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Is Uncertainty Causing Reshoring? A Comparative study of U.S. pharmaceutical manufacturing and electrical manufacturing 1998-2020

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Abstract:

Discourse of reshoring as a possible risk mitigation strategy during times of uncertainty has during the recent decade become more prominent. This thesis examines the casual relationship between uncertainty and reshoring within the electrical manufacturing and pharmaceutical manufacturing industries in the U.S. The research question proposed is: How efficient are measures of uncertainty in predicting future reshoring patterns within the U.S. pharmaceutical manufacturing and electrical manufacturing industries? The thesis builds upon classic international trade theory to formulate an understanding of the causes of reshoring relating to industry complexity and centrality in times of uncertainty. The findings suggest a relationship between reshoring and uncertainty within the pharmaceutical manufacturing industry, but such a relationship is not found in the case of electrical manufacturing.

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Table of Contents

List of Figures

1. Introduction

Reshoring, a trend that has gained momentum during the last decade, refers to companies restructuring their global production and increasing production in the domestic country. The causes of reshoring are often summarized as the cost of offshoring, longer lead times, workforce demographics, technological development, and the aim to reduce risk and international interdependence (Downing, 2023). In this thesis, *the aim to reduce risk and international interdependence* will be studied using macroeconomic data on pharmaceutical manufacturing and electrical manufacturing in the United States (U.S.) from 1998 to 2020.

Starting in the late 20th century, manufacturing value chains have become increasingly globalized through the act of offshore outsourcing where parts of production are moved to a third party to benefit from cheap labor, economies of scale, and specialized capacities (Morai Logistics, 2021). Offshore outsourcing refers to the act of transferring parts of production to a more efficient external source. “Sourcing” refers to the act of obtaining materials for production. “Offshoring” refers to the allocation of production parts to a foreign production plant in the form of an internal branch. “Outsourcing”, on the other hand, refers to contracting parts of production to an external company (Pegoraro, De Propris & Chidlow, 2020). The combination of the concepts, “offshore outsourcing”, means sourcing production from an external company in another country, with intermediate goods produced abroad measured as imports. Reshoring, referring to moving production back to the country of the lead firm’s origin, can be the reversal of both offshoring and offshore outsourcing. (Pegoraro, De Propris & Chidlow, 2020).

A report based on survey responses from American manufacturing CEOs identified geopolitical risk exposure as the main incentive for manufacturing reshoring (Buss, 2023). Carney (2016), divides uncertainty into three major factors impacting economic performance: geopolitical uncertainty, which increased after events like the September 11 attacks and the Arab Spring; economic uncertainty which fluctuates with the global economy; and policy uncertainty, rising with ineffective institutions and policies. Ahir, Bloom, & Furceri (2020) examine global uncertainty during the last 60 years using the World Uncertainty Index which captures uncertainty related to economic and political events for 143 countries. In the study, it is noted that there are “few episodes where uncertainty has been at levels close to those observed in the last decade” (Ahir, Bloom, & Furceri, 2020, p.59).

Uncertainty is closely linked to risk, with a firm's risk exposure depending on its foreign market commitments and the political and economic stability of those commitments (Ciabuschi et al., 2019). A firm's perception of risk influences its sourcing decisions, such as internationalization or reshoring, because it depends on knowledge acquired about the firm's market and environment. Internationalization refers to a manufacturing firm's establishment in foreign markets (Ciabuschi et al., 2019). Restructuring of production networks can be seen as the result of changes in a firm's knowledge and environment, for example as caused by uncertainty (Ciabuschi et al., 2019). The U.S. is an interesting case as recent global events such as the COVID-19 pandemic, U.S. involvement in geopolitical conflicts, and the U.S.-China trade war have highlighted market vulnerabilities and supply chain disruptions in the U.S. (Phillips et al., 2022).

The U.S. is an ideal case for analyzing the relationship between manufacturing reshoring and uncertainty because of its size and impact as one of the world's largest economies, and since the U.S. has been prone to frequently undergo international trade policy changes (Baldwin, 1984). Policy uncertainty is important to the analysis because changes in economic policy, such as tariffs and import quotas, affect the profitability of offshore outsourcing. Geopolitical and economic uncertainty may influence an industry's internationalization decision based on the accumulation of knowledge and perceived risk, but the internationalization decision is also affected by domestic trade policies. Within the U.S. manufacturing sector risk exposure and vulnerability to uncertainty vary between industries. The Reshoring Initiative (2022) argues that essential industries are particularly sensitive to supply chain disruptions and that such production is too important to only rely on imports.

Pharmaceutical and electrical manufacturing are pertinent to this study because both industries are considered essential, research and development (R&D)-intensive, technologically sophisticated, and among the top four U.S. industries with the highest manufacturing wages. (Helper, Krueger, & Wial, 2012). Both sectors have faced significant attention and challenges, such as semiconductor shortages since 2020 and medical supply shortages during the COVID-19 pandemic, influencing market dynamics and risk perceptions (Mohammad, Elomri, & Kerbache, 2022; Socal, Sharfstein, & Greene, 2021). These similarities facilitate a comparative analysis of the two industries in the study of uncertainty as a cause of reshoring and allow for analysis of other factors that may influence reshoring intensity caused by uncertainty.

Offshore outsourcing can reduce the costs of production, but it also requires coordination and administration of production fragments (Pegoraro, De Propris & Chidlow, 2020). These heightened indirect costs associated with the lead firm's logistics and coordination have implications for manufacturing reshoring during periods of increased global uncertainty for two primary reasons. Firstly, the cost/benefit ratio of offshoring outsourcing will be affected by how complex the industry Global Value Chain (GVC) is and whether supply chain logistics are vulnerable to uncertainty. Secondly, the level of centrality of the global supply of goods within one industry will affect the costs of restructuring the supply chain to accommodate for risk associated with uncertainty. Therefore, the comparison of uncertainty-related reshoring between the U.S. pharmaceutical manufacturing and electrical manufacturing industries will also discuss GVC centrality and complexity.

1.1 Research Problem

Reshoring has during the last decade increased as a risk mitigation strategy in the discussion of supply chain management, especially following the COVID-19 pandemic, Russia's war in Ukraine, and the U.S.-China trade war (Pegoraro, De Propris & Chidlow, 2020). As mentioned in the introduction, pharmaceutical manufacturing and electrical manufacturing goods are too essential to rely simply on imports (Reshoring Initiative, 2022). The COVID-19 pandemic specifically uncovered gaps in the U.S. public health system, and in the manufacturing system of pharmaceutical products. The gaps presented themselves in the form of shortages of essential medications and distribution issues which denoted a lack of supply chain resilience (Socal, Sharfstein, & Greene (2021). Similarly, a lack of supply chain resilience was uncovered in the electrical manufacturing industry with the shortage of semiconductors. The global shortage of semiconductors was caused by a multitude of factors but can mainly be attributed to an increasing demand before the COVID-19 pandemic which worsened when manufacturers had to close their factories during the pandemic (Mohammad, Elomri, and Kerbache, 2022).

These two situations are different in many ways, and neither can be argued to perfectly be applied to the entire pharmaceutical manufacturing industry or electrical manufacturing industry. What makes the shortages relevant to this analysis is how shortages affect the perceived market of similar products. As mentioned in the introduction, Ciabuschi et al (2018) argue that a firm's internationalization strategy is based largely on knowledge and market perception. Although the shortages are only accounted for at the very end of the period analyzed in this thesis, basing the analysis on industries where the effects of risk and uncertainty have proven significant makes for an interesting analysis. These events brought the discourse of uncertainty closer to the public, but other shocks and events such as the 2008 financial crisis and the U.S.-China trade war indicate that volatility and uncertainty are not new concerns.

In the Global Value Chain Development Report facilitated by the World Trade Organization, Gao et al. (2023) note increasing awareness of mutual interdependence between countries trading globally. In the face of economic shocks or geopolitical risk, this interdependence puts pressure on countries engaging in international trade through GVCs. Phillips et al. (2022) examine these vulnerabilities concerning how GVC reconfiguration, such as through reshoring, can create more resilience and protect from future exogenous shocks. The conclusion is that global volatility and uncertainty are “calling for a more coordinated and responsive supply of goods and the relocation of production closer to the point of need” (Phillips et al., 2022, p.72). However, current GVCs and international linkages are differently constructed for different industries in terms of complexity and spatial distribution. This thesis composes an exploratory study of what factors impact reshoring decisions and examines how current linkages and value chains could impact an industry’s approach to uncertainty. The study is conducted by focusing on the cases of the pharmaceutical manufacturing and electrical manufacturing industries in the U.S. between 1997 and 2020.

