Impact of U.S.-China relations on the global semiconductor supply chain disruption and opportunities posed to Brazil's emerging economy

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The year 2023 marks one of the most hostile points of U.S.-China relations. While one would assume the absence of major political events and elections in all People's Republic of China (PRC), the U.S., and Taiwan this year would create a favorable environment for relationships to stabilize, tensions have reached the boiling point with all lines of security dialogues and communications on pause. While the rapid ascent of China has compromised America's invincible global dominance, its leading edge in the advanced semiconductor sector is one that could not be surpassed for imminent national security concerns. As the U.S. initiated domestic export controls and foreign alliances created production gaps in the global semiconductor value chain, opportunities arose for other nations to take part in the globalized chip-making process. This paper aims to unpack the following questions: How is the global semiconductor supply chain disrupted by the current U.S. export control policies and the CHIPS Act? How did the effects of the restrictions change China's positioning in the industry? What is Brazil's current technological know-how in the industry? And to what extent could Brazil benefit from China's expansion in the legacy chips sector through trade partnerships?

<u>Background of Brazil's Semiconductor Industry</u>

Brazil holds the largest economy and population size in the Latin America region, with the foundation of its semiconductor industry built in the 1980s. After a decade of unfavorable foreign direct investment (FDI) and import tax policies, all semiconductor companies were forced to relocate their operation to other countries, and export end-use products to Brazil. Subsequently, the Trade Liberalization Program that eliminated most import tariffs in the 1990s and the increasing domestic demands for electronic products attracted more FDI in the Brazilian semiconductor industry. The matured operation processes brought by foreign companies such as Dell, IBM, and HT Micron have eventually laid the groundwork for Brazil's skill specification in memory modules, IC design, and packaging. However, the lack of fundamental know-how and funding to engineer a domestic semiconductor industry that does not depend on foreign suppliers remained virtually impossible in the 2000s.

Ceitec was established in 2008 as the first and only state-owned integrated device manufacturer (IDM) in the Latin American region. With prior engineer knowledge in IC design and packaging from foreign investors, namely the upstream and downstream processes in the value chain, a foundry venture named SIX Semiconductores (later Unitec) in 2012 was built through the financing of IBM, the National Bank for Economic and Social Development, and EBX with the intent to bridge the gap in the production process in the midstream wafer fabrication and manufacturing. However, a series of uncommitted funding challenges have led to the closure of the foundry in 2018, and the wafer fabrication functionality in Ceitec remained largely unsuccessful with most efforts conducted offshore. The future of the industry became more grim when President Bolsonaro initiated the liquidation process of Ceitec in 2020 as he deemed the company unprofitable. Although the narrow victory of President Lula de Silva in 2023 reversed the privatization of Ceitec after a thorough evaluation conducted by the Inter-Ministerial Working Group in Brazil, the Lula government has yet to develop a long-term sustainable strategy for rejuvenating its semiconductor industry and establishing its competitive edge in the global semiconductor supply chain.

Brazil currently has 11 operating semiconductor companies, producing 10% of the national demand for chips and generating 3.2% of global revenues in 2020. Based on the groundwork laid by historical operations and current foreign investments, the Brazilian semiconductor industry specializes in IC design, memory modules, and packaging of consumer products, which is the upstream and downstream segment in the value chain. In particular, most of its chips are applied to memory-related products and embedded DRAMs.

DRAM refers to Dynamic Random-Access Memory that stores data in memory cells, and is usually presented in the form of an integrated circuit (IC) chip. In Brazil, the current DRAM ICs available are embedded multimedia controllers (eMMCs) like automotives and drives, embedded multi-chip packages (eMCPs) like Internet of Things (IoT) devices and smartphones, and solid-state storage drives (SSDs) in computers. With increasing foreign investments by Smart Modular, a U.S.-based semiconductor company specializing in data storage chips, and HT Micron, a joint venture with South Korea-based Hana Micron as its major shareholder that offers advanced memory products, Brazil's assembly, testing, and packaging (ATP) ecosystem is expected to become more advanced in application of system in package (SiP) and IoT industry. The development of an advanced packaging laboratory in Brazil's largest R&D center Eldorado, which designed chips applied in medical ICs and radio frequency identification devices (RFIDs), also marks the increasing supply of advanced chips to the domestic market.

With Brazil's current semiconductor technology and hardware facilities, how can the industry take advantage of the semiconductor supply chain disruption caused by the current U.S.-China hostile trade relationship?

