What We Can Learn from CHIPS and Science Act Of 2022: A Case Study of Domestic Semiconductor Manufacturing

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

> *"Now that we have seen how vulnerable these lines of global commerce can be, we cannot go back to business as usual. This pandemic won't be the last global health crisis we face. We also need to increase our resilience in the face of climate change, natural disasters, and even planned attacks."*

- Joe Biden, *The White House*

Only three years ago, it was hard to imagine the President of the United States would be signing legislation to subsidize domestic semiconductor manufacturing to solve semiconductor supply chain issues Most do not think about supply chains fail until they fail. People have witnessed a rising surge in demand for products which contain semiconductors in recent years, but chip shortages affected 169 industry sectors in the U.S. at the same time including car production to a standstill, delayed consumer electronics product launches, and companies' ability to onboard new employees (Howley, 2021). To ameliorate domestic supply chain resilience for semiconductors, President Biden signed the bipartisan federal statute on August 9th, 2022, The CHIPS and Science Act of 2022 (P.L. 117-167) to encourage the construction of microprocessor manufacturing facilities in the United States. The bill appropriates $54.2 billion for subsidies to build chip plants in the U.S. and support U.S. chip research and development (Division A, CHIPS ACT of 2022). This law also aims to prevent U.S.'s overreliance on foreign semiconductor manufacturers such as TSMC and Samsung. At the same time, many experts including Alan O. Sykes, Stanford Law Professor, raised concerns toward the act regarding potential injury to foreign producers of semiconductors seeking to sell into the U.S. market. Consequently, in comparison with other Asian countries, it is more expensive to produce the same quantity of semiconductors in the U.S. given the expensive labor, inexperience with construction, and lack of building materials (Man & Rui, 2014).

Seeking to fill up the uncertainty from The CHIPS and Science Act of 2022 (the CHIPS Act), this paper applied Bijker's "Differences in Risk Conception and Differences in Technological Culture" model to compare the U.S. and Asian semiconductor manufacturing and argues the difference between express different concepts and goals in terms of public, technology culture, politics, and socio-technical systems. This difference can raise many concerns toward whether this policy can solve domestic computer shortage issues; Therefore, to determine whether these concerns are parlous toward the policy itself or they are exaggerative this paper uses "Sociotechnical Matters: Reviewing and Integrating Science and Technology Studies with Energy Social Science (Hess & Sovacool, 2020)" to constructs a defined actor-network diagram and investigates the answers toward the concerns the CHIPS Act.

Part I: Trade-off Between Domestic Manufacturing and Foreign Manufacturing

According to Semiconductor Industry Association, Figure 1 shows the U.S. share of global semiconductor manufacturing has plummeted from 37% to 12% from 1990 to 2020, and in the future, the share of global semiconductor will continue decrease to 10% by 2030. Mostly because competing governments offer large incentives, and the U.S. does not (Ravi, 2020). A continuously large gap in semiconductor manufacturing between the U.S. and other Asian

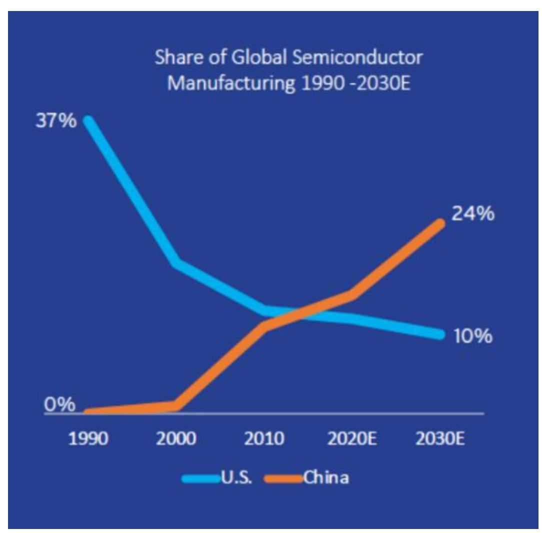

Figure 1. Statics from Semiconductor Industry Association Indicates the United State Fell Behind the Share of Global Semiconductor Manufacturing Since 1990. Such Decline Will Continue until 2030 as Prediction.

