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CTPECC is a full member of Pacific Economic Cooperation Committee (PECC), which is an international organization for economic cooperation in the Asia-Pacific region and plays a key role in consultation and advice on APEC's major initiatives and plans. The participation of CTPECC is to assist the government in researching and analyzing economic cooperation plans, and to strive for greater opportunities to participate in cooperation mechanisms and dialogues.

Sustainable Supply Chain: Environmental, Social and Economic Resilience

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Introduction

Resilience is one of the most important issues in the modern economic world. Organizations and their supply chains that are resilient to unfavorable economic, environmental or negative social pressures may effectively protect themselves against uncertainty, risk, and loss of competitive position, with the implication that they may have to abandon business, while at the same time being flexible and adaptive to negative phenomena and threats arising from different directions and to different extents.[1]

Recent events that have affected all global economies are contributing to a greater importance and attention to preparing supply chains to respond to sudden disruptions.[2] They have different sources and nature. They also bring companies problems with maintaining business continuity and all types of consequences (financial, environmental, social, reputational) at once, what needs proper resilient strategies and practices implementation.[3] This means there is need for changing the approach and remodeling, reconfiguring, and rethinking how the long-term goals of supply chains can be achieved both with resilience and sustainability in mind.[4]

Over the past three decades a broad concept of supply chain resilience (SCRES) has been developed. The foundation of understanding this concept is the three phases: before, during, and after the disruption. For each of them, the specific strategies are assigned and then the

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detailed directions for their implementation. The guidelines in this area are a variety of principles, recommendations, elements, enablers, capabilities, and practices.

Four Main SCRES Principles

SCRES was first mentioned in 2003, when highlighting the need for configuring not only secure but also resilient supply chains capable of responding to various threats, especially terrorism. It was explained that building SCRES is possible mainly by enhancing flexibility and redundancy.[5]

Tere are four main SCRES principles.[6] The first is "supply chain reengineering." Mainly, resilient strategies should be based on several open options and a new trade-of between efficiency and redundancy must be reconsidered. This is possible thanks to flexibility and redundancy. The second principle refers to the "collaboration" which is developed on trust, information sharing, and visibility. Visibility is understood as having knowledge about the structure and resources of the entire supply chain. Such an approach makes it possible to recognize upstream and downstream uncertainties, quickly identify the places where disruptions arise, and adequately react to the crisis.[7]

All activities aimed at building supplier–buyer cooperation based on joint-decision-making, information and knowledge sharing, supplier certification, and supplier development co-create collaboration.[8] The third principle is "agility," which consists of visibility and velocity, that is, the pace of flexible adjustments. The last principle, "supply chain risk management culture," is based on innovation implementation, risk management leadership, and team.

The SCRES framework is built on four key principles. The first principle is "supply chain reengineering." Resilient strategies should consider multiple options, balancing efficiency with redundancy, enabled by flexibility and backup resources. The second principle is "collaboration," grounded in trust, information sharing, and transparency. Transparency means understanding the full structure and resources of the supply chain, allowing for early recognition of upstream and downstream risks, quick identification of disruptions, and effective crisis response. Supplier–buyer cooperation, enhanced through shared decision-making, information exchange, supplier certification, and development, is essential to collaboration. The third principle, "agility," combines transparency with speed, facilitating quick, flexible adjustments. The final principle, "supply chain risk management culture," emphasizes the importance of innovation, leadership in risk management, and a collaborative team approach.

Resilience in terms of social, environmental, and economic dimensions can protect against new risk factors that have emerged in recent years, negative factors such as the ripple effect, which is becoming increasingly important in global governance and business, black swans or the

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8.Hohenstein, N. O., Feisel, E., Hartmann, E., & Giunipero, L. (2015). Research on the phenomenon of supply chain resilience: A systematic review and paths for further investigation. International Journal of Physical Distribution & Logistics Management, 45(1/2), 90-117.

effects of emerging armed conflicts, or the threat of changing settlements in financial markets and the development of financial markets toward demonetization.[9]

Sustainable Supply Chain 2.0

A new sustainable supply chain concept—namely sustainable supply chain 2.0, which incorporates risk and resilience factors in its structure, activities, elements, and processes, as a basis for an innovative concept. This concept can be considered in the context of the traditional view of a sustainable supply chain and risk factors that are present and determining the functioning of a given strategy. By adding the criteria of resilience, variously understood, one can expand sustainable supply chain strategies and try to create an even more innovative competitive strategy.

