

## Article

# The Predicament of Carbon Pricing Under Developmental States

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## Abstract

This study analyzes carbon-pricing mechanisms in Taiwan and Republic of Korea—two high-carbon manufacturing economies embedded in global supply chains—to examine how developmental-state institutions shape the design and effectiveness of carbon-pricing policies and whether these mechanisms effectively contribute to emissions reduction. Using a comparative case study design, policy document analysis, and quantitative emission and survey data, this study compares the evolution and outcomes of carbon pricing in both economies. While carbon pricing is recognized as a key climate mitigation tool, its effectiveness varies across institutional settings. Through a comparative analysis, this study shows that developmental-state structures—characterized by strong state–industry linkages, the dominance of carbon-intensive industries, and conservative policy design—constrain its effectiveness. Republic of Korea’s Target Management System and Emissions Trading Scheme have not curbed emissions growth, while Taiwan began debating an energy tax as early as 2006 but only institutionalized carbon pricing after the 2023 Climate Change Response Act. The carbon fee, initially planned for 2024, was postponed to 2026 with a low and lenient price. The findings suggest that carbon pricing is mediated by industrial policy priorities, limiting its capacity to drive low-carbon transitions.

**Keywords:** developmental states; carbon pricing; net-zero transition; carbon lock-in; high-carbon manufacturing supply chains

## 1. Introduction

In East Asia, both Republic of Korea and Taiwan are key bases in the international manufacturing supply chain. However, their vast manufacturing industries have shaped a high-carbon-emission and high-pollution industrial structure. Not only has environmental justice been undermined, but social equity, including labor rights, ethnicity, and gender equality has also been neglected to varying degrees. In the industrial context, latecomers such as Republic of Korea and Taiwan have been defined as sacrifice systems, characterized by a brown economy built on a developmental state model that prioritizes economic development over environmental and social equity [1,2]. This model faces structural challenges in responding to the rapid decarbonization driven internationally since 2015 and the net-zero transition accelerated since 2021.

Internationally, the 2005 Kyoto Protocol established the global decarbonization trajectory, and the 2015 COP21 Paris Agreement hastened the end of the fossil fuel era. The growing climate emergency since 2018 has spurred calls for deep decarbonization. In 2021, the COP26



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resolution established the global goal of achieving net-zero emissions by 2050. International climate governance has now reached a significant scale and level, creating an inescapable imperative for the manufacturing-oriented East Asian economies to engage with it.

Greenhouse gas (GHG) emissions saw a near twofold increase from 1990 to 2007 in both Republic of Korea and Taiwan, driven by their developmental state-oriented industrial policies. Republic of Korea's emissions surged from 632.87 MtCO<sub>2</sub>e in 2009 to peak at 780.14 MtCO<sub>2</sub>e in 2018, while Taiwan's emissions rose from 221.40 MtCO<sub>2</sub>e in 1998 to peak at 302.07 MtCO<sub>2</sub>e in 2007 and then stabilized until after 2018 [3,4].

This study focuses on carbon pricing in these two economies. Republic of Korea and Taiwan have long been regarded as representative developmental states with considerable state capacity and statecraft. However, both have encountered growing challenges in advancing sustainability transitions in recent years. Consequently, examining their experiences in implementing and initiating carbon pricing policies provides an important opportunity to understand how major manufacturing economies embedded in global supply chains respond to the pressures of global decarbonization and the transition toward net-zero emissions by 2050.

First, this study begins by examining the international context in which these two governments planned and implemented carbon pricing policies. It discusses how the exogenous forces highlighted in the climate governance literature have driven the adoption and development of carbon pricing instruments. Specifically, driven by its transitional status as an OECD member under international pressure, the Republic of Korea shifted from a non-binding stance under the 1997 Kyoto Protocol to adopting ambitious voluntary emissions reduction targets in 2009, followed by the domestic implementation of the Target Management System (TMS) in 2012 and the Korea Emission Trading System (K-ETS) in 2015. In contrast, Taiwan proposed an Energy Tax Bill in the Legislative Yuan in 2006, but only began planning carbon fee policies nearly two decades later under external pressures such as the European Union's Carbon Border Adjustment Mechanism (EU CBAM).

Second, this study examines the overall greenhouse gas emissions of the two economies in 2015 (when Republic of Korea implemented the K-ETS) and 2021 (when Taiwan initiated the planning of its carbon fee). It analyzes how the manufacturing sector accounted for around half of total national emissions in both economies and further discusses the dominant shares contributed by the top 30 and top 10 manufacturing enterprises in each year. Given the similarities in their industrial structures and highly concentrated emission patterns, these two economies provide a useful context for examining the implementation of carbon pricing under developmental-state conditions.

Third, this study provides a preliminary discussion of the political compromises involved in the formulation of carbon pricing policies in the two economies. In Republic of Korea, carbon pricing was shaped by bargaining between government ministries and industrial lobbying efforts. In Taiwan, policymaking has been influenced by geopolitical considerations as well as pressure from industrial interests.

Fourth, this study further discusses the consequences arising from the relatively lenient design of carbon pricing in Republic of Korea and Taiwan. In Republic of Korea, the generous allocation of free allowances under the K-ETS contributed to a sluggish carbon market and weakened incentives for corporate emission reductions. In Taiwan, the repeated postponement of carbon fee implementation, combined with a relatively low carbon price, has generated a range of negative effects, which are examined through the analysis of three consecutive years of Task Force on Climate-related Financial Disclosures (TCFD) surveys (2023–2025).

Finally, carbon pricing has become a key climate governance instrument and an essential component of the global policy mix for achieving net-zero emissions. However, the implementation and development of carbon pricing in Republic of Korea and Taiwan have encountered significant structural constraints. The challenges associated with transitioning

from carbon-intensive development pathways, as well as the potential strategies for overcoming these obstacles, offer important implications for Asian manufacturing economies that play a critical role in global carbon-intensive supply chains. Based on these findings, this study concludes with a discussion of the policy implications and recommendations.

## 2. Literature Review

Carbon pricing has become one of the most important climate policy instruments worldwide. Major industrialized economies and regions have adopted either emissions trading systems or carbon taxes, with policy designs adjusted according to domestic industrial structures in order to maximize emissions reduction outcomes [5]. Carbon taxes were first introduced in the early 1990s by Nordic countries with strong environmental policy traditions, including Finland (1990), Norway and Sweden (1991), and Denmark (1992). Beginning in the late 2000s, concerns over the relatively high administrative and regulatory costs associated with ETS led several governments, including Switzerland, Australia, and Japan, to adopt or expand carbon tax policies. The EU Emissions Trading System (EU ETS), launched in 2005, has been widely regarded as a leading example of climate and environmental governance and has served as an important reference point for policy learning and institutional reflective reform. At the subnational level, California's Cap-and-Trade Program (CAT), implemented in 2008, not only emerged in response to the uncertainty of federal climate policy in the United States [6], but also addressed several shortcomings identified in the EU ETS through a series of institutional revisions and regulatory adjustments [7].

Laing, et al. [8] pointed out that during the early phases of the EU ETS, the excessive allocation of free allowances, an oversupply of permits, and the decline in emissions caused by the global financial crisis limited its environmental effectiveness. Nevertheless, the EU ETS established the world's first large-scale carbon market governance framework and achieved a certain degree of emissions reduction overall.

Hepburn [9] argued that the EU ETS has long faced problems of permit oversupply and carbon price volatility, and that the Market Stability Reserve (MSR) is needed to provide a stable and predictable carbon price signal in order to encourage long-term low-carbon investment. Perino [10] also supported the role of the MSR and noted that the allowance cancellation mechanism introduced in Phase IV helps convert part of the additional emissions reductions into actual reductions in overall emissions. Bayer and Aklin [11] found that although the EU ETS was criticized for its low carbon prices during Phases I to III, it nevertheless reduced more than one billion tonnes of CO<sub>2</sub> emissions between 2008 and 2016, accounting for 3.8 percent of total emissions during that period, and gradually established institutional credibility.

However, whether through carbon taxes or emissions trading systems, carbon pricing policies have undergone revisions at different stages across jurisdictions. Overall, carbon pricing has become an effective policy instrument for reducing emissions. The question then becomes: how do carbon pricing systems operate when introduced into Asian or East Asian economies?

Recent years have seen a growing body of research and evidence identifying Asian and East Asian economies as developmental states. Most Asian economies have become critical players in global manufacturing supply chains, and their energy consumption and GHG emissions from manufacturing have also been emphasized [12]. Much of their manufacturing sector could be characterized as a brown economy [13], referring to carbon-intensive sectors such as steel, fossil fuels, chemicals, and cement. Drawing on the concept of new developmentalism, Dent [14] argued that state bureaucracies in Asian economies continue to prioritize economic competitiveness when addressing international low-carbon and climate governance issues.

Using Singapore and Republic of Korea as examples, he demonstrated that industrial upgrading and economic development remain the primary policy objectives, while climate mitigation remains a secondary concern. Consequently, many inconsistencies and contradictions persist between the economic and environmental policies of these two economies. Similar observations have been made in studies conducted in China, Japan, Republic of Korea, and Taiwan [1,2,15–19].

This study focuses on the development of carbon pricing in Republic of Korea and Taiwan, two economies that are commonly regarded as representative developmental states in East Asia. The analysis begins with their recent experiences in green transition policies.

Regarding Republic of Korea's Green Growth Strategy launched in 2009, Chang [20] and Heo [21] argued that Republic of Korea continued to prioritize economic development under a developmental-state model. In their view, the government's promotion of green technologies primarily served as a tool to support economic growth rather than a genuine commitment to climate mitigation and environmental sustainability. Kim and Thurbon [17] similarly argued that although the Green Growth Strategy was presented as a climate mitigation initiative, it lacked a substantive climate governance framework and instead treated green technology industries as a means of enhancing future international economic competitiveness.

Kim [16] further criticized the climate change policies of the Lee Myung-bak administration, arguing that they represented a distinctly Korean form of green development in which the state coordinated with the chaebol while excluding environmental groups from the policymaking process. According to Kim, these policies were not genuinely aimed at reducing emissions and largely neglected environmental protection and social welfare.

Thurbon et al. [18] and Thurbon et al. [22] drew upon Joseph Schumpeter's (1942) [23] concept of creative destruction, arguing that the Republic of Korean government promoted investment in green technology industries as the creative component of industrial transformation, thereby facilitating the transition of traditional carbon-intensive industries. They cited the coal phase-out policies proposed by both the central and local governments after 2018 as evidence of the deconstruction process. However, this study takes a different view regarding the decarbonization effects of these developments.

Chou [2] and Chou [24] made similar observations regarding Taiwan's decarbonization policies. He pointed out that Taiwan had earlier promoted initiatives such as the "One Thousand Wind Turbines" and the "One Million Solar Rooftops" programs. In 2012, the government launched the Green Pioneer Industry initiative, and in 2015 identified Taiwan as a future Asian green energy component supply center. In 2016, the green energy industry was incorporated into the more ambitious 5 + 2 Industrial Innovation Plan, and was subsequently included in the expanded Twelve Key Strategic Industries initiative, which positioned Taiwan as an Asian supply hub. According to Chou, both Republic of Korea and Taiwan have clearly adopted green technology industries as a central policy priority and have developed relatively clear industrial strategies. However, the goals of climate mitigation and the commitments made through Nationally Determined Contributions (NDCs) have remained considerably less clear in terms of policy planning, implementation, and actual execution.

