Onshoring Semiconductor Supply Chains: Subsidies or Shocks?

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Abstract

The CHIPS Act of 2022 seeks to onshore semiconductor supply chains and production. Shock events such as recessions and pandemics also have the ability to shift supply chain locations. My research focuses on identifying the relative effect of industrial policy and shocks in relation to supply chain location decisions within the semiconductor industry. I utilize multivariate regression analysis with event study models to determine significant correlations between indicator variables and dependent variables. These trade flow findings are then used to draw broader conclusions about supply chain adjustments as a whole. My analysis shows that the CHIPS Act has had a very limited effect on semiconductor trade data; this is likely due to the limitation of the recent nature of the policy. I also conclude that non-policy shocks have affected semiconductor supply chain decisions. These conclusions provide preliminary results, but further research is needed to gain a more in depth understanding on the relative effect of shocks and industrial policy on a targeted industry.

Table of Contents

Tables and Figures

Chapter 4: Semiconductor Export Analysis and Onshoring

Chapter 5: Application of the Trade Flow Translation Framework

Chapter 1: Introduction

1.1: Overview

In August of 2022, the United States Government passed the "Creating Helpful Incentives to Produce Semiconductors Act"[1] (CHIPS Act) into law. This law heavily subsidizes and provides tax credits to the semiconductor industry with the goal of onshoring these entities to the US. Eligible entities include companies that fabricate, manufacture, assemble, test, and conduct direct research and development.[2] In addition to the CHIPS Act, the semiconductor industry has also undergone a multitude of shocks ranging from supply chain disruptions spurred by the Covid-19 Pandemic, increasing deep sea freight costs, recent financial crises and increased geopolitical tensions with China. With shocks contributing to industry-wide risks, I contend that semiconductor companies also make strategic decisions to move their supply chains away from areas of risk. With policy and non-policy factors capable of moving supply chains, indepth research is necessary to determine which is responsible for semiconductor supply chain movement and onshoring to the US.

1.2: Research Questions

To what extent has United States industrial policy, such as the CHIPS Act, brought semiconductor supply chains and production to the United States? Semiconductor supply chains have been shifting location and onshoring for a variety of reasons including shocks and industrial policy. Is there empirical evidence that US legislation has actually *changed* business decisions pertaining to supply chain location, or has it merely subsidized an onshoring movement already set in motion due to global supply chain shocks? This thesis will assess the relative importance

[1] Official Law: Creating Helpful Incentives to Produce Semiconductors Act of 2022 (CHIPS Act)
[2] U.S. Congress. House, *Creating Helpful Incentives to Produce Semiconductors For America (CHIPS Act)*. HR 4346, 117th Cong., Introduced in House 1 July 2021.

of US industrial policy, the CHIPS Act, in light of these other shocks as it pertains to US onshoring of the semiconductor industry.

In answering these research questions, my research will encounter several challenges and limitations. The first major challenge in my research lies in the complexity of supply chains. I develop a framework that explains supply chain movement based off of trade data. Due to every supply chain being unique, it is difficult to predict consistent supply chain movement based on shocks alone. In some cases, my analysis yields inconsistent and inconclusive results. This highlights the challenge of creating a model that takes into account the sheer complexity of supply chain management and decision-making. Another primary limitation I face is the recent nature of the CHIPS Act. Moving a corporation's manufacturing sector of a supply chain takes time. It is possible that the critical supply chain movements this law is seeking to incentivize have not occurred yet. However, my research will still provide valuable insight into what supply chain shifts have occurred thus far. There is no research in the literature pertaining to semiconductor industry behavior in light of both industrial policy and shocks, making my efforts all the more important. I acknowledge these challenges and limitations while also recognizing that preliminary research on the effects of policy events and shocks can help us understand supply chain adjustments in this important industry.

1.3: Roadmap of the Thesis

Before beginning the review of the literature, this section provides a roadmap for the rest of the thesis. Continuing in Chapter 1, the literature review will explore the importance of semiconductor technology, provide key definitions, and end with a discussion on multiple rationales surrounding theories found in the literature. Following this, I will present my hypotheses. Chapter 2 begins with an explanation of my research design. This section will not only discuss my correlational research design, but also cover other studies on industrial policy that have used similar approaches. This approach coupled with multivariate regression analyses gives valuable insight into the correlation between shocks and policy events on supply chain movement and onshoring. A discussion of how I divert from typical industrial policy research designs in order to minimize limitations can also be found in this chapter. The methodology section begins with a discussion of how trade data can be used to measure supply chain adjustments. This section also discusses the timelines and datasets I use for the event study models, a form of correlational analysis. Chapter 2 finishes with a summary of findings.

Chapters 3 and 4 analyze event study models for imports and exports of three types of semiconductor goods: finished goods, capital goods, and raw materials. Chapter 3 focuses on the impact of shocks and policy on imports. The effects of these shocks and policy on finished goods imports is analyzed first, followed by a consistent analysis of capital goods and raw material imports. Chapter 4 looks at the impact of shocks and policy on exports. This chapter performs an identical analysis to that in Chapter 3 except that Chapter 4 focuses on the effects of the shocks and policy on finished goods exports followed by capital goods exports.

Chapter 5 uses the trade data findings from Chapters 3 and 4 to determine supply chain movement. The goal of this chapter is to use the framework to translate trade flow findings into supply chain movement. A discussion findings based on the input data from Chapters 3 and 4 takes place here. The thesis concludes with Chapter 6. Here, I review my research questions and hypotheses and assess the findings of my research. After drawing conclusions, I discuss the limitations of my research and suggest avenues for future research.

1.4: Literature Review

1.4.1: Importance of Semiconductor Technology

The US government is concerned that semiconductors are produced almost exclusively offshore. Today, the U.S. is responsible for a mere 10% of the total semiconductor chip production worldwide. Even more concerning, as of August 2023, the US does not produce any of the leading edge semiconductor technologies; this creates reliance on foreign countries and supply chains to provide the US with critically important goods .[3] It is not only economically beneficial to bring more semiconductor manufacturing and development to the US, but it is also a national security imperative. Cutting edge microchips are used in many applications from military communications to surveillance. Maintaining a competitive edge in chip design translates to a competitive edge in national security.[4] The economic benefit and national security importance are two major driving factors behind the CHIPS Act.

With an understanding of the importance of the semiconductor industry, my research will provide insight as to what factors, if any, are bringing these critical supply chains to the US. As previously mentioned, industrial policy and shocks can theoretically produce similar results in terms of supply chain location movement. Companies, politicians, and scholars alike will have a better understanding of the forces that affect semiconductor industry onshoring with the contribution of my research.

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[3] The White House, "Fact Sheet: Chips and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China." The White House, February 3, 2023.

[4] Hideki Tomoshige and Bailey Crane, "Rai Explainer: Strategic Importance of Continued U.S. Leadership in Chip Design: Perspectives on Innovation." CSIS, January 19, 2024.

1.4.2: Definitions

Industrial policy and shocks are two central concepts to my research question and analysis. Policies and shocks have the ability to onshore semiconductor supply chains to the US. This section will first define onshoring. Following that, I'll define what industrial policy is, and what a shock is in the context of this paper. In addition to this, I will discuss the concept of de-risking. An understanding of de-risking is crucial to explaining how a shock can cause onshoring.

In the literature, there is no consensus on the definition of onshoring. It is used interchangeably with the term reshoring, which is both misleading and improper. I propose the definition of onshoring as a combination of those in the literature. Onshoring is the act of moving a foreign supply chain back to domestic facilities[5]. Onshoring can also be the inverse of offshoring. For example, if ASML, a Netherlands headquartered semiconductor fabrication company, moves production to the US, they would be offshoring from the Netherlands, and onshoring to the US. This definition of onshoring is crucial to understanding the CHIPS Act. Foreign companies such as TSMC (Taiwan-based) and ASML (Netherlands-based)[6] are eligible for US subsidies in the CHIPS Act if they onshore their manufacturing process to the US. The act of moving a supply chain to the US is classified as onshoring from the perspective of the US. Having explored this concept, it is also imperative to understand industrial policy.

At its' core, industrial policy has been widely accepted as a deviation from policy neutrality[7] . For example, this could be a positive deviation to encourage growth in a sector, or a

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[5] David Owen Kazmer, *Manufacturing Outsourcing, Onshoring, and Global Equilibrium.* (Business Horizons, 2014),464.

[6] "Taiwan Semiconductor Manufacturing Company" and "Advanced Semiconductor Materials Lithography"

[7] Ann Harrison and Andrés Rodríguez-Clare. *Trade, Foreign Investment, and Industrial Policy for Developing Countries* (Handbook of Development Economics, 2010), 4039.

negative deviation in order to discourage trading in a certain region or country. More specifically, industrial policy can be defined as "government policies that explicitly target the transformation of the structure of economic activity in pursuit of some public goal. The goal is typically to stimulate innovation, productivity, and economic growth."[8] When looking at the CHIPS Act, this industrial policy seeks to do all three within the semiconductor industry: innovate, increase productivity, and spur economic growth. With semiconductors being on the leading frontier of technology, stimulating innovation is critically important to remain competitive in the industry. Furthermore, due to the lack of semiconductors manufactured in the US, increased productivity resulting in economic growth are also goals of the policy. However, industrial policy isn't the only variable that can persuade a semiconductor company to onshore or shift their supply chain locations.

"Shocks" are also capable of moving supply chains and production. Drawing from the literature, shocks can be defined as sudden jolts to the world economy in the form of financial crises, recessions, wars, and political conflict; shocks can also include natural disasters and sudden policy changes[9]. Of course, shocks can range in intensity and magnitude, but the important aspect to consider is that they are sudden or unexpected. An important distinction is that sudden policy changes differ from industrial policy. For example, a sudden policy change would be an executive order that directly affects the semiconductor industry. Comparatively, industrial policy takes time; it requires approval by Congress, and has to be signed into law.

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[8] Réka Juhász, Nathan Lane, and Dani Rodrik, *The New Economics of Industrial Policy*, (NBER Working Paper 31538, 2023), 4.

[9] Douglas Irwin and Kevin O'Rourke, *Coping with Shocks and Shifts: The Multilateral Trading System in Historical Perspective,* (Discussion Papers in Economic and Social History, 2011), 1, 22.

Richard Baldwin and Rebecca Freeman, *Risks and Global Supply Chains: What We Know and What We Need to Know* (Annual Review of Economics, 2022), 156.

For the purpose of my research, I am only concerned with shocks that are potentially large enough to disrupt semiconductor supply chains, production, or industrial structure. This disruption is what could cause them to onshore towards the US, or away from the shock. These shocks ultimately produce an increased level of risk to a company or supply chain operating within its effects. Companies manage this increased risk in their supply chains through a process called de-risking[10]. This process involves reducing dependency on a single country or source of risk. In short, the risk factors cause a company to diversify its supply chain. This provides the supply chain resilience in the case that one node fails. De-risking is the concept that translates a shock into supply chain movement. In work by Alforo and Chor, they have established a period of "Great Reallocation" from 2017-2022. The period has been marked with mass shifts in trade and supply chains from China to other East Asian countries and Mexico [11]. This piece of literature identifies a shift in US sourcing due to multiple factors including rising wages abroad and US policy efforts. While this work is not focused solely on onshoring to the US, it still has identified industrial policy and shocks as factors contributing to the reallocation that occurred. Although more narrow in scope, my research contributes to the literature by assessing the relative importance of industrial policy and shocks when it comes to US onshoring in the semiconductor industry.

[10] Christopher Gopal, *China's Current Economy: Implications for Investors and Supply Chains: Testimony before the U.S.-China Economic and Security Review Commission,* (118th Congress, 2023), 14.

[11] Laura Alfaro and Davin Chor, *Global Supply Chains: The Looming 'Great Reallocation.'* (NBER Working Paper No. w31661, 2023), 3-6, 14-16.

1.4.3: Rationales for Industrial Policy

Upon a thorough review of the literature, I identified multiple rationales regarding the effects of industrial policy and its interaction with shocks. Based on this, I have summarized and broken down the literature into what I argue are the three dominant rationales:

1. Industrial policy does not lead to productivity growth. (Rationale 1)
2. Industrial policy causes productivity growth. (Rationale 2)
3. Industrial policy and shocks have similar effects when it comes to moving a supply chain as companies are motivated by maintaining resilience. (Rationale 3)

The first two rationales are classic takes on industrial policy. The third rationale accounts for more modern constraints and variables. Starting with Rationale 1, I would consider it the contrarian view compared to the others. Lee (1996) conducted a case study on South Korea industrial policy from 1963-1983 using four panel data. He concludes that industrial policies, including tax incentives and subsidies, were not correlated with total factor productivity growth in the promoted sectors[12]. His evidence even suggested that less government intervention in trade is linked to higher productivity growth. In short, Lee claims industrial policy does not work.

A similar sentiment is echoed in Thorbecke (2022). Thorbecke does not claim that industrial policy is ineffective, but he discusses how the insulation of the US semiconductor market has caused it to fall behind in innovation compared to East Asian countries and the rest of the world. He claims that even though semiconductors and components were primarily invented

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[12] Jong-Wha Lee, *Government Interventions and Productivity Growth,* (Journal of Economic Growth, 1996), 392, 394.

in the US, domestic electronic firms were "coddled" by defense contracts, thus insulating them from external competition[13]. Thorbecke argues that industrial policy subsidies are less significant than facing competition; this is why the semiconductor industry largely left the US as companies that stayed had no incentive to innovate. His comparison of government intervention and industrial policy insulating an industry from competition is highly related to the takeaway from Lee.

Continuing the conversation on Rationale 1, we also see similar conclusions that industrial policy does not cause productivity growth in Young (1993). Young uses a theoretical model to reason that industrial policy grows an industry's innovation faster than its' education can support the productivity increase[14]. In other words, industrial policy is a way for a government to attempt to climb the technology ladder at a pace beyond the industry capacity and maturity. This is an intriguing conclusion, especially considering the relevance to the semiconductor industry, which I contend relies on innovation to stay competitive while requiring specialized higher education. In line with this conclusion, Thorbecke also warns that policymakers need to be aware of lower educational attainment in the US compared to East Asian countries when it comes to knowledge needed to research and produce semicons before subsidizing the industry[15]. Where Rationale 1 deems industrial policy ineffective, Rationale 2 contrasts with that view.

R2 is a more "mainstream" take on industrial policy in the literature. This rationale contends that industrial policy works. In Lane (2022), he researches a similar timeframe as Lee (1996) in Korea, but reaches a contrasting conclusion. Lane claims that in this case, industrial

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[13] Willem Thorbecke, *Exogenous Shocks, Industrial Policy, and the US Semiconductor Industry,* (CEPR, 2022).
[14] Alwyn Young, *Invention and Bounded Learning by Doing* (Journal of Political Economy, 1993), 444, 465.
[15] Thorbecke, CEPR 2022.

policy spurred economic development. This allowed targeted industries to enter more advanced markets while creating a lasting change in the industry[16]. There are many pieces of literature that reach the same conclusion. This school of thought is very supportive of industrial policy and the positive changes it can bring.

In addition to this concept, the success of an industrial policy increases as more companies are able to see the permanence of the policy. Companies are more likely to shift their production structures when they perceive a permanent policy shift in policy.[17] This means that if the industrial policy is permanent and comprehensive, then it has a better chance of succeeding. It is important to note that the longer time horizon of industrial policy may be able to bring about effects that shocks can't based on Antras' claim. However, shocks occur more often and still retain the possibility of a longer time horizon as well (ie. recessions and pandemics).

The shift away from these classic views to modern views takes into account the growing importance of supply chains to an industry. This has caused Rationale 1 and Rationale 2 to become outdated, deeming them insufficient rationales to guide modern industrial policy research. My research takes inspiration from the third rationale. This nuanced approach to observing the effects of industrial policy takes into account other forces such as shocks.

Rationale 3 accounts for the motivation of maintaining supply chain resiliency in the face of industrial policy incentives. Rodrik (2004) discusses modern uses of industrial policy. He contends that industrial policies should be used to complement existing market forces. Rodrik also claims that modern industrial policy needs to be less about Pigovian taxes and subsidies, but rather about strategic collaboration between the government and private sector to meet the

[16] Nathaniel Lane, *Manufacturing Revolutions: Industrial Policy and Industrialization in South Kore*a (SSRN Electronic Journal, 2022), 34-35.

[17] Pol Antràs, *De-Globalisation? Global Value Chains in the Post-Covid-19 Age* (NBER Working Paper, 2020), 5, 31.

specific needs of the industry[18]. Based on this, I contend that it is possible the CHIPS Act is subsidizing an onshoring movement already set in motion by shocks in an effort to attract an even larger share of the semiconductor industry.

Modern industrial policy is also motivated by supply chain resilience and responsiveness[19], rather than the classic motivations of development. Instead of being used by developing countries to compete in international trade, industrial policy is now being used by high income countries to attract supply chains from abroad. Bown argues that firms respond to shocks and adjust accordingly[20]. This is in line with the de-risking concept I discussed earlier. However, Bown goes on to say that little is known about the prevalence and importance of industrial subsidies for sectors and countries[21]. I contend that the reason for this is because industrial policy and shocks can produce the same result; this makes it difficult to show which has a larger effect on supply chain movement, and specifically in my research: onshoring.

Through the use of trade data to determine supply chain movement, my research shows the relative importance of industrial policy and shocks to semiconductor supply chain onshoring. Rationale 1 and Rationale 2 have proven to be simplified and outdated rationales. Rationale 3 describes current industrial policy interactions with shocks, but there is no widely accepted way industrial policy or complementary shocks can be measured. This thesis not only presents a novel way to comparatively measure shocks and industrial policy, but it also addresses measurement concerns laid out by Juhasz, Lane, and Rodrik. Coinciding with a shift to a modern rationale on industrial policy, there is also a shift to modern means of measurement and analysis. Reviewing this source, they contend that policymakers do not randomly target

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[18] Dani Rodrik, *Industrial Policy for the Twenty-First Century* (SSRN Electronic Journal, 2004), 2-3, 36-39.
[19] Chad Bown, *Modern Industrial Policy and the WTO*, (PIIE Working Paper 23-15, 2023), 1, 21.
[20] Bown, *Modern Industrial Policy and the WTO,* 21, 23.
[21] Bown, 5, 10, 12.

promotion of certain activities; this makes non-targeted units unlikely to be credible counterfactuals. They contend that this creates significant challenges for observational studies of industrial policy and further complicates research design and analyses.[22] The Research Design section will address this concern in detail and explain how my design handles this obstacle. Instead of comparing the semiconductor industry to a non-targeted industry, I employ event study models—a common approach in correlational analysis and econometrics—to evaluate the correlations between shocks, policy, and trade data. This strategy allows me to identify key correlations without the need for a credible counterfactual.

1.5: Hypotheses

I hypothesize the CHIPS Act has so far not successfully onshored semiconductor manufacturing supply chains. Furthermore, I contend that industrial policy through the CHIPS Act subsidies is no more significant than the shocks I will measure as they pertain to supply chain outcomes.

Chapter 2: Research Design, Methodology, and Summary of Findings

2.1: Research Design

My research design consists of a correlational study that aims to expand the literature past its current experimental limitations. Correlational research designs have been used to study the relationship between industrial policy and the targeted industry in the past.[23] A correlational study aims to examine whether hypothesized changes in one outcome variable are associated

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[22] Juhász, Lane, and Rodrik, *The New Economics of Industrial Policy*, 13.

[23] including Krueger and Tuncer 1982; Harrison 1994; Lee 1996; Lawrence and Weinstein 2001

with changes in the indicator variables[24]. This research design allows me to evaluate the relative strength of the relationship between shocks and industrial policy with the trade data. Despite the use of this research design in industrial policy literature, correlational studies have not been used to compare the relative effects of industrial policy with other shocks. This thesis takes a novel approach by comparing the effects of policy events in addition to shocks in an attempt to determine which is associated with greater shifts in trade data and supply chain onshoring. My claim that the CHIPS Act has not produced more onshoring comparatively to shocks is an unexplored theory regarding the interaction between industrial policy, shocks, and the targeted semiconductor industry.

The goal of this research is to investigate correlations between indicator variables including shocks and policy events with the dependent variable of the analysis. In each of my analyses, the dependent variable is either an import or export value of semiconductor goods in the categories of raw materials, capital goods, and finished goods. The specific correlational analysis that will be used to determine the relationship between these factors include a multivariate regression and an event study model for statistically significant factors.

For the regression and event study models, the dataset is composed of Harmonized Tariff Schedule (HTS) codes for the semiconductor industry. The timeline of the dataset is 2003 to 2023 and the data is recorded in monthly increments. For each respective HTS code, the values are recorded as monthly import or export values. Within this dataset, benign factors restrict me from measuring the same exact HTS codes month to month. First, the semiconductor industry is at the cutting edge of technology innovation. As new products come to market, the former HTS codes are disaggregated, or new codes are created if the product is unique from those in existence. This does not result in spikes or sudden drops in the data that could affect the model

[24] Francis Lau and Craig Kuziemsky, Methods for Correlational Studies, (2017), Chap. 12.

or regression. In many cases, the new product was already traded under a similar HTS code, and then was reassigned a new HTS code upon review. Next, not all HTS codes are imported, and not all HTS codes are exported. For example, when we look at raw materials for semiconductors, the US imports the germanium needed to produce a semiconductor chip. The US does not mine germanium, thus meaning we do not export that product. This limitation in the data reflects reality, thus making it harmless to my analysis.

Before I create an event study model, I run a multivariate regression model for each category of semiconductor goods. Each regression model includes all shocks and policy events as indicator variables. Additionally, I also include a one month lag of the dependent variable. This is because supply chains can not move immediately. Shifting where a product is developed, manufactured, or even warehoused takes planning and time to execute. By including a one month lag into the regression, it helps the model reflect actual conditions. Only statistically significant indicator variables will be put into the event study models.[25] Due to the recent nature of the CHIPS Act, I have relaxed the P-value criteria for significance. I consider a P-value=0.1 significant at the 90% level, with distinctions made for P-value=0.05 significant at the 95% level, and P-value=0.01 significant at the 99% level.

Event study models are a powerful econometric tool used to estimate dynamic treatment effects. In this model, the x-axis is measured in time. Time can be displayed as "event-time" or "calendar time"[26]. Each of my event study figures will be measured in "calendar time" displaying month and year on the x-axis. This will keep all figures consistent, and also give context to the time period a shock or policy event is occurring. The y-axis is measured in dollar

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[25] This lag will be statistically significant in every regression, so I will not analyze the lagged variable each time as the focus of my research is the correlation between the indicator variables and the dependent variable.

[26] Douglas L. Miller, *An Introductory Guide to Event Study Models,* (Journal of Economic Perspectives, 2023), 203, 206.

amount. My goal of using this approach is to identify the correlation between changes in trade data during shock and policy events compared to the entire selected timeline. An important interpretation I make in this model is that an increase or decrease in dependent variable value is equivalent to an increase or decrease in dependent variable trade volume. As a default setting, the event window consists of the shock period or occurrence, plus 10 months of data before and after the treatment.[27] If a shock occurs near the beginning of the dataset and I cannot go back 10 months, I utilize whatever months are available, and maintain the 10 months following the treatment period. The same selection rule applies if there are not enough months in the dataset after a treatment to fulfill a 10 month period. I will utilize what is available in the dataset and maintain the 10 month period before the treatment. In some event study models, I encounter a cluster of shocks. The model will still maintain the 10 months before and after the shock if possible in the dataset, but it will also include the months between each treatment as well.

