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# Semiconductor Supply Chain Disruptions – Its Effect on Automotive Industry: China and U.S.

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## ABSTRACT

This paper analyses and defines the causes of supply chain disruptions in the semiconductor industry and explains how the automotive industry was therefore affected, including the industries' challenges and opportunities. In the research, China and the U.S. were primarily analysed. This study emphasises the Covid-19 consequences on the semiconductor and automotive industries and the effect of the increase in crude oil prices on the semiconductor industry. To provide an answer to the research question, a cointegration analysis was performed on five estimated models.Therefore, this paper provides an overview of the literature on semiconductor supply chain disruptions and their effect on the automotive industry and analyses the potential impact of the increase in crude oil prices on the volume of the semiconductor supply chain.

**Keywords:**semiconductor industry, automotive industry, supply chain disruptions, China, the U.S., Covid-19, pandemic, economic effects, crude oil, motor vehicles, semiconductors, impacts

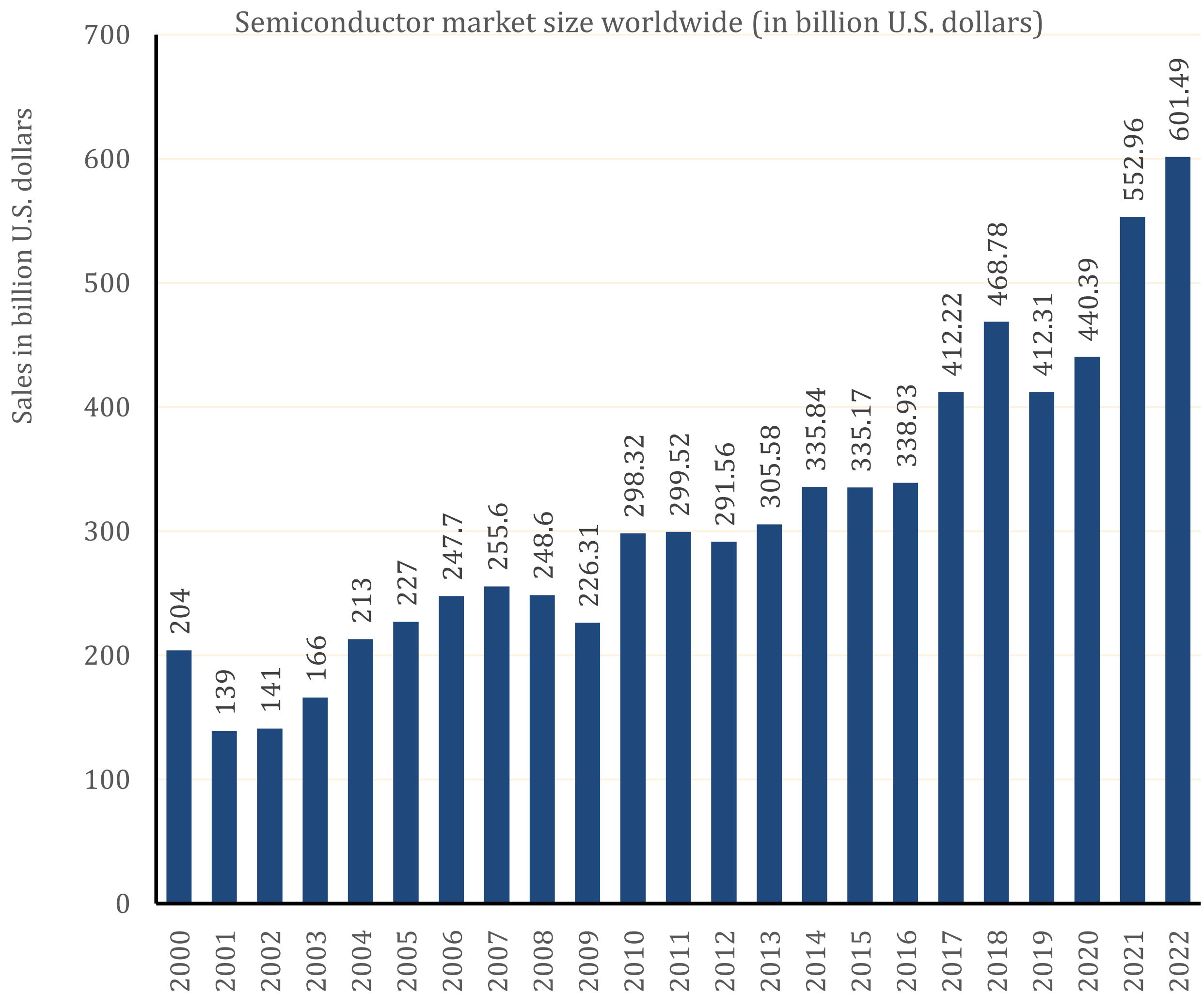
## 1. INTRODUCTION

### *1.1 BACKGROUND INFORMATION*

Over the years, the application of semiconductors, also known as chips, which are tiny electronic components that function as hybrids of an insulator and a conductor, became widely regarded as an essential building block of modern industrial and national security technologies. Semiconductors are primarily implemented to produce or finalise the production of many different technological devices and goods, including automobiles. In order to be efficient and functioning, the semiconductor supply chain, as defined and described by TSMC, Taiwan Semiconductor Manufacturing Company Limited (2022), comprises and involves plenty of procedures and various steps in the procurement process, production, and fulfilment process.Additionally, TSMC (2022)points out that to reduce the environmental impact semiconductor production has and promote sustainability, the semiconductor supply chain management should improve the manufacturing processes and the quality of the products.Especially since digital advancements and the use of semiconductors in the contributions to quality technological progress and its implementation are essential, its environmental impact is vital for sustainability and further economic improvements and developments in the semiconductor and automotive industries, respectively.Digital technologies are changing traditional business models, and new opportunities and new business environments are provided with Industry 4.0 or the Fourth Industrial Revolution-the Fourth Industrial Revolution refers to the convergence of biological, physical, and digital innovations, intending to strive toward achieving and converting to cyber-physical systems(Schwab, 2021)- giving intelligent automation and interconnectivity much importance and leaving opportunities for the industrial growth of the semiconductor industry since most electronic devices require the installation of semiconductors in the production process.

The semiconductor market size has grown substantially from a global perspective in the past twenty years. According to Statista (2022), Figure 1 shows the worldwide rising trend of semiconductor market size. Over the last twenty-two years, the market size has noticeably increased by 294.85 per cent in 2022, with sales of 601.49 billion U.S. dollars compared to 2000 with 204 billion U.S. dollars sales. With this point being made, any disruptions in the supply chain of semiconductors will immensely affect other industries since, in most industries, during production, semiconductors are one of the main components.During the production process in the automotive industry, semiconductors are critical, and the disruptions in the supply chain will halt the production of automobiles.

Figure 1: Semiconductor market size worldwide from 2000 to 2022 (in billion U.S. dollars)

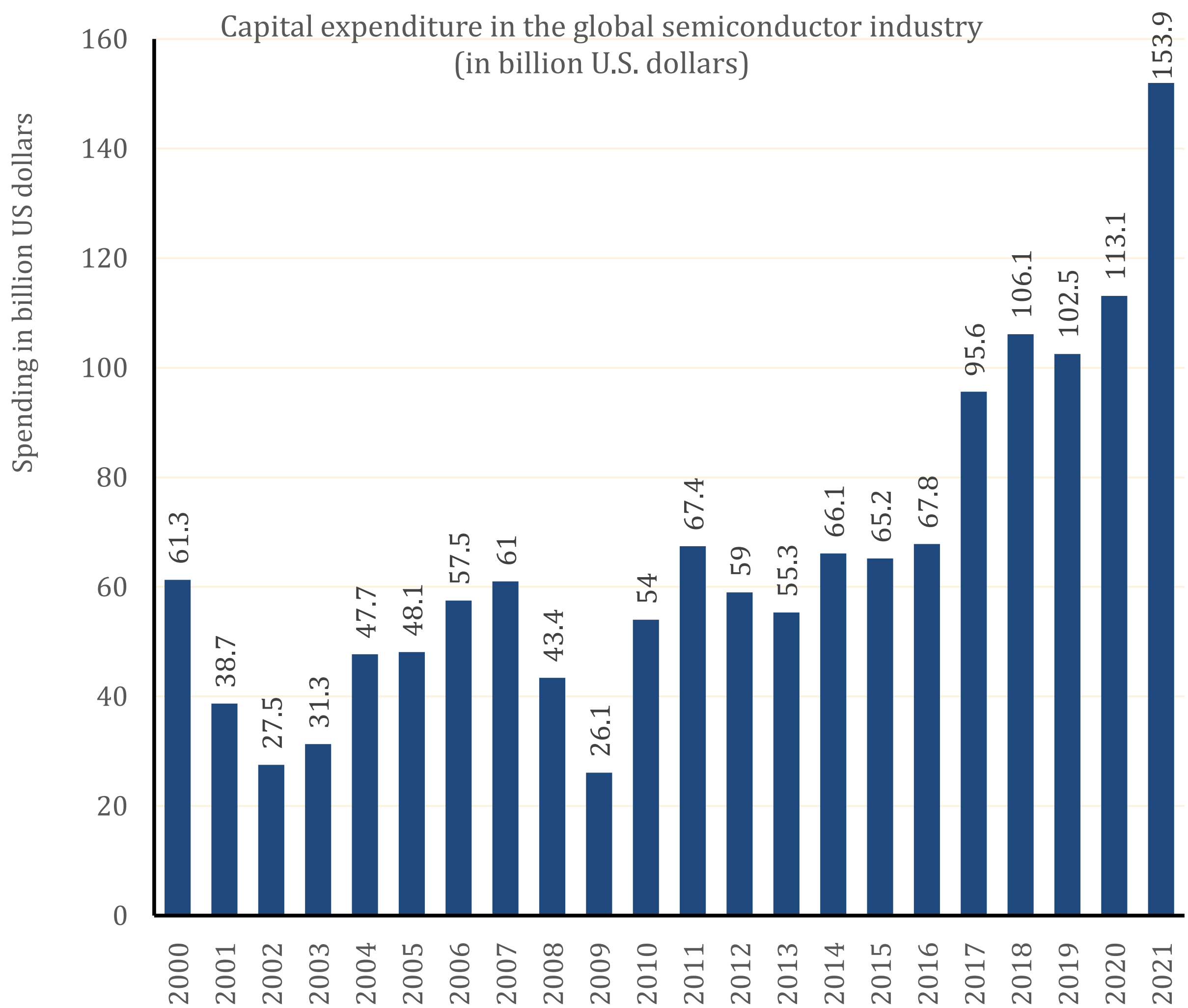



*Source: Statista, 2022*

According to the data releasedby Statista (2022), the global capital expenditure in the semiconductor industrywas the lowest at the end of the Great Recession in 2009, amounting to 26.1 billion U.S. dollars in spending, which was about 42.4 per cent of the industry's capital expenditure in 2000, which amounted to 61.3 billion U.S. dollars. As the economy recovered, capital expenditure increased, and the most significant increases, compared to the capital expenditures in the previous year, happened in 2010, 2017, and 2021.

In 2021, the global capital expenditure in the semiconductor industry, which was the highest increase percentage-wise -a jump of 36 per cent- since 2000, amounted to 153.9 billion U.S. dollars.The semiconductor market size is consistent with the capital expenditure in the semiconductor industry.

Figure 2: Capital expenditure in the global semiconductor industryfrom 2000 to 2021 (in billion U.S. dollars)




*Source: Statista, 2022*

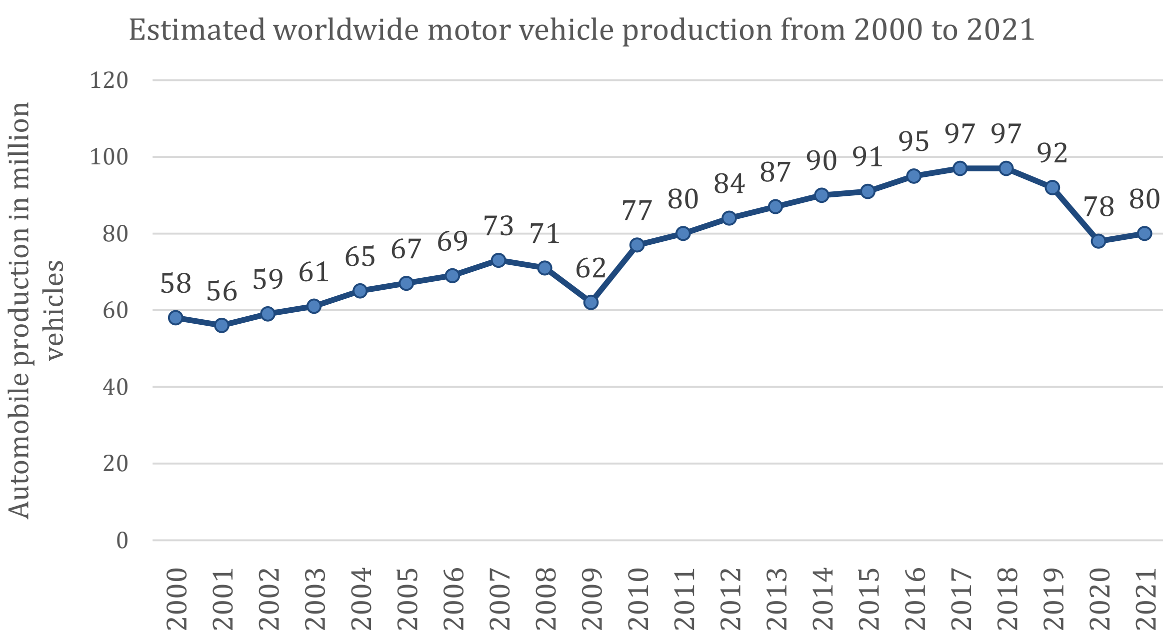
### *1.2 AUTOMOTIVE AND SEMICONDUCTOR INDUSTRY IN CHINA AND U.S.*

The consistent growth in semiconductor capabilities and performance has boosted economic output and productivity in most countries like the United States of America and China, including 5G, Artificial Intelligence (A.I.), and autonomous electronic automobiles. In particular, the United States has been a leading state in semiconductor research and development, chip design, and semiconductor manufacturing. On the other hand, the semiconductor supply chain comprises the US and several foreign companies from Europe and the Middle East that control fabrication facilities(Min & Jianwen, 2020).