1.2 Aim and Scope

The thesis aims to contribute to the literature on the effect of uncertainty on reshoring and reshoring as a possible supply chain risk mitigation strategy. With an increasingly volatile global environment, the discussion of supply chain risk management has increased in research. This thesis aims to contribute to the field by examining how industry characteristics and international trade linkages can act to promote or restrain reshoring and discuss whether these characteristics impact the functionality of risk reduction through reshoring. The thesis takes upon a quantitative approach to examine the relationship between reshoring and uncertainty and the statistical hypothesis Granger causality test (Granger, 1969) is used to examine whether changes in uncertainty are useful in predicting changes in reshoring. For the empirical analysis, the following research question is asked:

How efficient are measures of uncertainty in predicting future reshoring patterns within the U.S. pharmaceutical manufacturing and electrical manufacturing industries?

As previously mentioned, the mechanisms behind reshoring are many and cannot be limited to only uncertainty and risk. The method of Granger causality, however, allows for the examination of the isolated relationship between reshoring and uncertainty. The focus of the study is therefore limited to how uncertainty affects reshoring in the U.S. pharmaceutical manufacturing and electrical manufacturing sectors, without considering quantitative measures of the other factors affecting reshoring. This increases the external validity of the study, but it is still important to note that factors such as uncertainty, labor costs, lead times, and economic policy may exhibit mutual causation, implying that complete isolation of factors is impossible. Furthermore, to capture the entirety of pharmaceutical and electrical manufacturing value chains, the thesis examines U.S. trade flows with the rest of the world (ROW) rather than specific countries. The discussion of empirical results and theory is centered around countries that are prominent within the international linkages of pharmaceutical and electrical manufacturing, but it is important to note that the data represents flows between the U.S. and the ROW.

1.3 Outline of The Thesis

The thesis is structured as follows: Firstly, the theoretical structure and background is provided in the section *Theory* which presents classic international trade theory as a framework for the discussion of reshoring-decisions under uncertainty and how centrality and complexity of global networks affect internationalization. The theoretical background is also discussed in relation to pharmaceutical manufacturing and electrical manufacturing to form a hypothesis for how, or if, reshoring in each industry follows uncertainty. Next, the section *Data* provides a brief introduction of the data used in the quantitative study and a more thorough explanation for how variables for uncertainty and reshoring are constructed as well as data limitations. The section *Methodology* explains Granger causality, its implications, and limitations, and how the analysis was conducted with the results presented in the next section, *Results.* In the section *Discussion*, the results are discussed and related to the theoretical findings. The last section provides concluding remarks as well as suggestions for further research and discussion of the limitations of the thesis.

2. Theory

The drivers of reshoring have generally been divided into push and pull factors. Hidden long-term costs of offshoring are one of the main push factors, where seemingly hidden frictions caused by price and lead time fluctuations, macro-political risk, and country-risk factors increase the cost of offshoring. On the other hand, the reduction of friction through flexibility and the shortening of lead times through a more agile production process has been labeled as the main pull factors of reshoring (Pegoraro, De Propris & Chidlow, 2020).

Arriola et al. (2020) discuss the efficiency and risk of offshoring through production process fragmentation and argue that the benefit of GVCs is finer specialization and greater economies of scale, which results in productivity gains. However, this dependency also induces risk exposure, especially for firms operating in complex and interdependent production networks, since a shock to any part of the production process can negatively affect the entire system Arriola et al. (2020). To understand the process of manufacturing reshoring, classic international trade theory and the costs and benefits of outsourcing production abroad must be considered. This section provides a theoretical framework of international trade theory relating to business sourcing decisions and a discussion of pharmaceutical and electrical manufacturing concerning previous research on reshoring and uncertainty.

2.1 Theoretical perspective and previous research

In the early 1800s, British economist David Ricardo established the foundation of international trade with the theory of comparative advantage according to which countries will fully specialize in the production of the goods in which they have a comparative advantage (Feenstra & Taylor, 2017). The business strategy of offshoring the lowest value-added stages of production to a foreign country is in theory exemplified by how the foreign country, due to lower production costs, has a comparative advantage in the production of the lowest value-added stages of production (Feenstra & Taylor, 2017).

During the late twentieth century these theoretical findings, of trade flows following the theory of comparative advantage, seemed to correspond with empirical findings as U.S. manufacturers outsourced their supply chains to countries where production was cheaper (Wang et al., 2023). The trend of offshoring outsourcing to cheaper production locations was feasible through the rapid development of communication, information, and transformation technology which allowed for the segmentation of production processes into multiple geographically distant segments according to Inomata (2017). This development of GVCs needs to be understood to examine the causes of reshoring and why industry characteristics affect reshoring intensity (Pegoraro, De Propris & Chidlow, 2020).

During the first decade of the 21st century, patterns of increasing internationalization and outsourcing offshoring were observed across the world in upstream production based on a measure of an economy's use of foreign-sourced intermediate goods (Mariasingham, Lumba, & Jabagat, 2023). However, the disruptions caused by the 2008 financial crisis reached supply chains through the effect of decreased demand for final goods multiplying through all production parts, resulting in disruptions in the supply chains of intermediate goods and components (Mariasingham, Lumba, & Jabagat, 2023). After the 2008 financial crisis, the patterns of globalization through outsourcing offshoring seemed to return, but in 2018, the U.S.-China trade war again affected American manufacturing supply chains (Mariasingham, Lumba, & Jabagat, 2023).

Kapustina et al. (2020) argue that the U.S.-China trade war was partly caused by geopolitical tension and U.S. incentives to reduce trade deficits between the two countries and to limit Chinese access to American resources. The trade war was carried out through trade protectionism, which refers to economic policy that restricts imports through for example tariffs and import quotas, often to encourage domestic production (World Bank, 2023). As seen during the U.S.-China trade war, the ideal production location may also be affected by uncertainty and geopolitical tensions in addition to the costs and benefits of offshore outsourcing (Cigna, Gunella & Quaglietti, 2022). In times of uncertainty, the perceived costs of offshoring may increase due to the risk of trade disruptions affecting the domestic economy and the cost/benefit ratio of reshoring production (Gao, 2024).

The U.S.-China trade war exemplifies how trade uncertainty in the form of geopolitical tension can incentivize protectionism and reshoring, but industry characteristics also affect the costs of sourcing internationally versus domestically. When modeling GVCs for economic analysis, two of the main areas of focus have generally been the "mechanism of the fragmentation of production processes" and the "Firm's choice of an organizational form of global value chains" (Inomata, 2017, pp. 20).

Reorganizing global value chains is a process that may be lengthy and according to Gao (2024), factors affecting reshoring duration can for example be unwillingness to breach contracts with current suppliers, conduction of cost/benefit analysis, the amount of time to complete reallocation of production. These factors are not explicitly measured in duration, but the average time required to reshore production is by Gao (2024) explained as between months and a few years. Bofelli et al. (2020) divide the process of reshoring into two phases: *decision-making* and *implementation.* Through a case study of four companies operating in different countries, Bofelli et al (2020) conclude that the average time for both decision-making and implementation of reshoring varied. Most notably, a high degree of complexity of the process was found to indicate a flexible approach to reshoring, with increased overlapping of the phases and an on average shorter reshoring process.

Jones & Kierzowski (1990) model outsourcing and production fragmentation based on market size and costs of production. Jones & Kierzowski (1990) conclude that international outsourcing generally has larger differences in production factor costs compared to domestic outsourcing, so offshore outsourcing following the theory of comparative advantage will improve productivity more than domestic outsourcing. Moreover, the model indicates higher costs of connecting production units through international logistics than through domestic logistics due to direct import and customs costs, coordination costs, and indirect costs of communication and differences in legal and cultural systems (Jones & Kierzowski, 1990). Through these implications, Jones & Kierzowski (1990) predict increased international fragmentation of the production process when the market is large, connection complexity and costs are low, and the countries involved in the production network are diverse in their factor endowments, making exploitation of comparative advantage more feasible.

The implication that international offshore outsourcing is incentivized through low connection complexity costs can also be seen in Henry Ford's business model of vertical integration (Barreyre, 1988). Ford's model expands the degree of supply chain complexity to the complexity of negotiations and bureaucratic regulations. Vertical integration explains pure offshoring, meaning that a part of the production process is geographically reallocated but included under the same management (Bresnahan & Levin, 2012). Although reshoring, as measured by domestic versus foreign input/output data, is not limited to pure offshoring and Ford's model is more microeconomic than macroeconomic, the implications of the vertical integration concept can be applied to the discussion of industry-level reshoring incentives.

The differentiation between a firm's governance schemes may be attributed to differences in how administrative, contractual, and regulatory hazards affect the cost and time efficiency of a possible segmentation of production (Inmata, 2017). According to Joskow (2003), a firm or industry will benefit from vertical integration of production segments when integration simplifies transaction costs through dual incentivizing but gives the firm or industry a disadvantage if segmentation of production processes increases costs of bureaucratic organization and negotiation. In addition to vertical integration being profitable in terms of costs of production, the implied diversification of suppliers may also mitigate risk. Disruption of production due to choke points, a point in the process able to disturb the entire supply chain, can in some cases be mitigated by maintaining a diverse set of suppliers (Reiter & Stehrer, 2021; Alimahomed-Wilson & Ness, 2018).