Because visual analysis of these event study models is limited, I quantify each model using the same equation. I refer to this equation as a magnitude test. It expresses the percent difference between the treatment mean with the mean of the event window. The equation is as follows:

$$\%\Delta Y = \frac{\bar{x}_{\text{treatment}} - \bar{x}_{\text{event window}}}{\bar{x}_{\text{event window}}} \times 100$$

[27] I experimented with different event windows. A 12-month window before and after diluted the magnitude of the shorter shocks. A 6 month window before and after showed dramatic magnitudes as the event window was so short. A 10 month before and after window picks up on shocks and policy events of all magnitudes while providing a solid baseline of time to compare against.

The mean of the event window is subtracted from the mean of the treatment, then it is divided by the mean of the event window and multiplied by 100 in order to produce the percent change of the dependent variable. This percent change can then be compared across all significant indicator variables to determine which indicator variables affect the dependent variable with the most magnitude. Whether positive or negative, magnitude decreases as a percentage change value moves towards zero.

2.2: Methodology

2.2.1: Using Trade Flows to Measure Semiconductor Supply Chain Adjustments

A central element of my methodology is measuring trade flow data and trends, then I use that information to determine supply chain adjustments. This original analytical framework identifies three types of goods in supply chains: raw materials, capital goods, and finished goods. This framework starts by classifying semiconductor industry HTS codes into the three categories. Raw materials in the semiconductor industry are usually refined minerals ready to be processed or plastics and metals ready to be molded. Capital goods are the machinery or measurement tools used to produce finished good semiconductor wafers, chips, and devices. Semiconductor finished goods, chips, wafers, and devices, are used in a wide range of electronics and technologies. Breaking the semiconductor industry down into these categories is necessary to translate the trade data into supply chain movements. It is unlikely that supply chains from all categories will move at once, so breaking down the semiconductor industry into goods categories allows me to investigate supply chain movement in each category as well as cumulatively.

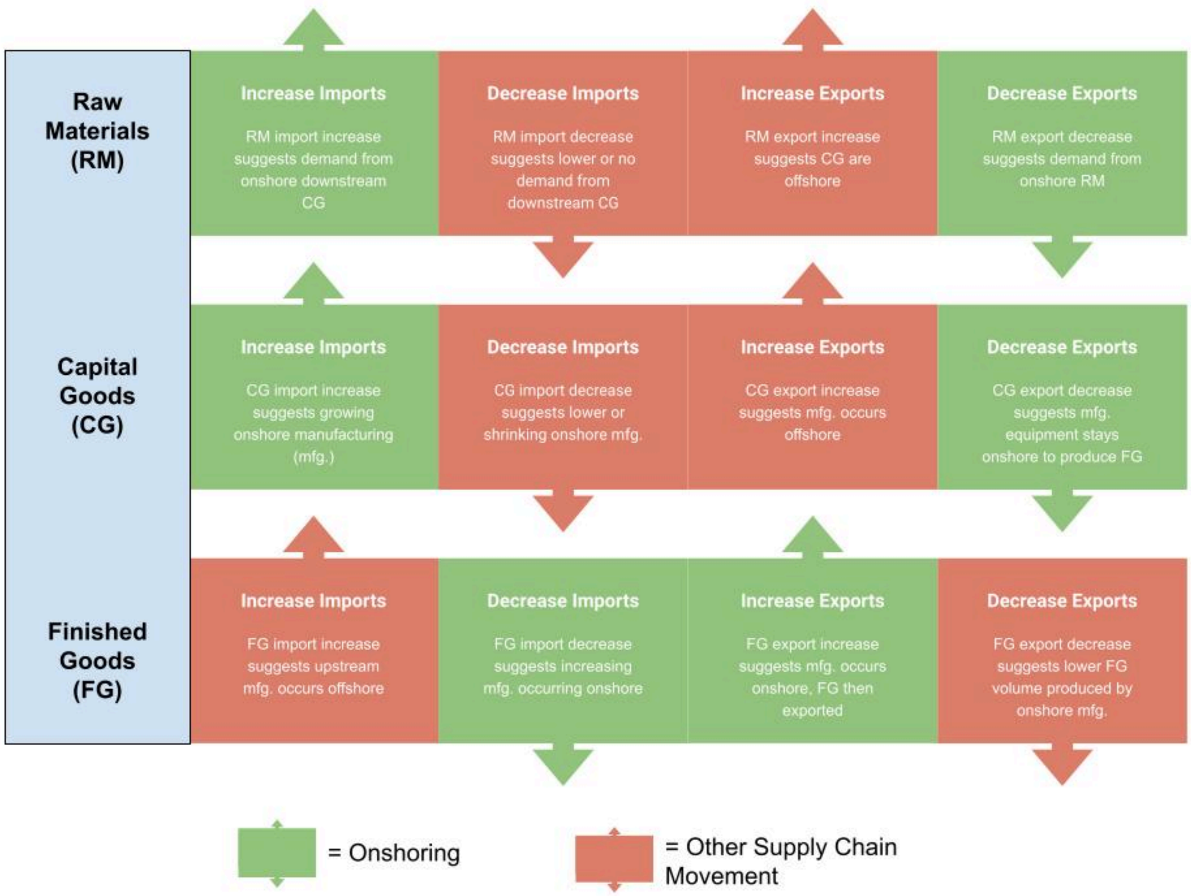
Applying the framework to onshoring of supply chains in the semiconductor industry, we should see the following. For raw materials, an increase in raw material imports and a decrease in raw material exports should be observed. This would suggest there is an increased demand from a downstream onshore manufacturing sector, and that there is a decreasing need to export these raw materials to offshore manufacturing sectors. In the case of the semiconductor raw materials, the US does not export raw materials needed to produce chips and wafers themselves so only raw material imports will be measured.

Looking at capital goods, an increase in capital goods imports and decrease in exports should also be observed. Capital goods are needed to manufacture a product, so increased imports suggests a growing manufacturing sector onshore. A decrease in capital goods exports, at the least, means the US is not supporting offshore manufacturing. It could suggest a decrease in offshore manufacturing if coupled with further data and analysis. In terms of onshoring a production process, the most important aspect of the framework to look at would be capital goods as this category includes the machinery necessary to manufacture semiconductor chips. While this category is the most important for manufacturing, I contend it is also the most rigid supply chain. This means it is harder to move and adjust the supply chains of capital goods than it would be raw material or finished goods supply chain locations.

Finished goods are the most mobile supply chain of the categories I have covered. If onshoring of semiconductor production is occurring, then we would expect to see an increase in finished goods exports, and a decrease in finished goods imports. This would suggest that the upstream manufacturing category is increasing in capacity. This would support domestic semiconductor consumption, as well as consumption in offshore markets. What this model would not be able to predict is if finished goods onshoring would occur before capital goods onshoring. Because finished goods are more mobile, their supply chain location could be moved faster than capital goods supply chains. This model will however be able to decipher such movement if it does occur.

The figure below shows how changes in raw materials, capital goods, and finished goods trade could translate into supply chain movement. Because my research is focusing on onshoring semiconductor production supply chains to the US, conditions for onshoring these supply chains have been highlighted in green.

Figure 1: Using Trade Flows to Measure Supply Chain Adjustments: Assumptions



Note: Trade flows are established through trend analysis of USITC HTS Codes.

While this framework is being used to translate trade data into supply chain onshoring for the semiconductor industry, it can be applied to any country, industry, or supply chain movement (ie. offshoring). The indicator variables that could cause semiconductor supply chain onshoring are detailed in the next section.

2.2.2: Event Study Model: Timeline and Indicator Variables

My research seeks out correlations between policy and shocks and supply chain outcomes. I use multiple shocks in addition to industrial policy in the multivariate regression and event study models with a 20 year window from 2003-2023. The goal of this timeline is to establish a pattern of behavior over time. The table below covers all shocks and policy events I will be measuring as well as the time frame in which they occur.

Table 1: Shock and Policy Events

Shock Event	Date(s) of Occurrence	Type of Shock
Freight Cost	*See Text Following Table*	Aggregate
Trump Election	Nov. 2016; Jan. 2017	Political Instability
Biden Chip Export Control	Oct. 2022	Sudden Policy Change
US/China Trade War	Jul. 2018 - Feb. 2020	Political Conflict
Japan Tsunami/Aftermath	Mar. 2011 - Apr. 2011	Natural Disaster
Pandemics	Apr. 2009 - Mar. 2010; Jan. 2020- Dec. 2021	Pandemic
Recessions	Dec. 2007 - Jun. 2009; Feb. 2020 - Mar. 2020	Financial Crises
Policy Event	**Date(s) of Occurrence**	**Type of Policy Event**
CHIPS Act Amendments Approved	Jul. 2022	Passed Congress
CHIPS Act Law Passed	Aug. 2022	Public Law

Note: The sources below determine the date range of each shock.
Sources: fred.stlouisfed.org, apnews.com, congress.gov, piie.com, cfr.org, cdc.gov, bis.doc.gov, trumpwhitehouse.archives.gov, nytimes.com

Due to the fluid nature of deep sea freight cost, it was not as easy to identify a shock. In order to identify a shock, I had to identify a significant increase in freight price. Nielsen et. al. (2011) encounters a similar problem in identifying what to consider an “aid shock”. They take the mean of aid dollars, and consider a shock a change of more than one standard deviation between two occurrences.[28] In my analysis, I only consider a freight cost increase to be a shock, as a decrease would not be disruptive to the semiconductor industry. Dates of occurrence for this variable are derived from any increase greater than two standard deviations from the mean increase in the data, lasting until a month to month change of 0 or less. I expect deep sea freight cost increase shocks to yield a negative effect on the dependent variable.

Following down the "Shock Event" column in Table 1, we have recession shocks. A recession is a shrinkage in the overall economy. I would expect this to have a negative effect on the semiconductor industry. Similarly, I contend a negative effect of pandemics will also be observed. The specific pandemics covered in the two respective date ranges are the H1N1 pandemic and the Covid-19 pandemic. During the Covid-19 pandemic, demand for semiconductor products was especially high. We will see if this high demand can balance the otherwise negative effects I predict will occur. Looking to Japan, they historically have been an epicenter for semiconductor manufacturing. This was disrupted with the tsunami of 2011. The purpose of including this shock was to see if derisking was occurring before the concept was popular in the supply chain literature. I predict that this shock may bring onshoring to the US as supply chains would be avoiding the risk area of Japan after the tsunami. The Trump election was considered a shock as it was unexpected by political researchers. Additionally, Trump was the first anti-globalist president since Herbert Hoover. This increases risk for companies abroad that would be affected by protectionist policies. Supply chain decisions depend on where they are headquartered due to the anti-globalist feature of this shock. The US-China Trade War also increases uncertainty in the supply chain for semiconductor manufacturers. I predict this will also have a negative effect on the dependent variable. Biden Chip Export Control comes from

[28] Richard Nielsen et. al., *Foreign Aid Shocks as a Cause of Violent Armed Conflict* (American Journal of Political Science, 2011), 223-224.

the US attempt to isolate China from semiconductor innovations.[29] No semiconductor components handled in the US are currently allowed to be exported to China. I have chosen indicator variables that I believe will have a negative effect on the semiconductor industry. If I am correct, I would then look to derisking theories to determine if the disruption and risk from the shock triggered supply chain movement. The policy events are more self-explanatory. The first policy event was when the bill was passed through Congress. While not signed into law, I measure this event to see if there is any movement in anticipation of the law. Lastly, I measure the effect of the law on the trade data. Both policy events have the intention of bringing onshoring to the US. I predict that we may see this, but my results will yield if this factor is any more powerful than that of the shock events.

2.2.3: Harmonized Tariff Schedule Dataset for Event Study Model

Based on the three categories of semiconductor goods (raw materials, capital goods, finished goods), thorough research was done in order to determine what HTS codes fit into each category.[30] As a disclaimer, it is impossible to capture the entire industry through disaggregation. For example, silica is one mineral used as a raw material in semiconductors. It is also used in mass amounts for beaches, concrete, and glass. Including HTS codes like silica would render my analysis imprecise and not useful. The HTS codes used in the event study model provide the best picture of the industry as a whole while using product codes that pertain specifically to semiconductors. The following table shows the HTS codes used for the raw material analysis.

[29] U.S. Department of Commerce. Bureau of Industry and Security. *Commerce Implements New metho Export Controls on Advanced Computing and Semiconductor Manufacturing Items to the People's Republic of China (PRC),* (2022).

[30] For a more indepth look into how each product code may fit into each category, refer to Appendix I

Table 2: Semiconductor Raw Material HTS Codes

Import Codes	Export Codes
8112.92.1000	N/A
8112.30.6000	N/A

Note: Refer to Appendix I for full HTS Code Descriptions
Source: dataweb.usitc.gov

As I mentioned earlier, the US is not endowed with semiconductor specific raw materials. These materials are mined abroad and imported to the US. For this reason, there is no export data available for these raw materials. Despite this complication in the dataset, it is a reflection of reality and I do not expect it to affect the quality of my analysis. Without these two inputs, it is not possible to create a semiconductor wafer, diode, or chip. This highlights the fact that each category consists of HTS codes critical to semiconductor production.

Table 3: Semiconductor Capital Goods HTS Codes

Import Codes	Export Codes
7017.10.3000	8486.10.0000
7020.00.3000	8486.20.0000
8480.71.4000	8486.30.0000
8486.10.0000	8486.40.0010
8486.20.0000	8486.40.0020
8486.30.0000	8486.40.0030
8486.40.0010	8486.90.0000
8486.40.0020	9030.82.0000
8486.40.0030	
8486.90.0000	
9030.82.0000	
9031.41.0020	
9031.41.0040	
9031.41.0060	
9031.49.7000	

Note: Refer to Appendix I for full HTS Code Descriptions
Source: dataweb.usitc.gov

Table 3 shows the HTS codes used for the capital goods analysis. There are 15 codes measured for imports and 8 codes measured for exports. The reason for this difference is that not all import codes are exported. This does not negatively affect my data analysis as I am not measuring correlations between imports and exports; they are analyzed separately for their trade data trend before using that information to see if onshoring of the semiconductor industry is occurring.

Another factor that contributes to the difference in HTS codes is relative aggregation. As I discussed earlier, the number of HTS codes measured each year changes due to changes in aggregation by the USITC.[31] More HTS codes are available to measure when innovation and disaggregation occurs. Again, this does not negatively impact the results from the data analysis. This phenomenon occurs throughout Table 3 and Table 4.

Table 4: Semiconductor Finished Goods HTS Codes

Import Codes	Export Codes
3818.00	3818.00
8541.10	8541.10
8541.21	8541.21
8541.29	8541.29
8541.30	8541.30
8541.41	8541.41
8541.42	8541.42
8541.43	8541.43
8541.49	8541.49
8541.51	8541.51
8541.59	8541.59
8541.60	8541.60
8541.90	8541.90

Note: Refer to Appendix I for full HTS Code Descriptions
Source: dataweb.usitc.gov

[31] United States International Trade Commission

Table 4 shows the HTS codes measured for finished goods imports and exports. The same codes are able to be used in each category because whether the product is made in the US or abroad, it is identical. With my datasets explained and analytical frameworks in place, I can present the key findings derived from the analysis of all models and frameworks.

2.3: Summary of Findings

The models in my analysis have shown some clear correlations, but they have also shown inconsistencies and no correlation as well. The interaction between industrial policy, shocks, and the semiconductor industry makes for a very complex field to study. My research has identified some strong correlations, but the sophisticated nature of my research subject makes designing an all-encompassing model very difficult. This leads me to conclude that these models are useful in establishing preliminary correlations based on the current status of the CHIPS Act implementation, however more scholarly work is necessary to further refine a correlational model.

Within the limitations of the models, I find that there is a strong positive correlation between finished goods supply chain onshoring and the CHIPS Act Law. Being the most mobile supply chain of the three categories, it is possible finished goods supply chains are moving to the US before other categories. I also find correlations to suggest that shocks are capable of creating the same effects as industrial policy in certain categories. Lastly, I find that there are no correlations in the data to support the notion that semiconductor manufacturing is onshoring to the US. These findings are limited to the current state of the CHIPS Act implementation and timeline, and do not implicate any future predictions. To better understand the underlying mechanisms driving the observed patterns in these findings, I turn to the analysis of my first set of event study models and magnitude tests.

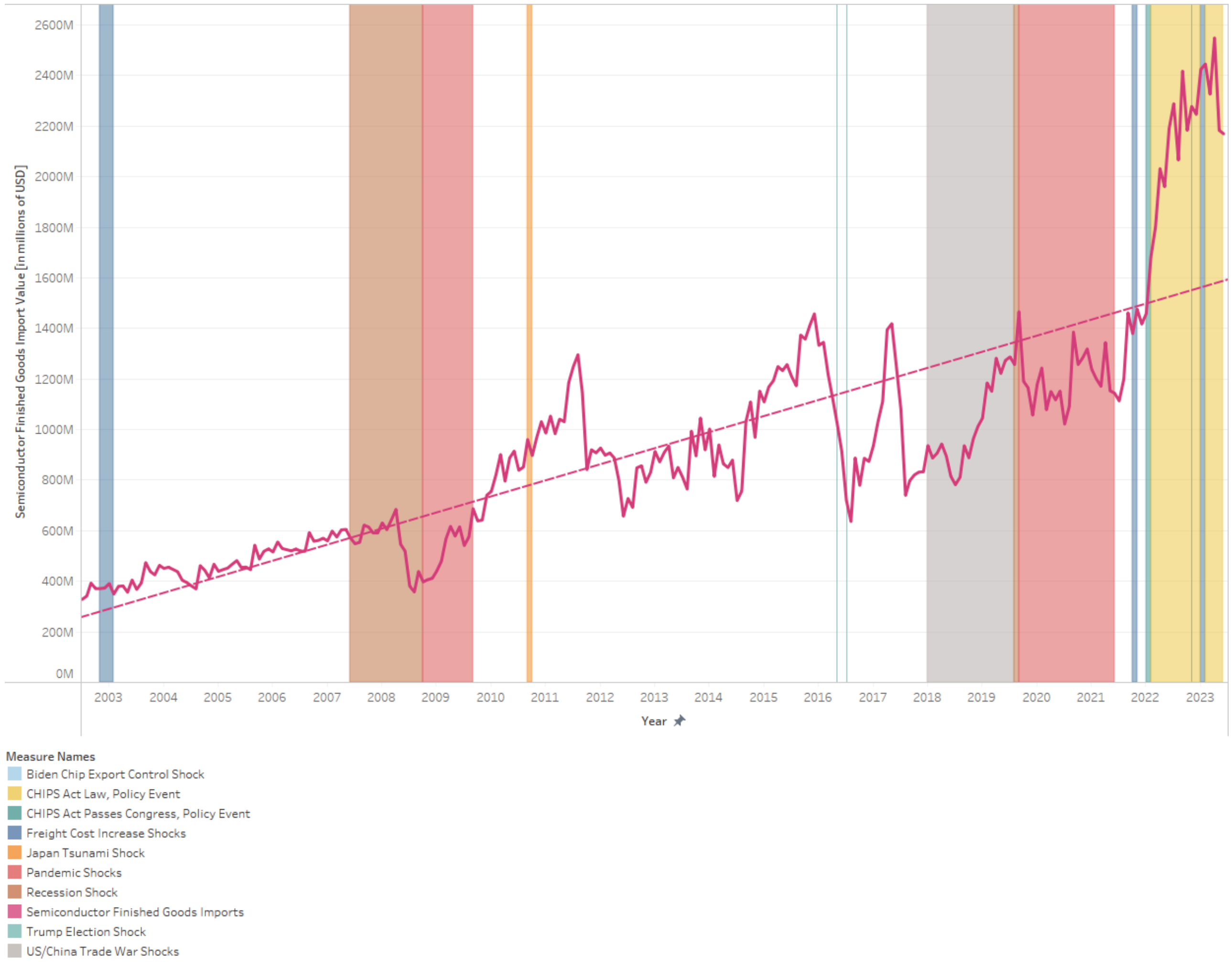
Chapter 3: Semiconductor Imports and Onshoring

3.1: Finished Goods

3.1.1: Finished Goods Imports: Overall Trend and Multivariate Regression Analysis

Finished goods supply chain locations are more flexible than supply chains consisting of raw materials and capital goods. Because of this, finished goods imports have yielded the most useful data from my analyses as there are more statistically significant shocks that affect finished goods import value. Figure 2 shows the overall trend in semiconductor finished goods import value as well as the shock and policy treatments as they occur throughout the timeline.

Figure 2: US Imports of Semiconductor Finished Goods



Note: This figure shows finished goods import value in millions of USD. Each indicator variable is highlighted for the duration of its occurrence.

Source: dataweb.usitc.gov

The overall trend line is increasing across the timeline. However, there is a considerable spike in finished goods import value in 2022. Finished goods imports are not subsidized, as it is domestic production of these finished goods that is being targeted by the industrial policy. The increase in finished goods import value happening the same year as the CHIPS Act policy events creates an interesting juxtaposition. To further investigate this pattern, Table 5 highlights the variables used in the regression model to identify which indicator variables are significant..

