BILLION DOLLAR FACTORIES:

FOREIGN DIRECT INVESTMENT AND U.S. MANUFACTURING COMPETITIVENESS

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SUMMARY OF FINDINGS

The 2021-2023 period marked a boom in U.S. manufacturing investment. In these three years alone, manufacturing construction grew by 174%, and approximately 50 new factory investments over $1 billion were announced. Public reporting has attributed recent growth to federal subsidies for new investments in computer chip and electric vehicle manufacturing, as well as to the restructuring of supply chains after the COVID-19 pandemic. Studies of the manufacturing surge have largely overlooked the role of Foreign Direct Investment (FDI) as a significant share of U.S. manufacturing growth. Approximately 40% of the new billion-dollar factory projects are from foreign-owned companies, and the two largest new FDI projects in U.S. history were announced during this three-year period: the semiconductor fab investments from TSMC in Arizona and Samsung in Texas.

The rise of FDI matters because "transplant factories," or foreign-owned factories operating in the United States, typically perform differently than their American-owned peers. Past FDI projects have been associated with direct and indirect benefits for the U.S. economy. The direct benefits stem from the foreign investment itself. Studies of FDI in the United States, United Kingdom, and elsewhere have shown that foreign-owned factories are typically more productive, invest more in technology, and pay higher wages than their domestic counterparts.

There is also evidence that when foreign-owned companies invest in the United States, domestic factories in the same industry become more productive, wages for their workers go up, and the domestic companies learn from knowledge that the foreign-owned company brings to bear. A 2021 study of U.S. FDI spillovers indicates that for every 1 job created at a foreign factory, there are .5 jobs created at domestic-owned companies and $135,000 in additional value added to the domestic economy.

The evidence from past FDI provides reason for optimism. There is the potential for planned FDI projects to boost the competitiveness of U.S. manufacturing. However, the positive spillovers of the past – which occurred primarily in the automotive industry – are not guaranteed for new FDI projects, which are planned for different industries (semiconductor) and product areas (electric vehicles). What lessons can current FDI projects draw from past FDI investments that have generated positive spillover effects?

Case studies of foreign-owned "billion-dollar factories" show that past FDI projects have affected regional economies in three distinct ways. Foreign investments have made an impact by augmenting regional workforce development, supplier relations, and innovation networks. In some cases, FDI projects have "raised the bar" for their domestic manufacturing peers, leading to substantially different workforce development and supplier relations for manufacturers operating in the region. In other cases, FDI projects have had a more incremental effect without noticeably changing regional manufacturing environments.

The highest-impact FDI projects have become "anchor firms" in their regions, transforming the trajectory and capabilities of the regional manufacturing economy by generating new demand for workers and attracting new suppliers to locate near the foreign-owned factory. Other large FDI investments have served as "accelerators" for the regional economy. In these cases, the foreign-owned factory builds on the existing strengths of the regional economy, helping speed progress along an established economic trajectory. Finally, some FDI projects look similar to their domestic peers. A foreign-owned factory might assimilate with the surrounding region if, for example, the foreign-owned factory is a foreign-owned company's acquisition of a domestic firm with a pre-existing supplier and workforce ecosystem, or a merger of a domestic company with a foreign-owned parent. These "assimilation" firms are unlikely to have the same spillover benefits as the typical FDI project.

- BMW's factory investment in South Carolina exemplifies the *anchor* path, where BMW's arrival in the region was directly related to improvements to the state workforce development system. BMW also helped contribute to the launch of an innovation ecosystem in the region around the automotive industry. Toyota's U.S. investments in Kentucky and elsewhere are another example of *anchor* investments, where Toyota's factories introduced new supplier relations strategies into an existing system. The introduction and diffusion of the "Toyota Production System" led to new workforce development, supplier relations, and innovation strategies at small and large firms in the automotive industry and more broadly.

- The Novo Nordisk investment in biomanufacturing in North Carolina's Research Triangle represents the *accelerator* path, where the foreign investor grew its presence as its business grew and the resources of the innovation ecosystem in the Raleigh-Durham area became more developed. It is unclear how – if at all – Novo Nordisk shaped the emergence of the biomanufacturing cluster in the Research Triangle, but nonetheless Novo Nordisk has expanded its manufacturing footprint there and now manufactures some of its most advanced products in the region.

- The final path is *assimilation* with domestic companies in the region where the transplant factory is investing. When foreign-owned Stellantis established new automotive factories in the Detroit region to produce Chrysler vehicles, it reflected the characteristics of its fellow domestic automakers. Although Stellantis is foreign-owned, a merger between American and European automakers, Chrysler's long legacy of American manufacturing suggests that it will rely on pre-existing suppliers and workforce pipelines, making it hard to distinguish from domestic manufacturers.

The question for new FDI investments in the semiconductor industry is how these advanced facilities might serve as anchors that will raise the bar for competitiveness in their industry and the region where they invest. The size of these investments does not guarantee that they will have a transformative impact on the region. While it is unlikely that large semiconductor fabs will "assimilate" – after all, they are the first of their kind in the United States to perform advanced-node chip manufacturing – they could merely accelerate pre-existing practices in their regions, which have some existing microelectronics infrastructure.

The key lesson semiconductor FDI projects can learn from past anchor firms is openness. At BMW and Toyota, the companies became hubs and shared resources for workforce training, supplier knowledge, and – in limited cases – research & development. The companies were not islands looking inward. Instead, they developed strong networks with organizations comprising the industrial commons, including technical training organizations and universities. And in Toyota's case, they opened their factory doors to suppliers and others looking to learn from their production system. These lessons apply to semiconductor firms today.

Seizing these opportunities will depend on foreign-owned companies being open to cooperation with other institutions in the places where they invest. The stronger the networks that these companies build with workforce development organizations, ecosystem partners and suppliers, and universities, the more likely they will have positive spillover effects on the domestic economy that raise the bar for the region's manufacturing performance.

1. INTRODUCTION

In the desert foothills north of Phoenix, on more than a thousand acres, a new kind of American manufacturing complex is taking shape. Cranes tower overhead, scaffolding still hangs alongside industrial buildings, and a network of roads has been paved to connect factories with R&D offices and supplier facilities. The campus, where the Taiwan Semiconductor Manufacturing Company plans to locate multiple chip fabs, represents the largest new foreign direct investment in U.S. history: $65 billion across three chip fabs.[i] When completed, the company estimates it will employ approximately 6,000 workers and represent the first advanced-node computer chip manufacturing in the United States.

In some ways, the campus reflects previous giant investments in U.S. manufacturing, such as Honda's manufacturing campus in Ohio or BMW's auto assembly plant in South Carolina, both of which aimed to "transplant" a foreign model of manufacturing into the United States. Although the TSMC campus can follow in the tradition of these successful foreign investments in American factories, the nature of the TSMC project is importantly different: the company is recruiting primarily college-educated workers to serve in a technology-intensive plant that will be responsible for managing an advanced production process – making up to 2nm node silicon chips – that has never been performed in the United States.

TSMC's investment is part of a new wave of investment in higher-wage, higher-skill U.S. manufacturing, enabled by federal industrial policy investments and a shift in corporate strategy to locate production facilities closer to customers. Building on a steady expansion of U.S. manufacturing activity between 2010 and 2019, factory construction increased by 174% between October 2020 and October 2023 from $75.6 billion to $206.8 billion.[ii] The growth in factory construction has been driven in large part by the announcement of large new factory complexes – investments over $1 billion, often promising to employ thousands of people – for semiconductor, electric vehicle, and pharmaceutical production. There were approximately the same number of "billion-dollar factory" investments in 2021, 2022, and 2023 as there were for the previous 8 years combined.

Nonetheless, there is uncertainty around where this short-term surge in U.S. manufacturing may lead. Although there has been steady growth in American manufacturing employment over the past decade, U.S. manufacturing wages, productivity, and technology investments have stagnated since at least 2010 (see Figure 1). Increasing manufacturing productivity is a key lever for the health of the manufacturing economy overall. Higher manufacturing productivity is a key ingredient for higher wages and increased profitability, which will attract more workers and investors to support domestic industries. If new American factories are mirrors of existing American factories, however, they risk replicating the same type of manufacturing that has fallen behind foreign competitors in key performance categories.

The new wave of manufacturing in the United States represents an opportunity to break this pattern and increase American manufacturing competitiveness. Three dimensions of the current manufacturing wave suggest that new manufacturing can be different from past manufacturing.

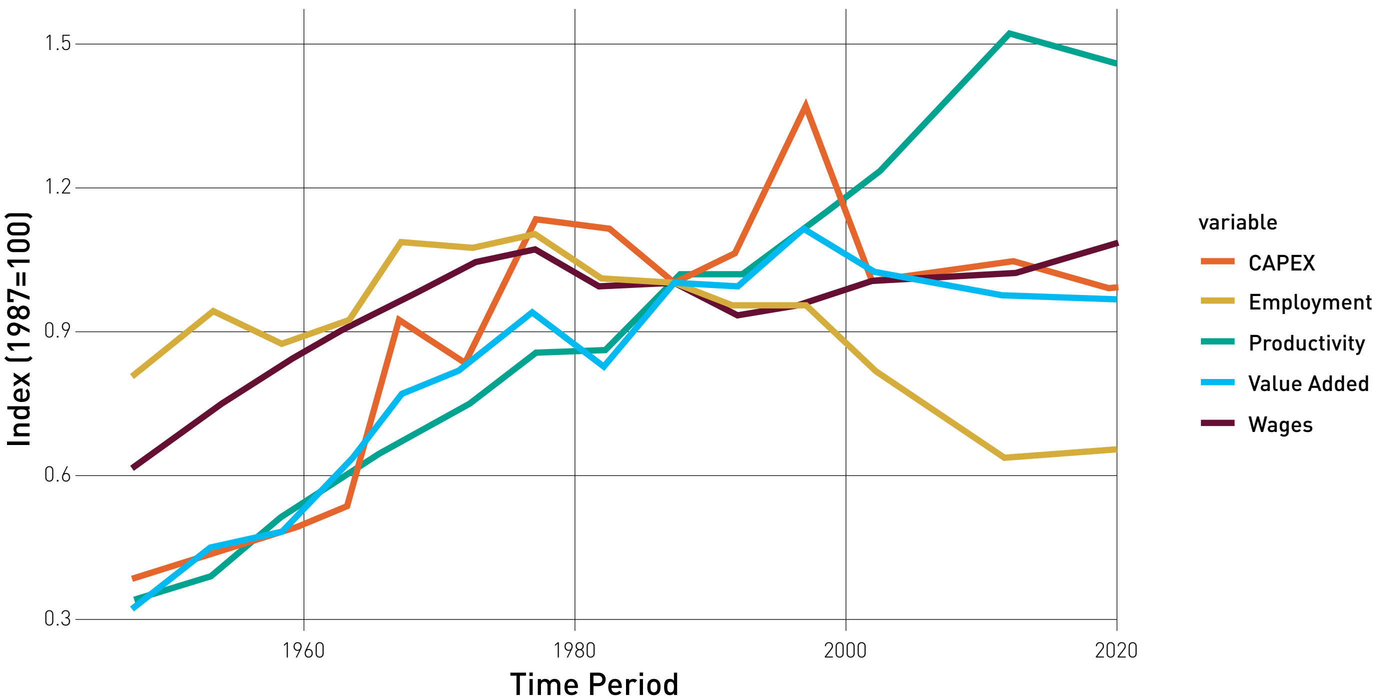
First, whereas past waves of manufacturing investment have focused on traditional automobile manufacturing and chemicals manufacturing, the current manufacturing activity is focused on innovative sectors where the United States has lost competitiveness (semiconductors) and new product markets (electric vehicles) where comparative advantages are still being formed. These sectors are more capital intensive, require continuous innovation, and in some cases will require more skilled labor demanding higher wages.

