THE IMPACT OF CHANGES IN TRADE POLICIES ON THE ELECTRIC VEHICLE (EV) SECTOR– A CGE ANALYSIS

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Abstract

In this paper, we develop a CGE model which considers both the upstream and downstream of an EV supply chain, analyzing the impact of global tariffs on Chinese exports of EVs and hybrids and EV parts on trade, output, and the overall economy. Simulation results indicate significant differences in the effects of tariffs on upstream EV parts compared to downstream EVs and hybrids. A global tariff increase on Chinese EVs and hybrids leads to a decline in China's exports of such products, while major EV producers increase their exports of EVs and hybrids. The magnitude of the trade diversion effect varies and depends, in part, on Chinese EV exports' share of domestic EV consumption in each region. Moreover, global tariffs on downstream EVs and hybrids affect upstream production and trade: major EV producers expand their EV and hybrid production, subsequently increasing their demand for EV parts and ICE parts from China. This leads to a rise in Chinese exports of EV parts and ICE parts to these regions. By contrast, global tariffs on Chinese exports of EV parts depict a different picture: global tariffs against Chinese exports of EV parts cause a significant decline in Chinese exports of EV parts to other regions, while other regions increase their exports of EV parts. This, in turn, affects downstream EV prices, leading to a change in global trade and production patterns of EVs. Certain major EV producers in the industry increase their production and exports of EVs and hybrids, while others experience a decline. The macroeconomic consequences are also different in the two scenarios: Notably, China experiences a greater decline in welfare when global tariffs increase against Chinese exports of EV parts compared to EVs and hybrids.

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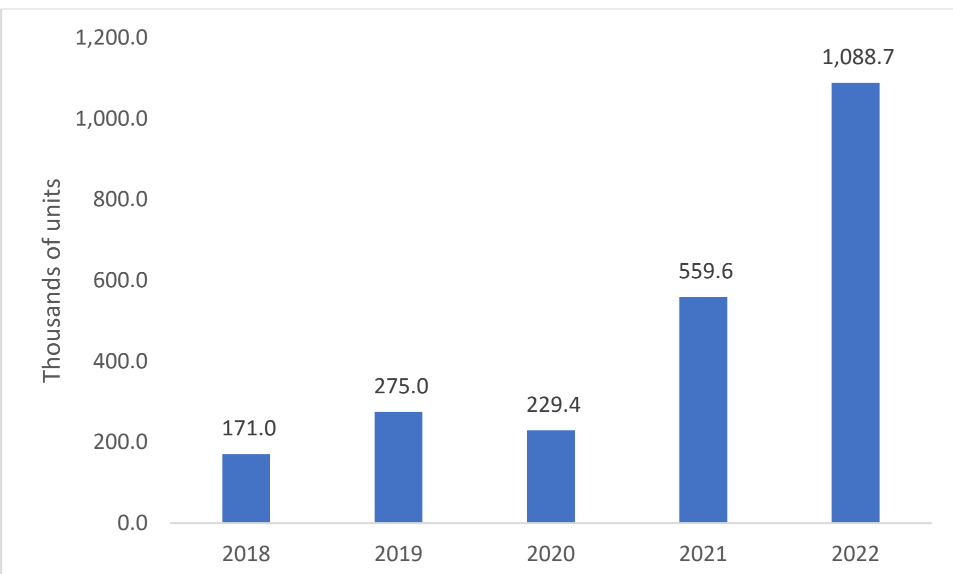
Introduction

Since 2018, China has emerged as a dominant player in both EV sales and production. From 2018 to 2022, global demand for electric vehicles (EVs) increased rapidly from 1.6 million units in 2018 to 7.7 million units in 2022.[1] Chinese sales and production have outpaced other countries, with an increase in sales from 1.3 million units in 2018 to 6.1 million in 2022, and similar levels of production. By 2021, China had also become a global leader in EV exports, when its exports increased from 230,000 units in 2020 to 560,000 units in 2021. Then they nearly doubled again to almost 1.1 million units in 2022 (figure 1). This rapid growth has increased the importance of economic impact analysis of the EV sector and its effects on traditional internal combustion engine (ICE) vehicles and supply chains.

The automotive industry, which employs millions globally (including more than a million workers in the United States) and tends to represent the largest import and export category in U.S. trade, is currently undergoing a transition from ICE vehicles to EVs. Due to its size, changes within this sector can reverberate throughout the entire economy. However, existing economy-wide models lack the necessary granularity to capture the upstream and downstream effects of an EV supply chain. To address this gap, we create a novel computable general equilibrium (CGE) model that distinguishes between EVs and ICE vehicles. For each, the model also distinguishes upstream parts from downstream finished vehicles. As a result, our model allows novel analysis of how changes in trade policies affect the EV sector, the ICE vehicle sector and other vehicles sector, including downstream production and trade, as well as upstream EV parts, ICE parts, and other vehicle parts. Additionally, it examines the corresponding macroeconomic and income effects.

Figure 1: Chinese EV Exports, in thousands of units, 2018–2022



Source: S&P Global, Global Trade Atlas, accessed February 15, 2024. HS subheadings 8701.22, 8701.23, 8701.24, 8702.20, 8702.30, 8702.40, 8703.40, 8703.50, 8703.60, 8703.70, 8703.80, 8703.90, 8704.41, 8704.42, 8704.51, 8704.52, 8704.60.

[1] International Energy Agency (IEA), "Global EV Outlook 2023 – Analysis," April 2023.

The remainder of our paper is structured as follows: Section 2 offers a review of existing literature pertaining to the EV sector. Section 3 outlines our modeling framework and methodology. Section 4 presents the simulation scenarios and discusses the results. Section 5 concludes our paper.

Literature Review

This paper builds upon existing literature studying how tariffs affect trade flows. Often, this literature examines tariffs levied by a single country targeting goods from a certain country, such as the United States' Section 301 tariffs against certain goods from China. However, our research develops a computable general equilibrium (CGE) model to simulate the effect of all other regions levying a global tariff against Chinese exports of EVs and EV parts. Our primary objective is to demonstrate how simulation results differ when imposing a global tariff on an upstream intermediate input sector versus a downstream final goods sector. Given the significant volume of Chinese EV and EV parts production and exports to the global market, we consider the EV industry as an ideal case study for our analysis. Moreover, our research can also be used to understand the role of Chinese vehicle and vehicle parts manufacturing in both the global supply chain and in consumer markets.

This research is particularly salient due to the growth of the Chinese EV industry. Historically, Chinese vehicles were not significant competitors for the major car producing economies, namely the United States, Japan, South Korea, and the European Union (EU). However, China is emerging as a leader in EV and hybrid vehicle trade, with exports increasing 537 percent from 2018 to 2022, to just under a million EVs exported in 2022 (the largest volume of any exporter).[2] This rapid growth is in-part attributed to former Chinese President Hu Jintao's 2009 decision to promote Chinese "new energy vehicles," which include EVs, hybrids, and hydrogen-fueled vehicles. Following this decision, the Chinese government proposed goals, policy incentives, and subsidies to encourage new energy vehicle production.[3]

EU imports of EVs and hybrids from China have grown by 873 percent by volume from 2018 to 2022.[4] This rapid increase prompted the EU to launch an anti-subsidy investigation against Chinese EVs. However, half of EU imports of Chinese EVs are from Tesla's gigafactory in Shanghai. EV brands originating in China, such as BYD, account for 0.03 percent of the EU's automotive sales.[5] Inflows of Chinese EVs have been significantly less pronounced in the U.S. market, which is primarily due to Section 301 duties against China, which levy an additional 25 percent tariff on imports of vehicles and vehicle parts from China.[6] Other factors include domestic manufacturing requirements for EV tax credits under the Inflation Reduction Act (IRA),[7] different vehicle standards,[8] and a negative impression of Chinese EVs

[2] S&P Global, Global Trade Atlas Database, accessed April 4, 2024. HS subheadings included: 8701.22, 8701.23, 8701.24, 8702.20, 8702.30, 8702.40, 8703.40, 8703.50, 8703.60, 8703.70, 8703.80, 8703.90, 8704.41, 8704.42, 8704.51, 8704.52, 8704.60.
[3] He et al., *Assessment of Electric Car Promotion Policies in Chinese Cities*, 2018, iii, 12.
[4] S&P Global, Global Trade Atlas Database, accessed April 4, 2024. HS subheadings included: 8701.22, 8701.23, 8701.24, 8702.20, 8702.30, 8702.40, 8703.40, 8703.50, 8703.60, 8703.70, 8703.80, 8703.90, 8704.41, 8704.42, 8704.51, 8704.52, 8704.60.
[5] Busch and Lee-Makiyama, "The US May Be the Loser in Europe's Case against China's Electric Vehicles," September 22, 2023.
[6] Mazzocco, "China's Current Economy: Implications for Investors and Supply Chains," August 21, 2023, 8.
[7] Inflation Reduction Act of 2022, Pub. L. No. 117-169; Minott and Nguyen, "IRA EV Tax Credits," February 24, 2023.
[8] Amariei, "U.S. Citizens Can Import Cheap EVs From China," June 26, 2022.

among consumers.[9] Furthermore, national security concerns may hamper the ability for Chinese EV manufacturers to enter and produce in the U.S. market in the future.[10]

Chinese production has not been limited to EVs. It incorporates significant upstream portions of the supply chain, from critical mineral refining to EV battery production. Scott and Ireland (2020) examined the critical minerals used in lithium-ion batteries and found that mineral refining for manufactured products is concentrated in China.[11] Coffin (2021) found that Chinese production capacity made up the majority of global production capacity for each major battery component (cathode, anode, separator, electrolyte). Horowitz et al. (2021) found that China was the largest producer of EV batteries and that its exports were increasing.[12] Coffin and Walling (2024, forthcoming) provide more information showing that Chinese battery capacity makes up more than 75 percent of global capacity, and will continue to make up the majority through at least 2027.