While the Semiconductor industry in the US declined due to its reliance on global supply chains from East Asia and the Covid-19 pandemic, China has witnessed an emerging increase in power and stability in the market size for semiconductors due to state-led efforts, thus posing a high level of competition to the United States.

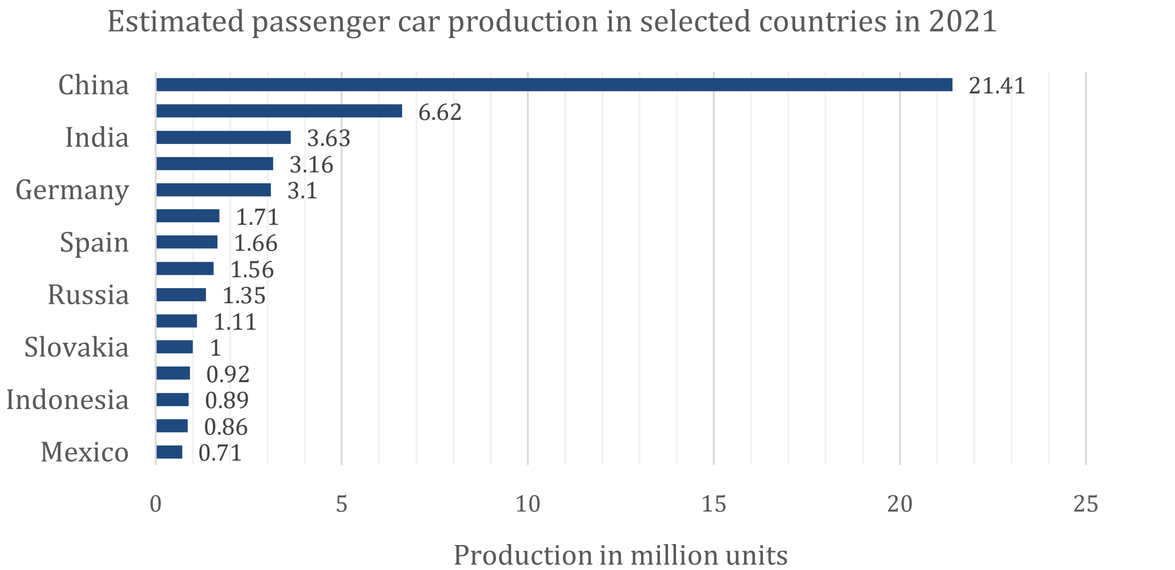
Statista (2022)released data regarding estimated worldwide motor vehicle production from 2000 to 2021; as we can notice in Figure 3, in 2021, the vehicle production amounted to 80 million worldwide produced vehicles, which increased about three per cent when compared to 2020. Predating the Covid-19 pandemic, in 2018, the estimated worldwide motor vehicle production was about 97 million produced vehicles worldwide. Two significant drops in the production of motor vehicles in the last twenty years occurred; the first drop was during the Great Recession from 2008 to 2009, and the second one was during the Covid-19 Pandemic from 2019 to 2020. Additionally, Statista Research Department (2022)estimated countries' ranking regarding the estimated production of passenger cars, four-wheeled motor vehicles that are meant for transporting passengers and have no more than nine seats when the drivers' seat is included, and the leading representative country in 2021, as we can see in Figure 4, was China, producing about 21.4 million units and amounting to almost a third of the passenger vehicle production in the world, and emerging as the globally primary growth market zone for automotive industry players. The U.S. was placed eighth, with the production amounting to 1.56 million units in 2021.

Figure 3: Estimated worldwide motor vehicle production from 2000 to 2021 (in million vehicles)




*Source: Statista, 2022*

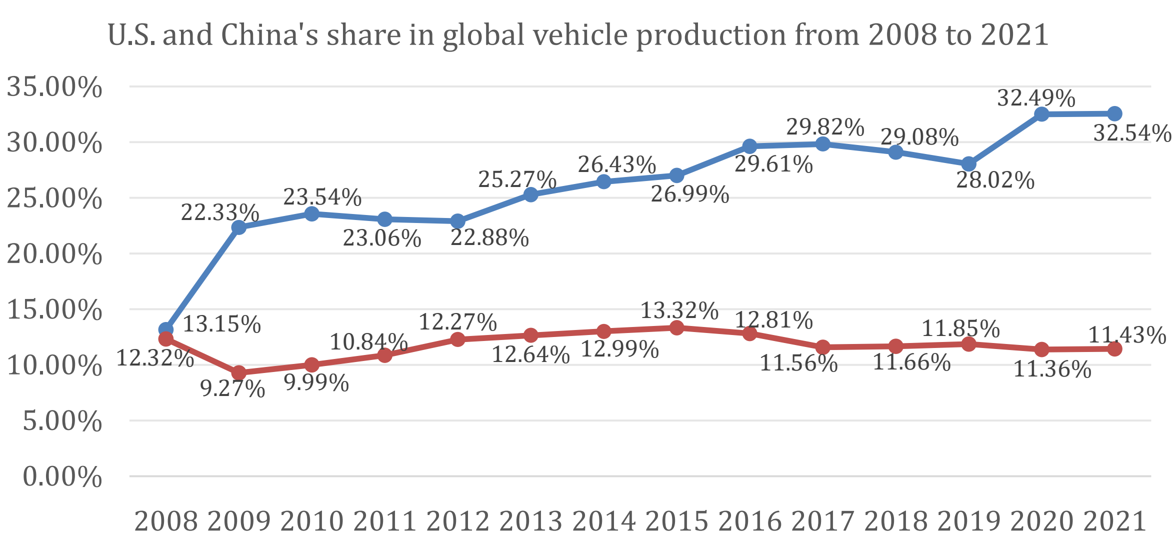
Figure 4: Estimated passenger car production in selected countries in 2021(in million units)




*Source: Statista, 2022*

Figure 5 is a representation of China's and U.S. share in global vehicle production from 2008 to 2021. Vehicle production of the U.S. expressed in a fraction of the vehicle production worldwide, in 2008 amounted to 12.32 per cent, while China's was 13.15%. They were in a close proximity. Recently, in 2021, U.S. production was equal to 11.43 per cent of global share, China's share in global vehicle production in 2021 amounted to 32.54 per cent.China has significantly increased its share -China's share in global vehicle production almost tripled- in global vehicle production since 2008, while the U.S. share in 2021 was lower -U.S. share in global vehicle production was almost one per cent lower than it was in 2008.The production of motor vehicles in the U.S., when calculated as the fraction of worldwide production, has halved in the span of 22 years. There are plenty of possible explanations, and one of those would be semiconductor supply chain disruptions and chip shortages.

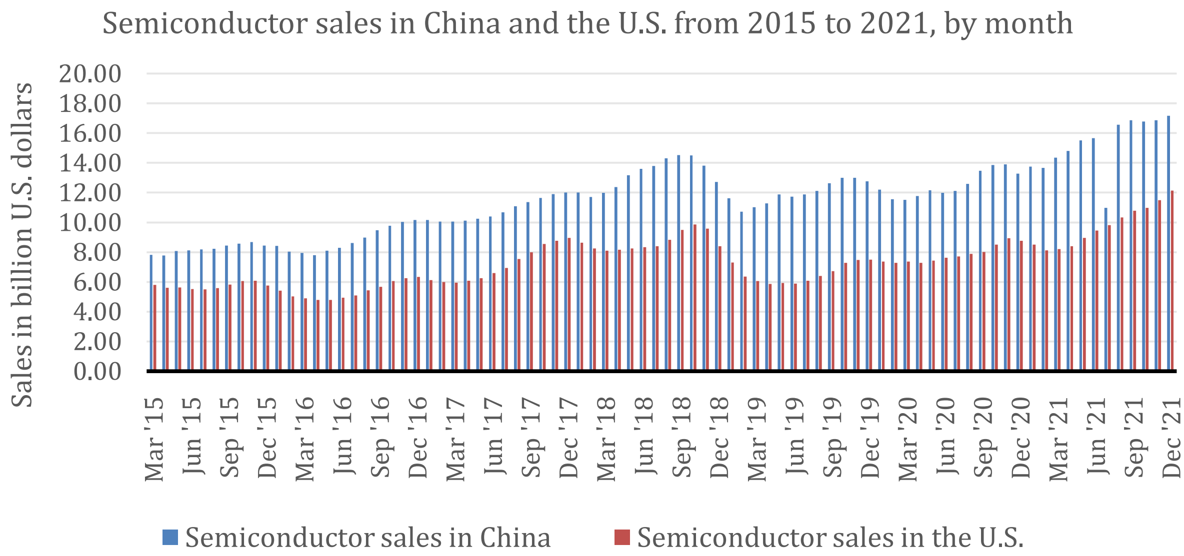
Figure 5:U.S. and China's share in global vehicle production from 2008 to 2021.




*Source: Statista, 2022*

When we observe semiconductor sales in China and the U.S. from 2015 to 2021, as the Figure 6 dictates, China's sales are larger than the U.S. semiconductor sales. In December 2021, Statista(2022)reported that China's semiconductor sales reached 17.16 billion U.S. dollars, while the U.S. sales reached 12.14 billion U.S. dollars. According to Statista (2022), worldwide, total semiconductor sales were estimated to be 50.85 billion U.S. dollars in 2021.

Figure 6: Semiconductor sales in China and the U.S. from 2015 to 2021, by month (in billion U.S. dollars)




*Source: Statista, 2022*

Since attention is paid to maximising profits and increasing market share additionally, more than before, the semiconductor global value chain is facing some challenges of vulnerability(Boquet, 2021).

### *1.3 PROBLEM STATEMENT*

The semiconductor industry is very competitive since, as technology changes consistently through innovation, competitors tend to bring the latest designs into the global market. The global supply chain for semiconductors comprises the U.S., Japan, South Korea, Taiwan, and China, which has experienced immense growth in the industry, accounting for a more significant percentage of global demand for semiconductors. However, some changes in the supply chain of semiconductors were applied due to the COVID-19 pandemic due to increased demand for specific electronic devices, resulting in supply shortages of semiconductors in the automotive industry. Therefore, this study tries to identify the factors affecting the semiconductor industry, its supply chain, and the emergence of semiconductors in China and the United States of America while defining difficulties in the automotive industry that arose due to semiconductor supply chain shortage alongside providing the recommendation for automotive companies to remaining competitive in the industry.

### *1.4 RESEARCH QUESTION*

Given the information provided so far in the introduction, the primary motivation behind this study is to examine the following questions of *how the semiconductor industry has been affected* in recent years, *what caused the supply chain disruptions* and *how that reflected on other industries, specifically the automotive industry*, correspondingly answering the question *how changes in semiconductor industry affect changes in the automotive industry.*

Additionally, particularly considering recent events of the COVID-19 pandemic and its influence on the semiconductor and automotive industry are considered in this research,as well as the increase in crude oil prices, which is directly connected to the manufacturing process since the equipment used functions on it.Moreover, emphasising how the semiconductor supply chain disruptions affect the automotive industry in China and the U.S., how to cope with these disruptions, the associated challenges, and the direction of the semiconductor and automotive industries are discussed.

### *1.5 RESEARCH AIMS AND OBJECTIVES*

This research aims to ascertain and discuss the causes of the semiconductor supply shortage and how the shortage affected the semiconductor industry. In addition, it analyses the effect of chip manufacturing shortage on the production and global distribution of automobiles. The research provides an outline for approaching the semiconductor industry's future perspective of resolving supply chain disruptions and the prospect of implementing electronic automobiles considering the semiconductor industrial possibilities and opportunities in the long term.

Current disruptions in the supply chain of the semiconductor industry that present an impactful element for lately occurred challenges in the automotive industry have been caused by several factors, including increased demand in both industries, recent events of the COVID-19 pandemic, the increased price of crude oil, and the deficiency of labour capacities, which affects the undertaking for implementation of electric vehicles (E.V.s) and impacts the planned course for reduction of greenhouse gas emissions.

### *1.6THESIS STATEMENT*

The Covid-19 pandemic, measures implemented to recover the economy and industries' capacities, and changes in crude oil prices caused the semiconductor supply chain disruptions, decreasing worldwide motor vehicle sales and increasing China's share in global vehicle productionin the long run.

## 2. LITERATURE REVIEW

### *2.1 SEMICONDUCTOR INDUSTRY AND ITS KEY SUCCESS FACTORS*

Accomplishing success in the semiconductor industry is influenced by some key factors. The most critical factors for the development of companies in the semiconductor industry are (1) R&D expenditures, (2) governmental aids and policies, (3) the innovation cycle, (4) collaboration and cooperation, (5) the level of dependency on foreign countries, (6) education and workforce, (7) restrictions to foreign competitors, (8) demand form space industry and defence.(Boquet, 2021)

*Research and development (R&D) expenditures*– since the semiconductor industry is constantly innovating, and technological innovations and industries require a creative approach to developing and designing better and more efficient products, one of the critical success factors in the semiconductor industry is R&Dand expenditures on R&D.Chinese companies have the lowest percentage of investments in R&D in terms of percentage of GDP; however, they have experienced the highest growth rate of investments in information and communications technologies (ICTs). Both U.S. and Chinese companies are investing in information and communications technology.Manufacturing equipment holds tremendous importance regarding the produced quality and quantitiesin research and development as a success factor.One can recognise how well have companies implemented R&D strategies based on the number of innovations regarding development or discoveries; based on the number of granted patents.(Boquet, 2021)

*Governmental aids and policies*– are vital because they allow companies to invest more in innovation due to reduced costs. They are provided in the form of new program implementations, financial incentives, and the provision of new policies and standards for enhancing the national market.