Second, a large share of new factory investment comes from foreign-owned companies. Over 40% of the new billion-plus-dollar factory investments in the United States come from foreign-owned firms. Foreign Direct Investment pledges in 2022 were over 20 times what they were in 2019, and the position of foreign investors in U.S. manufacturing had already been growing rapidly since 2010 (see Figure 2).[iii] The Taiwan Semiconductor Manufacturing Company's planned $65 billion investment in its Arizona manufacturing complex represents the largest new foreign investment in U.S. history.[iv]

The rise in foreign direct investment in U.S. manufacturing both because it represents the direct benefits of outside capital stimulating the U.S. economy, but also because foreign firms often bring new knowledge and business practices to their U.S. operations that can spill over to benefit domestic firms as well. Past studies of foreign-owned U.S. manufacturers have shown that these plants are on average more productive and pay higher

Figure 1

U.S. Manufacturing Performance Over Time



wages.[v] There is also evidence that foreign investment can contribute to domestic innovation by drawing on technologies and ideas from one context, and recombining and applying them in another.[vi]

Third, new manufacturing investments – particularly in semiconductor manufacturing – are concentrated in regions of the United States without a deep historical legacy of manufacturing. For example, approximately 60% of new manufacturing construction investment is concentrated in semiconductor manufacturing commitments in the American southwest, where ecosystems supporting manufacturing innovation and training are still being formed.[vii] As manufacturing grows in these regions, there is clearly an opportunity to develop a different model of regional manufacturing activity from the models that have dominated in the traditional nodes of American manufacturing: the Great Lakes region and the U.S. South.

As TSMC invests in establishing advanced fabs in Arizona, the company's investment could accelerate the growth and competitiveness of the U.S. semiconductor industry writ large, which has seen its share of advanced-node chip production shrink to zero. TSMC, along with its ecosystem of suppliers and partners, are the innovation leaders in semiconductor manufacturing. The hypothesis is that when these companies invest in the United States, they will bring new knowledge of processes and techniques that will contribute to innovation and skill development at other firms in the industry, raising the bar across the United States.

But there is no guarantee that TSMC's investment will translate into improved manufacturing performance more broadly. Can TSMC's production in Arizona perform like its production in Taiwan? And even if it can, will other U.S. manufacturers become more productive because TSMC is close by? The question is ultimately how to seize the opportunity that the TSMC investment – and other foreign investments like it – present for U.S. manufacturing and American prosperity.

Although these themes are forward-looking, there is historical evidence that can help identify what has differentiated foreign direct investments that have spilled over from foreign direct investments that have not yielded long-term benefits. The key insight is that the higher-impact foreign firms have made active investments to the industrial commons that have benefited not just their private interests, but the broader interests of firms and workers in the region where they are investing.

Investments in the industrial commons include programs to improve the workforce development system, expand the capabilities of suppliers, or generating new knowledge through R&D partnerships. These investments can train workers who will bring their skills to neighboring firms, expand the capabilities of firms who can then pursue new business, and even lead to startup companies based on knowledge generated through R&D. In cases like BMW and Toyota, investments in the industrial commons have been a win-win: good for their partners and the region where they are investing, as well as positive for their ability to perform competitively in the United States.

This study proceeds in three parts. The first details the evolution of foreign direct investment in the United States, reviewing data on the evolution of large FDI projects across industries, as well as the scholarship on the impact of FDI on regional economies and domestic firms. The second part zooms in on select cases of large FDI projects to understand *how* they made an impact on the regions where they invested. The section underlines the variety of *models* by which foreign companies can cultivate economic spillovers. The third part assesses the plausibility of those models as they apply to the microelectronics industry, identifying existing and potential paths for foreign direct investment to "raise the bar" for the domestic industry.

2. Foreign Direct Investment: Theory and Practice

For government economic development offices, Foreign Direct Investment (FDI) is a coveted resource. Like other investments in "traded industries" such as new factory construction or capital equipment,[viii] FDI has a direct impact on the economy where it is targeted, creating jobs and generating demand for suppliers, as well as spillover effects due to the increased demand for non-tradable services such as housing construction, healthcare, restaurants and other amenities. One reason why the recent expansion of FDI has generated such excitement among government officials and economic analysts is that the foreign companies investing in the United States are typically leaders in their fields and promise to hire high-wage workers and perform innovative activities in their U.S. operations. The potential direct and indirect benefits of foreign investments are the core components of the dominant economic model for understanding the impact of FDI.

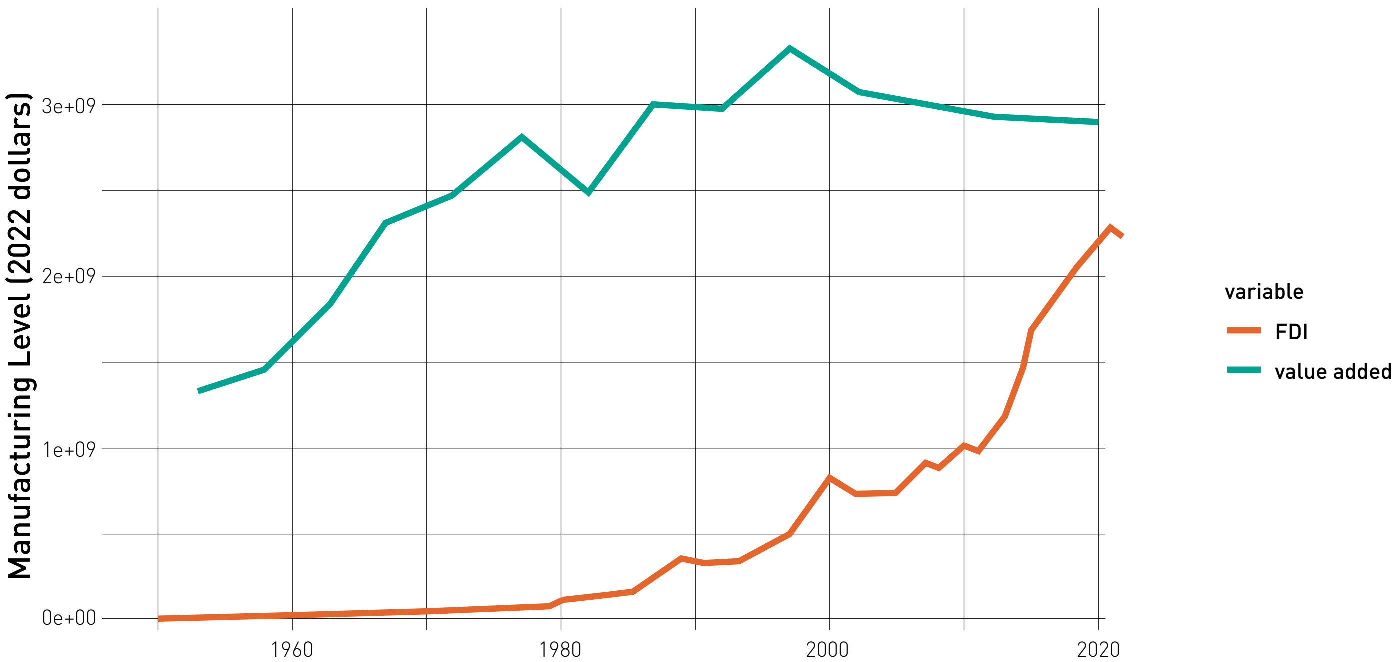
Data on the evolution of FDI over time highlight the changing role of FDI in practice. Although these data cannot pinpoint the impact of individual investments, they do highlight how for multiple decades the majority of large FDI projects were concentrated in automotive and chemicals manufacturing. After 2020, FDI projects increased substantially in number and began shifting toward new industry areas, including the semiconductor and electric vehicle sectors. These data highlight that the scale and industry concentration of recent FDI is new – and it is unclear how the models of the past two decades will apply to the current set of investments.

I. THE EVOLUTION OF FDI IN THE UNITED STATES

Before 1980, Foreign Direct Investment in the United States manufacturing economy was minimal as a share of overall manufacturing value added or output. Beginning with the investments of leading European and Japanese automakers including Volkswagen, Honda, and Toyota in the 1970s and early 1980s, FDI in U.S. factories began to grow, even as overall U.S. manufacturing output suffered during the 1981-1982 recession. The wave of foreign investment in U.S. factories – primarily in the automotive industry – continued throughout the U.S. South during the 1980s and early 1990s, only to stagnate in the late 1990s and early 2000s as investment poured into Mexico (after the passage of the North American Free Trade Agreement) and China (after its accession to the World Trade Organization).