Since the United States imposed Section 301 tariffs against certain goods from China, a growing body of literature has found that Section 301 tariffs have limited imports of targeted goods from China, and that higher prices due to the tariffs were generally passed almost entirely to consumers. For example, USITC (2023) uses a partial equilibrium (PE) model to focus on the direct effect of Section 301 and Section 232 tariffs on the U.S. economy and finds a 13 percent decline in the import value of U.S. imports from China in sectors affected by Section 301 duties.[13] Almost all Chinese imports in the motor vehicle parts sector are subject to Section 301 duties, and the USITC (2023) finds that the duties reduced motor vehicle parts imports from China by more than 50 percent.[14] Furthermore, the USITC (2023) also finds that the tariff amount was generally passed through to consumers almost completely, which is supported by similar findings from by Amiti et al. (2019), Fajgelbaum et al. (2020), Cavallo et al. (2021), and Jiao et al. (2022).[15]

Using a regional input-output model (RIIMS II), Schultz et al (2019) predict the effects of ten different combinations of policies related to Section 232 tariffs, Section 301 tariffs, and USMCA Rules of Origin on

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[9] Meyer, “Americans Are Willing to Pay More to Reject Chinese EVs,” March 29, 2023.

[10] For example, in 2023, the U.S. Department of Energy rejected a $200 million grant to an EV battery manufacturer due to alleged ties to China. In 2024, the U.S. House of Representatives Select Committee on the CCP requested that the Biden administration investigate Ford’s proposed partnership with CATL, a Chinese battery company, to build an EV battery plant in Michigan. The Biden Administration has also directed the U.S. Department of Commerce to investigate national security risks associated with automotive imports from China. Ferris and Posaner, “Miles Apart,” June 23, 2023; Daly, “Energy Dept. Rejects $200M Grant to Battery Maker after GOP Criticism over Alleged Ties to China,” May 24, 2023; U.S. House of Representatives Select Committee on the CCP, “Letter on Ford’s Plan to Use Chinese Technology at Joint Factory with CATL,” January 29, 2024; White House, “Fact Sheet,” February 29, 2024.

[11] Scott and Ireland, “Lithium-Ion Battery Materials,” June 2020.

[12] Horowitz, Coffin, and Taylor, “Supply Chain for EV Batteries: 2020 Trade and Value-Added Update,” 2021.

[13] U.S. International Trade Commission (USITC), *Economic Impact of Section 232 and 301 Tariffs on U.S. Industries*, March 15, 2023, 23.

[14] U.S. International Trade Commission (USITC), *Economic Impact of Section 232 and 301 Tariffs on U.S. Industries*, March 15, 2023, 159.

[15] U.S. International Trade Commission (USITC), *Economic Impact of Section 232 and 301 Tariffs on U.S. Industries*, March 15, 2023, 140, 316; Amiti, Redding, and Weinstein, “Who’s Paying for the US Tariffs?,” May 2020; Fajgelbaum and Khandelwal, “The Economic Impacts of the US-China Trade War,” September 2021; Cavallo et al., “Tariff Pass-Through at the Border and at the Store,” March 2021; Jiao et al., “The Impacts of the U.S. Trade War on Chinese Exporters,” December 9, 2020.

the automotive sectors. In all scenarios, the authors find that more restrictive trade policies caused prices to rise and sales to fall, however the magnitude of these effects vary significantly. [16]

Research prior to the growth of Chinese EV exports may also provide insight into the effects of limiting Chinese exports. For example, Rosyadi and Widodo (2017) do not model the effects of the Section 301 tariffs specifically, but instead use a CGE model to predict the short-run effects of two different policy scenarios: the U.S. imposition of a 45 percent tariff on all Chinese goods and the U.S. imposition of a 45 percent tariff on Chinese manufacturing goods. For both scenarios, the authors find a negative effect on the terms of trade between the United States and China and a global decline in GDP and welfare.[17] Furthermore, the authors find evidence of trade diversion, which was not supported by Cigna et al.'s (2021) difference-in-differences estimation on the short-run effects of the United States' Section 301 tariffs against China.[18] However, research studying the effect of the United States' Section 421 tariffs on Chinese tires finds evidence of trade diversion and higher prices for tires.[19]

Other research prior to the growth of Chinese EV exports may provide insight into using GTAP CGE models to estimate the effect of tariffs levied against China. Dong, Ishikawa, and Hagiwara (2015) use a GTAP CGE model to study the effect of certain policies on emissions by simulating the effect a coalition of countries imposing certain carbon abatement policies, including import tariffs against non-compliant countries and an export carbon tax against China. The authors find that trade-restricting measures for carbon abatement have varying policy effects on economic growth, carbon leakage, emissions, and welfare and a generally negative effect on China's exports of commodities in energy-intensive and trade-exposed sectors.[20] Similarly, Sheng and Wang (2022) use a GTAP model to study the effect of carbon tariffs imposed on China by the European Union, the United States, and Japan. They find that such measures will have a negative effect on China's exports of energy-intensive industries, but a positive effect on less energy-intensive industries in China. The authors also find evidence of trade diversion, particularly in the scenario when all three economies impose a carbon tariff on Chinese goods.[21]

Extensive research has also been done on factors related to EV adoption. A comprehensive literature review found 53 papers on mathematical modeling of EV adoption.[22] However, literature modeling or mapping the economic impacts of the EV transition are relatively sparse and do not include country-level effects or upstream trade, instead focusing on consumer impacts. Chen et al (2021) use a single-country CGE model – the U.S. Computable General Equilibrium (USCGE) Model to analyze the environmental and economic impact of EV adoption in the United States.[23] USCGE separates the U.S. economy into 58 producing sectors, nine household groups, three U.S. government actors, and foreign producers. It does not examine international supply chains in detail.[24] Chen et al find that subsidies and price reductions would further increase adoption of battery-electric vehicles (BEV) and spur economic growth. However,

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[16] Schultz, Dziczek, and Swiecki, *U.S. Consumer & Economic Impacts of U.S. Automotive Trade Policies*, February 2019.
[17] Alim Rosyadi and Widodo, "Impacts of Donald Trump's Tariff Increase against China on Global Economy," May 29, 2017.
[18] Cigna et al., "The Impact of US Tariffs against China on US Imports: Evidence for Trade Diversion?," January 2022.
[19] See e.g., The US-China Business Council, "Issues Brief: Tariffs on Chinese Tires 10 Months Later-- Right or Wrong Remedy?," August 2010; Hufbauer and Lowry, "US Tire Tariffs," March 2, 2016.
[20] Dong, Ishikawa, and Hagiwara, "Economic and Environmental Impact Analysis of Carbon Tariffs on Chinese Exports," July 1, 2015.
[21] Sheng and Wang, "Influence of Carbon Tariffs on China's Export Trade," 2022.
[22] Maybury, Corcoran, and Cipcigan, "Mathematical Modelling of Electric Vehicle Adoption," June 1, 2022.
[23] Chen et al., "Environmental and Economic Impact of Electric Vehicle Adoption in the U.S," April 2021.
[24] Rose and Chen, "Resilience to a Cyber-Attack on the Automobile Industry," November 17, 2017.

they also find that a higher subsidy ($8,000) would increase manufacturing activity (and thus non-tailpipe emissions) so much that it would result in a net increase in CO_2 emissions.[25] Yuan et al (2021) modeled the EV transition, focusing on energy usage.[26] This paper uses a bottom-up model for the road transport sector and EnergyPLAN (an hourly energy system simulation tool) to explore the effects of increased EV and renewable energy adoption with the Beijing-Tianjin-Hebei urban agglomeration as a case study. Vega-Perkins et al (2022) map the impacts of electric vehicles in the United States. They find that over 90 percent of U.S. households would see savings in GHG emissions and energy burden from EV adoption and at-home charging.[27]

As outlined above, none of the existing literature considers both the upstream and downstream aspects of an EV supply chain to assess the impact of trade policy changes on trade and output of EVs and EV parts, and the broader economy. Our paper addresses this gap by developing a CGE model framework that considers both upstream and downstream components of the EV supply chain to examine these effects.

Theoretical Framework/Methodology

We create a CGE model framework which incorporates the specifics of the upstream and downstream of an EV supply chain to analyze how changes in global tariffs on electric vehicles or electric vehicle (EV) parts affects changes in output, trade, consumer demand of EVs, EV parts, and ICE parts, as well as the corresponding macroeconomic consequences. For this analysis, EV parts include HS tariff lines 8507.60 (lithium-ion batteries), 8507.90 (battery parts), and 8501.32 (electric motors). EVs and Hybrids include all battery-electric and hybrid motor vehicles from buses to cars to pickup trucks. HS tariff lines include 8702.40 (electric buses), 8703.60 (plug-in hybrid electric vehicles), and 8704.41 (hybrid diesel light trucks), as well as 14 other lines.