In the U.S., research departments, such as the Defence Advanced Research Projects Agency (DARPA), the United States Department of Energy (DOE), and the National Institute of Standards and Technology (NIST) were provided with subsidies and investments since they promote and pay attention to innovations and technological progress, boosting the country's position in the technological industry, as well as the country's technological security.The U.S. government introduced the "Chips for America Act" as federal support for expanding capacities within semiconductor manufacturing companies.Since the U.S. plans to relocate their companies in China to the U.S., and because relocating costs would be massive, the government's provision of sufficient incentives is essential for companies to endure the relocation difficulties and not be discouraged.However, in China, the government is also providing incentives and aid and subsidies for manufacturing equipment, especially since they emphasized the semiconductor industry's importance and implemented "the medium- and long-term plan for Science and Technology".(Boquet, 2021)

*The innovation cycle*– as in any industry, the semiconductor industry places enormous importance on innovation, but innovation is not a sporadic process or just some phase of a particular process and therefore requires constant investment to provide better qualities and improved technologies to initiate the innovation cycle.Its importance additionally lies on and is also reflected in providing opportunities for future generations to implement innovative approaches in the semiconductor industry.(Boquet, 2021)

*Collaboration and cooperation*–for efficient industrial development, cooperation and collaboration with economic entities are the required factors for success in the semiconductor industry. Both the U.S. and China have substantial levels of collaboration and cooperation.(Boquet, 2021)

*The level of dependency on foreign countries*– for semiconductors to be produced, the involvement of several countries is necessary since the production of semiconductors is like a global ecosystem. The amounts of imports and exports can determine the levels of interdependency; lower exports mean higher economic and manufacturing interdependence, and lower imports mean lower economic and manufacturing interdependence. Additionally, since oil is necessary for the manufacturing equipment required for the production of semiconductors, the dependency on foreign countries that export oil is high, especially for China, because the U.S. is one of the countries that export oil.(Boquet, 2021)

*Education and workforce*–given that education and training play a significant role in the semiconductor industry because the semiconductor industry is based mainly on applying knowledge to make and achieve innovations, the country's level and the possibility of education are fundamental. Since a country's education is correlated to the number of provided universities, in the U.S., there are eight universities of engineering and technology that are ranked within the top twenty-five in the world, while in China, there are only two of the same rank.(Boquet, 2021)

*Restrictions to foreign competitors*–to protect the domestic market from the tactical aggression of competition from foreign companies, it is necessary to set restrictions and controls at the federal or regional level. Due to geopolitical tensions, both China and the United States have imposed stricter and increased regulations and controls to protect their markets. In the U.S., the Entity List was established, and in China, the Unreliable Entity List was also released alongside Cybersecurity Law.(Boquet, 2021)

*Demand from the space industry and defence*–investments in the military sector for better defence and the space industry increase the research and development resources of the semiconductor industry since semiconductors are crucial components for the utilised equipment - it is, however, inconclusive that the higher the spending for the military sector, the higher the growth within the semiconductor industry.(Boquet, 2021)

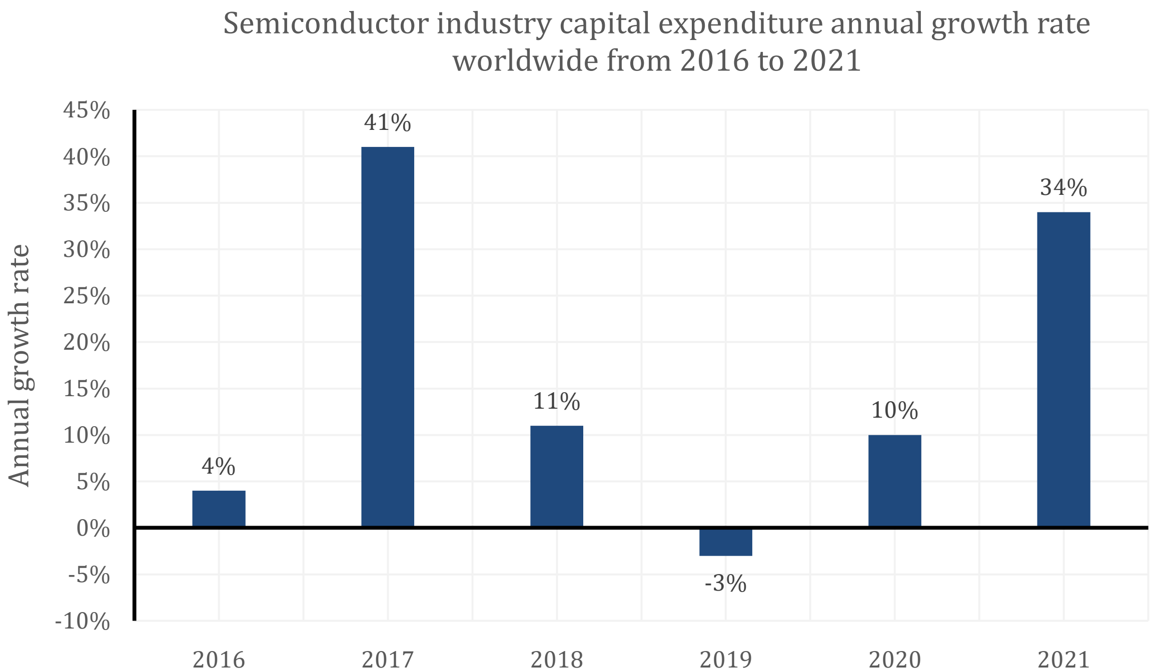
### *2.2 IMPACT OF COVID-19 ON THE SEMICONDUCTOR INDUSTRY*

Due to the Covid-19 pandemic between 2020 and 2021, the demand for semiconductors significantly increased, resulting in global chip shortages (Wu, et al., 2021). During the pandemic, chipmakers saw the surging demand for semiconductors in various sectors such as health, virtual learning, and other automotive sectors. As a result, the semiconductor industry witnessed a projection in the expenditure in the following year of 2021 to 152 billion U.S. dollars from around 113 billion U.S. dollars in 2020, as illustrated in Figure1. Prior to 2021, the industry had never spent above 150 billion U.S. dollars on annual capital expenditure, and the need for the global semiconductor industry to meet this projected market growth in the years ahead has prompted industries to not only increase the fabrication capacity alone but also other sectors like the transportation sector. Generally, as the demand for electronics and automobiles continues to grow, the demand for chips will also continue to rise, leading to an increase in annual capital expenditure in the semiconductor industry.While the 2020 markets forecasts fluctuated throughout the year due to demand uncertainty resulting from the Covid-19 pandemic, the sales volume for semiconductors increased in 2020, forecasting further growth in the coming years.As the semiconductor industry in China is one of the fastest-growing industries globally, a sales increase of 16% accommodated the leading Chinese semiconductor companies, despite the Covid-19 pandemic and the global sales increase of 5.8%(Boquet, 2021).

Covid-19 influenced customer behaviour, corporate operations, and companies' revenues in the semiconductor industry. Unpredictability and uncertainty due to the pandemic have caused difficulties in semiconductor companies' strategic decision-making. Bauer et al. (2020), senior partners of McKinsey & Company, a trusty management consulting firm founded in 1926, conducted a study to develop recovery strategies for the semiconductor industry to emerge stronger after the Covid-19 crisis. As the market recovers, the situation regarding revenue growth, which is experiencing negative revenue growth, is expected to improve—trends of videoconferencing open new possibilities for innovations in the semiconductor industry. The semiconductor industry can become stronger after the Covid-19 crisis by (1) reducing capital expenditure, (2) focusing on R&D, and (3) strategically approaching acquisitions and mergers. Uncertainty in the market and creating possible future scenarios that show different outcomes are essential for formulating strategies for the upcoming years—the uncertainty should be embraced as part of the operation management model because adapting quickly to the situations will be of greater importance following long-term plans.(Bauer, et al., 2020)

When we observe the semiconductor industry capital expenditure annual growth rate worldwide from 2016 to 2021, as the Figure 7 shows, we can notice that there is a significant noticeable change in the year when the Covid-19 pandemic started; the industry had a positive growth rate until 2019 when a negative growth rate of three per cent was noted. We can conclude that the pandemic impacted the amount of capital expenditure in the industry and that the following increase in capital expenditure growth rate is due to increased demand and supply shortages to recover the industry's supply as to demand requirements.

Figure 7:Semiconductor industry capital expenditure annual growth rate worldwide from 2016 to 2021




*Source: Statista, 2022*

***2.3 IMPACT OF THE SEMICONDUCTOR SUPPLY CHAIN AND COVID-19 ON THE AUTOMOTIVE INDUSTRY***

Automobile supply chains have developed, are dispersed geographically and are more complex when compared to three decades ago; however, unpredictable disruptions caused difficulties with automobile supply chain management. The World Trade Statistics (2021)project that a significant 527 billion U.S. dollars increase in total sales of semiconductors is likely to be realised. These projections only show that the future of the automotive industry is majorly reliant on the production of chips in the semiconductor industry, which has been witnessed to be inadequate. Therefore, research and development sectors in the semiconductor industry are left with a great responsibility for production to meet the surging demand for the chips.

Companies have problems with delivery plans in the automotive industry because of the poor planning environment. Johansson and Westmark(2021) designed new processes for handling orders and freeze periods to decrease the volatility within delivery plans. Four pilot customers were tested with methods for implementing the new process. Minor changes and easily interpreted processes created a more straightforward implementation of the new processes. Automation saves time; however, it is vital to check all deviations manually. It is also essential to arrange meetings with customers, reach agreements, and implement contracts for freeze periods. The pilot experiment resulted in customers reducing the number of changes and agreeing on new freeze periods. The limitations of their experiment are that the sample size was too small, and the duration of the experiment was limited. When volatility is high, making decisions and planning the production is complicated and challenging, increasing expenses, creating inventory imbalances, and questioning quality. However, the limitation of their study is that the duration of the experiment was too short. The opportunity to meet with the companies' staff who participated in the experiment was disabled due to the pandemic. The occurrence of the semiconductor crisis disturbed data.

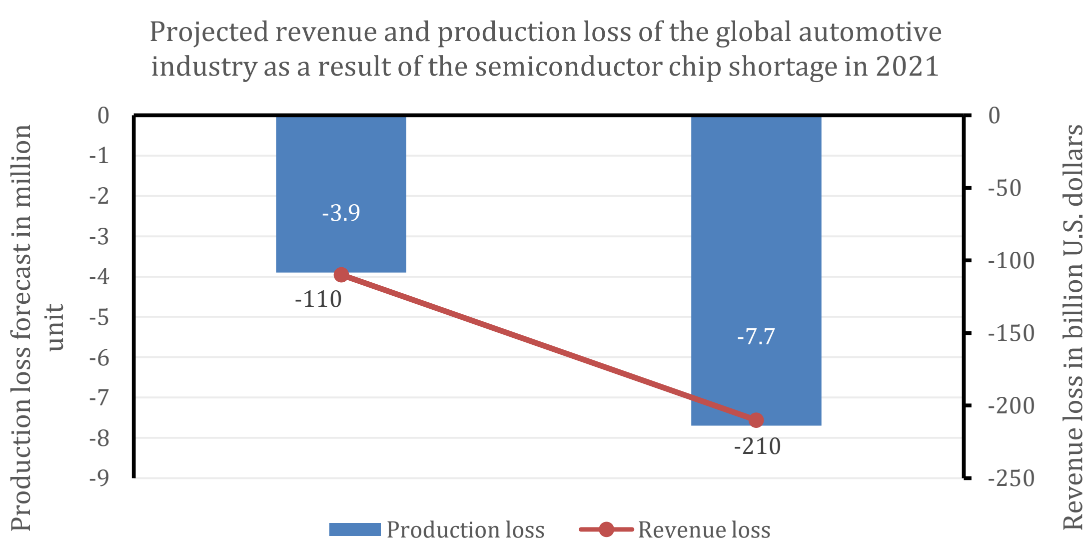
If agreements on freeze times are achieved and customers are included in that decision, volatility assurance will be lessened, and processes will be improved.(Johannson & Westmark, 2021)

Jiang, Shu, and Miao. (2021), Professors at Sichuan NormalUniversity, University of Electronic Science and Technologyof China, and The Hong Kong Polytechnic University, who have expertise in mathematics, management, and logistics, have conducted a study to propose an optimal plan of production of vehicles by substituting each chip and sourcing for maximising the total revenue. A deterministic mixed-integer programming model is proposed, and a min-max robust model is constructed based on the deterministic model. A two-stage stochastic programming model is defined. A set of numerical experiments is conducted to demonstrate the advantage of the min-max robust model compared to the deterministic model. The robust model proposed in the study prohibits disturbances from uncertain parameters. The results of calculations for the robust model, when compared with the other two proposed models, are not negligible.(Jiang, et al., 2021)

Nayak et al. (2021), Professors at different universities in India that have expertise in electronics and information technology, have conducted a research to study Covid-19 impact on six different industries, approaching the automotive industry in detail – the study seeks to provide a base for overcoming the crisis in the automotive industry regarding purchases. Purchase decisions were affected by household income, the pandemic's effect on local regions, and travel difficulties. Lockdowns decreased immigrant labour, on which the automotive industry relies – the welfare of active workers and communication with them is essential. The disruptions of China's exports of parts for automobiles affected the U.S. the most, and the production of automobiles declined because of continuous lockdowns that influenced consumer and producer demand. Evidence of vehicle sales before and after Covid-19 and empirical analysis of scientific studies and models supports the study's claim. (Nayak, et al., 2021)

When we observe the projected revenue and production loss of the global automotive industry as a result of the semiconductor chip shortage in 2021, as the Figure 8 illustrates, we can see that the projected revenue loss amounted to 250 billion U.S. dollars and that the production loss was forecasted to be 7.7 million units of production.The industry suffered huge losses due to the Covid-19 pandemic, and they have increased since the beginning of the pandemic.