Figure 2

Evolution of FDI in U.S. Manufacturing



Aggregate foreign investment data traces back to the 1950s, and transaction-level data for FDI projects is available beginning in the late 1990s and early 2000s. This study relies on FDI Markets data from the *Financial Times*, which includes investment projects across sectors from foreign entities, as well as domestic entities investing in states where they are not headquartered.

The FDI Insights database provides more detailed data on each project, allowing for an analysis of inflation-adjusted investments over time (see Figure 3), as well as industry-specific patterns (see Figure 4).

The growth in manufacturing projects in the past three years – particularly FDI projects – has been stark. There were 39 commitments to build "billion-dollar factories" among foreign-owned firms in 2021, 2022, and 2023. There were the same number of billion-dollar factory commitments in the whole period 2013-2020 combined. The wave of recent and forthcoming investment from foreign firms in the United States calls for a deeper and more nuanced understanding of the industry and regional spillover impact of such FDI projects in the United States.

The concentration of large investment commitments in the last three years reflects a variety of factors, including federal subsidies and the restructuring of supply chains in the wake of the COVID-19 pandemic. These industrial policy efforts include as much as $2 Trillion in public support for new manufacturing investment, including direct subsidies for capital investments in the CHIPS and Science Act, as well as consumer incentives to boost demand for electric vehicles in the Inflation Reduction Act, and public spending to boost demand for domestic manufacturing in the Bipartisan Infrastructure Bill.

Billion-dollar factory commitments have been concentrated in four industries: automotive, chemicals (including pharmaceuticals), batteries, and semiconductors. Three-fourths of all billion-dollar FDI factory investments fall into one of these four categories. Semiconductor fabs, while the fewest in number, are the largest total investment given the high capital investment required to build each fab.

The data from FDI Markets helps demonstrate the shift in FDI projects over time. Even among automotive investments, which have long been the dominant form

Figure 3

Growth in Foreign-Owned Billion-Dollar Factories

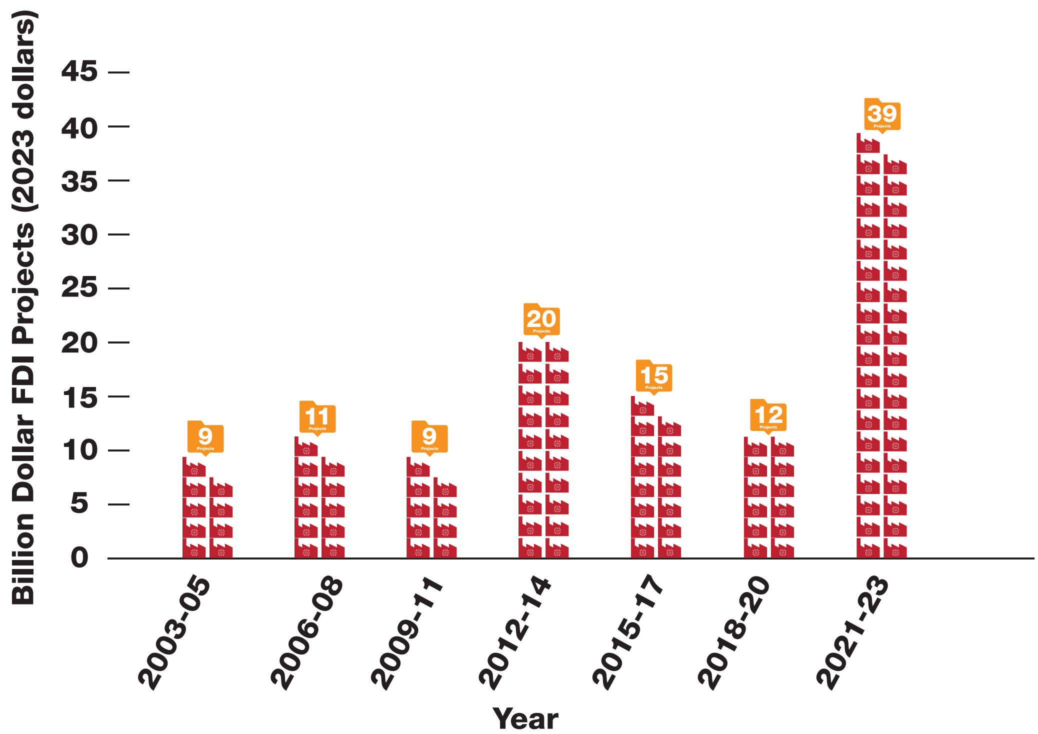
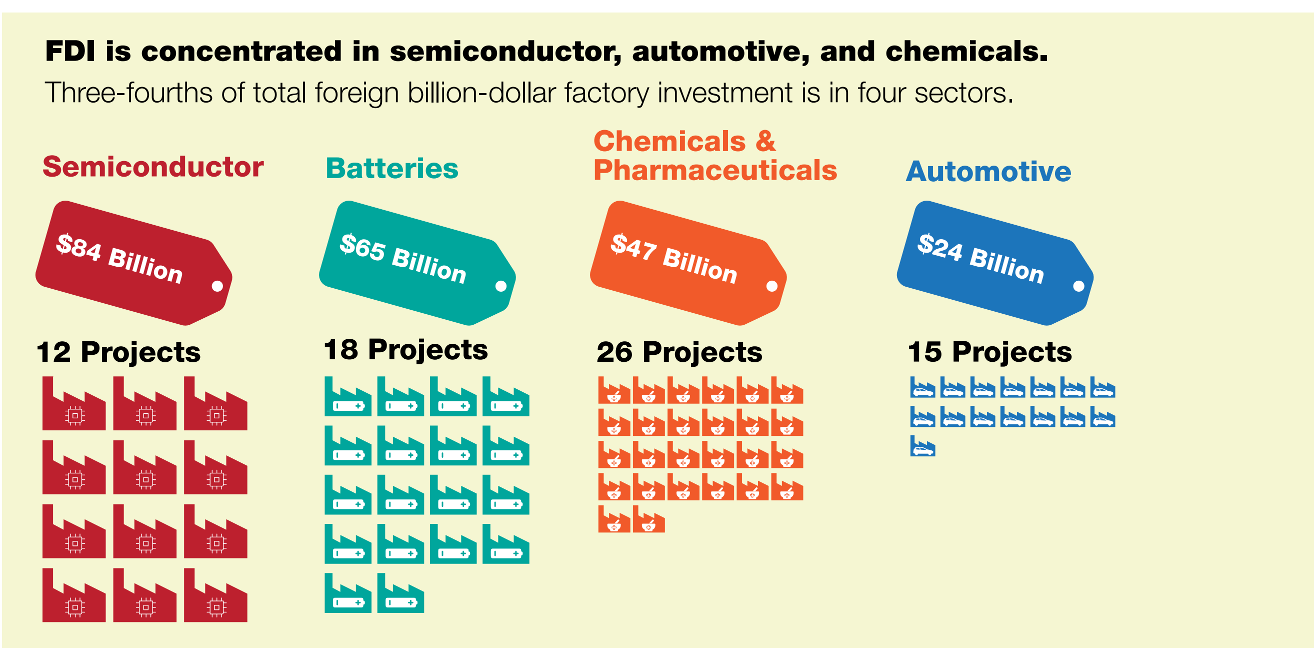


Figure 4

Foreign-Owned Billion-Dollar Factories by Industry (2003-2023)



of FDI projects in manufacturing, there is a bifurcation between automotive assembly plants, which are typically smaller projects, and battery-related factories for electric vehicles, which are larger by comparison. According to FDI Markets, although there have been a comparable number of billion-dollar factories for batteries and automotive facilities, the dollar value of the investment in foreign-owned battery factories has been nearly triple that of automotive factories. Many of these factory commitments have been made in the past decade.

II. ESTIMATING THE IMPACT OF FDI

FDI matters for U.S. economic development as a potential driver of output and productivity and growth, as well as new, higher-wage jobs. The aim of economic development is not just to generate more economic activity, but also to support more productive economic activity, which is associated with more long-term competitiveness and better employment opportunities.

This study's focus on "billion-dollar factories" arises from recent research emphasizing the impact of individual, large factory investments on regional economic activity. Two findings stand out. The first is that individual "million-dollar plants" have a significant impact on the regions where they locate. The study uses data on companies' first- and second-choice sites for locating their plants. The regions that eventually won the plants experienced substantially higher productivity than the second-choice regions that never won the plant investment.[ix]

A second finding suggests that large manufacturing investments such as billion-dollar factories have the potential to transform regional economies and have impact beyond their immediate infusion of cash into the local economy. The underlying study aims to explain the productivity gap between high-productivity and low-productivity regions. After controlling for industry mix and other factors, the authors find that large, high-performing factories – outliers even in their industry – help explain between two-thirds and three-fourths of the productivity premium of the highest-performing regions.[x]

Constructing a billion-dollar factory has spillover benefits, supporting the employment of construction workers and production workers and engineers, who in turn add demand to the local economy, spending their money on housing, food, and amenities. And the direct impact of FDI on the domestic economy is more significant than internal investment because FDI is bringing *new* capital into an economy via tradable industries. Growth in tradable industries is significant for economic development because they produce goods and services that can be consumed elsewhere, bringing outside capital into an economy. "Non-tradable" industries produce goods or services that are consumed locally and merely re-circulate existing local capital.[xi]

Beginning in the 1970s and 1980s, when the global flows of capital began accelerating, FDI became a key pillar of the economic development strategies in developing countries that sought foreign investment to kickstart new industries, particularly in manufacturing. During this period, there were prominent cases of FDI contributing to positive economic outcomes, but it was clear that FDI was not a panacea. The local economic environment needed strong institutions and reliable governance for foreign business investments to scale up. Studies of FDI have sought to trace the patterns of FDI policies and national strategies, as well as the impact of FDI on the economic development trajectories of low- and middle-income countries.[xii]

The model for how FDI can benefit a regional economy suggests three channels through which FDI investment in new factory construction, or factory expansion, can provide benefits beyond that of typical domestic investment in manufacturing. The first channel is direct: the foreign-owned factory can generate more economic activity than the domestic factory. The idea is that foreign-owned factories investing in the United States have the capital and rationale to do so only when they are prepared to exploit some strategic advantage in the region where they are investing. Multiple studies have found evidence supporting this model: indeed, foreign-owned firms in U.S. manufacturing typically operate more productively, more profitably, invest more in technology, and pay higher wages to their workers than their industry peers.[xiii] These studies provide evidence that by attracting FDI investment, regions are attracting high-performing factories.