The CGE model we create adopts version 11 of the GTAP database, which contains information of the world economy of 2017 for 160 regions and 65 sectors. This database has separate regions for each of the major electric vehicle-producing and -consuming countries. However, GTAP's motor vehicles and parts sector combines all types of vehicles and parts into a single commodity (Carrico, Jones, and Tsigas, 2012). This means that for an analysis of world EV production and trade, the GTAP database is sufficiently disaggregated in terms of regions, but not sectors.

Meanwhile, Chinese production and exports of EV parts and EVs began to rise rapidly only after 2020. To assess the impact of trade policy changes on global EV production and trade, it is crucial to update the GTAP version 11 database to a more recent year. To update the GTAP database, we first aggregate the GTAP database from 160 regions into six key regions —namely, the United States, the European Union (EU), China, Japan, Korea, and the rest of the world (ROW). The five regions — the United States, the EU, China, Japan and Korea are major producers of EV parts and EVs. We maintain the sector details of the 65 GTAP sectors. Subsequently, we update the aggregated GTAP database by updating the numbers of Gross Domestic Product (GDP), total trade flows, and motor vehicles and parts (MVH) sector output from 2017 to 2022 for the United States, EU, China, Japan, and Korea.

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[25] Chen et al., "Environmental and Economic Impact of Electric Vehicle Adoption in the U.S," April 2021, 9.
[26] Yuan et al., "The Electrification of Transportation in Energy Transition," December 1, 2021.
[27] Vega-Perkins, Newell, and Keoleian, "Mapping Electric Vehicle Impacts," January 2023.

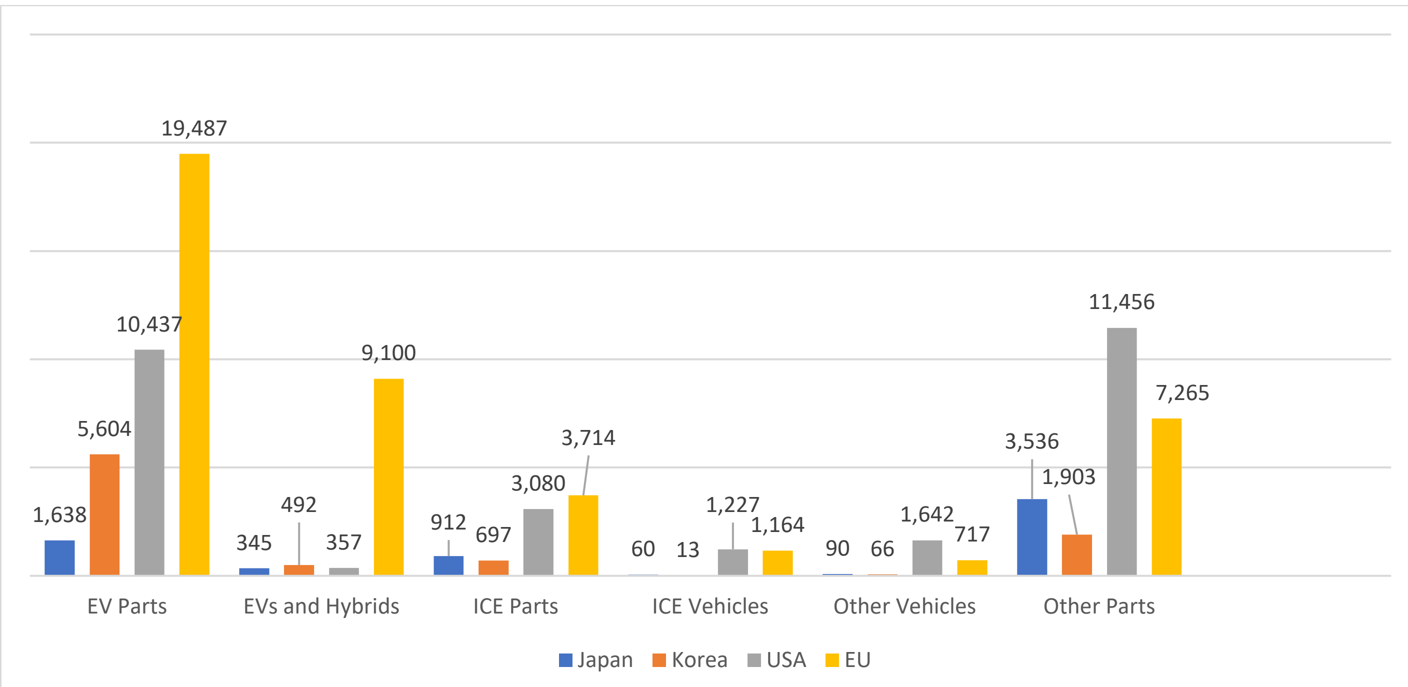
Splitting the Motor Vehicles and Parts (MVH) Sector in the Updated GTAP Database

After updating the baseline data, we split the MVH sector within baseline statistics into six sub-sectors:

- EV parts
- EV and Hybrid Vehicles
- ICE parts
- ICE Vehicles
- Other Vehicles
- Other Parts

To achieve this disaggregation, we utilize SplitCom—a set of auxiliary programs designed to enhance GTAP sector details. Specifically, we supply SplitCom with the details of bilateral export flows between the United States, the EU, China, Japan, Korea, and the ROW for the six sub-sectors. Here is an example of the Chinese export flow data that is used to split the MVH sector:

Figure 2: Chinese Exports to Major Destinations in 2022 of EV Parts, EV and Hybrid Vehicles, ICE Parts, ICE Vehicles, Other Vehicles and Other Parts, in million dollars



Source: Baseline Statistics for the CGE Model, 2022, Data from UNComtrade

As can be seen from figure 2 above, in 2022, the majority of Chinese exports of EV parts and EVs (including hybrids) went to the EU. Specifically, Chinese exports of EV parts to the EU amounts to $19.5 billion, while exports of EVs reaches $9.1 billion. In contrast, exports to other major EV-producing countries were significantly smaller. For instance, Chinese exports of EV parts worth $10.4 billion to the United States, while its exports of EVs to the U.S. were only $357 million.

Besides splitting the trade data for the MVH sector, we also incorporate the production data and information about intermediate use for the aforementioned six sub-sectors. This approach allows us to accurately represent the supply chain dynamics in our model. We focus on how intermediate inputs (EV parts, ICE parts, and other parts) contribute to the production of final products: EVs and hybrid vehicles, ICE vehicles and other vehicles. Our production function follows a nested CES (Constant Elasticity of Substitution) structure, enabling substitution among different factors of production (including skilled and unskilled labor and capital) within the value-added nest, while maintaining fixed input-output ratios between value-added and intermediate bundles.

Table 1: Output of the Six Sub-Sectors, in 2022, in million dollars

	China	Japan	Korea	USA	EU	ROW
EV Parts	79,872	4,160	5,200	6,864	7,280	624
EV and Hybrid Vehicles	173,828	13,371	16,046	21,394	34,765	8,023
ICE Parts	168,687	60,727	36,549	71,973	120,892	103,461
ICE Vehicles	618,873	174,058	77,359	232,077	309,437	522,173
Other Vehicles	16,000	4,500	2,000	6,000	8,000	13,500
Other Parts	281,426	56,285	56,285	168,855	337,711	225,141
Total	1,338,686	313,101	193,439	507,163	818,085	872,922

Source: Baseline Statistics for the CGE Model; authors' calculations. OICA, "2022 Production Statistics," (accessed March 15, 2024); Automotive World, "Global Vehicle Engine Plant Database-2023 edition," May 25, 2023; IEA, "Global Supply Chains of EV Batteries," July 2022; S&P Global, Global Trade Atlas, (accessed March 15, 2024).

Table 1 above presents the output data from our model's baseline statistics for three sub-sectors representing intermediate goods: EV Parts, ICE Parts, and Other Parts. Additionally, it includes three sub-sectors of final goods: EV and Hybrid Vehicles, ICE Vehicles, and Other Vehicles. Notably, Chinese production of EV Parts and EVs (including Hybrids) constitutes a significantly larger proportion of its overall motor vehicles and parts production compared to other major EV manufacturers. Specifically, Chinese EV Parts and EV (including hybrids) production accounts for 6.0 percent and 13.0 percent of the total Chinese motor vehicle and parts production. In contrast, these shares are 1.4 percent and 4.2 percent for the United States, and 0.9 percent and 4.3 percent for the EU (table 1).

Table 2: Intermediate Use Table for EVs (including Hybrids) and Other Types of Vehicle Production

	EV Parts	EVs and Hybrids	ICE Parts	ICE Vehicles	Other Vehicles	Other Parts
EV Parts	0	1	0	0	0	0
EVs and Hybrids	0	0	0	0	0	0
ICE Parts	0	0.14	0	0.74	0.12	0
ICE Vehicles	0	0	0	0	0	0
Other Vehicles	0	0	0	0	0	0
Other Parts	0	0.08	0	0.79	0.13	0

Source: Applied in the Baseline Statistics for the CGE model, authors' calculations

Table 2 above is the intermediate use table we utilize to represent supply chain dynamics in our model. Rows in the table correspond to intermediate inputs, while columns represent final products. The table illustrates how these intermediate inputs contribute to the production of various vehicle types. For instance, EV Parts are exclusively used in the production of EVs (including hybrids). As for ICE Parts, 74 percent are used in ICE vehicle production, 14 percent are used in EVs (including hybrids), and the remaining 12 percent are used in other vehicle production. Due to data availability, this table is constructed using global production data. Consequently, our model assumes consistent shares of intermediate goods usage in final production across all six regions for three motor vehicle types: EVs and Hybrids, ICE vehicles, and other vehicles.