Figure 8: Projected revenue and production loss of the global automotive industry as a result of the semiconductor chip shortage in 2021(in billion U.S. dollars and million units)




*Source: Statista, 2022*

Digital transformation can, however, provide the advantage of the faster economic recovery of the automotive industry after or during the Covid-19 crisis. To remain competitive in the industry, automotive companies should invest in and adapt to digital transformation to be more productive, competitive and have more profit - companies should invest in research, innovation, and development activities.(Llopis-Albert, et al., 2021)

### *2.4 CHALLENGES AND OPPORTUNITIES*

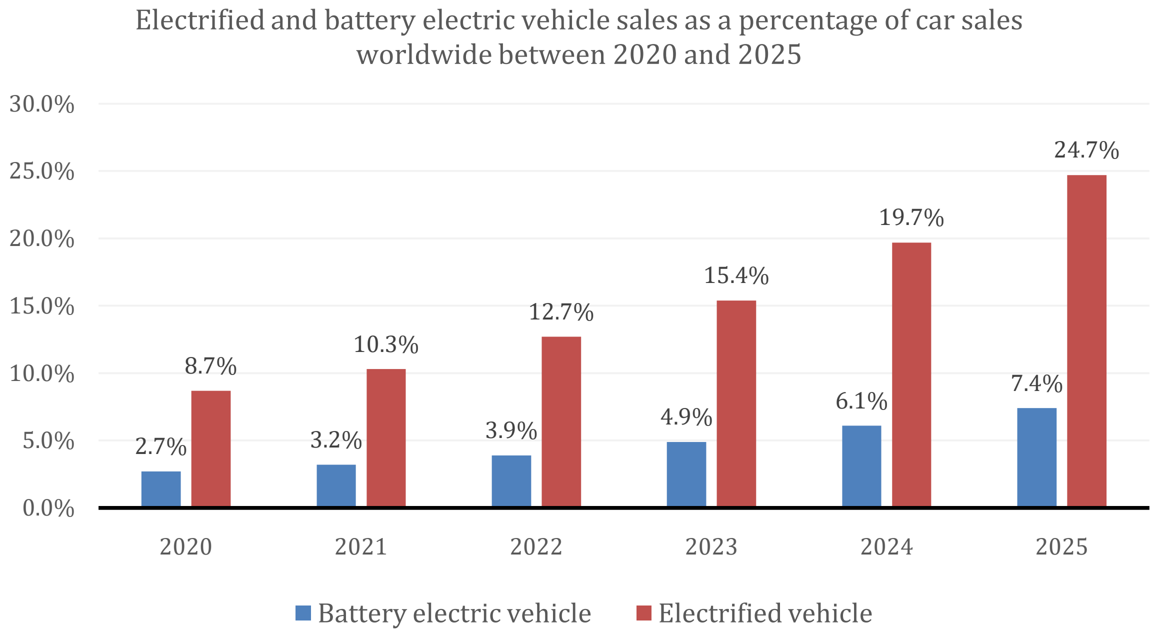
Unpredicted events of the Covid-19 pandemic affected the semiconductor supply chain, which was impacted by challenges and provided opportunities. Mainova and Bitri(2021), Professors at universities in Bulgaria and Albania who have expertise in technologies and management, have conducted a study to identify solutions applied to the automotive industry to issues caused by the pandemic in the semiconductor supply chain. During the Covid-19 pandemic, since the increased demand for electronic-based products increased the demand for semiconductors because of their necessity in the manufacturing, the lockdowns and implemented measures decreased and slowed down the production of semiconductors, which had a chain effect and created challenges in industries due to the supply shortages. For the automotive industry, an additional increase in demand besides semiconductor supply shortages caused multiple difficulties, especially in the green car market (e.g., Tesla Inc.), since green cars or electric vehicles rely solely on semiconductors, among other elements in the manufacturing phase. China and the U.S. have implemented initiatives to overcome or make the most out of the situation. (Marinova & Bitri, 2021)

Three responses to Covid-19 and chip shortage were noted, including how countries reorganised their approach to establishing local and independent production of semiconductors, with an emphasis on China. The instability in the semiconductor supply chain was due to inadequate decision making; allocation of resources was not conducted based on requirements, which opens opportunities for new companies to take the lead. This instability, however, including the lack of local opportunities in China, has increased the technological and trade war between the U.S. and China, which without investments in the semiconductor industry, provides a challenge for China's automotive industry, especially since China's government placed a regulation that the country will fully converge to electric vehicles by 2030(Hill, et al., 2020).This unstable situation led China to encourage investment from foreign companies to bring their research centres, technologies, and talents to China. Consequently, the U.S. is concerned about China's potential leadership in the semiconductor industry due to their foreign investment attraction policies.(Marinova & Bitri, 2021)

However, the situation regarding the semiconductor supply shortage was worsened due to the cold wave in Texas and a fire at the factory in Japan—Toyota, Volkswagen, and G.M. cut their production. In response to the supply shortage of automotive semiconductors, the U.S. Biden administration promised support for semiconductor manufacturers. It is necessary to build a cooperative network between the automotive and semiconductor industries to expand development and production capabilities in the long term.(Chun, et al., 2021)

When we observe electrified and battery vehicle sales as a percentage of car sales worldwide between 2020 and 2025, as Figure 9 displays, the estimation indicates that the demand is increasing both for electrified vehicles and battery electrified vehicles. This forecasted increase means the industry will open new opportunities for the semiconductor and automotive industries separately and collaboratively - the demand for semiconductors will be boosted since the production capacities will have to be met. More production capacities in terms of quantities and innovations are required to prevent the prolongation of semiconductor supply shortages.

Figure 9: Electrified and battery electric vehicle sales as a percentage of car sales worldwide between 2020 and 2025




*Source: Statista, 2022*

### *2.5 LIMITATIONS*

Potentially, an abundance of subjective and distorted information is currently present online and in other formats due to the existing geopolitical tensions between China and the U.S.(Boquet, 2021).Additionally, for the literature review, no studies were found to cover the impact and correlation of crude oil price increases on production capacities within the semiconductor industry.It is essential to note that data used for further analyses and obtained from Statista, one of the leading companies on the internet specialising in consumer and market data, was mainly available for different periods within the range 2000 to 2025.

## 3. METHODOLOGY AND DATA

Data explanation was presented as the first phase of the methodology section. For data explanation, descriptive statistical analysis was conducted in Stata. In the following phase, stationarity was checked by conducting a unit-root test using the augmented Dickey-Fuller (ADF) test. Conversion of the resulted variables into the first-differenced form was performed. Afterwards, a second difference was also taken. After that, to determine the presence of cointegration between the variables, Engle and Granger's (1987) two-step approach was implemented to test the long-run relation and connection between worldwide semiconductor unit shipments and worldwide motor vehicle sales, China's share in global vehicle production, average annual West Texas Intermediate crude oil spot prices, average annual Europe Brent crude oil spot prices, and average annual OPEC crude oil price respectively. *Cointegration* is an analysis that tests for and explains the long-run relationship of correlation between time series variables(Wooldridge, 2013).

### *3.1 DATA EXPLANATION*

For the purpose of this study, data on semiconductor unit shipments worldwide were used for the period from 2000 to 2025 (with estimates from 2022 to 2025). Data on worldwide motor vehicle sales was used from 2005 to 2021. Data regarding China's share in global vehicle production was used from 2008 to 2021.

Data regarding average annual West Texas Intermediate crude oil spot prices and average annual Europe Brent crude oil spot prices were used for 2000 to 2021, while data on average annual OPEC crude oil price was used for 2000 to 2022. The differences in the period were due to the unavailability of data.

The source of the statistical data is the publications of Statista, one of the leading companies on the internet that specializes in consumer and market data.

Descriptive statistics of each variable included in the econometric analysis -stationarity and cointegration- are presented in the following table:

Table 1: Descriptive statistics of variables

| NAME | DESCRIPTION | MEASURE | OBS | MEAN | STD. DEV. | MIN | MAX |
|---|---|---|---|---|---|---|---|
| semiconductorshipment | semiconductor unit shipments worldwide | in billions | 26 | 780.30 | 291.69 | 332.90 | 1305.70 |
| wwmotorsales | worldwide motor vehicle sales | in million units | 17 | 80.93 | 10.49 | 65.57 | 95.66 |
| chinashare | China's share in global vehicle production | percentage of global vehicle output | 14 | 0.26 | 0.05 | 0.13 | 0.33 |
| westtexas | average annual West Texas Intermediatecrude oil spot prices | in U.S. dollars per barrel | 22 | 61.06 | 24.33 | 25.60 | 99.67 |
| europebrent | average annual Europe Brentcrude oil spot prices | in U.S. dollars per barrel | 22 | 63.90 | 28.10 | 24.00 | 111.63 |
| opecprice | average annual OPEC crude oil price | in U.S. dollars per barrel | 23 | 63.33 | 28.03 | 23.12 | 109.45 |

*Source: Statista, 2022*

### *3.2 METHOD*

The method of this study includes:

— testing for cointegration between semiconductor unit shipments worldwide and worldwide motor vehicle sales
— testing for cointegration between semiconductor unit shipments worldwide and China's share in global vehicle production
— testing for cointegration between semiconductor unit shipments worldwide and average annual West Texas Intermediate crude oil spot prices
— testing for cointegration between semiconductor unit shipments worldwide and average annual Europe Brent crude oil spot prices
— testing for cointegration between semiconductor unit shipments worldwide and average annual OPEC crude oil price

Five models are tested on cointegration. First, the analysis begins with checking for stationarity and conducting the augmented Dickey-Fuller (ADF) test to check for unit root. In cases of non-stationarity, the first differences of variables are again tested using the ADF test. Additionally, the second difference of variables is taken and tested using the ADF test for variables that still did not achieve stationarity after the first differences. Engle and Granger's two-step method is applied for the cointegration analyses.

## 4. RESULTS

The following sections present the process in detail and explain the results of each analysis since the results are better explained while the process is discussed simultaneously.

### *4.1 STATIONARITY AND AUGMENTED DICKEY-FULLER (ADF) TEST*

To start with the process, firstly, all the variables were put in a time-line graph as shown in Appendix (see Appendix A), and it is seen that variables Semiconductor shipments, worldwide motor vehicle sales, and China's global share show a clear trend (upward) pointing towards non-stationarity of these variables. The oil prices, although rising, has strong volatility, and it is not clear if the time series is stationary. For this to formally be confirmed, a unit-root test was initially conducted using the augmented Dickey-Fuller (ADF) test. In the first half of the table, one can look at the variables in their basic form, and the result shows that most of these variables are non-stationary. Conversion into the first-differenced form was performed, and the ADF test was rerun - the result was that stationarity could still not be achieved for some of the variables, when compared to critical t-values. Thus, one step further was performed, the second differences were taken, and results provided that some of the variables now have achieved stationarity.

Table 2: Augmented Dickey-Fuller Test of Stationarity

| **Variable** | **t-Value** | **P-value** |
|---|---|---|
| Semiconductor unit shipments worldwide | -3.293 | 0.0674 |
| Worldwide motor vehicle sales | -1.062 | 0.935 |
| China's share in global vehicle production | -1.347 | 0.876 |
| West Texas Intermediate | -1.812 | 0.699 |
| Europe Brent | -1.776 | 0.716 |
| Average annual OPEC crude oil price | -1.929 | 0.64 |
| **Variable (First Differenced)** | **t-Value** | **P-value** |
| Semiconductor unit shipments worldwide | -4.211 | 0.00431 |
| Worldwide motor vehicle sales | -1.632 | 0.78 |
| China's share in global vehicle production | -1.766 | 0.721 |
| West Texas Intermediate | -2.475 | 0.341 |
| Europe Brent | -2.628 | 0.267 |
| Average annual OPEC crude oil price | -2.206 | 0.487 |
| **Variable (Second Differenced)** | **t-Value** | **P-value** |
| Semiconductor unit shipments worldwide | -4.170 | 0.00496 |
| Worldwide motor vehicle sales | -2.789 | 0.201 |
| China's share in global vehicle production | -1.783 | 0.713 |
| West Texas Intermediate | -3.154 | 0.0939 |
| Europe Brent | -3.204 | 0.0836 |
| Average annual OPEC crude oil price | -3.381 | 0.0540 |

### *4.2 COINTEGRATION ANALYSIS*

Once it was established that all the variables in the model are I(1) form, the Engle and Granger (1987) two-step approach proceeded. The Engle and Granger (1987) two-step approach includes fitting the model using least squares and estimating the residuals. The models estimated in the first step are given as follows:

$$wwmotorsales_t = \alpha + \beta_1(semiconductorshipment_t) + \varepsilon$$
$$chinashare_t = \alpha + \beta_1(semiconductorshipment_t) + \varepsilon$$
$$westtexas_t = \alpha + \beta_1(semiconductorshipment_t) + \varepsilon$$
$$europebrent_t = \alpha + \beta_1(semiconductorshipment_t) + \varepsilon$$
$$opecprice_t = \alpha + \beta_1(semiconductorshipment_t) + \varepsilon$$