Table 5: Regression Results for US Imports of Semiconductor Finished Goods

Variable	Coefficient	Std. Error	t-Statistic	P-value
(constant)	947915521.018	91091493.109	10.406	0.000***
Shocks				
Freight Cost Shocks	-7974175.916	104403790.128	-0.076	0.939
Recession Shocks	-191966505.038	71441341.492	-2.687	0.008***
Pandemic Shocks	195990760.230	54432206.834	3.601	0.000***
Japan Tsunami	188176885.955	213246357.114	0.882	0.378
Trump Election Shock	62362646.783	210971967.495	0.296	0.768
US-China Trade War	213275582.462	69652442.520	3.062	0.002**
Biden Chip Export Control	-146780403.787	306353248.932	-0.479	0.632
Policy				
CHIPS Act Passes Congress	137280921.130	174147955.587	0.788	0.431
CHIPS Act Law	1393447589.985	79813966.083	17.459	0.000***
Lag				
1-Month FG Import Lag	-0.310	0.179	-1.726	0.086*
R-Squared	0.605			
Adj. R-Squared	0.588			
F-Statistic	36.860			
Obervations	252.000			

*, **, *** indicate significance at 0.10, 0.05, and 0.01 levels respectively

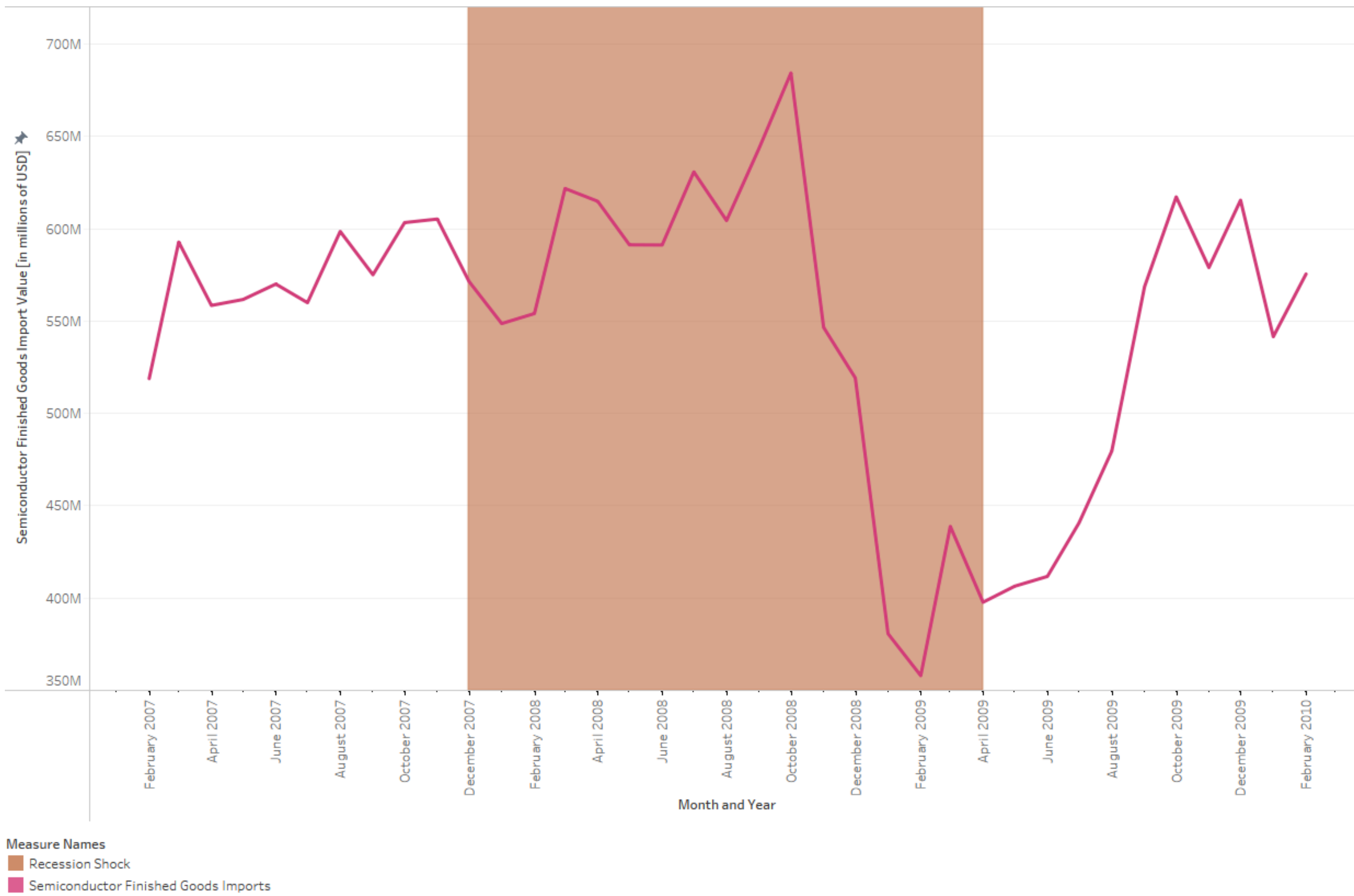
Note: Coefficient values are in dollars. Shock and policy timelines correspond to Table 1.
Source: dataweb.usitc.gov

Table 5 exhibits three statistically significant indicator variables correlated with finished goods import values at the 99% confidence interval (P-value <=0.01) . They are: recession shocks, pandemic shocks, and the CHIPS Act Law, respectively. The US-China Trade War shock is associated with a positive change in the dependent variable at a 95% confidence interval (0.01<P-value>0.05). The recession shock reflects a negative correlation in the regression, while the other three significant indicator variables reflect a positive correlation. Interestingly, the trade war shock yielded an increase in finished goods import value. We see our first and only clear cut, statistically significant effect of the CHIPS Act industrial policy. For each statistically significant shock and policy event, I create an event study model and apply the magnitude test to further analyze each variable.

3.1.2: Event Study: Recession Shocks

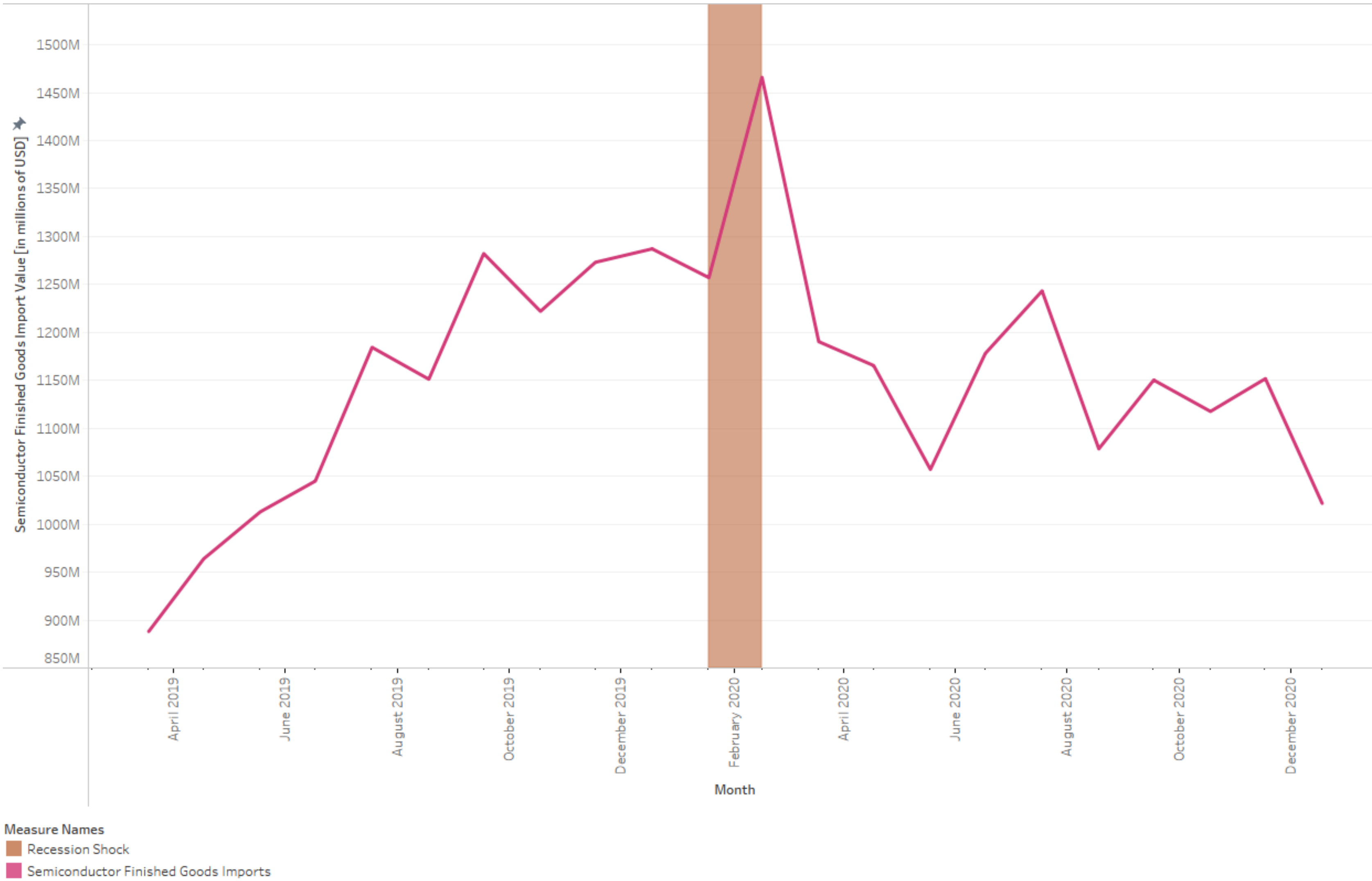
As with some of the other shocks I will, the recession shocks also occur in two separate areas of the timeline, prompting the need for two separate event study models. In the first recession shock, there is an apparent lag in the decrease in finished goods import value. With the shock occurring from Dec. 2007 to April 2009, we don't observe the dip in import value until after Oct. 2008 and before Oct. 2009. The concept of lag is one I have discussed, except here I observe a lag of 10 months from Dec. 2007 until the model reflects the change. Comparatively, it also takes about 10 months for the import value to recover after the initial drop in Oct. 2008. I propose this establishes a consistently slow reaction and recovery time. Also, important to point out is the large magnitude of this shock. Based on Figure 3 alone, we can see that finished goods import value dropped from approx. 680,000,000 in Oct. 2008 to just short of 360,000,000 in Feb. 2009. The second recession shock is harder to interpret in the event study model.

Figure 3: Event Study Model: Finished Goods Imports Recession Shock 1 of 2



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

Figure 4: Event Study Model: Finished Goods Imports Recession Shock 2 of 2



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

The shock occurs in Figure 4 at the peak of the selected timeline. Because of this, the event study model and robustness test for the second recession shock is largely inconclusive. The following reasoning could explain the complications in the model. The model shows around a $400 million drop directly after this recession shock. Due to lag, the effects of the recession are likely not reflected until after the shock period. I contend the second recession from Figure 4 will not yield useful magnitude results due to the shock period occurring at the relative maximum.

Table 6: Magnitude Tests: Finished Goods Imports Recession Shocks

Recession Shock 1/2			
Treatment Mean	Event Window Mean	Difference	% Change
546,906,814	548,026,174	-1,119,360	0%

Recession Shock 2/2			
Treatment Mean	Event Window Mean	Difference	% Change
1,361,619,348	1,153,996,824	207,622,524	18%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

The neutral and positive magnitudes are not what I had predicted would happen during a recession shock. However, Figure 3 can be interpreted as the finished goods import value recovering within the scope of the selected timeline. For Figure 4, the magnitude contrasts how high the import values were during the shock, with how low the timeline mean was including the values following the shock. Overall, this analysis yields mixed results and unclear correlation. I expected to see a clear negative correlation between a recession and finished goods import value. This is not what is observed, and any other associations are not clear. As I alluded to, these complications may be due to the model not capturing all of the complex forces acting upon the semiconductor industry.

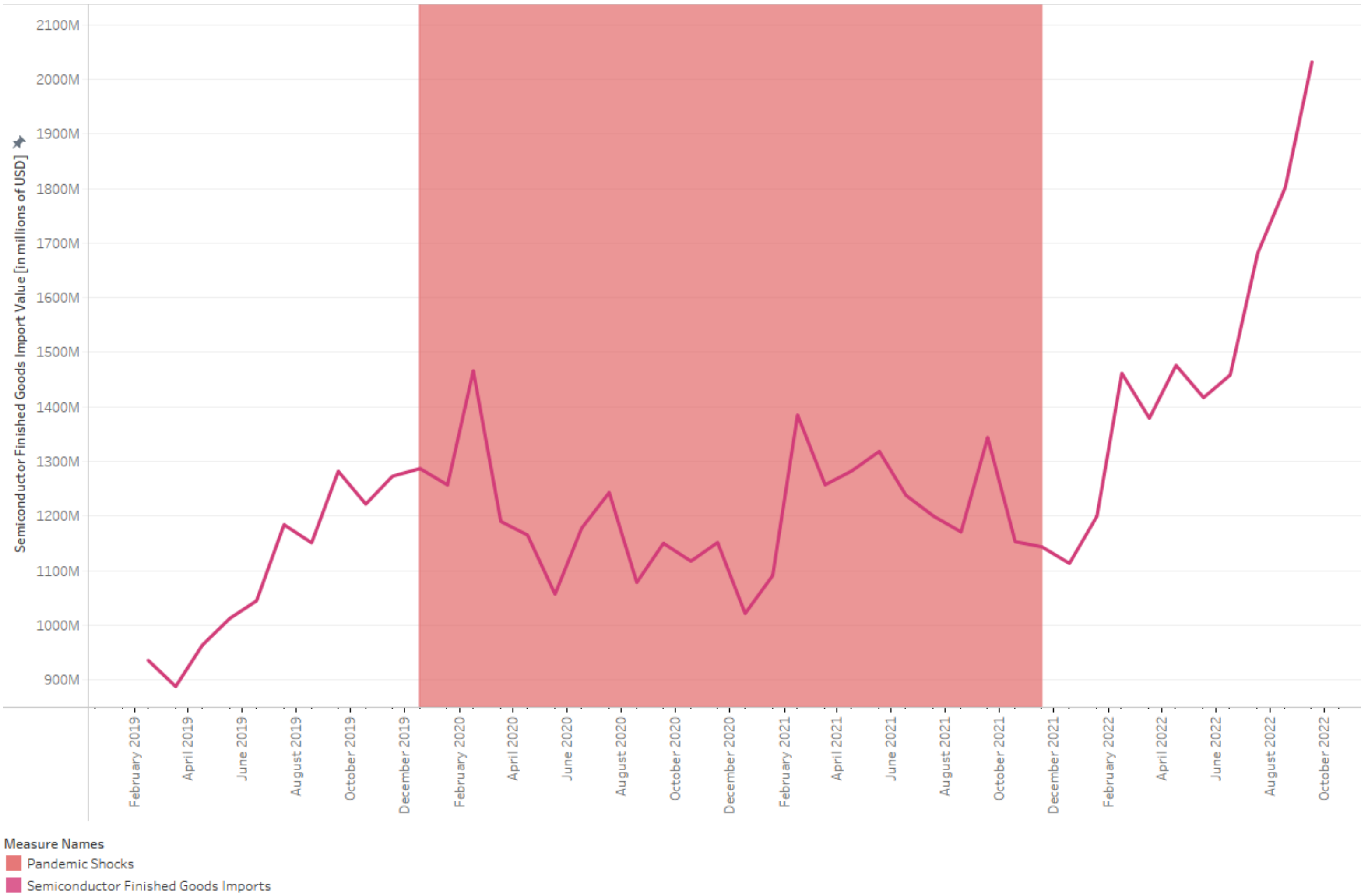
3.1.3: Event Study: Pandemic Shocks

Looking into another significant shock, the next models analyze the two pandemic shocks and their respective selected timelines. Figure 5 shows an increase of finished goods import value during the first pandemic shock. This leads me to suggest that the pandemic may have stifled growth that otherwise would have occurred, but it is difficult to tell with this model. The magnitude test will yield more insightful results. Figure 6 has a more visually clear path.

Figure 5: Event Study Model: Finished Goods Imports H1N1 Pandemic Shock 1 of 2

Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

Figure 6: Event Study Model: Finished Goods Imports Covid-19 Pandemic Shock 2 of 2



Note: See Table 1 for date range of shock or policy event.

Source: dataweb.usitc.gov

Figure 6 exhibits expected patterns. Shortly after the pandemic begins, the model shows a drop in finished goods import value. The value fluctuates during the pandemic and does not increase substantially until after the shock period is over. The magnitude of these shocks can be seen with the analysis below.

Table 7: Magnitude Tests: Finished Goods Imports Pandemic Shocks

Pandemic: H1N1			
Treatment Mean	Event Window Mean	Difference	% Change
526,721,556	614,206,855	-87,485,299	-14%

Pandemic: Covid-19			
Treatment Mean	Event Window Mean	Difference	% Change
1,206,307,249	1,248,466,773	-42,159,524	-3%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

Despite the trend during the H1N1 Pandemic shock, the treatment is associated with a 14% lower finished goods import value compared to the event window. Because the finished goods import value itself reflects a positive correlation, but the magnitude test yields a negative percentage, these findings lead me to believe that the H1N1 Pandemic slowed the growth of the semiconductor industry. While the pattern of the Covid-19 pandemic appeared to follow predicted directions, the magnitude reflects a small effect in the event window. This most likely is because of two reasons. The much larger finished goods import value during the Covid-19 timeline means a larger decrease has to occur to achieve higher magnitudes. The other reason takes into account the demand during the pandemic; demand for semiconductor chips reached a near all time high due to decreased production due to the Covid-19 Pandemic and increased demand from automobile and technology companies[32].

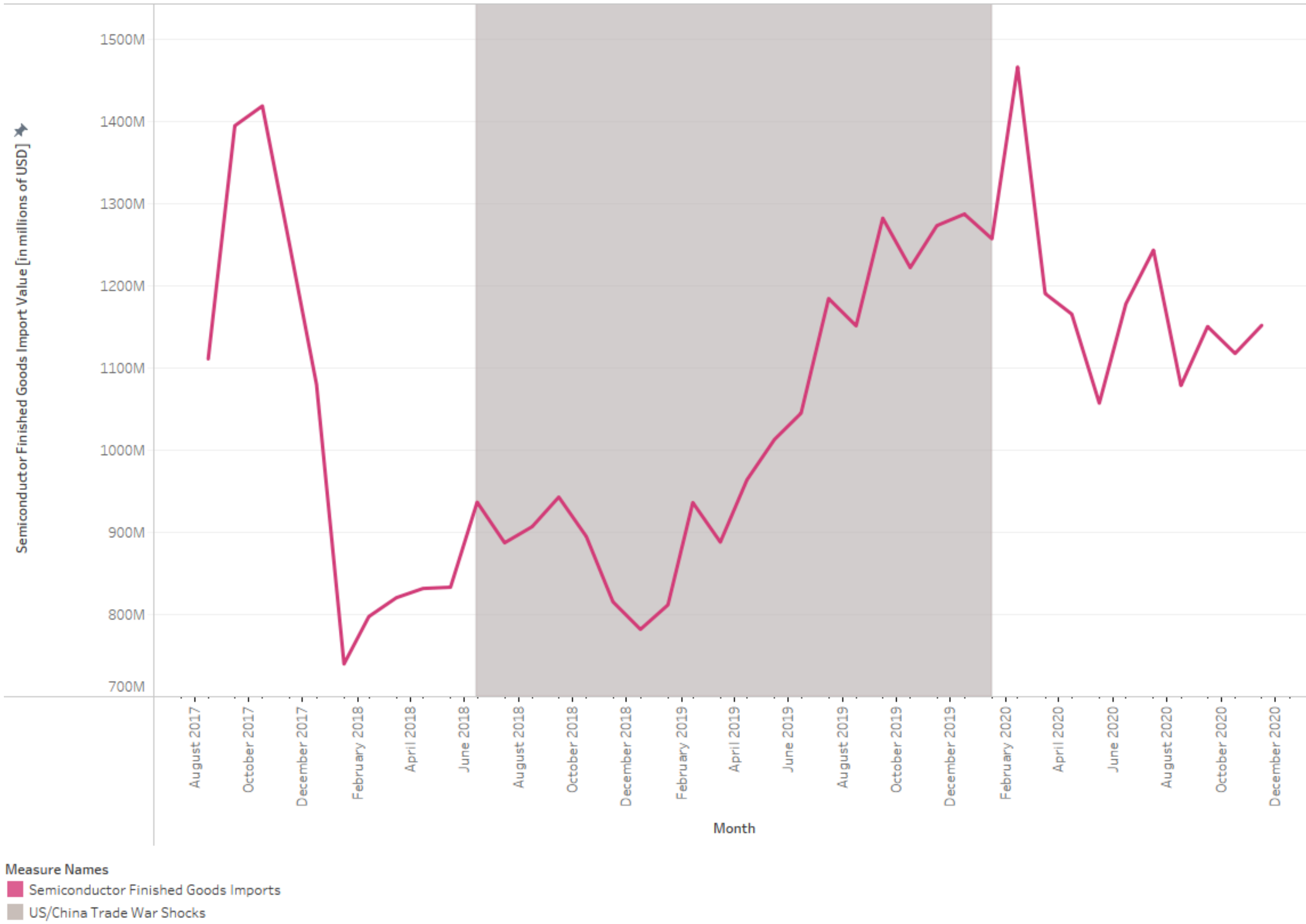
Overall, I again have unclear results that require further interpretation. I expected to see a clear negative correlation for each pandemic shock. The H1N1 Pandemic displays a positive correlation, but combined with the -14% magnitude, it reveals the possibility of slowed growth during that treatment. Conversely, we see a stronger visual negative correlation during the Covid-19 Pandemic, but the magnitude of the shock is much lower. It appears continued high demand throughout the pandemic kept the magnitude of the shock from being any larger. In both cases, I suspect the variation can be more accurately explained by forces outside of my model. I do offer possible explanations for what is observed, but analysis of the models lead me to conclude that these pandemic shocks are associated with finished goods import value by a weak negative correlation.

3.1.4: Event Study: US-China Trade War

The US-China Trade War also had a significant impact on finished goods import values. Table 5 identifies a positive correlation between this indicator variable and the finished goods import value.

[32] Ian King, Debby Wu, and Demetrios Pogkas, *Why Is There a Chip Shortage? Covid-19, Surging Demand Cause Semiconductor Shortfall,* (Bloomberg, 2021).

Figure 7: Event Study Model: Finished Goods Imports US-China Trade War Shocks



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

Looking at Figure 7, I contend the trade war had a negative effect on finished goods import value early on, but began a steady increase in April 2019. This is contrary to my expectation that the trade war would hurt finished goods import value. The magnitude test will be able to provide more insight into the relative effect of the shock on the selected timeline.

Table 8: Magnitude Test: Finished Goods Imports US-China Trade War Shock

US-China Trade War Shocks			
Treatment Mean	Event Window Mean	Difference	% Change
1,024,063,359	1,064,020,900	-39,957,541	-4%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

Over the course of the event window, the treatment is 4% lower than the event window. My interpretation is that the US-China Trade War negatively affected finished goods imports, but not with a high magnitude. As we have seen in each model thus far, there is likely another factor that is more highly correlated with the data. I investigated the sharp increase in finished goods import value partway through the trade-war as it goes against what I had predicted.

This trade war had negative effects on the global economy and international trade. Interestingly however, the early agreements made during the trade war required both the US and China to buy more of each country's microchips.[33] I contend that this agreement explains the increase in finished goods import value during the trade war shock period and after. Additionally, using the semiconductor industry as a start to ending the trade war limits the trade war magnitude from being greater. If we take the mean from July 2018 to Jan. 2019, compared to the rest of the timeline, this mean is 17% lower compared to the only 4% lower amount after

[33] Salitskii and Salitskaya, *The United States and China: Deadlocks and Paradoxes of Trade War* (Herald of the Russian Academy of Sciences, 2020)

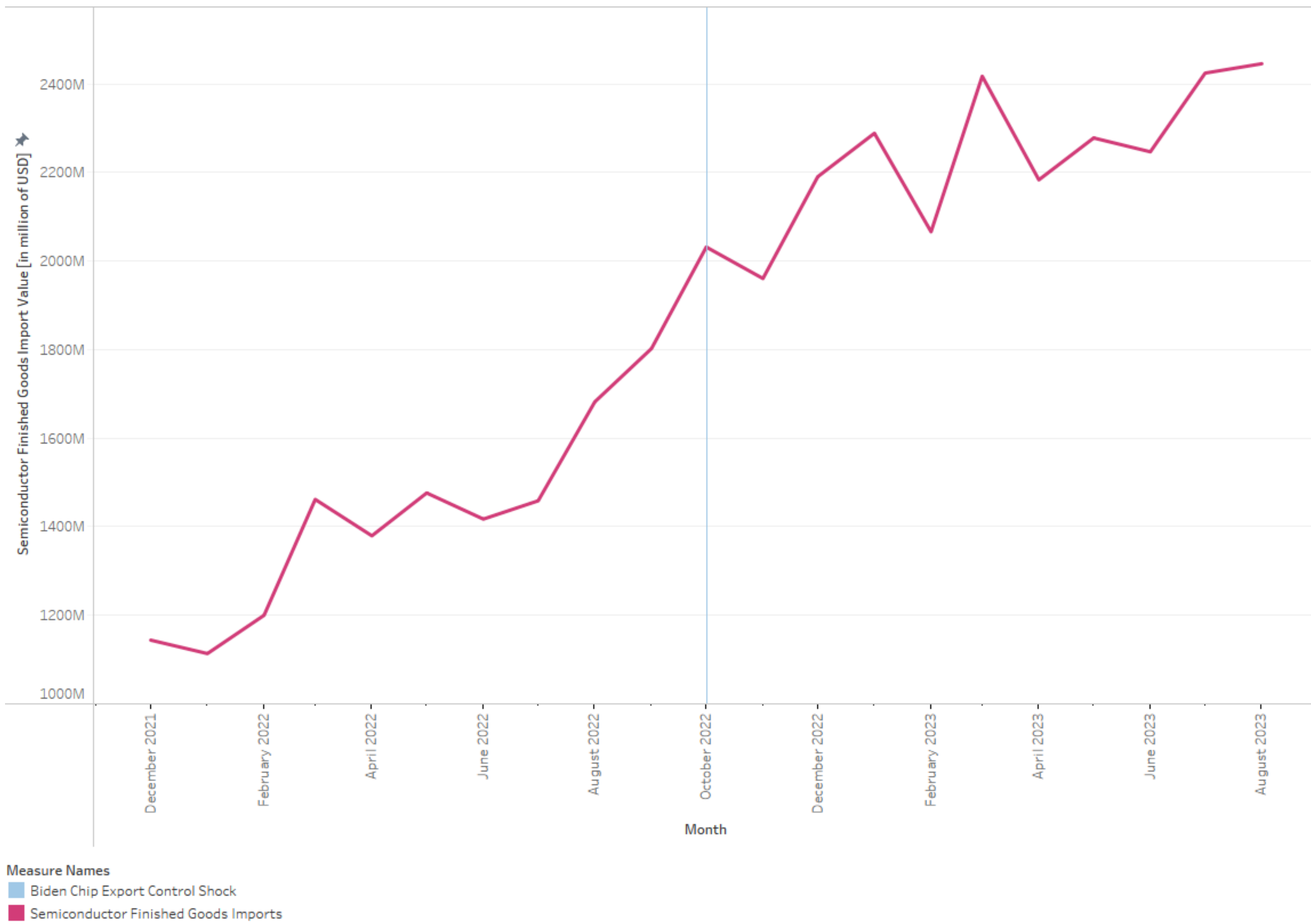
import values recover. In this situation, we not only see how vital semiconductors are to the US economy, but also to the world economy. The fact that the semiconductor industry was used as an initial means to bring the US and China out of their trade war speaks to the importance of the industry.