Although supplier diversification may mitigate supply-side risk and uncertainty, administrative hazards can impede diversification in highly complex industries (Reiter and Stehrer, 2021; Joskow, 2003). The U.S.-China trade war exemplifies how centralized dependence primarily contributed to trade protectionism rather than supplier diversification. Conversely, Ho et al. (2015) and Mariasingham, Lumba, & Jabagat (2023) argue that Russia's war in Ukraine shows the importance of supplier diversification in supply chain risk management. The following section presents a theoretical framework for the implications of uncertainty for pharmaceutical and electrical manufacturing.

2.2 Theoretical Implications for Pharmaceutical Manufacturing and Electrical Manufacturing

This section discusses previous research on the causes of reshoring and reshoring as a risk mitigation strategy relating to pharmaceutical manufacturing and electrical manufacturing. As abovementioned, Joskow (2003) notes that an industry where supply chain governance is highly complex may be negatively affected by global integration. Lacking supply chain responsiveness denoted to cultural differences, bureaucratic and administrative complexity, and cooperation between interdependent countries may be worsened during times of uncertainty (Moradlou et al., 2017; Barreyre, 1988).

When examining reshoring caused by uncertainty within pharmaceutical and electrical manufacturing networks, this analysis will be based on the following two points: **1. The diversification of total production of global supply within the industry as well as U.S.**

influence in the market (centrality). **2. Supply chain complexity regarding logistical barriers, regulatory constraints, and bureaucratic processes** (complexity).

2.2.1 Centrality

The first point, **the diversification of total production of global supply within the industry as well as U.S. influence in the market,** is discussed by Criscuolo & Timmis (2018), Borja, Reis & Pinto (2022), and Crowe & Rawadanowiz (2023). The comparison of pharmaceutical and electrical manufacturing indicates that even though there are connections between the U.S. and China for both industries, there are differences in industry centrality.

Central industries are sectors where global production networks are highly influential and both directly and indirectly connected to a large degree, while peripheral sectors are less influential and connected (Crisciolo & Timmis, 2018). Production of both pharmaceutical and electrical exports is highly concentrated within a few producing economies, and electrical manufacturing is among the industries with the highest share of the top five countries in global output (Crowe & Rawadanowiz, 2023).

Based on OECD calculations on Inter-country Input-Output data from the Input-Output database (ICIO), almost 40 percent of world exports of intermediate goods for electrical equipment come from China and the main part of world exports of intermediate pharmaceutical, medicinal chemical, and botanical products come from Ireland, Germany, and Switzerland (Crowe & Rawadanowiz, 2023). Heritage (2023) notes that 24.0 % of the value of imported pharmaceutical products to the U.S. has its origin in Ireland, but that 23.0 % of the total quantity of imported pharmaceutical products to the U.S. originates from China. Furthermore, exports at the product level within both industries are even higher, both for pharmaceuticals and electrical products. According to Koch & Schwarzbauer (2021), during the years 2000-2014, China was specialized in terms of value-added exports in the manufacturing of electrical equipment, and more specialized in general manufacturing compared to the U.S. which instead was largely specialized in service industries.

Reflecting on electrical manufacturing, Koch & Schwarzbauer (2021) also note that those branches of manufacturing where the U.S. has not invested in its domestic development are the branches where China has become most specialized. However, even though electrical manufacturing is highly centralized in China, Crisciolo & Timmis (2018) find that centrality measures of the electrical manufacturing industry went through severe changes between the period of 1995-2011. Since centrality is a relative measure, the shift towards China as the most central producer of electrical manufacturing does not necessarily mean that the concentration of production hubs has simply shifted to China. The measures of Crisiuolo & Timmis (2018) instead indicate increased diversification in electrical manufacturing GVCs. "In computing and electronics manufacturing, several of the same central hubs remain in 1995 and 2011, but the most central hubs are generally less influential in 2011, with influence in GVCs more evenly distributed across countries in 2011" (Crisciolo & Timmis, 2018, pp.27).

Once again considering centrality a relative measure, Borja, Reis & Pinto (2022) examine developments in the pharmaceutical manufacturing sector and their findings indicate a much higher degree of internalization within the pharmaceutical manufacturing industry compared to electrical manufacturing during the same period. Internalization refers to the act of bringing business operations into the control of the company, rather than relying on external relationships (Van Assche & Narula, 2022). The pharmaceutical industry is highly concentrated around a small number of highly influential hubs, where the U.S. is the core region in America. Borja Reis & Pinto (2022) connect the high degree of internalization within the pharmaceutical manufacturing sector to intellectual property rights protection and the high degree of regulations of manufactured drugs.

Similarly, Graham (2023) points to a significant increase in two-way trade of pharmaceutical goods between the U.S. and China over the last five years. The import of active pharmaceutical ingredients (API) from China to the U.S. has in absolute terms grown 24 percent since 2020. API products are the most important components in the production of pharmaceutical products as many medications cannot function without API components (Graham, 2023). Although the US pharmaceutical manufacturing supply chain is not completely dependent on importing API products from China, the increasing volume of trade with such goods is important to study since "disruptions to the delivery of APIs could seriously impede production of finished pharmaceutical goods" (Graham, 2023, para 8). Reshoring Initiatives (2023) also note that out of the U.S.'s biggest trading partners of pharmaceutical goods, supply chains connected to China imply the highest risk of a major disruption occurring within one year.

A relatively lower degree of centrality within the electrical manufacturing sector could indicate that uncertainty does not have as large of an effect on the industry compared to pharmaceutical manufacturing. The centralization of pharmaceutical manufacturing production and the high degree of complementary production dependence between the U.S. and China could on the other hand serve as an incentive for reshoring within the pharmaceutical manufacturing industry (Reiter & Stehrer, 2021). These observations of current production networks provide insight into each industry's sensitivity to risk and uncertainty, but industry complexity also needs to be considered.

2.2.2 Complexity

The second point; s**upply chain complexity regarding logistical barriers, regulatory constraints, and bureaucratic processes,** helps differentiate internationalization possibilities for pharmaceutical manufacturing and electrical manufacturing.

The pharmaceutical supply chain differs from many other supply chains in the number of regulatory constraints present in the production process (Shah, 2004).

Primary pharmaceutical manufacturing contains the production of APIs which ensures the functionality of the medication (Graham, 2023). Due to the importance of API functionality, multiple controls are necessary, and the production process is complicated and unresponsive to sudden changes in demand (Shah, 2004). The complexity of the pharmaceutical manufacturing process is confirmed as: “The liability of sharing expert knowledge required to run a commercial-scale proprietary chemical process combined with the quality risk and high level of regulatory scrutiny could deter a drug company from capturing the conventional benefits of outsourcing, such as a lower cost of goods and quicker product launch” (Bazerghi, 2015, pp.15). The model by Jones and Kierzowski (1990) indicates that high costs of production coordination and complexity decrease the profitability of international outsourcing.

Henry Ford’s business model of vertical integration explained by Barreyre (1988) corresponds with the theory of Jones and Kierzowski (1990) and further emphasizes that bureaucratic complexity also increases the incentive of a firm to reshore production. The high standards required for drugs to pass inspections increase coordination costs and complexity can be further heightened if there are bureaucratic obstacles to efficient organization of controls. Moradlou et al. (2017) argue that responsiveness is one of the key drivers of reshoring, and the extensive regulatory processes in pharmaceutical manufacturing act as a barrier to agility and responsiveness of the supply chain. Responsiveness is by Pegoraro, De Propris & Chidlow (2020, pp.169) defined as "long production lead times and logistics and transportation features such as electricity storage, excessive paperwork and cultural differences in working attitudes". Moradlou et al. (2017) further denote these barriers to not only geographical distance but also emphasize cultural distance in reducing responsiveness through increased complexity, increasing the profitability of reshoring pharmaceutical manufacturing in the U.S.

When examining the complexity and regulatory constraints of electrical manufacturing, there are some differences from pharmaceutical manufacturing. The production process of electrical manufacturing varies depending on the purpose of the goods produced. For example, the production of electrical components for the aerospace sector is highly controlled and held to high standards through both manual and automatically streamlined controls (Tiwari et al. 2021). However, Meng & Ye (2021) note that even though product controls are necessary for electrical equipment, strong intra-industrial linkages, especially between the U.S. and China and the U.S. and other Asian countries add value for firms engaging in the value chain of the upstream part of production. The efficient production processes already established in a relatively diverse production network could thereby support a claim for less complex coordination of international offshore outsourcing within the electrical manufacturing industry.

Based on the theories of Jones & Kierzowski (1990) and Moradlou et al. (2017), a high degree of complexity within the pharmaceutical manufacturing sector is hypothesized to incentivize reshoring. Conversely, such complexity barriers to efficient coordination appear less present in the global production network of electrical manufacturing, creating the hypothesis that the incentives to reshore production is weaker within that industry. A relatively higher degree of centrality and interdependence within the U.S. pharmaceutical manufacturing sector compared to the electrical manufacturing sector also contributes to the hypothesis that reshoring caused by uncertainty should be more prominent in the pharmaceutical manufacturing industry. This hypothesis will be tested using Granger causality tests with lagged values to examine whether a causal relationship exists between uncertainty and reshoring.