In the second step, the residuals were estimated from the above-estimated model, and an ADF was run on the obtained residuals to evaluate for cointegration. The residuals can also be plotted to see the behaviour. Although some of the residuals do not show a cointegrating relationship, estimation of the error correction model (ECM) was still proceeded by running the regression for the following model. The model's coefficients will provide information on the short-run and long-run relationship between the two variables. The following equations were estimated in the second step:

$$D2.wwmotorsales_t = \alpha + \beta_1(D2.semiconductorshipment_t) + \beta_2(L1.Residuals) + \varepsilon$$
$$D2.chinashare = \alpha + \beta_1(D2.semiconductorshipment_t) + \beta_2(L1.Residuals) + \varepsilon$$
$$D2.westtexas_t = \alpha + \beta_1(D2.semiconductorshipment_t) + \beta_2(L1.Residuals) + \varepsilon$$
$$europebrent_t = \alpha + \beta_1(semiconductorshipment_t) + \beta_2(L1.Residuals) + \varepsilon$$
$$opecprice_t = \alpha + \beta_1(semiconductorshipment_t) + \beta_2(L1.Residuals) + \varepsilon$$

The interpretation of the above model will provide the short-run and the long-run relationship of the explanatory variable to the dependent variables. The impact of change in short-run semiconductor shipments can be seen in the given and the long-run relationship measured by the lagged value of the residuals estimated in the first stage. The estimates of the five models are given in the following table:

Table 3: Estimates of the five models

| | (1)<br>D.Worldwide motor vehicle | (2)<br>D.China's share in global vehicle | (3)<br>D.West Texas Intermediate | (4)<br>D.Europe Brent | (5)<br>D.Average annual OPEC crude oil price |
|---|---|---|---|---|---|
| D. Semiconductor Shipment | 0.0109 | 0.000201*** | -0.0397 | -0.0547 | -0.0650 |
| | (0.0144) | (0.0000451) | (0.0492) | (0.0528) | (0.0470) |
| L.Residuals | -0.145<br>(0.245) | | | | |
| L.Residuals | | -0.979***<br>(0.166) | | | |
| L.Residuals | | | -0.386**<br>(0.175) | | |
| L.Residuals | | | | -0.356**<br>(0.167) | |
| L.Residuals | | | | | -0.369** |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | (0.160) |
| Constant | 1.125 | 0.0126*** | 3.061 | 3.496 | 3.871 |
| | (1.281) | (0.00378) | (3.942) | (4.250) | (3.964) |
| Observations | 16 | 13 | 20 | 20 | 21 |

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

**1) Semiconductor unit shipments worldwide from 2000 to 2021 & Worldwide motor vehicle sales from 2005 to 2021**

The result shows that semiconductor shipment has no short-run or long-run relationship with the worldwide motor vehicle sales. This can be seen from the significance of the coefficient of semiconductor shipment and the coefficient of lagged Residuals value. No interpretation can be made for this relationship.

**2) Semiconductor unit shipments worldwide from 2000 to 2021 & China's share in global vehicle production from 2008 to 2021**

It is found that semiconductor shipments have both a short-run and long-run relationship with China's share in global sales. The result shows that, in the short run, the increase in the share of China in global motor vehicle sales increases semiconductor shipments worldwide. In the long run, this relationship is converging at a rate given by 0.979, i.e., 97% of the disequilibrium will converge in the following time period.

**3) Semiconductor unit shipments worldwide from 2000 to 2021 & Annual average WTI and Brent crude oil spot prices from 1990 to 2021 (West Texas Intermediate)**

It is found that semiconductor shipments have only a long-run relationship with the Annual average WTI crude oil spot prices. The result shows that, in the short run, the crude oil prices as measured by the WTI rate have no impact on the increase in semiconductor shipments worldwide. In the long run, this relationship is converging at a rate given by 0.386, i.e., 38.6% of the difference will converge in the following time period.

**4) Semiconductor unit shipments worldwide from 2000 to 2021 & Annual average WTI and Brent crude oil spot prices from 1990 to 2021 (Europe Brent)**

It is found that semiconductor shipments have only a long-run relationship with the Annual average crude oil price measured by Europe Brent. The result shows that, in the short run, the crude oil prices as measured by the Europe Brent rate have no impact on the increase in semiconductor shipments worldwide. In the long run, this relationship is converging at a rate given by 0.356, i.e., 35.6% of the difference will converge in the following time period.

**5) Semiconductor unit shipments worldwide from 2000 to 2021 & Average annual OPEC crude oil price from 1960 to 2022**

It is found that semiconductor shipments have only a long-run relationship with the Annual average crude oil spot prices measured by OPEC. The result shows that, in the short run, the crude oil prices as measured by OPEC have no impact on the increase in semiconductor shipments worldwide. In the long run, this relationship is converging at a rate given by 0.369, i.e., 36.9% of the difference will converge in the following time period.

## 5. DISCUSSION

### *5.1 IMPLICATIONS OF THE FINDINGS*

The aim of this study is to detail the cause of supply chain disruptions in the semiconductor industry and describe its effect on the automotive industry focusing on China and the U.S.; more succinctly said, to demonstrate that (1) the Covid-19 pandemic, together with measures that countries implemented to encourage economy's recovery and industries' capacities improvements affected the semiconductor supply chain disruptions, and that (2) the supply disruptions in the semiconductor industry are also related to crude oil price changes since the equipment used in the production process is dependent on its use, alongside causing a decrease in worldwide motor vehicle sales while increasing China's share in vehicle production in the long run globally.

Although it was stated that the worldwide semiconductor unit shipments were correlated to worldwide motor vehicle sales, the cointegration analysis showed that the relationship between these variables could not be interpreted; thus, one cannot conclude that the semiconductor supply chain is correlated to the sales of motor vehicles. On the other hand, according to the conducted cointegration analysis, the worldwide semiconductor unit shipments were proven to be correlated to China's share in global vehicle production. The analysis showed that the semiconductor shipments increased with China's share growth in global vehicle production in the short run. However, in the long run, the stability of supply, demand, and prices in the semiconductor shipments decreases; in other words, the disequilibrium with the rate of 97% will converge sometime in the future. Regarding the effect of crude oil prices on the supply chain of semiconductors, West Texas Intermediate, Europe Brent, and OPEC were analysed. In the cointegration analysis between semiconductor supply and its distributions and annual average WTI and Brent crude oil spot prices in West Texas Intermediate, it was found that in the short run, there is no increase in the supply shipments, but in the long run, there would be a difference in terms of the relationship converging by 38.6%. The same conclusions were reached for Europe Brent and OPEC; however, the convergence rate for Brent is 35.6%, and for OPEC, it is 36.9%.

These findings may broaden the horizons of researching and analysing the causes of the semiconductor supply chain disruptions to alleviate the industrial and economic impact. This study may help policymakers perceive the importance of good organisational structure and the prospects for developing and innovating other energy sources for manufacturing equipment. With this study, the significance of the semiconductor industry on the economy and automotive industry can be pursued to focus on creating the educational environment as the basis of possible future development of the semiconductor industry in Bosnia and Herzegovina or other developing countries. Since this study focuses on China and the U.S., the limitation regarding econometric analysis is that there were no data available to collect regarding the U.S. share growth in global vehicle production to test for cointegration with semiconductor supply and unit shipment.

### *5.2RECOMMENDATIONS*

The semiconductor industry is a promising industry that, with the right approach and knowledge, can become prosperous and boost the country's economy, especially in developing countries. Technology is constantly developing, and semiconductors are the core elements of technological innovations. Therefore, it is recommended to invest in making the semiconductor companies more efficient and productive by, for example, employing more people, building more production factories to increase the production capacities, and encouraging younger people to get a good education so that innovations are in perspective as well. Also, in the automotive industry, it is recommended not to rely only on one or few semiconductor suppliers because if the procurement is stopped for some unknown reason or unexpected circumstance, the reliability of companies within the industry is not decreased, and the production of motor vehicles is not halted.

## 6. CONCLUSION

In conclusion, the primary aim of this study was to define and characterise the cause of semiconductor supply chain disruptions and note how that disruption affected the automotive industry while prioritising the outcomes in the industry due to the Covid-19 pandemic and analysing the occurrence of supply chain disruptions due to the increase of crude oil prices since its use for the generation of energy that is obligatory to the manufacturing part is essential. For the research purpose, semiconductor and automotive industries in China and the U.S. were analysed. Critical success factors in the semiconductors industry were provided and described; additionally, the impact of Covid-19 on the semiconductor industry was analysed, and the impact of the semiconductor supply chain and Covid-19 on the automotive industry was explored. The challenges and opportunities were presented and discussed. Additionally, empirical data implied that oil crude prices were significantly correlated with the semiconductor industry and thus indirectly affected the supply chain in the long run. However, the empirical data in Cointegration analysis between the semiconductor supply chain and China's share in global vehicle production could not be interpreted. In this paper, recommendations for the approach to entering the industry for developing countries, and the increase of efficiency in countries that already have entered the semiconductor industry were provided. Additionally, a recommendation for the automotive industry to prevent the halt of production in the future not to rely on one or few semiconductor suppliers was provided. Finally, this research is supposed to expand the point of view regarding the causes of disruptions in the semiconductor supply chain and help understand the importance of creating a prosperous educational environment which is the primary condition for any developing country to enter the semiconductor industry and for countries that already are in that industry to continue to create innovations or to meet the industry's standards.