Analyzing both the trade war event study model and magnitude data, I conclude that the finished goods imports were sensitive to different stages of the US-China Trade War. At its worst, the shock mean was nearly 20% less than the selected timeline mean. Combining information from further research on factors outside of my model, I explained why the semiconductor industry was able to recover as semiconductor finished goods trade was used as a means of starting talks to end the trade war. The finished goods import value was then able to recover to pre-trade war values. The sensitivity to individual trade war agreements provides a possible explanation for the initial decline in value, followed by a quick recovery while still in the trade war shock period.

3.1.5: Event Study: Biden Chip Export Control

The Biden Chip Export Control, targets semiconductor chip exports. This export control measure restricts exports of US produced chips to China. A positive coefficient exists between the export control shock and finished goods imports based on Table 5.

Figure 8: Event Study Model: Finished Goods Imports Biden Chip Export Control Shock



Note: The Export Control is mandated in October 2022. It is not a sustained shock as companies almost immediately enacted work-arounds.

Source: dataweb.usitc.gov

Figure 8 shows an increase in import value in the months leading up to the export control shock. The export control may have had a month-long negative effect as it created uncertainty in supply chains, however import values continued on their trajectory thereafter.

Table 9: Magnitude Test: Finished Goods Imports Biden Chip Export Control Shock

Biden Export CHIP Control Shock			
Treatment Mean	Event Window Mean	Difference	% Change
2,031,450,149	1,841,189,230	190,260,919	10%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

The shock mean is 10% higher than that of the timeline. I offer the following explanation: the chip export control shock came at a time of substantial growth in finished goods import value, and did not have a great effect on changing that trajectory thereafter. There is weak correlational evidence that the export control shock directly affected finished goods import values. I can however offer the following explanation.

One possible explanation for the continued finished good import value increase (other than growing demand) is a derisking strategy. With this export control reminiscent of the past trade war, companies could buy excess stock levels now in expectation of future shortages. The US had one goal with this export control: make sure China stays behind in semiconductor innovation. China's retaliation to this export control has come in various forms with the goal of disrupting US semiconductor supply chains.[34] Whether this has been successful or not is outside the bounds of my research. However, semiconductor companies had reason to expect retaliation. This increased level of risk may have led to increased inventory levels to hedge against future disruptions. Again, the correlational analysis yields weak findings as factors outside the model

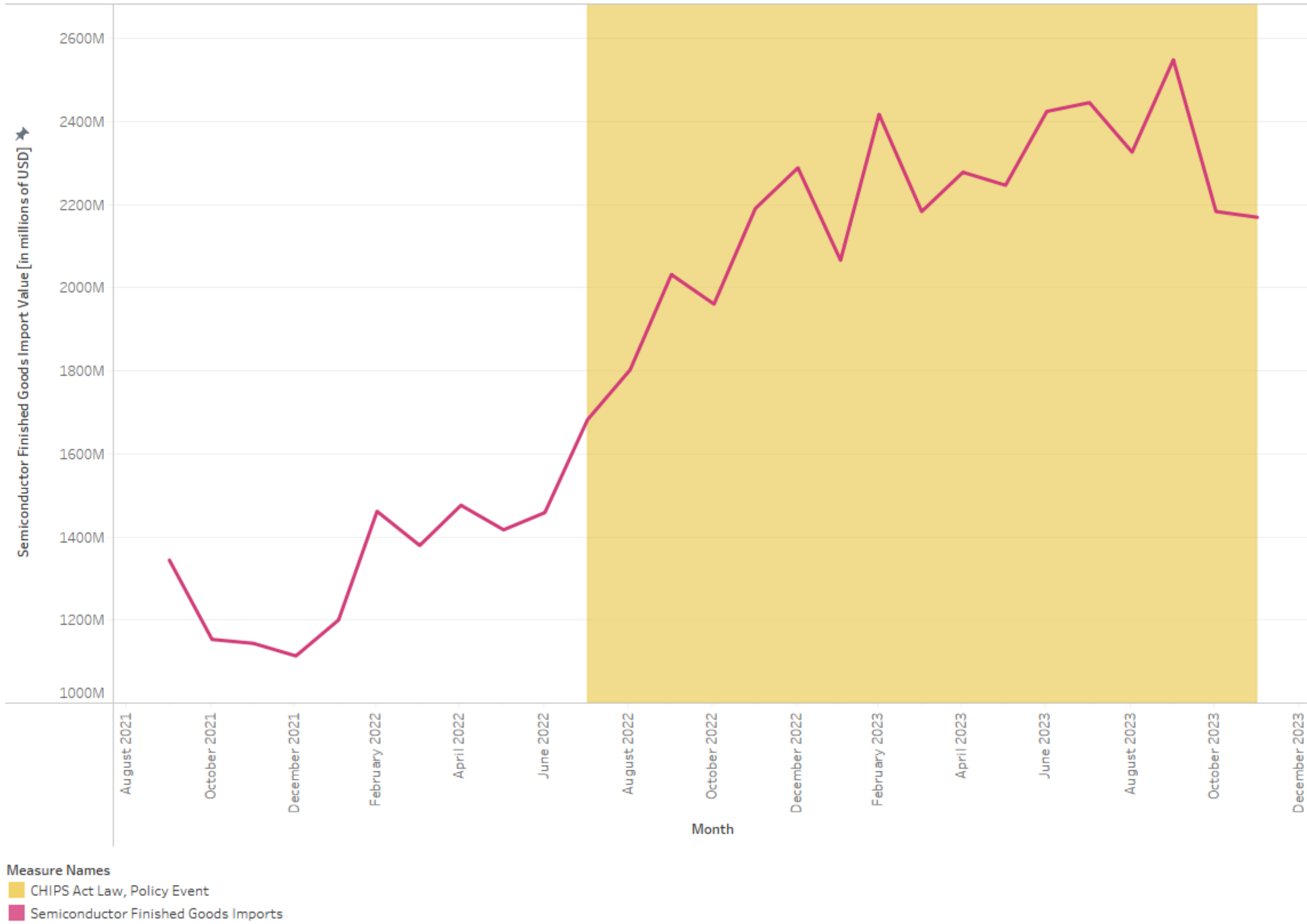
[34] Megha Shrivastava, *Decoding China's Escalation of the Chip War,* (The Diplomat, 2023)

are affecting the finished goods import value. The possible explanation I do offer is well-informed with current events and is consistent with de-risking strategies.

3.1.6: Event Study: CHIPS Act Law

Based on the regression models, this is the only time where the CHIPS Act industrial policy has had a statistically significant effect on any of the dependent variables. The event study model and magnitude test will provide insight into what is occurring.

Figure 9: Event Study Model: Finished Goods Imports CHIPS Act Law



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

Figure 9 clearly shows an increase in finished goods import value during the CHIPS Act Law period. An increase in finished goods imports is an interesting phenomenon considering the law is meant to increase US production of these finished goods. To get a sense of the magnitude of this increase, I look at the following test.

Table 10: Magnitude Test: Finished Goods Imports CHIPS Act Law Policy Event

CHIPS Act Law			
Treatment Mean	Event Window Mean	Difference	% Change
2,190,705,882	1,866,283,806	324,422,076	17%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

The CHIPS Act Law period is associated with a 17% higher mean than that of the event window. I consider this a high level of magnitude affecting semiconductor finished goods imports, especially after taking into account previous magnitude tests. The juxtaposition still remains, how does a law meant to onshore manufacturing of semiconductor products result in a comparative 17% increase in finished goods imports from offshore manufacturing facilities? This was not the category I expected to see a strong positive correlation with. The CHIPS Act mainly targets semiconductor manufacturing, so I expected to see an increase in capital goods imports. I will explore this question as a means of concluding my finished goods imports analyses.

3.1.7: Finished Goods Imports: Overall Conclusion

In drawing conclusions about finished goods imports to the US, I cannot ignore the larger amount of statistically significant shocks and policy events compared to all of the other categories I will analyze. As I mentioned, finished goods are comparatively the easiest goods to move supply chain location quickly with the least amount of disruption. The increase in finished goods imports during the CHIPS Act Law policy event could signal the beginning of the onshoring process. Companies are able to move their mobile finished goods to the US first. The movement of capital goods takes time. In addition to production facilities that are hundreds of thousands of square feet, semiconductor companies have to carefully plan the movement of their capital goods within the supply chain to eliminate or at least mitigate possible disruptions. Returning back to finished goods, they primarily only require warehousing space. Given the small size of finished goods semiconductors, the mass amount of space needed for a production facility is not needed to simply store the finished goods. If this explanation is correct, then we should see an increase in capital goods imports over time as they follow the finished goods already being shipped to the US. Concluding solely based on my analyses, I find that finished goods imports to the US are more sensitive to shocks and policy than any other category of semiconductor product. Correlations regarding shocks and finished goods import values are mixed. I observed correlations as I predicted, but there were many inconclusive models due to the complexity of semiconductor supply chains. The positive correlation between the CHIPS Act and an increase in finished goods imports was clear, and it is the strongest correlation we will see between industrial policy and the trade data.

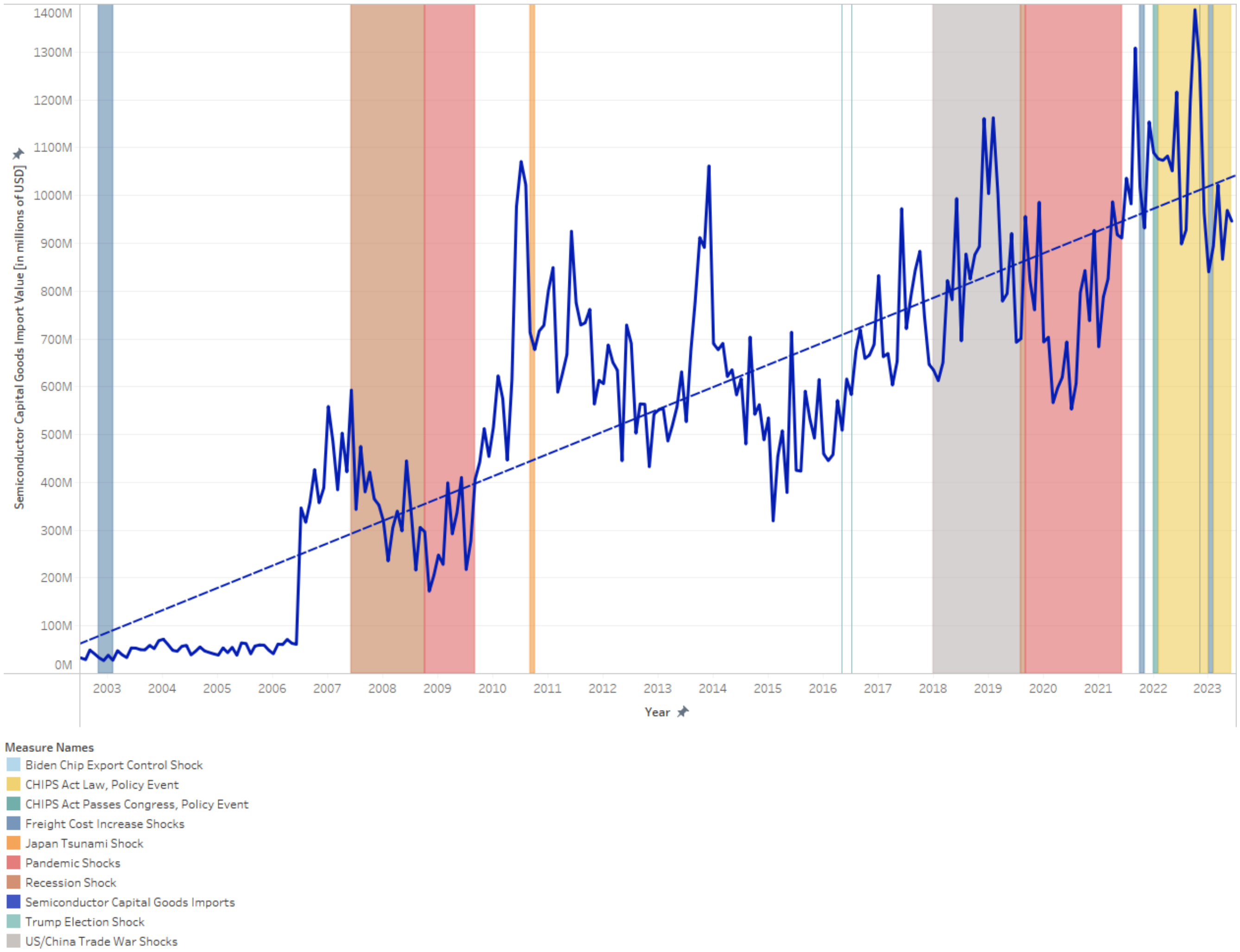
3.2: Capital Goods Imports

3.2.1: Capital Goods Imports: Overall Trend and Multivariate Regression Analysis

Before diving into the semiconductor capital goods import analysis, it is important to remember characteristics of capital goods. This is the machinery and equipment to manufacture and produce semiconductors. Because the manufacturing process is dependent on capital goods, I contend that import and values of capital goods will be more robust in light of shocks and policy. Moving this category within the semiconductor industry would take more careful planning. I expect to see fewer significant shocks, and I am speculative of the CHIPS Act effect as little time has elapsed since the law was passed.

To begin the semiconductor capital goods import analysis, I consider overall trends and statistical significance of the indicator variables. Based on the trend line in Figure 10, we can see that capital goods imports to the US have increased significantly over the 20 year timeline.

Figure 10: US Imports of Semiconductor Capital Goods



Note: This figure shows capital goods import value in millions of USD. Each indicator variable is highlighted for the duration of its occurrence.

Source: dataweb.usitc.gov

The increasing trend is a promising prospect for increased semiconductor production in the US as capital goods are necessary for the manufacturing of a product. Detailed conclusions regarding shock and policy interaction cannot be drawn from this graph, so it is necessary to refer to the regression model to identify statistically significant shocks and policy.

Table 11: Regression Results for US Imports of Semiconductor Capital Goods

Variable	Coefficient	Std. Error	t-Statistic	P-value
(constant)	49418866.476	16037011.611	3.082	0.002**
Shocks				
Freight Cost Shocks	-76226726.821	42345279.975	-1.800	0.073*
Recession Shocks	-11102692.800	29235957.074	-0.380	0.704
Pandemic Shocks	5586485.593	22380162.866	0.250	0.803
Japan Tsunami	-149057762.092	87032008.080	-1.713	0.088*
Trump Election Shock	-47300232.256	86361351.623	-0.548	0.584
US-China Trade War	23522079.321	30329916.547	0.776	0.439
Biden Chip Export Control	1020210.264	125352738.548	0.008	0.994
Policy				
CHIPS Act Passes Congress	-86130121.162	72003450.226	-1.196	0.233
CHIPS Act Law	48228053.171	36338407.154	1.327	0.186
Lag				
1-Month CG Import Lag	0.917	0.028	32.721	0.000***
R-Squared	0.869			
Adj. R-Squared	0.864			
F-Statistic	160.208			
Obervations	252.000			

*, **, *** indicate significance at 0.10, 0.05, and 0.01 levels respectively

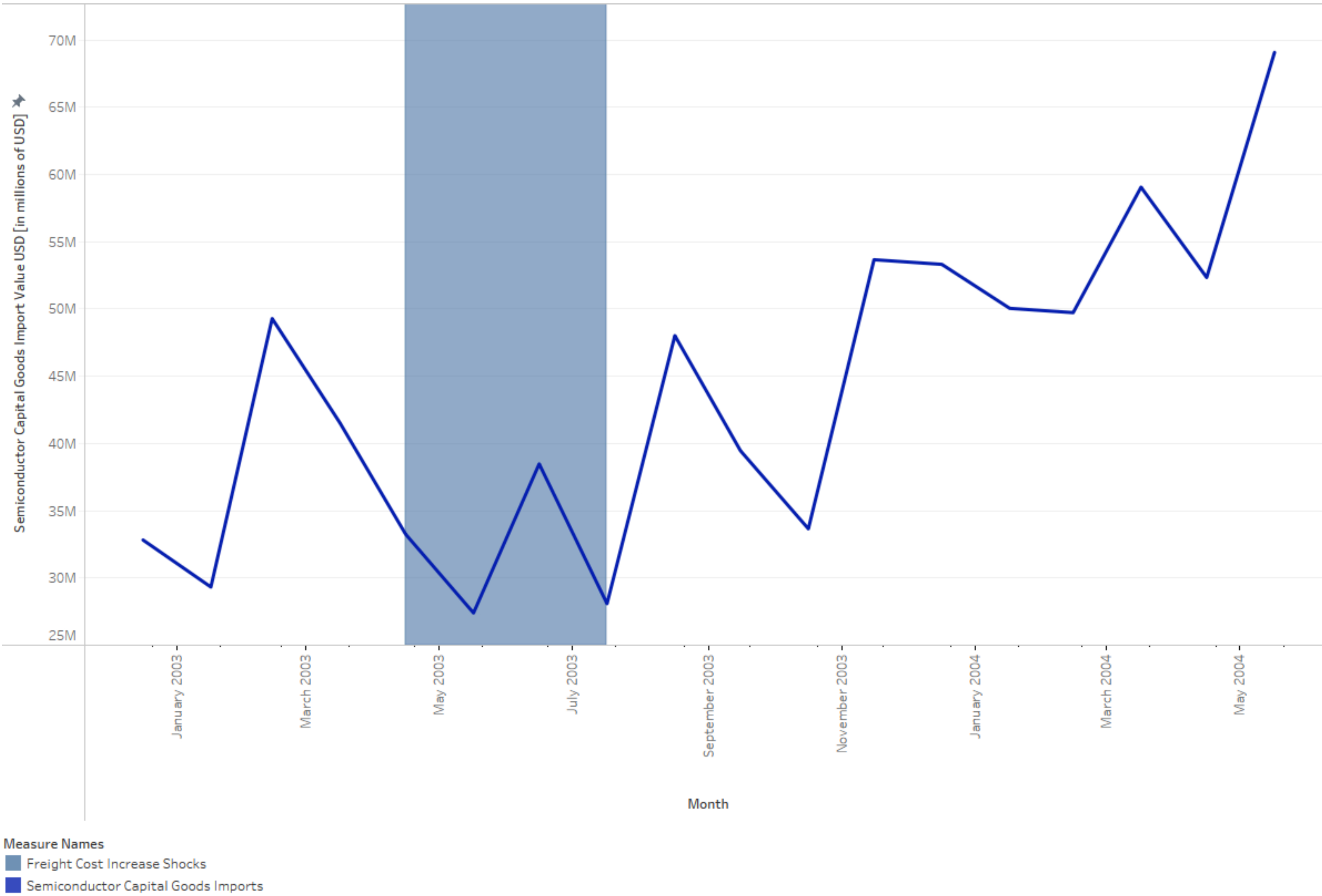
Note: Coefficient values are in dollars. Shock and policy timelines correspond to Table 1.
Source: dataweb.usitc.gov

In this regression model, the only statistically significant indicator variables are Freight Cost Shocks and the Japan Tsunami Shock. Both of these shocks are significant at the 90% significance level (P-value = 0.1). Both shocks are negatively correlated with capital good import values. Before investigating the significant shocks, I want to discuss the CHIPS Act Law variable in more detail as it appears in this regression table. There is positive correlation at the 80% confidence interval (P-value = 0.186) between the CHIPS Act Law and capital goods import value. As I have already disclosed, the recent nature of this law could be a reason why the CHIPS Act law is not more significant. While I will not analyze this as a significant variable, I will note the CHIPS Act Law as a variable with potential to become more significant as time goes on. The purpose of my research is to provide insight into current supply chain onshoring pertaining to shocks and industrial policy within the semiconductor industry . Thus far, the CHIPS Act has not proven to be significantly correlated with an increase of capital good imports based on trade data.

3.2.2: Event Study Model: Freight Cost Shocks

The first event study models and magnitude tests I examine pertain to the Freight Cost Shocks. As a reminder, freight cost increases outside two standard deviations from the mean are considered shocks. Because these shocks occur on opposite ends of the overall timeline, they will be analyzed in separate event study models and magnitude tests. These shocks occur at the beginning of the overall timeline, and there is a cluster of these shocks near the end of the timeline. The freight cost shock at the beginning of the timeline does not allow for a 10 month range before the shock, as there are only four months prior in the dataset.

