The Human Circuit: A Comparative Study of the Semiconductor Industry's Labor Conditions in the US and Taiwan

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Question: How have labor conditions in the semiconductor supply chain evolved from the 1960s to the present as the industry moved from the US to Taiwan?

Abstract: This pilot study investigates the evolution of labor conditions in the semiconductor supply chain from the 1960s to the present, focusing on the industry's geographic shift from the United States to Taiwan. This chip industry move mirrors persistent cycles of labor exploitation via socioeconomic, racial, and gender-based inequities. As Taiwan has risen to dominate the semiconductor sector, producing 92% of the world's advanced chips, its labor practices reflect a legacy of exploitative strategies initially developed by US-based firms like Fairchild Semiconductor, which outsourced assembly, testing, and packaging to marginalized groups, including Native American and Asian communities. In Taiwan, the labor force now includes a significant number of South and Southeast Asian migrant workers, who face systemic inequities including low wages, stringent control mechanisms, and limited labor protections. The study examines the root causes of these disparities, applying labor process theory and interviews to uncover how deskilling and structural bias perpetuate a hierarchical labor dynamic replicated across geographic and cultural borders. The analysis also identifies proximal causes—globalization, geopolitical tensions, and the rapid expansion of AI—which exacerbate exploitative chip industry labor practices. Recommendations include establishing international tech sector labor standards, promoting fair employment practices, and collaborating via public-private initiatives to support equitable labor practices. The study underscores the urgency of addressing chip industry labor disparities to prevent continued exploitation throughout the broader tech supply chain.

1. *Introduction*

Semiconductors are the material backbone of modern technology, requiring a complex global supply chain. Like other technologies, however, the semiconductor supply chain hides a complex web of labor power inequities. Exploitative labor practices are acute in the mines that provide raw materials inputs for the higher value-added elements of the semiconductor supply chain (Judge, 2023), but they are especially pernicious in semiconductor manufacturing and assembly, testing, and packaging (ATP). The chip industry shift from the US in the 1960s to Taiwan in the present conceals an entrenched history of labor exploitation. As countries invest more in developing localized semiconductor manufacturing and ATP, they should avoid replicating existing labor power disparities. In this paper, I examine the root and proximal causes behind chip industry's continual labor power disparities in semiconductor manufacturing and ATP, namely racial, gender, and socioeconomic exploitation through labor process theory (LPT) along with globalization, geopolitical tensions, and AI development respectively.

Semiconductor industry investments are becoming increasingly common, exacerbating semiconductor manufacturing and ATP labor power disparities. Given their central role in advanced technologies like AI (Crawford, 2018), chips have been described as 21st-century "oil," and demand for them will exponentially increase (Blank, 2020). The semiconductor industry began in the US (Khan, 2021), where its labor exploitation also began. However, in recent decades, Taiwan has surpassed the US to dominate semiconductor manufacturing and ATP, producing 68% of all semiconductors, 92% of the most advanced semiconductors, and 29% of global ATP (Sacks, 2023) while maintaining exploitative networks. Yet Taiwan and its semiconductor industry also seem to be plagued by other acute issues, including brain drain, high housing prices, droughts, energy shortages, frequent natural disasters, and China's intensifying geopolitical threat, causing *The Economist* to label Taiwan "The most dangerous place on Earth" (*The Economist*, 2021). The technology sector's rapid growth incentivizes the US and other countries to aggressively pursue consequentialist industrial policies to gain semiconductor manufacturing and ATP market share. After all, the US is significantly investing in reshoring semiconductor manufacturing and ATP through policies like the CHIPS and Science Act. Besides state actors, tech titans are also seeking to dramatically augment the global semiconductor industry, perhaps most evidenced by Sam Altman's $7 trillion AI chips proposal (Hagey, 2024). Nevertheless, mindlessly pursuing more semiconductor manufacturing and ATP may only amplify the vicious colonial cycle of chip tyranny. Understanding the root and proximal causes of such semiconductor supply chain disparities is necessary to avoid perpetuating pernicious deontological consequences.