Environmental, social, and economic resilience in sustainable supply chain should be considered in this context. Triple Bottom Line (TBL) issues can become a component of sustainable supply chain resilience.

Each element can be considered separately, but also as a component of the TBL concept (holistic view). It seems reasonable to identify the interrelationships and relationships between sustainability and resilience in the supply chain and then to consider the individual elements as drivers of the whole and as a strategic element of the new concept of supply chain management. Supply chains can thus enhance their resilience by using their abilities to 'anticipate', 'adapt' and 'respond' to external disruptions in order to cope with disruptions, ultimately moving to state before the disruption or a better state. In addition to managing disruption through the use of resilient elements (especially flexibility redundancy), the stage of learning and improvement is important; that comes last and thus becomes an input to the risk and uncertainties anticipation for the pre-disruption phase.

That resilience is often added to aspects of sustainability, but there is no clear definition, understanding, and presentation of a theoretical framework as to whether sustainability includes attributes of resilience and vice versa.[10] Lack of guidance and clarity on what elements of TBL can create supply chain resilience, and which may give rise to distortions and risks, often, a certain degree of over-interpretation can also contribute to potential problems in their implementation. Resilience can be achieved through sustainable development and sustainability can also be determined by resilience. It seems unjustified to use both terms as synonyms.

Mainly, sustainable development may strengthen organizations and supply chains in the context of achieving TBL goals, through efficient sustainable practices implementation as well as financial, environmental, and social risk management for endogenous and exogenous sources. Consequently, it shapes processes and resources toward robustness and resilience. On the other hand, the resilience of organizations and supply chains achieved in the context of three

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phases of disruption enables effective TBL risks management what may translate into sustainable development and the maintaining systemic homeostasis in the future.

Tere are many sources of literature, including systematic literature reviews[11] containing aspects of sustainability and resilience; however, these are usually based on bibliometric studies.[12] They do not result in theoretical frameworks or management models that can be verified or reflected in business practice and focus on risk management rather than building a system whose resilience will be both integral to sustainability and such a supply chain strategy.

In another context, existing knowledge is reviewed through four dimensions of analysis:[13] concepts and theory building, implementation (practices, pressures or drivers, decision-making and barriers, performance and measurement, and barriers), outcomes and measurement, and the future research agenda. It is difficult to explicitly address both elements indicated and to develop one common definition and concept. The areas can be considered in different dimensions. From one perspective, it can be pointed out that resilience builds sustainability. In support of this thesis, it can be said that organizations and supply chains, if they are resilient, are sustainable; if they are not sustainable, they lose resilience at the same time. Only sustainable systems can operate effectively and counter sudden, unforeseen emergencies.

The application of TBL principles alone is not sufficient for systems to be resilient to various types of disruption. TBL needs to be integrated with other risk management functions.[14] Therefore, when building sustainable and resilient supply chains, one should think about integrating these concepts by developing management of external and internal TBL risks and disruptions of a financial, environmental nature, in relation to the comprehensive understanding of SCRES framework, that is, taking into account especially SCRES strategies, phases, abilities and elements.

Concluding Remarks: resilience and sustainability

The context of resilience and sustainability can be understood as achieving environmental, social, and economic objectives while being able to mitigate and adapt to a variety of (often simultaneous internal and external) risks and uncertainties, through the appropriate identification and application of resilience attributes. It is important to ensure the durability of the chain despite the many adverse conditions Implementation of defense mechanisms contributes to balancing systems and entire supply chains.[15] In such cases, a skillful risk management, collaborative, proactive

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13.Negri et al., 2021.

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approach is required, both to the sustainability aspect and to building a supply chain resilience system.