3. Data

3.1 Source material

The data used to construct the variables are publicly available secondary data. The time series data, covering the years 1997-2020, was collected from two publicly available sources. The data used to construct an uncertainty index was gathered from the World Uncertainty Index created by Ahir, Bloom, & Furceri (2022) and the Economic Policy Uncertainty Index created by Baker, Bloom, & Davis (2016). The data used to construct a measure for reshoring intensity was gathered from the OECD inter-country input-output (ICIO) database (OECD, 2023). The data extracted from the OECD (2023) inter-country input-output tables is measured in current U.S. dollars (USD) and the measurement represents intermediate use at basic prices. The data I collected from the OECD ICIO database (2023) is data on manufacturing, as indicated by the prefix C, industry codes C27: Electrical equipment and C21: Pharmaceuticals, medicinal chemical and botanical products. Industry code C27 includes "the manufacture of products that generate, distribute, and use electrical power" (Eurostat, 2008, pp. 171). In industry code C21, the notation of medicinal chemicals and botanical products refers to chemical preparations for pharmaceutical use and biotech pharmaceutical and preparation of botanical products for pharmaceutical use (Eurostat, 2008).

The usage of the data for further research is encouraged by the creators (Ahir, Bloom, & Furceri, 2022: Baker, Bloom, & Davis, 2016; OECD, 2023). The only obligation was that an explanatory file regarding the OECD ICIO tables needed to be thoroughly consulted before using the data which I complied with. Further ethical considerations have been ensured compliance by following the Lund University School of Economics and Management guidelines, and the type of data used in the thesis does not require ethical control and permission.

3.2 Uncertainty Index

The uncertainty index used in the analysis is an index I created combining three published indexes all measuring different aspects of global uncertainty. The choice of creating a combined index was based on reducing the complexity of the analysis due to the risk of multicollinearity and variance inflation between the three similar indexes if they were to be used separately in the analysis. When combined, the three indexes: the World Trade Uncertainty Index (WTUI) Ahir, Bloom & Furceri, 2022), the Economic Policy Uncertainty Index (EPUI) (Baker, Bloom, & Davis, 2016), and the World Uncertainty Index (WUI) (Ahir, Bloom &

Furceri, 2022), provide a comprehensive index for uncertainty concerning reshoring. Ciabuschi et al. (2018) argue that the perceived environment, which can be captured by the WUI, is central to business risk mitigation strategies such as reshoring. Furthermore, according to Baker, Bloom & Davis (2016), measurements of EPU have spiked around times when the U.S. economy has been subjected to exogenous shocks. Since the U.S. is a large economy with significant market power, the EPU provides further insight into how U.S. economic policy affects reshoring, especially concerning industries highly centralized in the U.S. (Baldwin, 1984). Trade-related uncertainty causing trade protectionism through tariffs, captured by the WTUI, may significantly impact the costs and benefits of sourcing abroad, thereby affecting U.S. reshoring (Cigna, Gunella & Quaglietti, 2022).

The Economic Policy Uncertainty Index (EPU), created by Baker, Bloom, and Davis (2016), is a three-component monthly index based on the three following components: The first component is newspaper coverage, where Baker, Bloom & Davis (2016) quantified the number of articles from ten large American newspapers containing words related to uncertainty, economy, and policy. Secondly, temporary federal tax code provisions as reported by the Congressional Budget Office (CBO) are quantified to complement the first component. Thirdly, forecasts and predictions of future macroeconomic values are quantified to complement the two first components, resulting in a well-rounded coverage of fluctuations of economic policy uncertainty (Baker, Bloom & Davis, 2016).

The second uncertainty index is the World Trade Uncertainty Index (WTUI) created by Ahir, Bloom & Furceri (2022). The WTUI measures uncertainty related to trade every quarter using the Economist Intelligence Unit's (EIU) country reports. The third index, the World Uncertainty Index (WUI), was also created by Ahir, Bloom & Furceri (2022) and measures economic uncertainty at a quarterly interval based on frequency counts of the word uncertainty and variants in Economist Intelligence Unit (EIU) country reports. The authors of all three indexes provided both global and country-specific measures, but in this thesis, the WUI and WTUI are global GDP-weighed averages which means that bigger economies have a bigger impact on the indexes. The U.S., as a large open economy, can thereby be expected to be generally well represented in the construction of WUI and WTUI, as well as capturing global dynamics of uncertainty. The EPUI is on the other hand specific to the U.S. because domestic changes in economic policy can be aimed at promoting or discouraging reshoring (Bornert & Musolino, 2024). As this thesis aims to examine reshoring domestic to the U.S., country-specific policy uncertainty is an insightful complement to the global measures of WUI and WTUI.

The uncertainty index used in the analysis is then created through a weighted average analysis of the data. Firstly, the quarterly and monthly measures are averaged to a yearly measure for each of the three uncertainty indexes. Then, the mean for each of the three indexes during the period 1997-2018 is calculated and then subtracted from each of the yearly measures, leaving a yearly indication of deviation from the mean value. The yearly deviation values are then divided by the mean value for the period 1998-2018 which creates a fluctuation of the yearly measures around the mean value given in percentages. A positive number for a year indicates that the uncertainty is higher than the period average. The changes in the uncertainty index between 1999-2018 are visualized in Figure 3.1. When plotting the temporal dynamics of the uncertainty index, there were outliers in the data which corrupted the presentation of data in the graphs. The period visualized in the graphs was therefore altered from the period examined in the analysis and Figure 3.1, Figure 3.2, and Figure 3.3, include the years 1999-2018.

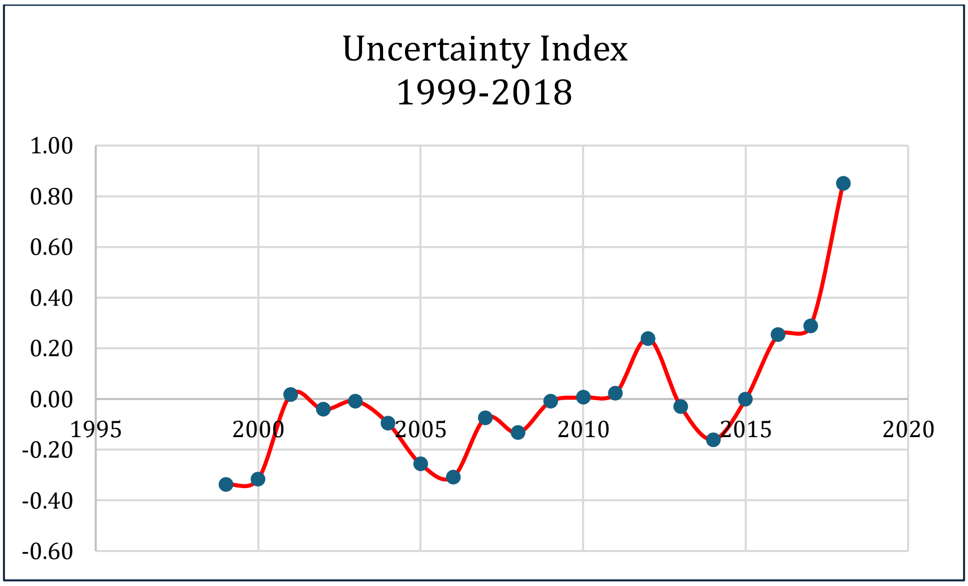

Figure 3.1 - Uncertainty index 1999-2018 (Author's own- see section 3.1 for data source)

To combine the three indexes, each index was assigned a weight based on its importance relevant to reshoring. This was constructed as follows: Economic Policy Uncertainty: 0.3, World Trade Uncertainty: 0.4, and World Uncertainty: 0.3. World Trade Uncertainty was assigned a slightly larger weight since the trade uncertainty captures trade the volatility of global trade agreements which can impact tariffs and costs of trade on a global level (European parliament, 2021). The intensity of trade uncertainty is, as mentioned in section 1, important to the cost/ benefit ratio of reshoring production. According to the Ricardian model, increasing costs of imports can affect how the cost-benefit ratio of offshoring production affects the reshoring intensity (Lacara, 2022). Lastly, the indexes are multiplied by their assigned weight and summed to create a weighted average of the three indexes which is used as the indication of uncertainty in this analysis.