When the green transitions of these two economies are characterized by such a degree of formalism, how should we evaluate their implementation and planning of carbon pricing? Aklin and Urpelainen [25] argued that sustainable energy transitions are fundamentally political in nature. Without improvements in energy technologies, achieving emissions reductions can be extremely costly unless governments regulate carbon emissions through direct regulation or price-based instruments. Therefore, national GHG reduction targets require carbon pricing as a policy instrument to drive emissions reductions across different sectors.

However, as Unruh [26] pointed out, when national, economic, and social systems become locked into a technical and industrial complex (TIC) or a carbon-intensive development pathway, it is difficult to expect such systems to generate change from within. Instead,

exogenous forces are required to facilitate transformation. Aklin and Urpelainen [25] further emphasized that exogenous shocks, such as changes in oil prices or international circumstances, can influence national policies and generate positive reinforcement, thereby creating new vested interests and supporting coalitions that may drive the transition process.

Therefore, the next question is whether exogenous forces or shocks, such as international climate agreements or the EU CBAM, can genuinely drive the effectiveness of carbon pricing in Republic of Korea and Taiwan. Related studies may provide partial answers.

Oh, et al. [27] found that although the K-ETS encouraged firms to improve energy management and efficiency, its overall emissions reduction effect remained relatively limited. This was mainly because the Republic of Korean government, in order to maintain the international competitiveness of its manufacturing sector, has long provided a high proportion of free allowances to carbon-intensive industries, resulting in insufficient actual pressure on firms to reduce emissions. This institutional design reflects Republic of Korea's governance characteristics as a developmental state.

Chou and Liou [28] analyzed how Taiwan's carbon-intensive industrial forces are highly powerful. The techno-institutional complex built upon the manufacturing and energy industries has shaped reinforced carbon lock-in, while also enabling strong lobbying efforts that influence the government. As a result, Taiwan missed three windows of opportunity to promote an energy tax.

In contrast to the exogenous forces that drive transitions, institutional inertia is often regarded as an important factor influencing the success or failure of change in developmental states. Although it provides stability for the functioning of society, institutional inertia often causes institutional structures to become favorable to rent-seekers during periods of change, thereby locking in inefficient development pathways and hindering inclusive growth [29]. Alternatively, institutional inertia has been defined as the stickiness or resistance of institutions to environmental change, limiting their ability to respond in a timely manner to newly emerging challenges [30].

More importantly, when developmental states undergo transformation, if existing governance structures fail to adjust to changes in economic, social, and technological conditions, they may evolve into counterproductive institutional inertia [31]. Developmental shifts often depend on critical junctures in history that are capable of breaking existing paths of institutional dependence and opening new turning points for institutional evolution [32].

Related discussions have already emerged in studies of Republic of Korea and Taiwan, covering financial crises [33], the relationships among government, business, and markets under democratic transition [34], industrialization [35], and governance transformations associated with global markets and transnational networks [31]. Building upon this literature, this study further examines the trade-offs involved in the planning and implementation of carbon pricing in developmental states from the perspective of institutional inertia. It analyzes how Republic of Korean and Taiwanese governments respond under carbon-intensive development pathways, particularly within the structural conditions shaped by their dominant GHG emission patterns.

### 3. Analytical Framework

This study focuses on the challenges that developmental states face in the planning and implementation of carbon pricing when they become embedded in carbon-intensive economic thinking and development pathways. It also explores whether such structural conditions can be altered by strong exogenous forces.

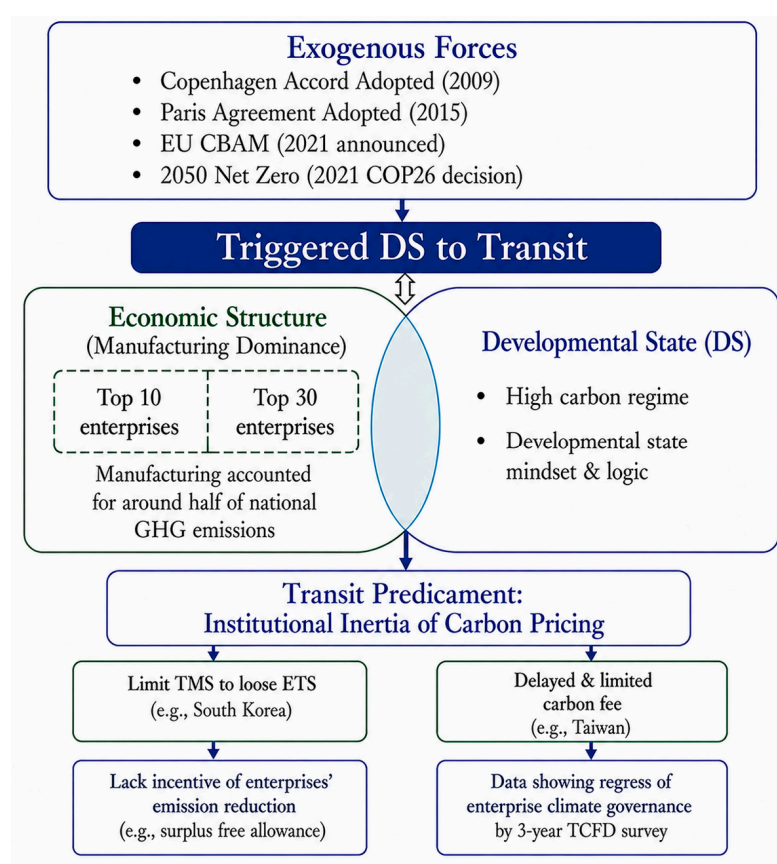
In the cases of Republic of Korea's introduction of the TMS in 2012 and its transition to the K-ETS in 2015, as well as Taiwan's renewed planning of a carbon fee in 2021, the exogenous pressures arising from international climate agreements and major regulatory developments include the adoption of the Copenhagen Accord in 2009, the adoption of the Paris Agreement at

COP21 in 2015, the COP26 decision in 2021 to pursue global net-zero emissions by 2050, and the European Union's announcement in 2021 that it would implement the CBAM.

In terms of the analytical framework, this study draws upon the preceding analysis of climate governance experiences in East Asian economies and incorporates relevant documents and survey data to propose the concept of institutional inertia in carbon pricing within developmental states. At the same time, major international climate agreements and regulatory frameworks are treated as exogenous pressures that serve as driving forces for transformation in developmental states.

From a structural perspective, the manufacturing sectors, as well as the top 10 and top 30 manufacturing enterprises in both economies, account for a substantial share of national GHG emissions, reflecting a dominant emission structure. At the same time, this structure interacts with the developmental-state mindset and decision-making logic that have become accustomed to a high-carbon regime.

Based on this framework, this study analyzes the limited effects of the TMS and the K-ETS in Republic of Korea in motivating corporate emissions reductions, particularly the effects of the government's extensive allocation of free allowances to firms. Similarly, under the pressure of international climate regulations, especially the European Union's 2021 announcement of the forthcoming implementation of the CBAM, Taiwan was compelled to restart the planning of a carbon fee. However, the effectiveness of this limited carbon fee framework remains questionable. Evidence from the Risk Society and Policy Research Center TCFD surveys conducted over three consecutive years (2023–2025) indicates noteworthy findings regarding corporate GHG reduction efforts, disclosure practices, supply-chain carbon inventories, and climate-related financial assessments (Figure 1).



**Figure 1.** Analytical framework of Institutional Inertia in Carbon Pricing. Note: Top 10 and Top 30 enterprises refer to the manufacturing enterprises with the highest greenhouse gas emissions in each economy. Source: Authors' compilation.

To ensure empirical objectivity and minimize normative bias, the performance of carbon pricing mechanisms in Taiwan and Republic of Korea is assessed through an analytical framework. First, environmental effectiveness is evaluated through changes in national GHG emissions and emission trends in covered sectors following the implementation of carbon pricing mechanisms. Second, economic incentive strength is assessed by examining carbon price levels, carbon fee rates, and the extent to which free allowance allocations and exemption mechanisms weaken the application of the Polluter Pays Principle. Together, these two dimensions serve as indicators for assessing the persistence of institutional inertia in the developmental state.

## 4. Methods

This study employs a multi-methodological approach combining comparative case study analysis, policy document analysis, and quantitative investigation to evaluate the carbon pricing mechanisms in Taiwan and Republic of Korea. By combining qualitative policy analysis with quantitative emission indicators, this framework ensures a comprehensive assessment of climate governance efficacy.

### 4.1. Cases Selection

This study adopts a “Most Similar Systems Design” (MSSD) to compare Taiwan and Republic of Korea. The two cases are selected because they share highly comparable economic, industrial, and energy structures while pursuing different carbon pricing pathways. The selection logic rests on two major pillars:

- Highly homogeneous economic, industrial, and emission structures: Both economies are export-oriented manufacturing hubs facing increasing pressure from the EU CBAM. The manufacturing sector in both economies account for around half of their national GHG emissions in 2021 [36–39]. Furthermore, a comparison of the major emitting sectors in both economies reveals substantial overlap, particularly in semiconductors, steel, petrochemicals, and cement [36–39]. As carbon pricing primarily targets emissions from energy-intensive industrial sectors, both economies face comparable decarbonization pressures and industrial adjustment challenges.
- Divergent policy paths: Despite operating within highly similar macroeconomic and structural environments, their regulatory approaches differ fundamentally. Republic of Korea established a mandatory K-ETS in 2015, whereas Taiwan pursued a carbon fee policy under the EU CBAM pressure.

Japan was excluded from this study due to significant structural differences that reduce its comparability within the MSSD framework. Manufacturing sectors accounted for around half of national greenhouse gas emissions in both Taiwan and Republic of Korea in 2021, compared with a lower share of 37.8% in Japan [40]. By contrast, emissions in Taiwan and Republic of Korea remain more heavily concentrated in manufacturing-intensive sectors such as semiconductors, steel, petrochemicals, and cement. Given that carbon pricing policies primarily target emissions from energy-intensive industries, the industrial decarbonization pressures and political-economic dynamics observed in Japan differ considerably from those found in Taiwan and Republic of Korea.

### 4.2. Data Collection and Sources

This study established a qualitative database consisting of 28 institutional documents and media records published between 2010 and 2025 to trace the evolution of carbon pricing policies and public discourse in Taiwan and Republic of Korea. The database comprises official policy documents, government reports, legislative records, institutional reports,

stakeholder statements and media reports that capture policy debates, industrial responses, and stakeholder perspectives regarding carbon pricing implementation.

To support the comparative analysis, quantitative data were collected from several official statistical databases, including the Korean Statistical Information Service (KOSIS), National Greenhouse Gas Management System (NGMS), Korea Energy Agency (KEA), Taiwan Climate Change Administration (TCCA), Taiwan Energy Administration (TEA), and the Corporate Greenhouse Gas Emissions Information Platform. These sources were used to examine national emission trends, industrial emission structures, carbon pricing implementation, and enterprise-level emission patterns in both economies.