A proactive approach will allow the creation of defenses and the skillful management of potential risks, not only operationally, but also in the long term. To effectively manage a sustainable supply chain, supply chain must be resilient at the same time. This is a prerequisite if TBL is to achieve its objectives. Life Cycle Assessment (LCA) also helps to realize these goals. LCA is an effective tool, not only for assessing sustainability, but also for resilience. In this perspective, it is necessary to be able to assess, interpret, and critically analyze issues related to social, environmental and economic risks, but also geopolitical risks, including the management of natural resources.[16]

Supplier involvement in product development, (understood as cooperation with a partner during designing product), processes, and supply chain, also impacts supply chain resilience positively, but under the condition of a mediating role of communication. Another perspective suggests that sustainability builds resilience. Implementing sustainability leads to having a socially, economically, and environmentally coherent supply chain that meets common goals and is most likely to withstand damaging situations.[17]

Being sustainable reduces risk while increasing the level of resilience, where resilience can be considered from two points of view: small scale (demand fluctuations, production risks, employee fluctuations) and large scale (natural disasters, climate change, political and financial crises). The aim of the measures taken is to build a system that is resilient to competition and to gain a competitive advantage, to reduce environmental risks (lowering of emissions). Reducing risks and increasing resilience will contribute to a forward-looking view and perspective on the future and give a greater chance of survival. The limitations of the traditional approach focusing on the short term must be overcome and a broader framework and assumptions on resilience and sustainability adopted.

More resilient chains can be created through a sustainability approach in an adaptive long-term planning situation and taking this perspective; this means that supply chains need to be rethought and reconfigured, taking into account other management perspectives, and also other elements and practices that affect the achievement of long-term sustainability goals while building a resilient system that supports and promotes sustainable and resilient behavior, while dynamically adapting to an everchanging economic environment, creating long-term social, environmental and economic value.[18]

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Resilience in Taiwan's Semiconductor Industry: Navigating Geopolitical Risks, Technological Competition, and Supply Chain Vulnerabilities

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Introduction

Taiwan plays a critical role in the global economy. Its semiconductor industry is the backbone of the global electronics supply chain, with Taiwan Semiconductor Manufacturing Company (TSMC), the market leader, dominating the market, particularly in advanced fabrication. TSMC alone accounted for 60% of the global foundry market share and 90% of advanced chip production in 2023. (Klingler, Counterpoint Research) TSMC is a major supplier to players in the semiconductor field, including Apple, Nvidia, Qualcomm, Broadcom, MediaTek, and AMD. Semiconductor products fabricated by TSMC are crucial to multiple industries, from consumer electronics and telecommunications to automotive technologies and artificial intelligence systems.

However, Taiwan's dominance in semiconductor production also places its industry at the center of geopolitical tensions, most notably regarding its relationship with China, and more recently potentially with the United States under Trump's policy. The risk of conflict could disrupt not only Taiwan's economy but also the global tech supply chain. Recent global events, such as the COVID-19 pandemic and the war in Ukraine, have exposed vulnerabilities, with disruptions in the supply of essential materials such as noble gases and semiconductor fabrication equipment. The industry's, and thereby Taiwan's, resilience is integral to ensuring stability amid escalating global demand for high-performance chips.

Despite these challenges, Taiwan's semiconductor industry remains indispensable to the global market, underscoring the need for continued resilience in the face of uncertain geopolitical developments. The ongoing geopolitical shifts are prompting governments worldwide to

rethink their reliance on Taiwan for semiconductor production. (Shivakumar et al.) Although efforts to onshore semiconductor manufacturing in certain regions are underway, Taiwan's unmatched expertise in advanced chip manufacturing continues to be a key pillar in global technological and economic stability.

Challenges Facing Taiwan's Semiconductor Industry

Taiwan's semiconductor industry, while integral to the global supply chain, is facing a variety of challenges that could affect its long-term resilience. The key issues stem from external factors such as geopolitical tensions, technological disruptions, and global supply chain vulnerabilities.

1.Geopolitical Risks

Taiwan's semiconductor industry is deeply intertwined with regional and global political dynamics. Tensions with China, particularly regarding Taiwan's sovereignty, pose a significant risk to the stability of semiconductor production in Taiwan. Given the island's importance in chip manufacturing, any geopolitical instability in the region could result in major disruptions to the global supply of semiconductors. In recent years, there has been growing concern about China's ambitions toward Taiwan and its potential impact on global technology supply chains, with industry leaders and governments worldwide keenly aware of these risks. (Shivakumar et al.)