Figure 11: Event Study Model: Capital Goods Imports Freight Cost Shock 1 of 2

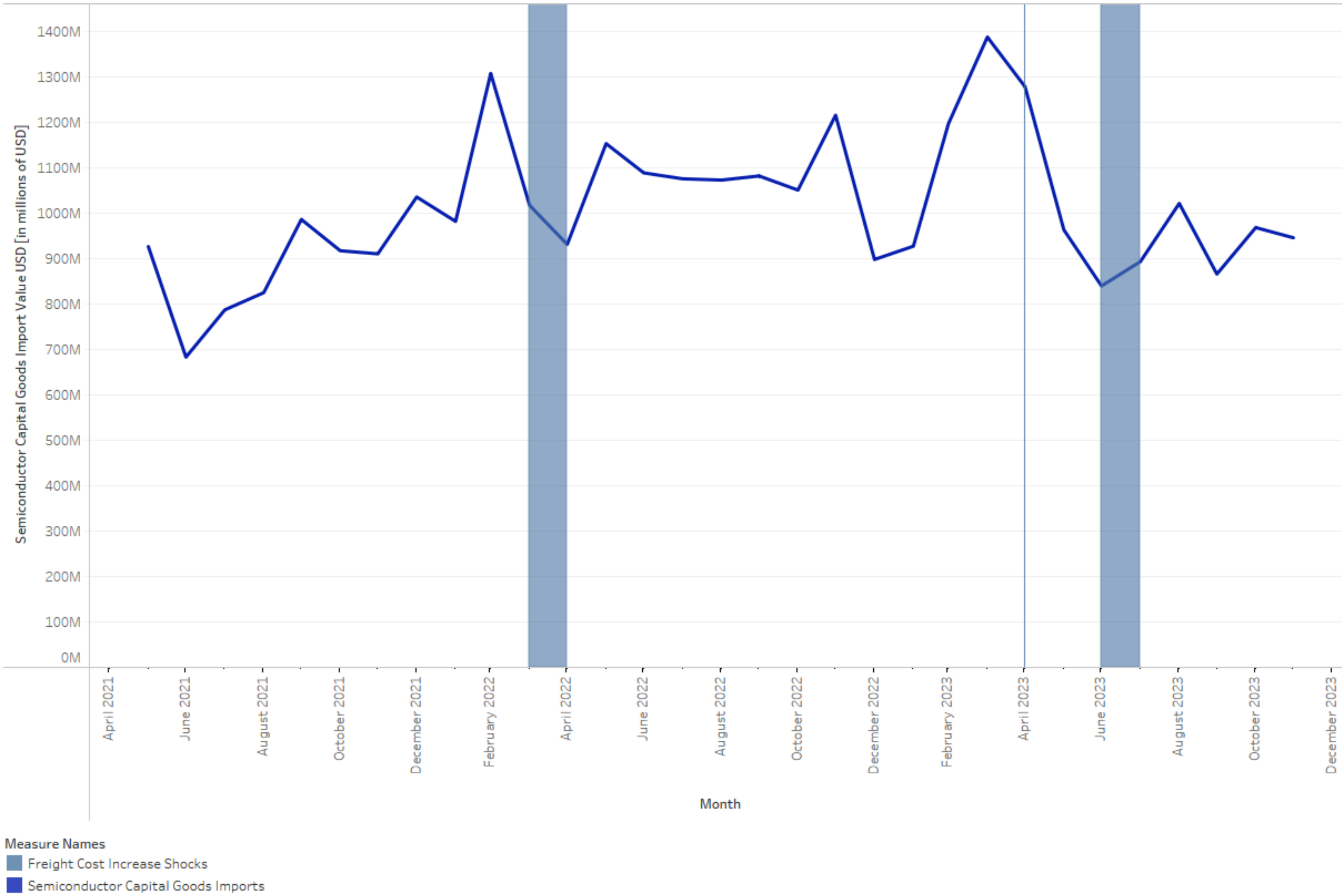


Note: See Table 1 for date range of shock or policy event.

Source: dataweb.usitc.gov

In this Figure 11, we can observe low capital goods import values compared to the data outside of the shock period. Unlike finished goods that include small wafers and chips the size of a fingernail, capital goods include lithography fabrication units that are the size of a full size pickup truck. These larger items would be more likely to be significantly affected by a shock increase in deep sea freight cost. With much of the semiconductor industry abroad in countries and regions such as China, East Asia, Taiwan, and Japan, deep sea freight is the only way to cost effectively ship many capital goods machinery components. I speculate that semiconductor companies may wait to ship these large capital goods until the deep sea freight cost fluctuates to a more favorable level. The second cluster of freight cost increase shocks display a similar phenomenon. Because the final shock is 4 months from the end of the dataset, only four months following the last shock period is included in the selected timeline.

Figure 12: Event Study Model: Capital Goods Imports Freight Cost Shock 2 of 2



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

In this Figure 12, we see a pattern where freight cost shocks are associated with lower capital goods import values compared to periods before and after where prices stabilize. The single shock occurrence in April 2023 is an exception in that The next shock occurs around a month later. I contend this would not give a supply chain time to react to the fluctuations, so consequently we observe a downward trend all the way through the shock beginning of the last treatment in Figure 12. In both freight cost increase shock models, there appears to be a consistent negative correlation between freight cost increases and capital goods import values. The magnitude test will give us an idea of how much the shock affects each timeline.

Table 12: Magnitude Tests: Capital Goods Imports Freight Cost Shocks

Freight Cost Shock 1/2			
Treatment Mean	Event Window Mean	Difference	% Change
31,807,075	43,810,233	-12,003,158	-27%

Freight Cost Shock 2/2			
Treatment Mean	Event Window Mean	Difference	% Change
992,582,576	1,008,123,121	-15,540,545	-2%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

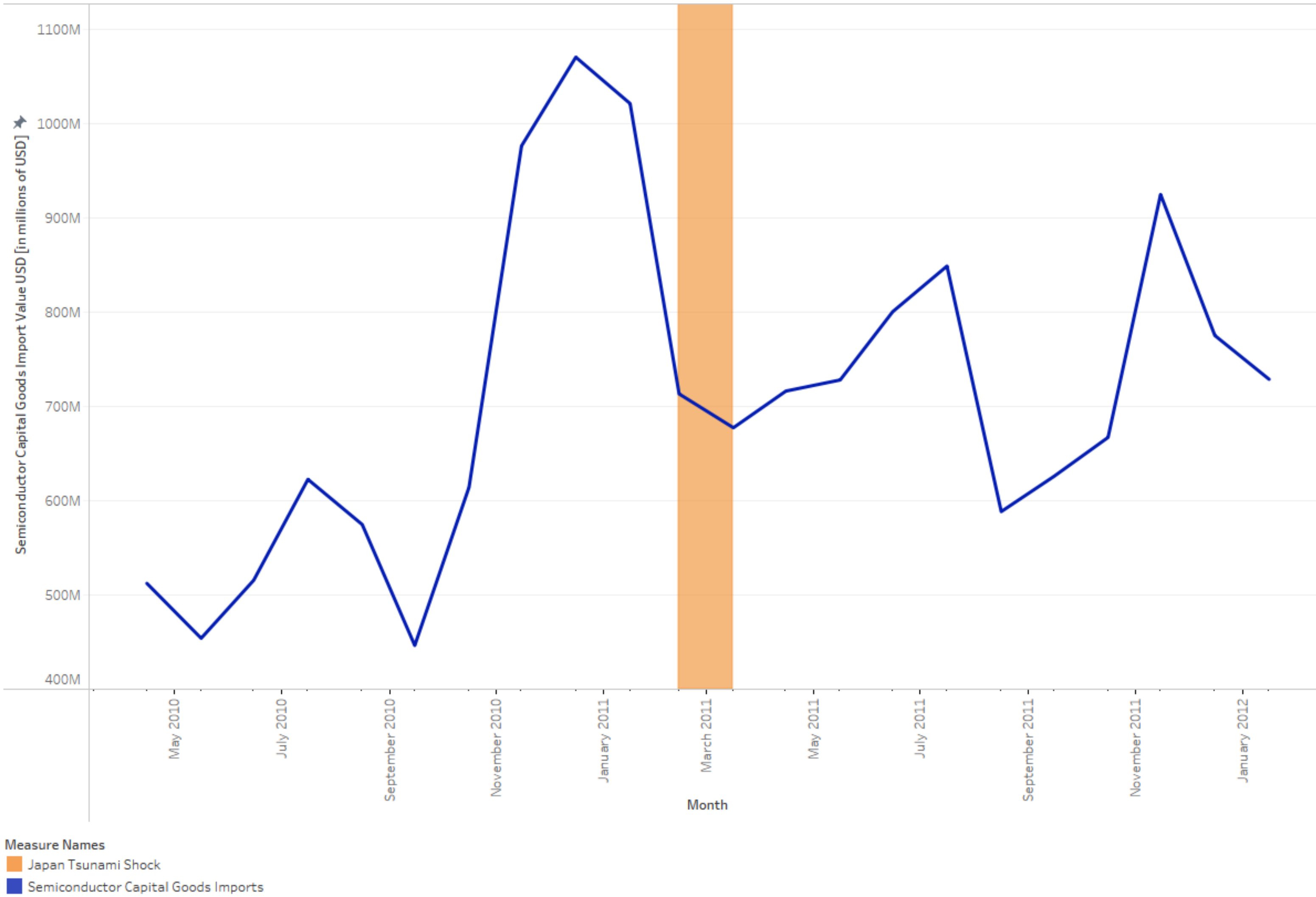
The first freight cost shock yields a higher magnitude than the second. Interestingly, each shock results in a similar difference between the treatment and event window. The overall volume in the second freight cost event window is over 20x higher than the first. This is reflected in the first freight cost shock being associated with a 27% lower capital good import value compared to only a 2% decrease in the second.

Upon analyzing these event model studies and magnitude tests, it is apparent that freight increase shocks are negatively correlated with capital goods import value. The magnitudes of the correlations vary due to industry growth over time, but the similar exists. These shocks have also produced consistent results, something that was not common amongst finished goods import shocks.

3.2.3: Event Study: Japan Tsunami Shock

The Japan Tsunami event study model in Figure 13 shows the tsunami occurring at a point of lower capital goods import value, and then increasing after the tsunami hits Japan.

Figure 13: Event Study Model: Capital Goods Imports Japan Tsunami Shock



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

This is a puzzling result, as I expected to see a lag in the decrease of capital goods import value. In this case, the drop in value proceeds the shock period. The shock period itself occurs in a trough in the data, but capital goods import value increases again thereafter. Outside factors of the model make this correlational analysis largely inconclusive. However, a de-risking scenario could provide insight into these trends. I speculate that weather forecasts of this natural disaster could have triggered derisking strategies. Capital goods supply chains importing goods into the US may have been reconfigured to provide supply without relying on Japan. This is consistent with de-risking theory, but there is no direct research to back these claims. Using this logic however, we can also make sense of the magnitude test.

Table 13: Magnitude Test: Capital Goods Imports Japan Tsunami Shock

Japan Tsunami Shock			
Treatment Mean	Event Window Mean	Difference	% Change
695,581,531	709,458,059	-13,876,528	-2%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

Here, we see that the treatment mean is only 2% smaller than the event window mean. Given this, I propose two possible explanations the correlational analysis fails to capture. The first explanation is that de-risking strategies were timely and successful. This would help mitigate the negative effects of this shock. Considering this tsunami hit in March, yet the industry as a whole still hit record annual numbers despite the disruption of US supply chains to major producer Japan, this conclusion is plausible. The other possible explanation is that Japan is not a large exporter of capital goods, rather they import them and utilize them for increased finished goods output. This would reflect the low magnitude as Japan would not be seen as a critical part of the supply chain for capital goods.

While the predicted negative correlation is present, the trends before and after the shock adds limitations to my analysis. Factors that caused the dip in capital goods import value before the tsunami and factors that caused the quick recovery after this devastating natural disaster are likely outside the scope of my model. The explanations I offer are consistent with theoretical scenarios, but require further research to reach anything conclusive.

3.2.4: Capital Goods Imports: Overall Conclusion

I have now provided a thorough analysis into the statistically significant indicator variables affecting capital goods import values over the 20 year timeline. As I suspected, capital goods had less significant shocks that changed the trajectory of the category. Moving capital goods takes time, and assuming shocks are not permanent, it may prove advantageous for companies to "wait out" these shocks rather than plan to de-risk. The shock and aftermath could be over by the time a strategic plan is made.

While both shocks were negatively associated with capital goods import value, only increased freight cost shocks provided consistent correlations across all treatment periods. The strong negative correlation suggests that increased freight cost shocks are associated with lower capital goods imports. Zooming out from the event study models, the overall growth of the semiconductor capital goods was rather unphased by the shocks.

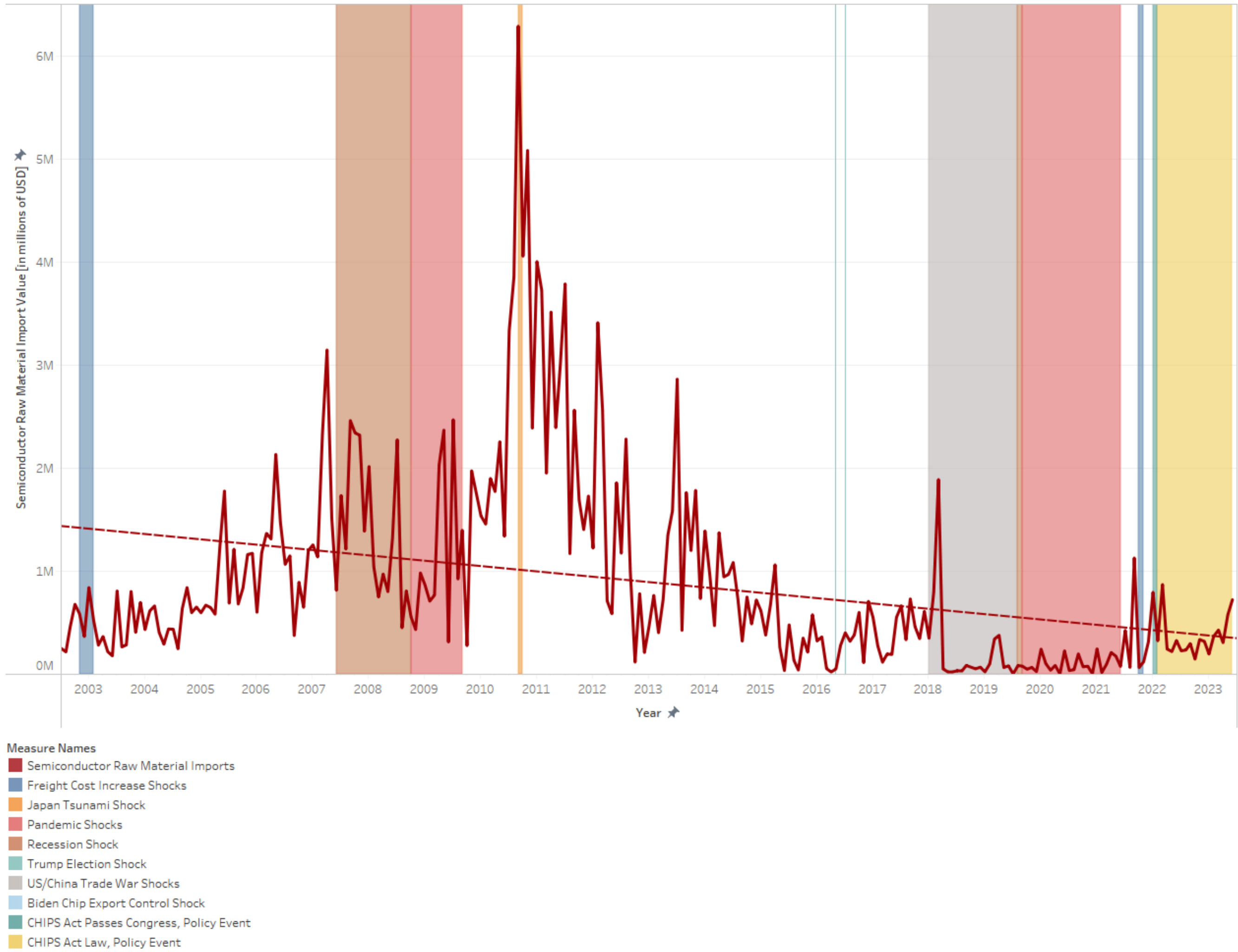
The CHIPS Act Law has not yet yielded a significant effect on increasing capital goods import values. In addition to what I have already discussed, another challenge making it difficult for the CHIPS Act to yield a significant effect is the growth trajectory of the industry. The law would also have to provide increased capital goods imports beyond growth the industry is naturally experiencing in order to be significant.

3.3: Raw Material Imports

3.3.1: Raw Materials Imports: Overall Trend and Multivariate Regression Analysis

Before examining my event window models, I again look at the overall trend across the timeline, and at the multivariate regression analysis for semiconductor raw material imports. When looking at the overall trend, I identify a decrease in raw material imports over 2003 to 2023.

Figure 14: US Imports of Semiconductor Raw Materials



Note: This figure shows raw material import value in millions of USD. Each indicator variable is highlighted for the duration of its occurrence.

Source: dataweb.usitc.gov

Figure 14 shows a spike in raw material imports in 2011. If my indicator variables within the model do not shed light on this spike, I will provide further reasoning following the discussion of the event models. With this overall trend analysis, we can identify general trends such as a decrease in raw material imports during the first recession shock, or continually low imports during the second pandemic shock. However, this graph does not shed light on the statistical significance of each shock on raw material import value. The following table shows the multivariate regression for raw material semiconductor imports to the US.

Table 14: Regression Results for US Imports of Semiconductor Raw Materials

Variable	Coefficient	Std. Error	t-Statistic	P-value
(constant)	413240.469	73193.842	5.646	0.000***
Shocks				
Freight Cost Shocks	-264232.831	228304.195	-1.157	0.248
Recession Shocks	90823.149	157489.659	0.577	0.565
Pandemic Shocks	-218686.845	122328.877	-1.788	0.075*
Japan Tsunami	1664107.176	506483.192	3.286	0.001***
Trump Election Shock	-278241.013	465784.148	-0.597	0.551
US-China Trade War	-323101.469	157420.886	-2.052	0.041**
Biden Chip Export Control	-506934.316	674225.152	-0.752	0.453
Policy				
CHIPS Act Passes Congress	-94900.292	469716.464	-0.202	0.840
CHIPS Act Law	-192553.609	179115.313	-1.075	0.283
Lag				
1-Month RM Import Lag	0.610	0.051	12.083	0.000***
R-Squared	0.555			
Adj. R-Squared	0.537			
F-Statistic	30.072			
Obervations	252			

*, **, *** indicate significance at 0.10, 0.05, and 0.01 levels respectively

Note: Coefficient values are in dollars. Shock and policy timelines correspond to Table 1.
Source: dataweb.usitc.gov

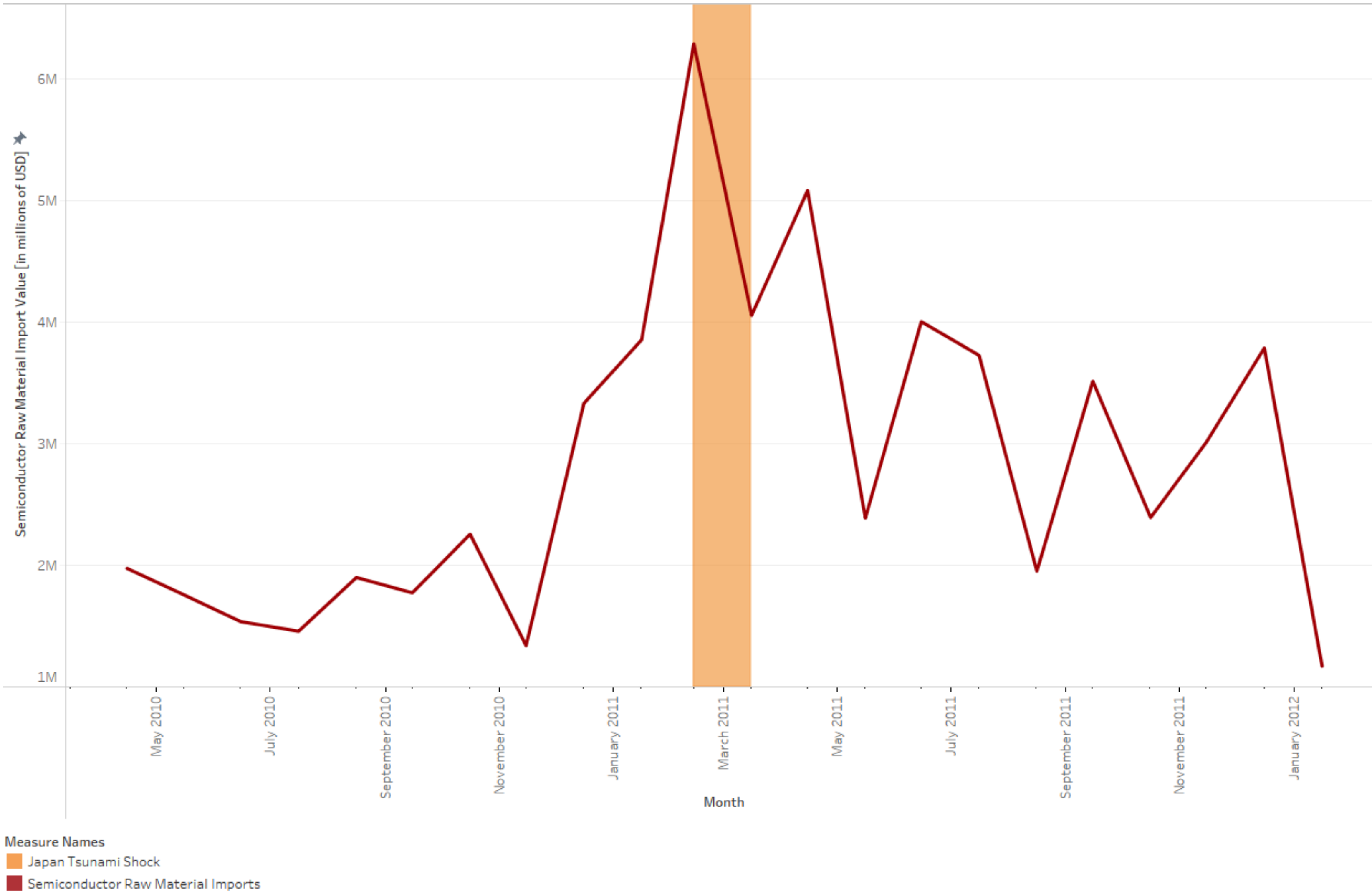
Table 14 identifies shocks with varying levels of statistical significance. The Japan Tsunami is associated with the import value at a 99% confidence level. Looking for further significant indicators variables, we have the US-China Trade War Shocks correlating at a 95% confidence interval. The regression also shows Pandemic Shocks as being significant at the 90%

confidence level. The high confidence values in these shocks yield a need for further investigation into the magnitude of the shocks.

3.3.2: Event Study Model: Japan Tsunami Shock

As mentioned, the Japan Tsunami Shock is correlated with a change in raw material import value at the 99% confidence interval. To further investigate this, I utilize an event study model in Figure 15.

Figure 15: Event Study Model: Raw Material Imports Japan Tsunami Shock



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

In this model, we see a significant decrease in raw material imports of semiconductors as soon as the tsunami hits Japan. Japan was an epicenter of semiconductor research and production at the time. Unlike other possible explanations I have provided for other shocks, we do not see a lag in this graph after the shock period begins. This model suggests that the increasing trajectory of raw material imports were abruptly stopped due to the tsunami. In the months following the tsunami, I also observe that the import values struggle to bounce back to pre-tsunami levels. While other variables could have played a role in this change in trajectory, the combined evidence of Japan being a major semiconductor development and manufacturing hub with the 99% confidence level from the multivariate regression model strongly suggests the Japan Tsunami shock played a role in the change in semiconductor raw material import value to the US.

I expect the magnitude test for this shock to be inconclusive due to the shock occurring at a relative maxima. By nature of this, I suspect the event window mean to be lower than the treatment mean despite the shock being correlated with a clear decrease in import value.