2. *Methodology*

The semiconductor industry's labor dynamics have evolved significantly since its inception in the United States in the 1960s, transitioning to a globalized supply chain heavily concentrated in Taiwan. This methodology examines the historical trajectory of labor practices in the semiconductor sector, exploring socio-economic, racial, and gender dimensions through a mixed-methods approach, incorporating both literature review and qualitative interviews.

a. <u>Literature Review</u>

i. Historical Context and Labor Process Theory

Braverman (1974)'s foundational work on LPT provides a framework to analyze labor exploitation in industries undergoing rapid technological advancement. LPT argues that industries commodify and deskill labor to sustain employer control over the workforce. Early semiconductor firms in the US, particularly Fairchild Semiconductor, applied these principles by

establishing assembly operations in marginalized communities such as Native American reservations and outsourcing to low-cost Asian labor markets (Nakamura, 2021). The shift in manufacturing practices aligns with LPT's contention that labor conditions reflect an inherent capital-labor antagonism.

ii. Racial, Gender, and Socioeconomic Inequities in Labor Practices

Research studies indicate that racial, gender, and socio-economic disparities are embedded in semiconductor labor practices, disproportionately affecting minority groups. For instance, Qiu (2016) describes how Taiwanese technology companies use migrant labor in "iSlave" conditions, exemplifying how exploitative practices originating in the US are reproduced and adapted across borders. Other gender-focused literature reveals how chip companies prefer female workers for their perceived dexterity, but simultaneously limit their career advancement (Nakamura, 2021). This gender bias perpetuates structural inequalities, particularly among South and Southeast Asian migrant women in Taiwan's semiconductor sector who are made even more vulnerable due to their limited access to labor protections and cultural exclusion.

iii. Globalization, Geopolitics, and AI

A growing body of research highlights the intensifying role of globalization, geopolitical tensions, and the exponential rise of AI as drivers of chip industry labor exploitation. Im (2023) explains how globalization perpetuates a "race to the bottom" where companies establish manufacturing hubs in regions with lenient labor laws to minimize costs. Burkacky (2024) further argues that geopolitical interests, notably the US-China rivalry, are spurring countries to secure their semiconductor supply chains by replicating Taiwan's labor-intensive model. These studies suggest that as countries seek to reshore semiconductor industries, they risk replicating Taiwan's colonial-style labor practices unless they integrate labor standards in policy planning.

iv. Gaps in the Literature and Need for Qualitative Inquiry

While these studies provide a broad view of why labor inequities may be present in the semiconductor sector, qualitative research is necessary to capture the lived experiences of marginalized workers. Few studies examine how migrant workers perceive their roles within the semiconductor industry or the impact of language and societal barriers on their daily lives. Qualitative insights can reveal how systemic factors like racial and gender bias manifest in workplace practices, offering a more nuanced understanding of labor conditions across different cultural contexts. This literature review underscores the need for a mixed-methods approach, combining root and proximal causes of labor trends with qualitative insights into worker experiences, to comprehensively assess the social implications of labor practices in the semiconductor industry.

a. Qualitative Interviews

i. Research Design

This study employs a qualitative approach using semi-structured interviews to investigate the impacts of semiconductor industry expansion on various demographic groups, such as migrant workers, indigenous communities, farmers, and local residents, in Taiwan. The qualitative design allows for an in-depth exploration of participants' lived experiences, particularly regarding socioeconomic, environmental, and cultural shifts linked to semiconductor development. The methodology prioritizes confidentiality and security, and has received an IRB exemption (Yale University IRB #2000037477).

ii. Participant Selection and Recruitment

Participants were selected through purposive, convenience, and snowball sampling to identify individuals from relevant demographics affected by semiconductor industry developments. Recruitment efforts were directed at people involved in or impacted by the semiconductor industry in the study's target countries, with a particular focus on marginalized or vulnerable populations such as migrant laborers. Participants were approached via emails sent to community organizations, labor rights NGOs, and industry-related networks. Given the study's cross-cultural scope, interviews were conducted in English and Mandarin, with the assistance of translators fluent in migrant worker languages when required.

iii. Data Collection Procedures

Interviews were conducted in a semi-structured format, allowing for open-ended questions that enable participants to share detailed accounts of how the semiconductor industry has impacted them. Each interview lasted approximately 60 minutes and was conducted in a location chosen by the participant to ensure comfort and privacy. The interview guide was developed based on the themes identified in the literature review, with questions designed to elicit participants' reflections on:

- Workplace hierarchies and dynamics: How do participants perceive their role within the semiconductor company? What interactions do they have with supervisors or managers, and how do these interactions shape their experience?
- Labor protections and health and safety: Are workers provided with adequate safety equipment? How do they describe the company's health and safety protocols, and what resources are available to them in cases of injury or illness?
- Racial and gender experiences: How do race and gender affect their work experiences? Do participants feel included in workplace communities, or do they face social and cultural barriers?
- Aspirations and challenges: What are participants' long-term career goals, and how do they view their work in the context of these aspirations? Are participants provided opportunities for skill development or career advancement within the company?

The interview guide was flexible, with follow-up questions added as needed to clarify or expand upon participants' responses. Interviewees provided consent before participating, and translators, if used, signed confidentiality agreements.

iv. Data Security and Confidentiality

To ensure data confidentiality, all recordings and transcriptions were stored securely on an encrypted, password-protected device, with two-factor authentication for access. In data analysis and reporting, pseudonyms were used to protect participants' identities, in line with the study's confidentiality commitment. All transferred data adhered to security protocols, ensuring privacy compliance across international boundaries.

v. Data Analysis

Data analysis involved direct reporting of significant observations and themes emerging from the interviews. Specific anecdotes, descriptions, and reflections were documented to illustrate participants' lived experiences. This approach provided a narrative-driven account of how semiconductor developments have impacted labor disparities in Taiwan, especially for migrant workers.

vi. Ethical Considerations

Ethical considerations include ensuring voluntary participation, informed consent, and participant confidentiality. Exempt from full IRB review under 45 CFR 46.104(d)(2), the study has been structured to avoid risks to participants' employability, reputation, and legal standing.

Additionally, participants have the right to withdraw from the study at any point, and any identifying information will be removed to protect privacy.

vii. Limitations

The methodology's reliance on participants' self-reported experiences may introduce bias or selective recall. Additionally, language differences and translation may influence response nuances. While this limits generalizability, the study's focus on descriptive reporting provides valuable insights into the experiences of individuals within the semiconductor industry's complex labor environment. Furthermore, the study's exploratory design provides a basis for future research on labor conditions and social impacts within globalized semiconductor supply chains.

3. Results

a. Root Causes

The semiconductor industry fundamentally exploits vulnerable racial, gender, and socioeconomic groups through deskilling and stringent control mechanisms. Although the media portrays the semiconductor industry as high-tech and high-paying, the complex industry's increasing segmentation and monotonous assembly-line approach to labor reflects LPT—an approach that elucidates antagonistic employer-employee relationships—by perpetuating power imbalances and limiting opportunities for upskilling (Braverman, 1974). Given the industry's continual need to tailor manufacturing and ATP to individual customer demands for "automation's last mile" (Gray, 2019), however, the chip industry continues to rely on an "unskilled," underpaid, and invisible factory technician workforce. Oppressing vulnerable groups has been the norm rather than the exception throughout the semiconductor industry's history. In fact, industrial exploitation was instrumental to the very foundation of today's chip industry. Fairchild Semiconductor, the "godfather" of the modern semiconductor industry, began outsourcing chip manufacturing and ATP to Asia and Navajo reservations to cut costs as downstream demand from the US military and the burgeoning consumer technology market exploded. Such outsourcing leveraged Asian nation-states as conduits for expanded worker exploitation. While some Asian nation-states like Taiwan could capitalize on Fairchild's investments to develop indigenous semiconductor industries, the Navajo exploited by Fairchild never had a similar chance due to their marginalized status.