3.3 Reshoring Intensity Index

The Reshoring Intensity Index is created using data on the U.S. from the OECD (2023) ICIO tables, following the method proposed by Krenz & Strulik (2021). Krenz & Strulik (2021) define reshoring as a process where the production of a country uses a greater share of domestic inputs relative to foreign inputs, specifically noting that reshoring can be measured as a change in domestic-foreign input ratio in one year compared to the year before. This ratio is created by extracting data on domestic input (DI) and foreign inputs (FI) from input-output tables where reshoring is defined as DI/FI**.** The fluctuations of reshoring intensity on a yearly basis are measured through equation 1. A positive measure of this indicates that the intensity of reshoring has increased compared to the previous year (Krenz & Strulik, 2021).

$$\frac{DI}{FI}_{t} - \frac{DI}{FI}_{t-1}. \qquad \textbf{(Equation 1)}$$

Canals & Şener (2014) created an offshoring index based on the widely recognized method introduced by Feenstra and Hanson (1996, 1999) where offshoring is calculated using total imports, dollar value of inputs, and total domestic consumption in the industry of interest. Intuitively, reshoring should be the opposite of offshoring, but as explained by Krenz & Strulik (2021), the measure created by Canals & Şener (2014) following Feenstra & Hanson (1996, 1999) could potentially be misleading in estimating reshoring.

The differences between the classic measure of offshoring (Canals & Sener, 2014; Feenstra & Hanson, 1996,1999) and Krens & Strulik's (2021) measure of reshoring is that the classic measure of offshoring is measured as a "stock" of the share of intermediate goods that are produced abroad. Krens & Strulik's (2021) reshoring measure instead measures reshoring as dynamic changes in production location from year to year. In my analysis, creating a flow variable for reshoring as suggested by Krenz & Strulik (2021) allows for the comparison between reshoring practices and world uncertainty by also examining uncertainty as a variation around the mean uncertainty value of the period. The fluctuations of reshoring intensity for both electrical manufacturing (Figure 3.2) and pharmaceutical manufacturing (Figure 3.3) were also plotted in line graphs for visualization as described in section *2.3 Uncertainty Index.*

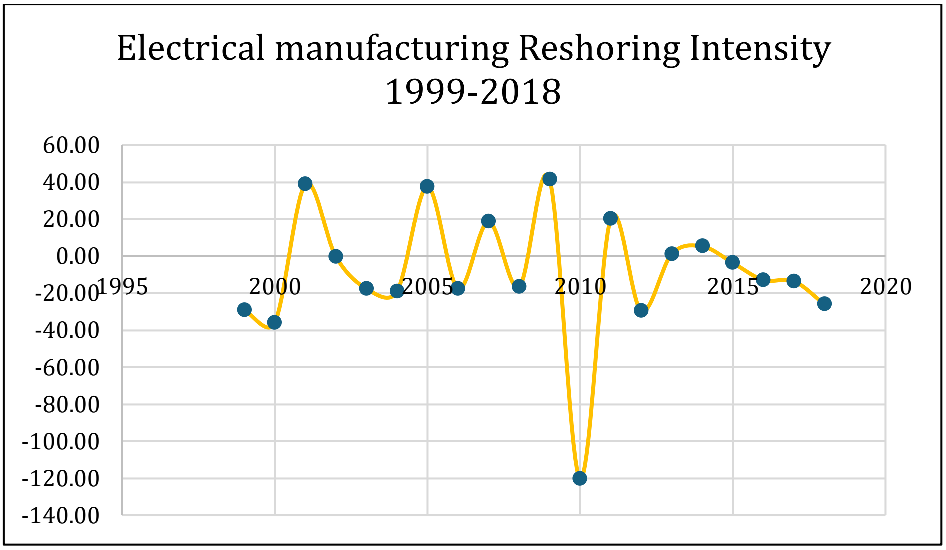

Figure 3.2 - Electrical manufacturing Reshoring Intensity 1999-2018 (Author's own- see section 3.1 for data source)

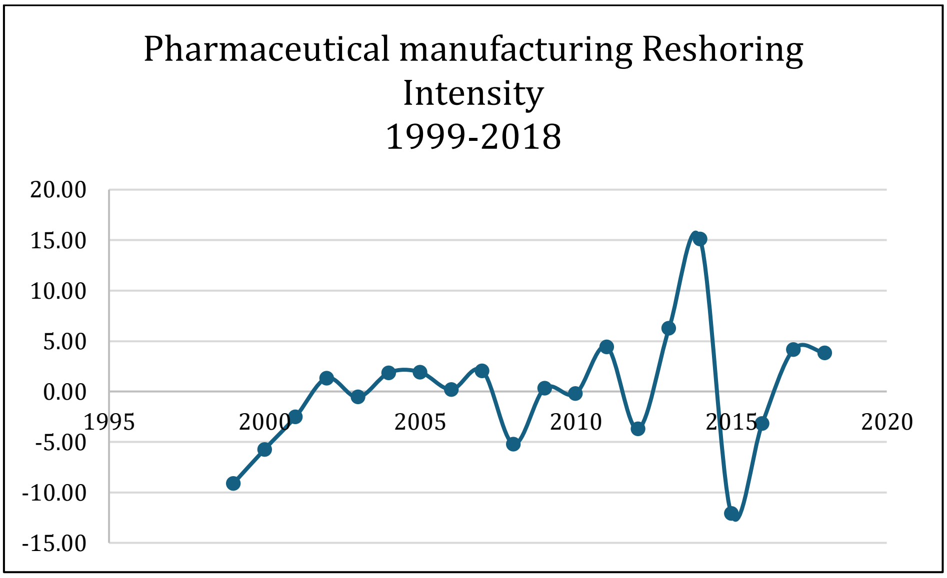

Figure 3.3 - Pharmaceutical manufacturing Reshoring Intensity 1999-2018 (author's own- see section 3.1 for data source)

The reshoring variable was constructed through the formula created by Krenz & Strulik (2021) where DI is domestic inputs and FI is foreign inputs, using data extracted from the OECD ICIO tables for the years 1997-2020 (OECD, 2023). Domestic input (DI) is the value of *intermediate use at basic prices* from the specific industry in the US to that same specific industry in the US, measured in 2023 U.S. dollars. Foreign input (FI) is *intermediate use at basic prices* from the specific industry in the rest of the world (ROW) to that same specific industry in the US, measured in 2023 U.S. dollars.

Equation 1 provides a measurement of reshoring intensity where a positive value indicates that the intensity of reshoring during that year is higher than the year before, and a negative value indicates that the reshoring intensity is lower than the year before. In the analysis, the approach of measuring difference from the year before means that the first year used in the analysis is 1998. This reshoring measure does not indicate the decisions of individual firms of geographic locations within a country, but instead provides an industry-specific indication of reshoring practices at a macroeconomic level. If the purpose was to only examine the trend of reshoring, the only values interesting for the analysis would be the positive values, but in this analysis, the negative reshoring intensity values are interesting as well. This is because the uncertainty value is fluctuating around the mean value, resulting in both positive and negative values (uncertainty that year relative to the mean value of the period).

3.4 Data Limitations

Using secondary data in the thesis has required some caution due to limitations such as a lack of control and knowledge about how the data was collected and handled. Because of this, the thesis could have benefitted from triangulation of the data, but multiple sources providing ICIO data for the specific industry classifications and the specific years examined in this thesis were scarce which made data triangulation difficult within the time frame of the thesis project. The data used for the creation of my uncertainty index is also quite isolated, but the combination of uncertainty measures from two different sources somewhat improves the data validity.

Furthermore, the data harmonization required to construct a weighted average of the three different components of my uncertainty index is also a limitation as harmonization poses a risk of data discrepancies. Additionally, the sample size is a limitation of the data. Partly because 22 observations only allow for the inclusion of a limited number of lagged values in the analysis, and because many events that caused significant fluctuations of uncertainty only occur at the very end, or even after, the period included in the sample.

4. Methodology

4.1 Granger Causality

This thesis uses a quantitative approach to examine if there are causal relationships between global uncertainty and reshoring using the Granger causality test. Granger causality is a method aimed at determining whether lagged values of one variable are useful in determining future variables of another variable, meaning that forecast accuracy is tested (Tekin, 2011).

Granger (1969, pp. 428) defined the relationship of Granger causality as "We say that Yt is causing Xt if we are better able to predict Xt using all available information than if the information apart from Yt had been used". The period included in the test of forecasting accuracy is accounted for through lagged values of the data. This is done through adding lagged values of one variable, to the regression of the lagged values of the other variable, where Y and X represent the variables and the index t is the period. It is however important to note that the usage of Granger causality implies an assumption that there are no omitted variables and that the number of lagged variables chosen is suitable for the analysis. Furthermore, limitations such as the definitive temporal direction of causality are not guaranteed in the results of Granger causality. Although unlikely, there is a risk that temporal dynamics are reversed in the results of the Granger causality test.

The three variables explained in the data section are used and labeled as follows: PMRI= pharmaceutical manufacturing reshoring index in the U.S. 1998-2020, EMRI = electrical manufacturing reshoring index in the U.S. 1998-2020, Uncertainty = weighted average of three uncertainty indexes, measured as fluctuating around the period average. Granger causality analysis relies on lagged values to assess how accurately one variable can be used to forecast another (Granger, 1969). This mode of analysis is also suitable for this analysis since the reshoring variable represents actual reshoring on a macroeconomic level rather than the decisions of individual firms to re-shore production. The number of lags for the variables are in the tables indicated by the number, n, before the variable name.