countries can put the U.S. in a dangerous spot as the U.S. becomes overdependent toward other Asian manufacturers on the semiconductor supply chain. Furthermore, such an overdependence becomes a threat to the U.S. defense industrial base and domestic capabilities in chip fabrication for America's national security needs. Semiconductors—the backbone of US growth—are also extremely crucial to delivering state-of-the-art capabilities for defense and national security that President Joe Biden has issued an executive order to accelerate the industry's resiliency and chart a path to trusted, reliable, and cybersecure supply chains through incentive funding toward semiconductor manufacturers and research corporation (Kapoor et al., 2021). To strengthen national security and invigorate economy, the U.S. will invest $54.2 billion to create robust incentives for semiconductor manufacturing in the next 5 years to catch the 56% increasing capacity from global manufacturing The funding includes $39 billion is allocated for the financial incentives for the development of domestic semiconductor manufacturing capacity as provided for in NDAA 2021 Sec. 9902; and $11 billion is allocated for R&D and workforce development programs as provided for in NDAA 2021 Section 9906 (Probasco, 2022). Within the incentive program, up to $6 billion may be used for the cost of direct loans and loan guarantees. According to Raimondo, the former governor of Rhode Island, said the law will create approximately 100,000 construction jobs and will prioritize half of the jobs going to women, along with creating apprenticeships for people of color (Lerner, 2022). From all the data above, this policy seems to bring enough incentives and reverse the decline.

In fact, the truth is not that simple. This act is the first act that U.S. plans to offer over $50 billion to prompt domestic semiconductor manufacturing, and many concerns are holding back whether the CHIPS act will work as expected. Alan O. Sykes claims the CHIPS Act could hurt public relationship with the People's Republic of China, as the Act only purports to prohibit recipients of financial awards from material expansions of non-legacy semiconductor manufacturing in China. “The Act is an effort to increase semiconductor manufacturing and development in the U.S. and to make the U.S. more competitive in the development of technology, especially vis-à-vis the People’s Republic of China […] this Act creates a risk that any increase in semiconductor manufacturing in the PRC might violate the agreement as a material expansion” (Pan-Giordano & Zhou, 2022). New Shenzhen fabrication in China was reported illegally stolen chip manufacturing information from TSMC/ ASML to get the expansion due to the CHIPS Act. Furthermore, based on Semiconductor Industry Association’s research, a new semiconductor manufacturer in the U.S. costs approximately 30% more to build and operate over 10 years than one in Taiwan, South Korea, or Singapore, and 37-50% more than one in China. As much as 40-70% of that cost differential is directly attributed to government incentives (Ravi, 2020). In fact, this law may not create more jobs as nowadays manufacturers are highly automated. By upgrading manual warehouse tasks with automation, semiconductor manufacturers can realize up to 65% decrease in operational costs by decreasing labor. For instance, the Automated Materials Handling System in Micron has achieved more than 70% automated production. As automated production becomes increasingly advanced, the job marketing for semiconductor manufacturing becomes less and less (Hart, 2022). This law may not be enough to allow the U.S. semiconductor manufactures to catch up to foreign competitors. Korea, for example, has already announced plans to invest $450 billion into semiconductors while the United States only plans to invest $50 billion (Moore, 2021).

Beyond what is outlined in the Act itself, it is a bit early to make definitive predictions about how the CHIPS Act will impact the semiconductor industry. Despite legislative tactics, there remain many uncertainties due to economy, technology, and politics. While the scope and depth of influence semiconductor manufacturing are extensive, this paper, with further analysis of the variety of interest areas through STS model by "American and Dutch Coastal Engineering: Differences in Risk Conception and Differences in Technological Culture" to help illuminate the problems with conflicts of interest on a more fundamental level. To extend further, using on Hess's review, "Sociotechnical Matters: Reviewing and Integrating Science and Technology Studies with Energy Social Science," this research goes through many credible resources such as Report from International Labour Organization, publications from United Nations Conference on Trade and Development, and Energy Independence Act of 2022 to categorize the fundings into four STS perspectives. Lastly, by remeasuring Actor Network Theory, this paper investigates whether all the goals from CHIPS act are achievable.