Regarding the quantitative component, this study integrated micro-level survey datasets exclusively tailored to Taiwan, adapted from the longitudinal corporate surveys conducted by NTU-RSPRC. To capture shifting focus areas, the sampling framework and organizational structure evolved dynamically across three consecutive waves: 2023 ( $N = 900$ ; 21.3% TWSE-listed firms and TPEx-listed firms vs. 78.7% non-listed firms) and 2024 ( $N = 901$ ; 14.9% TWSE-listed firms and TPEx-listed firms vs. 85.1% non-listed firms) primarily targeted high-carbon-emitting sectors facing supply-chain pressures, whereas 2025 ( $N = 906$ ; 23.5% TWSE-listed firms and TPEx-listed firms vs. 76.5% non-listed firms) expanded to encompass non-high-carbon manufacturing industries and financial services as important control groups.

In this study, listed firms refer to companies listed on either the Taiwan Stock Exchange (TWSE) or the Taipei Exchange (TPEx), while non-listed firms refer to companies that are not publicly traded on Taiwan's capital markets. This distinction is important because listed firms are generally subject to more stringent disclosure, governance, and sustainability reporting requirements than non-listed firms.

Conducted exclusively among corporate executives and ESG directors, this localized survey infrastructure was designed to analyze the micro-political economy and evolving patterns of industrial resistance associated with Taiwan's carbon pricing trajectory.

## 5. Results

### 5.1. Dominant GHG Emissions and Emission Structure of Carbon-Intensive Industries in Republic of Korea and Taiwan

This study compares the GHG emission structures of Republic of Korea and Taiwan in 2015, when Republic of Korea implemented the K-ETS, and 2021, when Taiwan drafted its carbon pricing policy.

Republic of Korea's GHG emissions reached 725.05 MtCO<sub>2</sub>e in 2015, ranking 13th globally, while Taiwan's emissions were 290.44 MtCO<sub>2</sub>e, ranking 30th globally [38,39,41]. We further examined the contribution of the manufacturing sector to national GHG emissions and the concentration of emissions among the top 10 and top 30 manufacturing enterprises [42,43]. The results reveal that Republic of Korea and Taiwan shared highly similar carbon-intensive industrial structures dominated by cement, petrochemicals, steel, and semiconductor industries (Table 1).

**Table 1.** Comparison of GHG Emissions between Taiwan and Republic of Korea in 2015.

| Carbon Emissions Data in 2015                                           |                | Taiwan                     | Republic of Korea          |
|-------------------------------------------------------------------------|----------------|----------------------------|----------------------------|
| National greenhouse gas emissions                                       | Global ranking | 30th place                 | 13th place                 |
|                                                                         | Emissions      | 290.44 MtCO <sub>2</sub> e | 725.05 MtCO <sub>2</sub> e |
| Manufacturing industry greenhouse gas emissions                         |                | 149.20 MtCO <sub>2</sub> e | 317.04 MtCO <sub>2</sub> e |
| Proportion of national carbon emissions from the manufacturing industry |                | 51.37%                     | 43.73%                     |

Table 1. Cont.

| Carbon Emissions Data in 2015         |                                      | Taiwan                                        | Republic of Korea             |
|---------------------------------------|--------------------------------------|-----------------------------------------------|-------------------------------|
| Top 10 companies                      | Emissions                            | 107.34<br>MtCO <sub>2</sub> e                 | 149.90<br>MtCO <sub>2</sub> e |
|                                       | Proportion of manufacturing industry | 71.94%                                        | 47.28%                        |
|                                       | Proportion of national total         | 36.96%                                        | 20.67%                        |
| Top 30 companies                      | Emissions                            | 131.93<br>MtCO <sub>2</sub> e                 | 207.81<br>MtCO <sub>2</sub> e |
|                                       | Proportion of manufacturing industry | 88.42%                                        | 65.55%                        |
|                                       | Proportion of national total         | 45.42%                                        | 28.66%                        |
| Major high-carbon-emission industries |                                      | Cement, petrochemicals, steel, semiconductors |                               |

Source: Compiled by the authors based on [36–39,41–45].

In Republic of Korea, manufacturing-sector emissions amounted to 317.04 MtCO<sub>2</sub>e in 2015, accounting for 43.73% of national emissions [39,44]. The top 10 manufacturing enterprises were responsible for 149.90 MtCO<sub>2</sub>e, representing 47.28% of manufacturing emissions and 20.67% of national emissions. The top 30 enterprises emitted 207.81 MtCO<sub>2</sub>e, accounting for 65.55% of manufacturing emissions and 28.66% of national emissions [39,44,45].

By comparison, Taiwan's manufacturing sector emitted 149.20 MtCO<sub>2</sub>e, accounting for 51.37% of national emissions [38,42]. The top 10 manufacturing enterprises generated 107.34 MtCO<sub>2</sub>e, representing 71.94% of manufacturing emissions and 36.96% of national emissions, while the top 30 enterprises emitted 131.93 MtCO<sub>2</sub>e, accounting for 88.42% of manufacturing emissions and 45.42% of national emissions [38,42,43].

Republic of Korea's GHG emissions increased to 739.51 MtCO<sub>2</sub>e in 2021, remaining the world's 13th largest emitter, whereas Taiwan's emissions rose to 297.91 MtCO<sub>2</sub>e, ranking 31st globally [38,39,41]. Manufacturing-sector emissions reached 349.88 MtCO<sub>2</sub>e in Republic of Korea and 158.03 MtCO<sub>2</sub>e in Taiwan, accounting for 47.31% and 53.05% of national emissions, respectively [38,39,42,46].

In Republic of Korea, the top 10 manufacturing enterprises emitted 180.86 MtCO<sub>2</sub>e, accounting for 51.69% of manufacturing emissions and 24.46% of national GHG emissions. The top 30 enterprises emitted 250.34 MtCO<sub>2</sub>e, representing 71.55% of manufacturing emissions and 33.85% of national GHG emissions [39,45,46]. In Taiwan, the top 10 manufacturing enterprises emitted 106.80 MtCO<sub>2</sub>e, accounting for 67.58% of manufacturing emissions and 35.85% of national emissions. The top 30 enterprises emitted 132.29 MtCO<sub>2</sub>e, representing 83.71% of manufacturing emissions and 44.41% of national GHG emissions [36–38,42,43] (Table 2). These findings indicate that Taiwan's industrial emissions were considerably more concentrated among a small number of large enterprises than those of Republic of Korea. In 2015, the top 30 manufacturing enterprises accounted for 88.42% of manufacturing emissions in Taiwan, compared with 65.55% in Republic of Korea. A similar pattern persisted in 2021, with the corresponding shares reaching 83.71% and 71.55%, respectively. This high degree of concentration suggests that a limited number of firms dominated industrial emissions in Taiwan. In both economies, the largest emitters were primarily concentrated in carbon-intensive sectors such as petrochemicals, steel, semiconductors, and electronics.

**Table 2.** Comparison of GHG Emissions between Taiwan and Republic of Korea in 2021.

| Carbon Emissions Data in 2021                                           |                                      | Taiwan                                                                       | Republic of Korea                                                                                         |
|-------------------------------------------------------------------------|--------------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|
| National greenhouse gas emissions                                       | Global ranking                       | 31st place                                                                   | 13th place                                                                                                |
|                                                                         | Emissions                            | 297.91 MtCO <sub>2</sub> e                                                   | 739.51 MtCO <sub>2</sub> e                                                                                |
| Manufacturing industry greenhouse gas emissions                         |                                      | 158.03 MtCO <sub>2</sub> e                                                   | 349.88 MtCO <sub>2</sub> e                                                                                |
| Proportion of national carbon emissions from the manufacturing industry |                                      | 53.05%                                                                       | 47.31%                                                                                                    |
| Top 10 companies                                                        | Emissions                            | 106.80 MtCO <sub>2</sub> e                                                   | 180.86 MtCO <sub>2</sub> e                                                                                |
|                                                                         | Proportion of manufacturing industry | 67.58%                                                                       | 51.69%                                                                                                    |
|                                                                         | Proportion of national total         | 35.85%                                                                       | 24.46%                                                                                                    |
| Top 30 companies                                                        | Emissions                            | 132.29 MtCO <sub>2</sub> e                                                   | 250.34 MtCO <sub>2</sub> e                                                                                |
|                                                                         | Proportion of manufacturing industry | 83.71%                                                                       | 71.55%                                                                                                    |
|                                                                         | Proportion of national total         | 44.41%                                                                       | 33.85%                                                                                                    |
| Major high-carbon-emission industries                                   |                                      | Petrochemicals, electronic components, steel, cement, paper, textiles, glass | Steel, electronic components, cement, petrochemicals, glass, automobile manufacturing, chemical materials |

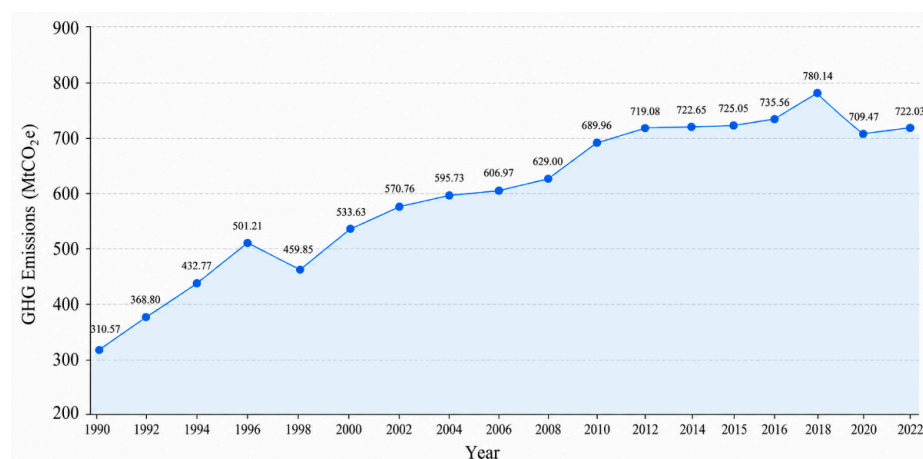
Source: Compiled by the authors based on [36–39,41–43,45,46].

The data suggest that within the global division of labor, these two manufacturing bases for global supply chains in East Asia are predominantly reliant on fossil fuels, making them high-carbon economies. Therefore, achieving the global goal of net-zero carbon emissions by 2050 requires concentrated efforts toward the green transition of these economies. The manufacturing sector in both Republic of Korea and Taiwan accounts for around half of total GHG emissions. They also share a remarkably similar structure in the dominance of the GHG emissions from their top 10 and top 30 manufacturing enterprises, all concentrated in four hard-to-abate sectors, i.e., petrochemicals, steel, electronics (semiconductors), and cement. These brown economy sectors and their dominant industrial structures have thus created a certain degree of social lock-in to a high-carbon economic pathway, making developmental states hesitant to implement carbon pricing.