Fairchild built semiconductor fabs on Navajo land and pursued cultural appropriation policies, claiming that Navajo women were simply performing the modern equivalent of ancient Navajo "weaving" traditions. However, while traditional Navajo weaving was exceptionally intricate and creative, microchip manufacturing was tedious and repetitive. Orwellian and overwhelmingly male Fairchild managers forced the low-wage Navajo women to tightly adhere to the exact manufacturing processes that highly paid process engineers designed at Fairchild's faraway California headquarters, facilitating deskilling. Fairchild connivingly subsumed gendered and racialized Navajo craftwork into an appendage of industrial machinery, valorizing detail-oriented traditions to justify non-Navajo-led labor regimes. Now, even though programs like Maricopa Community Colleges' Quick Start program exist to upskill local workers, many Arizona-based chip companies are refusing to hire such program graduates (Arizona site visit, 8 January 2024).

Asian countries like Taiwan were able to replicate Fairchild's exploitation due to their roles as outsourcing destinations. Semiconductor manufacturing and ATP were previously perceived as critical, yet they produced lower value than finished products like software or iPhones. Since US companies found more profit in producing finished hardware and software,

the US allowed peripheral nation-states like Taiwan to innovate beyond Fairchild's existing fabs and specialize in advanced semiconductor manufacturing and ATP facilities. However, as free market capitalism incentivized microchip manufacturing and ATP to be increasingly outsourced, new Taiwanese semiconductor giants replicated Fairchild's exploitation in their South and Southeast Asian periphery, again endorsed by downstream companies producing high-value finished technologies. After all, Taiwanese technology companies have had a long history of exploiting cheap labor, evidenced by Foxconn's generation of Chinese "iSlaves" (Qiu, 2016).

Backed by Taiwan's officially sanctioned New Southbound Policy, Taiwanese semiconductor manufacturing and ATP companies have increasingly exploited low-wage South and Southeast Asian migrant workers. Taiwan now has over 750,000 Southeast Asian migrant workers, 63% of whom work in manufacturing. While Taiwan has strong *de jure* labor laws and regulations, national and local labor boards often afford chip companies limited oversight and audits due to their crown jewel status in Taiwan. Especially in Taiwan's semiconductor sector, chip companies often force migrant workers to do unpaid work during the late-night shifts of accident-prone jobs (Li, 2021) without proper safety training and equipment, and have those workers pay for any damaged equipment or products (Taiwan site visit, 29 May 2024). While these migrant workers are in most need of physical and mental health treatment, they often have limited access with only select hospitals offering care (Taiwan site visit, 29 May 2024). Even worse, however, outsourced labor brokers oversee migrant worker paychecks and collect "monthly service fees" from them disguised as other costs like dormitory fees (Taiwan site visit, 29 May 2024), causing the State Department, Apple, and Cisco to label Taiwan as at high risk of forced labor (Liao, 2024). Even when workers live outside cramped and unsafe corporate-provided dormitories, brokers continue to charge them dormitory fees (Taiwan site visit, 29 May 2024). Companies leverage third-party brokers to absolve themselves of direct responsibility and disguise labor exploitation (Taiwan site visit, 29 May 2024). These issues are exacerbated by systemic racism against South and Southeast Asian migrant workers in Taiwan, causing enduring physical and emotional stress. During COVID, semiconductor manufacturers like ASE and the Miaoli county government forced migrant workers to travel only between work and shared dormitories that were often overcrowded and squalid (Davidson, 2021). Still, migrant workers face stark language and societal barriers, making communication and social engagements difficult. Although Taiwan's government has sought to provide token Mandarin and Hokkien language classes, migrant workers remain victims of societal exclusion and stringent control mechanisms. Most migrant workers lack the time to learn since exploitative semiconductor companies consistently force them to work overtime (Sang, 2021). Even those who can speak Mandarin or Hokkien are still largely ignored by local Taiwanese residents. These language barriers, combined with the lack of union representation and effective support groups, ensure many migrant workers are unaware of their full *de jure* rights and open to corporate exploitation. Taiwan's structural racism toward migrant workers is perhaps best evidenced by Taiwan's labor minister stating that Taiwan will seek to recruit more migrant workers from India's northeast, "[where people] have similar skin color and diets like us… Furthermore, most people in that region are Christians. Moreover, they are really good at sectors such as manufacturing, agriculture and construction" (Chang, 2024). Beyond just racism, however, chip companies also prefer hiring women due to their smaller hands (Taiwan site visit, 29 May 2024). Yet, migrant women face sexual harassment and assault in the workplace, and pregnant workers are often forced to return home instead of receiving maternity leave (Taiwan site visit, 29 May 2024). Stereotyping groups of migrant workers for their manufacturing skills based on their cultural and

gender background not only propagates cultural appropriation but also insidiously echoes Fairchild's exploitation of Najavo women for their weaving skills. South and Southeast Asian migrant workers are so vulnerable to deskilling due to officially sanctioned stringent control mechanisms from Taiwanese semiconductor manufacturing and ATP companies, exacerbating racial, gender, and socioeconomic disparities within Asia.