There is also evidence that FDI factory projects spill over to domestic factories. Models of FDI knowledge spillovers suggest that high-performing foreign-owned factories can "raise the bar" for their domestic counterparts, augmenting productivity, wages, and innovation at peer factories in the geography where they invest. The theory is that foreign-owned factories can improve local productivity by creating agglomeration economies, raise wages through competitive pressures and productivity gains, and stimulate innovation through knowledge spillovers.[xiv]

Early evidence of this phenomenon comes from the United Kingdom, where domestic factories with a higher share of foreign-owned competitors were more productive than factories in industries where the share of foreign ownership was lower.[xv] Although this was suggestive evidence that FDI could be raising the bar in terms of productivity, it could be that foreign investment was attracted to more productive sectors.

Later research in the United States shows that FDI is linked to higher productivity among domestic firms, particularly in higher-technology, higher-skill industries. The study compared productivity and other metrics of domestic publicly-traded manufacturers in industries where employment in foreign-owned firms was rising and compared these firms' performance to peer firms in industries where foreign-owned employment did not grow as fast.

The finding was that industries with high growth in foreign-owned employment – controlling for other factors – were associated with significantly higher productivity growth. This finding was especially true for technology-intensive industries like the automotive sector. The magnitude of the impact of FDI was significant. The paper argues between 8 and 17% of all productivity growth in U.S. manufacturing between 1997 and 2006 was attributable to growth in FDI.[xvi]

A series of papers have found similar positive spillovers from FDI for worker wages and innovation. In a study of South Carolina at the county level after the state's surge of FDI, scholars find that counties with more FDI experienced higher overall wage growth than counties with less FDI, after controlling for other factors.[xvii] Evidence from Brazil shows that when workers move from a foreign-owned company to a domestic company, their wages go up, suggesting value in the knowledge and experience coming from the foreign-owned firm.[xviii]

Table 3

Economics Literature on FDI Spillovers

Impact Type	Country	Estimated	Study
Regional effects	U.S., EU	Outlier plants account for 66-80% of productivity differences between regions. When a region wins a "million dollar plant," it sees sizable productivity gains.	Greenstone, Hornbeck, and Moretti 2010, Schoefer and Ziv 2022.
Direct effects	U.S., UK	"Foreign owned plants are more productive, rely relatively more on capital than labor, and pay higher wages than domestically owned plants."	Howenstine and Zeile 1992, 1994; Griffith 1999; Seltzer and Tintelnot 2021; Doms and Jensen 1998
Indirect wages	U.S., Brazil	"We find the average direct effect of a foreign multinational firm on its U.S. workers is a 7 percent increase in wages. This premium is larger for higher skilled workers and for the employees of firms from high GDP per capita countries."	Seltzer and Tintelnot 2022, Poole 2013.
Indirect productivity	U.S., UK	"The size of FDI spillovers is economically important, accounting for about 14% of productivity growth in U.S. firms between 1987 and 1996."	Haskel et al. 2007, Keller and Yeaple 2009.
Indirect innovation	Japanese companies in U.S.	"Foreign direct investment enhances knowledge flows in both directions.... Spillovers *from* the investing Japanese firms to indigenous American inventors appear to flow most strongly through Japanese firms' greenfield affiliates."	Branstetter 2006.

Although it is harder to measure, economists have also proposed that FDI can contribute to new innovations in the target country. Consider two potential mechanisms. The first is that individuals employed at foreign-owned companies can move to domestic companies, bringing new ideas and knowledge with them to inform new products and processes. The second channel is through interactions between foreign-owned firms and their domestic counterparts, either between a foreign firm and domestic suppliers, or by a foreign firm and domestic companies it acquires. The idea is that by sharing information and knowledge with suppliers, the foreign-owned firm can spark new advances and ideas that translate into innovation.

Several studies provide evidence for these effects. In a study of knowledge flows associated with Japanese firms' FDI in the United States, one paper finds that FDI is associated with knowledge spillovers – measured by patenting activity – to and from the foreign investing firm. In other words, the Japanese firms investing in the United States changed their patenting activities, although this happened primarily when Japanese firms set up "greenfield" plants in the United States rather than acquiring domestic firms.[xix] Although studies of "knowledge spillover" are sometimes separate from studies of productivity gains due to FDI, the knowledge spillover mechanisms are plausible explanations for the productivity benefits of FDI for domestic firms.

The most data rich study measures the impact of FDI on domestic firms from 1999 to 2017 using tax filings to identify worker-level and business-level outcomes for workers at domestic and foreign-owned firms in the United States by regional geography. Consistent with past findings, it finds that foreign-owned firms are higher-performing and pay their workers on average 7% more than comparable domestic firms. It finds strikingly positive spillover effects of FDI investments to domestic firms:

> *"An expansion in the foreign multinational share of commuting zone employment substantially increases the employment, value added, and—for higher earning workers—wages at local domestic-owned firms. Per job created by a foreign multinational, our estimates suggest annual gains of 13,400 USD to the aggregate wages of local incumbents, two-thirds of which are from indirect effects (domestic firms benefiting from proximity to foreign multinationals)."*[xx]

The conclusion of the study has sizable implications for policymakers. It associates one new hire at a foreign-owned firm with $135,000 additional value added to a region's economy. Comparing the potential value added to an economy from FDI to the cost in terms of tax incentives to attract FDI, the authors argue the benefits far outweigh the costs. They estimate $4.6 billion in subsidies to attract FDI and $36 billion in additional wages resulting from FDI investments.[xxi]

III. CHANNELS FOR TRANSPLANT FACTORY IMPACT

Foreign-owned factories differ from their U.S. counterparts in three primary ways, which help explain why they have the potential to "raise the bar" for productivity and wages in the areas they invest. Transplant factories invest differently in workforce development and organization; they engage differently with their suppliers and peer manufacturers; and they often pursue different types of innovation.

Research on the differences and contributions of foreign-owned factories does not attribute the high performance of foreign firms to any particular operational differences. Instead, it merely suggests the foreign-owned firms investing in the United States are a high-performing subset of foreign-owned firms, which are more likely to have higher wages and high productivity. Understanding how these firms can "raise the bar" for the regions where they invest in the United States requires an examination of the channels through which the companies can have an impact on the practices of their new neighbors – and improve their performance as a result.

Scholarship in economics and political science has highlighted three potential channels differentiating U.S. and foreign firms: workforce training, supplier relations, and innovation. Since the 1980s, there has been extensive research on how European and Asian firms operate differently than their American counterparts.[xxii] Studies of workforce development contrast strong legacies of vocational training in central European countries like Germany and Switzerland and cross-training in Asian countries like Japan with a tradition of on-the-job training for narrow tasks in the American Fordist tradition.[xxiii]

The German model of vocational training is associated with cooperation between representatives of industry, labor, and government to determine the necessary skills for different roles within firms. Vocational training institutions then develop and adjust their curricula in response to the consensus around necessary skills. In Japan, the workforce model associated with automotive manufacturers emphasizes cross-training workers to perform a variety of tasks and organizing work such that individuals switch frequently between tasks to ensure that the process is not dependent on one individual.[xxiv] One implication of different training systems is that European

Table 4

Transplant Factory Spillovers

Mechanism	U.S. Approach	Transplant Approach	Spillover Opportunity
Workforce	Fordist	Craft production	Upgrading talent pool for all firms
Supplier Relations	Market mediated	Long-term, information-sharing partnerships	Technology adoption, quality improvements
Innovation	Radical product innovation	Process-based, incremental innovation	Startups benefit

"coordinated market economies" favor industry-specific skills, whereas American training pathways deliver "general" skills.[xxv]

One channel through which transplant factories can influence domestic production is by introducing a new approach to skill development for American workers – and establishing new roles that might lead to higher wages and draw more highly-skilled workers. By offering more technical training to American employees of foreign-owned firms, the transplant factories can employ a more skilled workforce that can at once operate at a higher level of productivity and wages. If these firms contribute to training institutions that serve as public goods – training workers beyond those of the transplant firms – then there is the potential for the influence of the foreign-owned firms' approach to workforce development to spill over on domestic firms hiring a more skilled workforce.

Political economy research has also established that American firms, particularly large Original Equipment Manufacturers (OEMs), manage their business relationships with their suppliers differently from foreign-owned enterprises in similar positions. American OEMs typically search for and acquire suppliers in the market through an open bidding process whereby the OEM purchasing a component or service looks for a bid at the lowest price that can produce a component at a given quality. An American OEM might switch between suppliers on a short-term basis if they can find a better deal. This process has added risk to American suppliers that are subject to losing business if they cannot compete on price.

In regions of Europe and Asia, buyer-supplier relationships are mediated by networks and long-term business relationships, whereas American buyer-supplier relationships are primarily market transactions. In Central Europe, suppliers are engaged for long-term contracts, and there is typically mutual investment and knowledge-sharing between the OEM and the supplier to ensure that the supplier has the resources to succeed and grow.[xxvi] In Japan, suppliers have historically been part of an individual OEM's network, or keiretsu, where the OEM manufacturer has influence over the operations – and may even own a partial stake – of the supplier.[xxvii]

There are several ways in which these supplier relations could influence the regional environments where foreign-owned companies build factories in the United States. The first is that the longstanding foreign-owned suppliers of OEMs investing in the United States might also invest in the United States, leading to a clustering effect of high-performing firms. Alternatively, foreign-owned OEMs may opt to invest in new supplier relationships in the United States, building long-term relationships that support the growth of incumbent domestic firms.