Table 15: Magnitude Test: Raw Material Imports Japan Tsunami Shock

Raw Material Imports: Japan Tsunami Shock			
Treatment Mean	Event Window Mean	Difference	% Change
5,171,275	2,842,877	2,328,398	82%

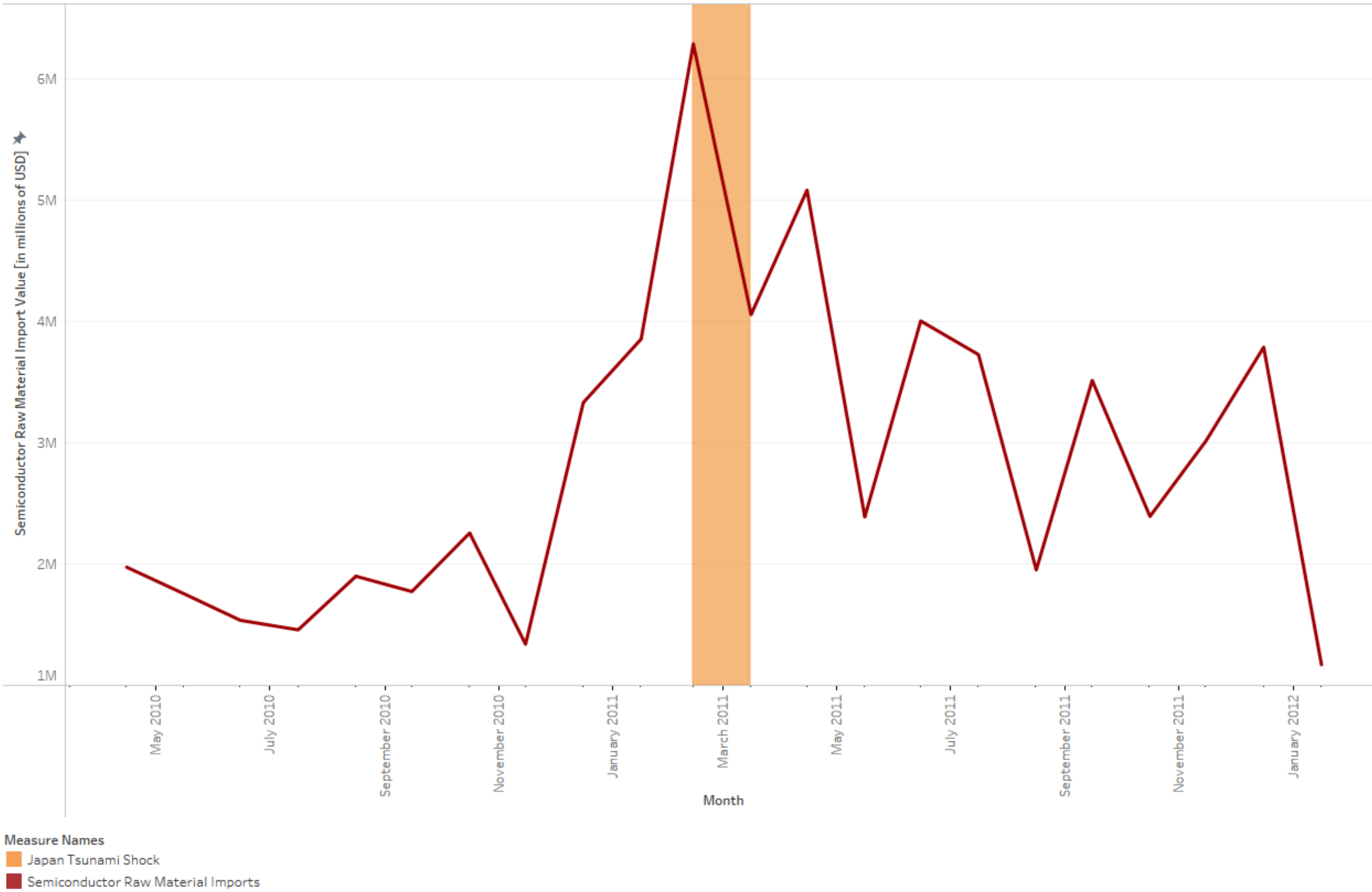
Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

As expected, the treatment mean is 82% higher than the timeline mean despite the decrease in import value over the course of the shock and after. The results of this equation will be compared with caution due to the fact this range includes the highest values in the overall raw material import value graph. While the shock mean is a higher value, if we combine this equation with the event study model, there is a decrease in value after the treatment period begins. This correlational analysis shows a negative correlation between the Japan tsunami shock and raw material imports values. The magnitude test is not useful for comparison due to the reasons covered above, but it does shed light on the relative drop in the timeline following the tsunami.

3.3.3: Event Study: US-China Trade War Shocks

Statistically significant at the 95% confidence interval are the US-China Trade War Shocks. For these shocks, Table 14 reflects a negative coefficient; this is consistent with the overall concept of trade wars decreasing levels of trade. I further probe this correlation with another event study model.

Figure 16: Event Study Model: Raw Material Imports US-China Trade War Shocks



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

In Figure 16, I observe a spike in imports followed by relatively low levels of raw material imports thereafter. This spike can be explained by ordering a surplus at the beginning of a risk event in order to have better supply chain resilience during times of uncertainty. While other factors could have caused this spike, the spike is still consistent with derisking theory. Furthermore, we see the import value drop between 1-2 months following the inception of the shock period. This reflects the time it takes for a supply chain to plan its strategic movements and changes due to increased risk.

With this model visually supporting the negative correlation from the regression, the magnitude test will provide further insight.

Table 16: Magnitude Test: Raw Material Imports US-China Trade War Shocks

US-China Trade War Shocks			
Treatment Mean	Event Window Mean	Difference	% Change
227,962	242,362	-14,400	-6%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

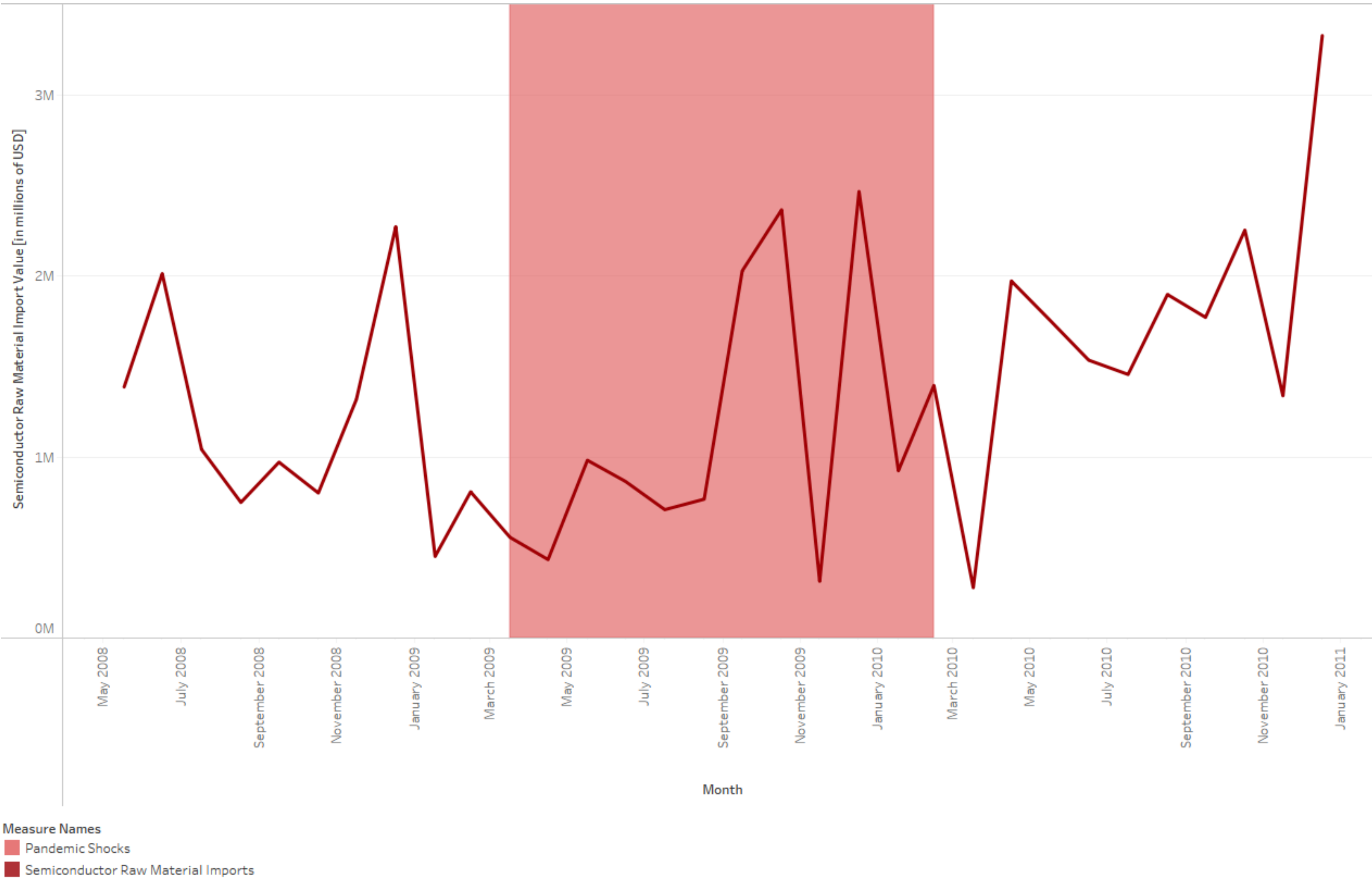
Compared to the surrounding timeline, even with the initial spike in import value, there is a 6% decrease in raw material import value. Importantly, inputs have not undergone their value added process yet. The 6% shrinkage pre-value added will only compound to become larger detrimental effects further down the production process. Based on this model and equation, I can conclude that there is an apparent association between the US-China Trade War Shocks and raw material imports. Additionally, the model may reflect possible de-risking strategies being utilized in anticipation of further supply chain risks.

3.3.4: Event Study: Pandemic Shocks

The final statistically significant shocks for raw material imports are the pandemic shocks. These shocks are significant at the 90% level and occur years apart from each other. They are analyzed in two separate event study models. The Table 14 reflects a negative coefficient for this variable, so I expect to see a drop in import value during pandemic shock periods. I will analyze both event study models first before exploring each respective magnitude.

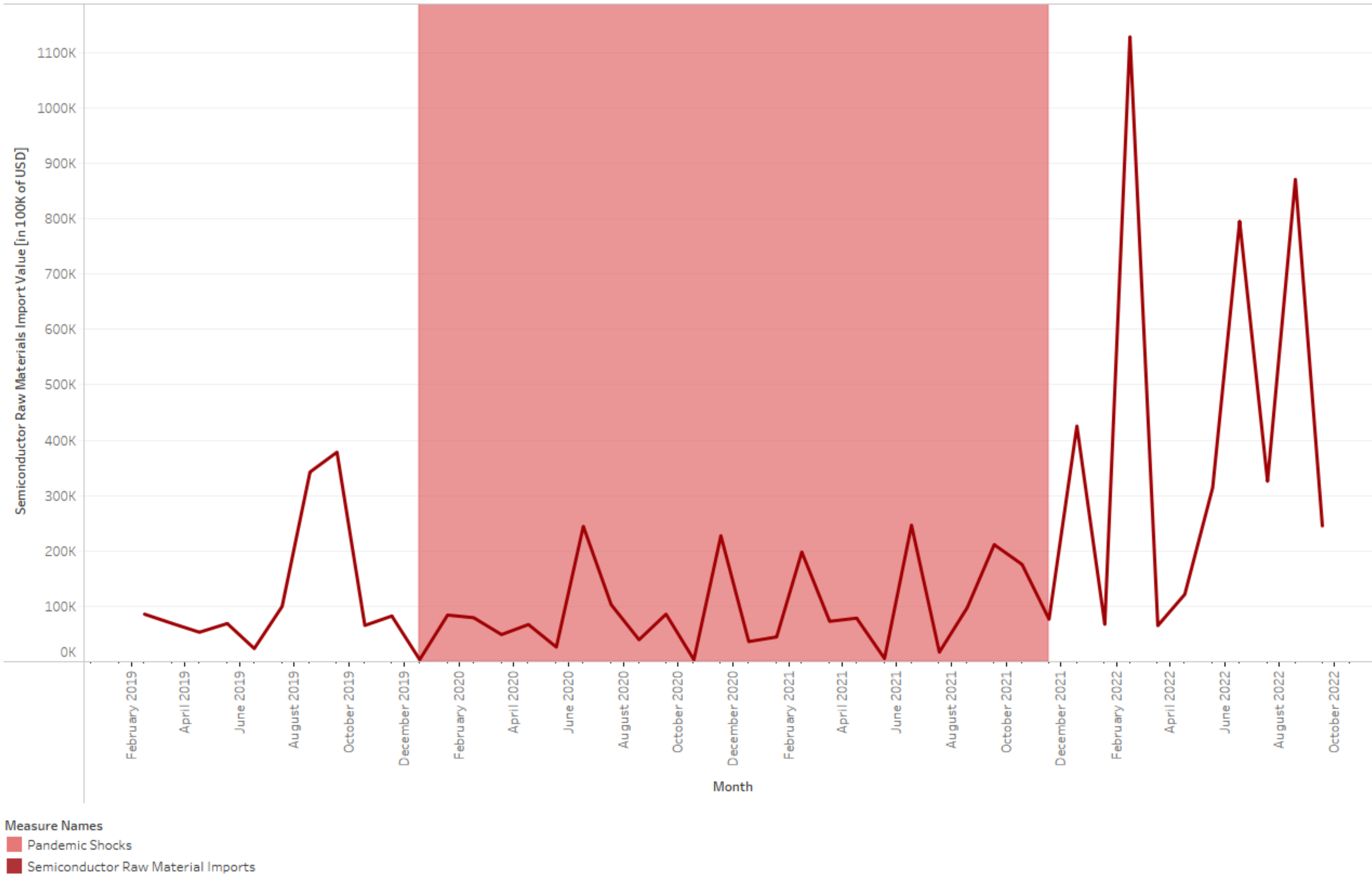
In Figure 17, any correlation that may exist is very weak during the shock period. The fluctuating trend continues throughout the time scale. Because this graph does not provide much insight, I look to the second pandemic shock and magnitude tests for further information.

Figure 17: Event Study Model: Raw Material Imports H1N1 Pandemic 1 of 2



Note: Coefficient values are in dollars. Shock and policy timelines correspond to Table 1.
Source: dataweb.usitc.gov

Figure 18: Event Study Model: Raw Material Imports Covid-19 Pandemic 2 of 2



Note: Coefficient values are in dollars. Shock and policy timelines correspond to Table 1.
Source: dataweb.usitc.gov

Contrasting from the H1N1 shock, the Covid-19 pandemic shock in Figure 18 looks to be associated with consistently low import value. The shock period ends once vaccines become available to the general public. After this, we see an increasing amount of import value. I reason that this is because during the pandemic, mines and refineries around the world were shut down. Many industries sat idle before vaccines became available. After vaccines had been largely distributed, industries began to start back up again. I contend we see this same phenomenon happening to semiconductor raw material imports. The Covid-19 pandemic shock looks to have a stronger correlation with low import values than the H1N1 Pandemic shock does. Further inspection of the evaluative equations will provide insight into the respective magnitudes of each shock.

Table 17: Magnitude Tests: Raw Material Imports Pandemic Shocks

Pandemic: H1N1			
Treatment Mean	Event Window Mean	Difference	% Change
1,151,769	1,351,411	-199,642	-15%

Pandemic: Covid-19			
Treatment Mean	Event Window Mean	Difference	% Change
94,814	179,650	-84,836	-47%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.

Source: dataweb.usitc.gov

The magnitude test provides very useful insight. Before comparing results, it highlights the limitations of visual analysis of the event study models alone. It was difficult to identify any clear correlation in the H1N1 Pandemic Shock event study model, however the treatment mean is 15% smaller than the event window mean. In the Covid-19 Pandemic Shock magnitude test the change is much higher. This pandemic is associated with an almost 50%

lower treatment mean compared to the event window. Using both the event study model and magnitude test, it is clear that both pandemics have had a negative effect on semiconductor raw material import value. The disruption in raw materials during the Covid-19 Pandemic may have played a role in the shortages of semiconductor chips. The correlational analysis of the pandemics shock yields consistent and substantial insight.

3.3.6: Raw Material Imports Conclusion

These analyses provide largely consistent findings regarding the effects of shocks and raw material import value. Putting aside the Japan Tsunami Shock for a moment, we clearly observe negatively correlated shocks on raw material import value. The shock variable with the highest magnitude is the Covid-19 Pandemic Shock. This provides insight into the disruption the Covid-19 Pandemic has caused in the raw material stage of the semiconductor supply chain.

The Japan Tsunami poses a challenge to my analysis due to the nature of the dataset. The magnitude analysis shows an 83% higher shock mean compared to the timeline mean. Again, I do not interpret this to mean the tsunami caused the higher mean. Rather, I am more focused on the sharp decline in import value following the tsunami. I suspect this could be correlated with the effects of the tsunami, but acknowledge the high likelihood of other variables outside what is being measured in the model. Upon further research, I found that 2011 was a record breaking year for the semiconductor industry. In 2011, semiconductor sales reached an all-time high; the market was experiencing massive demand. Additionally, due to aggressive spending of over $9.1 billion by Intel and Samsung North America, the North American continent took the top spot in growth for the year.[35] Considering this, I find it likely that the demand caused by Intel and Samsung spending was driving the increase in raw material imports to the US. The Japan

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[35] Lara Chamness, *2011: A Look Back at the Semiconductor Equipment and Materials Market and Outlook* (Semiconductor Engineering, 2013)

Tsunami Shock then caused a supply chain disruption to this demand, suggesting a causal mechanism to the decrease in import value following the shock. I expect to see continued conflation of a record year in spending from North America in 2011 and the Japan Tsunami of 2011.

Altogether, these shocks show evidence of negative correlation in raw material imports to the US. Shocks were more significant, statistically and in magnitude, than US industrial policy. Based on the correlational analyses performed for raw material inputs, there are consistent findings for the pandemic shocks and the US-China Trade War shocks. Both of these shock groups produced a negative effect on raw material imports with considerable magnitude. The Japan Tsunami presented measurement challenges with no clear conclusion without looking to elements outside the model.

Chapter 4: Semiconductor Export Analysis and Onshoring

4.1: Finished Goods Exports

4.1.1: Finished Goods Exports: Overall Trend and Multivariate Regression Analysis

I do not expect finished goods exports to have substantial findings due to the fact that the US is not a leading producer of semiconductors. Reviewing what happened in 2011, we find that this is the last time companies in North America led the industry in spending and development. If we do see statistically significant shocks on finished goods exports, I expect them to occur in that timeframe.

Figure 19: US Exports of Semiconductor Finished Goods

Note: This figure shows finished goods export value in millions of USD. Each indicator variable is highlighted for the duration of its occurrence.

Source: dataweb.usitc.gov

Based on Figure 19, finished goods exports have been dropping over the past 20 years. A period of increased finished goods exports can be observed from around 2006 to the end of 2011. Outside of this range, finished goods exports have fluctuated around what appears to be a consistent mean. The multivariate regression model will show which, if any, of the shocks or policy events are statistically significant.

Table 18: Regression Results for US Exports of Semiconductor Finished Goods

Variable	Coefficient	Std. Error	t-Statistic	P-value
(constant)	58597842.205	13729771.380	4.268	0.000***
Shocks				
Freight Cost Shocks	-15177692.937	15736268.237	-0.965	0.336
Recession Shocks	13421675.037	10768000.966	1.246	0.214
Pandemic Shocks	4601355.063	8204298.009	0.561	0.575
Japan Tsunami	67179761.429	32141571.412	2.090	0.038*
Trump Election Shock	-17304886.039	31798763.884	-0.544	0.587
US-China Trade War	-8032303.224	10498369.049	-0.765	0.445
Biden Chip Export Control	-31463437.957	46175113.896	-0.681	0.496
Policy				
CHIPS Act Passes Congress	-2494646.243	26248462.231	-0.095	0.924
CHIPS Act Law	-610407.260	12029965.366	-0.051	0.960
Lag				
1-Month FG Export Lag	0.882	0.027	32.617	0.000***
R-Squared	0.833			
Adj. R-Squared	0.826			
F-Statistic	120.082			
Obervations	252.000			

*, **, *** indicate significance at 0.10, 0.05, and 0.01 levels respectively

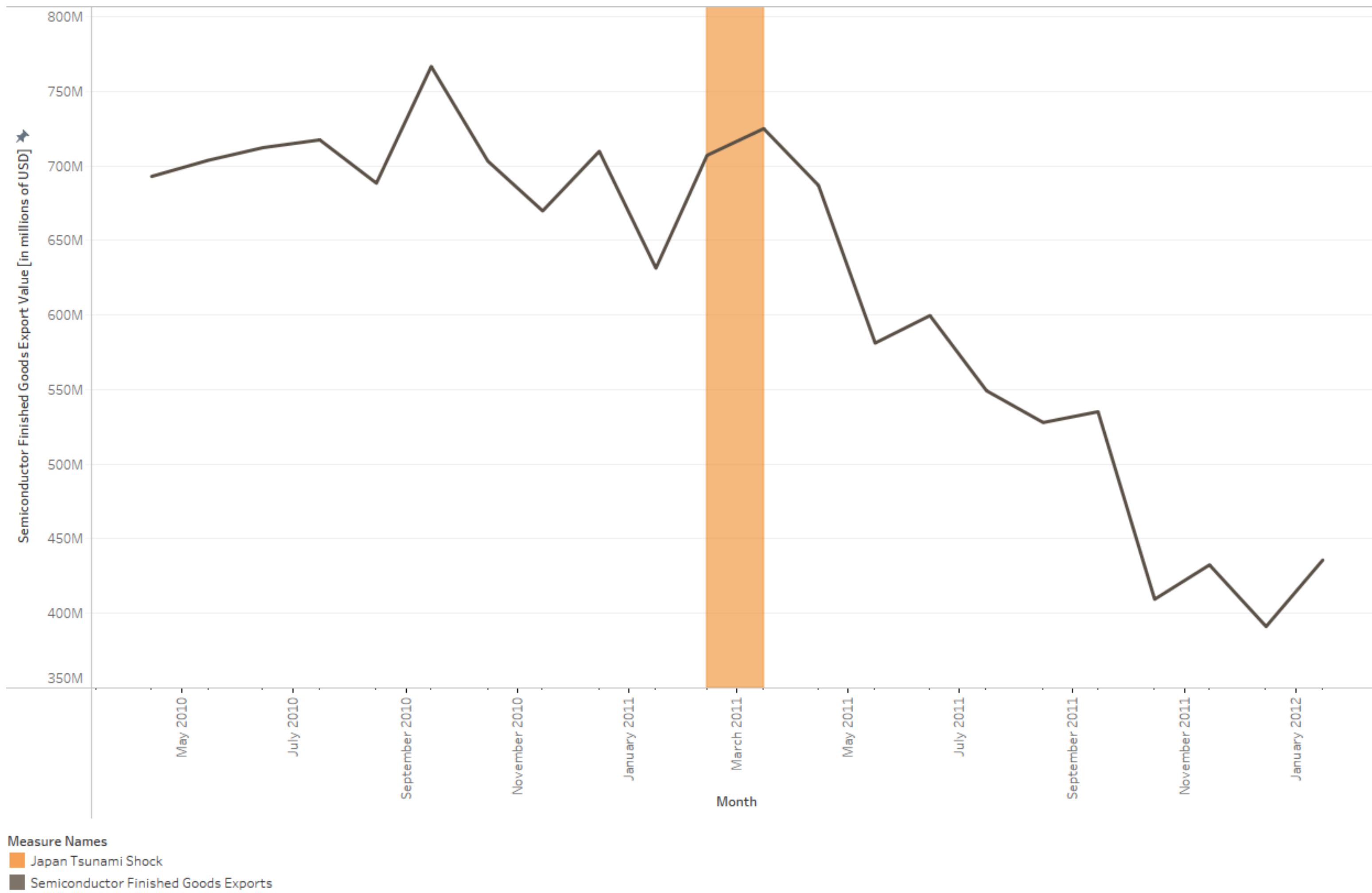
Note: Coefficient values are in dollars. Shock and policy timelines correspond to Table 1.
Source: dataweb.usitc.gov

This regression model indicates the Japan Tsunami Shock as the only statistically significant indicator variable on the dependent variable of semiconductor finished goods export value. Again, the tsunami is positively correlated with the dependent variable. To further investigate, I again utilize an event study model and magnitude test.