Current U.S.-China Semiconductor Trade Relations

Since the 1990s, China has invested heavily in building its domestic semiconductor industry starting with Project 808 in 1991. However, inconsistent development goals, insufficient funding and industry talents, corruption, and the industry's peripheral position in the wider economic agenda had hindered its ability to innovate and decrease dependence on imported technology. It was until Xi Jinping's ascension in 2012 did the state started investing in a concerted effort, with the founding of the National Integrated Circuit Industry Investment Fund (Big Fund) in 2014 and the Made in 2025 vision announced in 2015. Although China is not making positive progress in reaching its goal of achieving 70% self-sufficiency by 2025 as a "global powerhouse" with only approximately 30% self-sufficiency production rate in 2019, the government's $143 billion chip investment package in 2022 demonstrates a determined effort to innovate advanced IC chips that may further strengthen its military defense, prompting greater fears surrounding the higher possibility of Taiwan invasion. Currently, China state-owned company SMIC is able to produce 7 nanometer (nm) process chips, compared to the most advanced 3nm chips the U.S. has production access to. Yet, SMIC took less than 2 years to innovate the 7nm chip from its 14nm chip without any Western equipment and technology and demonstrated similarities with the TSMC 7nm chip that used the most advanced EUV lithography system from the Dutch ASML company. The speed of Chinese semiconductor innovation poses a serious threat to the U.S. in terms of rapidly growing capability to potentially surpass America's military, AI, quantum computing, and 5G wireless domination.

In order to counter the growing national security threat, the U.S. Bureau of Industry and Security (BIS) unveiled a set of export controls in October 2022 to ban Chinese companies from purchasing any advanced chips and chip-making equipment without an authorized license. The expanded U.S. Export Administration Regulations (EAR) limit the export and re-export of high-performance ICs, supercomputers, advanced IC manufacturing equipment, and any related technology to China. It also restricts all “U.S. persons” and companies, including U.S. citizens, permanent residents, and persons with U.S. asylum status worldwide from providing any type of support for the development or production of advanced IC in fabrication facilities in China, highlighting the intensive limitation in the outflow of know-how and talents in advanced technology from a strict top-down level.

To further counter the development of advanced technology in China, the U.S. initiated a deal with the Netherlands and Japan to prevent other industry leaders from backfilling the technologies restricted in January 2023. The Dutch company ASML is the only company in the world that’s capable of producing the machinery required for manufacturing the most advanced chips, namely 7nm, 5nm, and 3nm chips. Meanwhile, Japan is not only the top producer of specialized tooling equipment for manufacturing advanced chips, taking 27% of the global market share, but also China’s largest semiconductor manufacturing equipment exporter. As a result of the deal, the Dutch government restricts the export of all EUV equipment and at least 3 types of machines that use deep ultraviolet (DUV) lithography, a less advanced technology that turns electric circuits into semiconductor wafers with processes larger than 7nm. The Japanese government also restricted 23 equipment items used in film deposition to China, mainly affecting the production process of advanced chips.

At the core of these sanctions, the U.S. is determined to reestablish a domestic stronghold in its semiconductor industry to secure its national security. Within the $280 billion fund allocated in the U.S. CHIPS and Science Act passed in August 2022, $52.7 billion was dedicated to strengthening U.S. semiconductor manufacturing and research & development. In the face of

East Asia's dominance in the chips manufacturing market, accounting for 75% of global wafer fabrication capacity in 2021, and Taiwan (92%) and South Korea's (8%) monopoly in the manufacturing capacity of advanced chips (>7nm); as well as its shrinking manufacturing capacity by global share from 40% in 1990 to 12% in 2022, the Act aims to restore the semiconductor value chain and increase its semiconductor supply chain's resilience against any future disruption caused by both imposed tariffs or unpredictable natural incidents like COVID-19. Shortly after the plan was announced, Samsung announced its plan to build a $17 billion chip fab in Taylor, Texas for manufacturing advanced computer chips and logic semiconductors; with over 50 other new semiconductor ecosystem projects announced across the U.S. that amounted to nearly $200 billion of private investments. The International Technology Security Innovation (ITSI) Fund also passed under the CHIPS Act provides the Department of State with 500 million to diversify the global semiconductor supply chain, especially the downstream ATP process, in the Indo-Pacific and the Americas.

Opportunities for Brazil Amidst U.S.-China Tech Race

With the new Act and export controls, how could Brazil take advantage of the situation for its own benefit? The following section unpacks the production limitations and avenues for China under the U.S. export controls and potential opportunities Brazil may undertake with its pre-existing technology to strengthen its domestic semiconductor industry through partnership with the U.S. and/or China.