Finally, foreign-owned companies in manufacturing have been associated with more incremental, process-focused innovation than American companies, which have a history of more radical, product-focused innovation.[xxviii] Given the decline of U.S. manufacturing, innovation in manufacturing fields overall has stagnated compared to innovation in other areas of the U.S. economy like software and biotechnology.[xxix] The potential contribution of transplant factories to innovation and new knowledge at their domestic peers comes not necessarily from patents or particular documentation of new technologies, but from the introduction of new knowledge to workers and managers, who may learn from the transplant firm, then spin off their own innovative company or bring that knowledge and implement it at a peer firm in the region.[xxx]

3. Lessons from Billion-dollar Factories

Studies of the impact of foreign direct investment have demonstrated aggregate benefits from foreign-owned companies investing in the United States. However, not all foreign direct investment projects are created equal. There have been some companies, like Toyota and Samsung, that have scaled up their presence in the United States over decades, expanding their number of facilities and domestic partnerships. And there are other foreign-owned companies that have made investments in the United States that flopped. Two high-profile examples include Volkswagen's Pennsylvania auto assembly plant – the first foreign-owned car assembly plant in the United States – and Foxconn's promised flat-screen display plant in Wisconsin, which never materialized.[xxxi]

Even among FDI projects that are completed, the eventual factories constructed and producing the intended goods, there is variation in how transformative transplant factories are on the regional economy where they are located. Some, like BMW's investment in South Carolina, have sparked a new industry cluster, including a concentration of regional suppliers and a boost in regional productivity. Others, like Novo Nordisk's investments in the Research Triangle of North Carolina, have likely had some positive contribution to the regional manufacturing and innovation ecosystem focused on the life sciences, but were not primarily responsible for the growth of Research Triangle Park as a source of industrial and R&D growth.

Large FDI projects like these fall roughly into three categories based on their role in the regional ecosystem: anchor firms, accelerator firms, and assimilator firms.

By revisiting individual cases of each category that capture the variety of FDI experiences, this study aims to illustrate the several paths that the recent commitments to build new "billion-dollar factories" may follow. The overarching argument is that the potential economic impact of these investments is not settled – and there are strategies and public policies that can steer these companies' investments in a particular direction.

I. ANCHOR FIRMS

Anchor FDI projects represent the first major investment of a particular category in a region. They are the types of factory investments that can spark new, related economic activity around them. For example, the investments of BMW in South Carolina and Toyota in Kentucky both served as anchor investments for the regions where they invested – and related firms nearby. The investment of anchor firms provides new business opportunities to domestic-owned firms that might serve as suppliers to the anchor. They also serve to augment the capabilities of domestic firms through knowledge gained from the anchor or shared access to talent.

BMW and Toyota provide distinct cases of how a transplant factory can provide spillover benefits to domestic firms by augmenting regional workforce development, supplier relations, and innovation systems.

When BMW invested in its first U.S. manufacturing hub in 1993 in South Carolina, there was uncertainty among BMW leadership over whether the investment would pay dividends.[xxxii] South Carolina did not have a substantial manufacturing legacy beyond textiles, which were vastly different than luxury vehicles. Moreover, it was among the lowest states for manufacturing productivity in the U.S.

BMW's initial investment was a risk, but over three decades, it has paid off. By 2023, South Carolina had attracted a concentration of manufacturers in the automotive and aerospace industry, all while developing an acclaimed statewide apprenticeship program supporting the manufacturing workforce pipeline. South Carolina has also become among the most productive states in the country for automotive manufacturing.

As BMW established its U.S. presence, it did not fully import the workforce development system it used in Germany, which required strong labor representation, industry associations, and a nationwide system of technical schools. Instead, it worked with the State of South Carolina's technical college system to develop and invest in a scalable program to graduate production workers who could thrive on its factory floor.

There were two ways BMW's investments made an impact: first, by transferring knowledge from high-performing German manufacturing environments to American manufacturing leaders, including those charged with skill development. And second, by investing directly in expanding shared workforce institutions, including the State of South Carolina's technical training program. These investments would serve BMW, as well as other manufacturers in the region.

BMW invested in training its U.S. workforce on the production practices at its German factories. New U.S. employees at BMW's Spartanburg plant would travel to Germany to study how the shop operated, and BMW engineers from Germany traveled to South Carolina to help stand up the Spartanburg plant.

The President of the BMW U.S. facility, Allen Kinzer, emphasized skill development before technology and automation. BMW had already adopted automated systems, including robotic welding, at their plants in Germany. But they opted not to deploy these systems at the outset in their South Carolina plant.

"Our plant won't be highly automated," Kinzer said. "A lot of auto makers invest in technology, not in people. We're going back to the base line and investing in people." Kinzer, who previously supervised Honda's transplant factory in Ohio, emphasized the important of craft skills.

He explained the importance of teaching their workers manual skills like spot welding, which were not often needed in more automated plants with robotic welding. But, Kinzer said, the automated welding solution was expensive and inflexible. It would only work on a particular production line. Manual welding skills could be more flexible across the tasks that BMW might need in the future. Over time, BMW would introduce automation, Kinzer said, but after the workforce was "expert at building cars."[xxxiii]

Beyond the way it organized its own workforce, BMW invested in building up shared institutions for the benefit of the South Carolina automotive ecosystem. Leaders of the South Carolina technical college system also traveled to Germany to learn about and adapt techniques from the German workforce development system. BMW's investment in the broader South Carolina technical training system helped ensure that the workforce development practices that BMW expected for its workers could also be available for other South Carolina manufacturers.

An official from Clemson described the flexibility of the South Carolina technical college system as an attraction to BMW. The system allowed BMW to describe what it needed in terms of skills, and the technical colleges would purchase equipment and develop a curriculum around BMW's needs.[xxxiv] The state technical college system also established a program to reimburse BMW and similar manufacturers up to 50% of their training expenses coordinated through the state. In the first 7 years of their operations in South Carolina, BMW was reimbursed more than $25 million from the state in training alone, suggesting an ongoing collaboration between the company and state training institutions.[xxxv] The statewide training system continued to grow and differentiate itself with the launch of a statewide apprenticeship program in 2007. BMW is one of many employers recruiting, training, and hiring apprentices through the state program.[xxxvi]

In its supplier relations, BMW began by maintaining a high share of foreign suppliers – the same companies that they relied on in Germany – before gradually growing the share of American-made components in each vehicle. In the 1990s, the stated goal of BMW was to have 60% of components in the cars made in South Carolina to be sourced in the United States. By 2020, BMW reported 300 U.S.-based suppliers for their vehicles and approximately 40 tier 1 suppliers in South Carolina alone. The carmaker was also exporting far more from the South Carolina facility than they were importing.[xxxvii] The effect of BMW's investment was to expand the supplier base in the region, forming a cluster of highly productive manufacturers in South Carolina.

BMW followed their 1993 investment in an automotive assembly plant with support for R&D partnerships with local universities, primarily at Clemson University's International Center of Automotive Research, which serves as a R&D hub for the industry. The growth of BMW in the region helped shape the Clemson program, which has grown to support industry-wide training and research programs that can serve to benefit the broader regional manufacturing community.

At Toyota, the transplant factories trained workers internally to perform different roles than they would in an American automotive factory. The flagship factory in the United States was Toyota's investment in a Kentucky plant to produce the Camry, which opened in 1988.

The Toyota work teams expected workers to perform a higher variety of tasks and to collaborate with peers on the factory floor. They also gave workers more autonomy, the most visible example of which was a cord that any worker could pull if they noticed a problem on the production line or needed assistance. The cord was pulled an estimated 3,500 times per day in Toyota's Kentucky plant.[xxxviii]

The Toyota approach to workforce development scaled beyond Toyota both through recruitment of former Toyota employees and the openness of Toyota to share details of its production system with visiting company executives. Toyota emphasized the openness of their model and sought to share it with other manufacturers in the region and beyond. In 1991, the factory hosted 20,000 tours from outsiders interested in "the Toyota way," which became a central pillar of the lean production system that diffused through U.S. manufacturers in the 1990s and 2000s.[xxxix]

Toyota also affected the local production ecosystem by raising the standards and changing the practices of their suppliers. Supplier accounts of their relationships with Toyota suggest that the companies led them to adopt new business practices and quality standards. United Technologies recounts how Toyota equipped their workers with stopwatches to analyze their processes and cut down on time to improve productivity. The supplier also recalls how Toyota's model included workers proposing their own ideas to improve the process.[xl]

The supplier relations process for Toyota included carrots (assistance with process improvements) and sticks (measurement of errors and deviations from the standard).[xli] As one supplier who made the Camry's disk brakes recalled, "Every mistake is a demerit. When we started a few years ago our score was 62 percent. Within 18 months it was 99 percent and it stayed that way. If your score is low and doesn't improve you can lose the business." By supplying resources and adding pressure, Toyota helped upgrade its suppliers in the United States, contributing positively to the regional ecosystem.

By upgrading the capabilities and quality standards of suppliers, these foreign OEMs could also improve the manufacturing environment for their U.S. competitors – as well as the environment for startups to scale in the United States. One plant manager working with Toyota summarized their impact: "Nothing has changed our plant as much as the way Toyota taught us to look at all the little things."[xlii]

However, anchor investments also come with risks. An anchor firm that is bringing new industrial activity to a region will not necessarily have a pre-existing talent base from which to recruit workers – or an established network of suppliers. Although there is an opportunity to help establish a local cluster in the region where the firm is investing, the lack of pre-existing infrastructure could prove as a delay or deterrent to the anchor firm scaling up locally. These factors helped contribute to the difficulties with Foxconn's proposed anchor investment in Wisconsin, which was unraveled in part due to the lack of a key supplier network. The Foxconn factory was initially established to produce plasma displays, but there was no capable producer of the right type of glass in the region. For an anchor to have spillover effects, it needs to support the growth of an ecosystem of workers, suppliers, and ideas that can help its enterprise as well as those of its neighbors.

II. ACCELERATOR FIRMS

Accelerator firms enter an established ecosystem and make significant contributions to expand the capabilities of the ecosystem and contribute substantially to its growth. When accelerator firms invest in a region, the region may have a pre-existing network of manufacturers and established institutions dedicated to workforce training and research & development. The accelerator firm's contribution is to invest in these existing institutions and broaden their reach, drawing new firms to the region with complementary capabilities. The investment of Novo Nordisk in the Research Triangle of North Carolina exemplifies this type of investment.

When Novo Nordisk, a Danish company, invested in U.S. facilities in the Research Triangle of North Carolina, it followed a similar pattern. Novo Nordisk was one of dozens of companies contributing to a decades-old regional ecosystem. There was apparently less influence to steer the region's capabilities in a direction beneficial to the accelerator company.

The Novo Nordisk case highlights how a foreign company's scale-up can coincide with its embedding in a regional innovation ecosystem. Novo Nordisk first invested in a small enzyme production factory near Raleigh-Durham, NC in 1979, just as the Research Triangle was developing the infrastructure and university connections to support a regional biopharmaceutical industry.