Part II: Remeasuring Blueprint: The Interplay Between Domestic and Foreign Manufacturing and Construction of Actor Network Theory

Procedures

This research is conducted in three stages shown in Figure 2. The first stage compares the difference between the Asian and the U.S. manufacturing and identifies concerns caused by the CHIPS Act. Consequently, this paper synthesizes all the statistics, recent relative policies, and different literatures in responding to whether the concerns could destruct toward the CHIPS Act and what areas the legislators can adjust in the future. In the last step, this research develops an actor diagram to connect all the concerns and other fundings through Actor Network Theory and seeks to clarify all the concerns.

Figure 2. Research Flow Chart.

- This figure uses Bijker's "American and Dutch Coastal Engineering: Differences in Risk Conception and Differences in Technological Culture" to identify concerns
- To investigate further, this STS Research has used "Sociotechnical matters: Reviewing and integrating science and technology studies with energy social science" by Hess to break down the System
- Lastly, this STS research constructs an Actor Network Diagram to frame the problems

Literature Review

"American and Dutch Coastal Engineering: Differences in Risk Conception and Differences in Technological Culture" by Weiebe Bijker compares the styles of the U.S. and Dutch coastal enghineering and argue that they express diferent conceptions of risk management in relation to flooring. These differences can be explained by reference to the wider technological cultures of both countries, rather than to the specific engineering cultures. In his paper, he is not instrested in blaming artefacts, humans, politians, or engineers involved in their design or maintenance, but instead he conclued the historical style of American coastal engineering would encourage accepting the kind of flooding that occurred after Katrina. Using his methology, this paper can explore two internal histories as empirical base in serveral catories between the Asian countries and the U.S., and concluded serval important concerns in terms of working culture, technilogical culture, politics, and economy that caused by difference between two areas.

This paper uses "Sociotechnical Matters: Reviewing and Integrating Science and Technology Studies with Energy Social Science" by Hess to break the finding for the Chip and

Science Act of 2022 into four core perspectives in Figure 3. Hess provides a brief history of relevant STS concepts and frameworks and a structured analysis of how STS perspectives are appearing in energy social science research and how energy-related research such as Energy Independence Act of 2022 is appearing in social science STS. Drawing from an initial body of 262 journal articles and books with a stratified sample of 68 published from 2009 to mid-2019, the review identifies four major groups of perspectives: (1) STS-related cultural analysis, especially the study of sociotechnical imaginaries; (2) STS-related policy analysis, such as research on the social construction of risks and standards and on the performativity of economic models; (3) STS perspectives on public participation processes, expert-public relations, and mobilized publics; and (4) the study of sociotechnical systems, including large technological systems, the politics of design, and users and actor-networks. This STS research integrated some overlap and convergences from the fundings regarding the Chips act through Hess's review, and in turn the analysis of practices and users has connected with actor-networks, imaginaries, and publics.

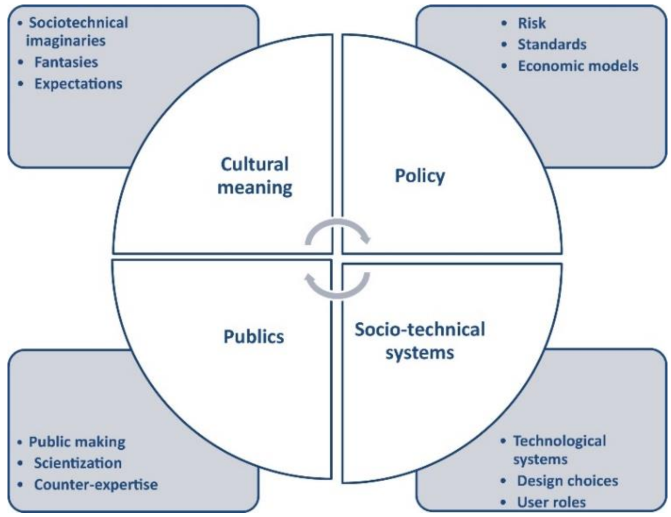

Figure 3. Summary Based on Hess's Review to Break an STS Research into Four Social Perspectives

