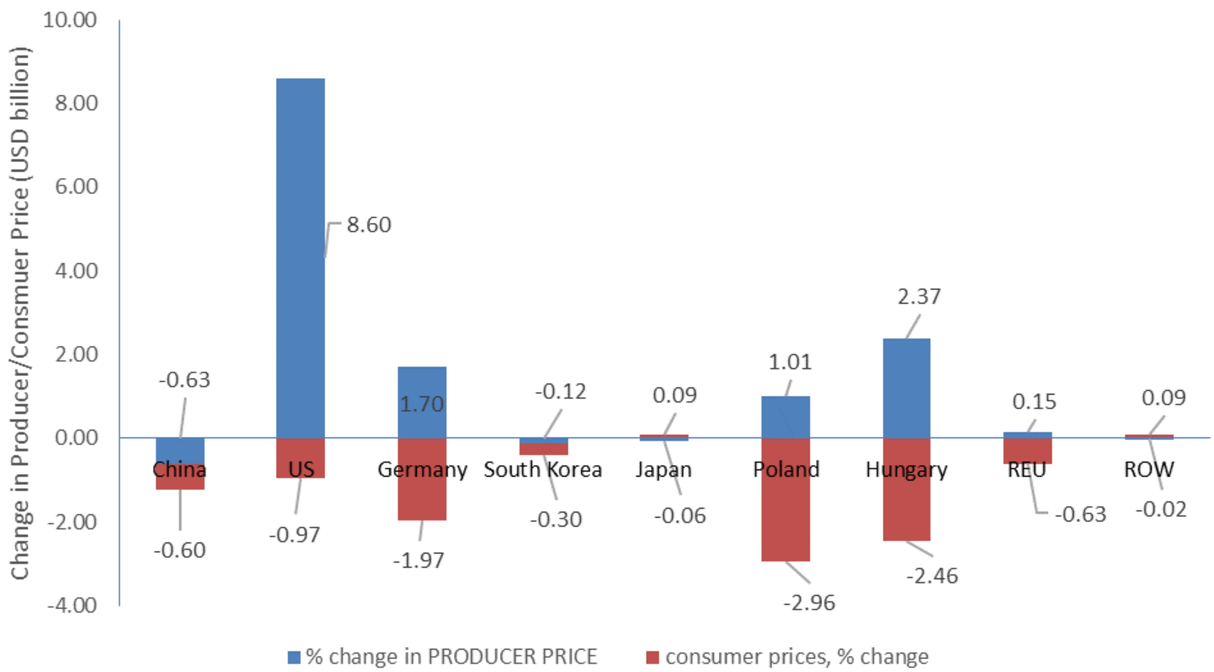


Figure 27 displays the price changes for producers and consumers. China's producer price decreased by 0.63% and China's consumer price decreased by 0.6%. The U.S. producer had an increase in price of 8.6%. While U.S. consumers would see a 0.97% lower price for batteries. Germany, Poland, and Hungary had producer prices rising at 1.7%, 1.01% and 2.37 % respectively. Germany, Poland, and Hungary also had a decrease in consumer prices.

South Korea and Japan, and the ROW didn't change much in terms of the consumer and producer price. This implies that the U.S. and EU policies had limited effect on those counties.

5. Conclusions

5.1. Key takeaways from the research

The conclusions of this thesis will focus on the national benefits and economic aspects.

Key Takeaway 1: The China-US trade conflict

China and the US have many long-rooted disputes covering the aspects from political to economic areas. These areas include the different opinions of political bodies, national narratives, trade protectionism, and national security. It is difficult to solve these problems due to a lack of trust between the two countries. The current economic clash will likely continue until a major turning point is reached. In the future, we predict that trade between China and the US will maintain tension.

Key Takeaway 2: The successes and failures of the US trade protectionism

According to the results in Scenario 1 and Scenario 3, the US tariff increase will cause China to lose its producer surplus. From this point, the US has successfully achieved the effect. China in the future may face a pushback in battery production.

Despite the high subsidy cost, the U.S. had an undisputable advantage through the combined effect of both the U.S. tariff and the EU subsidies.

The model suggests that the combined reality may indeed achieve its strategic goal. However, given the scale of Chinese battery manufacturing, could the U.S. push China over the dominance of the battery market is still questionable.

Key Takeaway 3: The benefited countries in this conflict

The U.S. and the European countries would benefit the most in this scenario. From the result, we can see that only China and the ROW would lose. But the loss wasn't significant either. This gives a green light to the U.S. tariffs and the EU NTMs.

Key Takeaway 4: The Necessity of the Policies

The U.S. and European countries will have to pay the price for their policies and yet have limited effects on a manufacturing giant like China. But it may be a necessary pain to endure if these two regions want to recapture power in this trending new energy industry. National security and political distrust have become a new phenomenon and pure economic interest sometimes has to give away for this old-timer's thinking. Let the economy flow China can and will continue to dominate the battery market, coming alone with more funds, production ability, and R&D research. If other countries want to alter the facts, they have to sacrifice the current interest for the longer goal. Ironically, despite the final outcome of many Chinese policies, this is exactly what China is good at.

Key Takeaway 5: The Future of the Lithium-ion Battery Market.
It is without doubt that the trend of Li-ion batteries will not stop. Countries will compete fiercely in this sector and the research of this product is far away from the bottom. We may face a future with more competition and investment. More Maga factories will be built. Despite many oppositions, the Chinese lithium battery will remain prosperous in the next decades.

5.2. Limitations and areas for further research

The author put in a lot of effort trying to find the most suitable data for the model, but as a new emerging product, the lithium-ion battery still remains a niche of the economic research scope. This means that many data we used was proximity. This includes the elasticities (demand, substitution, and composite). The market lacks the proper research of those data. The UNcomtrade also lacks the in-detailed product import and export records for lithium-ion batteries. We hope that in the future they can further specify the HS code for this import power product. We used data gathered from different sources including government reports and business reports, so the calibration may misalign.

The research also neglects the fact that China will likely retaliate. Given how important the lithium battery is to China, how will China react to these policies is interesting and yet to be further investigated. In the future, we believe that given how important is this product, we can see a better-documented properties both in terms of elasticity and trade flow. In that case, we can conduct a more precise result for the reader.

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