b. Proximal Causes

The proximal causes of globalization, geopolitical tensions, and AI development exacerbate semiconductor labor disparities. Beckoned by these proximal incentives, the global semiconductor industry has exacerbated colonial labor power disparities to further exploit oppressed racial, gender, and socioeconomic groups. In turn, these proximal causes indicate how inherently political technologies like semiconductors often impact broader societal politics (Winner, 1980). As the world invests more in semiconductors, stakeholders should ensure that further semiconductor supply chain development stops being built upon oppressive coloniality (Casilli, 2017).

Globalization facilitates migrant worker recruitment by encouraging the semiconductor supply chain to mask its pursuit of ever-cheaper labor. Semiconductor manufacturing and ATP companies will continually base themselves in countries with less stringent labor laws, facilitating a continual race to the bottom (Im, 2023). Countries maintain strong incentives to avoid implementing local and migrant labor laws if doing so would cause the semiconductor industry to move elsewhere, thus allowing companies to hide forced labor, hazardous working conditions, and exploitative brokerage fees. After all, the semiconductor supply chain is so complex that it is almost impossible for consumers to understand the plight of the invisible "ghost worker." International media further enables such exploitation as powerful semiconductor companies manufacture consent for globalization from the wider populace.

Geopolitical tensions are encouraging countries to reshore their semiconductor supply chain, enabling semiconductor companies to exploit labor from marginalized domestic groups again. The global media increasingly portrays Taiwan's chip dominance as exceedingly dangerous in the context of China's looming threat to use force against Taiwan. However, such proclamations conveniently arrive as demand for semiconductors within the technology sector is rapidly growing. Regardless, the pretense of geopolitical tensions is perspicuously incentivizing consequentialist semiconductor industrial policies within the US and other countries (Burkacky, 2024). As these initiatives seek to replicate Taiwan's chip success and indigenize national semiconductor industries, they pursue cheap domestic labor to remain profitable. The pursuit of cheap labor will likely lower labor standards, giving "indigenous" semiconductor manufacturing and ATP companies free rein to harm marginalized domestic groups. While Fairchild Semiconductor is now defunct, its colonial legacy of exploiting vulnerable BIPOC groups may astronomically metastasize.

AI development is exponentially increasing semiconductor demand, facilitating further upstream and downstream exploitation as companies strive to maximize production and reduce cost for novel use cases. AI is driving burgeoning growth in the chip sector, with AI leaders like Sam Altman even proposing $7 trillion to develop the semiconductor supply chain. Dramatic AI industry growth will likely push chip companies to aggressively expand while reducing overhead costs, thus more extensively recruiting marginalized local and migrant workers. While some may argue that AI will facilitate more manufacturing and ATP automation, the perpetual need for "automation's last mile" disproves the automated workforce theory. The AI supply chain will continue requiring an "unskilled," underpaid, and invisible workforce, especially as new AI

technologies and companies require more individually tailored chip manufacturing and ATP processes. Exponential demand for more chip quality control and testing processes may require the semiconductor industry to recruit more exploited labor than ever.

4. Discussion

Given that the root and proximal causes of semiconductor labor power disparities are consequentially linked, countries should pursue a deontological approach to chip reshoring and semiconductor industry expansion. Government- and industry-led semiconductor expansion initiatives should acknowledge the societal implications of chip coloniality and provide existing marginalized ghost workers with a collective bargaining voice. The US should critically assess domestic semiconductor industry expansions in Arizona, Texas, and elsewhere and ensure that semiconductor manufacturing and ATP companies provide upskilling opportunities for their workforce. Most importantly, however, the US must carefully consider the underlying power differentials amidst proposed semiconductor initiatives like the HBCU CHIPS Network and Latin America ATP nearshoring propositions that seek to recruit black and Latine laborers into the industry (Arizona site visit, 8 January 2024). Marginalized groups have historically been most affected by semiconductor industry exploitation, so the US must avoid disproportionately amplifying another vicious cycle of chip tyranny for these groups. Incorporating more women and other underrepresented minority ethnic and racial groups into senior semiconductor management positions would reduce chip industry power differentials and enable more just chip expansion initiatives.