In the end, this paper aids to use Actor Network Theory (ANT) to frame the funding toward the problems. ANT is a theoretical orientation based on the ontology of relational practices by Bruno Lator, Michael Callon, and John Law. Emerging in the 1980s, ANT instigated its own critique of representational thought by focusing on the heterogeneous practices of association, enrolment, and translation, between humans and nonhumans, which together engineer worlds. ANT prioritizes mobile practices and shares an appreciation for the complexity of the social world; it equally aims to resist becoming pigeonholed into a form of social theory. This paper is developing a framework works for the Chips Act, as it draws attention to innovations as whether this act will help engineers to make more innovative chips collaboratively, national security as whether this act will mitigate overdependence on foreign semiconductor manufacturing, and economy incentives as whether this act will create more jobs.

Evidence

In addition to understanding the circumstance that impacts of domestic manufacturing, several fundings were summarized by following literature reviews that can shape the concerns of the domestic chip manufacturing "Global manufacturing scorecard: How the US compares to 18 other nations" by Brooking Institute and looks at five dimensions of manufacturing: 1) overall policies and regulations, 2) tax policy, 3) costs for energy, transportation, and health, 4) workforce quality, and 5) infrastructure and innovation. This paper summaries all the serious concerns and investigates the concerns in four perspectives. There are many sources to help this paper explore the answers to the concerns. For example, many important statics conducted by the Semiconductor Industry Association indicate how much it costs to build chip fabrication plans domestically and foreign. Furthermore, this paper reviews many articles in terms of culture, policy, public, and sociotechnical design: "Sociotechnical Imaginaries and the Globalization of Converging Technology Policy: Technological Developmentalism in South Korea" for culture comparisons, "Negotiating climate change: A frame analysis of COP21 in British, American, and Chinese news media" (Pan et al., 2019) for political investigations, and "Semiconductor device history and its perspective" for historical perspectives (Atwood et al., 2014). As the uncertainties get clearer after answering the concerns, this paper will construct a final framework to help more people to understand CHIPS.

Part III: Remeasuring the Uncertainty from CHIPS and Science Act of 2022

Concerns

Before understanding such shift from Asian to Domestic manufacturing could work, it is essential to focus on what are the stones laid on the pavement. Using Bijker's model to find the regional difference in manufacturing, research concluded articles by International Labour Organization, Semiconductor Industry Association, and United Nations Conference on Trade and Development to make a table of concerns. This table serves as a summarization of all concerns regarding the difference between the Asian and the U.S. manufacturing. Following Table 1 is a summarized list for the concerns related to culture, public, politics, and socio-technical design.

Concerns	Source
Total number employed in manufacturing in South Korea, China, Japan is higher than the number of employed in the U.S. Therefore, the question remains where to find more experienced workers here in the U.S.	China, Japan, and South Korea where the U.S. tends to build semiconductor plants have more than 140 million of employees working in manufacturing, while the U.S. has only 16 million employees *(International Labour Organization,* 2017).
Based on significant shifts in manufacturing employment between 1970 and 2011, the percentage of the workforce employed in manufacturing in developed countries has plummeted from 26.8 percent to 12.8	In contrast, several regions have increased their focus on manufacturing. For example, manufacturing in East Asia (including China and South Korea) totaled 13.9 percent of the workforce in 1970, but 21.5 percent in 2011