Updating the Tariff Statistics in the Model Baseline

In addition to incorporating trade, production, and intermediate use information for the abovementioned six sub-sectors, we also enhance the tariff statistics for these sectors in our model baseline, using data from the MacMap database by the International Trade Centre. Specifically, we retrieve the tariff schedule for the year 2022 from MacMap, covering five countries: the United States, the European Union, China, Japan, and Korea. Next, we calculate the trade-weighted average tariff imposed by these five regions on all their trading partners across the six sectors. To update the baseline tariff in our database, we utilize Altertax, an auxiliary program designed to update tariff data in the GTAP database.

Model Structure and Trade Elasticities

In our CGE model, domestic products and imports are consumed by firms, governments, and households. Product markets are assumed to be perfectly competitive. In the model, imports are imperfect substitutes for domestic products (i.e., consumers distinguish between products based on their foreign or domestic origin), and sectoral production is determined by global demand and supply. The Armington trade elasticities, which determines the magnitudes of changes in trade patterns in response to changes in tariff rates or other trade policies, is mainly drawn from Hertel et al. (2007). Meanwhile, we re-calculate the Armington trade elasticities for the abovementioned six sub-sectors using the methodology from Ahmad and Riker (2020).[28] This methodology uses U.S. NAICS-based shipment data as a measure of net selling value, and wages as variable costs. We estimate two elasticities, one for vehicles using NAICS 3361 (motor vehicles), and one for automotive parts using both NAICS 3362 (bodies and chassis) and 3363 (motor vehicle parts). Ideally it would be possible to calculate separate elasticities for ICE vehicles and EVs, as well as the different parts categories, but that level of data granularity is not available. However, we expect that separating vehicles and parts into two buckets for elasticity purposes will be reasonably accurate. Vehicles are a final good that is generally sold to consumers in one-off transactions, and consumers are free to purchase a different vehicle in their next transaction, leading them to be more willing to substitute a different vehicle based on price. Parts, on the other hand, are an intermediate good purchased by a vehicle manufacturer as part of its supply chain. These parts have multi-year contracts, and suppliers need to meet vehicle manufacturer requirements in order to sell the vehicles. The complexity of these supply chains as well as high barriers to entry reduce the substitutability of parts relative to vehicles. The import-import Armington trade elasticity[29] is calculated to be 4.07 for motor vehicle parts, including EV parts, ICE parts and other parts, while the Armington trade elasticity is 5.68 for motor vehicles, including EV and hybrids, ICE vehicles and other vehicles.

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[28] Ahmad and Riker, "Updated Estimates of the Trade Elasticity of Substitution," May 2020.

[29] The Armington elasticity of substitution (σ) describes how consumers shift between imports from different sources, for instance, Japanese electric vehicles vs Korean electric vehicles, as a result of changes in relative prices. Our CGE model also has a value for the elasticity of substitution σ_d to determine how consumers switch between domestic and imported commodities. In our CGE modeling framework, the "rule of two" applies, that is, $\sigma=2\sigma_d$.

Simulation Scenarios and Results

Simulation Scenarios

As previously discussed, our CGE model is comparative static and is applied to a baseline year of 2022. This baseline encompasses 6 regions and 70 sectors, with detailed information retained for the 65 GTAP sectors.[30] Additionally, as discussed above, we split motor vehicles and parts sector into six distinct sectors. Apart from the Armington trade elasticities previously specified, all other model parameters are set to their default values.

Our analysis focuses on scenarios where all regions increase their tariff levels on Chinese exports of EV parts or EVs and hybrids. We explore two distinct hypothetical scenarios:

1) The United States, the EU, Japan, Korea, and ROW all raise their tariffs by 20 percent against Chinese exports of EVs and hybrids.
2) The same group of regions (United States, EU, Japan, Korea, and ROW) increase their tariffs by 20 percent on Chinese exports of EV parts.

The simulation scenarios are designed to illustrate how simulation outcomes differ when tariffs are applied to final goods (EVs and hybrids) versus when they are imposed on intermediate goods (EV parts). Since the scenarios are purely hypothetical, the simulation results are not intended to be prescriptive regarding how a government should use tariff protection. Moreover, it's essential to recognize that factors like global demand shifts and advancements in battery technology might have far greater impact on the EV industry than tariffs. As a result, the comparative static CGE model we developed does not project economic conditions into the future, and these simulation results should not be interpreted as expected future changes.

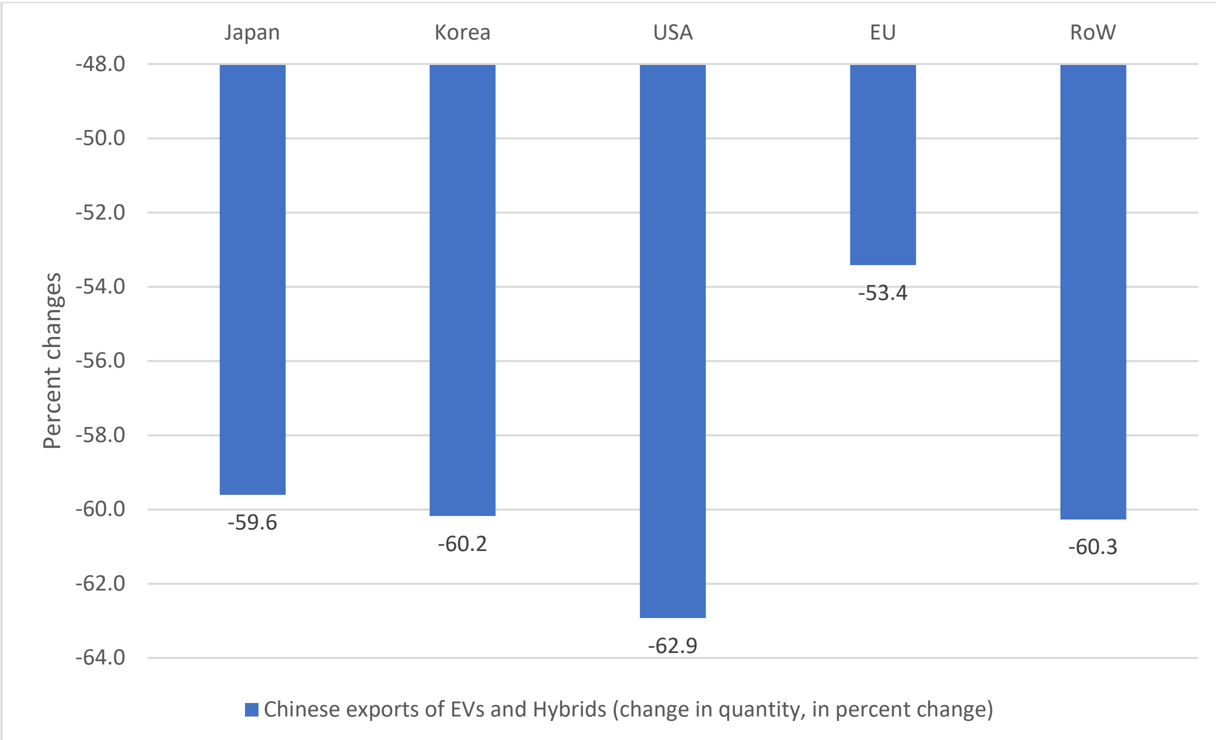
Simulation Results from the First Simulation

Trade Effects of EVs and Hybrids from the First Simulation

As a result of the simulated increased tariffs imposed by the United States, the EU, Japan, Korea, and ROW on Chinese exports of EVs and hybrids, Chinese exports to these regions decline significantly. Figure 3 illustrates the extent of this decline: Chinese exports (in quantity) of EVs and hybrids to Japan, Korea, the United States, the EU, and ROW declines by 59.6 percent, 60.2 percent, 62.9 percent, 53.4 percent and 60.3 percent, respectively (figure 3). In terms of value, since trade statistics (reflected in the baseline) demonstrate that Chinese exports of EVs and hybrids were mainly destined towards the EU market in 2022, the EU market sees the most substantial decrease, with Chinese exports declining by $4.9 billion. Meanwhile, Chinese exports to Korea, the United States, and Japan also decrease, albeit by smaller amounts—$296 million, $225 million, and $206 million, respectively.

[30] Appendix Table 1 provides a list of the 70 sectors.