Rather than determining Lag-lengths through theorized lag-length selection criteria such as those presented by Akaike (1969) or Schwarz (1978), the lag lengths were determined based on the approximate time of a reshoring implementation process as discussed in section *2, Theory* (Gao, 2024; Bofelli et al, 2020). I have included two lags in the analysis: one year and two years (L1, L2). Since the data was measured yearly and Granger causality relies on lagged values, monthly lags that may have improved the analysis, could not be included. This limitation is further discussed in section 5.2.1. *Analysis of the data.* The analysis could perhaps benefit from including more years as lags, but due to the relatively low number of observations (22), including more lags might decrease the reliability of results as the number of observations decreases when including lagged values.

4.2 Method

To generate time series with lagged values of the variables, a differential from the lagged value was constructed as in equation 2 and applied to all three variables. The lagged variables were created through differentiation because differentiated time series can improve forecasting performance as it better captures changes in the variables and allows for analysis of time series containing trends. In equation 2, X represents the variable for which a lagged value will be created, n represents the number of lagged values (measured in years), the index t represents the period and L generates the lagged value in Stata.

$$nX = X_t - Ln.X_t \quad \textbf{(Equation 2)}$$

After creating the lagged variables, unit root tests were conducted to determine if the time series data are stationary as Granger causality analysis requires data stationarity to conduct the econometric analysis (Vasile et al. 2020). If the time series are non-stationary, the time series requires transformative measures to generate temporally differenced data from the original time series. All three of the variables with a one-year lag were first tested for non-stationarity values using the augmented Dickey-Fuller test with zero drift lags and zero trend lags, as well as the Phillips-Perron test, including the *trend* option to account for possible linear trend of increasing values in the uncertainty variable. Both in the augmented Dickey-Fuller test and the Phillips-Perron test, the null hypothesis is that the variable contains a unit root and the alternative to the null hypothesis is thereby that the variable was generated through a stationary process. The conventional critical p-value of 0.05 is used to determine whether the data series are stationary. A significance level of 0.05 indicates that the risk of getting a false-positive result, meaning that the null hypothesis is wrongfully rejected, is 5 % which I deem acceptable (Banarjee et al., 2009). To perform the tests of the data, the statistical platform Stata 17.0 was used.

Table 4.1- Unit Root Test Results - 1-year lag

Variable	Augmented Dickey-Fuller: MacKinnon approximate p-value for Z(t), Trend lags(0)
1 Uncertainty	0.0000.
1 PMRI	0.0000.
1 EMRI	0.0000.
	Augmented Dickey-Fuller: MacKinnon approximate p-value for Z(t), drift lags(0)
1 Uncertainty	0.0000.
1 PMRI	0.0000.
1 EMRI	0.0000.
	Phillips-Perron: MacKinnon approximate p-value for Z(t), trend
1 Uncertainty	0.0000.
1 PMRI	0.0000.
1 EMRI	0.0000.

Table 4.1 shows the results from conducting unit root tests for the three variables, where none of the variables showed a MacKinnon approximate p-value for Z(t) above the critical value of 0.05, concluding the absence of unit root and significance of the p-values, indicating that the null hypothesis can be rejected, and the data is stationary. The two-year lagged variables were then tested for stationarity through the same process as above and with 0.05 as the critical MacKinnon approximate p-value for Z(t).

Table 4.2 - Unit Root Test Results - 2-year lag

Variable	Augmented Dickey-Fuller: MacKinnon approximate p-value for Z(t), Trend lags(0)
2 Uncertainty	0.0011.
2 PMRI	0.0000.
2 EMRI	0.0001.
	Augmented Dickey-Fuller: MacKinnon approximate p-value for Z(t), drift lags(0)
2 Uncertainty	0.0061.
2 PMRI	0.0000.
2 PMRI	0.0001.
	Phillips-Perron: MacKinnon approximate p-value for Z(t), trend
2 Uncertainty	0.0062.
2 PMRI	0.0000.
2 PMRI	0.0002.

Table 4.2 shows that the two-year lagged values of each variable do not exceed the critical MacKinnon approximate p-value for Z(t) of 0.05 which indicates data stationarity. After deeming all variables suitable for Granger causality analysis, I conducted Vector auto-regression (VAR) to prepare the variables of interest for Granger causality tests. VAR was to fit a time-series regression of each dependent variable on itself and the other variable for the two variable relationships of interest.

The two reshoring variables (PMRI & EMRI) were considered dependent variables and Uncertainty was the independent variable. The Granger causality analysis was then performed in Stata 17.0 with the resulting values of the VAR from the following combinations of variables:

Table 4.3 - VAR Estimates

Lag, L (years)	**Dependent variable**	**Independent variable**
0	PMRI	Uncertainty
0	EMRI	Uncertainty
1	1 PMRI	1 Uncertainty
1	1 EMRI	1 Uncertainty
2	2 PMRI	2 Uncertainty
2	2 EMRI	2 Uncertainty

5. Empirical analysis

5.1 Results

Table 5.1 - Results Granger Causality Test - Pharmaceutical Manufacturing Index and Uncertainty

Null Hypothesis	**Lags**	**Obs**	**Prob**	**Result/ decision**
Lagged values of PMRI do not Granger-cause current values of Uncertainty	1	21	0.078	Do not reject
Lagged values of Uncertainty do not Granger-cause current values of PMRI	1	21	0.009	Reject
Lagged values of PMRI do not Granger-cause current values of Uncertainty	2	20	0.188	Do not Reject
Lagged values of Uncertainty do not Granger-cause current values of PMRI	2	20	0.182	Do not reject

According to Table 5.1, the comparison of PMRI and uncertainty indicates differences in the relationship between pharmaceutical manufacturing reshoring intensity and uncertainty depending on the chosen lag time. With the lag of 1 year, there is no statistically significant evidence for the hypothesis that reshoring is affected by uncertainty (0.078 > 0.05), so the null hypothesis cannot be rejected and there is no evidence that PMRI granger-cause Uncertainty.

However, the null hypothesis that *Lagged values of uncertainty do not Granger-cause current values of PMRI* (0.009 < 0.05) is statistically significant, indicating that with a 1-year lag, Uncertainty Granger-cause PMRI. With the 1-year lag period, there is unidirectional Granger causality where only Uncertainty Granger causes PMRI while the opposite is not true.

When the lag is instead set to 2 years, the P-values for both null hypotheses cannot be rejected (0.188 and 0.182 > 0.05). There is no statistically significant evidence supporting the hypothesis that reshoring and uncertainty affect each other so the null hypothesis cannot be rejected. In practical terms, these results indicate that PMRI and Uncertainty do not affect each other in any direction.

Table 5.2 - Results Granger Causality Test - Electrical Manufacturing Index and Uncertainty

Null Hypothesis	**Lags**	**Obs**	**Prob**	**Result/ decision**
Lagged values of EMRI do not Granger-cause current values of Uncertainty	1	21	0.648	Do not reject
Lagged values of Uncertainty do not Granger-cause current values of EMRI	1	21	0.890	Do not reject
Lagged values of EMRI do not Granger-cause current values of Uncertainty	2	20	0.617	Do not Reject
Lagged values of Uncertainty do not Granger-cause current values of EMRI	2	20	0.988	Do not reject

According to Table 5.2, there is no statistically significant evidence for the hypotheses of EMRI and Uncertainty affecting each other in any direction with any of the lagged values (L1, L2), so the null hypothesis cannot be rejected for any of the tests (P-value > 0.05). This means that there is no Granger causality, in either direction, between EMRI and Uncertainty with the lag periods chosen for this analysis.

5.2 Discussion

5.2.1 Analysis of the Data.

The results of the Granger causality test are used to answer the research question: **How efficient are measures of uncertainty in predicting future reshoring patterns within the U.S. pharmaceutical manufacturing and electrical manufacturing industries?**

The term causality relates to the concepts *cause* and *effect,* which corresponds with the aim of Granger causality where x would be causal to the variable y if variable x is the cause, and variable y is the effect (Kirchgässner and Wolters, 2007). As proposed by Clive Granger (1969), examining whether the forecast accuracy of future values of variable y is improved if lagged values of variable x are included in the analysis indicates if there is a causal relationship between the variables, all other factors excluded (Kirchgässner and Wolters, 2007). The results of the Granger Causality test can, if causality between the variables is present, indicate different directions of causality between the variables. Bidirectional causality implies that there is a dynamic relationship of causality between the variables, the variables are mutually affecting each other and both variables impair the forecast accuracy of the other when removed from the analysis. On the other hand, unidirectional causality implies that one variable Granger-causes the other variable. If there is unidirectional Granger causality in the direction from variable x to variable y, removing variable x from the analysis will impair the forecasting accuracy of variable y, but the opposite is not true.