percent. Trying to reverse the trend will raise many challenges for the U.S.)	(*United Nations Conference on Trade and Development*, 2016).
Compared to East Asia, the cost to build a semiconductor factory in the U.S. is higher due to the cost of the labor, the number of available laborers and equipment, the cost of the resources, and the experience in large-scale construction. Commercial semiconductor plants are over 10 billion infrastructure projects, which will be discouraging for stakeholders.	A new fabrication in the U.S. costs approximately 30% more to build and operate over 10 years than one in Taiwan, South Korea, or Singapore, and 37-50% more than one in China. As much as 40-70% of that cost differential is directly attributed to government incentives (*Semiconductor Industry Association*, 2022).
Manufacturing semiconductors involved thousands of procedures such as wafer cleaning, processing, transferring, probing, cutting, packaging, etc. Thus, not only constructing but also operating semiconductor manufacturers requires many workers. Compared to Asian countries, where they have a large pool of workforce, the U.S. can encounter many blockers while	Long hours are so common in China's tech industry that the schedule has been referred to as "9-9-6" — shorthand for a 72-hour work week, from 9 a.m. to 9 p.m., six days a week. In contrast, the national average in China is 46.3 hours (about 2 days) per week and 34.4 hours in the U.S., according to official statistics for May (Marketplace Organizations, 2022)

dealing with large-scale projects in manufacturers.	
The US's lengthy regulatory and permitting process could slow down the construction of new factories, and the US already builds new fabs at a slower rate than countries in East Asia. Even after these facilities are constructed, they may not produce the number of chips or jobs that companies promise.	Some of this is due to changes in the global semiconductor value chain, which has concentrated resources in Asia as foundries have risen in prominence, and countries like Taiwan, South Korea, and China have established significant market share in the industry from 1990 to 2020. However, during this same 30-year period, the time required to build a new fabrication in the United States increased 38 percent, rising from an average of 665 days (1.8 years) during the 1990 to 2000 time to 918 days (2.5 years) during the 2010-2020 period (World Fab Forecast, 2021)
Micron announce that they will create up to 40,000 new jobs in construction and manufacturing. However, the future of manufacturing implements many services as automated services such as Automated Materials Handling System, which replace labor with machine transferring wafer.	Micron is announcing a $40 billion investment in memory chip manufacturing, critical for computers and electronic devices, which will create up to 40,000 new jobs in construction and manufacturing (*The While House*, 2022). When the next step of a material's process sequence is in another building or another

Therefore, the future of manufacturing may not create as many jobs as expected.	department in some other area of the building, a labor cost is incurred in moving this material to its next destination … the AMHS does the rest, leaving the operator to tend to their current tasks without leaving their assigned station (SYSTMA, 2022).

Table 1. Summary of Raising Concern from Various Research Institutions, Major Organizations, and Essential Statistics While Applying Bijker's Model to Compare Manufacturing Between Asian and the U.S.

Based on the summary above, this paper concluded these problems in the list below. Consequently, this paper in the next section tries bringing more answers toward these major concerns.

1. The U.S. manufacturer is lack of experience or specific workers.
2. Domestic construction costs more than the Asian manufacturing.
3. Domestic manufacturers could find a challenging time in adapting the Asian working cultures.
4. It is questionable whether such constructions could create the number of jobs as promising because manufacturers are planning to replace physical jobs with automatic robots.

Findings

The paper applied sociotechnical matter model to all the funding and statistics from many creditable institutions including United States Citizenship and Immigration Services (USCI), A National Security Strategy for A New Century, and The While House. The findings toward the concerns are presented below to show whether the proposal concerns have direct link toward this Act or have fatal affect toward the domestic computer chip supply chains. All findings involve the size of the worker pools, significance of ultimate goals, the public relationship toward the foreign actors, and working culture. The answer breaks down into four areas – high demanding experienced workers, working culture adaptation, capital cost to build semiconductor manufacturer, and number of jobs will be created.