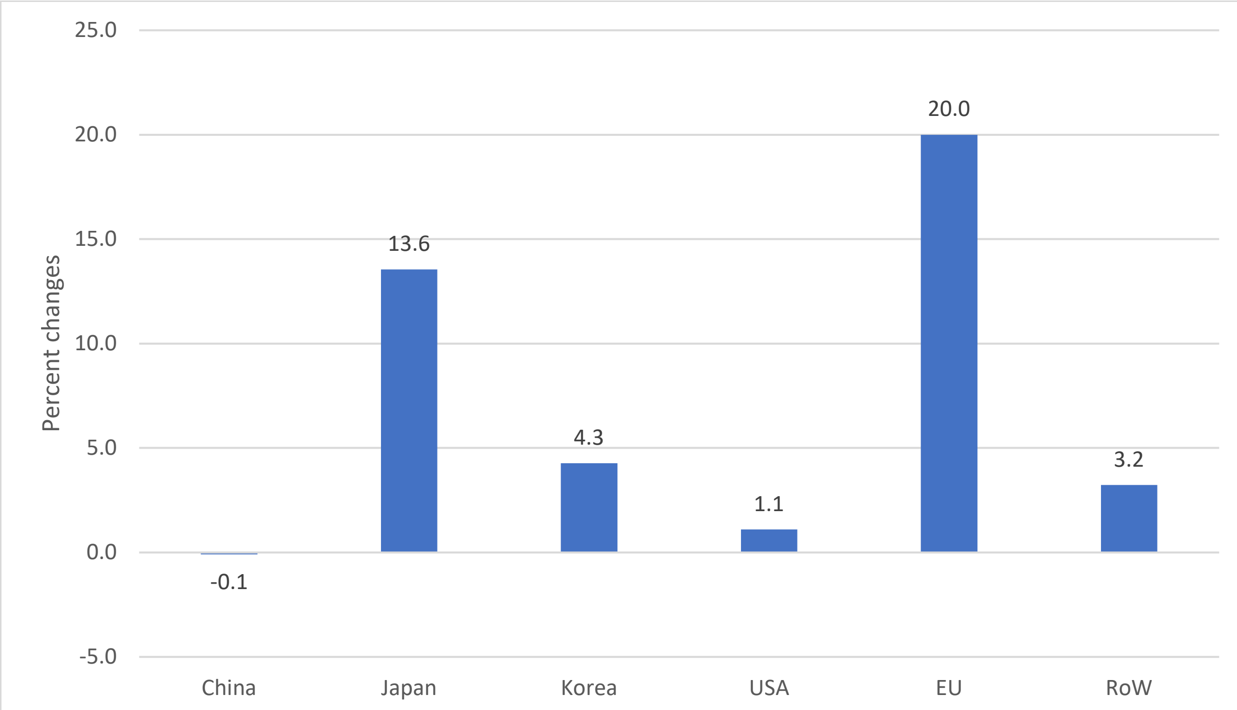
Figure 3: Change in Chinese Exports of EVs and Hybrids to Different Regions (percent deviations from the baseline)



Source: simulation results, authors' estimates.

Decreasing imports from China lead to increased demand for exports from other countries. Therefore, total exports of EVs and hybrids from the EU, the United States, Japan and Korea to the world increase by 7.8 percent, 13.6 percent, 4.6 percent and 10.0 percent, respectively. Taking the change in EU exports of EVs and hybrids as an example, EU exports of EVs and hybrids to China decline slightly, while EU exports to all other regions increase (figure 4). Intra-EU trade increases the most, rising by 20.0 percent. Meanwhile, EU exports to the United States of EVs and hybrids only increase by 1.1 percent in the simulation (figure 4). This difference in the magnitude is because Chinese EV exports to the EU constituted a substantial share of EU domestic consumption in 2022, leading to a large trade diversion effect. Conversely, Chinese EV exports to the United States accounted for only a small share of U.S. domestic consumption in 2022. Thus, U.S. imports from other regions only increase slightly as a result of trade diversion in this simulation.

Figure 4: Change in EU Exports of EVs and Hybrids (percent deviations from the baseline)



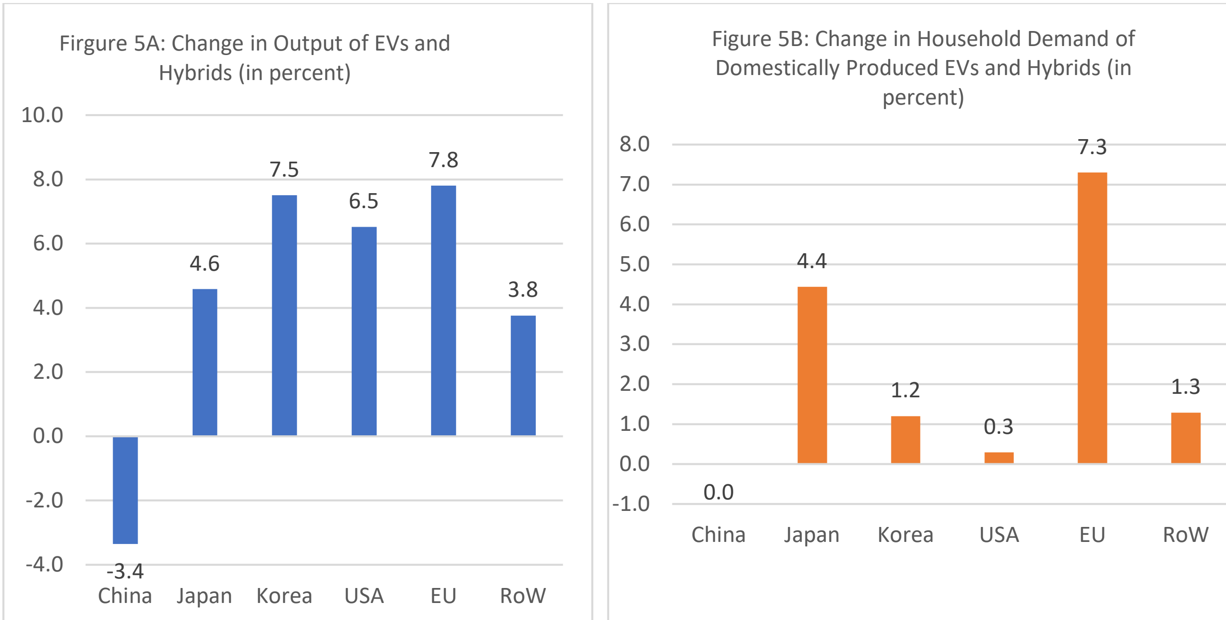
Source: Simulation Results, authors' estimates

Output and Consumption Effects of EVs and Hybrids from the First Simulation

Increases in EV and hybrid exports from the EU, the United States, Japan, and Korea boosts their domestic production. Specifically, these regions' output of EVs and hybrids increases by 7.8 percent, 6.5 percent, 4.6 percent and 7.5 percent, respectively. On the other hand, the decrease in Chinese exports of EVs and hybrids globally leads to a decline in China's domestic production of such products by 3.4 percent (figure 5A). Meanwhile, households in Japan, Korea, the United States, and the EU consume more domestically produced EVs and hybrids.[31] Notably, EU consumption of domestically produced EVs and hybrids increases the most (7.3 percent) (figure 5B). This shift occurs because Chinese exports account for a large share of the EU's domestic consumption. With the EU imposing tariffs on Chinese exports, the overall import price of EVs and hybrids in the EU rises, encouraging consumers to opt for domestically produced EVs and hybrids. In contrast, Chinese exports of EVs and hybrids account for a small share of U.S. domestic consumption, resulting in limited effects on U.S. consumer preferences of domestic-produced versus imported EVs and hybrids.

[31] The change in consumer demand of EVs and Hybrids is reflective of the environment welfare related to EVs and hybrids in these countries.

Figure 5: Change in Output of EVs and Hybrids and Change in Household Demand of Domestically-Produced EVs and Hybrids (percent deviations from the baseline)