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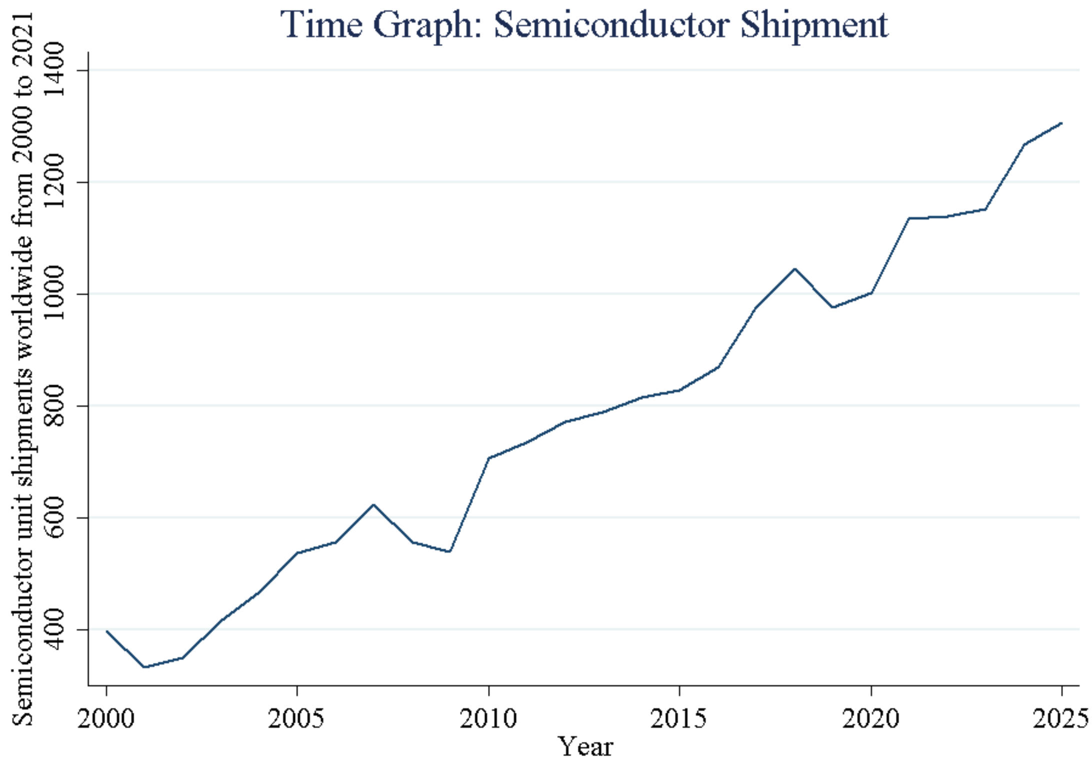
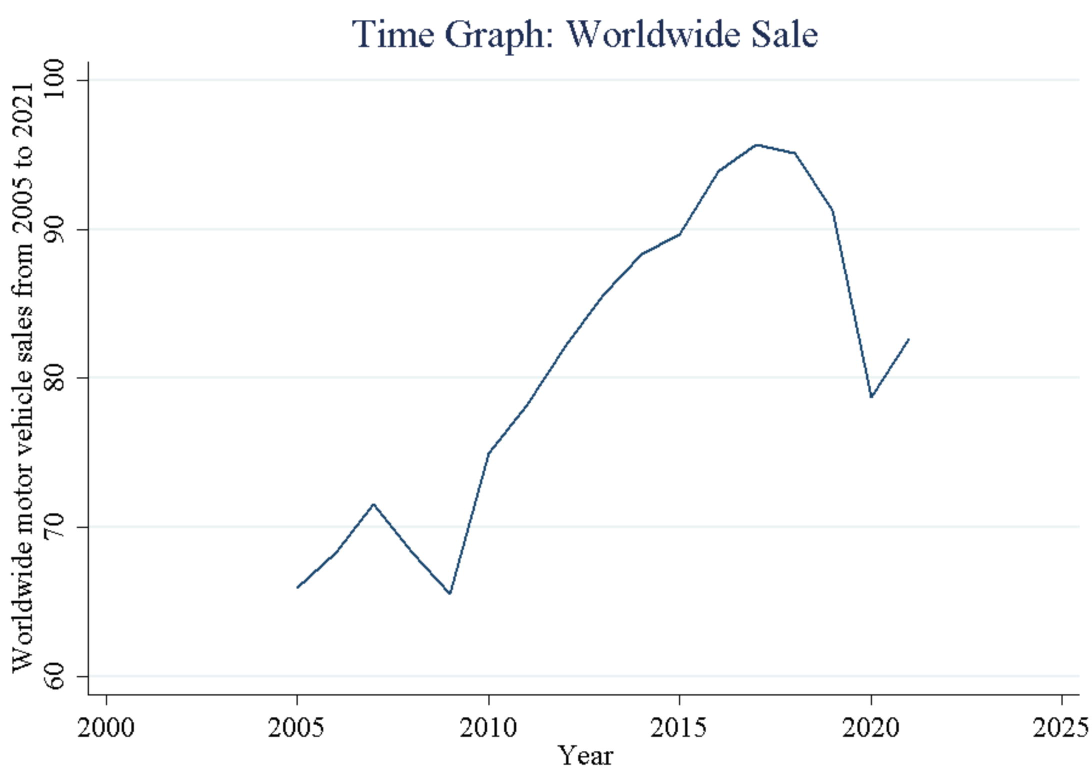
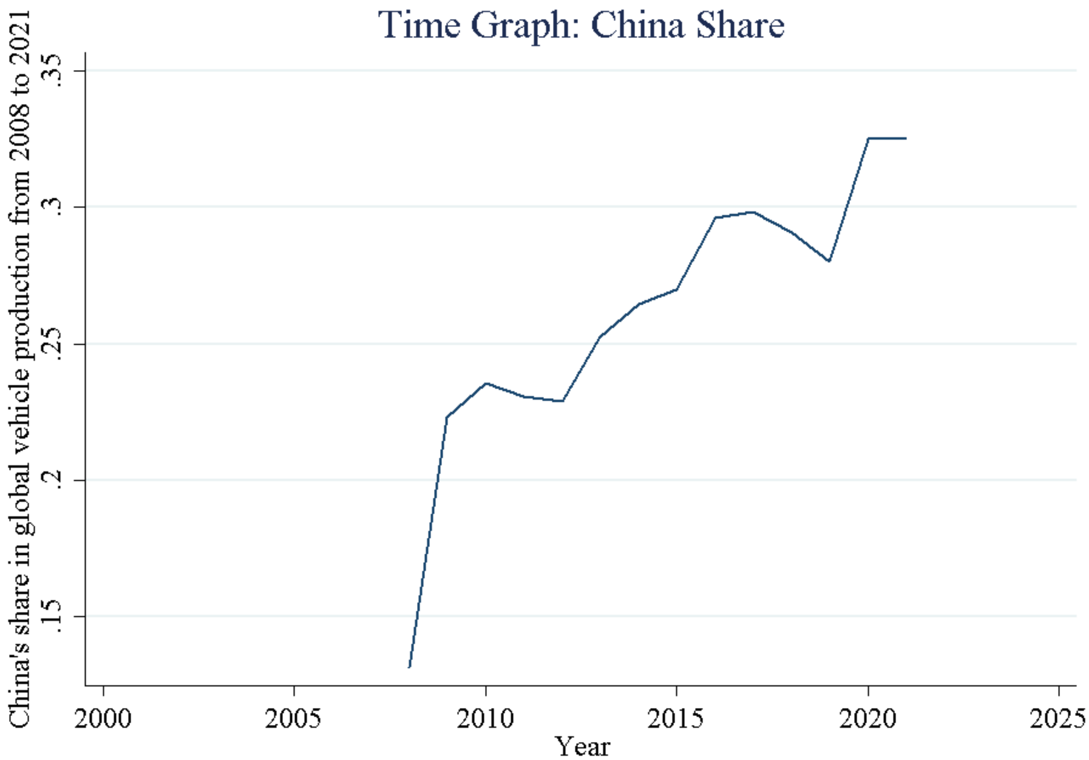
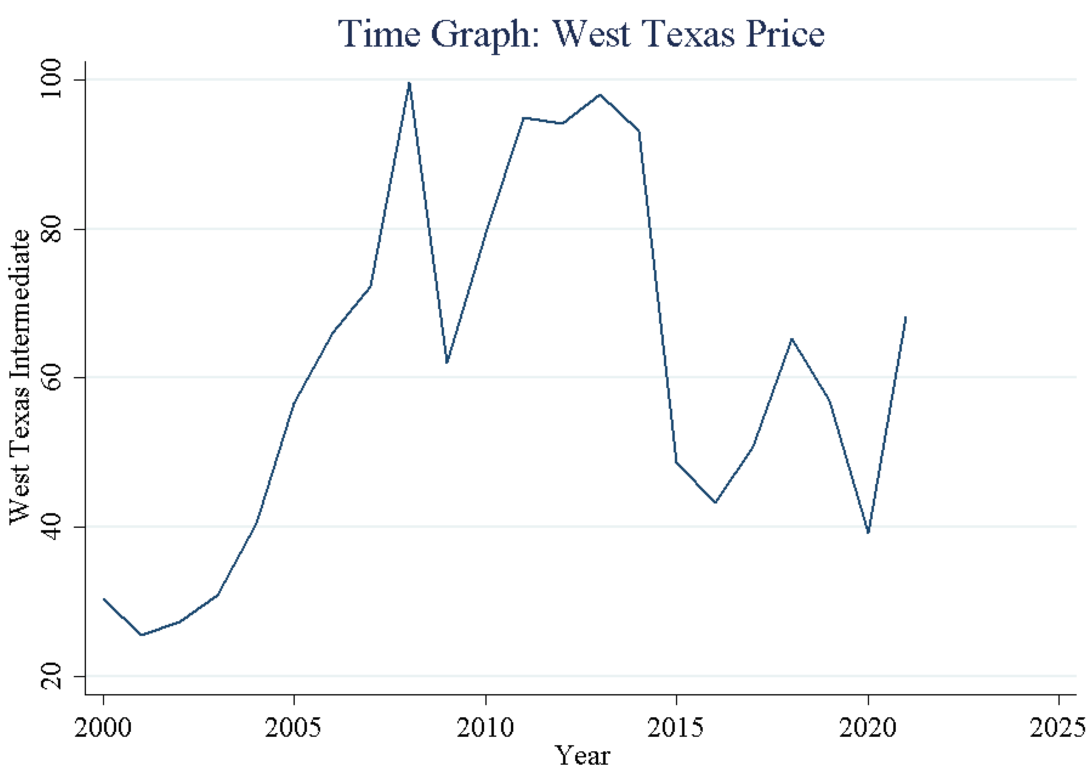
## 9. APPENDICES

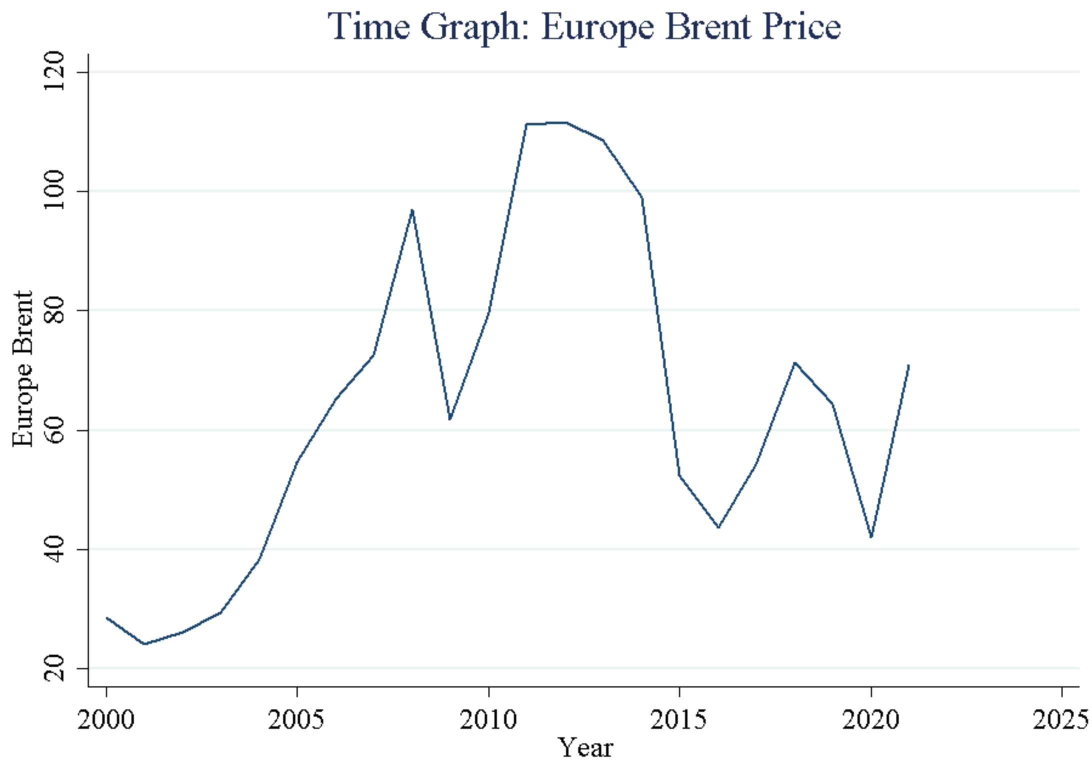
***Appendix A – Timeline Graphs***

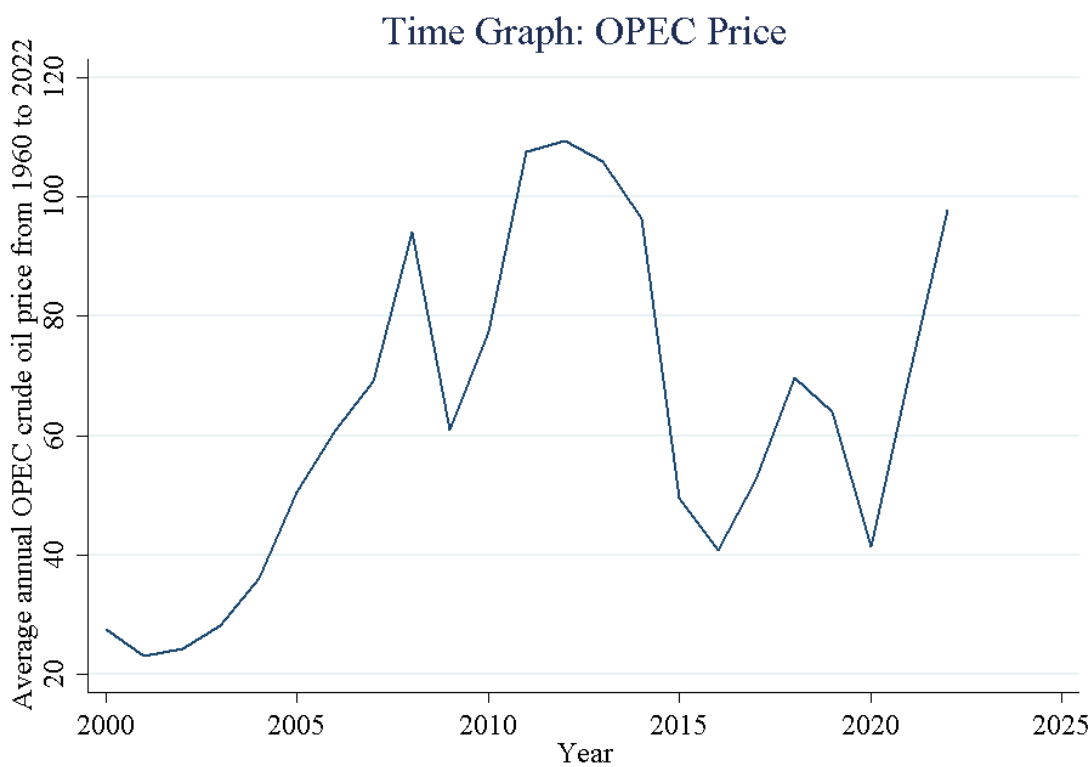



Time Graph: China Share
China's share in global vehicle production from 2008 to 2021
.15
.2
.25
.3
.35
2000
2005
2010
2015
2020
2025
Year


Time Graph: West Texas Price
West Texas Intermediate
20
40
60
80
100
2000
2005
2010
2015
2020
2025
Year


Time Graph: Europe Brent Price
Europe Brent
20
40
60
80
100
120
2000
2005
2010
2015
2020
2025
Year


Time Graph: OPEC Price
Average annual OPEC crude oil price from 1960 to 2022
20
40
60
80
100
120
2000
2005
2010
2015
2020
2025
Year