## 5.2. Republic of Korea's Carbon Pricing

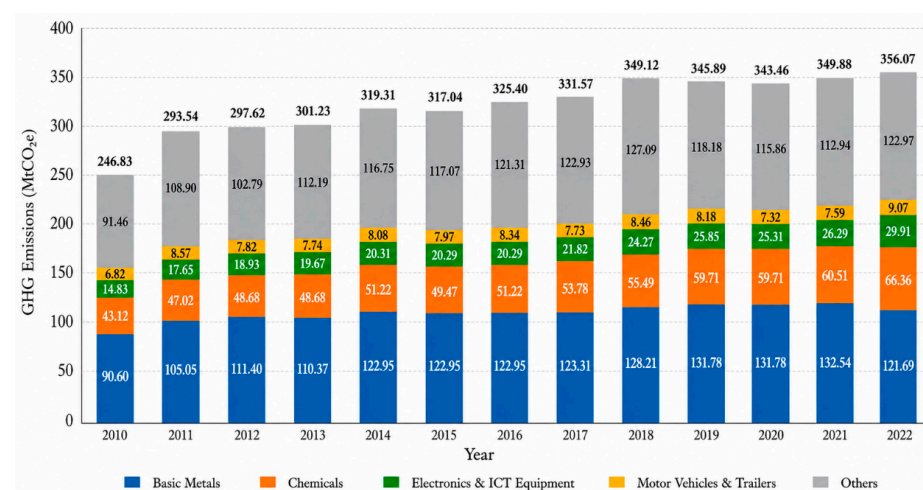
### 5.2.1. Sharp Increase in GHG Emissions During 1990–2022

During 1990–2022, the GHG emissions of Republic of Korea showed an overall upward trend, with a notable increase between 2009 and 2018. Emissions rose from 632.87 MtCO<sub>2</sub>e in 2009 to 725.05 MtCO<sub>2</sub>e in 2015 and then to 780.14 MtCO<sub>2</sub>e in 2018 (Figure 2) [39]. This represents an increase of 147.27 MtCO<sub>2</sub>e (approximately 23.27%) over the decade, with 2018 having the highest emissions on record. This increase was primarily driven by a significant increase in carbon emissions from the steel, chemical materials, and electronics industries.



**Figure 2.** Trends in Republic of Korea's National GHG Emissions (1990–2022). Source: Compiled by the authors based on data from [39].

First, the basic metal industry ranks the highest with its carbon emissions increasing by 46.60% between 2010 and 2018. Second, the chemical material and chemical product industry saw a 28.67% rise in emissions during the same period, accounting for 17.68% of the national growth. By 2018, its emissions reached 55.49 MtCO<sub>2</sub>e, representing approximately 7.11% of the national total. The automobile and trailer equipment industry also continued to grow during this period, indicating persistent pressures from energy dependence and process emissions. The electronics industry has experienced the most rapid increase (by 63.63%) in emissions between 2010 and 2018. With the total emissions reaching 24.27 MtCO<sub>2</sub>e in 2018, it became the fourth largest emitting industry in the country for the first time. Overall, steel and petrochemical industries continue to dominate the total emissions, while the electronics industry has emerged as a growing source of emissions in Republic of Korea (Figure 3) [44,46,47].



**Figure 3.** GHG Emissions of Major Manufacturing Industries in Republic of Korea (2010–2022). Note: “Others” includes the following manufacturing sectors: food, beverage, tobacco, textile, apparel, leather, wood products, paper products, printing, petroleum and coal products, pharmaceuticals, rubber and plastics, non-metallic mineral products, fabricated metals, medical and precision instruments, electrical equipment, specialized machinery, other transport equipment, furniture, other manufacturing industries, and machinery repair and maintenance. Source: Compiled by the authors based on data from [44,46,47].

The growth of Republic of Korea's carbon emissions is also attributed to its electricity mix. Although nuclear power accounted for a considerable share of the electricity mix, ranging

between 23.4% and 34.1% during 2009–2018, thermal power (coal and oil) continued to be the primary source, although its share gradually declined from 47.6% to 32.8%. Over the same period, renewables increased from 1.1% to 8.9%, while hydropower remained almost constant between 0.6% and 1%. As a result, Republic of Korea made little progress in reducing its electricity emission intensity, which declined by only 1.85% from 0.4653 tCO<sub>2</sub>eq/MWh in 2009 to 0.4567 tCO<sub>2</sub>eq/MWh in 2018. Meanwhile, total electricity consumption rose substantially from 433,604 GWh to 594,400 GWh, an increase of 37.08%. As the demand for electricity grew faster than the reduction in the emission intensity, carbon emissions continued to rise, indicating an ongoing expansion of energy-intensive industries.

The top 30 manufacturing enterprises contributing to the GHG emissions in Republic of Korea in 2015 constituted nine enterprises in petrochemicals, seven in cement, four in electronics, three each in steel and energy, one in automobiles, and three in other industries [43] (Table 3). While petrochemicals and steel were the highest contributors, the electronics industry represented by only four enterprises collectively generated over 22 million tons of emissions. Samsung Electronics ranked the highest among them, and LG Display, Samsung Display, and SK Hynix also ranked among the top 20 emitters, highlighting the emerging influence of the electronics industry in the national emission structure. However, the continued domination by the traditional high-carbon-emitting industries (petrochemicals, steel, and cement) was the primary reason for the structural challenges facing Republic of Korea in implementing carbon pricing.

**Table 3.** Top 30 GHG emitters in Republic of Korea in 2015.

| Ranking | Company Name               | Emissions (MtCO <sub>2</sub> e) | Ranking | Company Name         | Emissions (MtCO <sub>2</sub> e) |
|---------|----------------------------|---------------------------------|---------|----------------------|---------------------------------|
| 1       | POSCO                      | 73.06                           | 16      | YNCC                 | 3.48                            |
| 2       | Hyundai Steel              | 19.57                           | 17      | SK Global Chemical   | 3.35                            |
| 3       | SsangYong Cement           | 12.02                           | 18      | Korea Zinc           | 3.02                            |
| 4       | LG Display                 | 7.35                            | 19      | Asia Cement          | 2.98                            |
| 5       | LG Chem                    | 7.29                            | 20      | SK Hynix             | 2.80                            |
| 6       | Tongyang Cement            | 6.83                            | 21      | OCI                  | 2.52                            |
| 7       | Samsung Electronics        | 6.70                            | 22      | Hanwha Chemical      | 2.35                            |
| 8       | SungShin Cement            | 6.08                            | 23      | GS E&R               | 2.28                            |
| 9       | Lotte Chemical             | 5.63                            | 24      | POSCO ChemTech       | 2.24                            |
| 10      | Halla Cement               | 5.38                            | 25      | Kumho Petrochemical  | 2.20                            |
| 11      | Samsung Display            | 5.11                            | 26      | Gunjang Energy       | 2.08                            |
| 12      | Hanil Cement               | 4.64                            | 27      | Dongkuk Steel        | 1.91                            |
| 13      | Hanwha Total Petrochemical | 4.27                            | 28      | SK Incheon Petrochem | 1.65                            |
| 14      | Hanwha Energy              | 4.10                            | 29      | Hyundai Motor        | 1.53                            |
| 15      | Hyundai Cement             | 3.90                            | 30      | KCC                  | 1.49                            |

Source: Compiled by the authors based on data from [43].

### 5.2.2. Republic of Korea's Carbon Pricing Policy Transition Struggle from TMS (2012) to ETS (2015)

Before the 2009 Copenhagen UN Climate Change Summit, the Lee Myung-bak administration in Republic of Korea launched the Green Growth Strategy, announcing a goal of 30% reduction in national GHG by 2020 compared to the 2009 business-as-usual level [48]. To achieve this goal, the Framework Act on Low Carbon, Green Growth [49], which laid the foundation for a phased implementation of policy instruments ranging from direct regulation to market mechanism, was formulated and passed in 2010. Under this Act, the GHG and Energy Target Management System (TMS) was first implemented in 2012 as a policy instrument of direct regulation. The TMS requires enterprises whose GHG emissions and energy consumption exceed statutory thresholds to negotiate with the government to establish specific GHG reduction targets [50]. Failure to meet these targets would result in a government order to submit and implement an improvement plan within one year or an imposition of fines under the Act. However, the amount of the fine could be negotiated between enterprises and the government.

In 2015, Republic of Korea launched a GHG ETS based on the cap-and-trade principle, marking a shift from direct regulation to a market-based mechanism. This policy allows enterprises to meet their emission reduction targets while reducing costs by trading surplus allowances through the market mechanism. Initially, most allowances were allocated free of charge [51]. However, as the system matured, Republic of Korea gradually increased the proportion of paid allowances and introduced third-party traders to improve market liquidity.

Kawakatsu et al. [52] attributed Republic of Korea's success in becoming the first East Asian country to implement carbon emission trading in 2015 to its strict regulation over the electricity industry, which was partially owned by the government. While the adoption of the ETS was driven by strong government guidance, its design remained business-friendly. During the transition from the TMS to ETS, disagreements among government ministries and enterprises led to conflicting groups and lobbying efforts. Kim [16] noted that the Ministry of Environment and environmental groups argued in favor of the ETS as it would guide enterprises toward carbon reduction and align Republic of Korea with international carbon pricing mechanisms. By contrast, the Ministry of Knowledge Economy (now the Ministry of Trade, Industry and Energy) and industry associations favored maintaining the TMS, emphasizing the need to consider carbon reduction costs and pursue gradual reforms. They worried that alignment with international carbon pricing (per-ton carbon cost) under the ETS would impose excessive costs on Republic of Korean industries and thereby undermine their competitiveness. This illustrates the internal government conflicts and industry constraints that developmental states typically face when transitioning to a carbon pricing mechanism.

#### Ineffective GHG Emission Reduction by Enterprises Due to Loose ETS with Emission Allowances

As per Article 46 of the Framework Act on Low Carbon, Green Growth, 2010, the Republic of Korean government divided the total emission cap into discrete units of emission allowances under the cap-and-trade principle. These allowances were then allocated among enterprises, which could choose to buy additional allowances or sell surplus ones in the trading market based on their actual emission reduction performance. The criteria for enterprises covered under the Act were that they must have an average annual GHG emission level exceeding 125,000 tons of CO<sub>2</sub>e over the past three years or operate at least one facility with emissions surpassing 25,000 tons of CO<sub>2</sub>e [51]. The number of enterprises covered by the K-ETS grew from 525 in its first phase (2015–2017) to 684 in

the third phase (2021–2025), accompanied by a gradual reduction in the proportion of free allowances. While Republic of Korea’s ETS now covers 73.5% of the nation’s total GHG emissions, it has neither effectively incentivized enterprises to increase energy efficiency investments, nor has it driven large enterprises to invest in renewable energy.

The government’s allocation of a substantial number of free allowances to high-carbon-emitting industries diluted the pressure to reduce emissions, undermining the policy’s incentive function. This approach originated from concerns during the initial ETS implementation phase (2015–2017) that imposing carbon costs on high-cost and trade-intensive sectors could undermine the competitiveness of domestic products. Major high-carbon-emitting industries such as steel, oil refining, petrochemicals, semiconductors, displays, and cement thus received free allowances initially. Even by the third phase of the ETS, the industrial sector paid for only 0.48% of its total allocated allowances, reflecting insufficient pressure to reduce emissions [53].