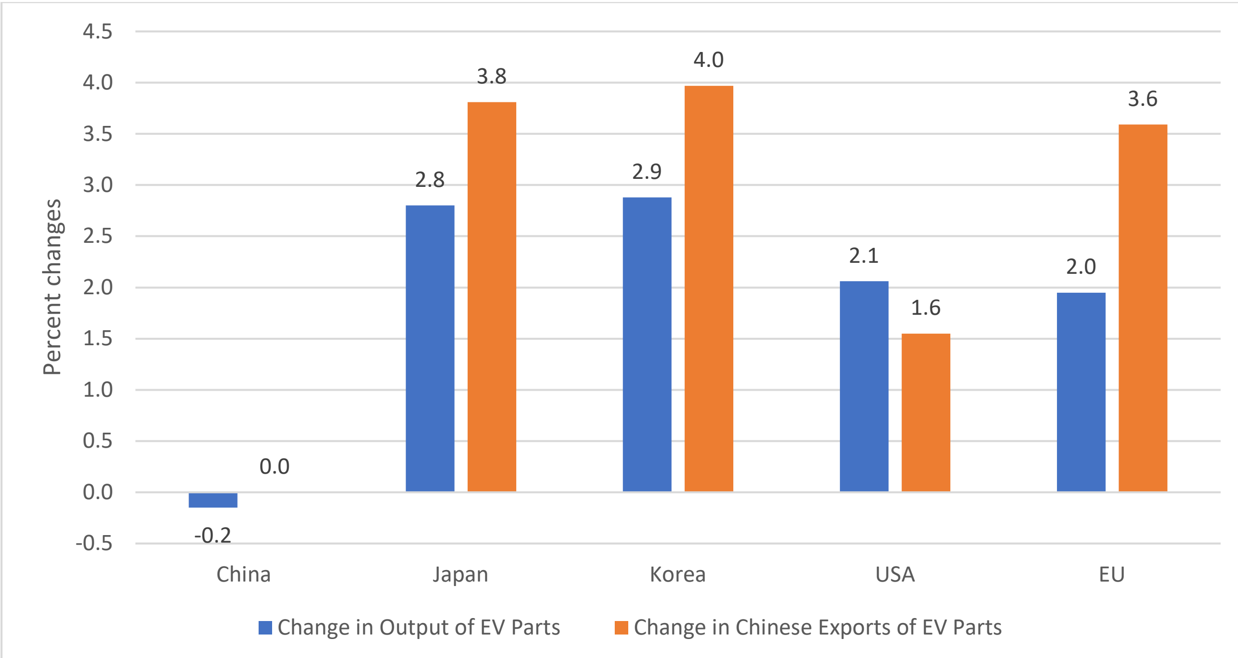


Source: Simulation Results, authors' estimates

Trade and Output Effects of EV Parts and ICE Parts from the First Simulation

As previously discussed, our CGE model considers both the upstream and downstream EV supply chain. When all regions impose tariffs on Chinese exports of EVs and hybrids, it affects not only the downstream EVs and hybrids production, but also the upstream production of EV parts and ICE parts. Specifically, the expansion of EV and hybrid production in the EU, the United States, Japan, and Korea leads to increased production of EV parts in these countries (see figure 6 below). EV parts production in these countries rises by approximately 2.0 to 2.9 percent (figure 6). Simultaneously, the growing production of EVs and hybrids in these regions drives up their demand for EV parts from other areas. Consequently, Chinese exports of EV parts to Japan, Korea, the United States, and the EU also rise, and the increase is between 1.6 to 4.0 percent. However, within China, the decline in domestic production of EVs and hybrids reduces the demand for EV parts from Chinese domestic manufacturers. As a result of these combined factors, Chinese domestic production of EV parts declines slightly (by 0.2 percent).

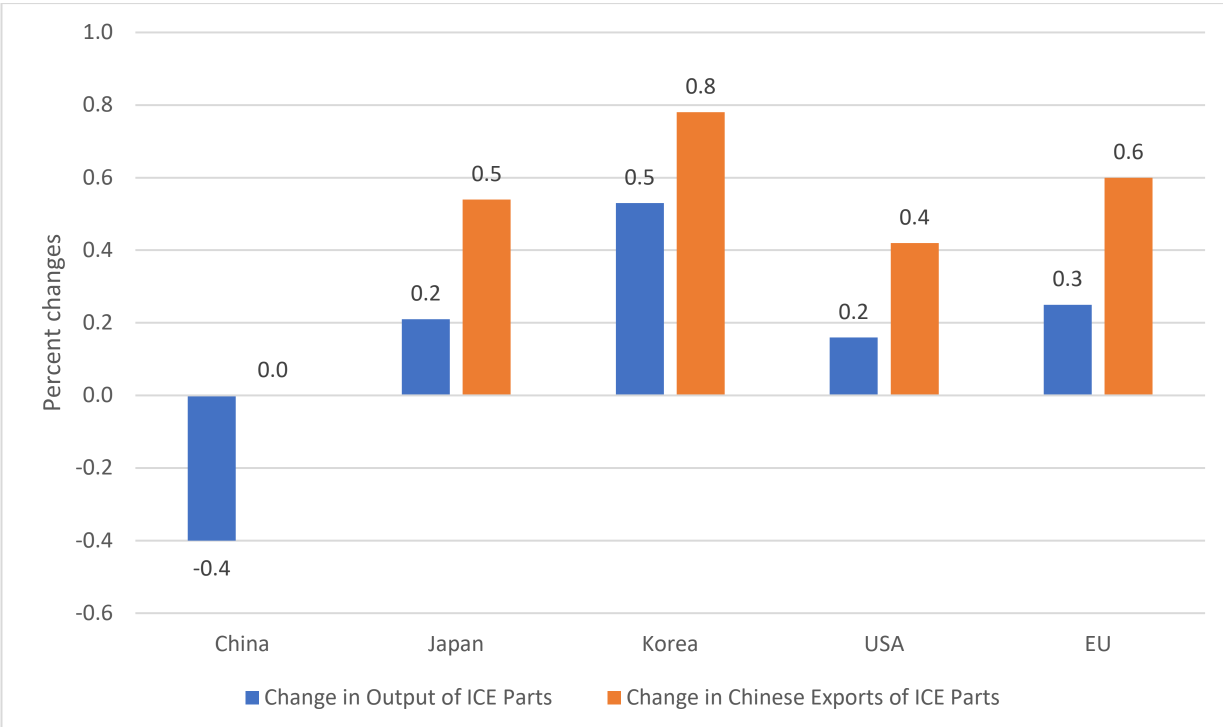
Figure 6: Change in Output of EV Parts and Change in Chinese Exports of EV Parts (percent deviations from the baseline)



Source: Simulation results, authors' estimates

From the data in table 2, we observe that 14 percent of ICE parts are utilized in the production of EVs and hybrids. Consequently, an increase in EV and hybrid production across Japan, Korea, the EU, and the United States results in a moderate rise in these regions' production of ICE parts, estimated to be between 0.2 to 0.5 percent. Simultaneously, these regions also increase their demand for ICE parts from external sources, leading to a moderate increase in Chinese exports of ICE parts to these regions, ranging from approximately 0.4 to 0.8 percent (figure 7). As for Chinese production, a slight reduction in ICE vehicle production within China, coupled with growing demand for Chinese ICE parts from other regions, results in a minor decline in output of Chinese ICE parts (by 0.4 percent)

Figure 7: Change in Output and Change in Chinese Exports of ICE Parts (percent deviations from the baseline)



Source: Simulation results, authors' estimates

Macroeconomic and Income Effects from the First Simulation

In terms of the macroeconomic impact, Table 3 provides an overview of the changes in welfare and regional household income resulting from a global tariff increase on Chinese exports of EVs and hybrids. Notably, China's welfare decreases by $2.6 billion, while welfare in Japan, Korea, and the United States increases by $125 million, $173 million, and $709 million, respectively. Surprisingly, the welfare in the EU declines by $615 million. This decline is due to an allocative efficiency loss caused by the tariff increase, which outweighs the terms-of-trade gain for the EU. Conversely, Japan, Korea, and the United States benefit from terms-of-trade gains that surpass the allocative efficiency loss. Additionally, regional household income increases slightly in Japan, Korea, the United States, and the EU, while China experiences a small decline.

Table 3: Change in Welfare (measured in EV)[32] and Change in Regional Household Income

Region	Change in Consumer Welfare (in million dollars)	Change in Regional Household Income (in percent)
China	-2,558.6	-0.07
Japan	125.4	0.02
Korea	172.8	0.05
USA	709.1	0.02
EU	-614.7	0.003
ROW	624.1	0.01

Source: Simulation results, authors' estimates

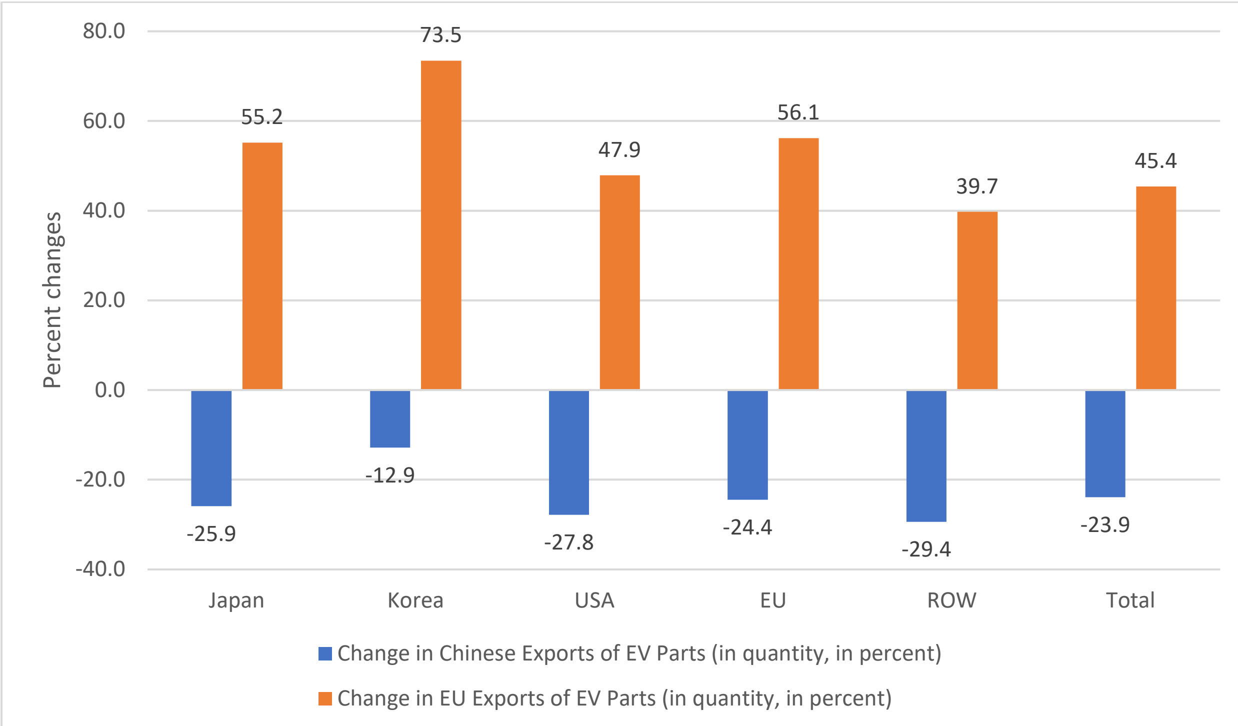
Simulation Results from the Second Simulation