As the region's R&D infrastructure for biomanufacturing grew beginning with the 1984 establishment of the North Carolina Biotechnology Center, Novo Nordisk's operation in North Carolina grew and transformed from a small facility producing enzymes to a set of multiple factories, along with R&D operations. Novo Nordisk became a funder of related research at North Carolina State University and – in 2021 – launched a new $2 billion manufacturing facility in the United States to produce Ozempic, one of its highest-growth and most innovative therapies. The billion-dollar factory investment is clearly an accelerator for the growth of the regional ecosystem, but it is layered on pre-existing anchor investments in the Research Triangle that established it as a hub for biotechnology.

There is early evidence that new foreign investment in the electric vehicle and battery industries could follow a similar model. On the one hand, the commitment to produce battery cells and modules in the United States represents a new kind of production that will require new skills and elements of a new supply chain. Given foreign expertise in battery production, there is an expectation that new knowledge is required and foreign investment could provide significant spillovers. However, transplant battery factories thus far do not seem to resemble anchor investments where foreign companies are building an entirely new ecosystem. Instead, the firms are adding elements to a pre-existing supplier network with existing channels for workforce development and R&D.

Multiple automakers have initiated joint ventures with battery companies to produce new car batteries in the United States, often linked to pre-existing automotive supply chains. For example, Ford Motor Company and SK Innovation (part of a South Korea-based conglomerate) have initiated a U.S.-based joint venture called Blue Oval to produce batteries. Notably, the flagship battery plant is connected to a larger Ford assembly facility where it plans to produce electric vehicles. The facilities are located in Tennessee, which has a pre-existing automotive supply chain, as well as an established and acclaimed statewide technical training system that is widely accessible.[xliii]

Also, BMW has partnered with another foreign-owned battery maker, AESC, to produce batteries near its South Carolina campus. AESC will produce battery cells, and BMW will produce battery modules in close coordination for its electric vehicles. The plants will be in the same region as one another and BMW's larger automotive campus in South Carolina. They will draw on the pre-existing resources of the established BMW supply chain, all while adding new capabilities to it.

III. ASSIMILATOR FIRMS

Assimilator firms invest in the United States and end up performing similar to their peers in the region. Unlike the typical foreign-owned firms, which pays higher wages and exhibits higher productivity than the typical domestic firm, the assimilator firm operates in a way that resembles the typical firm in the U.S. region where it operates, despite having headquarters abroad. The assimilation could be due to the foreign-owned firm acquiring or merging with a pre-existing American firm. The assimilator firm could have also recruited regional leadership or adopted management practices that led it to mirror its regional peers. In this case, the assimilator firm still makes significant contributions to the regional economy, only with the more typical economic spillovers of any regional manufacturing firm.

Table 5

Transplant Factory Spillovers

Mechanism	Anchor Model: BMW, Toyota	Accelerator Model: Novo Nordisk	Assimilator Model: Stellantis
Workforce	Shaping statewide workforce system	Recruits from pre-existing pool of talent, adds incremental skills and experience	Domestic workforce largely unchanged
Supplier Relations	Increases quality standards, maintains long-term relationships	Attracts new suppliers while benefitting from existing population of suppliers	Maintains pre-existing supplier relations
Innovation	University partnerships to connect to the ecosystem	Invests in pre-existing local institutions and infrastructure to advance research and development	Comparable innovation approach to domestic peers

Assimilation does not necessarily have a positive or negative connotation. If the foreign firm is higher-performing than the peers in the U.S. region where it's investing, assimilation would lead to lower performance (and fewer positive spillovers) than the accelerator or anchor model. However, if the firm is assimilating in a high-performing regional cluster, there could be performance benefits.

For example, consider assimilation that occurs when a foreign-owned firms merges with or acquires domestic American firms. Rather than raise the bar for transplant factories, as anchor and accelerator investments aim to do, assimilator investments like these resemble domestic U.S. investments in manufacturing assets. For example, the automaker Stellantis was formed from the merger of Fiat Chrysler (which itself was a merger of Chrysler and Fiat) and Peugeot S.A. When Stellantis announced investments in new Michigan factories to expand production of its legacy American vehicle brands, such as Dodge and Jeep, there was not clear evidence that Stellantis was going to import a different approach to production from the legacy practices at Chrysler, which had nearly a century of manufacturing in Michigan. Instead, the main "foreign" dimension of the investment was where the company was headquartered.

However, assimilation can also occur where foreign firms invest in a high-performing U.S. regional economy and invest to gain benefits from a pre-existing cluster. In this case, assimilation may lead the transplant firm to experience even higher productivity and hire more local workers than it would have otherwise. After all, manufacturing firms locating in regions where there is pre-existing expertise tend to generate more innovation and operate more productively than if they had located elsewhere. If this is the case, an assimilating factory could contribute more benefits to the domestic economy than it would have otherwise.

For example, in Columbus, IN, which has the highest concentration of employees at foreign-owned firms in the United States, there is already a critical mass of high-performing foreign-owned companies, as well as an anchor American manufacturer, Cummins Engine. When new manufacturing firms assimilate into the Columbus regional economy, they are recruiting a skilled workforce and performing with high productivity.[xliv]

IV. WHAT DIFFERENTIATES ANCHOR FIRMS?

Anchor firms like BMW and Toyota have had the most demonstrative spillover effects on the regional workforce and peer domestic firms. Regions attracting FDI and firms pursuing FDI projects might justifiably attempt to replicate their success. Two factors appear to have contributed to the ability for these firms to "raise the bar" for firms and workers in the region where they invested.

First, anchor firms are pioneering a new type of production in the region. Even if the companies themselves are not experimenting with building a new product, it is important that the FDI factory requires new capabilities from the region. This is important because it requires mobilization from workforce development institutions and suppliers to generate new practices and strengths to meet a new kind of demand. This is in contrast to accelerator and assimilator firms, which enter into a region with pre-existing strengths and where it is more difficult to redefine the production paradigms. The novelty of trying to produce something that the region has not produced before yields an openness to adopting new practices and building new partnerships.

Second, anchor firms exhibit an openness to collaboration and promoting the industrial commons. They serve more as a park where outsiders can visit and learn, as opposed to an island that's guarded from outside visitors. BMW's partnership with and contributions to the workforce development commons through the technical school system in South Carolina, as well as Toyota's openness to visitors, and encouragement of suppliers to study their practices, both exemplify an open and cooperative approach to building a regional network with other firms.

4. The Path Forward in the Semiconductor Industry

The anchor, accelerator, and assimilator models make several core assumptions about what drives highly productive manufacturing firms. These models assume that manufacturers primarily recruit a skilled production workforce, as well as capable suppliers, from their immediate regional surroundings. It also assumes that a density of manufacturers next to related R&D can generate cluster effects that make firms more productive. These assumptions are drawn from regional manufacturing data across industries, as well as industry-specific examples cited above from the automotive and pharmaceutical sectors. However, as foreign investment in the U.S. semiconductor industry grows, it is unclear whether these assumptions and models apply to new investments in the microelectronics industry.

I. THE MICROELECTRONICS DIFFERENCE

The semiconductor industry has several important differences from other manufacturing industries in terms of the workforce skills required, the relationship between organizations in the ecosystem, and the paths to innovation.

A. Workforce

The semiconductor manufacturing workforce – particularly in advanced-node chip fabrication environments – includes a higher share of college-educated engineers, including those with specialized degrees, than other manufacturing industries. In the countries where they are headquartered, for example, TSMC and Samsung hire primarily workers with college degrees to fill technician roles at advanced fabrication facilities. And across the industry, the demand for engineers far outpaces the demand for production workers who do not require a college degree and earn lower wages.

The workforce demands for semiconductor fabs contrast sharply with workforce requirements in other manufacturing sectors, like the automotive industry. Most manufacturing sectors recruit workers without a college degree into production roles, which are typically lower-wage jobs, many of which require minimal technical training before being hired. In many manufacturing sectors, the demand for workers is polarized – there is high demand for lower-wage production workers and high demand for skilled, higher-wage engineers. There are fewer jobs in middle-wage, middle-skill occupations. The skill demand for semiconductor workers is weighted toward the high-wage, high-skill end of the distribution (see Figure 5).

Although the skill demands of chip foundries like TSMC and Samsung have historically focused on college-educated workers, it is important to emphasize that skill demands for the re-emerging semiconductor ecosystem in the United States are more diverse. Partners for chip manufacturers, such as specialists in packaging, testing, and assembly, as well as suppliers of chemicals and equipment, have more diverse skill needs and still require a pipeline of skilled workers without a college degree.

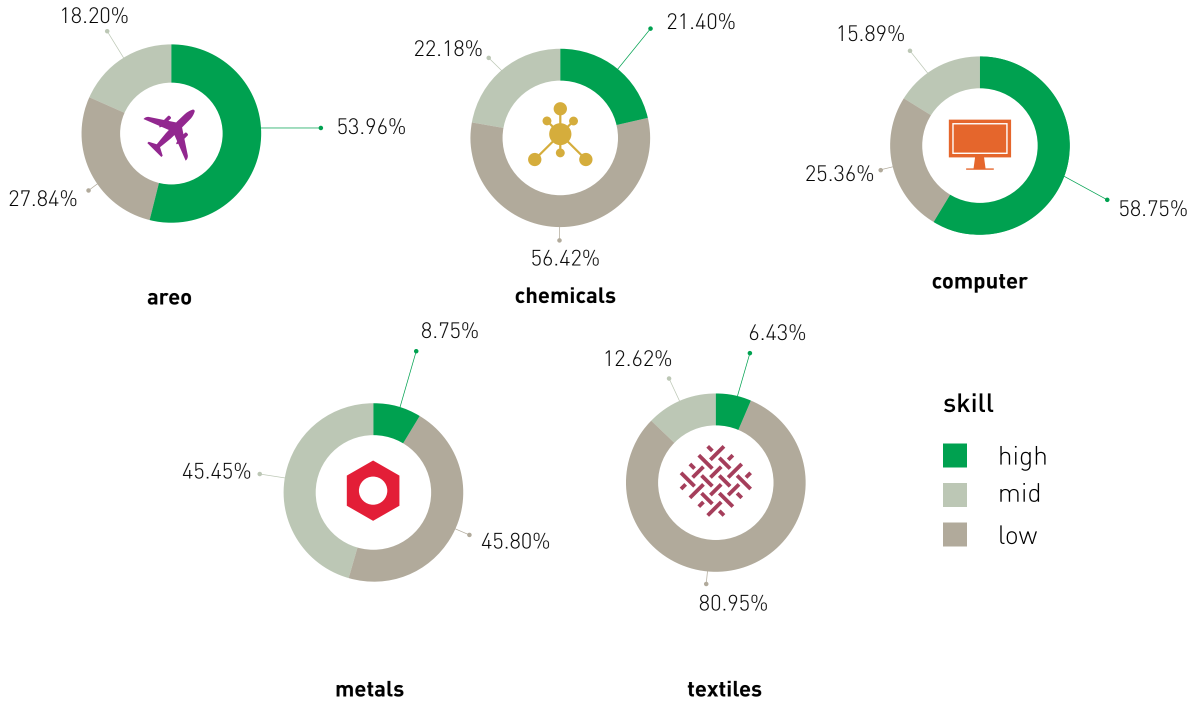
Moreover, as part of TSMC's investment in Arizona chip fabs, it has begun recruiting technicians without requiring new hires to have a four-year college degree. The same technical skills will be required to perform technician jobs will be required in Arizona as they are in Taiwan, but the Arizona jobs will operate in a different workforce development system.