Due to the over-generous allocation of emissions allowances by the Ministry of Environment, enterprises such as Pohang Iron and Steel Company (POSCO) and Samsung Electronics profited from selling surplus allowances across the three phases of the ETS. Between 2015 and 2022, the top 10 high-carbon-emitting enterprises collectively traded 21.84 million tons of CO<sub>2</sub>e, generating a total revenue of approximately KRW 474.7 billion. The steel industry accounted for the largest trading volume. In particular, POSCO traded 7.85 million tons across the first and third phases, and its revenue reached KRW 164.9 billion, ranking first among all participating industries. Hyundai Steel traded 1.38 million tons in the third phase, generating KRW 31.6 billion in revenue (Table 4) [54].

**Table 4.** Estimated Carbon Allowance Trading Volume and Revenue of Major Emitters in Republic of Korea during 2015–2022.

| Company Name        | Industry      | Allowance Trading Volume (Tons) |                     |                     |            | Auction Revenue (100 Million KRW) |
|---------------------|---------------|---------------------------------|---------------------|---------------------|------------|-----------------------------------|
|                     |               | Phase 1 (2015–2017)             | Phase 2 (2018–2020) | Phase 3 (2021–2022) | Total      |                                   |
| POSCO               | Steel         | 5,796,069                       | -                   | 2,057,525           | 7,853,594  | 1649                              |
| Hyundai Steel       | Steel         | -                               | -                   | 1,375,260           | 1,375,260  | 316                               |
| Samsung Electronics | Semiconductor | 1,168,638                       | -                   | -                   | 1,168,638  | 237                               |
| SsangYong C&E       | Cement        | -                               | 2,379,000           | 2,379,000           | 4,758,000  | 1113                              |
| S-Oil               | Refining      | -                               | 516,183             |                     | 516,183    | 131                               |
| LG Chem             | Petrochemical | -                               | -                   | 833,837             | 833,837    | 192                               |
| GS Caltex           | Refining      | -                               | 1,038,643           | 833,837             | 1,872,480  | 456                               |
| Hyundai Oilbank     | Refining      | -                               | 119,512             | -                   | 119,512    | 30                                |
| SK Energy           | Refining      | -                               | 972,796             | 972,796             | 1,945,592  | 333                               |
| Lotte Chemical      | Petrochemical | -                               | 699,371             | 699,371             | 1,398,742  | 290                               |
| Total               |               | 6,964,707                       | 5,725,505           | 9,151,626           | 21,841,838 | 4747                              |

Source: Adapted from [54].

Samsung Electronics received an allowance allocation of approximately 1.168 million tons during the first phase of the ETS, with the trading revenue reaching KRW 23.7 billion. SsangYong Cement received a combined allocation of 4.758 million tons across the second and third phases, earning KRW 111.3 billion from the trading. GS Caltex received a combined allocation of 1.872 million tons in the second and third phases, with the trading revenue reaching KRW 45.6 billion. SK Energy received a combined allocation of 1.945 million tons in the second and third phases, earning KRW 33.3 billion. Lotte Chemical received a total of 1.398 million tons, with the trading revenue reaching KRW 29 billion. Table 4 thus illustrates that the high-carbon emitting industries did not really have any incentive to pursue aggressive decarbonization as they were able to trade surplus allowances to offset the costs associated with operating the ETS [54].

The year 2018 marked the peak of Republic of Korea's GHG emissions. The start of the second phase of implementation of the ETS (2018–2020) in this year should, in theory, have strengthened carbon pricing as a tool to regulate industrial GHG emissions. However, in practice, the government expanded both the industrial coverage and the allowances for carbon trading compared to the first phase. Many of the industries included in this expansion were the four hardest-to-abate industries.

The analysis above shows that the oversupply of carbon emission allowances by the government has led to low market prices, reducing enterprises' incentives for early emission reductions. In this scenario, the effectiveness of price signals is significantly diminished, making it difficult for both enterprises and policymakers to clearly assess the emission reduction progress, thereby undermining the policy effectiveness. According to the 2023 Emissions Trading System Operation Report released by the Republic of Korean Ministry of Environment in June 2024, the average annual trading price of Korean Allowance Units (KAUs) rose from KRW 12,044 (NT\$279) per ton in 2015 to KRW 30,713 (NT\$712) in 2020 [55]. However, it fell to KRW 11,178 (NT\$259) per ton in August 2023 and has continued to decline since. As of September 2024, the price was KRW 9990 (NT\$231), indicating a gradual decline on account of the oversupply of emission permits. The government set an excessively loose total emission cap (3.048 billion tons), which led participating enterprises to prefer purchasing emission permits to investing in GHG reduction facilities and technologies [56].

The carryover restrictions in Republic of Korea's carbon trading system, originally designed to stimulate market trading, are also now considered to lead to the low prices of emission permits. In this system, participating enterprises can carry over unused carbon allowances to the following year, encouraging them to reduce emissions early and accumulate future allowances. However, in the Republic of Korean carbon market, enterprises tended to hoard allowances to hedge against future risks, leading to sluggish trading and insufficient liquidity at any given point in time. To address this, the government started limiting allowance carryovers in 2017, further restricted them based on the market trading volume in 2019, and gradually tightened the restrictions. Notwithstanding this, the carryover restrictions have reduced enterprises' demand for additional allowances, thereby suppressing the increase of emission permit prices and preventing the carbon trading system from generating price signals. Even efficient enterprises have thus lacked the incentive to reduce emissions early [57].

In summary, the Republic of Korean government launched the TMS in 2012 and transitioned its carbon pricing system to an ETS in 2015 in response to international pressure from the Paris Agreement. This ostensibly addressed international climate governance requirements. However, the regulatory model for the TMS, internal government struggles during the transition, industry lobbying, and generous carbon emission allowances during the first three ETS phases all highlight the structural obstacles that developmental states would face

in implementing carbon pricing. The government's strong espousal of the brown economy locked in high-carbon industries into institutional pathways, further limiting the impact of ETS reforms. Industrial commitment to carbon reduction was also somewhat limited, and the shift in pathways that encouraged industrial carbon reduction were not necessarily achieved. These developments demonstrate that the characteristics of developmental environmentalism are deeply embedded in Republic of Korea's climate policy.

Although Republic of Korea's greenhouse gas emissions continued to increase following the introduction of the Emissions Trading Scheme (ETS), attributing this outcome solely to the technical performance of carbon pricing risks overlooking the broader institutional context within which the policy operates. While emissions may have grown even more rapidly in the absence of regulatory instruments such as the ETS and the Target Management System (TMS), the more analytically relevant question concerns why the ETS has exerted only limited pressure on major emitters despite its formal regulatory design.

This study argues that the effectiveness of the K-ETS has been constrained by the state's continued prioritization of industrial competitiveness alongside decarbonization objectives. Throughout successive phases of the ETS, the government maintained relatively generous emissions caps and extensive free allowance allocations, particularly for energy-intensive export sectors such as semiconductors, steel, and petrochemicals. By Phase III, firms were required to purchase only a very small proportion of their allocated allowances, substantially reducing the compliance costs associated with carbon emissions. Rather than reflecting a simple policy design failure, this pattern illustrates the persistent influence of developmental-state institutions in shaping climate policy implementation.

This interpretation is consistent with Kim and Thurbon's (2015) [17] concept of developmental environmentalism and subsequent analyses of Republic of Korea's green industrial transformation [16–18]. These studies suggest that decarbonization policies in Republic of Korea have frequently been integrated into broader industrial development strategies. Instead of relying primarily on stringent carbon constraints to induce industrial restructuring, the state has combined climate governance with active support for strategic industries through subsidies, public investment, and technology promotion programs. Under this approach, carbon pricing functions alongside, rather than above, industrial competitiveness objectives.

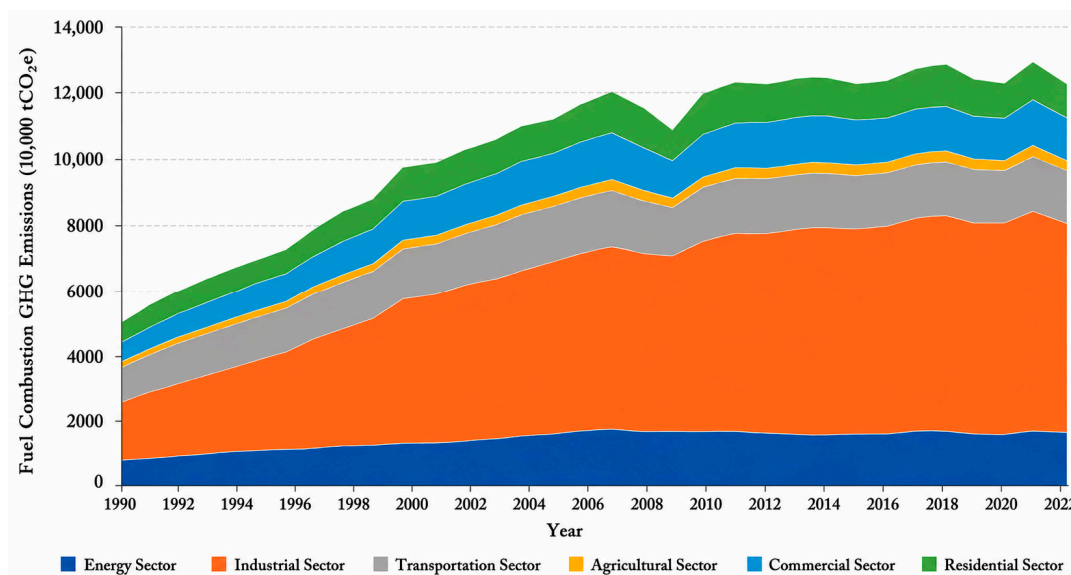
From this perspective, the K-ETS should not be viewed as an ineffective policy instrument. Rather, its decarbonization effects have been moderated by the institutional and political imperatives associated with maintaining export competitiveness and supporting core manufacturing sectors. Generous allowance allocations can therefore be understood as a mechanism through which the state balances international climate commitments with domestic industrial priorities. This helps explain why the TMS and K-ETS have exerted only limited pressure on major emitters.

### 5.3. *Taiwan's Carbon Pricing*

#### 5.3.1. GHG Emissions and Carbon-Intensive Industrial Structure in Taiwan

As a developmental state, Taiwan has been developing various energy and industrial policy plans in response to international climate regulations since 1998. However, the formalistic blueprint for sustainable development has been unable to override the continued promotion of high-carbon-emitting industries. A key structural issue is that Taiwan's domestically produced energy is quite scarce, and it imports almost 99% of its fossil fuels. Energy-intensive manufacturing industries have therefore continued to drive carbon emissions. Figure 4 shows the cumulative emission trends of various sectors from 1990 to 2022. Taiwan's total GHG emissions increased from 110.23 MtCO<sub>2</sub>e in 1990 to 210.20 MtCO<sub>2</sub>e in 2000, with the industrial sector accounting for 46.49% in 2000. The total emissions increased

drastically to 261.02 MtCO<sub>2</sub>e in 2007, even though the industrial sector's share rose only marginally to 47.96% [42]. They declined to 255.85 MtCO<sub>2</sub>e in 2013, with the industrial sector accounting for just over half (50.13%) of the total emissions for the first time. In 2021, total emissions peaked at 268.61 MtCO<sub>2</sub>e, with the industrial sector reaching a 20-year high of 135.44 MtCO<sub>2</sub>e (50.42%) [42].