### *Appendix B – Analyses in Stata*

```
.
. ren Semiconductorunitshipmentswor semicondshipment

. ren Worldwidemotorvehiclesalesfr worldwidesale

. ren Numberofcarssoldworldwidebe worldwidecar

. ren Chinasshareinglobalvehicle chinashare

. ren WestTexasIntermediate westtexas

. ren EuropeBrent europebrent

. ren AverageannualOPECcrudeoilpr annualopec

. ren Electrifiedvehiclesalesasap electricvehicle

. ren Batteryelectricvehiclesalesa battery

. ren Sizeofthememorycardmarketi sizememory

.
. tsset Year
        time variable:  Year, 2000 to 2025
                delta:  1 unit

. tsline semicondshipment, graphregion(color(white)) bgcolor(white) title("Time Graph: Semicon
> ductor Shipment")

. graph export "semicondshipment.png", as(png) replace
(file semicondshipment.png written in PNG format)

. tsline worldwidesale, graphregion(color(white)) bgcolor(white) title("Time Graph: Worldwide
> Sale")

. graph export "worldwidesale.png", as(png) replace
(file worldwidesale.png written in PNG format)

. tsline chinashare, graphregion(color(white)) bgcolor(white) title("Time Graph: China Share")

. graph export "chinashare.png", as(png) replace
(file chinashare.png written in PNG format)

. tsline westtexas, graphregion(color(white)) bgcolor(white) title("Time Graph: West Texas Pri
> ce")

. graph export "westtexas.png", as(png) replace
(file westtexas.png written in PNG format)
```

```
. tsline europebrent, graphregion(color(white)) bgcolor(white) title("Time Graph: Europe Brent
>  Price")

. graph export "europebrent.png", as(png) replace
(file europebrent.png written in PNG format)

. tsline annualopec, graphregion(color(white)) bgcolor(white) title("Time Graph: OPEC Price")

. graph export "annualopec.png", as(png) replace
(file annualopec.png written in PNG format)

.
. foreach i of varlist semicondshipment worldwidesale chinashare westtexas europebrent annualo
> pec {
  2. gen d`i'=D2.`i'
  3. }
(2 missing values generated)
(11 missing values generated)
(14 missing values generated)
(6 missing values generated)
(6 missing values generated)
(5 missing values generated)
. foreach i of varlist semicondshipment worldwidesale chinashare westtexas europebrent annualo
> pec {
  2. reg `i'
  3. dfuller `i', regress lags(3) trend
  4. estadd scalar DF=r(Zt)
  5. estadd scalar pvalue=r(p)
  6. eststo `i'
  7. }

      Source |       SS           df       MS      Number of obs   =        26
-------------+----------------------------------   F(0, 25)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  2127020.85        25  85080.834    R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  2127020.85        25  85080.834    Root MSE        =    291.69

------------------------------------------------------------------------------
semicondsh~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   780.3038   57.20437    13.64   0.000     662.4892    898.1184
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        22

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.293            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0674

------------------------------------------------------------------------------
D.semicond~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
semicondsh~t |
         L1. |  -1.812613   .5504483    -3.29   0.005    -2.979511   -.6457149
         LD. |   1.044217   .4522404     2.31   0.035     .0855105    2.002924
        L2D. |   .2687669   .3155156     0.85   0.407    -.4000963      .93763
        L3D. |   .3868799   .2360932     1.64   0.121    -.1136153    .8873751
      _trend |   68.08262   20.49903     3.32   0.004     24.62662    111.5386
       _cons |    461.665   121.9024     3.79   0.002     203.2434    720.0866
------------------------------------------------------------------------------

added scalar:
                 e(DF) =  -3.2929763

added scalar:
             e(pvalue) =  .06741521
```

```
      Source |       SS           df       MS      Number of obs   =        17
-------------+----------------------------------   F(0, 16)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  1761.87981        16  110.117488   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  1761.87981        16  110.117488   Root MSE        =    10.494

------------------------------------------------------------------------------
worldwides~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   80.93412   2.545093    31.80   0.000     75.53876    86.32947
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        13

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.062            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9351

------------------------------------------------------------------------------
D.worldwid~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
worldwides~e |
         L1. |  -.8212535   .7730327    -1.06   0.323    -2.649185    1.006678
         LD. |   .8170463   .8240683     0.99   0.354    -1.131566    2.765658
        L2D. |   .3064345   .6959044     0.44   0.673    -1.339118    1.951987
        L3D. |   .4327635   .6485147     0.67   0.526     -1.10073    1.966257
      _trend |   1.487212   2.056808     0.72   0.493    -3.376367    6.350791
       _cons |   52.96277   42.71685     1.24   0.255    -48.04653    153.9721
------------------------------------------------------------------------------

added scalar:
                  e(DF) =  -1.0623788

added scalar:
              e(pvalue) =  .93511329

      Source |       SS           df       MS      Number of obs   =        14
-------------+----------------------------------   F(0, 13)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  .033069732        13  .002543826   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  .033069732        13  .002543826   Root MSE        =    .05044

------------------------------------------------------------------------------
  chinashare |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   .2608643   .0134797    19.35   0.000     .2317432    .2899854
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        10

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.347            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8758

------------------------------------------------------------------------------
D.chinashare |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  chinashare |
         L1. |  -1.641482   1.218641    -1.35   0.249    -5.024971    1.742007
         LD. |   .5340399   .8670321     0.62   0.571    -1.873227    2.941307
        L2D. |   .3121213   .8643899     0.36   0.736     -2.08781    2.712052
        L3D. |   -.134125   .2642782    -0.51   0.638    -.8678788    .5996288
      _trend |   .0141662   .0119428     1.19   0.301    -.0189924    .0473247
       _cons |   .3338401   .2209791     1.51   0.205    -.2796962    .9473764
------------------------------------------------------------------------------
```

```
added scalar:
                 e(DF) =  -1.3469781

added scalar:
             e(pvalue) =  .87581332

      Source |       SS           df       MS      Number of obs   =        22
-------------+----------------------------------   F(0, 21)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  12427.0225        21  591.762974   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  12427.0225        21  591.762974   Root MSE        =    24.326

------------------------------------------------------------------------------
   westtexas |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   61.06136   5.186359    11.77   0.000     50.27574    71.84699
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        18

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.812            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.6990

------------------------------------------------------------------------------
D.westtexas  |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   westtexas |
         L1. |  -.4591796   .2534134    -1.81   0.095     -1.01132    .0929609
         LD. |  -.0156929   .3223924    -0.05   0.962    -.7181257    .6867399
        L2D. |  -.0794006   .3028599    -0.26   0.798    -.7392757    .5804745
        L3D. |   .0930941   .2902092     0.32   0.754    -.5392174    .7254057
      _trend |  -.7315346   1.070761    -0.68   0.507    -3.064522    1.601453
       _cons |    41.5848    18.4135     2.26   0.043     1.465228    81.70438
------------------------------------------------------------------------------
```

```
added scalar:
                 e(DF) =  -1.8119781

added scalar:
             e(pvalue) =  .69895414

      Source |       SS           df       MS      Number of obs   =        22
-------------+----------------------------------   F(0, 21)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  16585.6753        21  789.794063   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  16585.6753        21  789.794063   Root MSE        =    28.103

------------------------------------------------------------------------------
 europebrent |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   63.90409   5.991638    10.67   0.000      51.4438    76.36438
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        18

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.776            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7163

------------------------------------------------------------------------------
D.europebr~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 europebrent |
         L1. |  -.4379821   .2466316    -1.78   0.101    -.9753463    .0993821
         LD. |   .1912073   .3217732     0.59   0.563    -.5098763    .8922909
        L2D. |   -.111556    .297013    -0.38   0.714    -.7586916    .5355796
        L3D. |    .138083   .2994321     0.46   0.653    -.5143234    .7904894
      _trend |   -.361065      1.178    -0.31   0.764    -2.927706    2.205576
       _cons |   37.14407   18.15464     2.05   0.063     -2.41149    76.69962
------------------------------------------------------------------------------
```

```
added scalar:
                 e(DF) =  -1.7758553

added scalar:
             e(pvalue) =  .7162825

      Source |       SS           df       MS      Number of obs   =        23
-------------+----------------------------------   F(0, 22)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  17278.7677        22  785.398533   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  17278.7677        22  785.398533   Root MSE        =    28.025

------------------------------------------------------------------------------
  annualopec |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   63.33652   5.843609    10.84   0.000     51.21762    75.45542
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        19

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.929            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.6396

------------------------------------------------------------------------------
D.annualopec |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  annualopec |
         L1. |  -.4677879   .2425309    -1.93   0.076    -.9917441    .0561683
         LD. |   .3249598   .2853505     1.14   0.275    -.2915024     .941422
        L2D. |  -.1345369   .2936898    -0.46   0.654    -.7690152    .4999413
        L3D. |   .1600318   .2956251     0.54   0.597    -.4786274    .7986909
      _trend |   .1625888   1.022843     0.16   0.876     -2.04713    2.372308
       _cons |   32.20834   17.12185     1.88   0.083    -4.781165    69.19786
------------------------------------------------------------------------------

added scalar:
                 e(DF) =  -1.9287765

added scalar:
             e(pvalue) =  .6396299
```

```
. esttab semicondshipment worldwidesale chinashare westtexas europebrent annualopec using dful
> ler.rtf, stat(DF pvalue) replace label compress
(output written to dfuller.rtf)

.
. foreach i of varlist dsemicondshipment dworldwidesale dchinashare dwesttexas deuropebrent da
> nnualopec {
  2. reg `i'
  3. dfuller `i', regress lags(3) trend
  4. estadd scalar DF2=r(Zt)
  5. estadd scalar pvalue=r(p)
  6. eststo `i'
  7. }

      Source |       SS           df       MS      Number of obs   =        24
-------------+----------------------------------   F(0, 23)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  167931.998        23  7301.39121   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  167931.998        23  7301.39121   Root MSE        =    85.448

------------------------------------------------------------------------------
dsemiconds~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   4.291667   17.44204     0.25   0.808    -31.78993    40.37327
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        20

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -4.170            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0050

------------------------------------------------------------------------------
D.dsemicon~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
dsemiconds~t |
         L1. |  -3.643039   .8735662    -4.17   0.001    -5.516652   -1.769425
         LD. |   1.839663   .7111327     2.59   0.022      .314435    3.364891
        L2D. |   .7865096   .4709783     1.67   0.117    -.2236384    1.796658
        L3D. |   .3250277   .2461881     1.32   0.208    -.2029932    .8530486
      _trend |   1.148196   2.643768     0.43   0.671    -4.522124    6.818515
       _cons |  -14.27728   38.85448    -0.37   0.719    -97.61185    69.05729
------------------------------------------------------------------------------
```

```
added scalar:
             e(DF2) =  -4.1703061

added scalar:
          e(pvalue) =  .00496176

      Source |       SS           df       MS      Number of obs   =        15
-------------+----------------------------------   F(0, 14)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  604.046789        14  43.1461992   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  604.046789        14  43.1461992   Root MSE        =    6.5686

------------------------------------------------------------------------------
dworldwide~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   .0986667   1.695999     0.06   0.954     -3.53889    3.736223
------------------------------------------------------------------------------
Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.789            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.2009

------------------------------------------------------------------------------
D.dworldwi~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
dworldwide~e |
         L1. |  -5.803443   2.080553    -2.79   0.038    -11.15168   -.4552112
         LD. |   3.180532   1.603027     1.98   0.104     -.940179    7.301244
        L2D. |   1.683788   .9463142     1.78   0.135    -.7487906    4.116366
        L3D. |   .6551144   .4676603     1.40   0.220    -.5470447    1.857274
      _trend |  -1.904293   1.128177    -1.69   0.152    -4.804366     .995779
       _cons |   14.73287   9.660438     1.53   0.188    -10.10008    39.56581
------------------------------------------------------------------------------
```

```
added scalar:
                 e(DF2) =  -2.7893752

added scalar:
              e(pvalue) =  .20087421

      Source |       SS           df       MS      Number of obs   =        12
-------------+----------------------------------   F(0, 11)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  .012917229        11  .001174294   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  .012917229        11  .001174294   Root MSE        =    .03427

------------------------------------------------------------------------------
 dchinashare |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |  -.0076083   .0098923    -0.77   0.458    -.0293812    .0141645
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =         8

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.783            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7130

------------------------------------------------------------------------------
D.dchinash~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 dchinashare |
         L1. |  -3.925986    2.20222    -1.78   0.217    -13.40137    5.549401
         LD. |    1.93566   1.760497     1.10   0.386    -5.639149    9.510469
        L2D. |   .8443323   1.046124     0.81   0.504    -3.656774    5.345439
        L3D. |   -.051763   .5066622    -0.10   0.928    -2.231754    2.128228
      _trend |  -.0016263   .0066234    -0.25   0.829    -.0301244    .0268719
       _cons |   .0126332   .0524314     0.24   0.832    -.2129607    .2382272
------------------------------------------------------------------------------


added scalar:
                 e(DF2) =  -1.7827404

added scalar:
              e(pvalue) =  .7130206

      Source |       SS           df       MS      Number of obs   =        20
-------------+----------------------------------   F(0, 19)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  14333.2496        19  754.381556   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  14333.2496        19  754.381556   Root MSE        =    27.466

------------------------------------------------------------------------------
  dwesttexas |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |     1.6875   6.141586     0.27   0.786    -11.16699    14.54199
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        16

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.154            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0939

------------------------------------------------------------------------------
D.dwesttexas |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  dwesttexas |
         L1. |  -3.574876   1.133359    -3.15   0.010    -6.100158   -1.049594
         LD. |   1.669162    .949965     1.76   0.109    -.4474918    3.785816
        L2D. |   .8337686   .6547579     1.27   0.232    -.6251229     2.29266
        L3D. |   .3143024   .3227664     0.97   0.353     -.404866    1.033471
      _trend |   .8192913    1.46746     0.56   0.589    -2.450413    4.088995
       _cons |  -10.13361   18.14389    -0.56   0.589    -50.56072     30.2935
------------------------------------------------------------------------------
```

```
added scalar:
                e(DF2) =  -3.1542296

added scalar:
             e(pvalue) =  .09391378

      Source |       SS           df       MS      Number of obs   =        20
-------------+----------------------------------   F(0, 19)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  14692.6978        19  773.299883   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  14692.6978        19  773.299883   Root MSE        =    27.808

------------------------------------------------------------------------------
deuropebrent |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |      1.678   6.218118     0.27   0.790    -11.33667    14.69267