The U.S., in fact, has a great solution for such sudden shift from Asian manufacturers to the U.S. by issuing L-1 visa. The L-1 visa program has no numerical limitations, meaning that multinationals can bring into the United States as many of their foreign employees as they need so long as they meet the requirements. The L-1 visa expanded quickly in the 1990s before peaking just before the recession at 84,532 in 2007. Through half of FY 2020, there were 35,228 L-1 visas issued (USCIS, 2020). By welcoming more experienced foreign engineers, the U.S. can reduce the surging demand for experienced workers. At the same time, by having more experienced engineers in the manufacturers, the manufacturers will have more smooth cultural adaptations than before.

In the meantime, the U.S. congress has noticed the cost difference to build a manufacturer between domestics and foreign. The U.S. allows 25-percent investment tax credits for investments in semiconductor manufacturing and includes incentives for the manufacturing of semiconductors, as well as for the manufacturing of the specialized tooling equipment required in the semiconductor manufacturing process. Taxpayers may elect to treat the credit as a payment against tax ("direct pay"). The credit is provided for property placed in service after December 31, 2022, and for which construction begins before January 1, 2027 (The White House, 2022). By encouraging foreign semiconductor companies to build manufacturer in domestic through taxation deduction, the U.S. also can lower the cost of building manufacturers themselves impact while bring back the semiconductors supply chain. Furthermore, as the number of foreign semiconductor manufacturers increases, the U.S. will have more smooth cultural adaptations as well.

Although many physical demand jobs will be reduced, the number of workers with the requisite technical backgrounds who are willing to engage with modern technology is increased.

The total number of jobs the semiconductor might not be as large as people expect; however, high-end jobs to create, collaborate, and maintain robots will always be demanding. Manufacturing firms that hope to maintain global competitiveness will need workers with the requisite technical backgrounds who are willing to engage with innovative technology, and hopefully stick around for long enough to knowledgeably contribute to factory improvements. As digital transformations across the economy automate repetitive tasks while requiring increased problem-solving, the need for better-trained and more engaged workers is likely to be similar across other sectors (Waldman-Brown, 2022). Although the U.S. prompts automation in production line to replace workers, in the same way, development of automation in manufacturing can bring down the cost of labor and resources while creating many jobs for high-tech to operate and prompt the machines. Automation is a tool to bring people convenience, but how to define automation is still our job.

Results

Through the finding above, although many concerns are caused by the difference between the characteristics of the U.S. and the Asian countries as well as foreign competitions, many of them can be solved by importing many experienced worker and promoting automations, which is the U.S. congress has been taking actions. In the other hand, eliciting domestic semiconductor manufacturing will hurt some public relations; however, taking consideration of national security, it is inevitable to hurt foreign companies and countries to improve domestic chip supply. Furthermore, the legislators have noticed such consequences so that they prompt tax reduction for foreign semiconductor manufacturers as well, which has made huge progress. Taiwan Semiconductor Manufacturing Co Ltd (TSMC), a major Apple Inc (AAPL. O) supplier and the world's largest contract chipmaker, is constructing a $12 billion plant in Arizona (Yang et al., 2022). To have a better visualization for all the actors, this paper continues to synthesize the funding and construct an actor-network diagram. This diagram also obeys uses "Sociotechnical Matters: Reviewing and Integrating Science and Technology Studies with Energy Social Science" and divides all the concerns into four categories.

The fundings shows many of the concerns are not related to the Act or not fatal enough as compared with national security. This paper has synthesized the fundings into an actor-network diagram in Figure 4. This diagram has broken down all actors as following Hess's four STS perspectives as cultural meaning (corner top left), policy (corner top right), publics (corner bottom left), and sociotechnical system (corner bottom right). The actor in gray has the most serious the concerns toward the CHIPS Act such as cultural fit as bringing the companies from Asia to the U.S., political intension between China and the U.S., lack of workers to do physical works, and under-experience in manufacturer constructions. However, based on the funding many of them do not have a direct link toward the Chips Act itself, as there are many ways to alleviate such concerns. With the introduction of L-1 visa, the gap for demanding more experienced workers can be filled. Development of automation in manufacturing can bring down the cost of labor and resource while creating more jobs for high-tech. Tax credit return policy will fix the relationship between the U.S. and foreign semiconductor manufacturers.