Perhaps more troubling, are the comments by president elect Donald Trump during his 2024 campaign. Most notably, Trump proposed imposing tariffs on semiconductor imports from Taiwan to encourage companies like TSMC to establish fabrication plants in the United States. (Howley) Trump also criticized the CHIPS Act, suggesting that tariffs would be more effective in achieving onshoring goals. (Howley) Such tariff measures, other than being of dubious WTO consistency, would severely disrupt global supply chains, increase consumer costs, and perhaps even weaken TSMC's (and thereby Taiwan's) position in the semiconductor market.

2.Technological Competition and Innovation

As the semiconductor industry evolves, Taiwan faces potential future competition in chip manufacturing from other regions, such as the United States and Europe. Governments are pushing to develop their own semiconductor manufacturing capabilities to reduce dependency on Taiwan. For example, the United States has invested significantly in initiatives like the CHIPS for America Act, which aims to boost domestic semiconductor production. (Thadani and Allen)

The European Union is also actively investing in its semiconductor ecosystem as part of its 2030 Digital Compass initiative, which aims to establish Europe as a global leader in the production of advanced microchips by 2030. (European Commission) The EU's goal is to produce 20% of the world's semiconductors by that time, focusing on advanced technologies such as sub-5nm chips, which are crucial for sectors ranging from automotive to telecommunications. (European Commission, MCKellop) To achieve this, the EU is supporting key projects like the €7.4 billion semiconductor manufacturing facility in France, developed by STMicroelectronics and GlobalFoundries, which will produce high-performance chips for critical European industries. (European Commission - Press Release)

In parallel, Japan is also taking significant steps to revitalize its semiconductor industry, releasing its Strategy for Semiconductors and the Digital Industry in March 2021. (METI, InvesTaiwan) As part of its strategy, Japan has aggressively courted TSMC with significant subsidies to boost onshore semiconductor manufacturing. (Chang and Huang)

While these initiatives may eventually lessen

reliance on Taiwanese companies, Taiwan's leadership in advanced manufacturing, particularly through TSMC's cutting-edge technology, remains unparalleled for the moment. The challenge for Taiwan lies in maintaining its technological edge and scaling innovation in an increasingly competitive global environment.

3.Supply Chain Vulnerabilities

The COVID-19 pandemic and the war in Ukraine have exposed vulnerabilities in global supply chains, including those crucial to semiconductor manufacturing. Taiwan's dependence on a global supply chain for raw materials, such as noble gases from Ukraine and semiconductor fabrication equipment from the United States and Japan, creates risks.

Natural events such as hurricanes can significantly disrupt the semiconductor supply chain, as evidenced by the impact of Hurricane Helene in 2024. The storm caused substantial damage to transportation networks in the United States, particularly in regions crucial to mining high-purity quartz, an essential material in semiconductor manufacturing. (Sheehy) The hurricane's damage to infrastructure, including roads and rail systems, halted mining operations in Spruce Pine, North Carolina, disrupting the production of ultra-pure quartz used in semiconductor fabrication.

Additionally, global demand for chips has outpaced supply, exacerbating the pressure on Taiwan's semiconductor industry to meet the world's needs. (Lin) Disruptions to these supply chains, whether due to logistical hurdles or political factors, could jeopardize Taiwan's ability to continue meeting global demand for high-performance chips. (Shivakumar et al.)

4.Environmental and Resource Constraints

Environmental and resource constraints are significant challenges for the semiconductor industry. The semiconductor industry, dependent on rare raw materials like high-purity quartz, rare earth metals, and water, faces increasing pressure due to resource limitations. Among those, water scarcity holds an inordinate impact over semiconductor production. (Zhang) Taiwan's semiconductor fabrication requires vast amounts of ultrapure water, and water shortages have led to production disruptions in the past. For example, the island faced water supply issues in 2021, which impacted the production of chips. (Cheng and Li).

As Taiwan faces increasingly severe droughts, and in light of global climate change, the strain on water resources could impact semiconductor production. The industry is under growing pressure to implement more sustainable practices while maintaining its high standards of performance and efficiency. (Göke et al.) As such, addressing issues such as climate change and seasonal droughts are also essential for ensuring the continued resilience and competitiveness of Taiwan's semiconductor sector.