The results of the analysis indicate a causal relationship between the variables, but the relationship varies depending on the lag time chosen for the variables. Summarizing the results of the Granger causality analysis from 5.1. *Results*, uncertainty Granger-causes reshoring within the pharmaceutical manufacturing sector within one year, but not within two years. For reshoring within the electrical manufacturing sector, this analysis shows no relationship with uncertainty.

Granger causality tests on VAR with 1-year lags presented significant differences between the two industries. The test of uncertainty and pharmaceutical reshoring intensity suggests a unidirectional relationship where changes in uncertainty affect reshoring intensity the following year. For electrical manufacturing, the test does not suggest any relationship between the variables, indicating that electrical manufacturing reshoring intensity also with 1-year lagged values presents stability to fluctuations in uncertainty.

When including lagged values, the results, if there is causality, indicate the reaction time of the affected variable to the causing variable. As discussed by Gao (2024), reshoring cannot be instantaneously implemented as a risk mitigation strategy due to contract obligations, cost analysis, and delays of reallocation. The lagged values in the analysis capture the practical implications of these delays. Bofelli et al. (2020) divide the reshoring process into the phases *of decision-making* and *implementation*. When the process is highly complex, Bofelli et al. (2020, pp.11) argue that the reshoring process is flexible, and "expected emotions and situational anxiety" may speed up the reshoring process. Home-country bias may also affect the reshoring process if the current sourcing location is unsatisfactory, resulting in evaluating the domestic country higher than alternative sourcing options (Bofelli et al., 2020).

In the results, only one-year lagged values show a relationship between uncertainty and reshoring and only for the pharmaceutical manufacturing sector. Perhaps this could be explained by the high complexity of the pharmaceutical factor based on the strict regulatory framework. Uncertainty and increased awareness of mutual dependence may increase situational anxiety and speed up the reshoring process as argued by Bofelli et al. (2020). The high centrality in the global pharmaceutical manufacturing network may also impact both the decision-making and implementation phases. Contract obligations and cost analysis, as mentioned by Gao (2024), could potentially be less impactful within the pharmaceutical manufacturing industry since the U.S. is an established production hub, and the number of foreign suppliers is lower relative to electrical manufacturing.

When the lag is instead specified to two years, the null hypothesis cannot be rejected for either uncertainty and electrical manufacturing reshoring intensity or pharmaceutical manufacturing reshoring intensity. The null hypothesis states that "lagged values of variable x do not granger cause lagged values of variable y". This suggests that neither uncertainty nor reshoring intensity Granger-cause the other in any direction in either industry. According to the results, reshoring intensity in both industries is stable from fluctuations in uncertainty two years previous. Reshoring intensity may still fluctuate due to other factors, but removing uncertainty from the analysis does not reduce the accuracy in forecasting reshoring intensity two years later. It is however important to note that this analysis does not provide any evidence that such a relationship does not exist with a lag of over two years. There is a possibility that a relationship between uncertainty and reshoring can be present over a period longer than two years, this discussion is however beyond the scope of this essay.

Based solely on one and two-year lags, the answer to the research question is that uncertainty can be used to improve the prediction of future reshoring patterns when the chosen lag is one year, and that uncertainty cannot be used to improve the prediction of reshoring patterns within the electrical manufacturing industry. As previously mentioned, lagged values are inherent to Granger causality analysis. Therefore, lagged variables are used to exclude the risk of previous values not accounted for in the test causing spurious correlation. A spurious correlation could occur if the persistence of previous values not captured in the analysis impacts the test, resulting in a false correlation being observed (Kirchgässner & Wolters, 2007). However, since Bofelli et al. (2020) indicate that reshoring processes can span less than a year, the possibility of reshoring occurring before the one-year lag period must be discussed.

5.2.2 Discussion of the Results

Due to the yearly interval of the time series and the measurement of reshoring being constructed of input/output in millions of U.S. dollars throughout the entire year, an increase in uncertainty during the first month of the year could be captured in the same year by a significant change in reshoring intensity up to eleven months later. The reshoring intensity index is calculated based on the input and output of “intermediate use at basic prices” in current million U.S. dollars (OECD, 2023). The construction of the measurement indicates that small alterations to the supply chain that may not require an extensive cost-benefit analysis or construction of new production facilities for each company, may be captured when examining the entire industry at a macroeconomic level. If this is the case, increasing reshoring intensity may be captured by the DI/FI ratio for the same year as uncertainty fluctuates, indicating that the reshoring intensity caused by those uncertainty fluctuations the following year could be underestimated.

In addition to Granger causality analysis relying inherently on lagged values, examining the relationship of uncertainty and reshoring without lagged values could capture situations of mutual causation between the variables. Situations of mutual causation between uncertainty and reshoring are important to keep in mind even though it does not contribute to the analysis of reshoring as a risk mitigation strategy. The measure of uncertainty used in this thesis is constructed based on counts of the word uncertainty (general uncertainty, trade-related uncertainty, and economic policy-related uncertainty) and its variants from Economist

Intelligence Unit (EIU) country reports. The EUI country reports provide "comprehensive political and economic analysis and forecasts" (Economist Intelligence Unit, 2024, no page) for each country and I have used an aggregate average of the WTU and WUI indexes, but an index specific to the U.S. for economic policy uncertainty. According to the EIU description of the scope of their country reports, exogenous events that may affect U.S. foreign and domestic inputs and cause uncertainty may be assumed to be reflected in the uncertainty index as well.

Mutual causation between reshoring and uncertainty can be exemplified by examining supply chain disruptions caused by exogenous events. Ho et al. (2015) discuss how exogenous events, such as natural disasters, can cause supply chain disruptions with severe effects. If a production facility included in the supply chain suffers production disruption due to a natural disaster, the domestic firm dependent upon that supply chain will experience a decrease in foreign inputs simply because production has been disrupted. The ratio of domestic inputs over foreign inputs (DI/FI) will then increase, manipulating the ratio to display increased reshoring intensity. This could imply reshoring if domestic production is increased because of the disruption, but it is also possible that the disrupted production instead causes loss for the firm and that the disruption falsely portrays conscious reshoring (Ho et al., 2015). Following the EUI definition of the scope of the EUI monthly country reports, exogenous events causing such disruptions could be noted in the reports concerning uncertainty, causing the uncertainty index to increase.

The discussion of supply chain disruption caused by exogenous events is also interesting for the analysis of the lagged variables. Craighead et al. (2007), in line with Ho et al. (2015), argue that supply chain disruptions can be aggravated by low supplier diversification, global sourcing, and sourcing from clusters of industries. As suggested by Crisciolo & Timmis (2018) and Borja Reis & Pinto (2022), the global network of production for electrical manufacturing has in its internationalization process taken a path of diversification while the pharmaceutical manufacturing industry is highly centralized to a few different production hubs.

5.2.3 Centrality

The first point of difference between pharmaceutical manufacturing and electrical manufacturing in section *2.3* is **1. The diversification of total production of global supply within the industry as well U.S. level of influence in the market.** The concept of centrality as presented by Crisciolo & Timmis (2018) indicates how influential and interconnected economies are in the global production network of a good or industry. As argued by (Mariasingham, Lumba, & Jabagat, 2023), the risk of supply chain disruptions is heightened if the industry production network is highly central to a few influential economies as exemplified by Russia's war in Ukraine. As discussed in section *3.2.1 Centrality,* although pharmaceutical manufacturing and electrical manufacturing are both relatively central to China, the degree of diversification divided by the rest of the economies in the production network varies. In the global production network of electrical manufacturing, the beginning of this century saw a shift towards increased diversification within the electrical manufacturing sector, while pharmaceutical manufacturing remains highly central to a few influential economies.

The results show that while EMRI remains stable amid fluctuations in uncertainty, there is unidirectional Granger causality from uncertainty- PMRI a 1-year lag. Market concentration and high centrality allow for efficient production allocation and, in the case of centrality, the influential firms can also reap the benefits of economies of scale. However, this structure of the global production network increases vulnerability to risk (Conceição, 2024). As noted by Borja Reis & Pinto (2022), the global production network of pharmaceutical manufacturing is highly centralized, with the key American production hub in the U.S. and the Asian production hub in China. This unidirectional Granger causality from uncertainty to PMRI corresponds with the theory stating that centrality and a low number of highly influential producers incentivize reshoring.

One of the factors causing vulnerability within highly centralized industries is the possible disruptions caused by choke points, where failure in a single point of the supply chain affects the entire value chain (Reiter & Stehrer, 2021). Moreover, the trade in pharmaceutical products between the U.S. and China is characterized by a high degree of complementary production, with the U.S. importing APIs from the Chinese production hub (Graham, 2023; Reiter & Stehrer, 2021). This interdependence means that the U.S. cannot simply depend on the U.S. hub in case of uncertainty disrupting supply at a choke point of production, and reshoring all production processes within pharmaceutical manufacturing is incentivized. This is evident in U.S. President Joe Biden's (2022) announcement of increased investment in the domestic biotechnology and pharmaceutical manufacturing sector, where dependence on the two-way trade of pharmaceutical goods with China is seen as a vulnerability.