Government, industry, and civil society stakeholders should pursue collective action to ensure labor equity within semiconductor manufacturing and ATP. First, semiconductor supply chain labor standards should be established, monitored, and enforced. International organizations like the International Labour Organization (ILO) should coordinate and enforce labor standards across the globalized semiconductor supply chain. Since semiconductor industry labor negotiations will likely be ineffective without Taiwan, Taiwanese perspectives must be represented in such multilateral forums despite likely Chinese opposition. If semiconductor labor standard negotiations falter due to the ILO excluding Taiwan, governments ought to explore alternative avenues for establishing such standards via international organizations where Taiwan holds membership, such as the World Trade Organization (WTO). Alternatively, supranational and national bodies like the EU and the US should forbid forced labor from the chip supply chain, imposing high semiconductor industry labor standards worldwide through the Brussels effect. Corporate social responsibility (CSR) campaigns from downstream technology companies like Apple should also hold semiconductor manufacturing and ATP companies accountable for allowing forced migrant labor to continue, although such CSR campaigns may be less effective due to conflicts of interest. Effective public-private chip partnerships could create a more localized, sustainable, and equitable manufacturing and ATP workforce. In turn, these collaborations could allow the semiconductor industry to be monitored by consumer civil society organizations aimed at upholding fair trade electronics while protecting trade secrets. After all, civil society groups are less susceptible to manufactured consent and can avoid direct retribution from semiconductor companies, making them ideal candidates for raising awareness about potential labor standard violations. Second, chip companies should adopt a human-centered approach to uplifting manufacturing and ATP workers. Semiconductor companies should invest in upskilling programs that empower workers through further education and training, reducing their vulnerability to exploitation and facilitating career advancement opportunities. Properly trained factory technicians can likely optimize fab operations better than faraway corporate

executives. Public-private chip partnerships can most effectively develop these training programs, and governments should include such initiatives in their industrial policy proposals. Beyond upskilling, semiconductor companies should allow workers to form unions and Project Labor Agreements, which many major chip companies currently prohibit (Arizona site visit, 12 January 2024). Collective bargaining rights would empower marginalized groups to counter discriminatory policies and negotiate fair wages, proper benefits, and safe working conditions. Furthermore, public-private industrial policies should proportion reparations to ghost workers exploited by the semiconductor industry while also investing in upskilling the local communities around existing fabs. Third, public-private industrial policies should allocate academic research funds to further uncover and rectify semiconductor labor power inequities.

5. Conclusion

The semiconductor industry, and subsequently modern technology, remains marred by deep-rooted labor power inequities continuing from the 1960s to the present throughout its complex global supply chain. The industry's exploitative labor practices, particularly in manufacturing and ATP, are symptomatic of broader racial, gender, and socioeconomic exploitation. The surge in semiconductor demand due to the extraordinary growth potential of AI makes addressing these inequities more urgent than ever. From Fairchild's historical abuse of the Navajo people to Taiwan's current exploitation of South and Southeast Asian migrant workers, the semiconductor manufacturing and ATP sectors maintain institutionally backed colonial legacies that continue to shape their labor practices. The proximal causes of these disparities—globalization, geopolitical tensions, and AI development—further exacerbate the situation, demanding a conscientious response from stakeholders. Pursuing industrial policies without addressing labor power disparities risks perpetuating a vicious cycle of exploiting marginalized groups. Therefore, governments, semiconductor companies, and civil society should enforce fair labor standards, uplift workers through a deontological human-centered approach, and fund further academic research into chip labor power inequities. After all, rectifying semiconductor manufacturing and ATP labor disparities will lay the groundwork for further equity throughout the semiconductor and broader technology supply chain.

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