In summary, while Taiwan's semiconductor industry is a critical driver of global technology, it faces challenges from political instability, technological competition, supply chain fragility, and environmental constraints. Addressing these issues will be essential for ensuring the continued resilience and competitiveness of Taiwan's semiconductor sector in an uncertain future.

Taiwan's Response to Challenges

In response to the challenges it faces, Taiwan has taken proactive measures to reinforce its semiconductor industry and safeguard its global position.

1.Diversifying Production and Expanding Capacity

Taiwan's semiconductor giant, TSMC, has made strategic investments to diversify its production footprint. It has established new

facilities in the United States, Japan, and Germany. This expansion is part of a broader strategy to mitigate risks related to geopolitical tensions, and maintain its global advantage.

2.BStrategic Partnerships and International Collaboration

Taiwan has sought to bolster its global influence through tech partnerships and a way to reinforce its position in the global chip industry, targeting closer economic ties with economic partners, such as the European Union. Through initiatives like TSMC's expansion into countries like Germany and its global partnerships, Taiwan aims to secure its role as a key player and stay competitive amid rising geopolitical tensions. (Wheeler)

3.Government Support and Investments

The Taiwanese government has recognized the strategic importance of the semiconductor sector and implemented measures to support its growth. For example, perhaps as an answer to the CHIPS Act, the Taiwanese government has offered tax credits as an incentive to encourage semiconductor manufacturers to invest in facilities and new technology in Taiwan. (Robinson)

4.Environmental and Sustainability Efforts

Taiwan is increasingly investing in environmentally sustainable practices within its semiconductor sector. TSMC, for example, has been investing in renewable energy to meet net-zero goals. (TMSC) TSMC has also implemented comprehensive water management measures in its production processes. (TSMC) Moreover, The Taiwanese government encourages sustainable practices in the semiconductor industry through regulatory measures, such as the requirement for companies emitting over 25,000 metric tons of CO_2 equivalent annually to conduct carbon inventories and report emissions. (Industry, Science and Technology International Strategy Center) In response, semiconductor packaging and testing companies are adopting energy-saving strategies, transitioning to renewable energy sources, and automating processes. For example, companies like Ardentec and ASE have embraced renewable energy and AI-driven automation to reduce their environmental impact. (Industry, Science and Technology International Strategy Center)

Conclusion

Taiwan's semiconductor industry faces an array of challenges that could threaten its long-term resilience, but the country's proactive measures and the strategic importance of the industry on the global stage offer hope for navigating these obstacles. Geopolitical tensions, particularly with China, and even to an extent the United States, pose a significant risk to Taiwan's semiconductor production, as do increasing technological competition and supply chain vulnerabilities. Taiwan is addressing these challenges by diversifying its production and forging strategic partnerships with global economies, notably through investments in facilities across the United States, Japan, and Europe.

The Taiwanese government has taken steps to encourage sustainability within the semiconductor sector, providing incentives for companies to adopt energy-saving strategies and invest in renewable energy. Companies like TSMC, ASE, and Ardentec are responding by integrating sustainable practices into their operations, including renewable energy adoption and automation.

The focus on sustainability aligns with APEC's broader agenda of fostering regional resilience, as Taiwan's leadership in semiconductor manufacturing plays a critical role in ensuring stability in global technology supply chains. However, the road ahead remains fraught with challenges, including the need for continued innovation, investment in infrastructure, and coordination between the government and

the private sector. While Taiwan's efforts are commendable, addressing the environmental, geopolitical, and resource challenges will be key to maintaining its position as a global semiconductor leader in an increasingly competitive and unpredictable world.

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Addressing Challenges Brought by Innovation and Application of AI for a Resilient Growth

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The innovation and application of artificial intelligence (AI) have brought significant economic benefits and profound impacts on the labor market. Specifically, there have been plenty of studies on AI adoption in the workplace that highlight its role in increasing economic opportunities and boosting productivity. For example, according to a report conducted by the IDC (2024), the adoption of AI is estimated to contribute US$19.9 trillion to the global economy through 2030; meanwhile, it would also drive 3.5% of global GDP in 2030. In addition, the introduction of AI in the workplace would also contribute to the reduction of weekly working hours from 40 to 32 hours, and an estimation of 28% of workforce in the United Kingdom and the United States would enjoy this benefit (The Guardian, 2023). Nonetheless, the adoption of AI is not without impacts. Concerns over technological unemployment, the lack of regulations, and privacy issues entail comprehensive policy responses so as to ensure inclusive and resilient growth in the digital age.