The export control has virtually cut off China from all the necessary technology needed to innovate and mass manufacture advanced chips at least for the next few years. In particular, the Dutch export control that restricts the supply of EUV and DUV equipment from ASML to

China would be most detrimental. The importance of this equipment is demonstrated by China's active stockpiling of DUV equipment before September 1, the start date of the Dutch export restriction of DUV equipment, with sales to China reaching 8 times more than the same period last year in January to July 2023. Without such equipment to conduct the film deposition in the manufacturing process, it casts a natural choke point in the future innovation of China's semiconductor industry until "indigenous" replacements appear. Besides, since almost all advanced chips in China today are tied to U.S. technology, from tools, design software, and intellectual property, with 95% of AI chips designed by U.S. companies, the CHIPS Act has heavily attacked its ability to not only innovate but also continuing its production of advanced chips to meet development goals. However, while the situation seemed utterly desperate from the Chinese perspective, it is important to note that such restrictions are largely confined to advanced chips for strategic reasons, rather than the entire industry as a whole.

In fact, the global semiconductor shortage during COVID-19 was largely confined to legacy chips, which are chips using pre-2005 technologies that make two-thirds of sales in the industry, rather than the advanced chips the export controls target. As the global legacy chip shortage prolongs especially in the automotive industry, many argue that the trade restrictions placed on Chinese companies are in fact enabling China to gain further dominance in the commercial chip industry. Since most funding in the U.S. is allocated to advanced chip production, with less than 4% allocated to the mass manufacturing of legacy chips, it creates a perfect loophole for China to use its pre-existing resources and unrestricted import products to expand its legacy chip fabs and increase its market share. Though it has a much lower profit margin compared to advanced chips, selling at less than 50 cents per chip, it has a favorable market demand to satisfy the growing commercial automotive and electronics market, which could be achieved with existing fabs.

With the expected decrease in sales and revenue with the U.S. after the series of export controls, China is becoming more attentive to expanding its trade relations with countries in the Latin America region. Since Brazil is one of the biggest markets with ample potential for growth, a trade partnership between the two countries may appear to be a win-win solution to cope with Brazil's insufficient technological know-how. In particular, Brazil has a growing demand for commercial chips applied in the automotive, electronics, and industrial sectors. Following President Lula's visit to China in April 2023, it is optimistic that both governments are building close partnerships in developing Brazil's domestic semiconductor industry, with plans to set up a working group for cooperation. With China's identified market of legacy chips and the existence of fabs in Brazil, Chinese investments in Brazil in the form of fab expansion and import of know-how may be a favorable trajectory for Brazil to rebuild its value chain and increase its level of technology for catching up with the industries' demand for more innovative products. Given that Brazil currently specializes in IC design, memory modules, and packaging, research and development inputs offered by Chinese investors and joint research would be greatly advantageous for reducing the time needed for domestic scientific innovation that suits the domestic market demands.

In terms of the U.S.-Brazil partnership potentials, given that the CHIPS Act is determined to onshore and strengthen its domestic semiconductor supply chain, opportunities for foreign companies are largely confined to countries with a well-established advanced semiconductor industry that could add value to America's current technology. While Brazil may also take advantage of the ITSI Fund allocated to invest in overseas partners' semiconductor industry, the disadvantage of such will very likely overweigh the benefits of the Fund. Firstly, the Fund only provides $100 million per year to the country, which is in no way sufficient for any infrastructural build-up with a fab costing at least $10 billion to build. Second, receiving the Fund also meant a major restriction from trading with China, which is the world's largest semiconductor market and a country with the essential know-how needed in Brazil.

However, regardless of how the Brazilian government decides to establish its semiconductor trade relations, fundamentally, it is critical for the Brazilian government to craft a comprehensively funded policy proposal that aims to sustain long term. The funding for not only building and importing the hardware but also for attracting the return of local talents who have left for international semiconductor companies that provide an amicable compensation package will be the core foundation of a solid semiconductor build-up. Taking Vietnam's emerging economy as an example, the government offers a weighted National Technology Innovation Fund of $50 billion USD to fund private enterprises like Vientel for advanced R&D and the Vietnam-Korea IT Incubator to welcome industry leaders to invest in their industry. It is also crucial for the government to lift the heavy import and export tax for semiconductor-related products to incentivize more Chinese investments and reduce product cost when exporting package chips overseas.

To conclude, whilst the ongoing policy-induced semiconductor supply chain disruption and the growing global demand for semiconductor chips, it is crucial for emerging markets like Brazil to carefully evaluate its development focus within the value chain based on existing technology and know-how, examine the specific market demands, and craft out a long term sustainable strategy resilient to macroeconomic and political changes. To expand this research, it would be essential to conduct a more thorough analysis of the current market offerings and infrastructure in the Brazilian semiconductor industry and articulate the Brazilian government's development goals - whether it is a local, regional, or global positioning.

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