**Figure 4.** Cumulative Emission Trends from Fuel Combustion by Sector, 1990–2022. Source: Authors' compilation based on data from [42].

Taiwan's major industries are the dominant contributors to its GHG emissions. Taiwan's manufacturing sector produced 158.03 MtCO<sub>2</sub>e of GHG emissions in 2021, accounting for 53.05% of the national total [38,42]. The top 10 manufacturing enterprises accounted for 67.58% of the manufacturing sector's GHG emissions and 35.85% of the national total, with six from the petrochemical industry, two from the steel industry, one each from the electronics and cement industries [38,42,43]. The top 30 manufacturing enterprises accounted for 83.71% of the manufacturing sector's GHG emissions and 44.41% of the national total, with ten from petrochemicals, five from steel, seven from electronics, two from cement, four from papermaking, one from glass, and one from textiles [38,42,43]. In the electronics industry, Taiwan Semiconductor Manufacturing Company (TSMC) was a primary contributor, and most other enterprises were also among the top 20 emitters. Overall, Taiwan's emissions were dominated by traditional high-carbon industries such as petrochemicals, steel, cement, textiles, and papermaking, posing the core industrial structural challenge to Taiwan's implementation of carbon pricing (Table 5).

**Table 5.** Taiwan's Top 30 GHG Emitters in 2021.

| Ranking | Company Name          | Emissions (ktCO <sub>2</sub> e) | Ranking | Company Name             | Emissions (ktCO <sub>2</sub> e) |
|---------|-----------------------|---------------------------------|---------|--------------------------|---------------------------------|
| 1       | Formosa Petrochemical | 26,681                          | 16      | Chang Chun Plastics      | 1528                            |
| 2       | China Steel           | 22,326                          | 17      | Cheng Loong              | 1414                            |
| 3       | TSMC                  | 10,124                          | 18      | Micron Technology Taiwan | 1163                            |
| 4       | Dragon Steel          | 9612                            | 19      | Dairen Chemical          | 1005                            |

Table 5. Cont.

| Ranking | Company Name              | Emissions (ktCO <sub>2</sub> e) | Ranking | Company Name            | Emissions (ktCO <sub>2</sub> e) |
|---------|---------------------------|---------------------------------|---------|-------------------------|---------------------------------|
| 5       | Formosa Chemicals & Fibre | 8481                            | 20      | Micron Memory Taiwan    | 1003                            |
| 6       | Formosa Plastics          | 7912                            | 21      | Tung Ho Steel           | 891                             |
| 7       | CPC Corporation           | 7252                            | 22      | Feng Hsin Steel         | 843                             |
| 8       | Nan Ya Plastics           | 6043                            | 23      | Chung Hwa Pulp          | 839                             |
| 9       | Taiwan Cement             | 5013                            | 24      | Longchen P&P            | 769                             |
| 10      | Chang Chun Petrochemical  | 3355                            | 25      | Far Eastern New Century | 752                             |
| 11      | Asia Cement               | 3074                            | 26      | Taiwan Glass            | 745                             |
| 12      | Innolux                   | 2952                            | 27      | Yieh United Steel       | 706                             |
| 13      | AUO                       | 2236                            | 28      | VIS                     | 694                             |
| 14      | CPDC                      | 1947                            | 29      | Chi Mei Corporation     | 692                             |
| 15      | UMC                       | 1555                            | 30      | YFY                     | 686                             |

Source: Authors' compilation based on [43].

### 5.3.2. Bumpy Start of Carbon Pricing in Taiwan

#### Delayed Carbon Pricing Draft Under CBAM Pressure in 2021

Taiwan has had three opportunities to implement an energy tax. Starting in 2006, the Ministry of Finance and the Legislative Yuan have drafted different versions of the Energy Tax Bill. In 2009, the Executive Yuan's Tax Reform Commission formulated a green tax system encompassing both carbon and energy taxes. In 2015, Taiwan officially implemented the Greenhouse Gas Reduction and Management (GRAM) Act, which included the concept of taxing GHG emissions. However, all three windows of opportunity failed due to political and economic lobbying by high-carbon industries. From a TIC perspective, Chou and Liou [28] analyzed the formation of a government–industry interest complex under the high-carbon economic structure, which in turn shaped industrial, energy, and labor policies to favor a brown economy model characterized by low electricity/water prices and labor costs. The failure of these three windows of opportunity for energy taxation substantially delayed the development of carbon pricing systems in Taiwan, especially when compared with those of Republic of Korea and Japan. This delay further reinforced Taiwan's carbon lock-in.

The powerful influence of carbon-intensive industries and the mindset of developmental states present enormous challenges to promoting a low-carbon transition within this brown economy. Taiwan's energy structure is highly dependent on fossil fuel imports, while the high-carbon government–industry TIC hinders the drive for energy transition, placing Taiwan's climate governance (i.e., GHG reduction) in a structural dilemma. As Aklin and Urpelainen [25] emphasized, implementing effective regulatory policy mechanisms is impossible. These circumstances necessitate exogenous forces to facilitate a low-carbon transition. However, the 2015 Paris Agreement, which aimed to phase out fossil fuels globally, merely managed to prompt Taiwan to pass the GRAM Act in the same year. Taiwan also submitted its INDC [58], setting its emission reduction targets; however, this was merely a formality as the agreement failed to spur the adoption of essential carbon pricing policies.

Taiwan's reopening of discussions on carbon pricing was triggered by the new geopolitical and economic landscape emerging from the 2020 US presidential election. The most robust exogenous force which impelled both the government and industrial sector to seriously address international climate governance and the transition toward a low-carbon economy was the EU's CBAM (Chou et al. [4]). The 2021 amendment to the GRAM Act renamed it the Climate Change Response Act, which explicitly mandated the introduction of carbon pricing. In addition to increasingly smooth communication between the Environmental Protection Administration (EPA, renamed the Ministry of Environment) and industry in 2021, the Chinese National Federation of Industries (CNFI), which had long opposed the introduction of an energy tax, released its unprecedented 2021 CNFI White Paper. This was the first time the CNFI publicly supported the establishment of a national carbon pricing mechanism to align with international carbon tariffs [59]. Even so, the CNFI, representing traditional carbon-intensive industries, continued to exert restraint on the implementation model and price level of carbon pricing.

The initial carbon price was set at a conservative level in response to industry lobbying with the government's administrative agencies. In September 2021, the EPA published a draft amendment to the Climate Change Response Act (CCRA), which was formerly known as the GRAM amendment. While Article 5 retained the phrasing of levying relevant taxes and fees on GHG consumption, Article 26 stipulated only a carbon fee [60], explicitly avoiding any mention of the controversial energy tax issue that had persisted for over a decade. At the end of 2020, the EPA had commissioned the London School of Economics and Political Science (LSE) to assess Taiwan's carbon pricing mechanism. The assessment report had recommended the urgent implementation of carbon pricing in the face of international pressure but had also suggested initially imposing a carbon fee and subsequently supporting it with an ETS. However, the EPA's plan limited the carbon fee to the industrial sector, defining it as an administrative regulatory fee with limited scope and purpose. It entirely circumvented the previously planned energy tax, which was designed to achieve a double dividend and facilitate social redistribution [61].

A 2021 survey of members by the CNFI indicated that 47% of enterprises considered NT\$100 per ton of carbon to be the most reasonable carbon fee price [62]. Simultaneously, the Vice Minister of the Ministry of Economic Affairs stated that the price of NT\$300 per ton of carbon would be a significant burden on industries [63]. The EPA-commissioned LSE report suggested that Taiwan's carbon fee could start at a low level of NT\$300 and increase annually [64]. The EPA accepted this recommendation after intensive and prioritized consultations with industry groups. The revenue generated would be held in a dedicated fund chiefly to subsidize industries for energy efficiency improvements and the use of carbon-reducing equipment and technologies. This development trajectory indicates that Taiwan's carbon pricing mechanism was, in its initial phase, shaped primarily by industry voices. While the low carbon price has been welcomed by carbon-intensive industries [65], the highly internationally integrated electronics industry has disagreed. Greenpeace and the Green Citizens' Action Alliance have also strongly criticized this dedicated fund, arguing that it essentially allows enterprises to concomitantly collect carbon fees and receive subsidies [66,67].

#### Re-Delayed Levy of Carbon Fee and Loose Carbon Fee

The carbon fee, drafted in 2021, was finally passed in early 2023 under the CCRA, which mandated the imposition of taxes or fees on GHG emission sources, marking the official launch of carbon pricing in Taiwan. However, the official levy date was repeatedly delayed. Although the carbon fee was originally planned to be based on 2023 emissions and levied in 2024, the EPA announced in August 2023 that its levy would be delayed

until 2025 [68]. In August 2024, at a press conference titled “Announcement of Three Carbon Fee Regulations: Officially Entering the Carbon Pricing Era,” the EPA minister announced that the carbon fee levy would be further delayed until 2026 [69,70]. This sparked strong criticism as it meant that it will have taken Taiwan an unconscionably long time (20 years) from the drafting of the energy tax by the Ministry of Finance and Legislative Yuan members in 2006 to the official implementation of carbon pricing.

In addition to the delay, the carbon fee was very low and its collection method agreed upon by the EPA and the Ministry of Economic Affairs was lax. On 3 January 2024, the EPA held a public hearing on the draft methodology of carbon fee collection, part of the CCRA. The EPA announced that based on the carbon pricing thresholds used by competitor economies such as Japan and Republic of Korea, the fee would be levied only on entities with GHG emissions exceeding 25,000 tons. The EPA also claimed that it had consulted with stakeholders between July and December 2023 [71], when in fact it had not done so with any environmental groups during this period. This sparked strong dissatisfaction among these groups, and non-governmental organizations (NGOs) subsequently issued a strongly worded joint statement [72,73].