In terms of technological unemployment, while the adoption of AI would enhance business productivity, labor-intensive and routine jobs are increasingly at risk of being replaced. Taking Taiwan's labor market for instance, a survey conducted byYes123 Job Bank (2024) revealed that many respondents are worried that AI could replace labor-intensive roles. Specifically, among 1,016 companies surveyed in 2024, 54.3% indicated that ticket selling jobs are likely to be replaced by AI, followed by call center agents (53.6%) and assembly line workers (52.2%). Aside from labor-intensive jobs, it is notable that several knowledge-intensive jobs, such as translators (37.2%), journalists (36.3%), and bank clerks (35.2%), have also been perceived as vulnerable to widespread of AI adoption in the workplace in the future. This underscores the need for businesses and governments to facilitate digital skills empowerment, as well as reskilling and upskilling initiatives, so as to assist workers in adapting to the evolving future of work.

Furthermore, following the widespread of AI adoption in the workplace, it has also raised a question of whether appropriate regulations have already been in place. A practical example illustrating the issue of inadequate regulation is the unclear assignment of responsibilities between manufacturers and operators in the event of automated vehicle accidents, which has sparked debates in many advanced economies. For instance, in the United Kingdom, although automated vehicles had already been on the roads for trial purposes, it was not until the promulgation of the Automated Vehicles Act 2024 that the responsibilities of manufacturers were clearly defined (Lexology, 2024).

In addition, other contentious issues generated by AI, such as disputed issues of privacy, intellectual property, the usage of collected data, algorithmic transparency and so on, remain to be carefully managed through a whole-of-system approach including making comprehensive regulations. In this regard, the European Union is leading the world by promulgating the EU Artificial Intelligence Act in 2024, which aims at harmonizing rules and regulations on AI. In general, the EU has catalogued risks of AI into different levels, and AI systems such as those are used to identify or categorize people will only be allowed for law enforcement purpose. Moreover, generative AI will also need to obey regulations on transparency and copyright (European Parliament, 2023).

Taiwan, as a leading economy in the innovation and manufacturing of information and communication (ICT) technology, has been largely benefited by the innovation and widespread adoption of AI. For example, as Taiwan plays an indispensable role in manufacturing AI chips, the development and innovation of AI technology has bred positive impact on export performance. Specifically, according to the official statistics (MOEA, 2024), semiconductors have accounting for 34% of Taiwan's total exports between January and October 2024. During this period, the total export value of semiconductors reached an impressive US$113 billion. While the United States remains a global leader in AI innovation and chip design, Taiwan has emerged as a vital partner in the supply chain. Between January and October 2024, Taiwan's semiconductor exports to the US market experienced remarkable growth, increasing by 116% compared to the same period in 2023.

To seize the economic opportunities brought by the adoption and innovation of AI technology, President Lai Ching-Te has endeavored to transforming Taiwan into an "AI Island." Through the implementation of the "Asia Silicon Valley Development Plan 3.0" (Executive Yuan, 2024), the government aims to promote innovative applications of AI and integration of emerging technology, foster an enabling environment for startups, and encourage collaboration among startups and corporations, as well as with research institutes, to advance technological R&D. Furthermore, the government also seeks to enhance Taiwan's role in global value chains by expanding the export of smart solutions. Moreover, the Taiwanese government also expects to advance Taiwan's presence and influence in multilateral mechanisms for AI governance.

Most importantly, to advance AI governance and mitigate the impacts of AI, Taiwan is in the process of drafting the Artificial Intelligence Basic Act. Drawing on key legislation and regulations from advanced economies and international organizations, this Act is expected to uphold values such as democracy, human rights, equality, diversity, fairness, intellectual

property, and non-discrimination. In the future, with comprehensive regulations and governance measures in place, Taiwan may not only share best practices for advancing AI applications but also the implementation of effective strategies to address AI-related challenges, contributing to resilient and sustainable growth.

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