Even though TSMC's new Arizona fabs are still under construction, it has signaled investments in the workforce development commons to build a pipeline of technicians who are equipped to work at TSMC fabs. Through partnerships with local career and technical education programs, as well as community colleges, TSMC is helping design curricula for particular technician jobs, which potential applicants can train for at local educational institutions. It is has also developed registered apprenticeships for several of its technician roles, defining a curriculum and committing to mentor and hire technicians who make a long-term commitment to complete the multi-year apprenticeship program, which includes working at TSMC and completing an Associate's Degree.[1]

1 Gary Hilson, "TSMC, NXP Scale Up Apprenticeships," *EE Times* (blog), March 14, 2024, https://www.eetimes.com/tsmc-nxp-scale-up-apprenticeships/.

Figure 5

Skill Demand by Sector



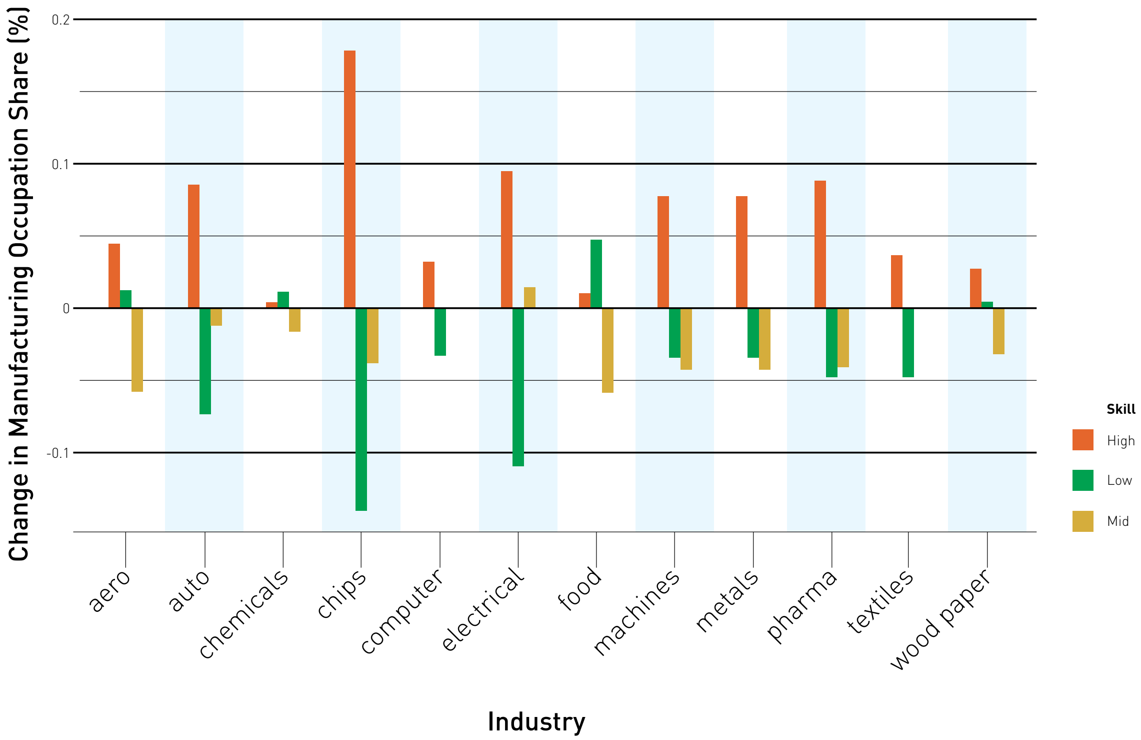
Recruiting a semiconductor workforce of highly-educated engineers, along with highly-skilled technicians requiring less formal education, has three implications for the regional ecosystem. First, it requires FDI factories to define the skills and personnel they require in order to partner with colleges, universities, and other training programs to define the curriculum that they will offer. There are potential spillover effects to defining industry-specific curricula for local training institutions. Since large FDI firms like Samsung and TSMC will not hire all the graduates that emerge from the programs they help define, the regional talent pool with skills relevant to the semiconductor industry will grow – and attract more related firms.

Second, the importance of the college-educated engineering workforce for the semiconductor industry expands the geographical scope of a company's workforce pipeline. Whereas companies recruiting a lower-wage, less-educated workforce often recruit from the region where they are based, companies recruiting higher-wage workers with more specific skills (e.g. high-technology and financial services companies) cast a wider net, recruiting from a national pool of workers. The latter approach would put less pressure on having a robust pre-existing regional ecosystem of talent.

Third, since chip manufacturers might require *specific skills* to work in a foundry – not just an advanced degree – it is unclear whether a chip manufacturer's investment in workforce training will spill over to other regional firms and suppliers to the extent that BMW's investments in technical training helped serve other regional manufacturers in need of similar skills. For companies like TSMC and Samsung, the workforce demand is in some ways distinct from their suppliers and other ecosystem partners, which are likely to demand different skills and expertise, despite being in the same industry.

Figure 6

Change in Skill Demand by Sector



However, early evidence from TSMC's approach to partnerships with training institutions suggest that industry-specific skill for technicians may be possible to provide. At the outset of establishing curricula for educational programs to train potential TSMC technicians, TSMC convened representatives from all the main training providers in their region of Arizona. The goal was to have a joint conversation about what skills the programs currently offered, where the gaps were, and to develop a holistic approach across the multiple training institutions. In the meeting, TSMC representatives learned that no other employer had gathered the multiple training providers together before this event. Convening activities like these bear some resemblance to BMW's early coordination with South Carolina's Technical College System.

There are several ways that TSMC's early investments in technician education programs could serve the industrial commons and anchor the growth of a highly-productive semiconductor workforce in Arizona. The first mechanism is the convening: by providing a focal point for educational institutions to develop new curriculum that meets high standards. The second mechanism is that the training is not TSMC specific. Graduates of the technician programs that TSMC is helping develop could work at TSMC or elsewhere in the semiconductor industry. In this way, the early workforce efforts are contributions to the industrial commons. If they succeed, the region will be capable of training a pool of semiconductor technicians that allow the companies hiring them in Arizona to operate more competitively than if they had located elsewhere.

B. Suppliers

The semiconductor industry ecosystem – the relationship between foundries, customers, suppliers, and other partners – is also different than the modal manufacturing sector. In the automotive industry, a small group of original equipment manufacturers (OEMs) manage a network of suppliers from which they buy parts and equipment. Moreover, some of their suppliers tend to cluster around the OEM to provide parts in a timely way, and learn as the OEM introduces new products and practices. This hierarchical relationship enabled companies like BMW and Toyota to influence other suppliers located nearby and raise the bar of manufacturing quality in the region. The phenomenon is known as agglomeration economies – when an innovative firm locates in a region, it tends to attract similar firms, or firms performing complementary functions, and the more concentration of talent and related activity, the more productive the average firm becomes.

The semiconductor ecosystem for TSMC and Samsung's foundry business is structured as a distributed network. TSMC and Samsung serve customers like Apple, Qualcomm, and Nvidia, which design the chips that TSMC or Samsung might produce. The customers also contract with other providers of essential tools like software for chip design and process control. They also access core intellectual property (IP) blocks from other companies that have innovated in chip design over generations. The foundries in turn work with suppliers of chemicals, equipment, and other core infrastructure and materials to produce the chips for their customers. Once chips are produced at foundries, they go through additional packaging, testing, and assembly, which the customer might choose to do within a foundry (if available) or through a third party.

One consequence of this distributed network is that it is not immediately clear how local customers and their foundries or other suppliers must be. The key semiconductor supply chains have evolved in the last several decades to be more global than other industries. Although there are some clusters of suppliers and R&D offices near TSMC's hub of chip foundries in Hsinchu, Taiwan, for example, there are also critical suppliers in the Netherlands, Japan, and the U.S., including critical customers and software providers in Northern California.

It is plausible that supplier relationships for Samsung and TSMC will evolve as they did for BMW and Toyota. While BMW and Toyota imported parts and equipment from many suppliers in their early years of operation, they slowly built up trust and confidence in a broader network of domestic suppliers. Since the announcements of the new fabs in 2020 and 2021, suppliers for the foundries have also announced moves near TSMC and Samsung on their respective campuses. TSMC has said that they expect a group of suppliers to move to Arizona to serve its new fabs, and they also plan to build new relationships with domestic suppliers that will expand their capabilities to meet TSMC's quality needs. The key question is how beneficial local concentration of semiconductor suppliers and fabs is for the productivity and innovation of the semiconductor industry, as compared to the automotive industry.

C. Innovation

On innovation, the R&D – rather than driven by an OEM – is a coordinated process between the foundry and customer designing the chip, as well as a network of software providers and equipment manufacturers. In many ways, the members of an ecosystem are at once guarded about their expertise and advantage, but cannot be walled off since they depend on other actors in the ecosystem to continue to innovate and make progress in the performance, cost, and energy efficiency of the chips they produce.