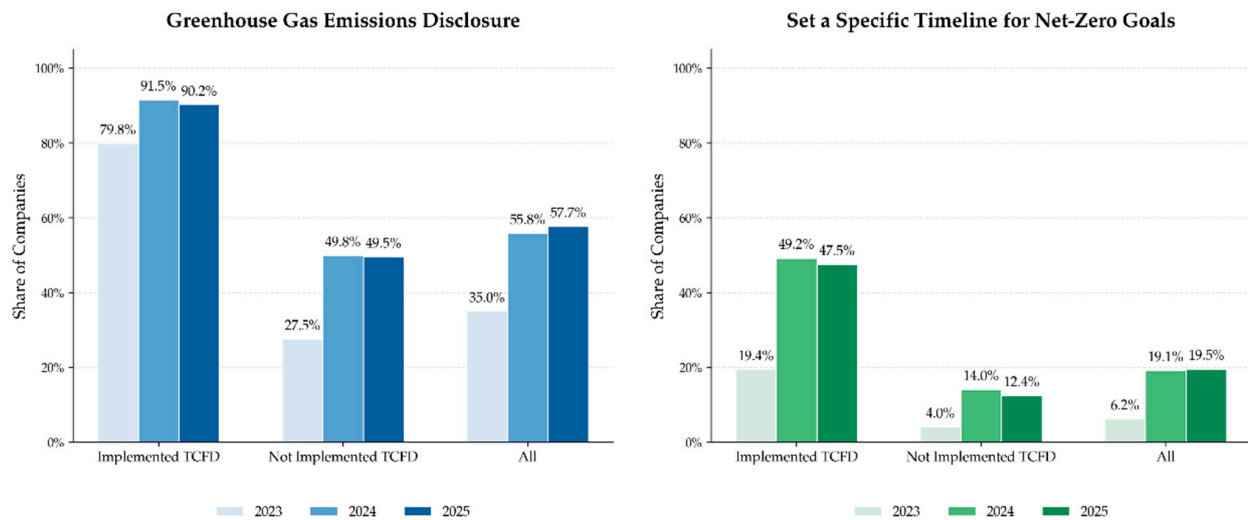
The authorities justified their decisions by citing the need to maintain industrial competitiveness and facilitate the transition, benchmarking against competitor economies such as Japan and Republic of Korea. On 29 August 2024, the EPA officially promulgated the three key regulations related to carbon fees, i.e., the Regulations Governing the Collection of Carbon Fees, the Designated Greenhouse Gas Reduction Goals for Entities Subject to Carbon Fees, and the Regulations for Administration of Self-Determined Reduction Plans. The carbon fee rate was announced on 7 October 2024, and it took effect on 1 January 2025, based on 2025 emissions [74], with actual collection from enterprises scheduled for the following year. The fee is levied on industries such as electricity, gas supply, and manufacturing with annual emissions exceeding 25,000 tons of CO<sub>2</sub>e, covering approximately 252 enterprises (464 factories in total). The fee rate is NT\$300 per ton, with two preferential rates available: Plan A (industry-specific reduction rate), at NT\$50 per ton of CO<sub>2</sub>e, and Plan B (technology-based reduction rate), at NT\$100 per ton of CO<sub>2</sub>e. A deduction of 25,000 tCO<sub>2</sub>e is applied to each entity’s chargeable emissions, reducing the burden on enterprises [75].

Many environmental groups have criticized these carbon fee regulations as ineffectual in driving substantial corporate carbon reductions. According to the Environmental Rights Foundation, the blanket exemption for enterprises with emissions below 25,000 tons will encourage those just above this threshold to prefer paying the fee to investing in carbon reductions [76]. Greenpeace argues that the carbon fee rates are significantly compromised, especially the excessively low preferential rates, undermining enterprises’ incentive to reduce carbon emissions [77].

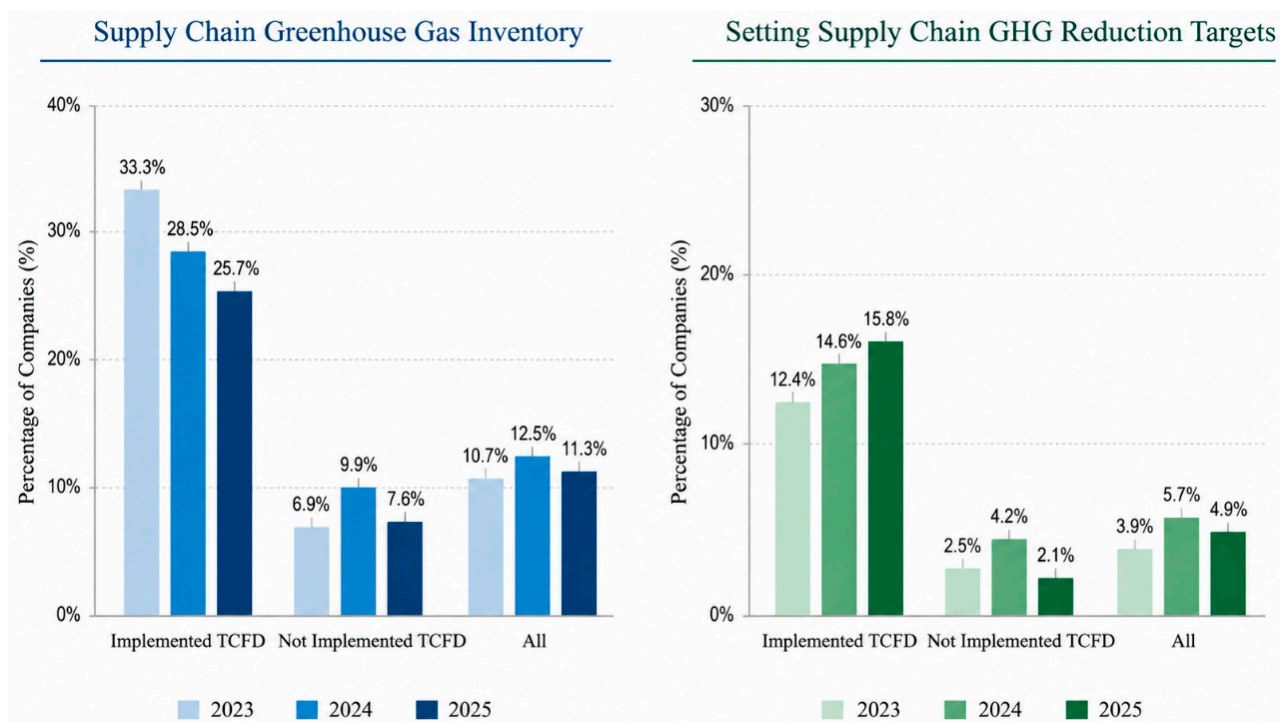
### Inadequate Policy Incentives in Carbon Pricing

We compared the 2023–2025 climate-related financial disclosure surveys on Taiwanese enterprises conducted by the Risk Society and Policy Research Center (RSPRC) at National Taiwan University. The results showed that Taiwanese enterprises have significantly regressed in GHG reduction, disclosure, supply-chain carbon inventory, and financial impact assessment since the EPA officially announced the carbon fee collection mechanism. According to past surveys, over 60% of corporations responded that their actions were contingent upon government regulations and policies [78–80]. Our analysis of the three-year survey results (Figures 5–7) revealed that enterprises were relatively proactive in launching various climate initiatives in 2023 and 2024 following the formulation of carbon pricing in Taiwan, the passing of the CCRA in early 2023, and the early 2024 announcement

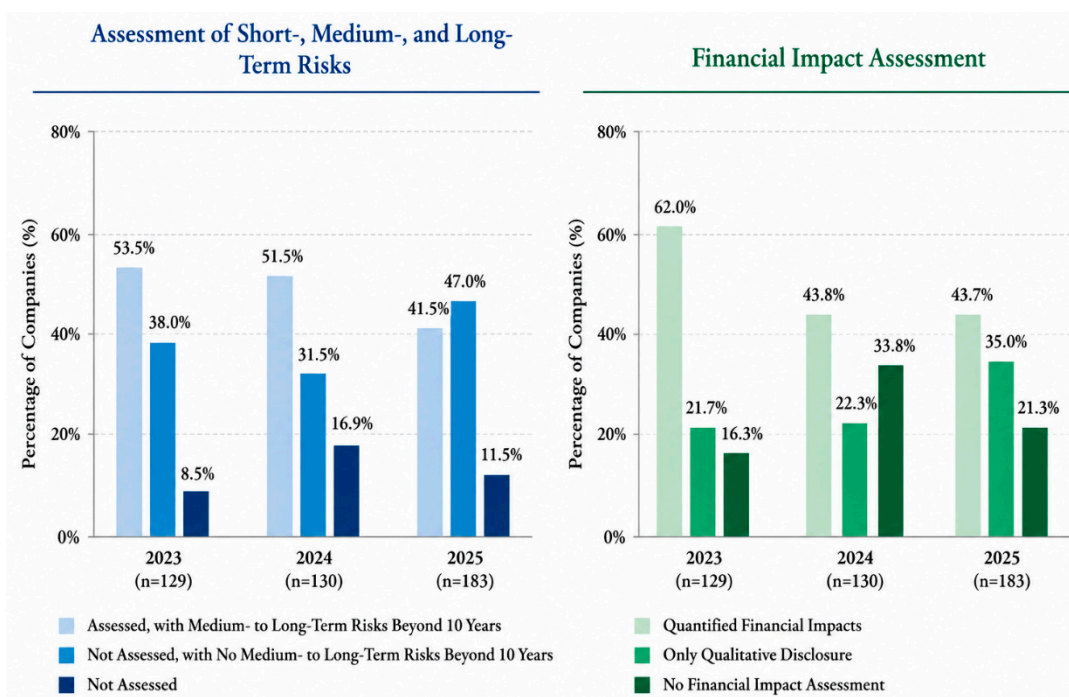
related to the carbon fee collection. However, after the EPA officially announced the relaxed carbon fee calculation formulas A and B and the deduction of 25,000 tons of carbon emissions in August 2024, the survey in March 2025 showed a decline in all these indicators.



**Figure 5.** GHG Emission Disclosure and Specific Timeline Setting for Net-zero Goals. Note: (1) 2023: Implemented TCFD:  $N = 129$ ; Not Implemented TCFD:  $N = 771$ ; All firms ( $N = 900$ ); (2) 2024: Implemented TCFD:  $N = 130$ ; Not Implemented TCFD:  $N = 771$ ; All firms ( $N = 901$ ); (3) 2025: Implemented TCFD:  $N = 183$ ; Not Implemented TCFD:  $N = 723$ ; All firms ( $N = 906$ ). Source: Authors' survey data collected by the Research Center for Risk Society and Policy Research (RSPRC), 2023–2025.



**Figure 6.** Supply-Chain GHG Inventory and Supply-Chain GHG Reduction Target Setting. Source: Authors' survey data collected by the Research Center for Risk Society and Policy Research (RSPRC), 2023–2025.



**Figure 7.** Assessment of Short-, Medium-, and Long-Term Risks and Quantitative Financial Impact Assessment. Source: Authors' survey data collected by the Research Center for Risk Society and Policy Research (RSPRC), 2023–2025.

Figure 5 shows that regardless of whether they implemented climate-related financial disclosures based on the TCFD framework, enterprises exhibited significant progress in both GHG emission disclosure and setting a specific timeline for net-zero goals from 2023 to 2024 but experienced a slight regression in 2025 [78–80].

Figure 6 shows that with respect to supply-chain GHG inventory, enterprises implementing TCFD-aligned disclosures were more proactive in 2023, but their engagement declined slightly in 2024 and further in 2025. Enterprises that did not implement TCFD-aligned disclosures showed slight progress from 2023 to 2024, but regressed in 2025, a pattern evident among all sample enterprises as well. Regarding supply-chain GHG reduction goals, enterprises implementing TCFD-aligned disclosures showed slight but steady progress over the three-year period. However, those that did not implement TCFD-aligned disclosures showed improvement from 2023 to 2024, but saw a significant regression in 2025. The overall sample of enterprises also reflected this pattern [78–80].

Figure 7 shows that over 50% of enterprises implementing TCFD-aligned disclosures were proactive in assessing short-, medium-, and long-term risks in both 2023 and 2024, but this percentage dropped significantly to 41.5% in 2025. Regarding the quantitative assessment of financial impact, enterprises implementing TCFD-aligned disclosures were more active in 2023, but the percentage of such enterprises dropped to only 43.8% in 2024, with similar results in 2025 [78–80].