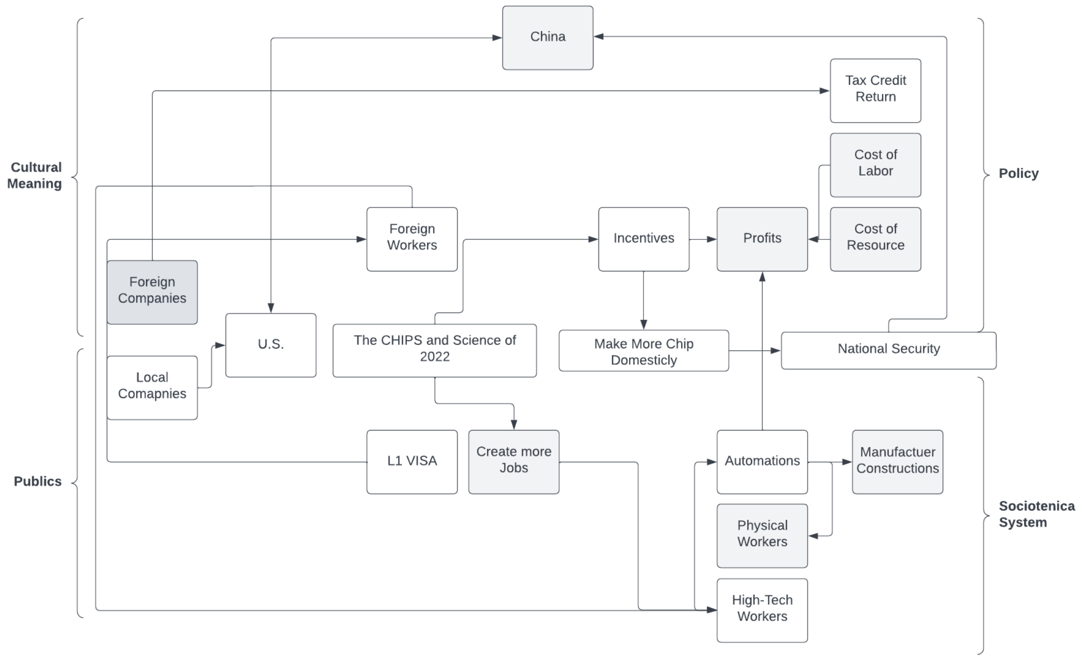

Figure 4. Actor-network Diagram for The CHIPS and Science Act of 2022 as Following "Sociotechnical matters: Reviewing and integrating science and technology studies with energy social science" by Hess

Conclusions

This paper analyzed all rising concerns regarding difference between the Asian countries and the U.S. in difference perspectives. Consequently, this paper has demonstrated its effectiveness by Bijke's and four core perspectives to analyze the concerns and synthesize the fundings. In addition to help more legislators to issue a further well-established the CHIPS Act. This research only established the essential factors for the diagram due to limited time. Given the scope of this Act, many other considerations can be conducted in further research.

By indemnifying the concerns and synthesizing evidence, this paper demonstrated many of the concerns are either not linked toward the concerns or it is reasonable trade-off as taking considerations of national security. Indeed, legislators have realized prioritizing national security would sacrifice many other factors such as public relations and expensive cost during constructions. However, through the Actor Network diagram, the legislators have tried to solve these problems for example encouraging foreign companies to build semiconductors in the U.S. with high tax credit return can rebuild the relationship between foreign companies and the U.S. These conclusions come from a very wide scope of studies, using Bijker’s and Hess's methods to highlight crucial factors such as working culture adaptations, economic concerns, and political impacts.

The implications of this study are clear: Actor Network Theory is a powerful tool by which to measure the connections between act purpose and recent raising encounter concerns regarding the act’s effectiveness. While this study is by no means the definitive work on shaping a fully objectives Actor Network frame, it establishes promising paths of research on future of the semiconductor manufacturing through the basis of Latour’s Actor Network Theory.

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