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        16

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.204            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0836

------------------------------------------------------------------------------
D.deuropeb~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
deuropebrent |
         L1. |  -3.239539    1.01109    -3.20   0.009    -5.492389   -.9866891
         LD. |   1.571032   .8460105     1.86   0.093    -.3139973    3.456061
        L2D. |   .8093492   .5944271     1.36   0.203    -.5151169    2.133815
        L3D. |    .388685   .3216581     1.21   0.255    -.3280138    1.105384
      _trend |   .7984509   1.575957     0.51   0.623       -2.713    4.309902
       _cons |  -9.422354   19.46986    -0.48   0.639    -52.80391     33.9592
------------------------------------------------------------------------------
```

```
added scalar:
              e(DF2) =  -3.2040052

added scalar:
           e(pvalue) =  .08360657

      Source |       SS           df       MS      Number of obs   =        21
-------------+----------------------------------   F(0, 20)        =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  13957.2033        20  697.860167   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  13957.2033        20  697.860167   Root MSE        =    26.417

------------------------------------------------------------------------------
 dannualopec |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   1.545714   5.764671     0.27   0.791    -10.47918    13.57061
------------------------------------------------------------------------------

Augmented Dickey-Fuller test for unit root         Number of obs   =        17

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.381            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0540

------------------------------------------------------------------------------
D.dannualo~c |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 dannualopec |
         L1. |  -3.250495   .9614509    -3.38   0.006    -5.366634   -1.134356
         LD. |   1.606781   .7962669     2.02   0.069    -.1457911    3.359352
        L2D. |   .8501181   .5610392     1.52   0.158     -.384721    2.084957
        L3D. |   .3969155   .3083101     1.29   0.224    -.2816704    1.075501
      _trend |   .8696813   1.358152     0.64   0.535    -2.119592    3.858955
       _cons |  -9.726225   17.53813    -0.55   0.590    -48.32738    28.87493
------------------------------------------------------------------------------

added scalar:
              e(DF2) =  -3.380823

added scalar:
           e(pvalue) =  .05400332
```

```
. esttab dsemicondshipment dworldwidesale dchinashare dwesttexas deuropebrent dannualopec usin
> g dfuller2.rtf, stat(DF2 pvalue) replace label compress
(output written to dfuller2.rtf)

.
.
. /*Engle and Granger Cointegration Test */
. foreach i of varlist worldwidesale chinashare westtexas europebrent annualopec {
  2. regress `i' semicondshipment
  3. predict resid_`i', residuals
  4. tsline resid_`i', graphregion(color(white)) bgcolor(white) title("Timeline for Residuals"
> )
  5. graph export residualsvecml_`i'.png, replace
  6. dfuller resid_`i', regress trend lags(3)
  7. regress D.`i' dsemicondshipment L.resid_`i'
  8. eststo vecm_`i'
  9. }

      Source |       SS           df       MS      Number of obs   =        17
-------------+----------------------------------   F(1, 15)        =     27.19
       Model |  1135.51959         1  1135.51959   Prob > F        =    0.0001
    Residual |  626.360223        15  41.7573482   R-squared       =    0.6445
-------------+----------------------------------   Adj R-squared   =    0.6208
       Total |  1761.87981        16  110.117488   Root MSE        =     6.462

------------------------------------------------------------------------------------
   worldwidesale |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+------------------------------------------------------------------
semicondshipment |   .0441904   .0084742     5.21   0.000     .0261281    .0622526
           _cons |   45.94289    6.89069     6.67   0.000     31.25573    60.63005
------------------------------------------------------------------------------------
(9 missing values generated)
(file residualsvecml_worldwidesale.png written in PNG format)
```

```
Augmented Dickey-Fuller test for unit root         Number of obs   =        13

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.706            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7484

------------------------------------------------------------------------------
D.resid_wo~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
resid_worl~e |
         L1. |  -1.025712   .6013949    -1.71   0.132    -2.447784    .3963613
         LD. |   .6544368   .6790633     0.96   0.367    -.9512927    2.260166
        L2D. |   1.198269   .5382757     2.23   0.061    -.0745502    2.471089
        L3D. |   1.759076   .7902948     2.23   0.061     -.109674    3.627826
      _trend |   .4213146   .6914285     0.61   0.562    -1.213654    2.056283
       _cons |  -4.217651   6.002536    -0.70   0.505    -18.41139    9.976092
------------------------------------------------------------------------------

      Source |       SS           df       MS      Number of obs   =        16
-------------+----------------------------------   F(2, 13)        =      0.55
       Model |  27.8944288         2  13.9472144   Prob > F        =    0.5908
    Residual |  330.740071        13  25.4415439   R-squared       =    0.0778
-------------+----------------------------------   Adj R-squared   =   -0.0641
       Total |    358.6345        15  23.9089667   Root MSE        =     5.044


-----------------------------------------------------------------------------------
   D.worldwidesale |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------+---------------------------------------------------------------
  dsemicondshipment |   .0109004   .0144187     0.76   0.463    -.0202492      .04205
                   |
resid_worldwidesale |
               L1. |  -.1445377   .2453277    -0.59   0.566     -.674536    .3854605
                   |
             _cons |   1.124899   1.280571     0.88   0.396    -1.641606    3.891404
-----------------------------------------------------------------------------------

      Source |       SS           df       MS      Number of obs   =        14
-------------+----------------------------------   F(1, 12)        =     40.74
       Model |  .025545495         1  .025545495   Prob > F        =    0.0000
    Residual |  .007524237        12   .00062702   R-squared       =    0.7725
-------------+----------------------------------   Adj R-squared   =    0.7535
       Total |  .033069732        13  .002543826   Root MSE        =    .02504

---------------------------------------------------------------------------------
      chinashare |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+---------------------------------------------------------------
semicondshipment |   .0002523   .0000395     6.38   0.000     .0001662    .0003384
           _cons |   .0492341   .0338246     1.46   0.171    -.0244633    .1229315
---------------------------------------------------------------------------------
(12 missing values generated)
(file residualsvecml_chinashare.png written in PNG format)
```

```
Augmented Dickey-Fuller test for unit root         Number of obs   =        10

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.034            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9394

------------------------------------------------------------------------------
D.resid_ch~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
resid_chin~e |
         L1. |  -1.473124   1.424977    -1.03   0.360    -5.429496    2.483248
         LD. |   .5501374      .8841     0.62   0.567    -1.904518    3.004793
        L2D. |    .175209   1.008006     0.17   0.870    -2.623466    2.973884
        L3D. |  -.0823839   .3902871    -0.21   0.843    -1.165995    1.001227
      _trend |  -.0016681   .0026402    -0.63   0.562    -.0089986    .0056623
       _cons |   .0172081   .0236875     0.73   0.508     -.048559    .0829751
------------------------------------------------------------------------------
```

```
      Source |       SS           df       MS      Number of obs   =        13
-------------+----------------------------------   F(2, 10)        =     20.82
       Model |  .00750025          2  .003750125   Prob > F        =    0.0003
    Residual |  .001801027        10  .000180103   R-squared       =    0.8064
-------------+----------------------------------   Adj R-squared   =    0.7676
       Total |  .009301277        12  .000775106   Root MSE        =    .01342

-----------------------------------------------------------------------------------
     D.chinashare |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------+----------------------------------------------------------------
dsemicondshipment |   .0002009   .0000451     4.45   0.001     .0001003    .0003015
                  |
 resid_chinashare |
              L1. |   -.978889   .1657376    -5.91   0.000    -1.348175   -.6096027
                  |
            _cons |   .0125701   .0037814     3.32   0.008     .0041446    .0209956
-----------------------------------------------------------------------------------
```

```
      Source |       SS           df       MS      Number of obs   =        22
-------------+----------------------------------   F(1, 20)        =      2.52
       Model |  1391.59146         1  1391.59146   Prob > F        =    0.1279
    Residual |   11035.431        20   551.77155   R-squared       =    0.1120
-------------+----------------------------------   Adj R-squared   =    0.0676
       Total |  12427.0225        21  591.762974   Root MSE        =     23.49

----------------------------------------------------------------------------------
      westtexas |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-----------------------------------------------------------------
semicondshipment |   .0339289   .0213645     1.59   0.128    -.0106367    .0784945
          _cons |   37.27444   15.79334     2.36   0.029     4.330121    70.21876
----------------------------------------------------------------------------------
(4 missing values generated)
(file residualsvecml_westtexas.png written in PNG format)

Augmented Dickey-Fuller test for unit root         Number of obs   =        18

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.801            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7041

------------------------------------------------------------------------------
D.resid_we~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
resid_west~s |
         L1. |  -.4398716   .2441925    -1.80   0.097    -.9719215    .0921782
         LD. |   -.029888   .3172613    -0.09   0.927    -.7211411    .6613651
        L2D. |  -.0453777   .3005033    -0.15   0.882    -.7001182    .6093628
        L3D. |   .1043129   .2889878     0.36   0.724    -.5253374    .7339632
      _trend |  -1.258156   .9935435    -1.27   0.229    -3.422901    .9065894
       _cons |   18.14804   13.23854     1.37   0.196    -10.69627    46.99234
------------------------------------------------------------------------------

      Source |       SS           df       MS      Number of obs   =        20
-------------+----------------------------------   F(2, 17)        =      2.46
       Model |  1495.34417         2  747.672086   Prob > F        =    0.1151
    Residual |  5162.31708        17  303.665711   R-squared       =    0.2246
-------------+----------------------------------   Adj R-squared   =    0.1334
       Total |  6657.66126        19  350.403224   Root MSE        =    17.426
```

```
------------------------------------------------------------------------------------
      D.westtexas |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------+-----------------------------------------------------------------
dsemicondshipment |  -.0396743   .0492171    -0.81   0.431    -.1435133    .0641648
                  |
   resid_westtexas |
              L1. |   -.385985   .1752679    -2.20   0.042    -.7557679    -.016202
                  |
            _cons |   3.061054   3.942183     0.78   0.448    -5.256226    11.37833
------------------------------------------------------------------------------------

      Source |       SS           df       MS      Number of obs   =        22
-------------+----------------------------------   F(1, 20)        =      3.62
       Model |  2544.64372         1  2544.64372   Prob > F        =    0.0714
    Residual |  14041.0316        20  702.051581   R-squared       =    0.1534
-------------+----------------------------------   Adj R-squared   =    0.1111
       Total |  16585.6753        21  789.794063   Root MSE        =    26.496

------------------------------------------------------------------------------------
    europebrent |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-------------------------------------------------------------------
semicondshipment |   .0458804    .024099     1.90   0.071    -.0043891    .0961499
          _cons |   31.73818   17.81471     1.78   0.090    -5.422652    68.89901
------------------------------------------------------------------------------------
(4 missing values generated)
(file residualsvecml_europebrent.png written in PNG format)

Augmented Dickey-Fuller test for unit root         Number of obs   =        18

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.758            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7248

------------------------------------------------------------------------------
D.resid_eu~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
resid_euro~t |
         L1. |  -.4163504    .236885    -1.76   0.104    -.9324785    .0997777
         LD. |   .1549153   .3159873     0.49   0.633    -.5335618    .8433924
        L2D. |  -.0667252   .2941857    -0.23   0.824    -.7077008    .5742505
        L3D. |   .1477733   .2977982     0.50   0.629    -.5010732    .7966197
      _trend |  -1.079355    1.05354    -1.02   0.326    -3.374823    1.216112
       _cons |   15.84599   14.00754     1.13   0.280    -14.67381     46.3658
------------------------------------------------------------------------------

      Source |       SS           df       MS      Number of obs   =        20
-------------+----------------------------------   F(2, 17)        =      2.44
       Model |  1721.89213         2  860.946067   Prob > F        =    0.1170
    Residual |  5995.90589        17  352.700346   R-squared       =    0.2231
-------------+----------------------------------   Adj R-squared   =    0.1317
       Total |  7717.79802        19  406.199896   Root MSE        =     18.78

------------------------------------------------------------------------------------
   D.europebrent |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------+-----------------------------------------------------------------
dsemicondshipment |  -.0546732   .0527813    -1.04   0.315    -.1660321    .0566856
                  |
resid_europebrent |
              L1. |  -.3562099   .1668072    -2.14   0.048    -.7081424   -.0042774
                  |
            _cons |    3.49558    4.24951     0.82   0.422    -5.470102    12.46126
------------------------------------------------------------------------------------
```

```
      Source |       SS           df       MS      Number of obs   =        23
-------------+----------------------------------   F(1, 21)        =      5.64
       Model |  3656.11573         1  3656.11573   Prob > F        =    0.0272
    Residual |   13622.652        21  648.697714   R-squared       =    0.2116
-------------+----------------------------------   Adj R-squared   =    0.1741
       Total |  17278.7677        22  785.398533   Root MSE        =     25.47

---------------------------------------------------------------------------------
     annualopec |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+----------------------------------------------------------------
semicondshipment |   .0512536   .0215891     2.37   0.027     .0063565    .0961507
          _cons |   26.42904   16.42833     1.61   0.123    -7.735548    60.59363
---------------------------------------------------------------------------------
(3 missing values generated)
(file residualsvecm1_annualopec.png written in PNG format)
Augmented Dickey-Fuller test for unit root         Number of obs   =        19

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.950            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.6285

------------------------------------------------------------------------------
D.resid_an~c |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
resid_annu~c |
         L1. |  -.4565147   .2341468    -1.95   0.073     -.962358    .0493287
         LD. |   .3026616   .2858779     1.06   0.309     -.31494     .9202632
        L2D. |  -.0869497   .2941893    -0.30   0.772     -.722507    .5486075
        L3D. |   .1905786   .2949033     0.65   0.529    -.4465211    .8276784
      _trend |  -.634939    .9315122    -0.68   0.507    -2.647349    1.377471
       _cons |   10.86368   12.98716     0.84   0.418    -17.19338    38.92073
------------------------------------------------------------------------------

      Source |       SS           df       MS      Number of obs   =        21
-------------+----------------------------------   F(2, 18)        =      3.21
       Model |  2113.59631         2  1056.79815   Prob > F        =    0.0643
    Residual |  5929.92175        18  329.440097   R-squared       =    0.2628
-------------+----------------------------------   Adj R-squared   =    0.1809
       Total |  8043.51806        20  402.175903   Root MSE        =     18.15

----------------------------------------------------------------------------------
     D.annualopec |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------+----------------------------------------------------------------
dsemicondshipment |  -.0649516   .0470025    -1.38   0.184    -.1637002    .0337971
                  |
  resid_annualopec |
              L1. |  -.3686831   .1603375    -2.30   0.034    -.7055396   -.0318265
                  |
            _cons |   3.870648   3.964202     0.98   0.342    -4.457831    12.19913
----------------------------------------------------------------------------------

. esttab vecm_worldwidesale vecm_chinashare vecm_westtexas vecm_europebrent vecm_annualopec //
> /
> using vecm.rtf, replace starlevels(* 0.1 ** 0.05 *** 0.01) se label
(output written to vecm.rtf)

.
. log close
      name:  <unnamed>
       log:  D:\Courses\Econ\vecm.log
  log type:  text
 closed on:   1 Jun 2022, 01:27:43
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