In theory, when a country plans and announces carbon pricing to regulate and incentivize corporate GHG reductions, surveyed enterprises should respond proactively. They should accelerate and strengthen their disclosures, GHG reduction goals, financial impact assessments, and short-, medium-, and long-term operational risk assessments. They should also implement more aggressive reduction strategies and assistance for their supply chains. In reality, however, our RSPRC surveys in the past three years clearly indicate that enterprises prioritizing government regulatory policies and regulations saw their previously proactive carbon reduction efforts stagnate or decline in 2025. This coincided

with the EPA's repeated delay and eventual implementation of a highly limited carbon pricing mechanism and carbon price.

## 6. Conclusions

### 6.1. Main Findings

This study argues that the implementation of carbon pricing in Republic of Korea and Taiwan is embedded within carbon-intensive industrial structures and lenient or significantly delayed carbon pricing policies. It reflects the institutional inertia of developmental state transition. Although these two brown economies have been compelled to pursue green transitions under exogenous pressures arising from international climate agreements and regulations, they remain constrained by carbon-intensive development pathways and have consequently adopted lenient and limited carbon pricing policies.

First, the top 10 and top 30 carbon-intensive industries in both economies have played a dominant role in shaping GHG emissions over time. Most of these industries consist of traditional sectors, particularly the large petrochemical and steel industries, as well as the electronics industry that emerged later.

Second, competition within government agencies and collaboration between governments and industries have also been evident in the carbon pricing decision-making processes of both economies. Republic of Korea's transition from the TMS to the K-ETS, and Taiwan's nearly two-decade delay from the proposal of an energy tax in 2006 to the reformulation of a carbon fee policy, provide clear examples.

Third, Republic of Korea designed a relatively lenient K-ETS characterized by low carbon prices and a high proportion of free allowances. As a result, it has been unable to immediately drive corporate emissions reductions, while national GHG emissions continued to increase. Similarly, Taiwan has adopted a low carbon fee as its starting point. In addition, implementation was postponed from 2024 to 2026, the coverage threshold was relaxed to industries emitting more than 25,000 tons of carbon emissions, and preferential fee rate schemes A and B were introduced. The effectiveness of these measures remains uncertain.

The institutional inertia of the developmental state significantly hindered rapid decarbonization. Although the Republic of Korea shifted toward a green development pathway by introducing the Target Management System (TMS) in 2012 under the 2009 Green Growth Strategy and subsequently establishing the Korea Emissions Trading Scheme (K-ETS) in 2015, greenhouse gas emissions continued to rise. Total emissions increased from 632.87 MtCO<sub>2</sub>e in 2009 to a historical peak of 780.14 MtCO<sub>2</sub>e in 2018, representing an increase of 147.27 MtCO<sub>2</sub>e over the period. Moreover, emissions remained at a persistently high level throughout Phases I–III of the K-ETS, reaching 722.03 MtCO<sub>2</sub>e in 2022. In practice, however, carbon pricing functioned as an instrument of the developmental state to maintain industrial competitiveness rather than to drive deep decarbonization.

Taiwan missed three windows of opportunity to introduce an energy tax in 2006, 2009, and 2015. Even in 2021, despite the strong exogenous pressure created by the EU CBAM, the institutional inertia of transition remained embedded in powerful industrial lobbying and the developmental-state mindset. As a result, the implementation date of the carbon fee was repeatedly postponed until 2026, while a low and lenient carbon pricing mechanism was adopted.

According to the TCFD surveys conducted by the RSPRC research team over three consecutive years (2023–2025), although the Taiwan government announced the introduction of the carbon fee in August 2024, most firms exhibited declines in climate-related disclosure, emissions reduction targets, climate-related financial assessments, supply-chain GHG inventories, and emissions reduction support measures in 2025 compared with the previous two years. This suggests that a lenient and delayed carbon pricing policy led firms

to perceive a lack of governmental commitment, thereby weakening corporate preparations for decarbonization.

This finding contributes to the international literature on carbon pricing by demonstrating that the formal establishment of carbon pricing does not necessarily translate into effective decarbonization, particularly when its implementation remains constrained by domestic political-economic institutions. Previous studies have shown that the early phases of the EU ETS were criticized for the excessive allocation of free allowances and the limited effectiveness of GHG emissions reductions [8–10], the system nevertheless reduced more than one billion tonnes of CO<sub>2</sub> emissions between 2008 and 2016 despite persistently low carbon prices during its first three phases [11]. In particular, following the introduction of the allowance cancellation mechanism during Phase IV, part of the additional emissions reductions has been translated into actual declines in total emissions [10].

By contrast, although Republic of Korea introduced the TMS and the K-ETS, as analyzed in this study, national greenhouse gas emissions continued to increase and reached a peak in 2018. Although reforms were introduced during Phases II and III of the K-ETS between 2018 and 2022, their overall emissions reduction effects remained relatively limited, despite improvements in corporate energy management and energy efficiency. The key reason is that the Republic of Korean government has long provided a high proportion of free allowances to carbon-intensive industries in order to maintain the international competitiveness of the manufacturing sector, resulting in insufficient pressure on firms to undertake substantial emissions reductions [27].

This developmental-state logic is also reflected in Taiwan's current carbon fee system. In particular, when Taiwan's Ministry of Environment announced in early 2025 that it would pilot an emissions trading system (ETS) in 2027, the proposal was welcomed by industrial sectors.

Although this study analyzes carbon pricing mechanisms in Republic of Korea and Taiwan based on limited policy documents, implementation periods, experiences, and observed outcomes, its findings are consistent with many previous studies on climate governance, carbon pricing, and low-carbon transitions in East Asian economies. These studies suggest that developmental states prioritize and sustain the economic goals of techno-industrial competitiveness and autonomy, while climate governance is seen as complementary [14,16,17,27,52,81].

Furthermore, the studies of Kim and Thurbon (2015) [17], Thurbon et al. (2021) [22], and Thurbon et al. (2023) [18] indirectly demonstrate that the Republic of Korean government places greater emphasis on the development of green technology industries than on substantive emissions reductions. This study further argues that the institutional inertia of developmental-state transition constitutes an important constraint on climate governance and the pursuit of net-zero emissions.

## 6.2. Policy Implications

The experiences of carbon pricing in Republic of Korea and Taiwan demonstrate the institutional inertia of transition and provide an important warning for Asia's carbon-intensive economies within global manufacturing supply chains. This is particularly relevant for many newly industrialized economies in Asia, where authoritarian forms of government, environmental governance, and climate governance are subject to even more complex structural constraints. The difficulties encountered in decarbonization and carbon pricing mechanisms across the region offer little cause for optimism regarding the achievement of global net-zero emissions goals.

Once the institutional logic and inertia of developmental states have been identified, overcoming these constraints is not impossible. Possible pathways can be considered from

the perspectives of changes in global markets, industrial and economic transformation, government responsibility, and the redirection of corporate behavior.

First, driven by developments in global markets, the EU CBAM has already generated a significant policy spillover effect. Although its practical implementation continues to face a number of technical challenges, it has in practice produced institutional diffusion, encouraging many economies to adopt similar mechanisms and prompting more governments to plan and implement carbon pricing policies [82,83]. Taiwan even explicitly incorporated CBAM-related provisions into the Climate Change Response Act enacted in 2023. As Republic of Korea and Taiwan are both major exporting economies to the European Union, matching the requirements of the EU CBAM will require the implementation of effective carbon pricing. Otherwise, products exported to the European market may not be fully exempt from CBAM-related obligations.

Second, among the top 30 and top 10 carbon-emitting industries in Republic of Korea and Taiwan, in addition to traditional sectors such as petrochemicals, steel, and cement, the semiconductor, electronics, and AI-related manufacturing industries are increasingly emerging as critical components of global supply chains. For these industries, the incorporation of carbon pricing into current operations represents only a relatively small cost. At the same time, they have the potential to drive the transformation of traditional domestic industries, including petrochemicals, steel, and machinery, through supply-chain linkages.

Under the growing influence of global climate governance, these industries must not only fulfill their corporate social responsibilities, but governments should also recognize that the industrial and economic landscape has changed substantially compared to two decades ago. It is no longer sufficient to delay carbon pricing in the name of maintaining the international competitiveness of domestic industries. Instead, governments should gradually establish forward-looking and effective mechanisms to guide their industries toward strengthening both manufacturing capabilities and sustainability performance in international markets.

Martin et al. [84], in their assessment of regulated firms after ten years of EU ETS implementation, found that the concerns raised during the initial design stage regarding industrial relocation and the loss of competitiveness did not materialize. On the contrary, a properly designed carbon market can achieve a balance between emissions reductions and industrial competitiveness, while also encouraging investment in low-carbon technologies.

Third, Republic of Korea and Taiwan are currently at a critical turning point. In recent years, both governments have placed considerable emphasis on the Task Force on Climate-related Financial Disclosures and have followed the European Union in developing the Korea Taxonomy and Taiwan Taxonomy. This indicates that both economies have begun to incorporate green finance into the pursuit of net-zero emissions and increasingly recognize the role of the financial sector in driving transition.

From a normative perspective, once markets and finance become active drivers of transition, they can generate substantial momentum. Taiwan provides a clear example, as the financial sector has invested heavily in green energy projects over the past decade, including solar photovoltaics, onshore wind, and offshore wind power. Therefore, such expectations are not unrealistic.

However, the TCFD surveys conducted by the RSPRC research team indicate that lenient carbon pricing not only weakens industrial incentives for emissions reductions, but also reduces the willingness and capacity of both financial institutions and industrial firms to collaborate on decarbonization initiatives and to facilitate emissions reductions throughout supply chains.

Finally, Republic of Korea is currently undertaking reforms in the fourth phase of the K-ETS, while Taiwan is likewise making adjustments to its newly introduced carbon

fee system. Both should place greater emphasis on the combined effects of international exogenous pressures, the restructuring opportunities arising from changes in domestic industrial and economic structures amid global geopolitical and economic conflicts, and the transition opportunities driven by green finance. These factors should be integrated into broader institutional reforms.

More fundamentally, as developmental states are embedded within these multiple layers of international and domestic governance contexts, their mindset and decision-making logic are being compelled to adapt. New forms of statecraft capable of responding to the evolving demands of global markets, politics, and society can no longer remain unchanged.

While this study provides important insights into the institutional inertia of developmental-state transition in Republic of Korea and Taiwan, several limitations should be acknowledged. First, the analysis focuses on two East Asian developmental-state economies, which may limit the broader generalizability of the findings. Second, the study relies primarily on policy documents, emissions statistics, and secondary materials, and therefore cannot fully capture the internal political negotiations and lobbying processes that shape carbon pricing decisions. Third, as Taiwan's carbon fee policy has only recently been implemented and Republic of Korea has entered Phase IV of the K-ETS (2026–2030), the long-term effectiveness of these policy adjustments remains uncertain. Future research could incorporate in-depth interviews, process-tracing approaches, and longitudinal analyses to further examine how developmental-state institutions influence the design, implementation, and effectiveness of carbon pricing policies over time.

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