TSMC, for example, hosts what they call the Open Innovation Platform, which is designed to convene the firm's customers, software providers, IP owners, and even firms involved in supplying equipment and performing testing and assembly. The goal of the convening and coordination is to discuss and understand the direction of new chip technology. In the past, this has focused on each node shift along Moore's Law. However, these conversations also focus on new advantages in packaging and materials, as well as other advances that improve performance and cost.

TSMC and Samsung have each emphasized the importance of R&D as a component of their new manufacturing campuses. TSMC in particular has said that they aim to recruit a high concentration of R&D engineers to work at the campus, in addition to their production technicians and engineers. They see benefits of having R&D personnel co-located with production personnel so that they can share knowledge of what is working in production – and what can be improved. The concentration of R&D near production for TSMC suggests that other partners in the Open Innovation Platform, such as software providers, may co-locate near production facilities as well. Although automotive FDI projects have had some R&D components, the investment in innovation and new process development appears to be more central to these semiconductor industry investments.

II. MODELS OF PAST SEMICONDUCTOR FDI PROJECTS

Past FDI projects in the semiconductor industry have not followed a single playbook. Samsung's prior investment in Austin, TX resembles the accelerator path. The Austin region already had a semiconductor ecosystem including suppliers, workforce, and R&D given previous investments from domestic chip producer Advanced Micro Devices (AMD) and the R&D consortium SEMATECH (which was first headquartered in Austin before moving to New York State). Unlike BMW and Toyota, which introduced new workforce approaches and supplier relations into the regions where they invested, Samsung's investment in a new chip fabrication plant in 1998 followed two decades of microelectronics investments in the region. By investing in Austin, Samsung was choosing to locate in a region with pre-existing strengths in semiconductor production and electronics more generally.

In 1978, Advanced Micro Devices (AMD), one of the pioneers in chip production based in Silicon Valley, chose to expand beyond their California headquarters to build a fab in Austin, Texas. At the time, the Austin area was home to the University of Texas at Austin and the state capital, but not much else beyond a Motorola electronics assembly plant. AMD appeared to be motivated at least in part by the rapid growth of the technology sector in the Bay Area along with the rising cost of land and rising competition for talent.[xlv]

In the two decades following the AMD investment, domestic semiconductor expertise began to concentrate in the Austin region. A prominent microelectronics research and development consortium, the MCC, decided to locate in Austin over Silicon Valley and the Research Triangle in North Carolina in 1984, part of a statewide concerted effort to attract more semiconductor expertise. The growth of Dell Computer and the arrival of SEMATECH, another industry-wide research consortium, helped continue the expansion of the microelectronics industry in the region through the 1980s.

By the time Samsung arrived and established its U.S. operations in Austin in 1996, there was already talent to engineer and produce chips, as well as a base of suppliers to provide critical inputs. There was also the University of Texas at Austin and SEMATECH, which represented sources of innovation for the domestic industry and could prove to be a source of new ideas for Samsung's domestic headquarters as well.

In these ways, Samsung did not need to establish a new network of suppliers or train an entirely new population of workers to thrive in the Austin region. However, by expanding local demand for semiconductor talent and expertise, as well as equipment and raw materials, the Samsung investment likely accelerated the growth of the existing ecosystem.

In 2022, Samsung committed to expand dramatically its existing investment in Texas, beginning construction of a new campus outside Austin, much larger than its previous campus. The new campus would produce more advanced-node chips, which represent a leap forward in technology compared to what the company had previously produced. However, early reporting on construction and ecosystem building suggests that the new campus is extending the networks of the previous facility in Austin.[xlvi] These investments represent a new type of chip production, but they appear to be drawing on the pre-existing ecosystem of talent, innovation, and suppliers that already exist in the region.

The foreign-owned AMD spin-off, GlobalFoundries, established a chip fab in Malta, NY that had elements of the accelerator and assimilation investment paths. Although upstate New York had pre-existing semiconductor R&D expertise at SUNY Albany and through investments from IBM and Tokyo Electron, the GlobalFoundries fab generated new demand for semiconductor production talent and required the establishment of a new supplier network. But given that GlobalFoundries is a spin-off from an American firm, it did not bring the competitive advantages of a foreign-owned firm. Instead, its investments were those of a semiconductor manufacturer with American roots.

TSMC's previous investment in the United States – a joint venture to acquire the U.S. semiconductor fab WaferTech – seemed to follow the assimilation path. WaferTech was a pre-existing U.S.-based semiconductor producer. Its campus was built in Camas, Washington near Intel's pre-existing network of semiconductor fabs, including a network of industry-specific suppliers, a pipeline of talent, and R&D expertise. But the joint venture did not expand as anticipated, nor has this U.S. operation adopted any of TSMC's advanced processes that they have deployed in Taiwan.[xlvii]

Based on these examples, what can be made of Samsung's new investment in Texas and TSMC's investment in Arizona?

Given Samsung's pre-existing investments in Texas, it is possible that the firm continues its role as accelerator, deepening the relationships and workforce pipeline that it already has, albeit adapting it to new processes. For Samsung to become an anchor of a new kind of semiconductor industry in the region – one that increases its level of innovation and cost competitiveness – it will likely need to bring in new suppliers and attract a higher density of skilled workers to the industry, beyond what has already occurred since the 1970s.

It appears more plausible that TSMC could prove to be an anchor firm developing a regional ecosystem of more advanced semiconductor production, given that it is introducing a process in its Arizona fab that has not been produced before in the United States. There is existing infrastructure for semiconductor production in the region. Intel already has an Arizona campus. However, TSMC's foundry model – which necessitates an innovation ecosystem – is distinct from Intel's legacy of integrated design and manufacturing in Arizona. There is an opportunity for TSMC to serve as an anchor for a new kind of production network that transforms the region's approach to workforce development and innovation.

III. A PATH FORWARD FOR THE SEMICONDUCTOR ECOSYSTEM

A. Workforce

Similar to BMW, TSMC has facilitated a workforce exchange between its "transplant" factory and its counterpart near the company's Taiwanese headquarters. Engineers based in Taiwan are helping stand up the fab in Arizona (similar to how German engineers helped establish the South Carolina factory), and new hires for the Arizona fab are spending time studying best practices in Taiwan (as South Carolina production workers did with BMW operations in Germany).

Semiconductor manufacturers aim to recruit a higher concentration of skilled workers – primarily engineers with four-year degrees or more – and compete for talent with other high-technology industries, not just other manufacturers. One challenge of becoming an anchor firm will be to help reshape university training programs that can serve as recruiting pipelines for the domestic firms, as well as their suppliers and competitors. The transformation of university training pipelines can also serve as new sources of semiconductor-related entrepreneurship.

The importance of college-educated engineers with industry-specific skills might appear to differentiate FDI projects from semiconductor firms like TSMC and Samsung from the investments of BMW and Toyota, which recruited a different population of workers. However, TSMC has also invested in supporting a regional pipeline of technicians in the industry to fill production and maintenance roles that require industry-specific knowledge. The development of regional workforce programs to fill these roles indicate that TSMC – like BMW – is investing in the industry commons for the Arizona region, providing technical training options for technicians not just at TSMC fabs, but at other firms requiring similar skills that emerge in the region.

B. Suppliers

The surge in semiconductor industry investment is clearly a growth opportunity for suppliers to chip fabs and other companies in the semiconductor ecosystem. The open question is whether foreign-owned multinationals will "raise the bar" for suppliers by providing new knowledge of production best practices that could spill over beyond the immediate semiconductor industry, similar to the "Toyota Production System" sparking a broader adoption of lean manufacturing.

Semiconductor industry value chains differ from automotive value chains in several ways. For one, semiconductor suppliers (chemical, machine, and component manufacturers) often rely on different workforce requirements and production processes than large chip fabs, which have made the largest investments. The specialized knowledge at the suppliers might limit the impact from chip fabs to raise the bar. Moreover, in the semiconductor industry's fabless model, where TSMC and Samsung both operate foundries, they operate much differently than OEMs, which serve as customer to their suppliers. For TSMC and Samsung, their customer is the chip designer, which may contract with TSMC to make wafers, another company for assembly and test, and another firm to provide software and R&D. TSMC has its own suppliers of equipment and chemicals, but it is just one hub in the ecosystem – it does not control the entire supply chain.

There is an opportunity for large chip fabs like TSMC to become knowledge hubs for their suppliers and ecosystem partners to support regional learning and standard-setting as new advanced-node technologies are introduced in the United States. If these chip fabs provide a reason for other ecosystem partners to locate nearby, other companies are more likely to learn from their practices and experience positive spillovers from the chip fab investments.

C. Innovation

Despite the substantial investments of the CHIPS Act, it is unclear whether the U.S. will become a more prominent source of innovation for the semiconductor industry (where R&D has been globally distributed), or merely support more semiconductor production. An innovation ecosystem focused on software and chip design for the semiconductor industry currently exists in Silicon Valley, but it is unclear whether foreign-owned chip producers will introduce new breakthrough product or process innovations first in the United States. Foreign-owned companies may use transplant factories to scale innovative products to meet local demand, but not initially develop and prototype those innovative products at the transplant factory.

Nonetheless, there is an opportunity for TSMC and Samsung's respective partnerships with universities and ecosystem partners to experiment with new innovations and concentrate R&D talent around their new fabs in Arizona and Texas. In this way, there are lessons the firms can draw from the limitations of SEMATECH, the U.S. government's consortium promoting semiconductor innovation, which supported advances among large companies, but not smaller ones at different stages of the value chain.

There are early indications that TSMC and Samsung will invest in the industrial commons for innovation by supporting new R&D and entrepreneurial efforts in their respective regions, particularly initiatives emerging from universities. TSMC has a legacy of such university partnerships by providing design tools and access to its advanced production technologies to researchers and students as they learn to develop new chips. The university program, which provides some production capacity to students experimenting with chip design, is an investment in building an ecosystem of students and researchers with the ability to develop new technologies that can advance the industry as a whole.[xlviii] Samsung has a related open innovation program, where it fields university research proposals related to its core R&D priorities, then selects academic teams with which to partner and provide resources.[xlix] There are manifold opportunities like these for foreign investments in R&D to contribute to a more fertile environment for semiconductor startups that can help attract new talent to the industry and increase the capabilities of domestic suppliers.

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