Trade and Output Effects of EV Parts from the Second Simulation

When all regions impose a 20 percent tariff on Chinese exports of EV parts, Chinese EV parts exports to all regions decline significantly (Figure 8). Simultaneously, other regions increase their exports of EV parts. For instance, consider the EU as an example: EU exports of EV parts to Japan, Korea, the United States, the EU itself, and the ROW rise by 55.2 percent, 73.5 percent, 47.9 percent, 56.1 percent and 39.7 percent, respectively(Figure 8). While total Chinese exports of EV parts to the world decrease by 23.9 percent, total EU EV parts exports to the world increase by 45.4 percent (figure 8). However, due to China's substantial role as a producer and exporter of EV parts, the reduction in the dollar value of Chinese EV parts exports is more significant than the rise in exports from other regions, which do not have the production capacity to make up for all of the lost imports from China. Consequently, total imports of EV parts by quantity for Japan, Korea, the United States, and the EU all decline significantly—by 12.4 percent, 9.4 percent, 7.1 percent, and 6.7 percent, respectively.

[32] The change in welfare measures households' benefit from economic activity. It consists of the sum of real private consumption, real government consumption, and real savings. The change in welfare can also be decomposed into efficiency gains and terms of trade effects, which are determined by changes in the prices of imports and exports.

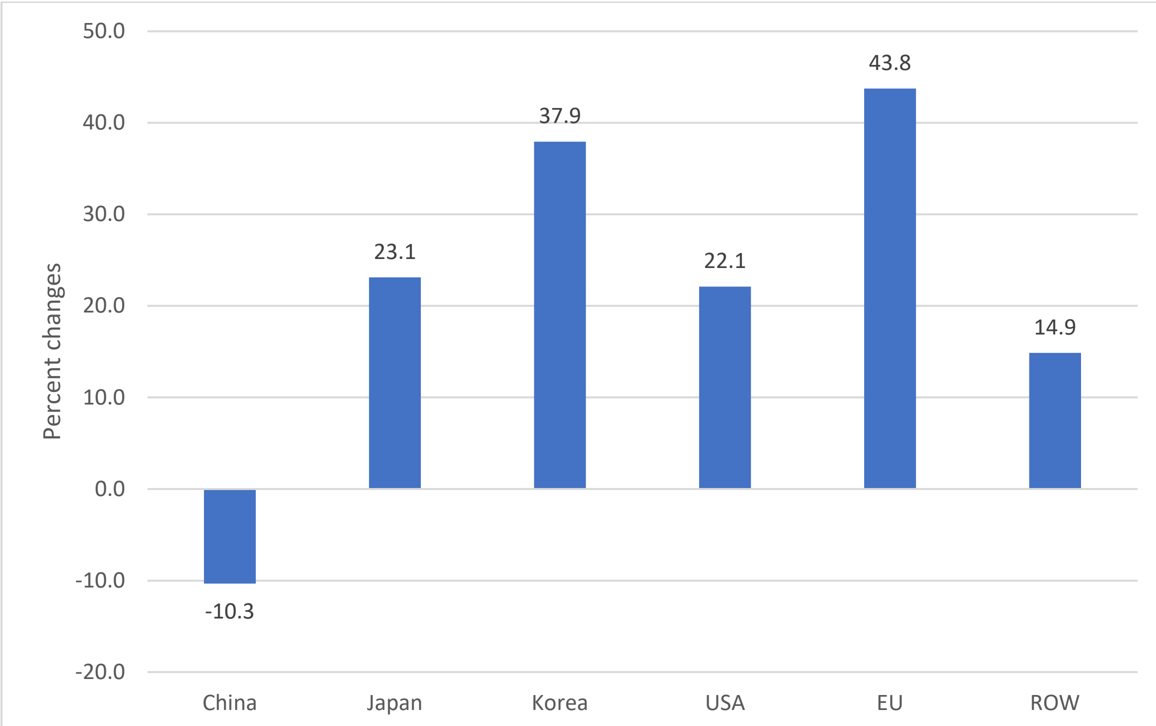
Figure 8: Change in Chinese and EU Exports of EV Parts (percent deviations from the baseline)



Source: Simulation results, authors' estimates

Regarding the shift in EV parts production, the decrease in China's export of EV parts globally leads to a reduction in their domestic production of such parts. Conversely, the rising exports of EV parts from Japan, Korea, the United States, and other regions lead to a large increase (in percent change terms) in their respective domestic production of EV parts (figure 9).

Figure 9: Change in Output of EV Parts (percent deviations from the baseline)

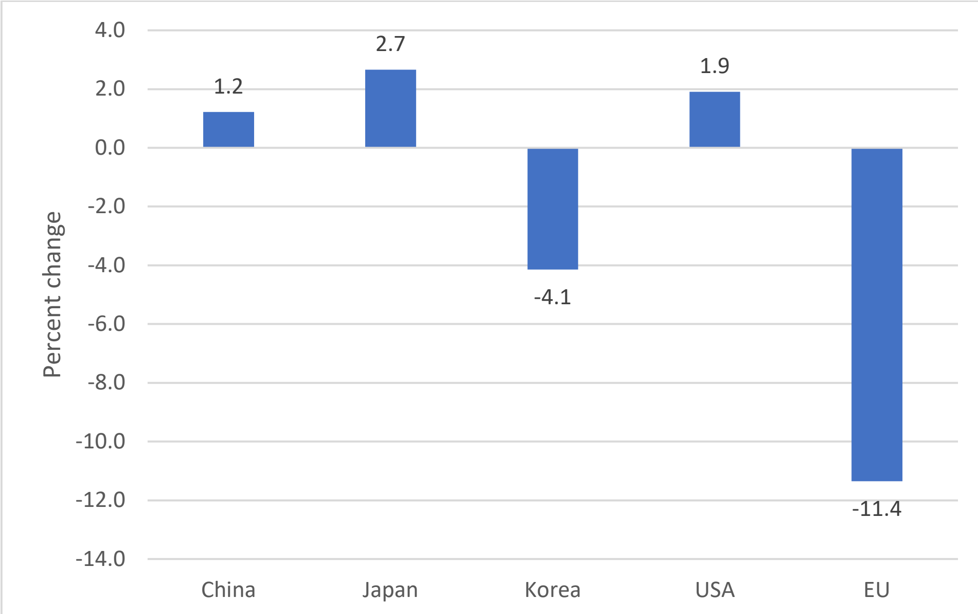


Source: Simulation results, authors' estimates

Trade and Output Effects of EV and Hybrids from the Second Simulation

With the imposition of global tariffs against Chinese exports of EV parts, some of the Chinese EV parts that would have been exported are no longer produced, while some are used in Chinese domestic production, leading to a downstream expansion of production of Chinese EVs and hybrids. Chinese EV and hybrid output increases by 1.2 percent (figure 10). Interestingly, we see an increase in production of EVs and hybrids in Japan and the United States, by 2.7 percent and 1.9 percent, respectively, and a decline in EV and hybrid production in Korea and the EU, by 4.1 percent and 11.4 percent, respectively.

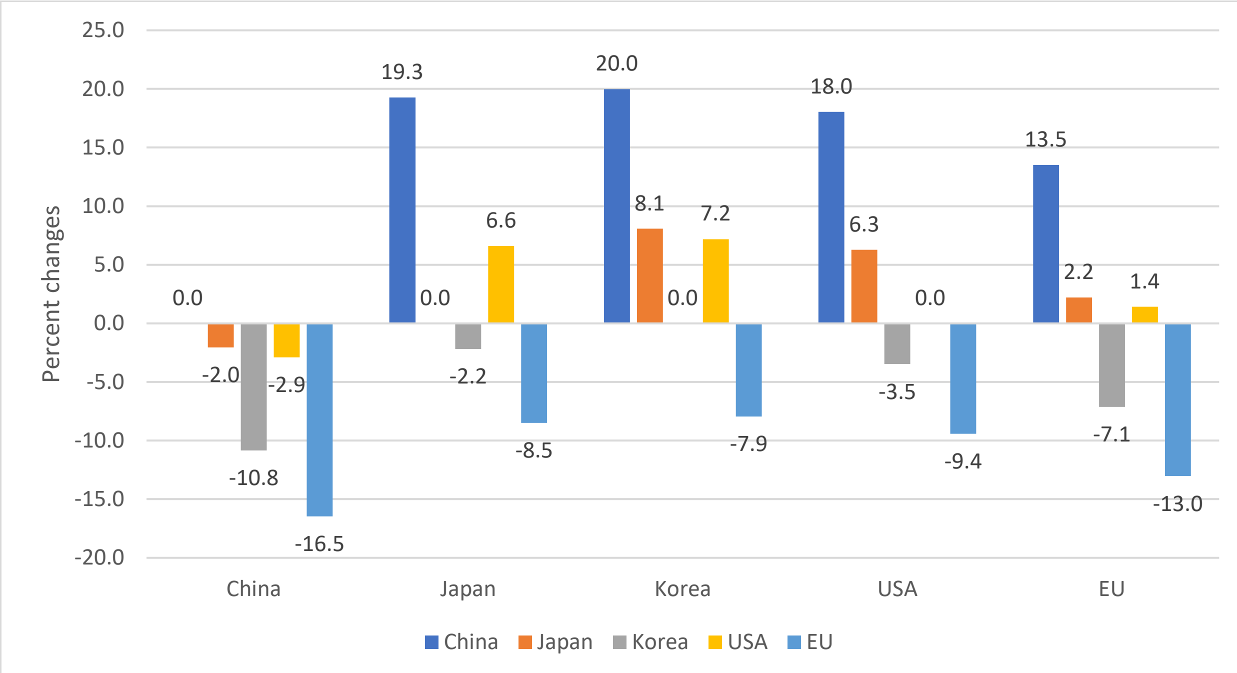
Figure 10: Change in Output of EVs and Hybrids (percent deviations from the baseline)