4.1.2: Event Study: Tsunami

The Japan Tsunami Shock has proven to be an outlier in terms of the dataset. This has made it harder to reach conclusive findings as values are not consistent with other statistically significant indicator variables. Figure 20 is no exception to this.

Figure 20: Event Study Model: Finished Goods Exports Japan Tsunami Shock



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

The shock period itself shows an increase in finished goods exports, however the following 10 months following the shock is also accompanied by a decrease in export value. I expected to see an increase in finished goods exports following the tsunami to make up for supply that was destroyed and disrupted in Japan. I evaluate the magnitude test looking for clarity.

Table 19: Magnitude Test: Finished Goods Export Japan Tsunami Shock

Japan Tsunami Shock			
Treatment Mean	Event Window Mean	Difference	% Change
716,073,361	617,157,867	98,915,494	16%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

The magnitude test reinforces what is observed in the event study model. The shock takes place at a level of export value that is 16% higher than the mean event window. There is a weak positive correlation present that can not be accurately described by the model variables. In attempting to explain this data, I look to variables outside the and back to trends in US semiconductor exports for 2011. We already know that 2011 was a record year for the semiconductor industry with Intel and Samsung NA posting record spending amounts. However, US exports of finished goods may be an indicator of how much of the Intel and Samsung spending came to product fruition. I will explore this idea more as I conclude my findings on capital goods export value.

4.1.3: Finished Goods Exports: Overall Conclusion

As we saw, the overall trend of finished goods exports has decreased over the past 20 years. To explain the overall trend, and the drop in export value following the Japan Tsunami in 2011, I look back to the literature for information. A report released by the Center for Public

Policy Innovation claims that in 2010, it would be $1 billion more expensive to build and operate a semiconductor manufacturing facility in the US compared to other countries abroad. Also, the report claims that other countries invested more in education to provide highly skilled workers that can spark innovation within the industry. In 2010, they found the US had a shortage of such educated workers.[36] These implications would pose a challenge to any investment in semiconductor production in the US during this time period. A possible explanation for the increase in spending by Intel and Samsung in 2011 but the decrease in export value are in fact these challenges. There was a shortage in the highly educated workforce in the US to drive product innovation. Additionally, higher cost projections would take from any company's bottom line with no subsidies at this point in time.

To support this possible explanation, I look further into the trends of the semiconductor industry in the US as predicted in 2010. Less than a year before the drop in semiconductor export value occurred, Bob Gartner, former VP at the Gartner analyst firm, predicted that by 2014 there would be a mere 10 companies operating on the leading edge of semiconductor production in the US.[37] Putting this into context, fast forward to today, the US has nine of the top 20 largest semiconductor companies. Of these nine, seven are dedicated purely to research and design, with only two producing finished products[38]. Gartner's prediction has played out to be even more grim today. While the US may be capable of supporting innovation through research in the semiconductor industry, the US only houses two semiconductor companies on the leading edge of production.

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[36] Center for Public Policy Innovation, *The Decline in Semiconductor Manufacturing in the United States* (CPPI Online, 2010)

[37] Center for Public Policy Innovation, *The Decline in Semiconductor Manufacturing in the United States*, 2010

[38] Ramish Cheema, *20 Largest Semiconductor Companies in the World,* (Yahoo Finance, 2023)

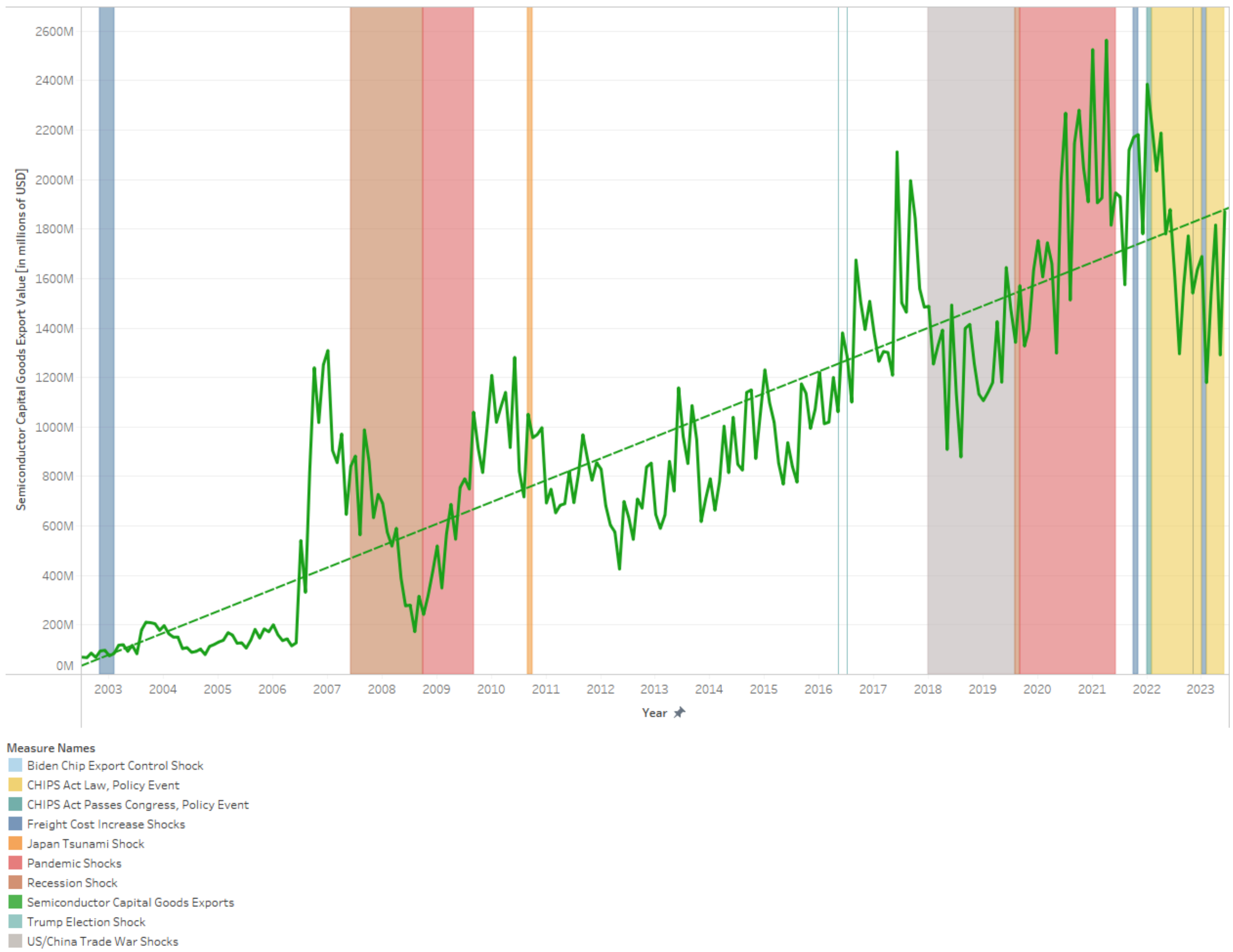
Taking into account what I have found from my models and the literature, finished goods export values have not recovered to peak levels after 2011. The factors I have explored pose a convincing explanation to why we are seeing this decline. Furthermore, this decline was even predicted during the peak export value period in 2010. The analytical models provided little useful insight into these proposed conclusions. Rather, variables outside the model could arguably explain the variation in finished goods exports better.

4.2: Capital Goods Exports

4.2.1: Capital Goods Exports: Overall Trend and Multivariate Regression Analysis

Capital goods imports ended with an all-time high in the overall trend analysis, and I expect the same to be occurring for capital goods exports. I do not credit the CHIPS Act or shocks with this growth, rather I credit growing demand around the world for semiconductor chips and wafers as the industry expands from TVs and phones to generative AI and self-driving car applications. I will return to this thought after a thorough analysis of capital goods exports.

Figure 21: US Exports of Semiconductor Capital Goods



Note: This figure shows capital goods export value in millions of USD. Each indicator variable is highlighted for the duration of its occurrence.

Source: dataweb.usitc.gov

In Figure 21, we see an increasing trend over the 20 year period. Consistent with the trade flow translation framework, increased exports of capital goods suggests supporting offshore manufacturing facilities. However, we can observe a decrease in capital goods export value near the end of the timeline. To determine which statistically significant variable is correlated with this variation, I examine the regression model for capital goods.

Table 20: Regression Results for US Exports of Semiconductor Capital Goods

Variable	Coefficient	Std. Error	t-Statistic	P-value
(constant)	104255947.167	28758794.415	3.625	0.000***
Shocks				
Freight Cost Shocks	-54899486.473	80597373.016	-0.681	0.496
Recession Shocks	-53314855.535	55724018.485	-0.957	0.340
Pandemic Shocks	83241524.278	45362177.527	1.835	0.067*
Japan Tsunami	123883603.734	164268988.622	0.754	0.451
Trump Election Shock	-63314134.856	164937187.749	-0.384	0.701
US-China Trade War	40509571.263	55883280.934	0.725	0.469
Biden Chip Export Control	252885868.128	238842674.804	1.059	0.291
Policy				
CHIPS Act Passes Congress	451950538.289	137477705.705	3.287	0.001***
CHIPS Act Law	45696832.504	67385773.096	0.678	0.498
Lag				
1-Month CG Export Lag	0.878	0.029	30.193	0.000***
R-Squared	0.860			
Adj. R-Squared	0.854			
F-Statistic	147.749			
Obervations	252.000			

*, **, *** indicate significance at 0.10, 0.05, and 0.01 levels respectively

Note: Coefficient values are in dollars. Shock and policy timelines correspond to Table 1.
Source: dataweb.usitc.gov

At the 99% confidence interval is the CHIPS Act Passes Congress policy event. This will also be referred to as anticipation of the CHIPS Act . Table 20 also shows Pandemic Shocks to be statistically significant at the 90% level. This coefficient relationship is puzzling, as past pandemic shocks have caused shrinkage, while this regression model suggests a positive correlation relationship. This will be investigated in correlational analyses to come.

I am surprised that the Biden Chip Export Control shock is not more significant. This emergency order restricts any semiconductor machinery, components, and products handled in the US from being exported to China[39]. Given the large demand from China, I am surprised this did not yield a larger decrease in exports. I take this to mean that if the US is not producing a large amount of semiconductors compared to other countries, the order is simply targeting a non-substantial market. I contend this order is more about political posturing than trade results as US domestic chip production output can not compete with China's domestic chip production output. There is merit in this bill protecting intellectual property and patents on the most cutting edge technology that China may not have, but that would not be reflected in trade data. Returning to the analysis of the significant indicator variables, I continue with the event study models and magnitude tests.

4.2.2: Event Study: Pandemic Shocks

As before, this shock is split into each respective shock as they occur along the overall timeline. However, due to comparable trends, I will analyze them side by side.

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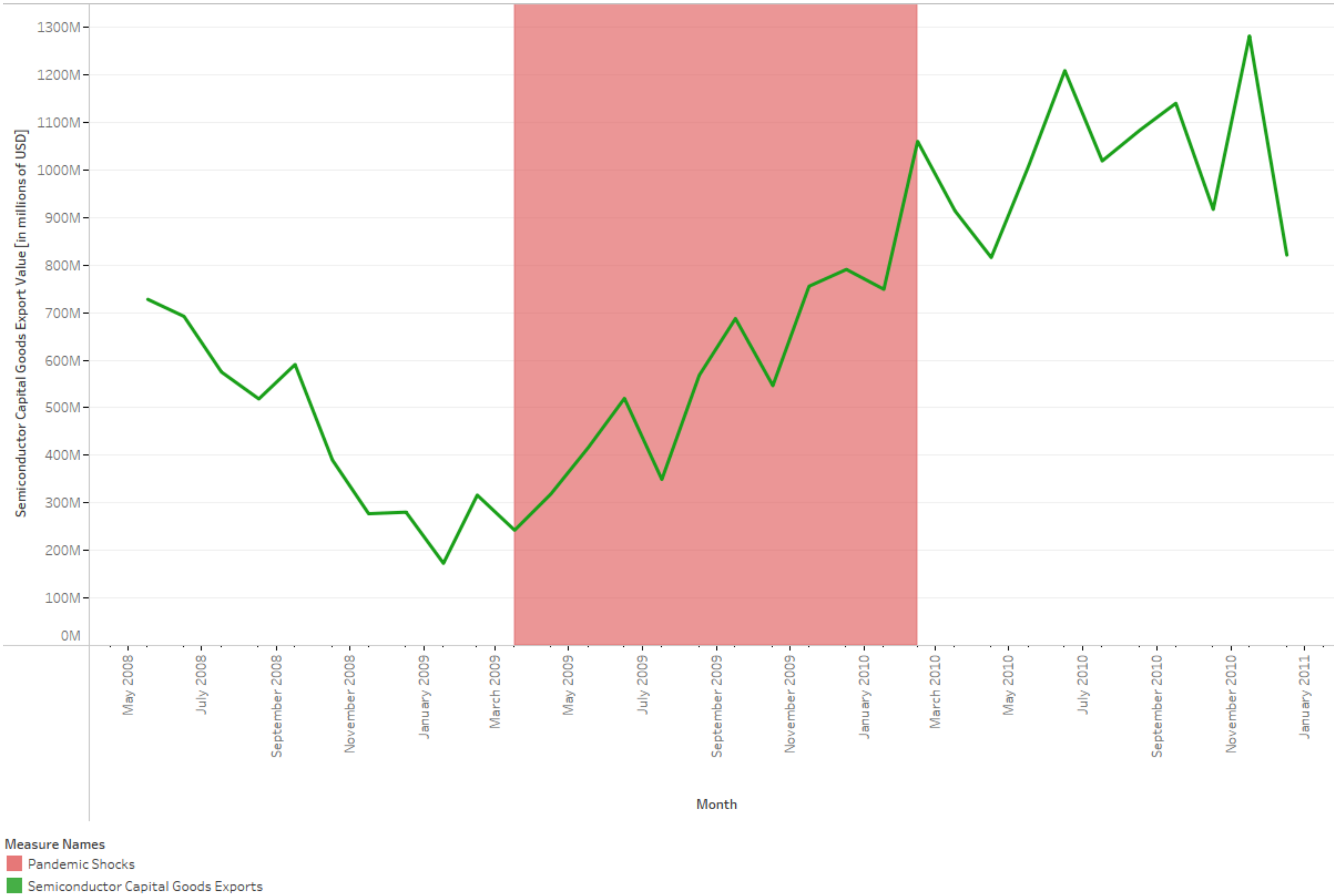
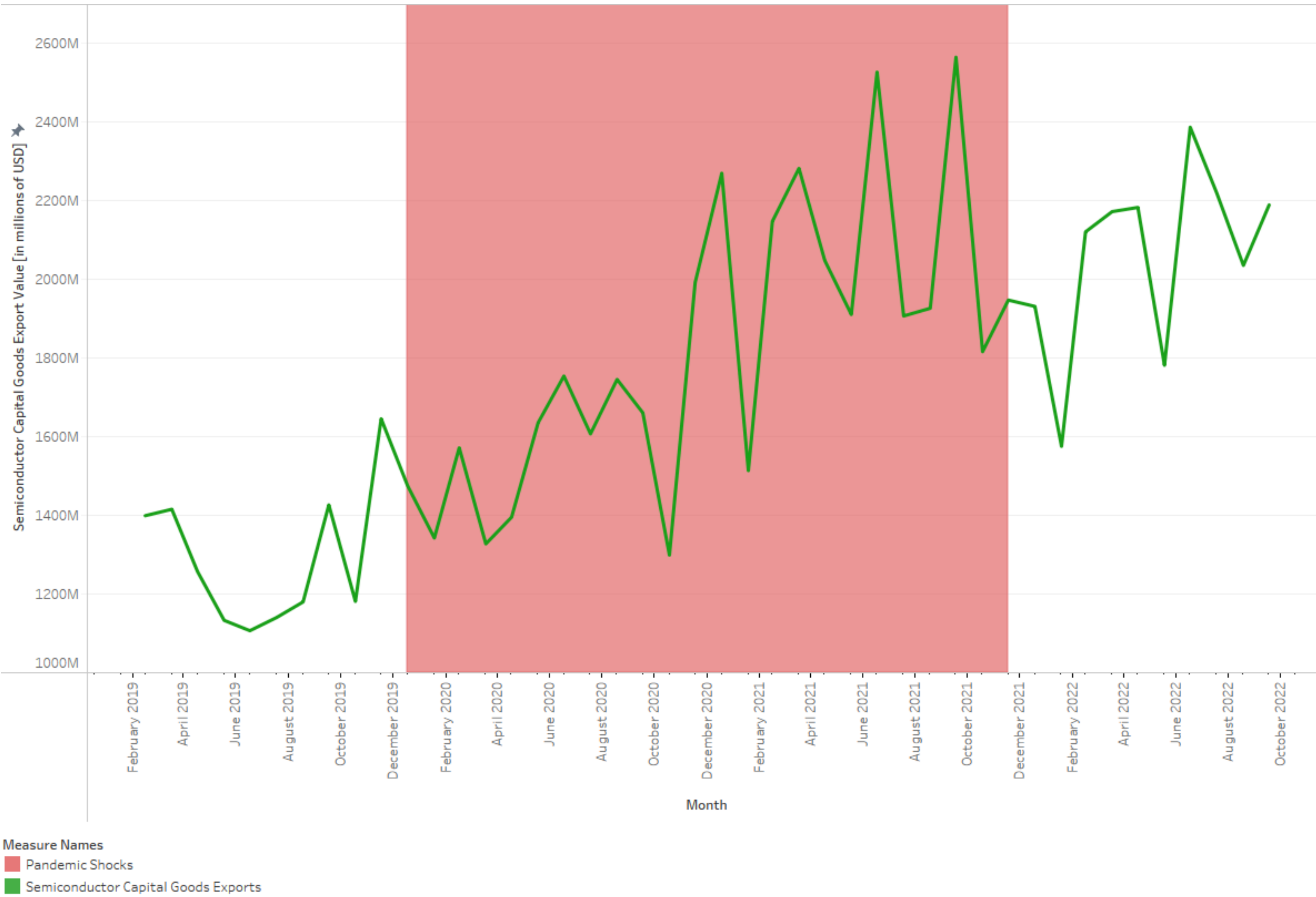
[39] U.S. Department of Commerce. Bureau of Industry and Security. *Commerce Implements New Export Controls on Advanced Computing and Semiconductor Manufacturing Items to the People's Republic of China (PRC),* (2022).

Figure 22: Event Study Model: Capital Goods Exports H1N1 Pandemic Shock 1 of 2



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

Figure 23: Event Study Model: Capital Goods Exports: Covid-19 Pandemic Shock 2 of 2



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

Contrary to the decrease in raw material imports during these shocks, we observe an increase in capital goods export value in both Figure 22 and Figure 23. The correlation is statistically significant, but the trend of these models are largely unchanged before and after the shock period. The visual analysis of these shocks reveal that the pandemic shocks each start in a relatively low point in the graph, but will require the magnitude analysis to reveal if the data following each shock period creates a higher or lower mean compared to the respective model.

Table 21: Magnitude Tests: Capital Goods Exports Pandemic Shocks

Pandemic: H1N1			
Treatment Mean	Event Window Mean	Difference	% Change
583,766,301	679,969,897	-96,203,596	-14%

Pandemic: Covid-19			
Treatment Mean	Event Window Mean	Difference	% Change
1,819,002,755	1,752,930,300	66,072,455	4%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.

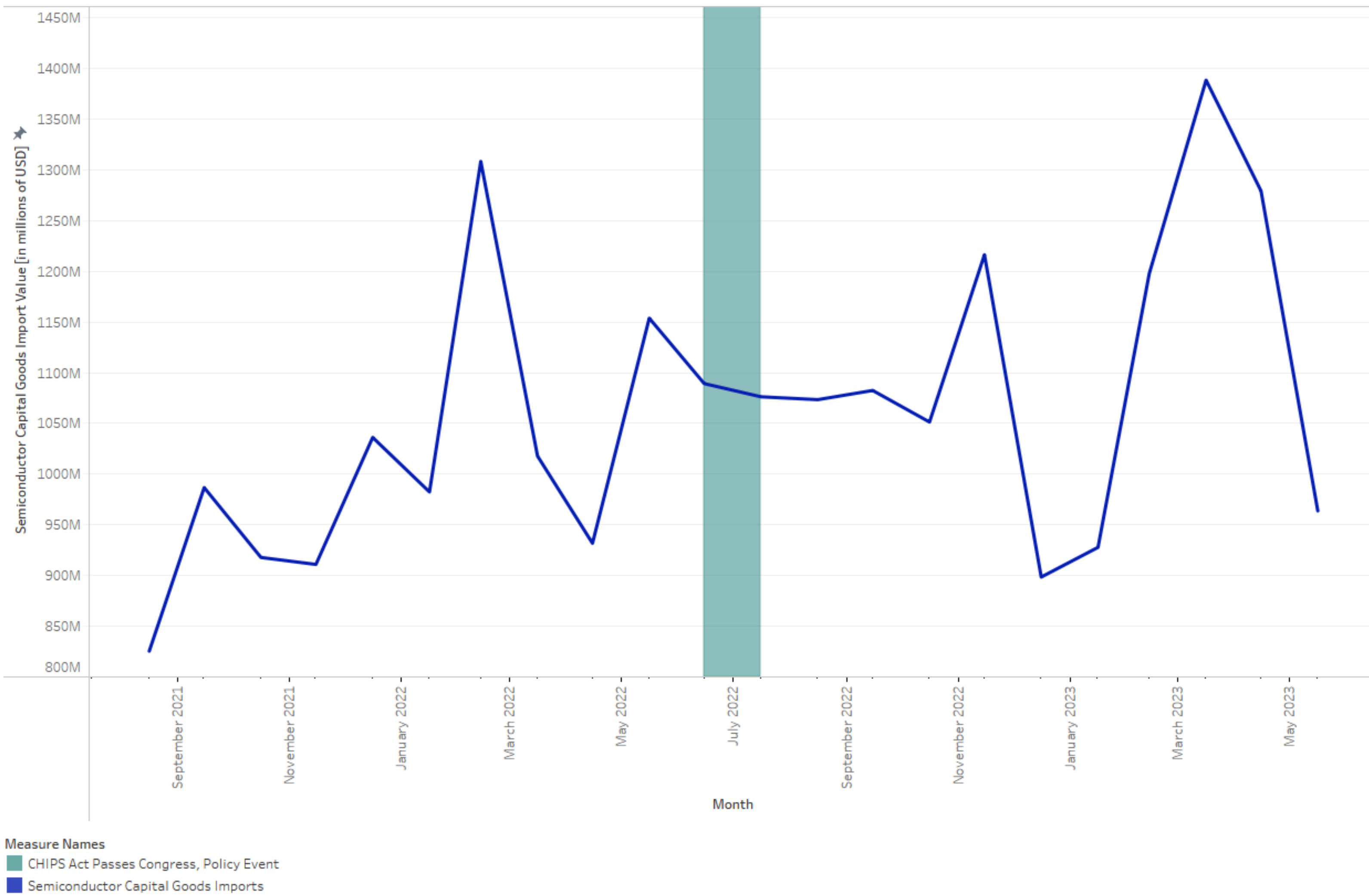
Source: dataweb.usitc.gov

The magnitude test provides inconsistent results. The H1N1 Pandemic shock is correlated with a 14% lower capital goods export value compared to the event window mean. For the Covid-19 Pandemic Shock, we see a 4% increase in capital goods export value during the shock period. This increase may be a crossover effect with the increased demand for semiconductors around the world, and does not yield a high magnitude. Based on this mixed evidence, it is difficult to identify any correlational evidence. While this shock is statistically significant at the 90% confidence level (P-value = 0.1) , my model does not uncover predicted or conclusive correlations.