As indicated by Criscuolo & Timmis (2018), the electrical manufacturing industry, although presenting a high degree of centrality in China, is becoming increasingly diversified among suppliers in the rest of the world. In literature, reshoring is discussed as a supply chain risk mitigation strategy, but diversification of suppliers of intermediate goods can also reduce vulnerability to risk through avoiding choke points and costs of trade tariffs and barriers such as during the U.S.- China trade war. The results show that there are no signs of Granger causality between EMRI and uncertainty with any number of lagged values. The results indicate that maintaining a diverse array of suppliers during times of uncertainty can substitute reshoring as a risk mitigation strategy, proving the hypothesis that industry centrality will affect how efficient uncertainty is in determining future values of reshoring in that industry.

5.2.4 Complexity

The second point of difference between pharmaceutical manufacturing and electrical manufacturing presented in section 2.3 is **supply chain complexity regarding logistical barriers, regulatory constraints, and bureaucratic processes.** The theories by Jones & Kierzowski (1990), Breshahan & Levin (2012), and Joskow (2003) discussed in section 2.2 indicate that firms will benefit from offshore outsourcing if the process of supply chain coordination is relatively simple in terms of coordination and complexity. As discussed in section 3.3 the pharmaceutical supply chain is characterized by significant complexity due to regulatory constraints and complicated production processes (Shah, 2004). As quoted by Bazerghi (2015, pp.15), “The liability of sharing expert knowledge required to run a commercial-scale proprietary chemical process combined with the quality risk and high level of regulatory scrutiny could deter a drug company from capturing the conventional benefits of outsourcing, such as a lower cost of goods and quicker product launch”.

Complex production networks, as within the pharmaceutical manufacturing industry, may be further complicated through vertical integration due to negotiation and bureaucratic regulations (Joskow, 2003) Additionally, bureaucratic regulations and cooperation become increasingly complex when there are significant cultural differences between the parts trading, worsening supply chain responsiveness and thereby incentivizing reshoring (Moradlou et al, 2017). The prospect of mitigating risk through diversification can thereby be disincentivized if the establishment of agreements with multiple new suppliers implicates negotiations and bureaucracy of establishing new regulatory frameworks. Thus, risk in times of uncertainty within the U.S. pharmaceutical sector could not easily be mitigated by establishing new connections with a diverse array of suppliers.

The complexity within the electrical manufacturing industry is less prominent, but it is important to note that the level of regulatory constraints varies between different products within the sector (Tiwari et al. 2021). However, according to Meng & Ye (2021), the complexity of internationalization strategies of pharmaceutical manufacturing and electrical manufacturing differ through established, strong intra-industrial linkages within the global production network of electrical manufacturing. The electrical manufacturing industry also exhibits great potential for further implementation of lean manufacturing models, characterized by low complexity and coordination (Jayanth et al., 2020). Lean production strategies are more feasible to maintain within the electrical manufacturing sector than the pharmaceutical sector since some pharmaceutical products, such as APIs, cannot be stored in inventory for a long time without endangering the quality of the goods (Shah, 2015). This indicates that agile production strategies, although more complex, are suitable for pharmaceutical manufacturing to maintain supply chain responsiveness. Pre-existing linkages of regulatory control frameworks, in combination with an already (relative to the pharmaceutical sector) diverse pool of suppliers, decreases the coordination costs of establishing or maintaining production offshore as a risk mitigation strategy alternative to reshoring.

The hypothesis regarding industry complexity stated that high connection complexity (pharmaceutical manufacturing) incentivizes reshoring as the most profitable risk mitigation strategy, while lower connection complexity (electrical manufacturing) allows for diversification as a risk mitigation strategy in times of fluctuating uncertainty. The results present similar patterns of reshoring intensity with fluctuating uncertainty, as there is no Granger causality between Uncertainty and EMRI, while Granger causality between uncertainty and PMRI is seen, with a statistically significant case of unidirectional Granger causality from uncertainty to PMRI with a 1-year lag. The significant Granger causality with a 1-year lag also corresponds with the estimated duration of the reshoring process of between one to a few years as discussed in section 4.1: *Granger Causality* (Gao, 2024).

6. Conclusion

6.1 Research Aims and Objectives

This thesis applied the quantitative approach of Granger causality aiming to answer the research question: How efficient are measures of uncertainty in predicting future reshoring patterns within the U.S. pharmaceutical manufacturing and electrical manufacturing industries? The results indicate that previous values of uncertainty can provide significant information in the prediction of uncertainty, but only for reshoring in the pharmaceutical manufacturing sector and only with values of uncertainty lagged one year. For electrical manufacturing, there is no causal relationship detected in this study, and this thesis suggests that the different results between the industries can be attributed to a relatively higher degree of centrality and complexity in the pharmaceutical manufacturing sector compared to the electrical manufacturing sector.

The thesis includes a discussion of differences in industry centrality and complexity within pharmaceutical manufacturing and electrical manufacturing to analyze if uncertainty can be useful in improving forecasting of reshoring. The results of the Granger analysis indicate that removing lagged values of uncertainty from the analysis impairs the accuracy of reshoring forecasts within the pharmaceutical industry in the U.S. This relationship is however only present when the values are lagged 1 year, and the relationship is not present with values lagged 2 years. The analysis of electrical manufacturing and uncertainty proposed no granger causality between the variables with any number of lagged variables, indicating that uncertainty cannot be used to improve the forecast accuracy of EMRI.

The differences between the results of Granger causality tests. between the two variables is attributed to differences in industry characteristics. Examining pharmaceutical manufacturing as an example of industries with relatively high complexity and centrality, such industries appear more likely to reshore production to mitigate risk during times when uncertainty is high. Contrarily, when examining electrical manufacturing as an example of industries where complexity and centrality in some regards are lower, reshoring as a risk mitigation strategy during times of uncertainty is not suggested by the results. In conclusion, the answer to whether there is a casual relationship between uncertainty to reshoring is ambiguous, but the findings in this study suggest that such as relationship may be present in industries with high complexity and centrality.

6.2 Practical Implications and Limitations

The practical implications of this study are perhaps mainly important for business owners and policymakers in the process of evaluating and implementing risk mitigation strategies. As mentioned in the sections on *theory* and *discussion*, the costs and benefits of reshoring could vary depending on industry characteristics, and the results indicate that policymakers and business owners need to be aware of this when making decisions during periods of fluctuating uncertainty. The main industry characteristics in need of attention are according to this thesis complexity and centrality. The findings of the thesis mainly provide insights into U.S. manufacturing of pharmaceutical and electrical products, which delivered insights to the analysis because both are considered essential and have experienced shortages due to risk and uncertainty. Moreover, the findings could also be useful for policymakers and business owners outside the U.S. engaged in similar activities. Lastly, the thesis provides the finding that although reshoring is increasingly discussed as a strategy to mitigate risk, all industries are differently affected by supply chain risk and uncertainty, and reshoring may not be the most cost-efficient strategy to mitigate supply chain risk during times of uncertainty.

There are also limitations to consider in the interpretation of the study. Firstly, the choice of pharmaceutical manufacturing and electrical manufacturing in the study of reshoring in relation to uncertainty limits the results to those specific industries. The thesis does not provide any explicit information about whether the relationships found are applicable to other manufacturing industries as well. Furthermore, the choice of industries also causes a limitation of generalization. Within both electrical manufacturing and pharmaceutical manufacturing, there are significant differences in the production of specific goods, and the results of the thesis do not necessarily indicate how product-specific supply chains will be affected by uncertainty.

Additionally, the study could have been improved by conducting Granger analyses for U.S. trade with specific countries rather than U.S. and ROW. This would have allowed for a more thorough analysis of trade flows, centrality, and complexity between the U.S. and these countries. In the study, the discussion is based on trade flows and production networks between the U.S. and China, and the study would have been improved if country-specific industry characteristics and reshoring intensity had been analyzed separately. Lastly, Granger causality cannot account for confounding factors, meaning other factors that affect the variables. The Granger-causality tests provide information about the relationship between uncertainty and reshoring to some extent, but due to the exclusion of confounding variables, conclusions drawn from the results need to be carefully considered.

6.3 Future Research

To further contribute to the literature on the relationship between uncertainty and reshoring in the manufacturing sector, a similar analysis could be constructed with the inclusion of more industries, countries, or specific products within the industries. Such a study would increase the robustness of conclusions drawn regarding the relationship between uncertainty and manufacturing reshoring. Another possible direction for future research is policy analysis to determine the impact of policies such as international trade policies or U.S. President Joe Biden's (2022) investment in the domestic biotechnology and pharmaceutical sector. Furthermore, a qualitative study of business owners' and policymakers' attitudes towards risk, uncertainty, and reshoring to complement quantitative findings would provide a more nuanced perspective of the perception of the market and business strategies in times of uncertainty.

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