Source: Simulation results, authors' estimates

The shift in global trade patterns for EVs and hybrids is the primary reason behind these changes in production. As the quantity of Chinese exports and domestic production of EV parts decreases, it leads to a reduction in prices for Chinese EV parts used in downstream production. Consequently, Chinese export prices for EVs and hybrids decline compared to other major producers. Specifically, the aggregate Chinese export prices for EVs and hybrids decline by 0.06 percent, while those from Japan, Korea, the United States, and the EU increase by 1.8 percent, 3.6 percent, 2.0 percent, and 4.8 percent, respectively. As a result, Chinese exports of EVs and hybrids to Japan, Korea, the United States, and the EU increase significantly (19.3 percent, 20.0 percent, 18.0 percent, and 13.5 percent, respectively, see figure 11 below). However, the relatively large increase in EU export prices for EVs and hybrids (4.8 percent) compared to other regions, such as the United States, decreases the attractiveness of EU exports. Consequently, EU exports of EVs and hybrids to China, Japan, Korea, the United States, and the EU itself decline by 16.5 percent, 8.5 percent, 7.9 percent, 9.4 percent, and 13.0 percent, respectively (figure 11). This decline in EU exports results in an 11.4 percent decrease in EU domestic production of EVs and hybrids.

Figure 11: Change in Exports of EVs and Hybrids (percent deviation from the baseline)



Source: Simulation results, authors' estimates

Macroeconomic and Income Effects from the Second Simulation

In terms of the macroeconomic impact, Table 4 provides an overview of the changes in welfare and regional household income resulting from a global tariff increase on Chinese exports of EVs. Comparing results from table 3 and 4, it shows that China suffers a bigger decline in welfare when there is a global tariff increase against Chinese exports of EV parts ($3.6 billion) compared to EVs and hybrids ($2.6 billion).

Table 4: Change in Welfare (measured in EV) and Change in Regional Household Income

Region	Change in Welfare, in million dollars	Change in Regional Household Income, in percent
China	-3620.1	-0.09
Japan	462.5	0.06
Korea	-51.7	0.08
USA	278.9	0.03
EU	-384.9	0.01
ROW	807.8	0.02

Source: Simulation results, authors' estimates

Conclusion

In this paper, we develop a CGE model that considers both the upstream and downstream aspects of the EV supply chain. We analyze how changes in global tariffs on Chinese exports of EVs and hybrids, as well as EV parts impact trade, output, and the overall economy.

Our simulation results indicate that the economic effects of imposing a tariff on upstream EV parts differs significantly from the economic effect of imposing a tariff on downstream EVs and hybrids. As all regions raise tariffs on Chinese EVs and hybrids, China's exports of EVs to all regions decline sharply. Simultaneously, all other regions increase trade amongst themselves, exporting more EVs globally. Notably, major EV producers—such as the EU, the United States, Japan, and Korea—see their total EV exports rise by 4.6 percent to 13.6 percent. The extent of this increase depends on how much Chinese exports contributed to each region's domestic consumption. For instance, Chinese EV exports constituted a substantial share of EU domestic consumption, leading to a significant trade diversion effect for the EU. Conversely, the trade diversion effect for the United States is small due to Chinese EV exports making up a relatively small share of U.S. domestic consumption. The change in EV trade patterns also affects output —while other major EV producers increase their domestic production of EVs, China's EV and hybrid production declines.

The imposition of tariffs on the downstream Chinese EV and hybrid exports also has interesting upstream effects: As the EU, United States, Japan, and Korea expand their EV and hybrid production, they also increase their demand for EV parts from China. Consequently, Chinese exports of EV parts to these regions rise. Additionally, since some ICE parts are used in EV and hybrid production, domestic ICE part production in these regions also increases, leading to a moderate rise in Chinese exports of ICE parts.

The imposition of tariffs on Chinese exports of EV parts depicts a different picture: the global tariff against Chinese exports of EV parts causes a sharp decline in Chinese exports of EV parts to other regions. Meanwhile, all other regions increase their exports of EV parts. Reduced Chinese exports and domestic EV part production lead to lower prices for Chinese EV parts used downstream. Consequently, Chinese export prices for EVs and hybrids decrease, resulting in increased Chinese exports of downstream EVs and hybrids to other regions. Conversely, higher import prices for EV parts in Japan, Korea, the United States, and the EU leads to elevated export prices for EVs and hybrids in those regions. As a result, some regions (such as the EU) experience a sharp decline in their exports and domestic production of EVs and hybrids. The global shift in the trade patterns of EVs and hybrids depends, in part, on the extent to which export prices of EVs in these countries change.

In terms of macroeconomic impact, simulation results show that China experiences a greater decline in welfare when global tariffs increase against Chinese exports of EV parts ($3.6 billion) compared to EVs and hybrids ($2.6 billion).

One limitation of our model is that it does not consider capacity constraints for EVs and hybrids, and EV part production across regions. Our estimated output increase may be limited by production capacity. In future work, we will explore incorporating capacity constraints into our model. Moreover, the focus of our paper has been on comparing simulation results when global tariffs are levied over downstream EV exports as compared to upstream EV part exports. As discussed earlier in our paper, factors such as shifts in global demand and advancements in battery technology may have a more substantial impact on the EV industry than tariffs. Therefore, the simulation results presented in our paper should not be interpreted as predictions of expected future changes. In future work, we plan to investigate how technological improvements in upstream EV part production affect trade, output, and the overall economy.

Appendix table 1: Sectors in the CGE model:

Number	Abbreviation	Sector
1	pdr	Paddy rice
2	wht	Wheat
3	gro	Cereal grains nec
4	v_f	Vegetables, fruit, nuts
5	osd	Oil seeds
6	c_b	Sugar cane, sugar beet
7	pfb	Plant-based fibers
8	ocr	Crops nec
9	ctl	Bovine cattle, sheep and goats, horses
10	oap	Animal products nec
11	rmk	Raw milk
12	wol	Wool, silk-worm cocoons
13	frs	Forestry
14	fsh	Fishing
15	coa	Coal
16	oil	Oil
17	gas	Gas
18	oxt	Other Extraction (formerly omn Minerals nec)
19	cmt	Bovine meat products
20	omt	Meat products nec
21	vol	Vegetable oils and fats
22	mil	Dairy products
23	pcr	Processed rice
24	sgr	Sugar
25	ofd	Food products nec
26	b_t	Beverages and tobacco products
27	tex	Textiles
28	wap	Wearing apparel
29	lea	Leather products
30	lum	Wood products
31	ppp	Paper products, publishing
32	p_c	Petroleum, coal products
33	chm	Chemical products
34	bph	Basic pharmaceutical products
35	rpp	Rubber and plastic products
36	nmm	Mineral products nec
37	i_s	Ferrous metals
38	nfm	Metals nec
39	fmp	Metal products
40	ele	Computer, electronic and optical products
41	eeq	Electrical equipment
42	ome	Machinery and equipment nec
43	EV parts	Parts used in electric and hybrid vehicle production
44	EVs and hybrids	Electric and hybrid vehicle production
45	ICE parts	Parts used in ICE and EV production

46	ICE vehicles	Internal Combustion Engine vehicles production
47	Other vehicles	Other vehicles
48	Other parts	Other parts used in EV, ICE and other vehicle production
49	otn	Transport equipment nec
50	omf	Manufactures nec
51	ely	Electricity
52	gdt	Gas manufacture, distribution
53	wtr	Water
54	cns	Construction
55	trd	Trade
56	afs	Accommodation, Food and service activities
57	otp	Transport nec

58	wtp	Water transport
59	atp	Air transport
60	whs	Warehousing and support activities
61	cmn	Communication
62	ofi	Financial services nec
63	ins	Insurance (formerly isr)
64	rsa	Real estate activities
65	obs	Business services nec
66	ros	Recreational and other services
67	osg	Public Administration and defense
68	edu	Education
69	hht	Human health and social work activities
70	dwe	Dwellings

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