4.2.3: Event Study: CHIPS Act Passes Congress

Table 20 shows that there is a positive coefficient between the CHIPS Act passing Congress and capital goods export value. Figure 23 displays what is happening during that event window.

Figure 23: Event Study Model: Capital Goods Exports CHIPS Act Passes Congress Policy Event



Note: See Table 1 for date range of shock or policy event.
Source: dataweb.usitc.gov

Figure 23 shows that the CHIPS Act passes congress during a period of lower capital goods import value from around June to Oct. 2022. In anticipation of this bill becoming law, it is difficult to define what finished goods exports should do without clear association from the model. Capital goods exports are still subsidized under the law as long as they are manufactured in the US. If they are just warehoused in the US or pass through the US in transit, companies that own these goods would not be eligible for subsidies. It is apparent that this model does not include the variables needed to draw meaningful conclusions related to my research and this policy event.

Looking into the magnitude test, I encounter similar, non-substantial findings.

Table 22: Magnitude Test: Capital Goods Exports CHIPS Act Passes Congress Policy Event

CHIPS Act Passes Congress			
Treatment Mean	Event Window Mean	Difference	% Change
1,082,766,939	1,059,816,645	22,950,294	2%

Note: The first three columns are in USD. The treatment mean is the average of the treatment period. The event window mean is the average of the dependent variable across the whole event window.
Source: dataweb.usitc.gov

The treatment mean reflects a 2% higher capital good export value compared to the mean of the timeline. The magnitude is very low, again making it challenging to rationalize what is happening here. Taking into account both the event study model and the magnitude test, I suggest that capital goods exports may be more resilient than other categories I have analyzed. This means they are not easily affected by shocks or even policy for that matter. The mechanisms for making this category more resilient compared to even capital goods imports is unclear and not explained by the model.

4.2.4: Capital Goods Exports: Overall Conclusions

My models and analyses have produced puzzling data regarding capital goods exports. From a regression model with statistically significant variables related inversely to my expectation of their effet, to event study models and magnitude tests with no consistent finding, I can only propose that capital goods exports from the US are a resilient category within the semiconductor industry. The US has comparatively little demand for capital goods imports as we do not have the infrastructure in place to produce semiconductor chips. However, other countries and regions do have this infrastructure, and are a source of constant demand for the capital goods exports that the US can provide to them in order to produce finished goods. Verifying this relationship would require research outside the scope of this thesis. Within the scope of research, I find no shocks or policy events that are significant both statistically and in magnitude that are consistent in their effects in relation to semiconductor capital goods exports.

Chapter 5: Application of the Trade Flow Translation Framework

5.1: Establishing Trends

To determine supply chain location changes, I look at the trade data trends and correlational analyses from the previous two chapters. . To do this, I will first review the trends we have established thus far. Raw material imports to the US have been decreasing over the past 20 years. Important to note, despite this overall trend, raw material imports in Figure 14 did increase from around 300,000 in October 2023 to over 700,000 by December 2023. I will take the overall trend, and the more recent pattern into account when applying the findings to the framework.

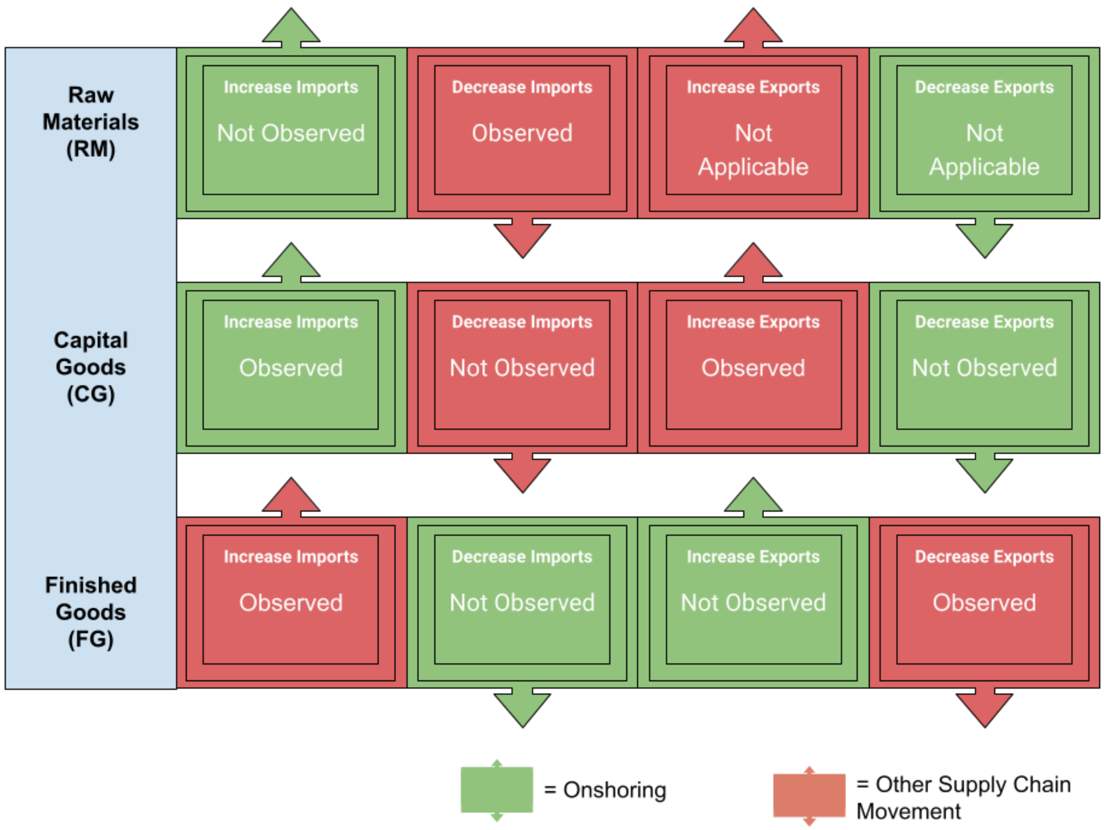
Capital goods imports and exports have been increasing steadily over the past 20 years with capital goods exports growing around 1.5 times faster than capital goods imports per Figure 10. This reflects an increased demand for semiconductor finished goods. However, the faster rate of capital goods exports suggests US exports are supporting offshore production facilities at a rate faster than they are importing capital goods to develop increased production capacity onshore.

Looking at trends of finished goods imports, an overall increase in finished good imports is observed in Figure 2. There is a drop of finished goods import value of just below $400 million between October 2023 and December 2023. The overall trend and this ending pattern will factor into the framework analysis. Finished goods exports have experienced a decline in value across the 20 year timeline. The end behavior of this timeline is consistent with the decreasing trend seen throughout the 20 years.

5.2: Analysis of Trade Flows to Determine Supply Chain Adjustments

The following figure illustrates the trends that are seen in the data set. This figure includes the same colors as earlier in this thesis. Green indicates possible onshoring of the semiconductor manufacturing process, while red does not. Each category is labeled with “Observed” or “Not Observed” based on the trends established through my analyses.

Figure 24: Using Trade Flows to Determine Supply Chain Adjustments: Application of Framework



Note: This figure uses consistent assumptions from Figure 1.

Analyzing this figure, I contend that the overall trend of raw materials does not indicate onshoring of semiconductor supply chains. A decrease in raw material imports, in theory, would mean less raw materials available for downstream manufacturing processes in the semiconductor industry. There is an increase in the dataset over the last two months of the dataset, however no statistical significance was identified between this and any CHIPS Act policy events. Over time, there is a potential for this relationship to become more significant, but according to the raw materials import regression model, this negative correlation is only significant at the 70%

confidence level. Had this relationship been significant at the 90% level or above, I would have one of three conditions to cautiously suggest recent raw material import trends suggest a shift towards increased onshoring. This is not what is observed from the regression, so consequently I maintain that based on the raw material category of the framework, onshoring of semiconductor production supply chains is not present in this category.

Looking at the capital goods category, an increased amount of capital goods imports is promising, however it is accompanied with an increase in capital goods exports. Additionally, the capital goods export increase takes place at a faster pace than the capital goods imports do. Based on capital goods trade flows, I am not able to confirm that onshoring of the semiconductor production process is occurring within the timeline of the data. Combining this finding with the raw materials category, I suggest that capital goods have not been onshored to the US at a rate that supports increased production capacity. When you couple this with the increasing capital goods exports, onshoring of raw material and capital goods supply chains is not likely.

Finished goods do not provide a promising outlook of production onshoring at first look. Raw materials are being increasingly imported rather than increasingly exported due to an increase in US semiconductor production capacity. Rather, we observe that the CHIPS Act Law has significantly increased finished goods import values. Consistent with the preliminary conclusion offered regarding finished goods imports, I propose that the finished goods category of the semiconductor industry is more likely to be onshoring to the US. This is not recognized in the framework as it was configured to measure capital goods and the onshoring of manufacturing supply chains. Due to the flexibility of finished goods at the end of the semiconductor production supply chain, it can respond to shocks and policy faster than capital goods can.

Putting together each individual category, it is unlikely that semiconductor manufacturing processes are being onshored to the US at this point in time. There is a possibility that semiconductor companies are onshoring their finished goods supply chains to the US in anticipation of moving their capital goods and manufacturing. I find the most substantial correlational evidence in support of this possibility.

Chapter 6: Conclusions, Limitations, ad Future Work

6.1: Conclusion

Given the available data, my models are underpowered such that I am not able to find the expected relationships I predicted. The relationships within my model are complicated, and I learn that it is not as simple as just looking at a shock or policy and observing the impact on trade flows. Acknowledging this, a more complex model is necessary to match the complex nature of not only the semiconductor industry but also supply chain dynamics. Each event model had its own set of variations in the data that could not be explained by the model. For example, the timelines surrounding 2011 were heavily impacted by market inertia, and the expected effects of the shocks were not always observed. This also occurred during more recent pandemic shocks where we saw positive growth instead of the expected shrinkage. Each model would have to be adapted for the time period in order to reflect more accurate results.

Analysis of my models lead me to suggest that there is no statistical evidence that the CHIPS Act industrial policy has successfully onshored semiconductor production supply chains to the US thus far. However, there is preliminary evidence that semiconductor finished goods supply chains may be onshoring to the US. Applying only to finished goods supply chains, it is plausible that the CHIPS Act has played a role in changing supply chain location decisions.

Lastly, shocks have been shown to affect the semiconductor industry with comparable statistical significance and magnitude to US industrial policy efforts within the finished goods category.

Manufacturing is dependent on capital goods, so this category within the semiconductor industry is crucial in my determination of this conclusion. Looking broadly, growth in semiconductor capital goods imports is slower than capital goods exports. The US can not gain in worldwide semiconductor production output if US capital goods exports are supporting offshore growth faster than onshore growth. Referencing Table 7, the capital goods imports regression model has the CHIPS Act associated with increasing capital goods value, but this association is not statistically significant. I cannot confirm any positive correlation between the CHIPS Act and capital goods imports, though it appears that with time the relationship may trend that way. Additionally, there is no concrete evidence to confirm that onshoring of semiconductor capital goods supply chains is occurring. The pattern of an increased amount of raw materials to support increased capital goods and the onshoring of semiconductor manufacturing is not observed. While growth in capital goods imports is observed, it does not result in increased finished goods exports. There is variation in the findings that is not explained by the model. However, the CHIPS Act is still in its' implementation stage. It is too early to tell if this legislation will have a larger impact in the future as measured by trade flows.

There is limited, but strong evidence supporting an onshoring movement of semiconductor finished goods. This can be seen through the event study model, regression models, and by using trade data to determine supply chain adjustments. The event study model investigating the relationship between the CHIPS Act Law and finished goods import value provides strong support for this conclusion. With a P-value of 0.000 for this relationship combined with a relative increase of nearly 20% in finished good import value with the presence of this law, I conclude that there is a notable positive correlation between the two variables. Further research would be required to confirm that this is not caused by an omitted variable from the model.

Lastly, I conclude that shocks can produce similar results to industrial policy in a limited manner. This conclusion is limited to the finished goods category as it is the only category where the CHIPS Act Law has had a significant effect on the dependent variable. Based on magnitude tests derived from the events study model timelines, shocks can negatively affect finished goods by up to 14%. The CHIPS Act Law has been shown to positively impact the finished goods category by 17% within the event study timeline. Without a longer timeline after the CHIPS Act was passed into law, I can not extend this conclusion to the raw material or capital goods categories. We do see raw materials negatively impacted by a pandemic shock resulting in a 47%[40] difference between the shock mean and the timeline mean. However, there is no significance of the CHIPS Act law that can be compared to. Similarly, we can see that capital goods are negatively impacted by up to 27% by freight cost increase shocks, but there is no significance of the law to compare to. Expectation of the CHIPS Act Law following the passing of the bill through Congress is associated with a 2% growth in this category, but the magnitude of this change is not substantial enough to draw a concrete conclusion.

My research has provided numerous insights into current effects of not only the CHIPS Act industrial policy, but also its relative effects compared to shocks affecting the semiconductor industry. Although semiconductor production is yet to be onshored to the US, evidence of finished goods onshoring provides an avenue of future research to follow up on this preliminary finding to determine if capital goods onshoring does in fact follow suit. I have also found that shocks can produce meaningful effects on supply chains. Without disaggregating the

[40] The Japan Tsunami Shock is considered an outlier and not included in conclusive analysis.

semiconductor industry into raw materials, capital goods, and finished goods, my research would not be able to yield the findings it does in each category. By looking at each category separately, and then combining each separate trade flow into a cumulative framework, I was able to determine which semiconductor supply chains are moving and due to what reasons. Looking forward, I expect my approach of using trade data to determine supply chain movement to become increasingly relevant. Some factories are yet to be constructed, and companies are still weighing multiple strategic supply chain options. As these scenarios all play out, their effects will eventually be reflected in the trade data. Once this happens, my approach would be able to provide valuable insight.

6.2: Limitations

My research and conclusions are bound by considerable challenges and limitations. As I mentioned, my regression models do not include every variable that could cause a variation in the dependent variable. The fact of the matter is that supply chains are extremely complex. A single model, or a combination of models for that matter, would not be able to cover every possible variable that could affect the dependent variable. Controlling for variation in a complex observational study is not easy, and it explains why industrial policy researchers are still looking for the best approach to observational research on the subject. Due to this, I view these conclusions as standout correlations that merit further research. I have found preliminary evidence that shocks impact semiconductor supply chains. Future research can further evaluate their relative importance to other factors. Comparing the relative effects of shocks and industrial policy on a target industry was an unexplored interaction in political science and industrial policy literature before this thesis.

As I discussed in Chapter 1, my conclusions are also limited by the small amount of elapsed time that has passed between the passing of the CHIPS Act into law and the commencement of my research. I acknowledge that even a few consecutive months of new trade data would have the potential to render the CHIPS Act Law statistically significant in favor of onshoring semiconductor manufacturing and production. However, my research never intended to provide future projections pertaining to onshoring. My finding provides a valuable insight on the current state of the CHIPS Act progress, and also provides significant correlational relationships that warrant future work.

My conclusions are also limited by category. Due to raw materials, capital goods, and finished goods having distinct characteristics, a blanket statement about the whole industry can not be made if an onshoring effect is not observed. Due to this, I am only able to conclude that onshoring is occurring within the finished goods category. I can rule out correlations suggesting onshoring is not occurring based on trade data, but cannot extend the onshoring data from the finished goods category to other categories of goods.

6.3: Future Work

I believe I have started an important line of research into how industrial policy affects semiconductor supply chains in relation to the effects of shocks. First, I encourage scholars to innovate the models used in this thesis. While they were useful in explaining key patterns in the data, they also fell short in explaining variations in other datasets. Innovating the models used here to explain more variation in the dependent variable will extend the work I have done in this field thus far.

Scholars should return to my line of research after more time has elapsed from the passing of the CHIPS Act Law. This would give time for company onshoring proposals to play out. With the finding of finished goods onshoring occurring, only time will tell if capital goods and raw materials onshoring will happen. Currently, some semiconductor companies have announced non-binding plans to construct US production facilities. More elapsed time will reflect if these plans come to fruition or not. A possible reason capital goods onshoring may not happen is the presence of semiconductor industrial policy all over the world. Scholars can use a similar research design to compare the relative effects of industrial policy on each individual country's onshoring outlook. I have contributed to the findings regarding US onshoring, but more research can be done regarding other countries.

In general, this thesis has opened the door to a new strand of industrial policy research. Instead of focusing on policy and the affected industry, my work draws attention to the effects of shocks relative to policy pertaining to the semiconductor industry. Being an unexplored concept before my research, more work needs to be done before definitive conclusions can be drawn about the interaction between industrial policy, shocks, and the US semiconductor industry.

Appendix 1 - HTS Codes and Descriptions

HTS Code	Description	
8112.92.1000	UNWROUGHT GALLIUM INCL POWDERS	Raw Material Imports
8112.30.6000	GERMANIUM UNWROUGHT	
9031.41.0060	OPTICAL INSTRUMENTS AND APPLIANCES FOR INSPECTING SEMICONDUCTOR WAFERS DEVICES, NESOI	
8486.40.0010	MACHINES AND APPARATUS FOR THE MANUFACTURE OR REPAIR OF MASKS AND RETICLES	
8486.10.0000	MACHINES AND APPARATUS FOR THE MANUFACTURE OF BOULES OR WAFERS	
9030.82.0000	INSTRUMENTS AND APPARATUS FOR MEASURING OR CHECKING SEMICONDUCTOR WAFERS AND DEVICES	
9031.41.0020	OPTICAL INSTRUMENTS AND APPLIANCES FOR INSPECTING PHOTOMASKS USED TO MANUFACTURE SEMICONDUCTOR DEVICES	
8486.40.0020	MACHINES AND APPARATUS FOR ASSEMBLING SEMICONDUCTOR DEVICES OR ELECTRONIC INTEGRATED CIRCUITS	
8486.30.0000	MACHINES AND APPARATUS FOR THE MANUFACTURE OF FLAT PANEL DISPLAYS	Capital Goods Imports
8486.40.0030	MACH & APPS FOR LIFTING, HANDLING, LOADING/UNLOADING OF BOULES, WAFERS, SEMICONDUCTOR DEVICES, ELECTRONIC INTEGRATED CIRCUITS & FLAT PANEL DISPLAYS	
9031.49.7000	OPTICAL INSTR & APPLIANCE FOR INSPECTING MASKS (OTHER THAN PHOTOMASKS) USED IN MFG SEMICONDUCTOR DEVICES;FOR MEAS SURFACE PARTICULATE CONTAMINATION ON	
8486.20.0000	MACHINES AND APPARATUS FOR THE MANUFACTURE OF SEMICONDUCTOR DEVICES OR OF ELECTRONIC INTEGRATED CIRCUITS	
9031.41.0040	OTHER OPTICAL INSTRUMENTS AND APPLIANCES FOR INSPECTING SEMICONDUCTOR WAFERS	
8486.90.0000	MACHINES USED FOR THE MANUFACTURE OF BOULES OR WAFERS, SEMICONDUCTORS, ELECTRONIC INTEGRATED CIRCUITS OR FLAT PANEL DISPLAYS; PARTS & ACCESSORIES	
7017.10.3000	PHARMACEUTICAL GLASSWARE, WHETHER OR NOT GRADUATED OR CALIBRATED, OF FUSED QUARTZ OR SILICA, QUARTZ REACTOR TUBES AND HOLDERS FOR PRODUCTION OF WAFERS	
8480.71.4000	INJECTION OR COMPRESSION TYPE MOLDS FOR RUBBER OR PLASTICS, FOR THE MANUFACTURE OF SEMICONDUCTOR DEVICES	
7020.00.3000	OTHER ARTICLES OF GLASS, QUARTZ REACTOR TUBES AND HOLDERS DESIGNED FOR INSERTION INTO DIFFUSION AND OXIDATION FURNACES FOR PRODCTN OF SEMICNDTR WAFERS	
8486.40.0010	MACHINES AND APPARATUS FOR THE MANUFACTURE OR REPAIR OF MASKS AND RETICLES	
8486.20.0000	MACHINES AND APPARATUS FOR THE MANUFACTURE OF SEMICONDUCTOR DEVICES OR OF ELECTRONIC INTEGRATED CIRCUITS	
8486.10.0000	MACHINES AND APPARATUS FOR THE MANUFACTURE OF BOULES OR WAFERS	
8486.90.0000	MACHINES USED FOR THE MANUFACTURE OF BOULES OR WAFERS, SEMICONDUCTORS, ELECTRONIC INTEGRATED CIRCUITS OR FLAT PANEL DISPLAYS; PARTS & ACCESSORIES	Capital Goods Exports
9030.82.0000	INSTRUMENTS AND APPARATUS FOR MEASURING OR CHECKING SEMICONDUCTOR WAFERS AND DEVICES	
8486.40.0020	MACHINES AND APPARATUS FOR ASSEMBLING SEMICONDUCTOR DEVICES OR ELECTRONIC INTEGRATED CIRCUITS	
8486.30.0000	MACHINES AND APPARATUS FOR THE MANUFACTURE OF FLAT PANEL DISPLAYS	
8486.40.0030	MACH & APPS FOR LIFTING, HANDLING, LOADING/UNLOADING OF BOULES, WAFERS, SEMICONDUCTOR DEVICES, ELECTRONIC INTEGRATED CIRCUITS & FLAT PANEL DISPLAYS	
8541.29	TRANSISTORS, OTHER THAN PHOTOSENSITIVE, NESOI	
3818.00	CHEMICAL ELEMENTS DOPED FOR USE IN ELECTRONICS, IN THE FORM OF DISCS, WAFERS OR SIMILAR FORMS; CHEMICAL COMPOUNDS DOPED FOR USE IN ELECTRONICS	
8541.90	PARTS FOR DIODES, TRANSISTORS AND SIMILAR SEMICONDUCTOR DEVICES; PARTS FOR PHOTOSENSITIVE SEMICONDUCTOR DEVICES AND MOUNTED PIEZOELECTRIC CRYSTALS	
8541.50	SEMICONDUCTOR DEVICES, EXCEPT PHOTOSENSITIVE AND PHOTOVOLTAIC CELLS, NESOI	Finished Goods Imports and Exports
8541.21	TRANSISTORS, OTHER THAN PHOTOSENSITIVE, WITH A DISSIPATION RATE OF LESS THAN 1 W	
8541.60	MOUNTED PIEZOELECTRIC CRYSTALS	
8541.40	PHOTOSENSITIVE SEMICONDUCTOR DEVICES, INCLUDING PHOTOVOLTAIC CELLS; LIGHT-EMITTING DIODES	
8541.30	THYRISTORS, DIACS AND TRIACS, OTHER THAN PHOTOSENSITIVE DEVICES	
8541.10	DIODES, OTHER THAN PHOTOSENSITIVE OR LIGHT-EMITTING DIODES	

Note: This appendix displays all HTS codes and their descriptions. Category of semiconductor goods is color-coded.
Source: dataweb.usitc.gov

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